ASTRONOMY

EXPLAINED UPON Patrick Noble

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.

RARE BOOK
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10th ed.
1799

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 TENTH EDITION,

WITH SOME ADDITIONAL NOTES.

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The time of the planets
falling to the sun pa. 81

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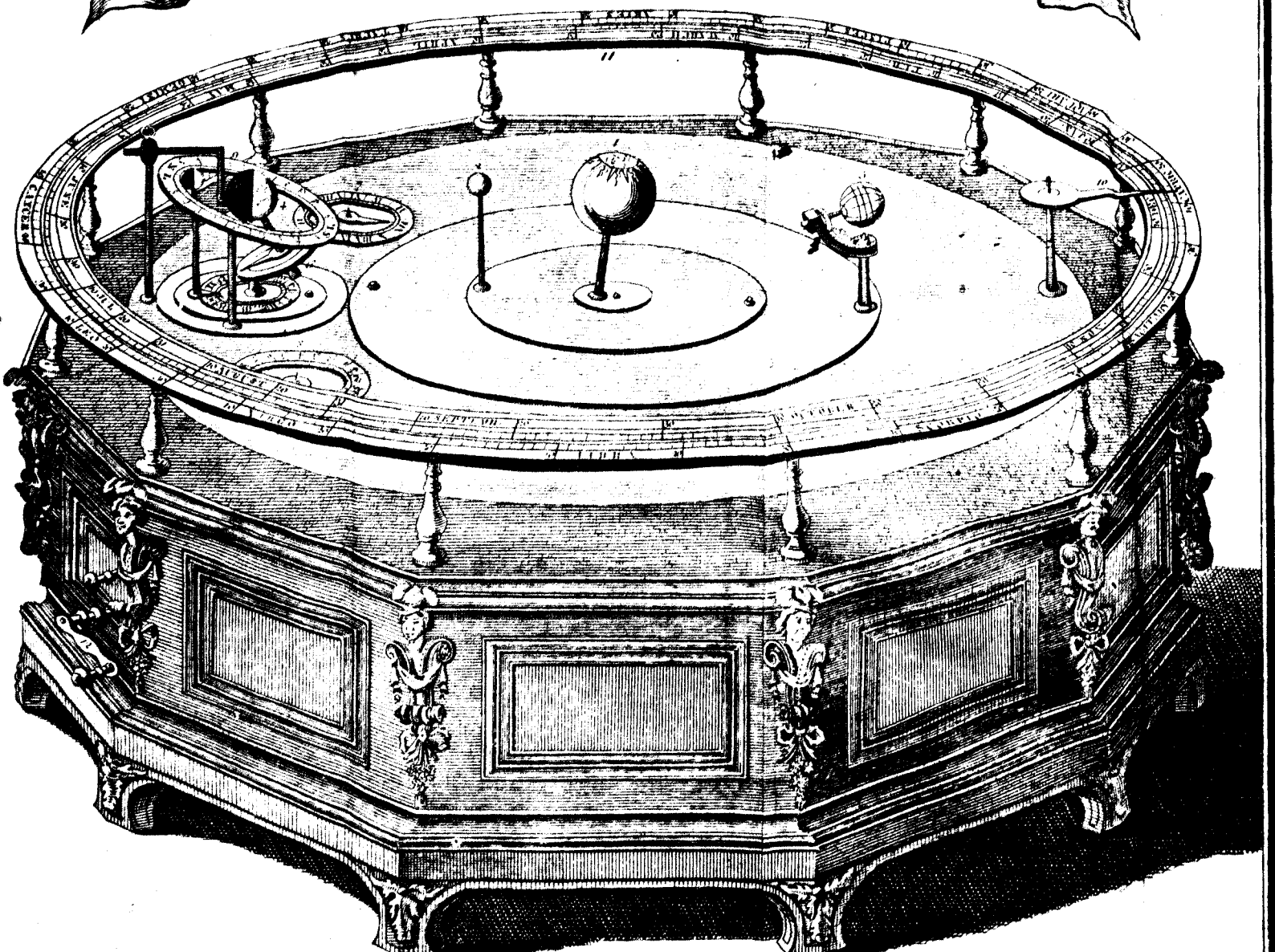

1. The Sun, 2. Mercury, 3. Venus, 4. the Earth, 5. the Moon, 6. the Spherical Dial plate, 7. the Hour Circle, 8. the Circle for the Moon's Age, 9. the Moon's Orbit, 10. the Pointer, shewing the Sun's Place & Day of the Month, 11. the Ecliptic, 12. the Handle for turning the whole machine

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ASTRO-

Henry P. Harrison's Book

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 part of the world, and the various products of several countries distributed for the health, comfort, and conveniency of its 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 wonderful harmony, order, and connexion observable throughout the planetary system; and are led by very powerful arguments to form this 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 its 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 about 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 placed 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 bare 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 carried his thoughts so far, as to believe it

and innumerable.

not impossible that there may be Stars at such inconceivable distances, that their light has not yet reached the Earth since its creation; although the velocity of light be a million of times greater than the velocity of a cannon-ball, as shall be demonstrated afterward, § 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.

Why the Sun appears bigger than the Stars.

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 its circumvolving planets; and would reckon it one of the Stars in numbering them.

The Stars are not enlightened by the Sun.

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 reflection. 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.

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 upward 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 access-

* The Georgian Planet, discovered since Mr. Ferguson's time, revolves round the Sun in an Orbit 5673 millions of miles in circumference.

sible

ſible 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 is almoſt an infinite variety in the parts of the Creation, which we have opportunities of examining, yet there is a general analogy running through and connecting all the parts into one ſcheme, one deſign, one whole!

11. And then, to an attentive conſiderer, it will appear highly probable, that the Planets of our Syſtem, together with their attendants called Satellites or Moons, are much of the ſame nature with our Earth, and deſtined for the like purpoſes. For they are ſolid opaque Globes, capable of ſupporting animals and vegetables. Some of them are bigger, ſome leſs, and ſome much about the ſize of our Earth. They all circulate round the Sun, as the Earth does, in a ſhorter or longer time, according to their reſpective diſtances from him; and have, where it would not be inconvenient, regular returns of ſummer and winter, ſpring and autumn. They have warmer and colder climates, as the various productions of our Earth require: and, in ſuch as afford a poſſibility of diſcovering it, we obſerve a regular motion round their axes like that of our Earth, cauſing an alternate return of day and night; which is neceſſary for labour, reſt, and vegetation, and that all parts of their ſurfaces may be expoſed to the rays of the Sun.

as our Solar Planets are.

12. Such of the Planets as are farthest from the Sun, and therefore enjoy leaſt of his light, have that deficiency made up by ſeveral Moons, which conſtantly accompany, and revolve about them, as our Moon revolves about the Earth. The remoteſt Planet has, over and above, a broad ring encompaſſing it; which like a lucid Zone in the Heavens reflects the Sun's light very copiouſly on that Planet: ſo that if the remoter Planets have the Sun's light fainter by day than we, they have

The farthest from the Sun have most Moons to enlighten their nights.

an addition made to it morning and evening by one or more of their Moons, and a greater quantity of light in the night-time.

Our Moon mountainous like the Earth.

13. On the ſurface of the Moon, becauſe it is nearer to 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 its 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!

CHAP.

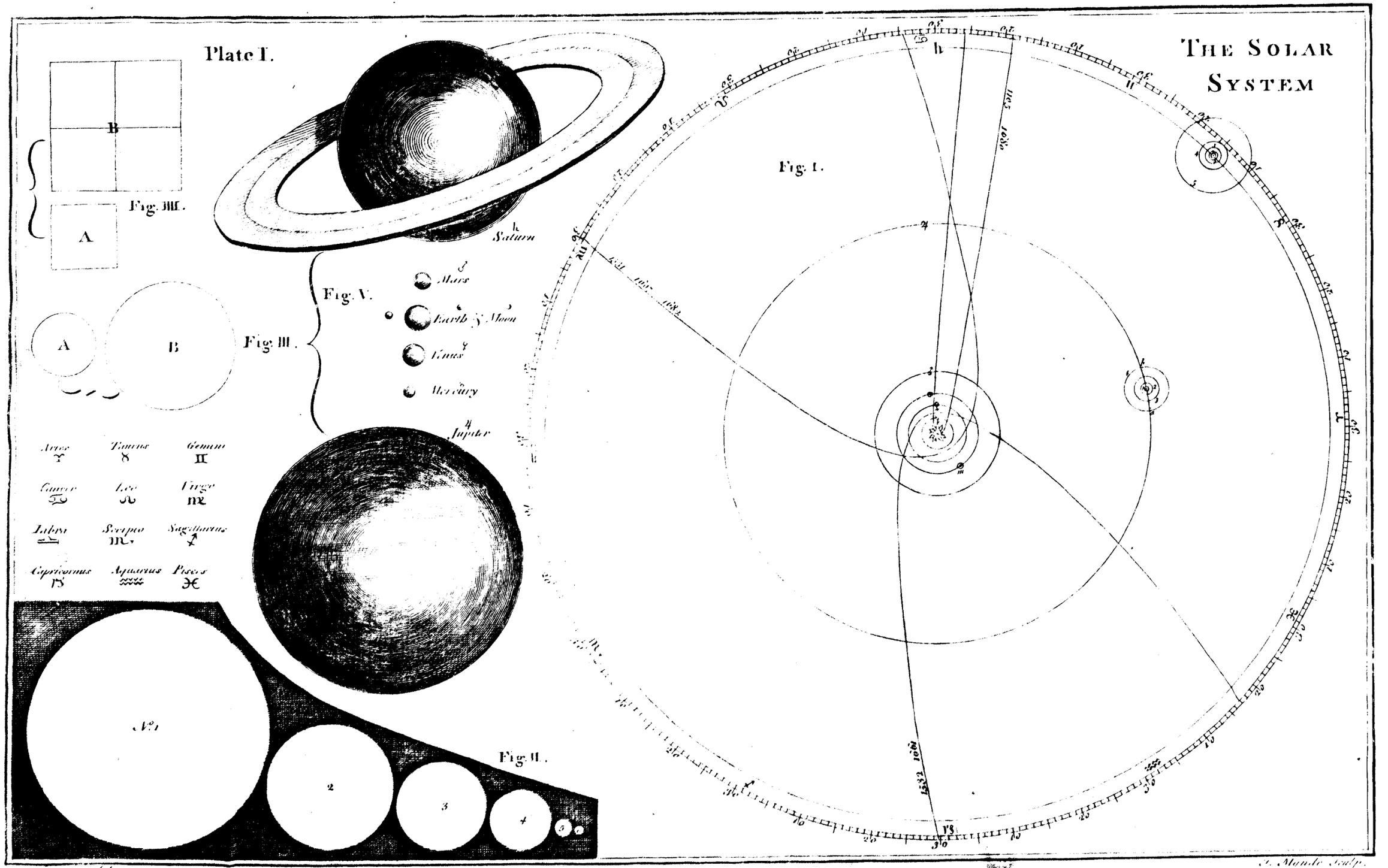
Plate I.
THE SOLAR SYSTEM
Fig. I.
Fig. II.
Fig. III.
Fig. IIII.
Fig. V.
Saturn
Mars
Earth & Moon
Venus
Mercury
Jupiter
Aries
Taurus
Gemini
Cancer
Leo
Virgo
Libra
Scorpio
Sagittarius
Capricornus
Aquarius
Pisces
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CHAP. II.

A brief Description of the SOLAR SYSTEM.

17. THE Sun, with the Planets and Comets which move round him 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. 1. 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 motions 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. 1.

* If the two ends of a thread be tied together, and the thread be then thrown 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; and the points where the pins are fixed are called the *foci* or focuses of the ellipsis. The Orbits of all the Planets are elliptical, and the Sun is placed in or near 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 Orbits. 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 the 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 its center, about which it revolves as if on a real axis. The extremities of this line, terminating in oppoſite points of the Planet's ſurface, are called its *Poles*. That which points toward the *northern* part of the Heavens, is called the *North Pole*; and the other, pointing toward 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, while 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.

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

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

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

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 its *Descending Node*. Saturn's Ascending Node * is in 21 deg. 32 min. of Cancer ♋, Jupiter's in 8 deg. 49 min. of the same Sign, Mars's in 18 deg. 22 min. of Taurus ♉, Venus's in 14 deg. 44 min. of Gemini ♊, and Mercury's in 16 deg. 2 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.

* In the year 1790.

22. MER-

PLATE I. Mercury. Fig. I.

22. MERCURY, the nearest Planet to the Sun, goes round him, in the circle marked ☿, in 87 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 its being inhabited; since the Almighty could as easily suit the bodies and constitutions of its 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 toward us, but when he is so near the Sun as to be lost to our sight in its 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.

24. His

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 16th degree of Taurus; and the opposite node is in the 16th degree of Scorpio. The Earth is in these points on the 7th of *November* and 5th of *May*, 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. His Orbit and Nodes.

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, *Nov.* 5th, 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, 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, to her, every Venus. Fig. I.

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

† The elder Cassini had concluded from observations made by himself in 1667, that Venus revolved on her axis in a little more than 23h. because in 24h. he found that a spot on her surface was about 15° more advanced than it was the day before; and it appeared to him that the spot was very sensibly advanced in a quarter of an hour. In 1728, Bianchini published a splendid work, in folio, at Rome, entitled *Hesperi et Phosphori nova phænomena*; in which are the observations here referred

PLATE I. every day and night together is as long as $24\frac{1}{4}$ 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, beside the 69,000 above-mentioned.

Her Orbit lies between the Earth and Mercury.

27. Her Orbit includes that of Mercury within it; for at her greatest Elongation, or apparent distance from the Sun, she is 96 times the breadth of that luminary from his center; which is almost double of Mercury's greatest Elongation. 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 its 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

referred to. Bianchini agrees perfectly with Cassini that the spots, which are seen on the surface of Venus, advance about 15° in 24h. but he asserts that he could not perceive they had made any advance in 3h. and therefore concludes, that instead of making one complete revolution and 15° of another, as Cassini conjectured, in 24h. those spots advance but the odd 15° in that time, and that the time of a revolution is somewhat more than 24 days. The arguments in favour of the two hypotheses are very equal; but almost every astronomer, except Mr. Ferguson, has adopted Cassini's.

the

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 51¼ 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 112½ † 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 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.

The Sun's daily Course,

32. As her annual Revolution contains only 9¼ of her days, the Sun will always appear to go through a whole Sign, or twelfth part of her Orbit, in a little more than three quarters of her

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

† One entire revolution, or 24 hours,

‡ These are lesser circles parallel to the Equator, and as many degrees from it, toward the Poles, as the Axis of the Planet is inclined to the Axis of its 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 toward 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.

natural

natural day, or nearly in 18¼ of our days and nights.

and great Declination.

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 36¼ 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 on that account, the heated places have time to cool.

To determine the points of the Compass at her Poles.

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 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 remarkable appearances.

The Sun will rise 22½ degrees * north of the east, and going on 112½ degrees, as measured on the plane of the † Horizon, he will cross the Meridian at an altitude of 12½ degrees; then making an entire revolution without setting, he will cross it again at an altitude of 48½ degrees; at the next revolution he will cross the Meridian as he comes to his greatest height and declination, 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.

altitude

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 on Venus, as the Sun is for half a year together above the Horizon of each Pole in its 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 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 $23\frac{1}{2}$ 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 autumn, a summer as long as them both, and a winter equal in length to the other three seasons.

36. At

At her polar Circles.

36. At the Polar Circles of Venus, the ſeaſons are much the ſame as at the Equator, becauſe there are only 15 degrees between 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 Tropics.

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. While 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.

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.

At her Equator.

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 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 thoſe Circles, as they are more or leſs diſtant from them.

41. From

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 on the Equator, or at the Poles.

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

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 have, because the daily change of the Sun's declination is by much too small for that important purpose.

The longitude of places easily found in Venus.

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.

Every fourth year a leap year to Venus.

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 Calendar always right.

When ſhe will appear on the Sun.

45. Venus's Orbit is inclined 3 degrees 24 minutes to the Earth's; and croſſes it in the 15th 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 be only twice viſible at *London* for one hundred and ten years to come. The firſt time will be in 1761, *June* the 6th, in the morning; and the ſecond in 1769, on the 3d of *June* in the evening. Excepting ſuch Tranſits as theſe, ſhe ſhews the ſame appearances to us regularly 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 its enlightened ſide can never be fully turned toward 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 its dark ſide toward us; and than we cannot ſee it any more than we can our own Moon at the time of Change. When

Venus

Venus is at her geateſt 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 have a Moon, it may certainly be ſeen with her upon the Sun, in the year 1761: unleſs its 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 *. PLATE 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, 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 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 its 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 its Axis, the inhabitants about the Equator are carried 1042 miles every hour, while thoſe on the parallel of *London* are caried only about 580, beſides the 58 thouſand miles by the annual motion above-mentioned, which is common to all places whatever. The Earth. Fig. I. Its diurnal and annual motion.

48. The Earth's Axis makes an angle of 23½ degrees with the Axis of its Orbit; and keeps always the ſame oblique direction; inclining to- Inclination of its Axis.

* Both her tranſits are over ſince this was written, and no Satellite was ſeen with Venus on the Sun's Diſc.

ward the same fixed Star * throughout its annual course, which causes the returns of Spring, summer, autumn, and winter; as will be explained at large in the tenth Chapter.

A proof of its being round.

49. The Earth is round like a globe; as appears, 1. By its 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 while the hull is hid by the convexity of the water. 3. By its 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.

Its number of square miles.

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 millions 456 thousand and 65; *Asia* 10 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 terrestial 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

* 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 its parallelism; but this is rather too small to be sensible in an age, except to those who make very nice observations.

almost

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.

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 toward us, and that her day and night taken together is as long as our lunar month. The Moon.

53. The Moon is an opaque Globe like the Earth, and shines only by reflecting the light of the Sun: therefore, while 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 toward 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 toward 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.

A proof that she shines not by her own light.

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.

Fig. I.

One half of her always enlightened.

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.

Our Earth is her Moon.

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 its third quarter to her; and *vice versâ*.

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.

A proof of the Moon's having no Atmosphere.

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

pear 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 ♈ 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 refraction to have ſuffered ſome change in its colour, or in its 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 its 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, its 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 Nor ſeas.

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 ſide 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.

She is full of caverns and deep pits.

The Stars always viſible to the Moon.

60. There being no Atmoſphere about the Moon, the heavens in the day-time have the appearance of night to a Lunarian who turns his back towards 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 its Axis, the ſeveral continents, ſeas, and iſlands appear to the Moon's inhabitants like ſo many ſpots of different forms and brightneſs, moving over its ſurface; but much fainter at ſome time 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

PLATE I.

fibly 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 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.

How the Lunarians may know the length of their year,

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 million of miles; and by travelling at the rate of 47 thousand miles every hour, in the circle ♂, he goes round

Mars.

Fig. I.

* 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 its Obliquity is 5⅓ degrees.

round the Sun in 686 of our days and 23 hours which is the length of his year, and contains 667¼ 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.

65. This planet being but a fifth part so big as the Earth, if any Moon attends him, it 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, 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 inclined to it in an angle of 1 degree 50 minutes.

Jupiter.

68. JUPITER, the biggest of all the Planets, is still higher in the system, being about 426 million of miles from the Sun: and going at the rate

of 25 thousand miles every hour in his Orbit, which is represented by the circle ♃. He 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. PLATE I. Fig. I.

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 equatorial 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 equatorial inhabitants are carried 25 thousand 920 miles every hour (which is 920 miles a hour more than an inhabitant of our Earth's equator moves in twenty-four hours) beside the 25 thousand above-mentioned, which is common to all parts of his surface, by his annual motion. The number of days in his year.

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 afterward 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 these near the Poles 9 hours 56 minutes. *See* Dr. SMITH's *Optics*, § 1004, *& seq.* His Belts and spots.

71. The

He has no change of seasons;

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 tracks of land would be rendered uninhabitable by any considerable inclination of his Axis.

but has four Moons.

72. The Sun appears but $\frac{1}{25}$th 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, except his Poles, whence only the farthest Moons can be seen, and where light is not there 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 4; 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 its revolution in 3 days 13 hours and 15 minutes, at 364 thousand miles distance: The third in 7 days 3 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.

74. The

74. The Angles under which the Orbits of Jupiter's Moons are seen from the Earth, at its 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 its 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.

Parallax of their Orbits, and distances from Jupiter.

How he appears to his nearest Moon.

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 passes by its opposition to Jupiter, without falling into his shadow, two years in every six. By these Eclipses, Astronomers have not only discovered 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.

Two great discoveries made by the Eclipses of Jupiter's Moons.

76. The difference between the Equatorial, and Polar diameters of Jupiter is 6230 miles; for his equatorial 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, toward 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

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

* Cassini *Elemens d' Astronomie, Liv.* ix. *Chap.* 3.

equilibrium,

PLATE I. *equilibrium*, and the equatorial parts rise no higher. Our Earth being but a very small Planet compared to Jupiter, and its motion on its Axis being much slower, it is less flattened of course; for the difference between its equatorial and polar diameters is only as 230 to 229, namely, 36 miles *.

The difference little in those of our Earth.

Place of his Nodes.

77. Jupiter's Orbit is inclined to the Ecliptic in an angle of 1 degree 20 minutes. His ascending Node is in the 8th degree of Cancer, and his descending Node in the 8th degree of Capricorn.

Saturn.

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

Fig. I.

His Ring. Fig. V.

79. This Planet is surrounded by a thin broad Ring, as an artificial Globe is by an 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 breadth; which is equal to its distance from Saturn on all sides. There is reason to believe that the Ring turns round its Axis, be-

* According to the French measures, a Degree of the Meridian at the Equator contains 340606.68 French Feet: and a Degree of the Meridian in Lapland contains 344627.40: so that a Degree in Lapland is 4020.72 French Feet (or 4280.02 English Feet) longer than a Degree at the Equator. The difference is $\frac{81}{100}$ parts of an English Mile.—Hence, the Earth's Equatorial Diameter contains 39386196 French Feet, or 41926356 English; and the Polar Diameter 39202920 French Feet, or 41731272 English. So that the Equatorial Diameter is 195084 English Feet, or 36.948 English Miles, longer than the Axis.

† The Georgian Planet was not discovered when this was written.

cause,

cause, 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 *. 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 †. PLATE I.

His five Moons.

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. But to compensate for the small quantity of sunlight, 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 Orbits in the Fig. I.

* Dr. Herschel from some spots he has seen on the exterior Ring, has determined that it revolves in about 10½ hours.

† Dr. Herschel having discovered that there are some belt-like appearances on this Planet, similar to those which are seen on Jupiter, concluded that it must revolve on its Axis, and that with a pretty quick motion. He also thinks he has determined, from some parts of those Belts which are less black than others, that this Revolution is performed in 10 hours 16 minutes.

‡ Dr. Herschel has discovered two other Moons belonging to Saturn, which revolve between the nearest of the old ones and the Planet; so that Saturn is now known to have seven Moons. The exterior of the new Satellites, called the sixth, revolves at the distance of near 120 thousand miles, in 1 day 8 hours 53 minutes; and that which is nearest the Primary, termed the seventh, is distant from it about 91 thousand miles, and performs its revolution in 22 hours 37 minutes: but the Doctor esteems this last article rather uncertain. He has moreover

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.

His Axis probably inclined to his Ring.

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 its 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 its Axis has no inclination to its 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 its Ring, and also of his Axis being perpendicular to his Orbit.

How the Ring appears to Saturn and to us.

82. This Ring, seen from Saturn, appears like a vast luminous Arch in the Heavens, as if it did

over discovered that the fifth Satellite revolves on its Axis, as our Moon does, in the same time it revolves in its Orbit: a very remarkable as well as curious coincidence in the motions of the Secondaries to two different, and very distant Primaries.

not

not belong to the Planet. When we see the Ring most open, its 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 its edge; which being then directed toward us, becomes invisible on account of its thinness; as shall be explained more largely in the tenth Chapter, and illuminated by a figure. The Ring disappears twice in every annual Revolution of Saturn, namely, when he is in the 20th degree both of Pisces and of Virgo. And when Saturn is in the middle between these points, or in the 20th degree either of Gemini or of Sagittarius, his Ring appears most open to us; and then its longest diameter is to its shortest, as 9 to 4.

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

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 a telescope, we should never have known any thing of his Moons; unless by chance we had directed the telescope towards that small part of the Heavens where they were, at the time of observation. And the like is true of the Moons of Saturn.

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

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 22d degree of Cancer and of Capricorn; so that Saturn's Nodes are only 14 degrees from Jupiter's, § 77 *.

Place of Saturn's Nodes.

85. The

* Since Mr. Ferguson's death, in 1776, a seventh primary Planet belonging to the Solar System, has been discovered by *Georgium Sidus.*

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

§5. The quantity of light afforded by the Sun to Jupiter, being but $\frac{1}{27}$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

by Dr. Herschel, and called, by him, the *Georgium Sidus*, out of respect to his present majesty King George III. This Planet is still higher in the System than Saturn, being about 1565 millions of miles from the Sun; and performs its annual circuit in 83 years 140 days and 8 hours of our time: consequently its motion, in its Orbit, is at the rate of about 7 thousand miles in an hour. To a good eye, unassisted by a telescope, this Planet appears like a faint Star of the fifth magnitude; and it cannot be readily distinguished from a fixed Star with a less magnifying power than 200 times. Its apparent diameter subtends an angle of no more than 4″ to an observer on the Earth; but its real diameter is about 34,000 miles, and, consequently, it is about 80 times as big as the Earth. Hence we may infer, as the Earth cannot be seen under an angle of quite 1″ to the inhabitants of the Georgian Planet, that it has never yet been seen by them, unless their eyes and instruments are considerably better than ours.

The Orbit of this Planet is inclined to the Ecliptic in an angle 46′ 26″. Its ascending Node is in the 13th degree of Gemini, and its descending Node in the 13th degree of Sagittarius.—As no spots have yet been discovered on its surface; the position of its Axis, and the length of its day and night are not known.

On account of the immense distance of the Georgian Planet from the source of light and heat to all the bodies in our System, it was highly probable that several Satellites, or Moons, revolved round it: accordingly, the high powers of Dr. Herschel's telescopes have enabled him to discover six; and there may be others which he has not yet seen. The first, and nearest to the Planet, revolves at the distance of 12½ of the Planet's semi-diameters from it, and performs its revolution in 5 days 21 hours 25 minutes: the second revolves at 16½ semi-diameters of the primary from it, and completes its revolution in 8 days 17 hours 1 minute: the third, at 19 semi-diameters, in 10 days 23 hours 4 minutes: the fourth, at 22 semi-diameters, in 13 days 11 hours 5 minutes: the fifth, at 44 semi-diameters, in 38 days 1 hour 49 minutes; and the sixth, at 88 semi-diameters, in 107 days 16 hours 40 minutes. It is remarkable that the Orbits of these Satellites are almost at right angles to the plane of the Ecliptic; and that the motion of every one of them, in their Orbits, are retrograde.

when

when the Sun is so much eclipsed to us, as to have 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 surprized 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 the nature of their mould 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 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 Planatary 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 its 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 its 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 harmony which exiſts throughout the Univerſe? Surely

It is highly probable that all the Planets are inhabited.

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! PLATE I.

87. In Fig. II. 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. V. 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, according to their proportionable bulks, as in our System, Mercury would be 28 yards from the Sun's center; Venus 51 yards 1 foot; the Earth Fig. V. Proportional bulks and distances of the Planets.

PLATE I. 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 its greatest distance, 10 thousand 760 yards. In this proportion, the Moon's distance from the center of the Earth would be only 7½ 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 its 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 in the center of the Orbits in which the Planets move, they come nearer to it and go farther from it, 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. III. 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. Each 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. 8

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 eccentric ellipses; and 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

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 its heat until it comes round again, although its 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 is delineated in the Scheme of the Solar Syſtem, and the years marked in which they made their appearance. 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 Planets, 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 afterward. The ſecond of them appeared in 1532 and 1661, and may be expected to return in 1789, and every 129th year afterward. The third, having laſt appeared in 1680, and its Period being no leſs than 575 years, cannot return until the year 2225. This Comet, at its greateſt diſtance, is about eleven thouſand two hundred millions of miles from the Sun; and at its leaſt diſtance from the Sun's center, which is 49,000 miles, is within leſs than a third part of the Sun's ſemidiameter from his ſurface. In that part of its Orbit which is neareſt the Sun, it flies with the amazing ſwiftneſs of 880,000 miles in a hour; and the Sun, as ſeen from it, appears a hundred degrees in breadth; conſequently 40 thouſand

Fig. 1.

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

The Periods only of three are known.

They prove the Stars to be at immense distances.

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.

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 adjudged uninhabitable; the Torrid Zone, by reason of excessive heat, and the two Frigid Zones because of their intolerable cold; it seems highly probable, that such numerous and

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

large

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 be 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 *Ptolomean 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 Chryſtalline Spheres; all which were included in and received motion from the *Primum Mobile*, which conſtantly revolved The Ptolomean Syſtem abſurd.

revolved about the Earth in 24 hours from Eaſt to Weſt. But as this rude ſcheme was found incapable of ſtanding 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 *Ptolomean*, 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 its 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 into one point of 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, on a supposition of the SUN's Parallax being 10". For their nearly true Distances from the SUN, as determined from Observations of the Transit of Venus, in the year 1761, see § 194.

Sun and Planets.	Annual period round the Sun.	Diurnal rotation on its Axis.	Diameter in English miles.	Mean diam. as seen fr. the Sun.	Mean distance from the Sun in English miles.	Eccentricity of its Orbit in miles.	Axis inclined to its Orbit.	Orbit inclined to the Ecliptic.	Place of its Aphelion.	Place of its Ascending Node.	Proportion of Diameters.	Proportion of Bulk.	Prop. of Gravity on the surface.	Proportion of Density.
SUN	—	25d 6h.	763000	—	—	—	8° 0′	—	—	—	10000	[illegible]7650	24	25½
Mercury	87d. 23h.	Unknown.	2600	20″	32,000,000	6,720,000	Unkn.	6° 54′	♑ 13° 8′	♉ [illegible]43′	3[illegible]	1/27	Unkn.	Unkn.
Venus	224d. 17h.	24d. 8h.	7906	30″	59,000,000	413,000	7° 0′	3° 20′	♒ 4° 20	♊ 1[illegible]9′	10[illegible]	1	Unkn.	Unkn.
Earth	365d. 6h.	1d. 0h.	7970	21″	82,000,000	1,377,000	23° 29′	—	♑ 8° 1	—	104[illegible]	1	1	100
Moon	365d. 6h.	29d. 12¾h.	2180	6″	82,000,000	13,000	2° 10′	5° 18′	—	Variable.	28½	1/50	34/50	123½
Mars	686d. 6h.	24h. 40m.	4444	11″	125,000,000	11,439,000	0° 0′	1° 52′	♍ 9° 10′	♉ 17° 17′	58 1/6	1/5	Unkn.	Unkn.
Jupiter	4332d 12h.	9h. 56m.	81000	37″	426,000,000	20,352,000	0° 0′	1° 20′	♎ [illegible]7° 50′	♋ 7° 29′	1061	1049	2	19
Saturn	10759d. 7h.	10h. 16m.	67000	16″	780,000,000	42,735,000	Unkn.	2° 30′	♑ 27° 50′	♐ 21° 13′	8[illegible] 1/6	586	1½	15
Georgian	30456d. 2h.	Unknown.	35000	0,9″	1565,000,000	74,404,000	Unkn.	0° 46′	♓ 13° 12′	♊ 12° 49′	448 7	79⅔	1 1/6	22

Sun and Planets.	Proportion of Light & Heat.	Proportion of quantity of Matter.	Hourly motion in its Orbit.	Hourly motion of its Equator.	Square miles in surface	Cubic miles in solidity.	Projectile force being destroyed would fall to the Sun in	
							days	hours
SUN	4500	227500	—	3818	1,828,911,000,000	232,577,115,137,000,000		
Mercury	6½	Unkn.	95000	Unkn.	21,236,800	9,155,534,500	15	13
Venus	1 3/9	Unkn.	69000	43	691,351,300	258,507,832,200	39	17
Earth	1	1	58000	1042	199,859,860	265,104,598,080	64	19
Moon	13 1/4	1/70	2290	9½	14,898,750	5,408,246,000	64	10
Mars	4/7	Unkn.	47000	556	62,038,240	45,969,335,840	121	0
Jupiter	1/27	220	25000	25920	20,603,970,000	278,153,595,000,000	290	0
Saturn	1/90	94	18000	20493	14,102,562,000	155,128,182,000,000	767	0
Georgian	1/363	18	7000	Unkn.	3,678,183,000	20,976,679,225,000	1367	0

Moons.	Periods round Jupiter.			Periods round Saturn.			Periods round the Georgian.		
No	D.	H.	M.	D.	H.	M.	D.	H.	M.
1	1	18	35	1	21	19	5	21	25
2	3	13	19	2	17	40	8	17	1
3	7	3	5	4	12	25	10	23	4
4	16	18	50	15	22	41	12	11	5
5				79	7	48	38	1	49
6				1	8	53	107	16	40
7				0	22	37			

The Moon belonging to the Earth goes round its Orbit in 27 days 7 hours 43 minutes.

CHAP. III.

The COPERNICAN SYSTEM *demonstrated to be true.*

Of matter and motion.

99. MATTER is of itself inactive, and indifferent to motion or rest. A body at rest can never put itself in motion; a body in motion can never stop or move slower of itself. Hence, when we see a body in motion, we conclude some other substance must have given it that motion; when we see a body fall from motion to rest, we conclude some other body or cause stopt it.

100. All motion is naturally rectilineal. A bullet thrown by the hand, or discharged from a cannon, would continue to move in the same direction it received at first, if no other power diverted its course. Therefore, when we see a body moving in a curve of whatever kind, we conclude it must be acted upon by two powers at least: one to put it in motion, and another drawing it off from the rectilineal course which it would otherwise have continued to move in.

Gravity demonstrable.

101. The power by which bodies fall toward the Earth, is called *Gravity* or *Attraction*. By this power in the Earth it is, that all bodies on whatever side, fall in lines perpendicular to its surface. On opposite parts of the Earth bodies fall in opposite directions, all toward the center, where the whole force of gravity is, as it were, accumulated. By this power constantly acting on bodies near the Earth, they are kept from leaving it altogether; and those on its surface are kept thereto on all sides, so that they cannot fall from it. Bodies thrown with any obliquity are drawn by this power from a straight line into a curve, until they fall to the ground: the greater the force by which they are thrown, the greater is the distance they are carried before they fall. If we suppose a body carried

several miles above the Earth, and there projected in a 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.

Projectile force demonstrable.

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.

The Sun and Planets attract each other.

103. The Moons of Jupiter and Saturn are observed to move round their primary Planets: therefore there is an attractive power 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 power, 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 whatever.

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, and 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 proportional 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 toward 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 toward 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 be 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, while one man pulls the rope, endeavouring to bring the ship and boat together, let another man, in the boat, endeavour to row it off sideway, 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; while the latter, endeavouring to row off the boat in a straight line, will, by means of the other's pulling it toward 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 toward the Sun with a quick motion; and would also in falling attract the Sun toward 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 toward it from the line of projection, so as to bend its motion into a curve. But the Sun being at least

227 thouſand times as heavy as the Earth, by being ſo much weightier as its 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 its falling to 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 upward to different heights in the Air, aud 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 its 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 mill-ſtone would go off, and carry the pebble along with it.

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.

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the power of gravity decreaſes as the ſquare of the diſtance increaſes; and from this it follows with mathematical certainty, that when two or more bodies move round another as their center of motion, the ſquares of their periodic times will be to one another in the ſame proportion as the cubes of their diſtances from the central body. This holds preciſely with regard to the Planets round the Sun, and the Satellites round the Planets; the relative diſtances of all which are well known. But, if we ſuppoſe the Sun to move round the Earth, and compare its period with the Moon's by the above rule, it will be found that the Sun would take no leſs than 173,510 days to move round the Earth, in which caſe our year would be 475 times as long as it now is. To this we may add, that the aſpects of increaſe and decreaſe of the Planets, the times of their ſeeming to ſtand ſtill, and to move direct and retrograde, anſwer preciſely to the Earth's motion; but not at all to the Sun's, without introducing the moſt abſurd and monſtrous ſuppoſitions, which would deſtroy all harmony, order, and ſimplicity in the Syſtem. Moreover, if the Earth be ſuppoſed to ſtand ſtill, and the Stars to revolve in free ſpaces 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 ſeveral Orbits; that is, of the ſeveral parallel Circles which the Stars on different ſides of the Equator deſcribe every day; and the like inferences may be drawn from the ſuppoſed diurnal motion of the Planets, ſince they are never in the Equinoctial but twice in their courſes with regard to the ſtarry Heavens. But, that forces ſhould be directed to no central body, on which they phyſically depend, but to innumerable imaginary points in the Axis of the Earth produced to the Poles of the Heavens, is a hypotheſis too abſurd to be allowed of by any rational creature. And it is ſtill more ab-

The harmony of the celeſtial motions.

The abſurdity of ſuppoſing the Stars and Planets to move round the Earth.

 ſurd

surd to imagine that these forces should increase exactly in proportion to the distances from this Axis; for that 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, its 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 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

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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, Mr. SIMPSON ¶, 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 its 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 its 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 Discs ††. 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 its rotation being smooth and uniform, we can neither The Earth's motion on its 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.
¶ Mathemat. Essays, p. 1. ** *Elements d'Astronomie*, § 381.
†† The face of the Sun, Moon, or any Planet, as it appears to the eye, is called its Disc.

see it move on its Axis as we do the Planets, nor feel ourselves affected by its motion. Yet there is one effect of such a motion, which will enable us to judge with certainty whether the Earth revolves on its 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 equatorial than in the polar Regions; for, as the equatorial parts move quickest, they will recede farthest from the Axis of motion, and enlarge the equatorial 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 toward the places which are nearest the center, would run toward the polar Regions, and leave the equatorial 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 equatorial diameter is 36 miles longer than its Axis.

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

117. Bodies near the Poles are heavier than those toward 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 its 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 its 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. A person on the Earth can no more be sensible of its undisturbed motion on its Axis, than one in the cabin of a ship on smooth water can be sensible of the ship's motion when it 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 cabin-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 its motionless Poles in two opposite points of the Heavens lying almost in our Equinoctial, To the different Planets the Heavens appear to turn round on different Axes.

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 upward 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 diurnal

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 its 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 cieling of the cabin, 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 cabin as in a fixed chamber. As for those scripture expressions which seem to contradict the Earth's motion, the following reply may be made to them all: 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 literal 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 any

Objections against the Earth's diurnal motion answered.

community. *Moses* call 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 its own, but by reflecting the light of the Sun. *Moses* might know this, but had he 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 its 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 toward 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 downward. But let either go

PLATE II. Fig. I.

Antipodes.

Pl. II.

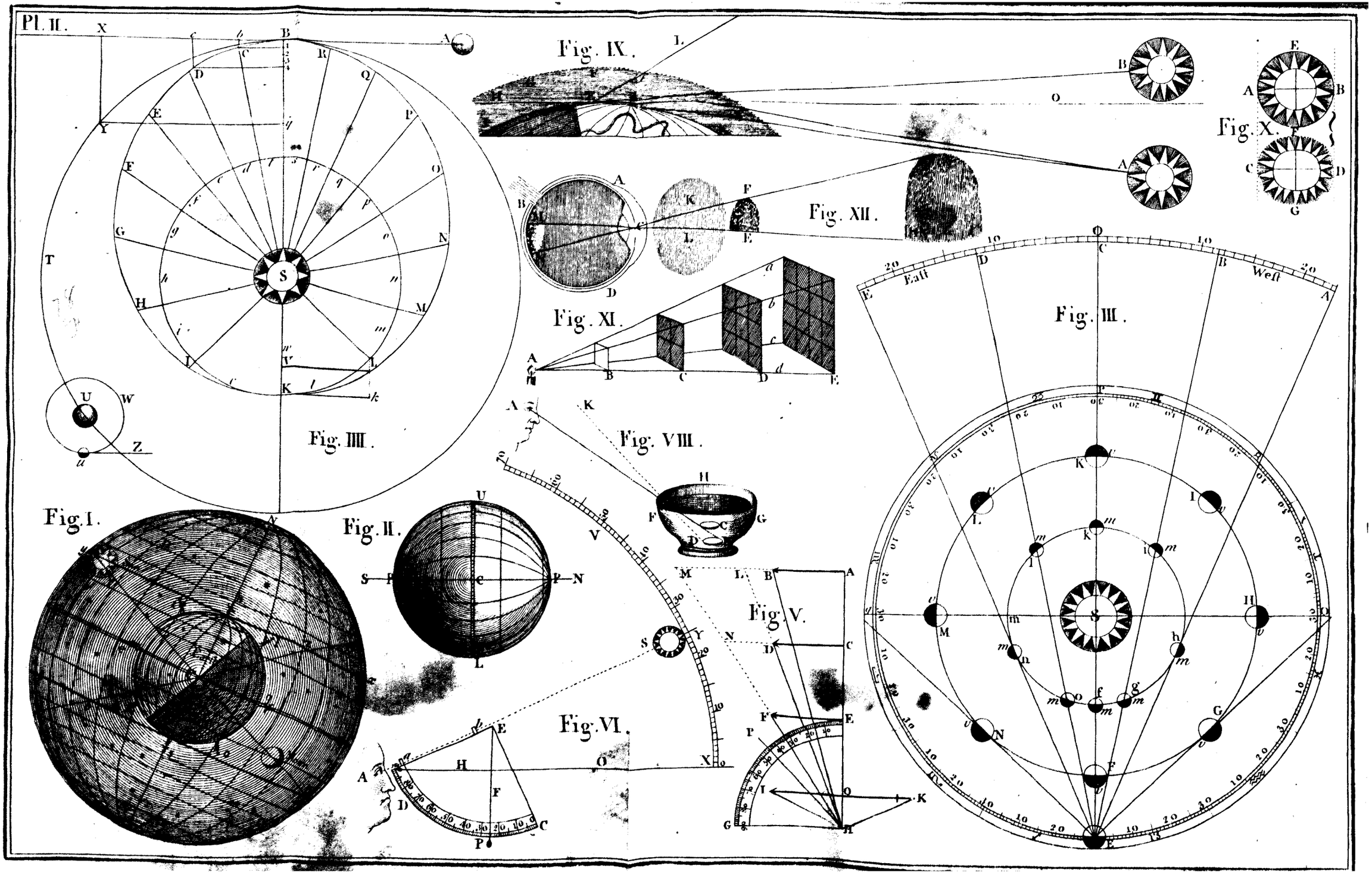


Fig. IX.
Fig. X.
Fig. XII.
Fig. XI.
Fig. III.
Fig. IIII.
Fig. VIII.
Fig. I.
Fig. II.
Fig. V.
Fig. VI.
East
West

go to the other, and he will tell him that he stood as upright and firm on the place where he was, as he now stands where he is. To all these observers the Sun, Moon, and Stars, seem to turn round the points *N* and *S*, as the Poles of the fixed Axis *NCS*; because the Earth does really turn round the mathematical line *nCs* as round an Axis, of which *n* is the North Pole, and *s* the South Pole. The inhabitant *U* (Fig. II.) affirms, that he is on the uppermost side of the Earth, and wonders how another at *L* can stand on the undermost side with his head hanging downwards. But *U* in the mean time forgets that in twelve hours time he will be carried half round with the Earth, and then be in the very situation that *L* now is, although as far from him as before. And yet, when *U* comes there, he will find no difference as to his manner of standing; only he will see the opposite half of the Heavens, and imagine the Heavens to have gone half round the Earth.

PLATE II.

Axis of the World.

Its Poles.

Fig. II.

123. When we see a Globe hung up in a room, we cannot help imagining it to have an upper and an under side, and immediately form a like idea of the Earth; from whence we conclude, that it is as impossible for people to stand on the under side of the Earth, as for pebbles to lie on the under side of a common Globe, which instantly fall down from it to the ground; and well they may, because the attraction of the Earth being greater than the attraction of the Globe, pulls them away. Just so would be the case with our Earth, if it were placed near a Globe much bigger than itself, such as Jupiter: for then it would really have an upper and an under side with respect to that large Globe; which, by its Attraction, would pull away every thing from the side of the Earth next to it; and only those on its surface at the opposite side could remain upon it. But there is no larger Globe near enough our Earth to overcome its central attraction;

How our Earth might have an upper and an under side.

PLATE II. attraction; and therefore it has no such thing as an upper and an under side; for all bodies on or near its surface, even to the Moon, gravitate toward its 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 toward 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 *E N Q*; and having the North Pole *N* of the Heavens just over his head, his Horizon * coincides with the Celestial Equator *E C Q*. Therefore all the Stars in the Northern Hemisphere *E N Q*, between the Equator and North Pole, appear to turn round the line *N C*, moving parallel to the Horizon. The Equatorial Stars keep in the Horizon, and all those in the Southern Hemisphere *E S Q* are invisible. The like Phenomena are seen by the observer *s* on the South Pole, with respect to the Hemisphere *E S Q*; and to him the opposite Hemisphere is always invisible. Hence, under either Pole, only 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 ♈ *C X*, 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 *E C* ♎ of the North Pole *n*; and the other half *C X* always below it. Therefore while the Sun describes the northern half ♈ *C* of the Ecliptic, he neither sets to the North Pole nor rises to the South; and while he describes the southern half *C X*, 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 its 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 23½ degrees, or the Arc *E y*, 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 *e C q*, as suppose at *e*, he is in the plane of the Celestial Equator; or under the Equinoctial *E C Q*; and the Axis of the Earth *n C s* 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 *N C S*, the whole Heavens *M O L l* 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 *S E N*; but in twelve hours after, he is carried half round the Earth's Axis to *q*, and then the Hemisphere *S Q N* becomes visible to him; and *S E N* 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 its Poles can be seen, the Equator *E C Q*, and all Circles parallel to it, as *D L*, *y z x*, *a b X*, *M O*, &c. will appear to be

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 *.

128. Let us now ſuppoſe that the obſerver has gone from the Equator *e* toward the North Pole *n*, and that he ſtops at *i*, from which place he then ſees the Hemiſphere *MEINL*; 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, while 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 toward the Circle of perpetual Apparition; while the con-

Phenomena between the Equator and Poles.

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

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 *D L* and *M O* are just as far from the Poles *N* and *S* as the observer at *l* (or one opposite to him at *o*) is from the Equator *E C Q*; it is plain, that if an observer begins to travel from the Equator toward 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 its south side, the Sun appears to change his place every day, so as to go once round the Circle *Y C X* every year, § 114. Therefore while the Sun appears to advance northward, from having described the parallel *a b X* touching the Ecliptic in *X*, the days continually lengthen and the nights shorten, until he comes to *y* and describes the Parallel *y z x*, when the days are at the longest and the nights at

the ſhorteſt: for then, as the Sun goes no farther northward, the greateſt portion that is poſſible of the diurnal Arc *y z* is above the Horizon of the inhabitant *i*; and the ſmalleſt portion *z x* below it. As the Sun declines ſouthward from *y*, he deſcribes ſmaller diurnal and greater nocturnal Arcs, or Portions of Circles, every day; which cauſes the days to ſhorten and nights to lengthen, until he arrives again at the Parallel *a b X*; which having only the ſmall part *a b* above the Horizon *M C L*, and the great part *b X* 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 *E C Q* 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, the 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 to or recede farther from the obſerver; the neareſt varying moſt in their ſize. They will alſo move quicker or ſlower with regard to the fixed Stars, but will never be retrogade or ſtationary.

134. If an obſerver in motion views the Heavens, the ſame apparent irregularities will be obſerved, but with ſome variation reſulting from his own motion. If he is on a Planet which has a rotation on its 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, in an oppoſite direction to that which his Planet moves in, changing its 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 place 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

paths which croſs at ſmall Angles in different parts of the Heavens, and then ſeparate a little from one another, § 20. So that, if the Solar Aſtronomer ſhould make the Path or Orbit of any Planet a ſtandard, and conſider it as having no obliquity, § 201, he would judge the paths of all the reſt to be inclined to it; each Planet having one half of its path on one ſide, and the other half on the oppoſite ſide of the ſtandard Path or Orbit. And if he ſhould ever ſee all the Planets ſtart from a conjunction with each other*, Mercury would move ſo much faſter than Venus, as to overtake her again (though not in the ſame point of the Heavens) in a quantity of time almoſt equal to 145 of our days and nights, or, as we commonly call them, *Natural Days*, which include both the days and nights: Venus would move ſo much faſter than the Earth, as to overtake it again in 585 natural days: the Earth ſo much faſter than Mars, as to overtake him again in 778 ſuch days: Mars ſo much faſter than Jupiter, as to overtake him again in 817 ſuch days: and Jupiter ſo much faſter than Saturn, as to overtake him again in 7236 days, all of our time.

The judgment that a ſolar Aſtronomer would probably make concerning the diſtances and bulks of the Planets.

136. But as our ſolar Aſtronomer could have no idea of meaſuring the courſes of the Planets by our days, he would probably take the period of Mercury, which is the quickeſt moving Planet, for a meaſure to compare the periods of the others by. As all the Stars would appear quieſcent to him, he would never think that they had any dependance upon the Sun; but would naturally imagine that the Planets have, becauſe they move round the Sun. And it is by no means improbable, that he

* Here we do not mean ſuch a conjunction, as that the nearer Planet ſhould hide all the reſt from the obſerver's ſight; (for that would be impoſſible, unleſs the interſections of all their Orbits were coincident, which they are not. *See* § 21.) but when they were all in a line croſſing the ſtandard Orbit at Right Angles.

would

Plate III.

Fig. I.

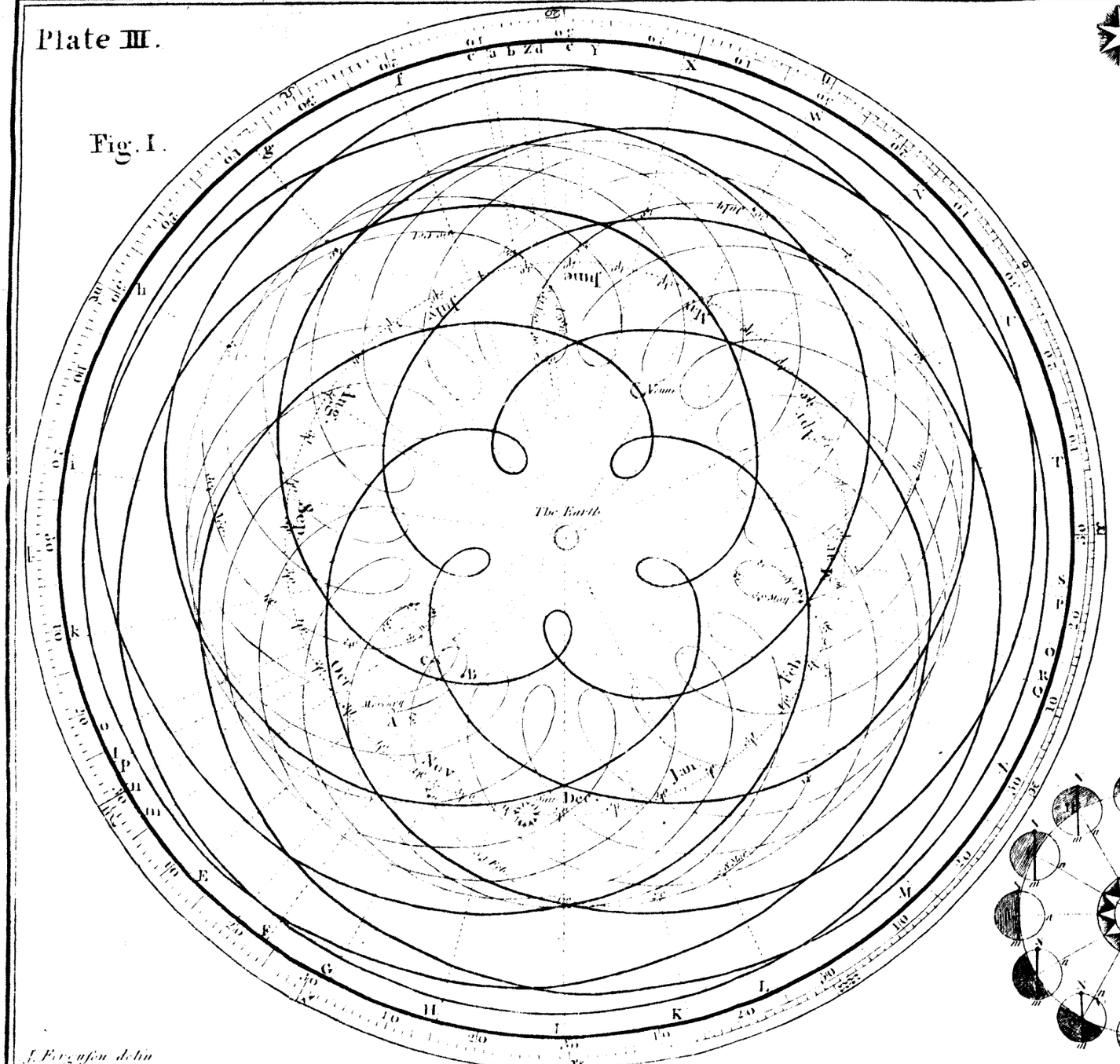


Fig. II.

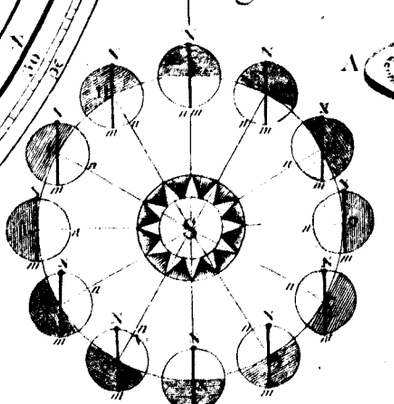


Fig. III.

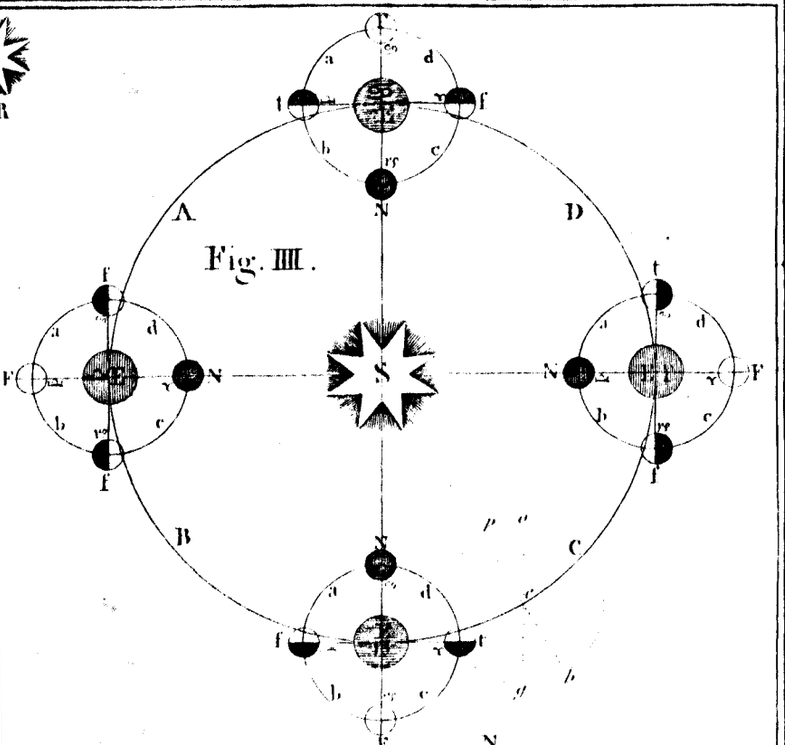
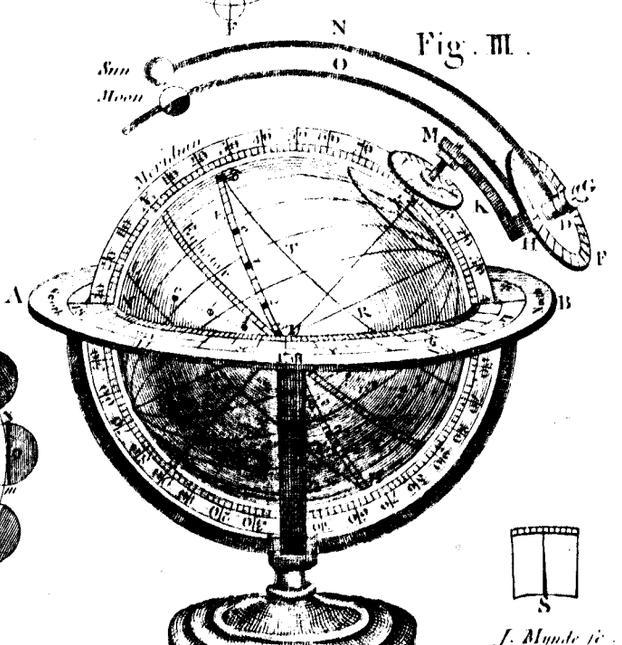


Fig. IV.



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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 its longer period. Mercury and the Earth would ſeem much of the ſame bulk; but by comparing its 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 its Orbit than in the oppoſite, and to move quickeſt when it ſeems biggeſt, the obſerver would be at no loſs to conclude that all the Planets move in Orbits, of which the Sun is not preciſely in the center.

The Planetary motions very irregular as ſeen from the Earth.

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-

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 irregularities; 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, and Venus, the Earth, and Moon, according to the *Copernican System*. Having taken off the Sun, Mercury, 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 its center in going round the Sun; and the paste-board kept its 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 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* toward *B* (between the Earth and left-hand corner of the Plate) and as seen from the Earth, his motion 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 *B F*. While he goes from *B* to *C*, the line *B F*, 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 of that month he will appear in the Heavens Fig. I.

as at 20, near *F*; on the 20th he will be seen as 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 ☋, 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 ☋ 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 hypothesis were true, Mercury and Venus could never be hid behind the Sun, as their Orbits are included within the Sun's: and again, these two Planets would always move direct, and be as often in Opposition to the Sun as in Conjunction with him. But the contrary of all this is true: for they are just as often behind the Sun as before him, appear as often to move backward as forward, and are so far from being seen at any time in the side of the Heavens opposite to the Sun, that they were never seen a quarter of a circle in the Heavens distant from him.

141. These two Planets, when viewed at different times with a good telescope, appear in all the various shapes of the Moon; which is a plain proof that they are enlightened by the Sun, and shine not by any light of their own: for if they did, they would constantly appear round as the Sun does; and could never be seen like dark spots upon the Sun when they pass directly between him and us. Their regular Phases demonstrate them to be spherical bodies; as may be shewn by the following experiment: Appearances of Mercury and Venus.

Hang an ivory ball by a thread, and let any person move it round the flame of a candle, at two or three yards distance from your eye; when the ball is beyond the candle, so as to be almost hid by the flame, its enlightened side will be toward you, and appear round like the Full Moon: When the ball is between you and the candle, its enlightened side will disappear, as the Moon does at the Change: When it is half-way between these two positions, it will appear half illuminated, like the Moon in her Quarters: But in every other place between these positions, it will appear more or less 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 seem either horned or gibbous. Experiment to prove they are round.

PLATE II. Experiment to represent the motions of Mercury and Venus.

142. If you remove about six or seven yards from the candle, and place yourself so that its flame may be just about the height of your eye, and then desire the other person to move the ball slowly round the candle as before, keeping it as near of an equal height with the flame as he possibly can, the ball will appear to you not to move in a circle, but to vibrate backward and forward like a pendulum, moving quickest when it is directly between you and the candle, and when directly beyond it; and gradually slower as it goes farther to the right or left side of the flame, until it appears at the greatest distance from the flame; and then, though it continues to move with the same velocity, it will seem to stand still for a moment. In every Revolution it will shew all the above Phases, § 141; and if two balls, a smaller and a greater, be moved in this manner round the candle, the smaller ball being kept nearest the flame, and carried round almost three times as often as the greater, you will have a tolerable good representation of the apparent Motions of Mercury and Venus; especially if the bigger ball describes a circle almost twice as large in diameter as the circle described by the lesser.

Fig. III.

143. Let *ABCDE* be a part or segment of the visible Heavens, in which the Sun, Moon, Planets, and Stars, appear to move at the same distance from the Earth *E*. For there are certain limits, beyond which the eye cannot judge of different distances; as is plain from the Moon's appearing to be as far from us as 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 the letters. When Mercury is at *f*, he disappears to the Earth at *E*, because his enlightened side is turned from it; unless he be then in one of his Nodes, § 20, 25; in which case he will appear like a dark spot upon the Sun. When he is at *g* in his Orbit, he appears at *B* in the Heavens, westward

The Elongations or Digressions 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*, but 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 it 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* goes 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 to Fig. III. The Elongations and phases of Venus.

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.

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.

Morning and Evening Star, what.

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 while 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 *h* 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 its 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 its annual path before Venus comes round again.

The Elongations of all Saturn's inferior planets as ſeen from him.

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.

A proof of the Earth's annual Motion.

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 its exiſtence, the Planets could never fall from the tangents of their

PLATE II. their Orbits toward 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 toward 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 toward 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 toward 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 magni-

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

fied

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 Eccentricities 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 its 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 its 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 its 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 its 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

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 each other, the Planet obeying them both will move in the circle *BYTU**.

152. But if, while the projectile force would carry 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 describe the arcs *BC*, *CD*, *DE*, *EF*, &c. all in equal times. Having its 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. its 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*, its projectile force is as much diminished from its mean state about *G*

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.

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 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 toward *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 its 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 *B D*, as is evident by the Figure. But, in as much time as the Planet moves from *B* to *C* in the higher part of its 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 its annual course. These Areas are represented by the triangles *B SC*, *C SD*, *D SE*, *E SF*, &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 on 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 its Orbit, that is, through four times as much space; but its 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 its falling from *K* to *w*, through a greater space than gravity can draw it, while the projectile force is such as would carry it from *K* to *k*: and therefore the Planet ascends in its Orbit *KLMN*, decreasing in its 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 Eccentricities 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 eccentricities.

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 a 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 proportion of

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

* Astronomical Principles of Religion, p. 66.

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 its 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 its 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 ποῦ στῶ, καὶ τὸν κοσμὸν κινήσω, *i. e.* Give me a place to stand on, and I shall move the Earth.

will

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 muſt be in the ſame proportion to the length of the ſhort one. Now, ſuppoſe a man to pull, or preſs 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, 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.

Hence Gravity should seem to arise from the agency of some subtle matter pressing toward 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 quanties 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 more an absurdity, to suppose the Deity capable of infusing a Law, or what Law 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; while 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. What-

162. Whatever Gravity be, it is plain that it acts every moment of time: for if its action ſhould 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 amnng 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, while 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 mutually attract 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 a 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 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 its 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. Its proportional Quantities on the different Planets. Its Refractions in Water and Air. The Atmoſphere; its 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 particles of light out of a burning candle; which number contains at leaſt

The amazing ſmallneſs of the particles of light.

* Religious Philoſopher, Vol. III. p. 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 as 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 its 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 wholly 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 or a table, facing a row of lighted candles standing by one another; then place a sheet of paper on 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 hindrance 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, toward 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 its 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-fourth, 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 its 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 to *A*; that is, 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

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 *D B*; which will be all in view when the bason is full, and appear as if lifted up to *C*. For the ray *A E B*, which was straight while the bason was empty, is now bent at the surface of the water in *E*, and turned out of its rectilineal course into the direction *E D*. Or, in other words, the ray *D E K*, that proceeded in a straight line from the edge *D* while 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 *D E K*, goes in the angled direction *D E A*, and by entering the eye at *A* renders the object *D B* 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 downward 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 on it, 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 being 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.

X 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 its diurnal motion, and goes round the Sun with it

it every year. This fluid is of an elastic or springy nature, and its lowest part, being pressed by the weight of all the Air above it, is pressed the closest together; and therefore the atmosphere is densest of all at the Earth's Surface, and becomes gradually rarer higher up. "It is well known* that the Air nearer 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 the Air at all heights whatsoever, supposing the expansion thereof to be reciprocally proportional to its 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 its rarity or expansion, supposing gravity to decrease in the duplicate ratio of the distances from the Earth's centre. 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 common pumps.

to the numbers expressed by the larger figures, as $0.^{17}1224$ for 0.00000000000000001224, 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	$0.^{207}7895$	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 upward is rarified in such manner, that a sphere of that Air which is nearest the Earth but of one inch diameter, if dilated to an equal rarefraction 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 distances, is at least 3400^{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 29½ inches high. And if the tube were a square inch wide, it would at that height contain 29½ cubic inches of mercury, which is just 15 pounds 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 pounds 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 counterbalanced by the spring of the Air diffused through all parts of our bodies, it is not in the least degree felt by us.

A common mistake about the weight of the Air.

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 above 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.

Without an Atmosphere the Heavens would always appear dark, and we should have no twilight.

177. According to * Dr. KEILL, and other astronomical writers, it is entirely owing to the Atmosphere than 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 toward the Sun, the whole Heavens would appear as dark as in the

* See his Astronomy, p. 232.

night,

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 its rotation has withdrawn our sight from the Sun, the Atmosphere being still higher than we, has the Sun's 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 above 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 its rectilineal

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

course *ACdG*, and bent down to the observer's eye at *E*; who then sees the Sun in the direction of the refracted ray *E d e*, 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 *E f L* 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 32¼ min. of a deg. in breadth, when at his mean distance from the Earth; and the horizontal refraction of his rays is 33½ 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.; and at the Zenith, it is nothing; the quantity throughout, is shewn by the annexed table, calculated by Sir Isaac Newton. The quantity of Refraction.

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

Appar. Alt.		Refraction.		Ap. Atl.	Refraction.		Ap. Alt.	Refraction.	
D.	M.	M.	S.	D.	M.	S.	D.	M.	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	9	32
1	0	23	7	25	1	54	60	0	31
1	15	21	20	26	1	49	61	0	30
1	30	19	46	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	26	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 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 *F C G D*, juſt after their riſing, and before their ſetting: the reaſon of which is, the refraction being greater in the Horizon than at any diſtance above it, the lower limb *G* is more elevated by it than the uppermoſt. But although the refraction ſhortens the vertical Diameter *FG*, it has no ſenſible effect on the horizontal Diameter *C D*, which is all equally elevated. When the refraction is ſo ſmall as to be imperceptible, the Sun and Moon appear perfectly round, as *A E B F*.

Fig. X.

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 *I H* and *K H*, 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 *I H* and *K H* meeting each other at *H* make the Angle *I H K*; and the point *H* is supposed to be the center of a Circle, the circumferance of which contains 360 equal parts, called Degrees. A fourth part of a Circle, called a Quadrant, as *G E*, 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 *E G*; but the Angle *E H F* is greater than the Angle *C H D* or *A H L*, because it cuts off a greater Arc.

The nearer an object is to the eye, the bigger it appears, and it is seen under the greater Angle. To illustrate this a little, suppose an Arrow in the position *I K*, 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 *H O*, which is its distance from the eye, divides into halves both the Arrow and the Angle under which it is seen, *viz.* the Arrow into *I O*, *O K*; 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 *I K*, be placed at the distances *H A*, *HC*, *HE*, still perpendicular to, and bisected by the right line *H A*; then will *AB*, *CD*, *EF*, be each equal to, and represent *O I*; and *AB* (the same as *O I*) will be seen from *H* under the Angle *AHB*; but *C D* (the same as *O I*) will be seen under the Angle *C HD*, or *A HL*; and *E F* (the same as *O I*) will be seen under the Angle *EHF*, or *CHN*, or *AHM*. Also *E F*, or *O I*, at the distance *H E*, will appear as long as *ON* would at the distance *HC*, or as *AM* would at the distance *HA*; and *C D*, or *I O*, at the distance *HC*, will appear as long as *A L* would at the distance *H A*.

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: Not 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.

H A. So that as an object approaches the eye, both its Magnitude and the Angle under which it is ſeen increaſe; and the contrary as the object recedes.

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 *F E*, seen by the eye *A B D*, appears under the same Angle *G C H* that the remote object *G H I* does: and the rays *GFCN* and *HECM*, crossing one another at *C* in the pupil of the eye, limit the size of the picture *M N* on the retina, which is the picture of the object *F E*; and if *F E* were taken away, would be the picture of the object *G H I*, only worse defined; because *G H I* being farther off, appears duller and fainter than *F E* did. But when a Fog, as *K L*, comes between the eye and the object *F E*, the object appears dull and ill-defined like *G H I*; which causes our imagination to refer *F E* to the greater distance *C H*, instead of the small distance *C E*, 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 *F E* seems to be as big as *G H I*.

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 sky was seen from low ground) 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 *perigee*, 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.

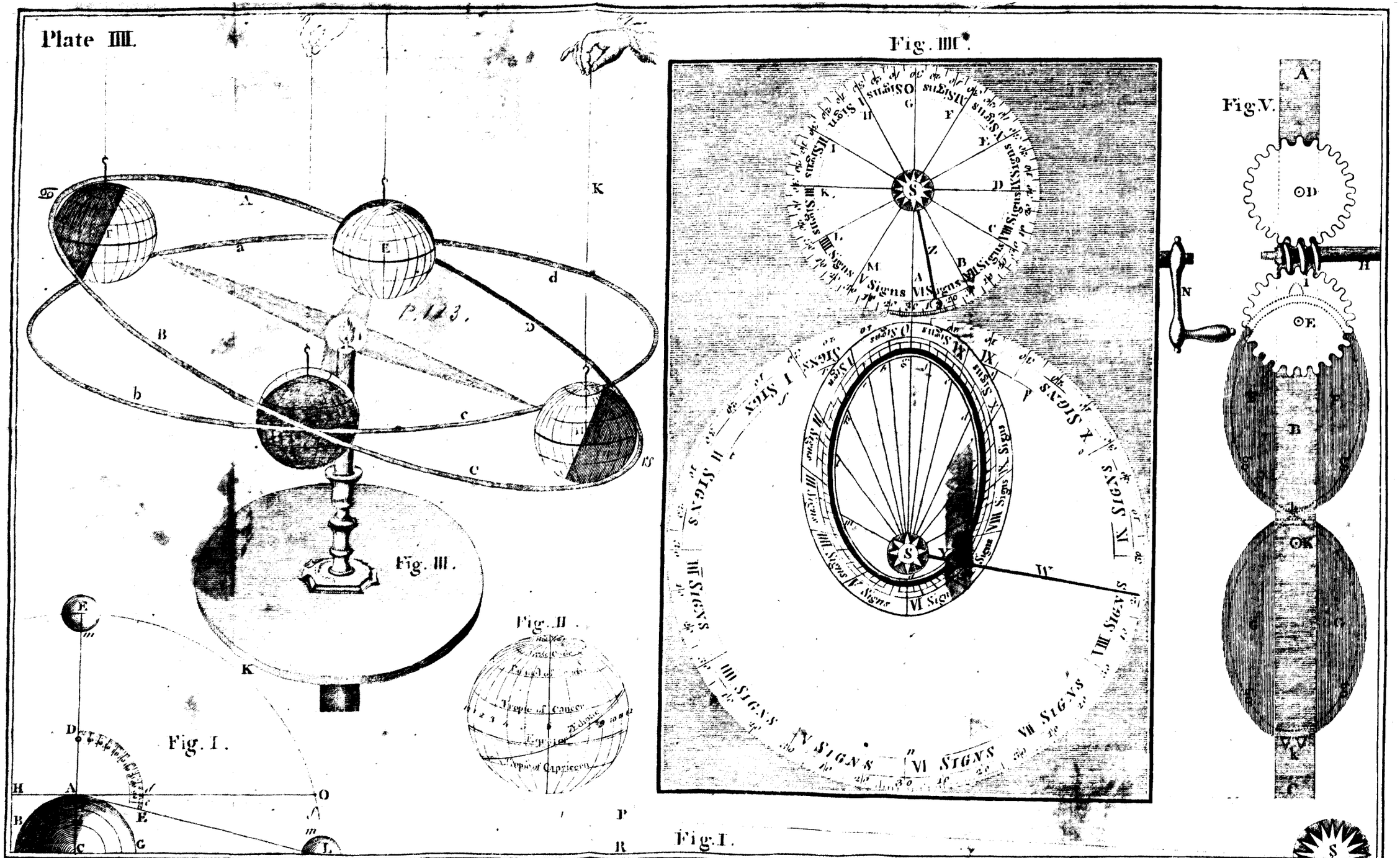
CHAP. IX.

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 Object is an Arc of the Sky intercepted between the Horizon and the Object. In Fig. VI. of Plate II. let *H O X* 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 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 its limb *D P C*, 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 which they ſtand on. 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.



J. Ferguson delin.

J. Mynde Sculp.

any thing of plain Trigonometry, may pafs over the firft Article of this fhort Chapter, and take the Aftronomer's word for it, that the diftances of the Sun and Planets are as ftated in the firft 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 folve a plain right-angled Triangle, the following method of finding the diftances of the Sun and Moon will be eafily underftood. PLATE IV.

Let *BAG* be one half of the Earth, *AC* its femi-diameter, *S* the Sun, *m* the Moon, and *EKOL* a quarter of the Circle defcribed by the Moon in revolving from the Meridian to the Meridian again. Let *CRS* be the rational Horizon of an obferver at *A*, extended to the Sun in the Heavens; and *HAO* his fenfible Horizon, extended to the Moon's Orbit. *ALC* is the Angle under which the Earth's femi-diameter *AC* is feen from the Moon at *L*, which is equal to the Angle *OAL*, becaufe the right lines *AO* and *CL*, which include both thefe Angles, are parallel. *ASC* is the Angle Fig. I.

either fide, and fo that the Horizon at *X* is feen through the fight-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 fo as to look through the fight-holes at any part of the Heavens, fuppofe the Sun at *S*, juft fo many degrees as he elevates the fight-hole *b* above the horizontal line *HOX*, fo many degrees will the plumb-line cut in the limb *CP* of the Quadrant. For, let the obferver's eye at *A* be in the center of the celeftial Arc *XYV* (and he may be faid 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, fuppofe 25 degrees high, and let the obferver hold the Quadrant fo that he may fee the Sun through the fight-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 obfervation. *N. B.* Whoever looks at the Sun muft have a fmoked glafs before his eyes to fave them from hurt. The better way is not to look at the Sun through the fight-holes, but to hold the Quadrant facing the eye at a little diftance, and fo that the Sun fhining through one hole, the ray may be feen to fall on the other.

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 *CRS* 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 may be 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 its plane surface may be parallel to the plane of the Equator, and its edge *AD* in the plane of 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 0, 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 about 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 its 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 *ALC*, to its oppoſite ſide *AD*, 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 its 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 might be found the ſame way, though with more difficulty, if his horizontal Parallax, or the Angle *OAS*, equal to the Angle *ASC*, were not ſo ſmall, as to be hardly perceptible, being ſcarce 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

the Moon's horizontal Parallax, or Angle *OAL*, equal to the Angle *ALC*, is very diſcernible, being 57′ 18″, or 3438″ at its 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

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*.

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 its distance from the Sun, so is the square of the period of any other Planet to the cube of its distance, such parts or measures as the Earth's distance was taken; see § 111. This proportion gives 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 demonstrated by Sir ISAAC NEWTON *.

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

* All the following calculations on the next page, except those in the two last lines before § 195, were printed in former editions of this work, before the year 1761. Since that time, the said two lines (as found by the Transit A. D. 1761) were added; and also § 195.

Periodical

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

Mercury	Venus	The Earth	Mars	Jupiter	Saturn	Georgian
87 9692	224.6176	365.2564	686.9785	4332.514	1079.275	30456.07

Relative mean distances from the Sun.

38710	72333	100000	152369	520096	954006	1908580

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	124,942,680	426,478,720	782,284,020	1,565,035,600

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

29,032,500	54,238,070	75,000,000	114,276,750	390,034,500	715,564,500	1,431,435,000

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

2,709,700	5,074,990	7,000,000	10,665,830	36,444,220	66,780,420	133,600,600

But, from the late Transit of Venus, A. D. 1761, the Sun's Parallax appears to be only 8″ $\frac{5}{10}$; and according to that, their real distances in miles are

36,841,468	68,891,486	95,173,127	145,014,148	494,690,976	907,956,130	1,816,455,526

And their diameters, in miles, are

3100	9360	7970	5130	94,100	77,990	35,226

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, in 1761, which we must confess was embarrassed with several difficulties. But another Transit of Venus over the Sun has now been observed, on the third of *June*, 1769, much better suited to the resolution of this great Problem than that in 1761 was; and the result of the observations does not differ materially from the result of those in 1761. Another Transit will not happen till the year 1874.

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

Why the celestial Poles seem to keep still

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

the

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, its 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 *Draconis*; 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 Heaven 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.

in the same points of the Heavens, notwithstanding the Earth's motion round the Sun.

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 completes all its 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 its 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 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

The amazing velocity of light.

* SMITH's Optics, § 1197.

hour,

PLATE IV. hour, shews that Light flies at the rate of more 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. 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 $23\frac{1}{2}$ 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 its centre, 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 centre of the Earth, perpendicular to the Equator, and terminating in the Poles at its 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, and turned

Fig. II.

Equator, Tropics, Polar Circles, and Poles.

Fig. II.

Earth's Axis.

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 centre 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 pleasing experiment, shewing the different lengths of days and nights, and the variety of seasons.

be in or near the centre. Then, having twisted the thread as toward 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 its 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 its centre 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 its 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 its 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 its 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 its 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 perpendi-

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 its 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 its places into the light. If the Earth were to continue in the like part of its 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, toward the arctic Circle, they would have longer days and shorter nights; while 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 its Axis, move your hand slowly forward, so as to carry the Globe from *H* toward *E*, and the boundary of light and darkness will approach toward the north Pole, and recede from 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, while 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 its Orbit; the candle is directly over the Equator, the boundary of light and darkness just reaches to both the Poles, and Autumnal Equinox.

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 toward the light, and the south Pole toward 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 Equator, which is always equally cut by the circle bounding light and darkness.

201. The

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 a 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 its annual course round the Sun, considering its Orbit as having no inclination, and its Axis as inclining 23½ degrees from a line perpendicular to the plane of its Orbit, and keeping the same oblique direction in all parts of its 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 its Orbit, equidistant from one another; *N s* its Axis, *N* its north Pole, *s* its south Pole, and *S* the Sun nearly in the center of the Earth's Orbit, § 18. As the Earth goes round the Sun PLATE V. Fig. I.

* All Circles appear elliptical 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 its 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. according to the order of the letters *a b c d*, &c. its Axis *N s* keeps the same obliquity; and is still parallel to the line *M N s*. When the Earth is at *a*, its north pole inclines toward 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* its 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 its center *S*, looking down upon it from its north Pole; and as the Earth's Orbit differs but very little from a Circle, we shall have its 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* is the Equator, *T* the Tropic of Cancer, the *dotted Circle*

The seasons shewn in another view of the Earth and its Orbit.

Plate V.

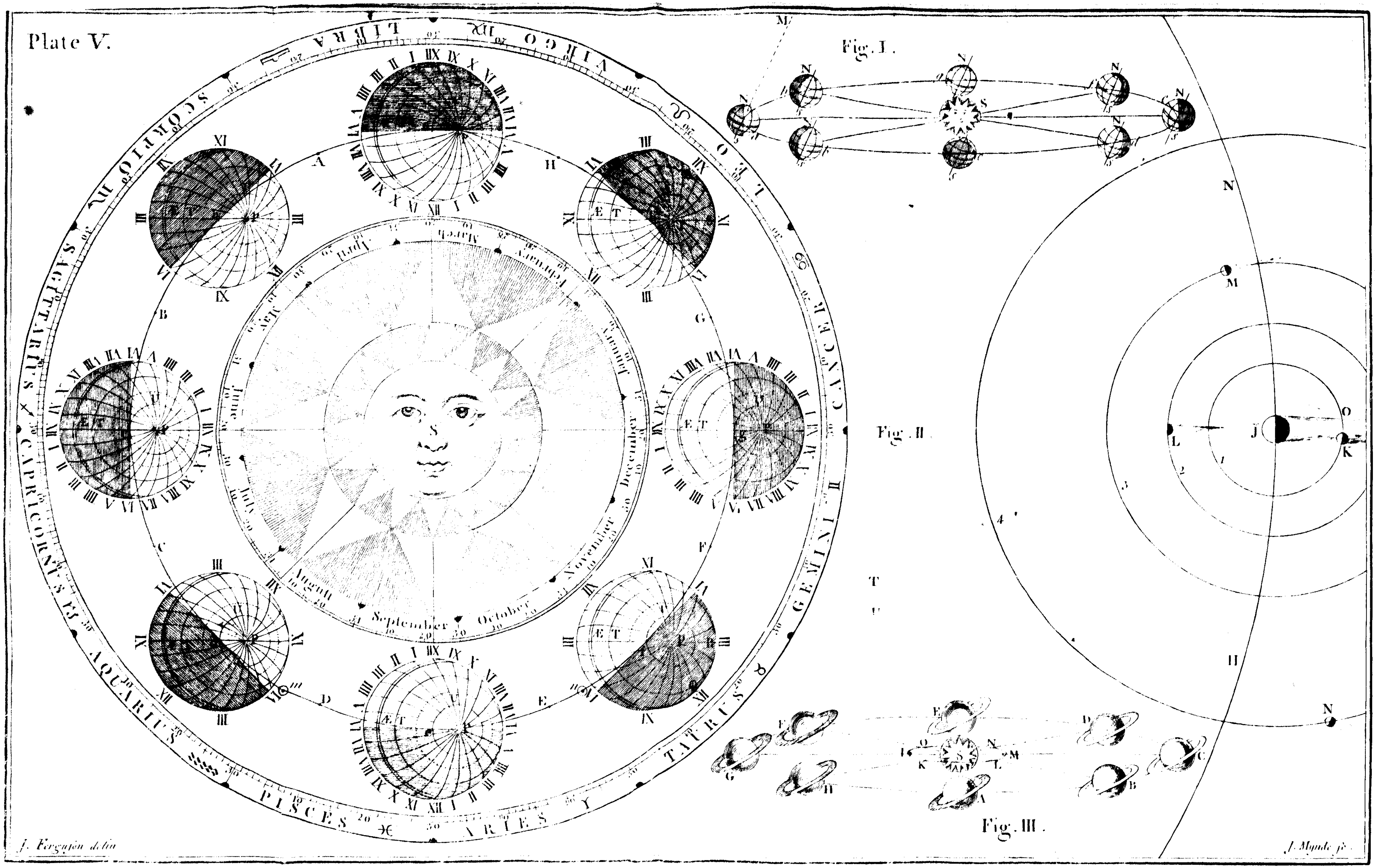


Fig. I.
Fig. II.
Fig. III.
LIBRA
VIRGO
LEO
CANCER
GEMINI
TAURUS
ARIES
PISCES
AQUARIUS
CAPRICORNUS
SAGITTARIUS
SCORPIO
March
April
May
June
July
August
September
October
November
December
January
February
J. Ferguson delin.
J. Mynde sc.

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 toward one part of the Heavens, as it does in the figure toward 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 Meridians *Æ* ? *La* 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 *A B C D*, &c. through the Signs Libra, Scorpio, and Sagittarius, the north Pole *P* 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. 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 its Axis.

Fig. II.

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 its north Pole inclines toward 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 toward Aries, and the Sun appears to move from Cancer toward Libra, the north Pole advances toward 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 its parallels equally, or in halves. The north Pole then goes into the dark, and continues in it until the Earth goes half way round its Orbit; or, from the 23d of *September* till the 20th of *March*. In the middle, between

Autumnal Equinox.

between these times, *viz.* on the 22d of *December*, the north Pole is as far as it can be in the dark, which is $23\frac{1}{2}$ degrees, equal to the inclination of the Earth's Axis from a perpendicular to its 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*, § 397. Only this must be noted, that whatever 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 toward the Sun, the southern declines from him. Winter Solstice.

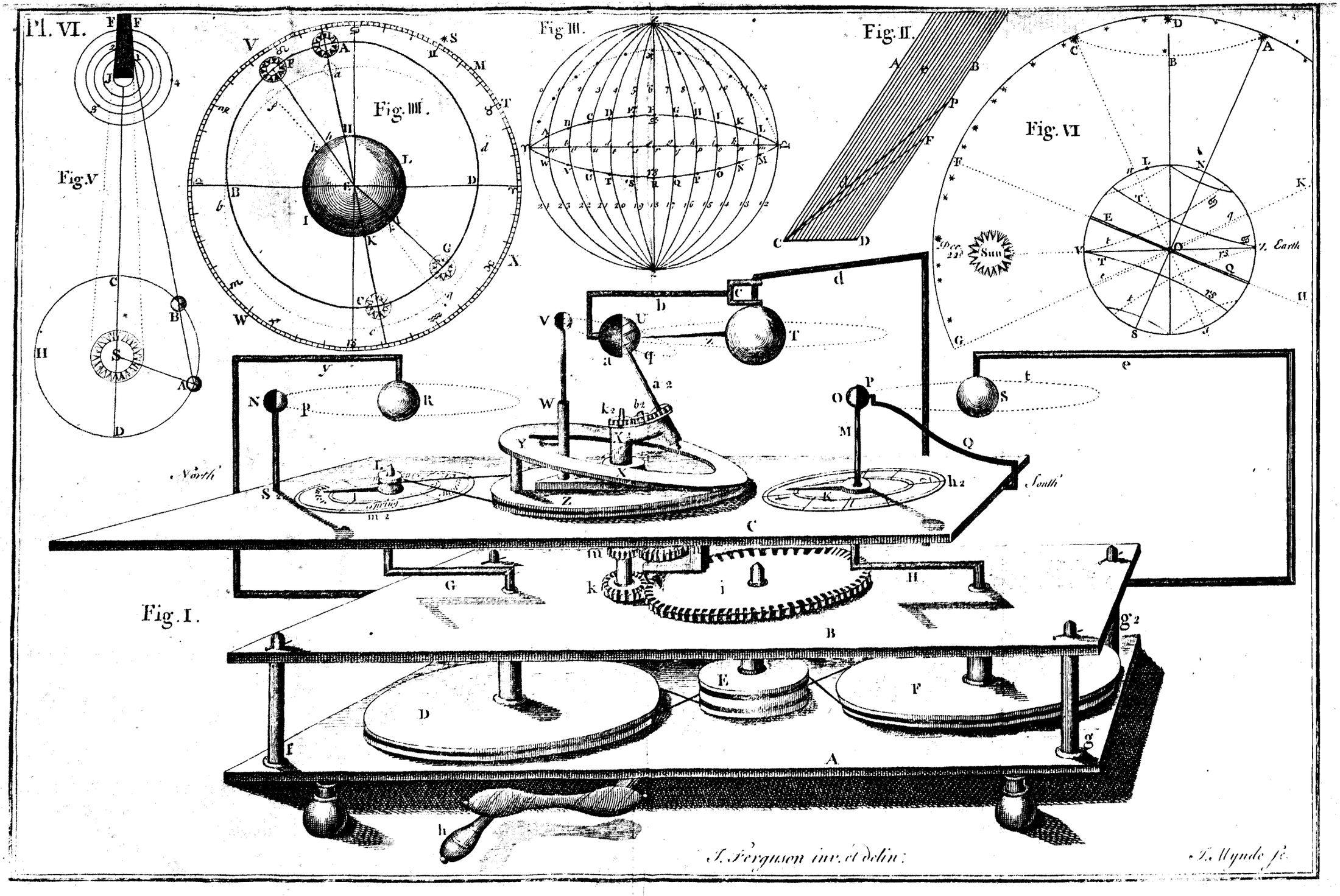
204. As Saturn goes round the Sun, his obliquely posited ring, like our Earth's Axis, keeps parallel to itself, and is therefore turned edgewise to the Sun twice in a Saturnian year, which is almost as long as 30 of our years, § 81. But the ring, though considerably broad, is too thin to be seen by us 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 its 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.

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 accordingly 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 its Orbit whatever, except between *N* and *O*; for while 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 its sides are illuminated, it is invisible to us, because its 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 its 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 while 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

Fig. I. and III. that all the various Phenomena of Saturn's Ring depend upon a cause similar to that of our Earth's seasons,


Pl. VI.
Fig. V
Fig. IIII.
Fig. III.
Fig. II.
Fig. VI
Sun
Earth
Dec. 22
North
South
Fig. I.
J. Ferguson inv. et delin.
T. Mynde sc.

seasons, he will readily allow that they are best explained together; and that the two Figures serve to illustrate each other. PLATE VI.

205. The Earth's Orbit being elliptical, and the Sun keeping constantly in its 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 Article* 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 eccentricity of the Earth's Orbit, or 1,377,000 miles, bears no greater proportion to the Earth's mean distance from the Sun, than 7 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 21st of *June*: but, on the Fig. II.

the 22d of *December*, the line *C D*, or *London*, has the oblique position *C d* 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 *e B* being expended on the space *d P*, which is more than double the length of *C D* or *C d*. 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 toward 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 toward 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 *C F*. 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 Semi-circles, which divide the Equator into 24 equal parts; and as the Earth turns on its Axis, the planes of theſe Semi-circles come ſucceſſively one after another every hour to the Sun. As in a hour of time there is a revolution of fifteen 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. A 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 its Axis, he riſes to ſome places at the ſame moment of abſolute Time that he ſets at 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 a hour ſooner than on that Meridian; becauſe their Meridian comes

to

to the Sun a hour sooner: and to all places 15 degrees westward, it is noon a hour later, § 208, because their Meridian comes a hour later to the Sun; and so on: every 15 degrees of motion causing a hour's difference of time. Therefore they who have noon a hour later than we, have their Meridian, that is, their Longitude, 15 degrees westward from us; and they who have noon a 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 much more quickly as they enter into Jupiter's shadow, and emerge more suddenly out of it. The first or nearest Satellite to Jupiter is the most advantageous for this purpose, because its motion is quicker than the motion of any of the rest, and therefore its immersions and emersions are more frequent and more sudden than those of the others are.

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 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 ♃ 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 otherwise material than to find the Earth readily in this scheme, where it is shewn in eight different parts of its Orbit. Let ♀ 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 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 ♀ and *R*, and that *R* is three hours forwarder in reckoning than ♀, it must be 45 degrees of east Longitude from the Meridian of ♀. Were this method as practicable at sea as at land, any sailor might almost as easily, and with almost equal certainty, find the Longitude as the Latitude. Fig. II. Illustrated by an example.

214. While the Earth is going from *C* to *F* in its Orbit, only the immersions of Jupiter's Satel- 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, while the Earth is between *D* and *E*, or between *G* and *A*; but never of the first Satellite, on account of the smallness of its 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 behind 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 while the Earth goes once round the Sun, Jupiter describes a twelfth part of his Orbit. And therefore, when the Earth has finished its 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 $16\frac{1}{2}$ minutes of time to go through a space equal to the Diameter of the Earth's Orbit, which is 190 millions of miles in length; and consequently the particles of Light fly about 193 thousand 939 miles every second of time, which is above a million of times swifter than the motion of a cannon-ball. And as light is $16\frac{1}{2}$ minutes in travelling across the Earth's Orbit, it must be $8\frac{1}{4}$ minutes in coming from the Sun to us; therefore, if the Sun were annihilated, we should see him for $8\frac{1}{4}$ minutes after; and if he were again created, he would be $8\frac{1}{4}$ minutes old before we could see him.

PLATE VI

Plate 6

The surprising velocity of Light.

217. To explain the progressive motion of Light, let *A* and *B* be the Earth, in two different parts of its Orbit, whose distance from each other is 95 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 $8\frac{1}{4}$ minutes sooner when the Earth is at *B*, than when it is at *A*. And so, as Mr. ROEMER 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 its 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*, its diſtance from the Sun.

218. As the Earth moves from *D* to *C*, through the ſide *AB* of its 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 its 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 toward 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 eccentric 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.

200. 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. / Thirds	Min. / Sec. / Thirds	* Min. / Sec. / Thirds	Deg. / Min. / Sec. / Thirds	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	430	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 equatorial 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
	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 its Axis, any given Meridian will revolve from any Star to the same Star again in every absolute turn of the Earth on its 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 its Orbit in the time that it turns eastward round its 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, 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 its Axis the same way from the Sun to the Sun again in 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 *Nm* be any particular Meridian of the Earth, and *N* a given point or place upon that Meridian. Fig. II.

When the Earth is at *A* the Sun *S* hides the Star *R*, which would be always hid if the Earth never removed from *A*; and consequently, as the Earth turns rounds its 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 its Orbit from *A* to *B*, its motion round its 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 *N B n* 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 its 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 its Meridian. When the Earth comes to *D*, the point *N* will have the Star on its 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 *A S D* is a right Angle, and so is *N D n*; that is, the Earth has advanced 90 degrees in its Orbit, and must turn 90 degrees on its Axis to carry the point *N* from the Star to the Sun: for the Star always comes to the Meridian when *N m* is parallel to *R S A*; because *D S* is but a point in respect to *R S*. 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 its 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	21	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	44	11	1	48	14	0	55	3
15	225	36	58	15	3	45	37	45	11	16	51	15	0	58	59
16	240	39	25	16	4	0	39	46	11	31	53	16	1	2	55
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	42
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	12	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	18
26	391	4	4	26	6	31	4	56	14	2	18	26	1	42	14
27	406	6	32	27	6	46	7	57	14	17	20	27	1	46	10
28	421	8	59	28	7	1	9	58	14	32	23	28	1	50	5
29	436	11	27	29	7	16	11	59	14	47	25	29	1	54	1
30	451	13	55	30	7	31	14	60	15	2	28	30	1	57	57

PLATE III.

An absolute turn of the Earth on its Axis never finishes a solar day.

222. Thus it is plain, that an absolute turn of the Earth on its Axis (which is always completed when any particular Meridian comes to be parallel to its 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 its 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 its Axis; and therefore, as a turn of the Earth on its 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 equally 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 its place at *A* would have its solar and sydereal days always of the same length; and so would have one solar day more than the other at its return. Hence, if the Earth turned but once round its 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, intituled,

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.

CHAP. XIII.

Of the Equation of Time.

224. THE Earth's motion on its 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 its Axis perpendicular to its Orbit. But the Earth's diurnal motion on an inclined Axis, and its 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 14th of *April*, the 15th of *June*, the 31st of *August*, and the 23d of *December*. The clock, if it goes equably and true all the year round, will be before the Sun

The Sun and Clocks equal only one four days of the year.

from the 23d of *December* till the 14th of *April*; from that time till the 16th of *June* the Sun will be before the clock; from the 15th of *June* till the 31st of *August* the clock will be again before the Sun; and from thence to the 23d 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 52 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 56 minutes 1 second past eleven: in the former case, the clock is 5 minutes 52 seconds before the Sun; and in the latter case, the Sun is 3 minutes 59 seconds faster than the clock. 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 its 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 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

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 its 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 its 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, namely, the obliquity of the Ecliptic, and the unequal motion of the Earth in it, we ſhall firſt explain

Equation of natural days explained.

explain the effects of these causes separately, and then the united effects resulting from their combination.

228. The Earth's motion on its Axis being perfectly equable, or always at the same rate, and the * plane of the Equator being perpendicular to its 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 equatorial 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 equatorial 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, let us henceforth call him the real Sun, and the other, which is supposed to move in the Equator,

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.

the

the fictitious: to which last, the motion of a well-regulated clock always answers. PLATE VI.

Let Z ♈ z ♎ be the Earth, $ZFRz$ its Axis, *abcde*, &c. the Equator, $A\,B\,C\,D\,E$, &c. the northern half of the Ecliptic from ♈ to ♎ on the side of the Globe next the eye, and $M\,N\,O\,P$, &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 while 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.

While 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 in coming to it: and as both Suns come at the same moment to the point ♎, they come to the Meridian at the moment of noon by the Clock.

In

In departing from Libra, through the third quadrant, the real Sun going through *MNOPQ* toward ♑ at *R*, and the fictitious Sun through *m n o p q* toward *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 ♑ toward ♈; and the fictitious Sun through *stuvw*, from *r* toward ♈, 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.

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 the Sun's place is ♉ Taurus 12 degrees, he is 9 minutes 47 seconds faster than the clock; and

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

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	23	8	45	30
1	0	20	8	34	8	35	29
2	0	40	8	43	8	24	28
3	1	0	8	53	8	13	27
4	1	19	9	1	8	0	26
5	1	39	9	9	7	48	25
6	1	59	9	17	7	34	24
7	2	18	9	24	7	20	23
8	2	37	9	30	7	6	22
9	2	56	9	35	6	50	21
10	3	15	9	40	6	35	20
11	3	34	9	44	6	18	19
12	3	52	9	47	6	2	18
13	4	11	9	50	5	44	17
14	4	28	9	52	5	27	16
15	4	46	9	53	5	8	15
16	5	3	9	54	4	50	14
17	5	20	9	54	4	31	13
18	5	37	9	53	4	11	12
19	5	53	9	51	3	52	11
20	6	09	9	49	3	32	10
21	6	25	9	46	3	11	9
22	6	40	9	42	2	51	8
23	6	54	9	37	2	30	7
24	7	9	9	32	2	9	6
25	7	22	9	26	1	48	5
26	7	36	9	19	1	26	4
27	7	48	9	12	1	5	3
28	8	0	9	4	0	43	2
29	8	12	8	55	0	22	1
30	8	23	8	45	0	0	0
2d Q. 4th Q.	♍ ♓		♌ ♒		♋ ♑		Deg.
Sun slower than the Clock in							

This Table is formed by taking the difference between the sun's longitude and its right ascention, and turning it into time.

230. This

PLATE III. 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 while theſe balls move once round the Globe according to the order of Signs, the Clock turns the Globe 366 times round its Axis weſtward. The Stars will make 366 diurnal revolutions from the brazen Meridian to it again, and the two balls repreſenting the real and fictitious Suns 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 way enough 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, and ſometimes later, than the time when it is noon by the clock; and on four days of the year, at the ſame time; while 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 its north Pole, and the ſilver ball round the Equator by a wire from its 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 ♈ ♐ ♎, the equal diviſions from ♈ to ♐ 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 ♐ 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. IV.

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 motion on its 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 the 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 *ABCD* be the Ecliptic or Orbit in

Fig. IV.

in which the real Sun moves, and the dotted Circle *a b c d* 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 its 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 *E H*, 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 *E H* 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* toward *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 its reſpective Orbit; and then being in conjunction, the Meridian *E H* revolving to *E K* 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 while the fictitious Sun moves from *c* to *g*,

PLATE VI. the real Sun moves through a greater arc from *C* to *G*: consequently the point *K* has its noon by the Clock when it comes to *k*, but not its 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 while the Sun goes from *C* to *A*, sooner while 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 *A E C*, 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 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 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 *A B C* of its Orbit, the solar noon precedes

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 *C D A* 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 sum is eleven minutes one 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													
	0 Signs.		1		2		3		4		5		
D.	M.	S	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	
0	0	0	3	47	6	36	7	43	6	45	3	56	30
1	0	8	3	54	6	40	7	43	6	41	3	49	29
2	0	16	4	1	6	44	7	43	6	37	3	41	28
3	0	24	4	8	6	48	7	43	6	32	3	34	27
4	0	32	4	14	6	52	7	42	6	28	3	27	26
5	0	40	4	21	6	56	7	42	6	24	3	19	25
6	0	47	4	27	6	59	7	41	6	19	3	12	24
7	0	55	4	34	7	2	7	40	6	14	3	4	23
8	1	3	4	40	7	6	7	39	6	9	2	57	22
9	1	11	4	47	7	9	7	38	6	4	2	49	21
10	1	19	4	53	7	12	7	37	5	59	2	41	20
11	1	27	4	59	7	14	7	36	5	54	2	34	19
12	1	34	5	5	7	17	7	35	5	49	2	26	18
13	1	42	5	11	7	20	7	33	5	43	2	18	17
14	1	50	5	17	7	22	7	31	5	38	2	10	16
15	1	57	5	22	7	24	7	29	5	32	2	2	15
16	2	5	5	28	7	27	7	27	5	26	1	54	14
17	2	13	5	34	7	29	7	25	5	20	1	46	13
18	2	20	5	39	7	31	7	23	5	14	1	38	12
19	2	28	5	44	7	32	7	20	5	8	1	30	11
20	2	35	5	50	7	34	7	18	5	2	1	22	10
21	2	43	5	55	7	35	7	15	4	56	1	14	9
22	2	50	6	0	7	37	7	12	4	50	1	6	8
23	2	57	6	5	7	38	7	9	4	43	0	58	7
24	3	5	6	10	7	39	7	6	4	37	0	49	6
25	3	12	6	14	7	40	7	3	4	30	0	41	5
26	3	19	6	19	7	41	7	0	4	23	0	33	4
27	3	26	6	24	7	41	6	56	4	17	0	25	3
28	3	33	6	28	7	42	6	53	4	10	0	17	2
29	3	40	6	32	7	42	6	49	4	3	0	8	1
30	3	47	6	36	7	43	6	45	3	56	0	0	0
	11 Signs		10		9		8		7		6		D.
Sun slower than the Clock if his Anomaly be													

This Table is formed by turning the Equation of the Sun's Center (see p. 316) into time.

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. Consequently, when these 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 these points. But the Apogee at present 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 these Signs, nor at any time of the year, except when the swiftness or slowness of the Equation resulting from one cause just balances the slowness or swiftness arising from the other.

243. The second table in the following Chapter shews the Sun's place in the Ecliptic at the noon of every day by the Clock, for the second year after Leap-year; and also the Sun's Anomaly to the nearest degree, neglecting the odd minutes of that degree. Its use is only to assist 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 shall give a few examples presently. The next Tables which follow them are made from those two; and shew the absolute Equation of Time resulting from the combination of both its causes; in which the minutes as well as degrees, both of the Sun's Place and Anomaly, are considered. The use of these Tables is already explained, § 225; and they serve for every day in Leap-year, and the first, second, and third years after: For on most of the same days of all these years the Equation differs, because of the odd six hours more than the 365 days of which the year consists.

EXAMPLE I. On the 14th of *April*, the Sun is in the 25th degree of ♈ Aries, and his Anomaly is 9 Signs 15 degrees; the Equation resulting from

Examples for making Equation Tables.

from the former is 7 minutes 22 seconds of time too fast, § 229; and from the latter, 7 minutes 24 seconds two slow, § 241; the difference is 2 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 8 degrees 11 minutes of ♍ Virgo (which we call the 8th degree, as it is so near), and his Anomaly is 1 Sign 29 Degrees; the Equation arising from the former is 6 minutes 40 seconds too slow; and from the latter 6 minutes 32 seconds too fast; the difference being only 8 seconds too slow at noon, and decreasing toward an equality, will make the Sun and Clocks equal in the evening of that day.

EXAMPLE IV. On the 23d of *December*, the Sun's place is 1 degree 58 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.

245. 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 its Axis, there is more matter accumulated all around the Equatorial 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, 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. 17¼ sec. of time, or 50 seconds of a degree, before he completes 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 completes the *Sydereal Year*, which contains 365 days 6 hours 9 minutes 14½ seconds. The *Sydereal Year* is therefore 20 minutes 17½ seconds longer than the Solar or Tropical Year, and 9 minutes 14½ 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 17½ 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*.

tic

A TABLE *shewing the Precession of the Equinoctial Points in the Heavens, both in Motion and Time; and the Anticipation of the Equinoxes on the Earth.*

Julian years.	Precession of the Equinoctial Points in the Heavens.								Anticipation of the Equinoxes on the Earth.			
	Motion.				Time.							
	s	°	′	″	Days	H.	M.	S.	D.	H.	M.	S.
1	0	0	0	50	0	0	20	17½	0	0	11	3
2	0	0	1	40	0	0	40	35	0	0	22	6
3	0	0	2	30	0	1	0	52½	0	0	33	9
4	0	0	3	20	0	1	21	10	0	0	44	12
5	0	0	4	10	0	1	41	27½	0	0	55	15
6	0	0	5	0	0	2	1	45	0	1	6	18
7	0	0	5	50	0	2	22	2½	0	1	17	21
8	0	0	6	40	0	2	42	20	0	1	28	24
9	0	0	7	30	0	3	2	37½	0	1	39	27
10	0	0	8	20	0	3	22	55	0	1	50	30
20	0	0	16	40	0	6	45	50	0	3	41	0
30	0	0	25	0	0	10	8	45	0	5	31	30
40	0	0	33	20	0	13	31	40	0	7	22	0
50	0	0	41	40	0	16	54	35	0	9	12	30
60	0	0	50	0	0	20	17	30	0	11	3	0
70	0	0	58	20	0	23	40	25	0	12	53	30
80	0	1	6	40	1	3	3	20	0	14	44	0
90	0	1	15	0	1	6	20	15	0	16	34	30
100	0	1	23	20	1	9	49	10	0	18	25	0
200	0	2	46	40	2	19	38	20	1	12	50	0
300	0	4	10	0	4	5	27	30	2	7	15	0
400	0	5	33	20	5	15	16	40	3	1	40	0
500	0	6	56	40	7	1	5	50	3	20	5	0
600	0	8	20	0	8	10	55	0	4	14	30	0
700	0	9	43	20	9	20	44	10	5	8	55	0
800	0	11	6	40	11	6	33	20	6	3	20	0
900	0	12	30	0	12	16	22	30	6	21	45	0
1000	0	13	53	20	14	2	11	40	7	16	10	0
2000	0	27	46	40	28	4	23	20	15	8	20	0
3000	1	11	40	0	42	6	35	0	23	0	30	0
4000	1	25	33	20	56	8	40	40	30	10	40	0
5000	2	9	26	40	70	10	58	20	38	8	50	0
6000	2	23	20	0	84	13	10	0	46	1	0	0
7000	3	7	13	20	98	15	21	40	53	17	10	0
8000	3	21	6	40	112	17	33	20	61	9	20	0
9000	4	5	0	0	126	19	45	0	69	1	30	0
10000	4	18	53	20	140	21	56	40	76	17	40	0
20000	9	7	46	40	281	19	53	20	153	11	20	0
25920	12	0	0	0	365	6	0	0	198	21	36	0

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 *S T* 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 completes the grand celestial period: within which any number and its 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 $2^s\ 20^\circ\ 2'\ 30''$ since the creation; which is as much as the Sun moves in $81^d\ 5^h\ 0^m\ 52^s$. 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	o	′	″	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 next following Table, page 159, 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.

it

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 where the significant figures are 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 365¼ diurnal rotations on its Axis, while 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 required 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 its 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 explain the Phenomena by a Diagram.

Fig. VI. Let *NZSVL* be the Earth, *SONA* its 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 *BQ* its Axis, both which are immoveable

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 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 to *A*, is 47 degrees in diameter, or double the inclination of the Earth's Axis. In consequence of this motion, 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 backward a degree every 72 years, will be directed toward the Star or point *B* in 6480 years from this time: and in twice that time, or 12,960 years, it will be directed toward 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 *e O q*, the Tropic of Cancer *T* ♋ *Z* into *V t* ♋ and the Tropic of Capricorn *VT* ♑ into *t* ♑ *Z*; as is evident by the Figure; and the Sun, when in that part of the Heavens where he is now over the

* The Equinoctial Circle intersects the Ecliptic in two opposite points; namely, the first points of the signs *Aries* and *Libra:* 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

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. And it will require 12,960 years more, or 25,920 from the 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.

A 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	14½	365	6	365	5	48	57
2	730	12	18	29	730	12	730	11	37	54
3	1095	18	27	43½	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	8	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	0
60	21915	9	14	30	21915	6	21914	12	57	0
70	25567	22	46	55	25567	12	25566	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	228730	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		1095726	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	2952051	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 its 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.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	11 ♑	23	6	2	12 ♒	56	7	4	11 ♓	10	8	2	11 ♈	57	9	3
2	12	24	6	3	13	57	7	5	12	10	8	3	12	56	9	4
3	13	25	6	4	14	58	7	6	13	10	8	4	13	55	9	5
4	14	27	6	5	15	58	7	7	14	10	8	5	14	54	9	6
5	15	28	6	6	16	59	7	8	15	10	8	6	15	53	9	7
6	16	29	6	7	18	00	7	9	16	10	8	7	16	52	9	8
7	17	30	6	8	19	01	7	10	17	10	8	8	17	51	9	8
8	18	31	6	9	20	01	7	11	18	10	8	9	18	49	9	9
9	19	32	6	10	21	02	7	12	19	09	8	10	19	48	9	10
10	20	34	6	11	22	03	7	13	20	09	8	11	20	47	9	11
11	21	35	6	12	23	03	7	14	21	09	8	12	21	46	9	12
12	22	36	6	13	24	04	7	15	22	09	8	13	22	44	9	13
13	23	37	6	14	25	04	7	16	23	09	8	14	23	43	9	14
14	24	38	6	15	26	05	7	17	24	08	8	15	24	42	9	15
15	25	39	6	16	27	06	7	18	25	08	8	16	25	40	9	16
16	26	40	6	17	28	06	7	19	26	08	8	17	26	39	9	17
17	27	42	6	18	29	07	7	20	27	07	8	18	27	38	9	18
18	28	43	6	19	♓	07	7	21	28	07	8	19	28	36	9	19
19	29	44	6	20	1	07	7	22	29	06	8	20	39	35	9	20
20	♒	45	6	21	2	08	7	23	♈	06	8	21	♉	33	9	21
21	1	46	6	22	3	08	7	24	1	05	8	22	1	32	9	22
22	2	47	6	23	4	08	7	25	2	05	8	23	2	30	9	23
23	3	48	6	24	5	09	7	26	3	04	8	24	3	28	9	24
24	4	49	6	25	6	09	7	27	4	03	8	25	4	27	9	25
25	5	50	6	26	7	09	7	28	5	03	8	26	5	25	9	26
26	6	51	6	28	8	09	7	29	6	02	8	27	6	23	9	27
27	7	52	6	29	9	10	8	0	7	01	8	28	7	21	9	28
28	8	53	7	0	10	10	8	1	8	00	8	29	8	20	9	29
29	9	53	7	1					9	00	9	0	9	18	10	0
30	10	54	7	2					9	59	9	1	10	16	10	1
31	11	55	7	3					10	58	9	2				

A TABLE

A TABLE shewing the Sun's true place, and distance from its 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	11	♉ 14	10	2	11	♊ 04	11	2	9	♋ 42	0	0	9	♌ 18	1	0
2	12	12	10	3	12	01	11	3	10	39	0	1	10	16	1	1
3	13	10	10	4	12	59	11	4	11	37	0	2	11	13	1	2
4	14	08	10	5	13	56	11	5	12	34	0	3	12	11	1	3
5	15	06	10	6	14	53	11	6	13	31	0	4	13	08	1	4
6	16	04	10	7	15	51	11	6	14	28	0	5	14	06	1	5
7	17	02	10	8	16	48	11	7	15	25	0	6	15	03	1	6
8	18	00	10	9	17	46	11	8	16	23	0	7	16	01	1	7
9	18	58	10	10	18	43	11	9	17	20	0	8	16	58	1	8
10	19	56	10	11	19	40	11	10	18	17	0	9	17	56	1	9
11	20	54	10	12	20	38	11	11	19	14	0	10	18	54	1	10
12	21	52	10	12	21	35	11	12	20	12	0	11	19	51	1	10
13	22	49	10	13	22	32	11	13	21	09	0	12	20	49	1	11
14	23	47	10	14	23	30	11	14	22	06	0	13	21	47	1	12
15	24	45	10	15	24	27	11	15	23	03	0	14	22	44	1	13
16	25	43	10	16	25	24	11	16	24	01	0	15	23	42	1	14
17	26	41	10	17	26	21	11	17	24	58	0	16	24	40	1	15
18	27	38	10	18	27	19	11	18	25	55	0	17	25	38	1	16
19	28	36	10	19	28	16	11	19	26	53	0	18	26	36	1	17
20	29	34	10	20	29	13	11	20	27	50	0	18	27	33	1	18
21	♊	31	10	21	♋	10	11	21	28	47	0	19	28	31	1	19
22	1	29	10	22	1	08	11	22	29	44	0	20	29	29	1	20
23	2	26	10	23	2	05	11	23	♌	42	0	21	♍	27	1	21
24	3	24	10	24	3	02	11	24	1	39	0	22	1	25	1	22
25	4	22	10	25	3	59	11	25	2	36	0	23	2	23	1	23
26	5	19	10	26	4	56	11	26	3	34	0	24	3	21	1	24
27	6	17	10	27	5	53	11	27	4	31	0	25	4	19	1	25
28	7	14	10	28	6	51	11	27	5	28	0	26	5	17	1	26
29	8	12	10	29	7	48	11	28	6	26	0	27	6	15	1	27
30	9	09	11	0	8	45	11	29	7	23	0	28	7	13	1	28
31	10	06	11	1					8	21	0	29	8	11	1	29

A TABLE shewing the Sun's true place, and distance from its Apogee, for the second Year after Leap-Year.

Days.	September.				October.				November.				December.			
	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	9	♍09	2	0	8	♎28	2	29	9	♏17	4	0	9	♐34	5	0
2	10	07	2	1	9	27	3	0	10	17	4	1	10	35	5	1
3	11	05	2	2	10	26	3	1	11	17	4	2	11	36	5	2
4	12	04	2	3	11	25	3	2	12	18	4	3	12	37	5	3
5	13	02	2	4	12	25	3	3	13	18	4	4	13	38	5	4
6	14	00	2	5	13	24	3	4	14	18	4	5	14	39	5	5
7	14	59	2	6	14	23	3	5	15	19	4	6	15	40	5	6
8	15	57	2	7	15	23	3	6	16	19	4	7	16	41	5	7
9	16	55	2	8	16	22	3	7	17	19	4	8	17	42	5	8
10	17	54	2	9	17	21	3	8	18	20	4	9	18	43	5	9
11	18	52	2	9	18	21	3	9	19	20	4	10	19	44	5	10
12	19	51	2	10	19	20	3	10	20	21	4	11	20	45	5	11
13	20	49	2	11	20	20	3	11	21	22	4	12	21	46	5	12
14	21	48	2	12	21	20	3	12	22	23	4	13	22	47	5	13
15	22	46	2	13	22	19	3	13	23	22	4	14	23	49	5	14
16	23	45	2	14	23	19	3	14	24	23	4	15	24	50	5	15
17	24	44	2	15	24	18	3	15	25	23	4	16	25	51	5	16
18	25	42	2	16	25	18	3	16	26	24	4	17	26	52	5	17
19	26	41	2	17	26	18	3	17	27	25	4	18	27	53	5	19
20	27	40	2	18	27	18	3	18	28	25	4	19	28	54	5	20
21	28	39	2	19	28	17	3	19	29	26	4	20	29	55	5	21
22	29	37	2	20	29	17	3	20	♐	27	4	21	♑	56	5	22
23	♎	36	2	21	♏	17	3	21	1	27	4	22	1	58	5	23
24	1	35	2	22	1	17	3	22	2	28	4	23	2	59	5	24
25	2	34	2	23	2	17	3	23	3	29	4	24	4	00	5	25
26	3	33	2	24	3	17	3	24	4	30	4	25	5	01	5	26
27	4	32	2	25	4	17	3	25	5	30	4	26	6	02	5	27
28	5	31	2	26	5	17	3	26	6	31	4	27	7	03	5	28
29	6	30	2	27	6	17	3	27	7	32	4	28	8	05	5	29
30	7	29	2	28	7	17	3	28	8	33	4	29	9	06	6	0
31					8	17	3	29					10	07	6	1

TABLES

TABLES

OF THE

EQUATION OF TIME,

FOR

LEAP-YEARS AND COMMON YEARS;

Shewing what Time it ought to be by the CLOCK when the SUN's Center is on the Meridian.

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The Biſſextile, or Leap-Year.

Days.	January.			February.			March.			April.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XII	4	02	XII	14	3	XII	12	30	XII	3	42
2		4	30		14	10		12	17		3	24
3		4	58		14	17		12	4		3	6
4		5	25		14	22		11	50		2	48
5		5	52		14	27		11	35		2	30
6	XII	6	19	XII	14	31	XII	11	21	XII	2	13
7		6	45		14	34		11	6		1	55
8		7	10		14	37		10	50		1	38
9		7	35		14	38		10	34		1	21
10		8	0		14	39		10	18		1	4
11	XII	8	24	XII	14	39	XII	10	2	XII	0	48
12		8	47		14	38		9	45		0	32
13		9	10		14	37		9	28		0	17
14		9	32		14	35		9	11		0	1
15		9	53		14	32		8	54	XI	59	47
16	XII	10	14	XII	14	28	XII	8	36	XI	59	32
17		10	34		14	24		8	18		59	18
18		10	53		14	19		8	0		59	4
19		11	12		14	13		7	42		58	51
20		11	30		14	7		7	24		58	38
21	XII	11	47	XII	14	0	XII	7	6	XI	58	26
22		12	3		13	52		6	47		58	14
23		12	19		13	44		6	29		58	2
24		12	34		13	35		6	10		57	51
25		12	48		13	26		5	52		57	41
26	XII	13	0	XII	13	16	XII	5	33	XI	57	31
27		13	13		13	5		5	15		57	21
28		13	25		12	54		4	56		57	12
29		13	36		12	42		4	37		57	4
30		13	45					4	19		56	55
31		13	54					4	0			

A TABLE shewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The Bissextile, or Leap-Year.

Days.	May.			June.			July.			August.		
	H.	M.	S.	H.	M.	S.	H.	M.	S	H.	M.	S.
1	XI	56	48	XI	57	30	XII	3	29	XII	5	51
2		56	41		57	40		3	40		5	47
3		56	34		57	49		3	51		5	42
4		56	28		57	59		4	02		5	36
5		56	23		58	10		4	12		5	30
6	XI	56	18	XI	58	20	XII	4	22	XII	5	23
7		56	14		58	31		4	31		5	16
8		56	10		58	42		4	40		5	2
9		56	7		58	54		4	49		5	0
10		56	5		59	6		4	57		4	51
11	XI	56	3	XI	59	18	XII	5	5	XII	4	41
12		56	1		59	30		5	13		4	31
13		56	0		59	42		5	20		4	21
14		56	0		59	55		5	26		4	10
15		56	01	XII	0	8		5	32		3	58
16	XI	56	2	XII	0	20	XII	5	38	XII	3	46
17		56	4		0	33		5	43		3	33
18		56	6		0	46		5	48		3	20
19		56	9		0	59		5	52		3	7
20		56	12		1	13		5	56		2	52
21	XI	56	16	XII	1	26	XII	5	59	XII	2	38
22		56	20		1	39		6	1		2	23
23		56	25		1	52		6	3		2	7
24		56	31		2	4		6	4		1	52
25		56	36		2	17		6	4		1	35
26	XI	56	43	XII	2	30	XII	6	4	XII	1	18
27		56	50		2	42		6	4		1	1
28		56	57		2	54		6	2		0	44
29		57	5		3	6		6	0		0	26
30		57	13		3	18		5	58		0	8
31		57	21					5	55	XI	59	40

A TABLE shewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The Bissextile, or Leap-Year.

Days.	September.			October.			November.			December.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	59	30	XI	49	22	XI	43	45	XI	49	43
2		59	11		49	3		43	45		50	7
3		58	52		48	45		43	45		50	31
4		58	32		48	27		43	47		50	56
5		58	12		48	9		43	49		51	21
6	XI	57	52	XI	47	52	XI	43	53	XI	51	47
7		57	32		47	36		43	57		52	13
8		57	12		47	19		44	2		52	40
9		56	51		47	4		44	8		53	8
10		56	30		46	48		44	14		53	35
11	XI	56	10	XI	46	33	XI	44	22	XI	54	3
12		55	49		46	19		44	30		54	32
13		55	28		46	6		44	40		55	01
14		55	7		45	52		44	50		55	30
15		54	46		45	40		45	1		56	0
16	XI	54	25	XI	45	28	XI	45	13	XI	56	29
17		54	5		45	16		45	25		56	59
18		53	44		45	6		45	39		57	29
19		53	23		44	55		45	53		57	59
20		53	2		44	46		46	8		58	29
21	XI	52	41	XI	44	37	XI	46	24	XI	58	59
22		52	21		44	29		46	41		59	29
23		52	0		44	21		46	58		59	59
24		51	40		44	14		47	16	XII	0	29
25		51	19		44	8		47	35		0	59
26	XI	50	59	XI	44	2	XI	47	55	XII	1	29
27		50	39		43	57		48	15		1	58
28		50	20		43	53		48	36		2	27
29		50	0		43	50		48	58		2	56
30		49	41		43	48		49	20		3	25
31					43	46					3	54

A TABLE shewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The first Year after Leap-Year.

Days.	January.			February.			March.			April.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XII	4	23	XII	14	9	XII	12	33	XII	3	47
2		4	51		14	16		12	20		3	39
3		5	19		14	21		12	7		3	10
4		5	46		14	27		11	54		2	52
5		6	13		14	31		11	40		2	35
6	XII	6	39	XII	14	34	XII	11	25	XII	2	17
7		7	4		14	37		11	10		2	0
8		7	30		14	39		10	55		1	43
9		7	54		14	40		10	39		1	25
10		8	18		14	40		10	23		1	9
11	XII	8	42	XII	14	39	XII	10	7	XII	0	52
12		9	4		14	38		9	50		0	36
13		9	26		14	36		9	33		0	20
14		9	48		14	33		9	16		0	5
15		10	9		14	30		8	58	XI	59	50
16	XII	10	29	XII	14	25	XII	8	41	XI	59	35
17		10	48		14	20		8	23		59	21
18		11	7		14	15		8	5		59	7
19		11	25		14	9		7	47		58	54
20		11	42		14	2		7	29		58	41
21	XII	11	59	XII	13	54	XII	7	10	XI	58	28
22		12	15		13	46		6	52		58	16
23		12	30		13	37		6	33		58	4
24		12	44		13	28		6	15		57	53
25		12	58		13	18		5	56		57	43
26	XII	13	10	XII	13	8	XII	5	38	XI	57	32
27		13	22		12	57		5	19		57	23
28		13	33		12	45		5	1		57	14
29		13	43					4	42		57	5
30		13	53					4	23		56	57
31		14	1					4	5			

A TABLE shewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The first Year after Leap-Year.

Days.	May.			June.			July.			August.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	56	49	XI	57	27	XII	3	26	XII	5	52
2		56	42		57	36		3	37		5	48
3		56	35		57	46		3	48		5	43
4		56	29		57	56		3	58		5	38
5		56	24		58	6		4	9		5	32
6	XI	56	19	XI	58	17	XII	4	19	XII	5	25
7		56	14		58	27		4	28		5	18
8		56	11		58	38		4	37		5	10
9		56	7		58	50		4	46		5	2
10		56	5		59	2		4	55		4	53
11	XI	56	2	XI	59	14	XII	5	3	XII	4	44
12		56	1		59	26		5	10		4	34
13		56	0		59	38		5	17		4	24
14		56	0		59	50		5	24		4	13
15		56	0	XII	0	3		5	30		4	1
16	XI	56	1	XII	0	16	XII	5	36	XII	3	49
17		56	2		0	29		5	41		3	37
18		56	4		0	42		5	46		3	24
19		56	7		0	55		5	50		3	10
20		56	10		1	8		5	54		2	56
21	XI	56	13	XII	1	21	XII	5	57	XII	2	42
22		56	17		1	34		6	0		2	27
23		56	22		1	47		6	2		2	12
24		56	28		2	0		6	3		1	56
25		56	33		2	13		6	4		1	40
26	XII	56	40	XII	2	25	XII	6	4	XII	1	23
27		56	47		2	38		6	4		1	6
28		56	54		2	50		6	3		0	49
29		57	02		3	02		6	1		0	31
30		57	10		3	14		5	59		0	13
31		57	18					5	56	XI	59	55

A TABLE shewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The first Year after Leap-Year.

Days.	September.			October.			November.			December.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	59	36	XI	49	28	XI	43	46	XI	49	38
2		59	17		49	9		43	46		50	01
3		58	58		48	51		43	47		50	25
4		58	38		48	33		43	48		50	50
5		58	18		48	15		43	50		51	15
6	XI	57	58	XI	47	58	XI	43	53	XI	51	41
7		57	38		47	41		43	57		52	7
8		57	18		47	24		44	1		52	34
9		56	57		47	8		44	7		53	01
10		56	37		46	53		44	13		53	28
11	X	56	16	XI	46	38	XI	44	21	XI	53	56
12		55	55		46	24		44	29		54	25
13		55	34		46	10		44	38		54	54
14		55	13		45	56		44	48		55	23
15		54	52		45	44		44	59		55	52
16	XI	54	31	XI	45	32	XI	45	13	XI	56	22
17		54	11		45	20		45	20		56	51
18		53	50		45	9		45	36		57	21
19		53	29		44	59		45	50		57	51
20		53	8		44	49		46	5		58	21
21	XI	52	47	XI	44	40	XI	46	21	XI	58	51
22		52	27		44	31		46	37		59	22
23		52	6		44	24		46	54		59	52
24		51	46		44	17		47	12	XII	0	22
25		51	25		44	10		47	31		0	52
26	XI	51	5	XI	44	5	XI	47	51	XII	1	21
27		50	45		44	0		48	11		1	51
28		50	26		43	56		48	31		2	20
29		50	6		43	52		48	53		2	50
30		49	47		43	49		49	15		3	19
31					43	47					3	47

A TABLE shewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The second Year after Leap-Year.

Days.	January.			February.			March.			April.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XII	4	15	XII	14	6	XII	12	35	XII	3	50
2		4	43		14	13		12	23		3	32
3		5	11		14	19		12	9		3	14
4		5	38		14	24		11	56		2	56
5		6	5		14	29		11	42		2	38
6	XII	6	31	XII	14	32	XII	11	27	XII	2	20
7		6	57		14	35		11	13		2	3
8		7	22		14	37		10	58		1	46
9		7	47		14	39		10	42		1	29
10		8	12		14	39		10	26		1	12
11	XII	8	35	XII	14	39	XII	10	10	XII	0	56
12		8	58		14	38		9	54		0	40
13		9	21		14	36		9	37		0	24
14		9	43		14	34		9	20		0	9
15		10	4		14	31		9	3	XI	59	54
16	XII	10	24	XII	14	27	XII	8	45	XI	59	39
17		10	44		14	22		8	28		59	25
18		11	3		14	17		8	10		59	11
19		11	22		14	11		7	52		58	58
20		11	39		14	4		7	34		58	45
21	XII	11	56	XII	13	57	XII	7	15	XI	58	32
22		12	12		13	49		6	57		58	20
23		12	27		13	40		6	38		58	8
24		12	41		13	31		6	20		57	56
25		12	55		13	21		6	1		57	45
26	XII	13	7	XII	13	10	XII	5	42	XI	57	35
27		13	19		12	59		5	24		57	25
28		13	30		12	47		5	5		57	15
29		13	40					4	46		57	6
30		13	50					4	27		56	58
31		13	58					4	9			

A TABLE shewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The second Year after Leap-Year.

Days.	May.			June.			July.			August.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	56	50	XI	57	24	XII	3	22	XII	5	53
2		56	43		57	33		3	33		5	49
3		56	36		57	42		3	44		5	44
4		56	30		57	52		3	55		5	39
5		56	24		58	3		4	5		5	33
6	XI	56	19	XI	58	13	XII	4	16	XII	5	27
7		56	15		58	24		4	26		5	20
8		56	11		58	35		4	35		5	13
9		56	7		58	47		4	44		5	5
10		56	5		58	59		4	53		4	56
11	XI	56	3	XI	59	11	XII	5	01	XII	4	47
12		56	1		59	23		5	9		4	38
13		56	0		59	37		5	17		4	27
14		56	0		59	48		5	23		4	17
15		56	0	XII	0	01		5	30		4	5
16	XI	56	1	XII	0	14	XII	5	36	XII	3	53
17		56	2		0	27		5	41		3	41
18		56	4		0	40		5	46		3	28
19		56	7		0	53		5	50		3	15
20		56	10		1	6		5	54		3	1
21	XI	56	13	XII	1	19	XII	5	57	XII	2	46
22		56	17		1	31		6	0		2	31
23		56	22		1	44		6	1		2	16
24		56	27		1	57		6	3		2	0
25		56	32		2	10		6	4		1	44
26	XI	56	38	XII	2	22	XII	6	4	XII	1	27
27		56	45		2	34		6	3		1	10
28		56	42		2	46		6	2		0	53
29		56	59		2	58		6	1		0	35
30		57	7		3	10		5	59		0	17
31		57	15					5	56	XI	59	59

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The ſecond Year after Leap-Year.

Days.	September.			October.			November.			December.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	59	40	XI	49	32	XI	43	46	XI	49	32
2		59	21		49	14		43	46		49	56
3		59	2		48	55		43	46		50	20
4		58	43		48	37		43	48		50	44
5		58	23		48	20		43	50		51	9
6	XI	58	4	XI	48	3	XI	43	53	XI	51	35
7		57	44		47	46		43	57		52	1
8		57	23		47	29		44	1		52	28
9		57	3		47	14		44	7		52	55
10		56	43		46	58		44	13		53	23
11	XI	56	22	XI	46	43	XI	44	20	XI	53	51
12		56	1		46	29		44	28		54	19
13		55	41		46	15		44	37		54	48
14		55	20		46	1		44	47		55	17
15		54	59		45	48		44	57		55	46
16	X.	54	38	XI	45	36	XI	45	8	XI	56	15
17		54	17		45	24		45	20		56	45
18		53	56		45	13		45	33		57	14
19		53	35		45	2		45	47		57	44
20		53	14		44	52		46	2		58	14
21	XI	52	53	XI	44	42	XI	46	17	XI	58	44
22		52	32		44	34		46	33		59	14
23		52	11		44	26		46	50		59	44
24		51	51		44	18		47	7	XII	0	14
25		51	30		44	11		47	26		0	44
26	XI	51	10	XI	44	6	XI	47	45	XII	1	13
27		50	50		44	0		48	5		1	43
28		50	30		43	56		48	26		2	12
29		50	11		43	52		48	47		2	42
30		49	51		43	50		49	9		3	11
31					43	48					3	40

A TABLE shewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The third Year after Leap-Year.

Days.	January.			February.			March.			April.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XII	4	8	XII	14	4	XII	12	38	XII	3	55
2		4	36		14	11		12	25		3	36
3		5	4		14	17		12	12		3	18
4		5	32		14	23		11	59		3	0
5		5	59		14	28		11	45		2	43
6	XII	6	25	XII	14	32	XII	11	31	XII	2	25
7		6	51		14	35		11	17		2	8
8		7	17		14	37		10	2		1	51
9		7	42		14	39		10	46		1	34
10		8	6		14	40		10	31		1	17
11	XII	8	30	XII	14	40	XII	10	14	XII	1	1
12		8	53		14	39		9	58		0	44
13		9	16		14	37		9	41		0	29
14		9	38		14	35		9	24		0	13
15		9	59		14	31		9	7	XI	59	58
16	XII	10	20	XII	14	27	XII	8	49	XI	59	43
17		10	39		14	23		8	32		59	28
18		10	58		14	17		8	14		59	14
19		11	17		14	11		7	55		59	0
20		11	34		14	5		7	37		58	47
21	XII	11	51	XII	13	57	XII	7	19	XI	58	34
22		12	7		13	49		7	0		58	22
23		12	22		13	41		6	42		58	10
24		12	36		13	32		6	23		57	58
25		12	50		13	22		6	4		57	47
26	XII	13	3	XII	13	12	XII	5	46	XI	57	37
27		13	15		13	1		5	27		57	27
28		13	27		12	50		5	8		57	17
29		13	37					4	50		57	8
30		13	47					4	31		57	0
31		13	56					4	13			

A TABLE shewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The third Year after Leap-Year.

Days.	May.			June.			July.			August.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	56	52	XI	57	22	XII	3	20	XII	5	54
2		56	45		57	31		3	31		5	50
3		56	38		57	41		3	42		5	46
4		56	32		57	51		3	53		5	41
5		56	26		58	1		4	4		5	35
6	XI	56	21	XI	58	12	XII	4	14	XII	5	29
7		56	17		58	23		4	24		5	22
8		56	13		58	34		4	34		5	15
9		56	9		58	45		4	43		5	7
10		56	6		58	57		4	52		4	58
11	XI	56	4	XI	59	8	XII	5	0	XII	4	49
12		56	2		59	21		5	8		4	40
13		56	1		59	33		5	15		4	29
14		56	0		59	45		5	22		4	19
15		56	0		59	58		5	28		4	7
16	XI	56	1	XII	0	10	XII	5	34	XII	3	55
17		56	2		0	23		5	39		3	43
18		56	4		0	36		5	44		3	30
19		56	6		0	49		5	48		3	17
20		56	8		1	1		5	52		3	3
21	XI	56	11	XII	1	14	XII	5	55	XII	2	48
22		56	15		1	27		5	58		2	34
23		56	20		1	40		6	0		2	19
24		56	25		1	53		6	2		2	3
25		56	30		2	6		6	3		1	47
26	XI	56	36	XII	2	18	XII	6	3	XII	1	31
27		56	43		2	31		6	3		1	14
28		56	50		2	44		6	2		0	57
29		56	57		2	56		6	1		0	39
30		57	5		3	8		5	59		0	22
31		57	13					5	57		0	4

A TABLE shewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The third Year after Leap-Year.

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

*** OBSERVE by a good Meridian Line, or by a Tranſit Inſtrument, properly fixed, the Moment when the Sun's Center is on the Meridian; and ſet the Clock to the Time marked in the preceding Table for that Day of the Year. Then if the Clock goes true, it will point to the Time ſhewn in the Table every Day afterward at the Inſtant when it is Noon by the Sun, which is when his Center is on the Meridian.—Thus, in the firſt Year after Leap-Year, on the 20th of October, when it is Noon by the Sun, the true equal Time by the Clock is only 44 Minutes 49 Seconds paſt XI; and on the laſt Day of December (in that Year) it ſhould be 3 Minutes 47 Seconds paſt XII by the Clock when the Sun's Center is on the Meridian.

The following Table was made from the preceding one, and is of the common form of a Table of the Equation of Time, ſhewing how much a Clock regulated to keep mean or equal Time is before or behind the Apparent or Solar Time every Day of the Year.

A

TABLE

OF THE

EQUATION OF TIME,

SHEWING

How much a CLOCK ſhould be FASTER or SLOWER than the SUN, at the Noon of every Day in the Year, both in Leap-Years and Common Years.

[*The Aſteriſks in the Table ſhew where the Equation changes to Slow or Faſt.*]

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The Biſſextile, or Leap-Year.

Days.	Jan.		Feb.		March.		April.		May.		June.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4	2	14	3	12	30	3	42	3	12	2	30
2	4	30	14	10	12	17	3	24	3	19	2	20
3	4	58	14	16	12	4	3	6	3	26	2	11
4	5	25	14	22	11	50	2	48	3	32	2	1
5	5	52	14	27	11	35	2	30	3	37	1	51
6	6	19	14	31	11	21	2	13	3	42	1	40
7	6	45	14	34	11	6	1	55	3	46	1	29
8	7	10	14	37	10	50	1	38	3	50	1	18
9	7	35	14	38	10	34	1	21	3	53	1	6
10	8	00	14	39	10	18	1	4	3	55	0	54
11	8	24	14	39	10	2	0	48	3	57	0	42
12	8	47	14	38	9	45	0	32	3	59	0	30
13	9	10	14	37	9	28	0	17	4	00	0	18
14	9	32	14	35	9	11	0	1	4	00	0	5
15	9	53	14	32	8	54	0*	13	3	59	0*	8
16	10	14	14	28	8	36	0	28	3	58	0	21
17	10	34	14	24	8	18	0	42	3	56	0	33
18	10	53	14	19	8	00	0	56	3	54	0	46
19	11	12	14	13	7	42	1	9	3	51	0	59
20	11	30	14	7	7	24	1	22	3	48	1	13
21	11	47	14	00	7	6	1	34	3	44	1	26
22	12	3	13	52	6	47	1	46	3	40	1	39
23	12	19	13	44	6	29	1	57	3	35	1	52
24	12	34	13	35	6	10	2	8	3	30	2	5
25	12	48	13	26	5	52	2	19	3	24	2	17
26	13	1	13	16	5	33	2	29	3	17	2	30
27	13	13	13	5	5	15	2	39	3	10	2	42
28	13	25	12	54	4	56	2	48	3	3	2	54
29	13	36	12	42	4	37	2	56	2	55	3	6
30	13	46			4	19	3	4	2	47	3	18
31	13	55			4	00			2	39		

Clock faſter. Clock ſlower.

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The Biſſextile, or Leap-Year.

Days.	July.		Auguſt.		Sept.		October.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	3	29	5	51	0	30	10	38	16	15	10	17
2	3	40	5	47	0	49	10	57	16	15	9	53
3	3	51	5	42	1	8	11	15	16	15	9	29
4	4	1	5	36	1	28	11	33	16	13	9	4
5	4	12	5	30	1	48	11	51	16	11	8	39
6	4	22	5	23	2	8	12	8	16	7	8	13
7	4	31	5	16	2	28	12	24	16	3	7	47
8	4	40	5	8	2	48	12	41	15	58	7	20
9	4	49	5	00	3	9	12	56	15	52	6	52
10	4	57	4	51	3	30	13	12	15	46	6	25
11	5	5	4	41	3	50	13	27	15	38	5	57
12	5	13	4	31	4	11	13	41	15	29	5	28
13	5	20	4	21	4	32	13	55	15	20	4	59
14	5	26	4	10	4	53	14	8	15	10	4	30
15	5	32	3	58	5	14	14	20	14	59	4	00
16	5	38	3	46	5	35	14	32	14	47	3	31
17	5	43	3	33	5	56	14	44	14	34	3	1
18	5	48	3	20	6	16	14	54	14	21	2	31
19	5	52	3	6	6	37	15	5	14	7	2	1
20	5	56	2	52	6	58	15	14	13	52	1	31
21	5	59	2	38	7	19	15	23	13	36	1	1
22	6	1	2	23	7	40	15	31	13	19	0	31
23	6	3	2	7	8	00	15	39	13	2	0	1
24	6	4	1	51	8	20	15	46	12	44	0	*29
25	6	4	1	35	8	41	15	52	12	25	0	59
26	6	4	1	18	9	1	15	58	12	5	1	29
27	6	4	1	1	9	21	16	3	11	45	1	58
28	6	2	0	44	9	41	16	7	11	24	2	27
29	6	00	0	26	10	00	16	10	11	2	2	56
30	5	58	0	8	10	19	16	12	10	40	3	25
31	5	55	0	*11			16	14			3	54

Clock faſter. Clock flower. Clock flower. Clock faſter.

A TABLE of the Equation of Time, shewing how much a Clock should be faster or slower than the Sun, every Day of the Year, at Noon.

The first Year after Leap-Year.

Days.	Jan.		Feb.		March.		April.		May.		June.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4	23	14	9	12	33	3	47	3	11	2	33
2	4	51	14	16	12	20	3	29	3	18	2	24
3	5	19	14	21	12	7	3	10	3	25	2	14
4	5	46	14	26	11	54	2	52	3	31	2	4
5	6	13	14	31	11	40	2	35	3	36	1	54
6	6	39	14	34	11	25	2	17	3	41	1	43
7	7	4	14	37	11	10	2	00	3	45	1	33
8	7	30	14	39	10	55	1	43	3	49	1	22
9	7	54	14	40	10	39	1	26	3	53	1	10
10	8	18	14	40	10	23	1	9	3	55	0	58
11	8	41	14	39	10	7	0	52	3	57	0	46
12	9	4	14	38	9	50	0	36	3	59	0	34
13	9	26	14	36	9	33	0	20	4	00	0	22
14	9	48	14	33	9	16	0	5	4	00	0	10
15	10	9	14	29	8	58	0	* 10	4	00	0	* 3
16	10	29	14	25	8	41	0	25	3	59	0	16
17	10	48	14	20	8	23	0	39	3	58	0	29
18	11	7	14	15	8	5	0	53	3	56	0	42
19	11	25	14	9	7	47	1	6	3	53	0	55
20	11	42	14	2	7	29	1	19	3	50	1	8
21	11	59	13	54	7	10	1	32	3	47	1	21
22	12	15	13	46	6	52	1	44	3	42	1	34
23	12	30	13	37	6	33	1	56	3	38	1	47
24	12	44	13	28	6	15	2	7	3	32	2	00
25	12	58	13	18	5	56	2	17	3	26	2	13
26	13	10	13	8	5	38	2	28	3	20	2	25
27	13	22	12	57	5	19	2	37	3	13	2	38
28	13	33	12	45	5	00	2	46	3	6	2	50
29	13	43			4	42	2	55	2	58	3	2
30	13	52			4	23	3	3	2	50	3	14
31	14	1			4	5			2	42		

Clock faster. Clock slower.

A TABLE of the Equation of Time, shewing how much a Clock should be faster or slower than the Sun, every Day of the Year, at Noon.

The first Year after Leap-Year.

Days.	July.		August.		Sept.		October.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	3	26	5	52	0	24	10	32	16	14	10	22
2	3	37	5	48	0	43	10	51	16	14	9	59
3	3	48	5	43	1	2	11	9	16	13	9	35
4	3	58	5	38	1	22	11	27	16	12	9	10
5	4	9	5	32	1	42	11	45	16	10	8	45
6	4	19	5	25	2	2	12	2	16	7	8	19
7	4	28	5	18	2	22	12	19	16	3	7	53
8	4	37	5	10	2	42	12	35	15	59	7	26
9	4	46	5	2	3	3	12	51	15	53	6	59
10	4	55	4	53	3	23	13	7	15	47	6	31
11	5	3	4	44	3	44	13	22	15	39	6	3
12	5	10	4	34	4	5	13	36	15	31	5	35
13	5	17	4	24	4	26	13	50	15	22	5	6
14	5	24	4	13	4	47	14	3	15	12	4	37
15	5	30	4	1	5	8	14	16	15	1	4	8
16	5	36	3	49	5	29	14	28	14	50	3	38
17	5	41	3	37	5	50	14	40	14	37	3	9
18	5	46	3	24	6	10	14	51	14	24	2	39
19	5	50	3	10	6	31	15	1	14	10	2	9
20	5	54	2	56	6	52	15	11	13	55	1	39
21	5	57	2	42	7	13	15	20	13	39	1	9
22	6	00	2	27	7	33	15	29	13	23	0	38
23	6	2	2	12	7	54	15	30	13	6	0	8
24	6	3	1	56	8	14	15	43	12	48	0	*22
25	6	4	1	40	8	35	15	50	12	29	0	52
26	6	4	1	23	8	55	15	55	12	9	1	22
27	6	4	1	6	9	15	16	00	11	49	1	51
28	6	3	0	49	9	34	16	4	11	28	2	20
29	6	1	0	31	9	54	16	8	11	7	2	50
30	5	59	0	13	10	13	16	11	10	45	3	19
31	5	56	0	*5			16	13			3	47

Clock faster. Clock slower.

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The ſecond Year after Leap-Year.

Days.	Jan.		Feb.		March.		April.		May.		June.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4	15	14	6	12	35	3	50	3	10	2	36
2	4	43	14	13	12	23	3	32	3	17	2	27
3	5	11	14	19	12	9	3	14	3	24	2	17
4	5	38	14	24	11	56	2	56	3	30	2	8
5	6	5	14	28	11	42	2	38	3	36	1	57
6	6	31	14	32	11	27	2	20	3	41	1	47
7	6	57	14	35	11	13	2	3	3	45	1	36
8	7	22	14	37	10	58	1	46	3	49	1	25
9	7	47	14	39	10	42	1	29	3	52	1	13
10	8	11	14	39	10	26	1	12	3	55	1	1
11	8	35	14	39	10	10	0	56	3	57	0	49
12	8	58	14	38	9	54	0	40	3	59	0	37
13	9	21	14	36	9	37	0	24	4	00	0	24
14	9	43	14	34	9	20	0	9	4	00	0	12
15	10	4	14	31	9	3	0*	6	4	00	0*	1
16	10	24	14	27	8	45	0	21	3	59	0	14
17	10	44	14	22	8	27	0	35	3	58	0	27
18	11	3	14	17	8	10	0	49	3	56	0	40
19	11	22	14	11	7	52	1	2	3	53	0	53
20	11	39	14	4	7	34	1	15	3	50	1	6
21	11	56	13	57	7	15	1	28	3	47	1	19
22	12	12	13	49	6	57	1	40	3	43	1	32
23	12	27	13	40	6	38	1	52	3	38	1	44
24	12	41	13	31	6	20	2	4	3	33	1	57
25	12	55	13	21	6	1	2	15	3	28	2	10
26	13	7	13	10	5	42	2	25	3	22	2	22
27	13	19	12	59	5	23	2	35	3	15	2	34
28	13	30	12	47	5	5	2	45	3	8	2	46
29	13	40			4	46	2	54	3	1	2	58
30	13	50			4	27	3	2	2	53	3	10
31	13	58			4	9			2	45		

Clock faſter. Clock flower. Clock faſter. Clock flower. Clock faſter. Clock flower. Clock faſter.

A TABLE of the Equation of Time, shewing how much a Clock should be faster or slower than the Sun, every Day of the Year, at Noon.

The second Year after Leap-Year.

Days.	July.		August.		Sept.		October.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	3	22	5	53	0	20	10	28	16	14	10	28
2	3	33	5	49	0	39	20	46	16	14	10	4
3	5	44	5	44	0	58	11	5	16	14	9	40
4	3	55	5	39	1	17	11	23	16	12	9	16
5	4	5	5	33	1	37	11	40	16	10	8	51
6	4	16	5	27	1	56	11	57	16	7	8	25
7	4	26	5	20	2	16	12	14	16	3	7	59
8	4	35	5	13	2	37	12	30	15	59	7	32
9	4	44	5	5	2	57	12	46	15	53	7	5
10	4	53	4	56	3	17	13	2	15	47	6	37
11	5	1	4	47	3	38	13	17	15	40	6	9
12	5	9	4	37	3	59	13	31	15	32	5	41
13	5	17	4	27	4	19	13	45	15	23	5	12
14	5	24	4	17	4	40	13	59	15	13	4	43
15	5	30	4	5	5	1	14	12	15	3	4	14
16	5	36	3	53	5	22	14	24	14	52	3	45
17	5	41	3	41	5	43	14	36	14	40	3	15
18	5	46	3	28	6	4	14	47	14	27	2	46
19	5	50	3	15	6	25	14	58	14	13	2	16
20	5	54	3	1	6	46	15	8	13	58	1	46
21	5	57	2	46	7	7	15	18	13	43	1	16
22	6	00	2	31	7	28	15	26	13	27	0	46
23	6	2	2	16	7	49	15	34	13	10	0	16
24	6	3	2	00	8	9	15	42	12	52	0	* 14
25	6	4	1	44	8	30	15	49	12	34	0	44
26	6	4	1	27	8	50	15	54	12	15	1	13
27	6	3	1	10	9	10	15	59	11	55	1	43
28	6	2	0	53	9	30	16	4	11	34	2	12
29	6	1	0	35	9	49	16	8	11	13	2	42
30	5	59	0	17	10	9	16	11	10	51	3	11
31	5	56	0	* 1			16	12			3	40

Clock faster. Clock slower. Clock faster.

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The third Year after Leap-Year.

Days	Jan.		Feb.		March.		April.		May.		June.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4	8	14	4	12	38	3	55	3	8	2	38
2	4	36	14	11	12	25	3	36	3	15	2	29
3	5	4	14	17	11	12	3	18	3	22	2	19
4	5	32	14	23	11	59	3	00	3	28	2	9
5	5	59	14	28	11	45	2	43	3	34	1	59
6	6	25	14	32	11	31	2	25	3	39	1	48
7	6	51	14	35	11	17	2	8	3	43	1	37
8	7	17	14	37	11	2	1	51	3	47	1	26
9	7	42	14	39	10	46	1	34	3	51	1	15
10	8	6	14	40	10	30	1	17	3	54	1	3
11	8	30	14	40	10	14	1	1	3	56	0	51
12	8	53	14	39	9	58	0	45	3	58	0	39
13	9	16	14	37	9	41	0	29	3	59	0	27
14	9	38	14	35	9	24	0	13	4	00	0	15
15	9	59	14	31	9	7	0	* 2	4	00	0	2
16	10	20	14	27	8	49	0	17	3	59	0	* 10
17	10	39	14	23	8	32	0	32	3	58	0	23
18	10	58	14	17	8	14	0	46	3	56	0	36
19	11	16	14	11	7	56	1	00	3	54	0	49
20	11	34	14	5	7	37	1	13	3	52	1	2
21	11	51	13	57	7	19	1	26	3	49	1	14
22	12	7	13	49	7	00	1	38	3	45	1	27
23	12	22	13	41	6	42	1	50	3	40	1	40
24	12	36	13	32	6	23	2	2	3	35	1	53
25	12	50	13	22	6	4	2	13	3	30	2	6
26	13	3	13	12	5	46	2	23	3	24	2	18
27	13	15	13	1	5	27	2	33	3	17	2	31
28	13	26	12	50	5	8	2	43	3	10	2	43
29	13	37			4	50	2	52	3	3	2	56
30	13	47			4	31	3	00	2	55	3	8
31	13	56			4	13			2	47		

Clock faſter. Clock ſlower. Clock faſter. Clock ſlower. Clock faſter.

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The third Year after Leap-Year.

Days.	July.		August.		Sept.		October.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	3	20	5	54	0*	15	10	23	16	13	10	33
2	3	31	5	50	0	34	10	42	16	14	10	10
3	3	42	5	46	0	53	11	00	16	14	9	46
4	3	53	5	41	1	12	11	18	16	13	9	22
5	4	4	5	35	1	32	11	36	16	11	8	57
6	4	14	5	29	1	51	11	53	16	8	8	31
7	4	24	5	22	2	11	12	10	16	5	8	5
8	4	34	5	15	2	32	12	27	16	1	7	39
9	4	43	5	7	2	52	12	43	15	55	7	12
10	4	52	4	58	3	13	12	59	15	49	6	45
11	5	00	4	49	3	34	13	14	15	43	6	17
12	5	8	4	40	3	54	13	29	15	35	5	49
13	5	15	4	29	4	15	13	43	15	27	5	20
14	5	22	4	18	4	36	13	57	15	17	4	52
15	5	28	4	7	4	57	14	10	15	7	4	23
16	5	34	3	55	5	18	14	23	14	56	3	54
17	5	39	3	43	5	40	14	35	14	44	3	24
18	5	44	3	30	6	1	14	46	14	31	2	54
19	5	48	3	17	6	22	14	57	14	18	2	24
20	5	52	3	3	6	43	15	7	14	3	1	54
21	5	55	2	48	7	4	15	17	13	48	1	24
22	5	58	2	34	7	24	15	25	13	32	0	54
23	6	00	2	19	7	45	15	33	13	15	0	24
24	6	2	2	3	8	5	15	41	12	57	0	* 6
25	6	3	1	47	8	25	15	48	12	39	0	36
26	6	3	1	31	8	46	15	53	12	20	1	6
27	6	3	1	14	9	6	15	59	12	00	1	36
28	6	2	0	57	9	25	16	3	11	39	2	6
29	6	1	0	39	9	45	16	7	11	18	2	35
30	5	59	0	22	10	4	16	10	10	56	3	5
31	5	57	0	4			16	12			3	34

Clock faſter. Clock flower. Clock faſter. Clock flower.

A concise EQUATION TABLE, adapted to the Second Year after Leap-Year, and will be within a Minute of the Truth for every Year; shewing, to the nearest full Minute, how much a Clock should be faster or slower than the Sun. *By Mr.* SMEATON.

Months.	Days.	Equ. in Minutes.	
Jan.	1	4	Clock faster than the Sun.
	3	5	
	5	6	
	7	7	
	10	8	
	12	9	
	15	10	
	18	11	
	21	12	
	25	13	
	31	14	
Feb.	6	15	
	21	14	
	27	13	
Mar.	4	12	
	8	11	
	12	10	
	15	9	
	19	8	
	22	7	
	25	6	
	28	5	

Months.	Days.	Equ. in Minutes.	
Apr.	1	4	Clock faster.
	4	3	
	7	2	
	11	1	
	15	0	
	*		
	19	1	Clock flower.
	24	2	
	30	3	
May	14	4	
	29	3	
June	5	2	
	10	1	
	15	0	
	*		
	20	1	Clock faster.
	24	2	
	29	3	
July	4	4	
	11	5	
	26	6	

Months.	Days.	Equ. in Minutes.	
Aug.	10	5	Clock faster.
	15	4	
	20	3	
	24	2	
	28	1	
	31	0	
	*		
Sept.	3	1	Clock flower than the Sun.
	6	2	
	9	3	
	12	4	
	15	5	
	18	6	
	21	7	
	24	8	
	27	9	
	30	10	
Oct.	3	11	
	6	12	
	10	13	
	14	14	
	19	15	

Months.	Days.	Equ. in Minutes.	
Oct.	27	16	Clock flower than the Sun.
Nov.	8	16	
	15	15	
	20	14	
	24	13	
	27	12	
	30	11	
Dec.	2	10	
	5	9	
	7	8	
	9	7	
	11	6	
	13	5	
	15	4	
	18	3	
	20	2	
	22	1	
	24	0	
	*		
	26	1	Faster.
	28	2	
	30	3	

This Table is near enough for regulating common Clocks and Watches. It may be easily copied by the Pen, and being doubled, may be put into a Pocket-book.

CHAP.

Plate VII.

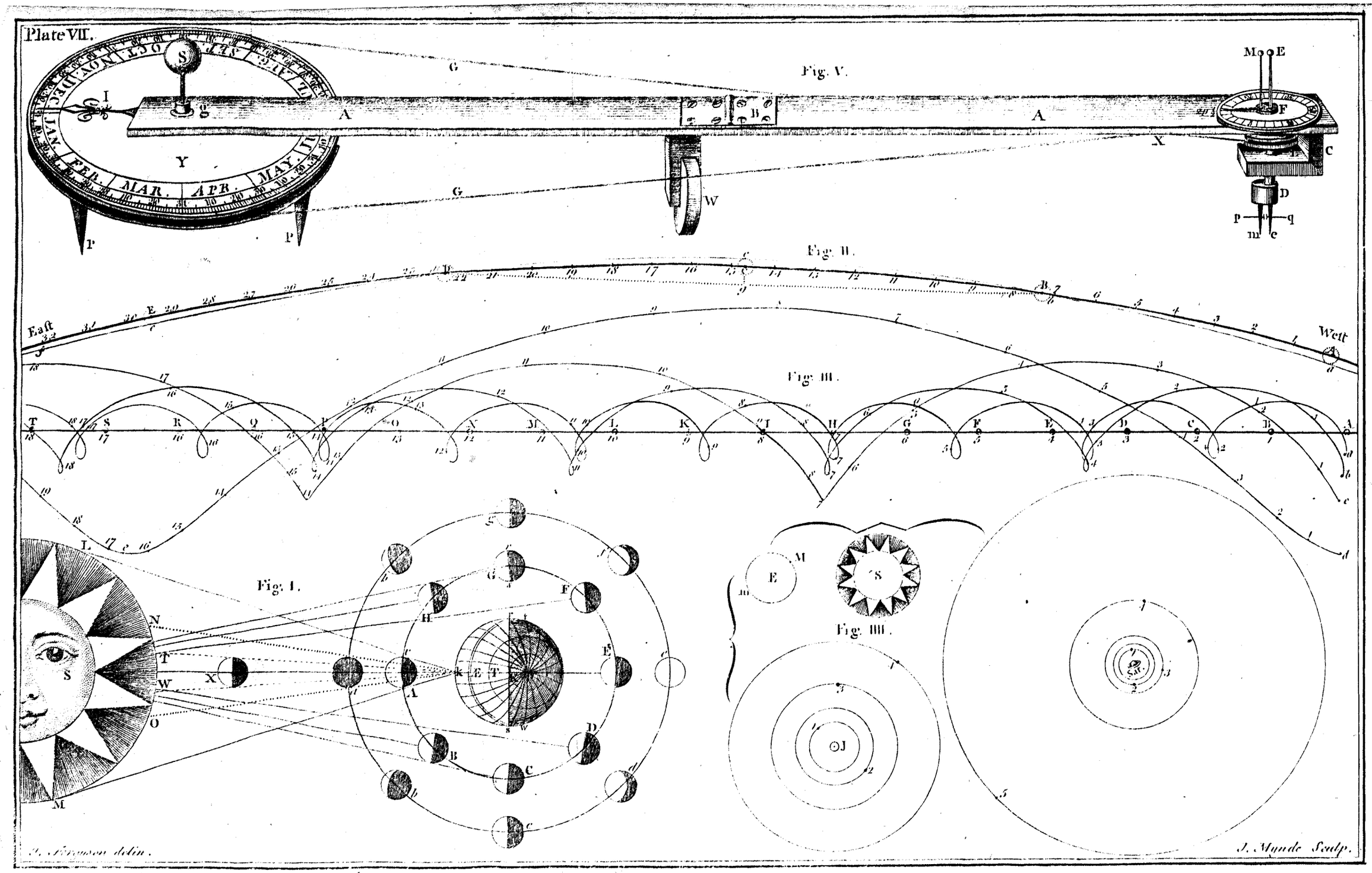


Fig. V.
Fig. II.
Fig. III.
Fig. I.
Fig. IIII.
East
West
JAN.
FEB.
MAR.
APR.
MAY.
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
SAT.
J. Munde Sculp.

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 parts. 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 fill up the inequalities so as to make her appear quite round; just as when one looks at an orange, although its 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 toward 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, as far as we know, 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 take off from its roundness) we can only see that part of the enlightened half of her which is toward the Earth. And therefore when the Moon is at *A*, in conjunction with the Sun *S*, her dark half is toward 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 seen toward 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 toward 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 toward 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 completed 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* to *E*, but as seen from the Sun *S*, she is always 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 Moon's Disc not always round when Full.

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 toward the Moon; and when the Moon is at *E*, *Full* to the Earth, its dark side is toward 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. The Phases of the Earth and Moon contrary.

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

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 inclined 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 which 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

PLATE VII.

ſenſible effect upon the poſition of her horns. Therefore, if a Quadrant be held up, ſo as one of its edges may ſeem to touch the Moon's horns, the graduated ſide being kept toward 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 ſeems to touch the Moon's horns will ſhew 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 ſhew the inclination of a line, touching the Moon's horns, to the Horizon.

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

261. The Moon generally appears as large as the Sun; for the Angle *y k A*, under which the Moon is ſeen from the Earth, is the ſame with the Angle *LkM*, under which the Sun is ſeen from it. And therefore the Moon may hide the Sun's whole Diſc from us, as ſhe ſometimes does in ſolar Eclipſes. The reaſon why ſhe does not eclipſe the Sun at every Change, ſhall be explained afterward. If the Moon were farther from the Earth, as at *a*, ſhe would never hide the whole of the Sun from us; for then ſhe would appear under the Angle *N k O*, eclipſing only that part of the Sun which lies between *N* and *O*: were ſhe ſtill further from the Earth, as at *X*, ſhe would appear under the ſmall angle *TkW*, like a ſpot on the Sun, hiding only the part *T W* from our ſight.

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

262. That the Moon turns round her Axis in the time that ſhe goes round her Orbit, is quite demonſtrable; for a ſpectator at reſt, without the periphery of the Moon's Orbit, would ſee all her ſides turned regularly toward him in that time. She turns round her Axis from any Star to the ſame Star again in 27 days 8 hours; from the Sun to the Sun again in 29½ days: the former is the length of her ſydereal day, and the latter the length of her ſolar day. A body moving round the Sun would have a ſolar day in every revolution, without turning on its Axis; the ſame as if it had

had kept all the while at rest, and the Sun moved round it: but without turning round its Axis it could never have one sydereal day, because it would always keep the same side toward 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 complete a Lunation, a sydereal, and a solar day, all in the same time. But because the Earth goes forward in its 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 completing a solar day, as the Earth has gone forward in its 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 its 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 point of the Circle where it was last conjoined with

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

Conj.	H.	M.	S.	″	‴	vpts.
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	10	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

the

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 while the hour-hand goes once round the dial-plate; and the other columns ſhew the times when the two hands meet at each 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 its point, and the quickeſt a little Moon.

265. If the Earth had no annual motion, the Moon's motion round the Earth, and her track in open ſpace, would be always the ſame*. But

The Moon's motion through open ſpace deſcribed.

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

PLATE VII.

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 complete number of Lunations in a year without any fraction.

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 of 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 the Earth's annual path round the Sun, as it describes while 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.

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 semi-diameter 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, while 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 its

Fig. II.

its path, and in so doing, 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 its 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 tracts 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. PLATE VII.

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 proportion 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 shall 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 337½.

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

* For the true distances, see p. 108.

PLATE VII. 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*. While 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*. And lastly, while the Earth describes the curve *D* 23 24 25 26 27 28 29, the Moon describes the curve *d e*; and is again in conjunction 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 toward 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 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 semi-diameter of her Orbit) behind the Earth at her first Quarter in *b*, when the Earth is at *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,

How her Motion is alternately retarded and accelerated.

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

268. The Moon's path being concave to the Sun throughout, demonstrates that her gravity toward the Sun at her Conjunction, exceeds her gravity toward 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 then appear

A difficulty removed.

PLATE VII. 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. For bodies in the cabin of a ship, may 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 toward the Sun should exceed that of the Moon toward the Earth; in that case the Moon when in conjunction, would abandon the Earth, and be either drawn into the Sun, or Comet, or circulate round about it.

269. The curves which Jupiter's Satellites describe, are all of different sorts from the path described by our Moon, although these Satellites go round Jupiter, as the Moon goes round the Earth. Fig. III. Let *ABCDE*, &c. be as much of Jupiter's Orbit as he describes 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 progressive motion.

Now let us suppose all these Moons to set out from a conjunction with the Sun, as seen from Jupiter at

at *A*; then, his first or nearest Moon will be at *a*, his second at *b*, his third at *c*, and his fourth at *d*. At the end of 24 terrestrial Hours after this conjunction, Jupiter has moved to *B*, his first Moon or Satellite has described the curve *a* 1, his second the curve *b* 1, his third *c* 1, and his fourth *d* 1. The next day, when Jupiter is at *C*, his first Satellite has described the curve *a* 2, from its conjunction, his second the curve *b* 2, his third the curve *c* 2, and his fourth the curve *d* 2, and so on. The numeral Figures under the capital letters shew Jupiter's place in his path every day for 18 days, accounted from *A* to *T*; and the like Figures set to the paths of his Satellite, shew where they are at the like times. The first Satellites, almost under *C*, is stationary at +, as seen from the Sun; and retrogade from + to 2: at 2 it appears stationary again, and thence it moves forward until it has passed 3, and is twice stationary, and once retrograde between 3 and 4. The path of this Satellite intersects itself every 42½ hours, making such loops as in the Diagram at 2. 3. 5. 7. 9. 10. 12. 14. 16. 18, a little after every conjunction. The second Satellite *b*, moving slower, barely crosses its path every 3 days 13 hours; as at 4. 7. 11. 14. 18, making only 5 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 its next conjunction. The fourth Satellite *d* is always progressive, making neither Loops nor Angles in the Heavens; but comes to its next conjunction at *e* between the numeral figures 16 and 17, or in 16 days 18 hours. In order to have a tolerable good figure of the paths of these Satellites, I took the following method.

PLATE VII. The absolute Path of Jupiter and his Satellites delineated.

Fig. III.

PLATE VII. Fig. IV.

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 $\frac{36}{100}$ 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, while 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 *A B*, *B C*, &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 its 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 motion, and transferred it to every horary division thereon, keeping always the same diameter-line on the line of Jupiter's path; and running a pin through each horary division in the Orbit of each Satellite as the card was gradually transferred along the line *A B C D*, &c. of Jupiter's motion, I marked points for every hour through the Card for the curves described by the Satellites, as the primary Planet in the center of the Card was carried forward on the line; and so finished the Figure, by drawing the lines of each Satellite's motion through those (almost innumerable) points: by which means, this is, perhaps, as true a Figure of the paths of these Satellites as can be desired.

How to delineate the paths of Jupiter's Moons.

And

And in the ſame manner might thoſe of Saturn's Satellites be delineated. And Saturn's.

PLATE VII.

270. It appears by the ſcheme, that the three firſt Satellites come almoſt into the ſame line of poſition every ſeventh day; the firſt being only a little behind with the ſecond, and the ſecond behind with the third. But the period of the fourth Satellite is ſo incommenſurate to the periods of the other three, that it cannot be gueſſed 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 ſuppoſing 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 Periods 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 Diſc of the Sun. *S* is the Sun; *M m* the Moon's Orbit (the Earth ſuppoſed to be at *E*); ♃ 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 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. Fig. IV. The proportions of the Orbits of the Planets and Satellites.

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 while they deſcribe the

the inferior Parts of their Orbits, and direct while 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 Planets Revolution to the Revolution of each Satellite.	Proportion of the Velocity of each Satellite to the Velocity of its 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 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.

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. In considerable distances from the Equator, where the weather and seasons are more uncertain, the autumnal Full Moons rise very soon after sun-

set

But remarkable according to the distances of places from it.

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.

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 its 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 its 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 versa*. 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 its Axis. 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 *F U P* is the Axis, ♋ *T R* the Tropic of Cancer, *L t* ♑ the Tropic of Capricorn, ♋ *E U* ♑ the Ecliptic touching both the Tropics, which are 47 degrees from each other, and *A B* 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 73½ 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 its Axis, till ♑ Capricorn comes to the Meridian and ♈ Aries rises in the East, and then the Ecliptic will have the low elevation *N L* above the Horizon, making only an Angle *N U L* of 26½ 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 while 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 afterward, 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, while she is in these Signs. The annexed Table shews the daily mean difference of the Moon's

Days.	Signs.	Degrees.	Rising Diff. H.	Rising Diff. M.	Setting Diff. H.	Setting Diff. 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	00	0	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 one minute 58 seconds shorter than 12 Solar hours.

rising and setting on the Parallel of *London*, for 28 days; in which time the Moon finishes her period round the Ecliptic, and gets 9 degrees into the same Sign from the beginning of which she set out. So it appears by the Table, that when the Moon is in ♏ and ♎ she rises an hour and a quarter later every day than she rose on the former; and differs only 28, 24, 20, 18 or 17 minutes in setting. But, when she comes to ♓ and ♈, she is only 20 or 17 minutes later in rising; and an hour and a quarter later in setting. PLATE III.

278. All these things will be made plain by putting small patches on the Ecliptic of a Globe, as far from one another as the Moon moves from any point of the celestial Ecliptic in 24 hours, which at a mean rate is * $13\frac{1}{6}$ degrees; and then in turning the Globe round, observe the rising and setting of the patches in the Horizon, as the Index points out the different times in the hour-circle. A few of these patches are represented by dots at 0 1 2 3, &c. on the Ecliptic, which has the position *L U I* when Aries rises in the East; and by the dots 0 1 2 3, &c. when Libra rises in the East, at which time the Ecliptic has the position *E U* ♍: making an angle of 62 degrees with the Horizon in the latter case, and an angle of no more than 15 degrees with it in the former; supposing the Globe rectified to the Latitude of *London*. Fig. III.

279. Having rectified the Globe, turn it until the patch at 0, about the beginning of ♓ Pisces in the half *L U I* of the Ecliptic, comes to the Eastern side of the Horizon; and then, keeping the ball steady, set the hour-index to XII, because *that* hour may perhaps be more easily remembered than any other. Then turn the Globe round West-

* The Sun advances almost a degree in the Ecliptic in 24 hours, the same way that the Moon moves; and therefore the Moon by advancing $13\frac{1}{6}$ degrees in that time goes little more than 12 degrees farther from the Sun than she was on the day before.

ward,

ward, and in that time, suppose the patch ♁ to have moved thence to 1, $13\frac{1}{7}$ degrees, while the Earth turns once round its Axis, and you will see that 1 rises only about 20 minutes later than 0 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 in setting on the Western side of the Horizon, which shews that the Moon's setting will be so much retarded 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 while 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 were 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 $2\frac{1}{13}$ 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 while the Sun goes once round the Ecliptic, the Moon makes $12\frac{1}{3}$ conjunctions with him: but while the hour-hand goes round the

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 to 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, seeing 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, while 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 the 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 while 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 its 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 5¼ 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 when 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 $19\frac{2}{3}$ 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 while ſhe is in Piſces and Aries, than ſhe would do 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 nine years, as there would be on two parallels $10\frac{2}{3}$ 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 pt. of her Orbit.		Full in her Descending Node.		In the lowest pt. 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 15	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
Diff.	13 9	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 14¼ 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 complete revolution of the Nodes in 18⅔ 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 risings, 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 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.

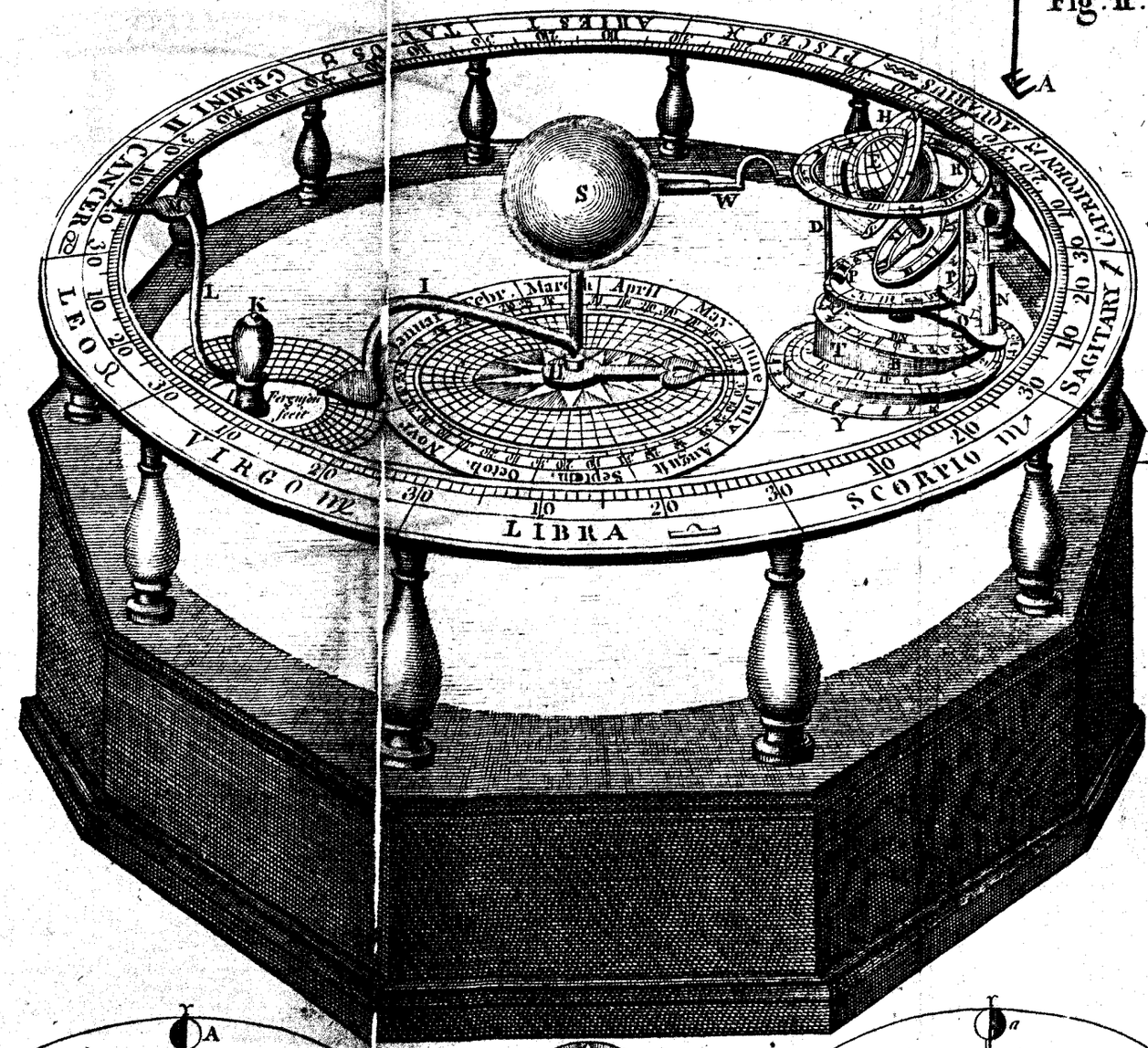


Fig. II.

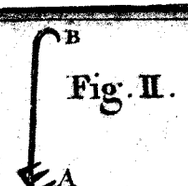


Fig. III.

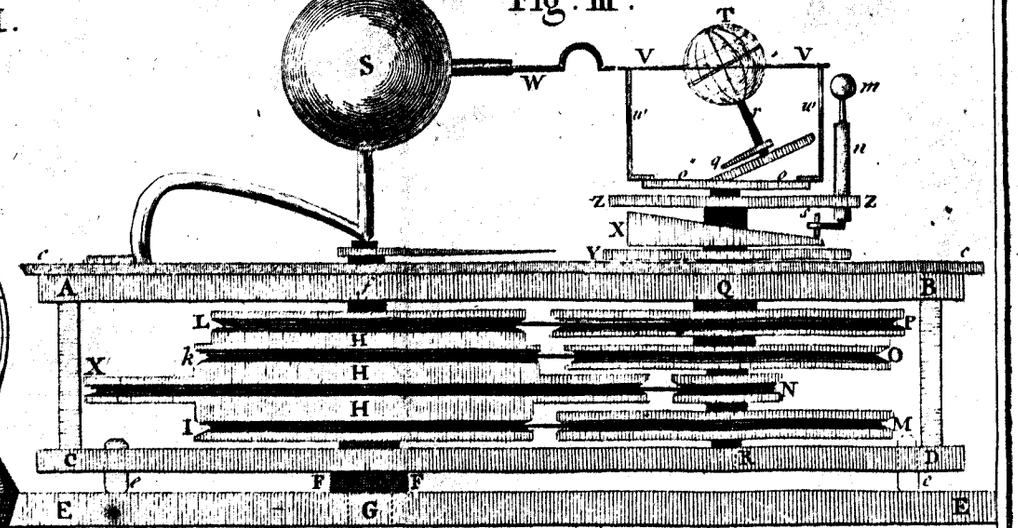
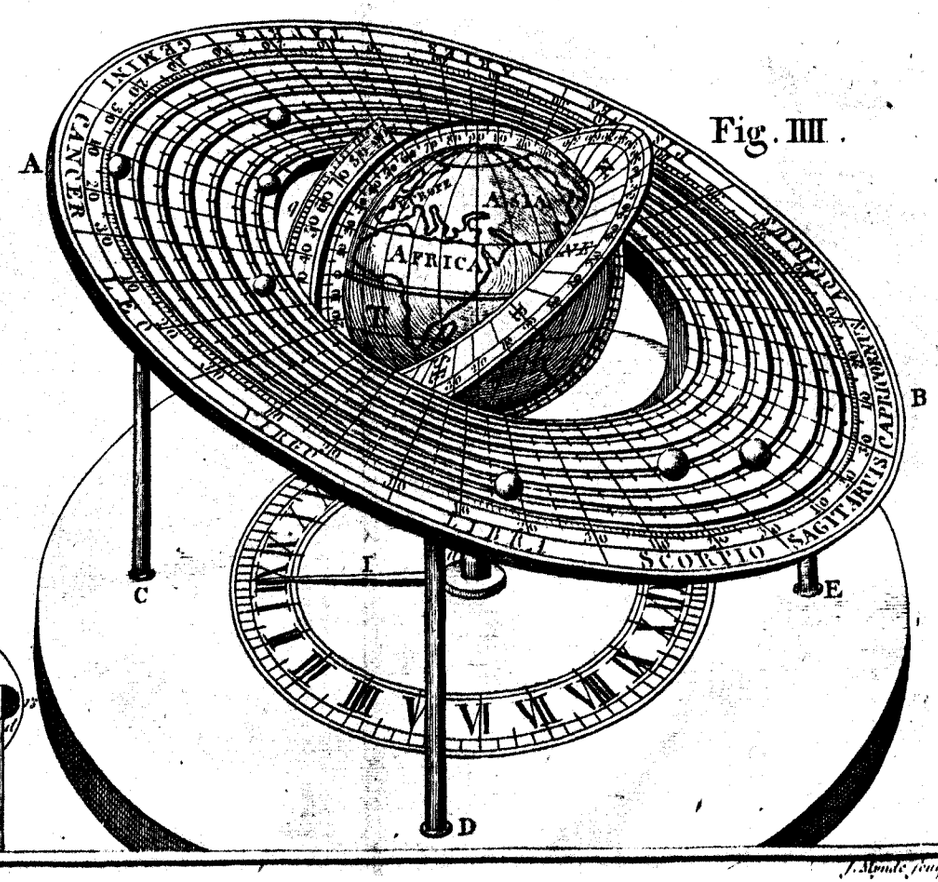


Fig. IIII.



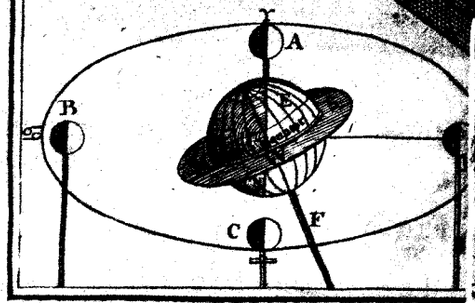
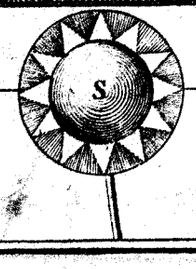
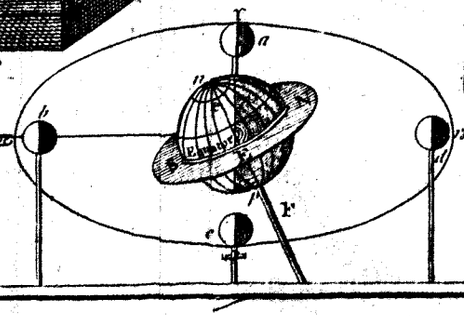


Fig. V.





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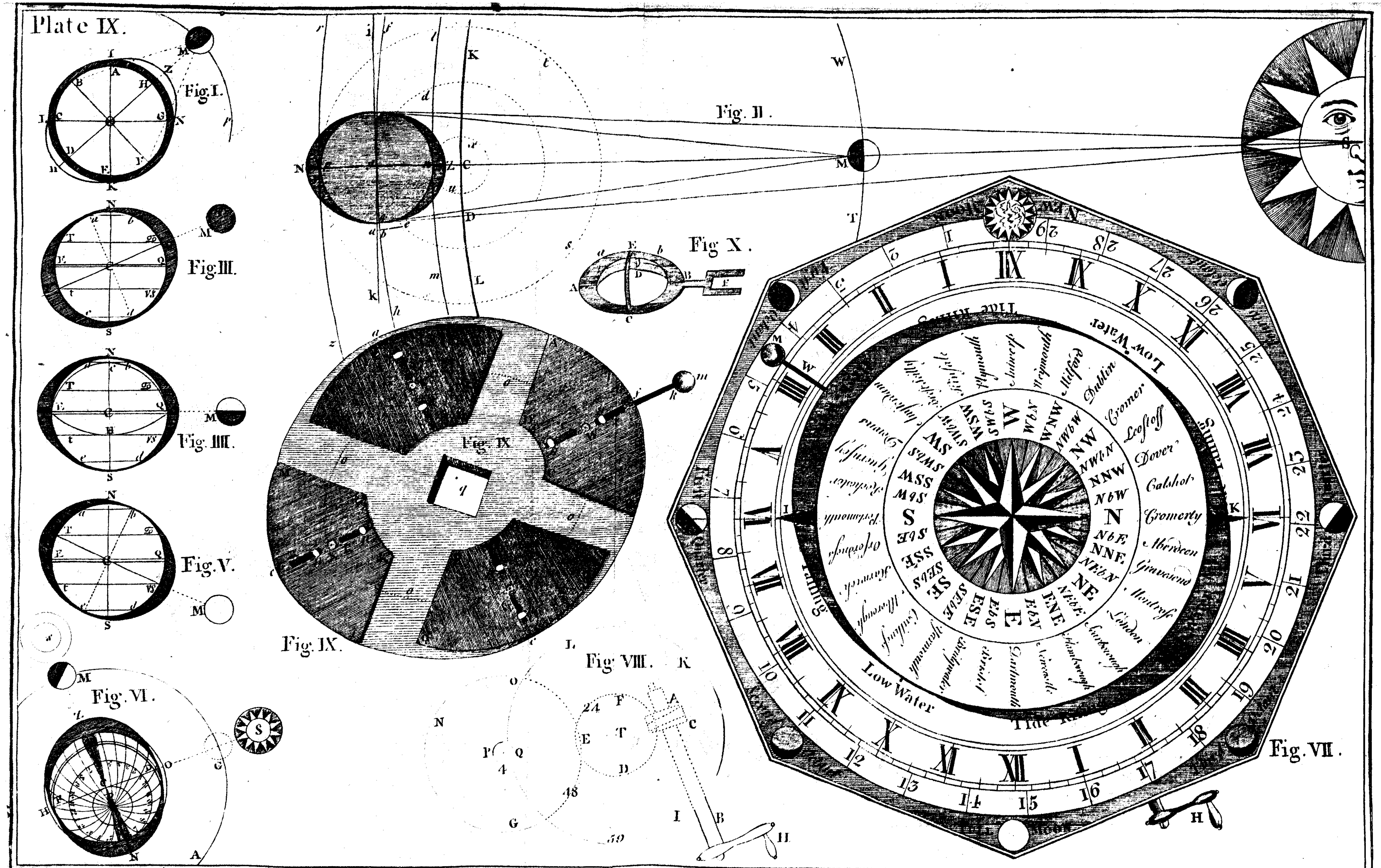
gine that the Sun continues half a year together above the Horizon of each Pole in its turn, and as long below it; rising to one Pole when he sets to the other. This would be exactly the case if there were no refraction; but by the Atmosphere's refracting the Sun's rays, he becomes visible some days 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 bare view of the Figure will make this plain; in which let *S* be the Sun, *e* the Earth in Summer, when its north Pole *n* inclines toward the Sun, and *E* the Earth in Winter, when its 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 toward him. Thus in our Summer, the Moon is above the Horizon of the north Pole while 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 its north Pole declines from the Sun, the New Moon at *D* it as 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

Fig. V.

Plate IX.



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and keeping above the Horizon till she comes to her Third Quarter *C*. At a mean state she is $23\frac{1}{2}$ 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* ♋ or *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. Fig. I.

on the ſide of the Earth *ABCDEFGH* next the Moon *M*, are more attracted than the central parts 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 its 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 its 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 toward *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 toward *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; while 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 *Z I B L n K F N Z*, whoſe longer Axis *n O Z* produced will paſs through *M*, and its ſhorter Axis *B O F* 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 while the Earth by its gravity falls toward the Moon, the Water directly below her at *B* will swell and rise gradually toward 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: while the Water at *B* and *F* is depressed, and falls below the former level. Hence, as the Earth turns round its Axis from the Moon to the Moon again in $24\frac{3}{4}$ 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 toward it, and therefore cannot fall contrary ways at the same time: or if the Earth is constantly falling toward 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 while 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 toward the Moon from a tangent to the Circle it deſcribes round the ſaid common center of gravity. Let *M* be the Moon, *TW* part of the Moon's Orbit, and *C* the center of gravity of the Earth and Moon; while the Moon goes round her Orbit, the center of the Earth deſcribes the Circle *d g e* 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 toward the Moon, from the tangent at *a* to *e*; and ſo on, 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 its diſtance from the Moon, it is next to nothing when compared to its diſtance from 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 communi-

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 equatorial 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, while the Moon raises the Tide under and opposite to her, the Sun acting in the same line, raises the Tide under 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 toward 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 toward the

the Pole to which ſhe is nereſt, and the other declines toward the oppoſite Pole; each elevation deſcribing parallels as far diſtant from the Equator, on oppoſite ſides, as the Moon declines from it to either ſide; and conſequently, the parallels deſcribed by theſe elevations of the water are twice as many degrees from one another, as the Moon is from the Equator; increaſing their diſtance as the Moon increaſes her declination, till it be at the greateſt, when the ſaid parallels are, at a mean ſtate, 47 degrees from one another: and on that day, the tides are moſt unequal in their heights. As the Moon returns toward the Equator, the parallels deſcribed by the oppoſite elevations approach toward each other, until the Moon comes to the Equator, and then they coincide. As the Moon declines toward the oppoſite Pole, at equal diſtances, each elevation deſcribes the ſame parallel in the other part of the lunar day, which its oppoſite elevation deſcribed before. While the Moon has north declination, the greateſt tides in the northern Hemiſphere are when ſhe is above the Horizon; and the reverſe while her declination is ſouth. Let *N E S* ☋ be the Earth, *N C S* its Axis, *E* ☋ the Equator, *T* ♋ the Tropic of Cancer, *t* ♑ the Tropic of Capricorn, *a b* the arctic Circle, *c d* the antarctic, *N* the North Pole, *S* the ſouth Pole, *M* the Moon, *F* and *G* the two eminences of water, whoſe loweſt parts are at *a* and *d* (Fig. III.) at *N* and *S* (Fig. IV.) and at *b* and *c* (Fig. V.) always 90 degrees from the higheſt. Now when the Moon is in her greateſt north declination at *M*, the higheſt elevation *G* under her, is on the Tropic of Cancer *T* ♋, and the oppoſite elevation *F* on the Tropic of Capricorn, *t* ♑; and theſe two elevations deſcribe the Tropics by the Earth's diurnal rotation. All places in the northern Hemiſphere *E N* ☋ have the higheſt Tides when they come into the poſition *b* ♋ ☋, under the Moon; and the loweſt Tides when the Earth's diurnal

PLATE IX.

Fig. III. IV. V.

Fig. III.

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 its 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 whole Phenomena being reversed, when the Moon Fig. V. 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 the Ecliptic. Let *H Z O N* be the Earth and Sea, Fig. VI. *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 T 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 *T*, 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 *T*, 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 *T* as it did from *T* 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 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 *M G A*, 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 23½ 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 accordin to Fig. IV. when the Moon is vertical to the Equator *E C Q*, the Poles of the Tides ſeem to fall-in with the Poles of the world *N* and *S*; but when we conſider that *F G H* 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 *P*, 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 its 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 toward 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.

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.

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

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-

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

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 have 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 consequently

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

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 toward 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 its equatorial 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 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 its 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, its shadow would only be circular when either of its sides directly faced the Moon; and more or less elliptical as the Earth happened to be turned more or less obliquely toward 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 toward 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 its Nodes, and opposite to the Sun, would be eclipsed in the Earth's shadow. Were the Earth bigger than the Sun, its 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 its 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 it 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 its 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 its 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 to 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 an 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 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

Limits of Eclipses.

* 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.

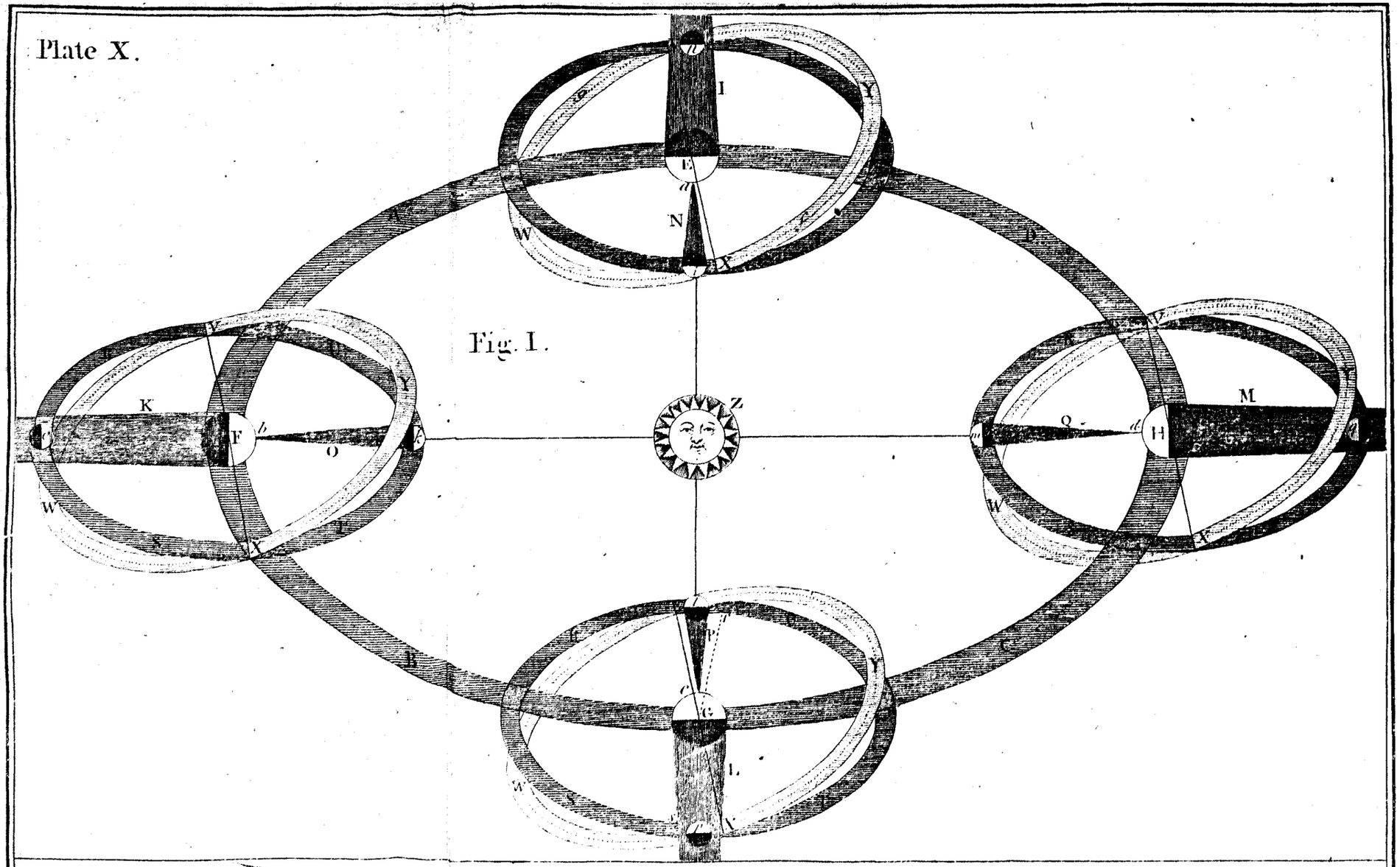
Fig. I.
Z
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K
M
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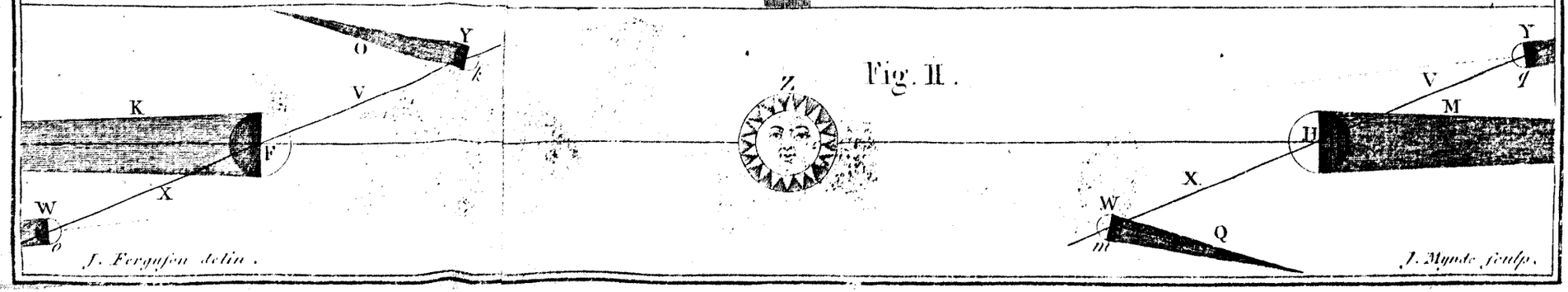
Fig. II.
Z
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F
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J. Ferguson delin.
J. Mynde sculp.

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

To illustrate this, let *ABCD* be the *Ecliptic*, *RSTU* a Circle lying in the same Plane with the Ecliptic, and *VWXY* 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 *VWX*, is always below the Ecliptic, and the other half *XYV* above it. The points *V* and *X*, where the Moon's Orbit intersects the Circle *RSTU*, which lies even with the Ecliptic, are the *Moon's Nodes*; and a right line, as *XEV*, 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 *RSTU*, 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 *XYVW*, the Earth advances from *E* to *e*, according to the order of the letters *EFGH*, and the line or the Nodes *VEX* 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 in 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 Υ 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, were 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 VGX, at the same time next year it will be in the situation rGs; 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 complete 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

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 completed. 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.

223
195
2007
446
111
6578

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 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 its mean revolutions, without equating the times, or the Sun's distance from the Node; and then according to its 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 its 77th periodical return, and will go quite

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 than 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 its 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 its returns, according to the rules laid down in the XVth Chapter; and have by that means 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 Stile, 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 its 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 its 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 its 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 D.st. from the Node.			
		Month	D.	H.	M.	S.	s.	o	′	″	s	o	′	″	s	o	′	″
0	1277	June	2	5	9	39	11	17	57	41	1	26	31	42	0	18	16	40
1	1295	June	13	12	52	59	11	28	27	38	1	23	40	19	0	17	48	27
2	1313	June	23	20	36	19	0	8	57	35	1	20	48	56	0	17	20	15
3	1331	July	5	4	19	30	0	19	27	32	1	17	57	35	0	16	52	2
4	1349	July	15	12	2	59	0	29	57	29	1	15	6	10	0	16	23	50
5	1367	July	26	19	46	19	1	10	27	26	1	12	14	47	0	15	55	37
6	1385	Aug.	6	3	29	39	1	20	57	23	1	9	23	24	0	15	27	25
7	1403	Aug.	17	11	12	59	2	1	27	20	1	6	32	1	0	14	59	12
8	1421	Aug.	27	18	56	19	2	11	57	17	1	3	40	38	0	14	31	0
9	1439	Sept.	8	2	39	39	2	22	27	14	1	0	49	15	0	14	2	47
10	1457	Sept.	18	10	2	59	3	2	57	11	0	27	57	52	0	13	34	35
11	1475	Sept.	29	18	6	19	3	13	27	8	0	25	6	29	0	13	6	22
12	1493	Oct.	10	1	49	39	3	23	57	5	0	22	15	6	0	12	38	10
13	1511	Oct.	21	9	32	59	4	4	27	2	0	19	23	43	0	12	9	57
14	1529	Oct.	31	17	16	19	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	48	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	14	0	7	56	5
23	1692	Feb.	6	14	46	20	7	19	26	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	Apr.	1	5	23	0	9	11	56	17	11	6	32	58	0	5	6	50
29	1800	Apr.	11	13	6	20	9	22	26	14	11	3	41	35	0	4	38	37
30	1818	Apr.	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

TABLE

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 its falling right against the Earth's Center, till it finally leaves the Earth according to the Julian or Old Style.*

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	°	′	″
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	16	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	0	22	10	10	24	28	7	20	51	48	11	17	43	8
66	2467	May	17	10	49	42	10	20	54	25	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	16	22	11	11	54	19	7	12	17	39	11	16	18	31
69	2521	June	18	9	59	42	11	22	24	17	7	9	26	16	11	15	50	18
70	2539	June	29	17	43	2	0	2	54	14	7	6	34	53	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	7	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	36	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	56	6	19	26	35	11	12	32	51
77	2665	Sept.	12	23	46	22	2	16	23	53	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 21*st*, *Old Stile,* A. D. 1764, *from the Time of its 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 Dist. from the Node.				Moon's true Latitude North.			
		Month.	D.	H.	M.	S.	s	o	′	″	o	′	″	Nor.
0	1295	June	13	12	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	24	0	14	46	8	1	16	39	N. A.
5	1385	Aug.	6	6	41	17	0	13	59	43	2	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.	4	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.	20	22	30	26	0	7	42	14	0	40	18	N. A.
27	1782	Apr.	1	5	37	4	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	14	8	50	40	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	0	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	5	0	0	47	38	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

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 its 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 Dist. from the Node.				Moon's true Latitude South.			
		Month.	D.	H.	M.	S.	s	o	′	″	o	′	″	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	26	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	26	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	17	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 that 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 examine 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 Incognita*, 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: its 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 *Ethiopian* continent, not far from the beginning of the Red Sea.

" Its 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 *Wittemberg* in *Germany*, and *Pekin* in *China*, soon after which it went off.

" Eighteen years more afforded us theEcli pse 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 expansion, 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 entire 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 in Winter, but then it begins to ceaſe
" from affecting us.

" Another concluſion from this revolution may
" be drawn, that there will ſeldom be any more
" than two great Eclipſes of the Sun in the interval
" of this period, and theſe follow ſometimes next
" return, and often at greater diſtances. That of
" 1715 returned again in 1733 very great; but
" this preſent Eclipſe will not be great till the
" arrival of 1820, which is a revolution of four
" *Chaldean* periods: ſo that the irregularities of
" their circuits muſt undergo new computations
" to aſſign them exactly.

" Nor do all Eclipſes come in at the ſouth Pole:
" *that* depends altogether on the poſition of the
" lunar nodes, which will bring in as many from
" the *expanſum* one way as the other: and ſuch
" Eclipſes will wear more ſoutherly by degrees
" contrary to what happens in the preſent caſe.

" The Eclipſe, for example, of 1736, in *Sep-*
" *tember*, had its center in the *expanſum*, and ſet
" about the middle of its obſcurity in *Britain*; it
" will wear in at the North Pole, and in the year
" 2600, or thereabout, go off in the *expanſum* on
" the ſouth ſide of the Earth.

" The Eclipſes 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 ſeems to have been entirely
" unknown to the ancients.

Why our preſent Tables agree not with ancient obſervations.

322. " It is particularly to be noted, that Eclipſes
" which have happened many centuries ago, will
" not be found by our preſent Tables to agree ex-
" actly with ancient obſervations, by reaſon of the
" great Anomalies in the lunar motions; which
" appears an inconteſtable demonſtration of the
" non-eternity of the Univerſe. For it ſeems con-
" firmed by undeniable proofs, that the Moon now
" finiſhes her period in leſs 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 bo-
"dies as constitute the solar system, which would
"come to ruin of itself, without some new regula-
"tion and adjustment of their original motions *.

323. "We are credibly informed from the testi- THALES's Eclipse.
"mony of the ancients, 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 ancient 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 ten 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 ancients 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 Chronologicum*, 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 year 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* 9^{d} 5^{h} 6^{m} 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 passed *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 its "reality.

324. "For a further 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 fourthy ear 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 passed over *Athens*, central about 6 in the "evening, but which our present Tables bring no "farther than the ancient *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 passed *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 ancient Eclipses; and refer them "to examine the Eclipse of *Nicias*, so fatal to the "*Athenian* fleet*; that which overthrew the *Ma-* "*cedonian* Army †, *&c.*" So far Mr. SMITH.

THUCYDIDES's Eclipse.

fourth year

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 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 $19\frac{1}{3}$ 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 afterward; 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 happened 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 Ptlaumen* 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: *Nicholus 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 *Ma-*

ginus, used the *Prutenic* Tables; *Origin* the *Prutenic* and *Tychonic*; *Montebrunus* the *Lanshergian*, as likewise those of *Durat*. 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 *Lanshergian*.
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 ☽ *Moon*.

STRUYK's Catalogue of ECLIPSES.

Bef. Chr.	Eclipses of the Sun and Moon seen at		M. & D.	Middle H.	M.	Digits eclipsed	
721	Babylon	☽	March 19	10	34	Total	
720	Babylon	☽	March 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	☽	April 25	12	12	1	44
431	Athens	☉	Aug. 3	6	35	11	0
425	Athens	☽	Oct. 9	6	45	Total	
424	Athens	☉	March 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	20	9	Total	
310	Sicily Island	☉	Aug. 14	20	5	10	22
219	Mysia	☽	March 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	☽	March 19	13	9	Total	
200	Athens	☽	Sept. 11	14	48	Total	
198	Rome	☉	Aug. 6				
190	Rome	☉	March 13	18	—	11	0
188	Rome	☉	July 16	20	38	10	48
174	Athens	☽	April 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	☉	March 16	setting		Central	
54	Canton	☉	May 9	3	41	Total	
51	Rome	☉	March 7	2	12	9	0
48	Rome	☽	Jan. 18	10	0	Total	
45	Rome	☽	Nov. 6	4	—	Total	
36	Rome	☉	May 19	3	52	6	47

STRUYK's

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	☉	March	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	☉	April	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	☉	March	8	20	42	11	6
55	Pekin	☉	July	12	21	50	6	40
56	Canton	☉	Dec.	25	0	28	9	20
59	Rome	☉	April	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	☽	March	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

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.

Att. Chr.	Eclipses of the Sun and Moon seen at		M. & D.		Middle H.	M.	Digits eclipsed	
810	Paris	☉	Nov.	30	0	12	Total	
810	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	Paris	☽	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	
926	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	1	10
990	Constantinople	☉	Oct.	21	0	45	10	5
995	Ausburgh	☽	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	☉	Apr.	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	0	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	☉	March	18	19	0	9	12
1114	London	☽	Aug.	17	15	5	Total	
1117	Triers	☽	June	15	13	26	Total	
1117	Triers	☽	Dec.	10	12	51	Total	
1110	Naples	☽	Nov.	20	15	46	4	11
1121	Triers	☽	Sept.	27	16	87	Total	
1122	Prague	☽	Mar.	24	11	20	3	49
1124	Erfurd	☽	Feb.	1	6	43	8	39
1124	London	☉	Aug.	10	23	29	9	58
1132	Erfurd	☽	Mar.	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	☽	Aug.	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.	Eclipses of the Sun and Moon seen at		M. & D.		Middle H.	M.	Digits eclipsed	
1154	Paris	☽	Dec.	21	8	30	4	22
1155	Auranches	☽	June	16	8	45	0	53
1160	Rome	☽	Aug.	18	7	53	6	49
1161	Rome	☽	Aug.	7	8	11	Total	
1162	Erfürd	☽	Feb.	1	6	40	5	56
1162	Erfurd	☽	July	27	21	30	4	11
1163	Mont Caſſin	☉	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	☽	Apr.	25	7	2	8	6
1176	Auranches	☽	Oct.	19	11	20	8	53
1178	Cologne	☽	Mar.	5	ſetting		7	52
1178	Auranches	☽	Aug.	29	13	52	5	31
1178	Cologne	☉	Sept.	12	—	—	10	51
1179	Cologne	☽	Aug.	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	☽	Mar.	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	
1216	Acre	☉	Feb.	18	21	15	11	36
1216	Acre	☽	March	5	9	28	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

STRUYK's Catalogue of ECLIPSES.

Aft. Chr.	Eclipses of the Sun and Moon seen at		M. & D.		Middle H.	M.	Digits eclipsed	
1245	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	☽	Aug.	30	14	39	Total	
1263	Vienna	☽	Feb.	24	6	52	6	29
1263	Augsburgh	☉	Aug.	5	3	24	11	17
1263	Vienna	☽	Aug.	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	☽	Aug.	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.	5	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	☽	Aug.	21	10	32	Total	
1310	Wittemburg	☉	Jan.	31	2	2	10	10
1310	Torcello	☽	Feb.	14	4	8	10	20
1310	Torcello	☽	Aug.	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	☽	Aug.	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
1367	Sienna	☽	Jan.	16	8	27	Total	
1389	Eugibio	☽	Nov.	3	17	5	Total	
1396	Augsburgh	☉	Jan.	11	0	16	6	22
1396	Augsburgh	☽	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	59	Total	
1448	Tubing	☉	Aug.	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	Nurimburg	☉	March	16	3	53	11	—

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	☽	Apr.	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
1400	☽	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 4
1506	☽	Aug.	3	10	—	*	1530	☽	Oct.	6	12	11	Total
1507	☉	Jan.	12	19	—	*	1531	☽	Apr.	1	7	—	*
1508	☉	Jan.	2	4	—	*	1532	☉	Aug.	30	0	40	3

RICCIOLUS's Catalogue of ECLIPSES.

Aft. Chr.		M. & D.	Middle H.	M.	Digits eclipsed	
1533	☽	Aug. 4	11	50	Total	
1533	☉	Aug. 19	17	—	*	
1534	☉	Jan. 14	1	42	5	45
1534	☽	Jan. 29	14	25	Total	
1535	☉	June 30	Noon		*	
1535	☽	July 14	8	—	*	
1535	☉	Dec. 24	2	—	*	
1536	☉	June 18	2	2	8	0
1536	☽	Nov. 27	6	21	10	15
1537	☽	May 24	8	3	Total	
153	☉	June 7	8	—	*	
1537	☽	Nov. 16	14	56	Total	
1538	☽	May 13	14	24	3	0
1538	☽	Nov. 6	5	31	3	37
1539	☉	Apr. 8	4	33	9	0
1540	☉	Apr. 6	17	15	Total	
1541	☽	Mar. 11	16	34	Total	
1541	☉	Aug. 21	0	56	3	
1542	☽	Mar. 1	8	46	1	38
1542	☉	Aug. 10	17	—	*	
1543	☽	July 15	16	—	*	
1544	☽	Jan. 9	18	13	Total	
1544	☉	Jan. 23	21	16	11	17
1544	☽	July 4	8	31	Total	
1544	☽	Dec. 28	18	27	Total	
1545	☉	June 8	20	48	3	45
1545	☽	Dec. 17	18	—	*	
1546	☉	May 30	5	—	*	
1546	☉	Nov. 22	23	—	*	
1547	☽	May 4	10	27	8	0
1547	☽	Oct. 28	4	56	11	34
1547	☉	Nov. 12	2	9	9	30
1548	☉	Apr. 8	3	—	*	
1548	☽	Apr. 22	11	24	Total	
1549	☽	Apr. 11	15	19	2	0
1549	☽	Oct. 6	6	—	*	
1550	☉	Mar. 16	20	—	*	
1551	☽	Feb. 20	8	21	Total	
1551	☉	Aug. 31	2	0	1	52
1553	☉	Jan. 12	22	54	1	22
1553	☉	July 10	7	—	*	
1553	☽	July 24	16	0	0	31
1554	☉	June 29	6	—	*	
1554	☽	Dec. 8	13	7	10	12
1555	☽	June 4	15	0	Total	
1555	☉	Nov. 13	19	—	*	

Aft. Chr.		M. & D.	Middle H.	M.	Digits eclipsed	
1556	☉	Nov. 1	18	0	9	41
1556	☽	Nov. 16	12	44	6	55
1557	☉	Oct. 20	20	—	*	
1558	☽	Apr. 2	11	0	9	50
1558	☉	Apr. 18	1	—	*	
1559	☽	Apr. 16	4	50	Total	
1560	☽	Mar. 11	15	40	4	13
1560	☉	Aug. 21	1	0	6	22
1560	☽	Sept. 3	7	—	*	
1561	☉	Feb. 13	29	—	*	
1562	☉	Feb. 3	5	—	*	
1562	☽	July 15	15	50	Total	
1563	☉	Jan. 22	19	—	*	
1563	☉	June 20	4	50	8	38
1563	☽	July 5	8	4	11	34
1565	☉	Mar. 7	12	53		
1565	☽	May 14	16	—	*	
1565	☽	Nov. 7	12	46	11	46
1566	☽	Oct. 28	5	38	Total	
1567	☉	Apr. 8	23	4	6	34
1567	☽	Oct. 17	13	43	2	40
1568	☉	Mar. 28	5	—	*	
1569	☽	Mar. 2	15	18	Total	
1570	☽	Feb. 20	5	46	Total	
1570	☽	Aug. 15	9	17	Total	
1571	☉	Jan. 25	4	—	*	
1572	☉	Jan. 14	19	—	*	
1572	☽	June 25	9	0	5	26
1573	☉	June 28	18	—	*	
1573	☉	Nov. 24	4	—	*	
1573	☽	Dec. 8	6	51	Total	
1574	☉	Nov. 13	3	50	5	21
1575	☉	May 19	8	—	6	
1575	☉	Nov. 2	5	—	*	
1576	☽	Oct. 7	9	45		
1577	☽	Apr. 2	8	33	Total	
1577	☽	Sept. 26	13	4	Total	
1578	☽	Sept. 15	13	4	2	20
1579	☉	Feb. 15	5	41	8	36
1579	☉	Aug. 20	19	0	*	
1580	☽	Jan. 31	10	7	Total	
1581	☽	Jan. 19	9	22	Total	
1581	☽	July 15	17	51	Total	
1582	☽	Jan. 8	10	29	0	53
1582	☉	June 9	17	5	7	5
1583	☽	Nov. 28	21	51	Total	

RICCIOLUS's

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. 2	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. 10	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	45	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	☽	Apr. 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	☽	April 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. 16	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	1	15	Total		1610	☽	July 5	16	58	11	13
1598	☉	Aug. 31	Magel.		8	34	1610	☉	Dec. 15	Cyprus		4	50
1599	☽	Feb. 10	18	21	Total		1610	☽	Dec. 29	16	47	4	23
1599	☉	July 22	4	31	8	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.		9	40	1613	☉	Apr. 20	Magel.		Ianica.	

RICCIOLUS's

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Aft. Chr.		M. & D	Middle H. M.	Digits eclipsed
1613	☽	May 4	0 35	Total
1613	☉	May 19	East	Tartary
1613	☉	Oct. 13	South	Amer.
1613	☽	Oct. 28	4 19	Total
1614	☉	April 8	N.Gui.	8 44
1614	☽	April 23	17 36	5 25
1614	☉	Oct. 3	0 57	5 2
1614	☽	Oct. 17	4 38	4 56
1615	☉	Mar. 29	Goa	10 38
1615	☉	Sept. 22	Salom	Isle
1615	☽	Mar. 3	1 58	Total
1616	☉	Mar. 17	Mexico	6 47
1616	☽	Aug. 26	15 35	Total
1616	☽	Sept. 10	Magel	10 33
1617	☉	Feb. 5	Magel	lanica
1617	☽	Feb. 20	1 49	Total
1617	☉	Mar. 6	22 —	
1617	☉	Aug. 1	Biarmia	*
1617	☽	Aug. 16	8 22	Total
1618	☉	Jan. 26	Magel	lanica
1618	☽	Feb. 9	3 29	2 57
1618	☉	July 21	Mexico	———
1619	☉	Jan. 15	Califor	nia
1619	☽	June 26	12 40	5 10
1619	☉	July 11	Africa	11 39
1619	☽	Dec. 20	15 53	10 47
1620	☉	May 31	Arctic	Circle
1620	☽	June 14	13 47	Total
1620	☉	June 29	Magel	7 20
1620	☽	Dec. 9	6 39	Total
1620	☉	Dec. 23	Magel	lanica
1621	☉	May 20	14 54	10 44
1621	☽	June 3	19 42	9 53
1621	☉	Nov. 13	Magel	lanica
1621	☽	Nov. 28	15 43	3 28
1622	☉	May 10	C.Verd	11 52
1622	☉	Nov. 2	Malac	ca In.
1623	☽	Apr. 14	7 19	10 54
1623	☉	Apr. 29	———	———
1623	☽	Oct. 8	0 22	8 35
1623	☉	Oct. 23	Califor	10 46
1624	☉	May 18	N.Zem	6 0
1624	☽	Apr. 3	7 9	Total
1624	☉	Apr. 17	Antar.	Circle
1624	☉	Sept. 12	Magel	lanica
1624	☽	Sept. 26	8 55	Total

Aft. Chr.		M. & D	Middle H. M.	Digits eclipsed
1625	☉	Mar. 8	Florida	
1625	☽	Mar. 23	14 11	2 11
1625	☉	Sept. 1	St. Pe	ter's Isle
1625	☽	Sept. 16	11 41	5 6
1626	☉	Feb. 25	Madag	8 27
1626	☽	Aug. 7	7 48	0 25
1626	☉	Aug. 21	In	Mexico
1627	☽	Jan. 30	11 38	10 21
6627	☉	Feb. 15	Magel	lanica
1627	☽	July 27	9 4	Total
1627	☉	Aug. 11	Tenduc	10 0
1628	☉	Jan. 6	Tenduc	5 40
1628	☽	Jan. 20	10 11	Total
1628	☉	July 1	CGood	Hope
1628	☽	July 16	11 26	Total
1688	☉	Dec. 25	In Eng	land
1629	☽	Jan. 9	1 36	4 27
1629	☉	June 11	Gange	11 25
1629	☉	Dec. 14	Peru	10 14
1630	☽	May 25	17 56	6 0
1630	☉	June 10	7 47	9 8
1630	☽	Nov. 19	11 24	9 27
1630	☉	Dec. 3	N.Gui.	10 10
1631	☉	Apr. 30	Antar.	Circle.
1631	☽	May 15	8 15	Total
1631	☉	Oct. 24	CGood	Hope
1631	☽	Nov. 8	12 0	Total
1632	☉	Apr. 19	CGood	Hope
1632	☽	May 4	1 24	6 35
1632	☉	Oct. 13	Mexico	8 37
1632	☽	Oct. 17	12 23	5 31
1633	☉	Apr. 8	5 14	4 30
1633	☉	Oct. 3	Maldiv.	Total
1634	☽	Mar. 14	9 35	11 18
1634	☉	Mar. 28	Japan	10 19
1634	☽	Sept. 7	5 0	Total
1634	☉	Sept. 22	CG.H.	9 54
1635	☉	Feb. 17	Antar.	Circle.
1635	☽	Mar. 3	9 26	Total
1635	☉	Mar. 18	Mexico	0 16
1635	☉	Aug. 12	Iceland	5 0
1635	☽	Aug. 27	16 4	Total
1636	☉	Feb. 6	In	Peru
1636	☽	Feb. 20	11 34	3 23
1636	☉	Aug. 1	Tartary	11 20
1636	☽	Aug. 16	4 34	1 25

RICCIOLUS's Catalogue of ECLIPSES.

Aft. Chr.		M. & D.	Middle H. M.	Digits eclipsed
1637	☉	Jan. 26	Cam-	boya
1637	☉	July 21	Jucutan	
1637	☽	Dec. 31	0 44	10 45
1638	☉	Jan. 14	Persia	9 45
1638	☽	June 25	20 17	Total
1638	☉	July 11	Mag	9 5
1638	☉	Dec. 5	ellan	2 10
1638	☽	Dec. 20	15 16	Total
1639	☉	Jan. 4	Tartary	0 30
1639	☉	June 1	5 29	10 40
1639	☽	June 15	2 41	11 9
1639	☉	Nov. 24	Magel.	14 0
1639	☽	Dec. 9	11 57	3 46
1640	☉	May 20	N. Spa.	10 30
1640	☉	Nov. 13	Peru 2	10 36
1641	☽	Apr. 25	1	9 49
1641	☉	May 9	Peru	10 16
1641	☽	Oct. 18	8 19	6 31
1641	☉	Nov. 2	18 46	—
1642	☉	Mar. 30	Estotl.	4 0
1642	☽	Apr. 14	14 31	Total
1642	☉	Sept. 25	Magel	lanica
1642	☽	Oct. 7	16 45	Total
1643	☉	Mar. 19	13 53	—
1643	☽	Apr. 3	21 10	3 9
1643	☉	Sept. 12	17 0	—
1643	☽	Sept. 27	7 38	6 0
1644	☉	Mar. 8	6 20	—
1644	☉	Aug. 31	18 10	—
1645	☽	Feb. 10	7 45	8 52
1645	☉	Feb. 26	Rom. I	10 46
1645	☽	Aug. 7	2 4	Total
1645	☉	Aug. 21	0 35	4 40
1646	☉	Jan. 16	Str. of	Anian
1646	☽	Jan. 30	18 11	Total
1646	☉	July 12	6 57	—
1646	☽	July 27	6 2	Total
1647	☉	Jan. 5	12 10	—
1647	☽	Jan. 20	9 43	4 47
1647	☉	July 2	0 9	—
1647	☉	Dec. 25	13 38	—
1648	☽	June 5	0 55	4 28
1648	☉	June 20	13 28	—
1648	☽	Nov. 29	19 17	7 40
1648	☉	Dec. 13	21 48	—
1649	☽	May 25	15 20	Total
1649	☉	June 9	Arct. C	4 0
1649	☉	Nov. 4	2 10	3 16
1649	☽	Nov. 18	19 56	Total
1650	☉	Apr. 30	5 54	—
1650	☽	May 15	8 37	7 57
1650	☉	Oct. 24	17 17	—
1650	☽	Nov. 7	20 29	5 3
1651	☉	Apr. 19	Tuber.	—
1651	☉	Oct. 14	2 15	—
1652	☽	Mar. 24	16 52	8 50
1652	☉	Apr. 7	22 40	9 59
1652	☽	Sept. 17	7 27	9 49
1652	☉	Oct. 2	5 2	—
1653	☉	Feb. 27	—	—
1653	☽	Mar. 13	17 9	Total
1653	☉	Aug. 22	—	—
1653	☽	Sept. 6	23 45	Total
1654	☉	Feb. 16	9 10	—
1654	☽	Mar. 2	19 25	3 14
1654	☉	Aug. 11	22 24	2 28
1654	☽	Aug. 27	11 40	1 53
1655	☉	Feb. 6	2 37	4 20
1655	☉	Aug. 1	14 19	—
1655	☽	Aug. 16	16 —	*
1656	☽	Jan. 11	9 4	10 0
1656	☽	July 6	3 17	Total
1656	☉	July 21	11 48	—
1656	☽	Dec. 30	23 30	Total
1657	☉	June 11	11 20	—
1657	☽	June 25	9 35	Total
1657	☉	Dec. 4	20 0	—
1657	☽	Dec. 20	7 47	3 9
1658	☉	May 31	16 0	—
1658	☽	June 14	22 58	—
1658	☽	Nov. 9	13 56	0 10
1658	☉	Nov. 24	11 36	—
1659	☽	May 6	8 34	8 5
1659	☉	May 20	17 4	—
1659	☽	Oct. 29	16 16	5 52
1659	☉	Nov. 14	4 25	9 51
1660	☽	Apr. 24	11 58	Total
1660	☉	Oct. 3	22 34	—
1660	☽	Oct. 18	0 32	Total
1660	☉	Nov. 2	13 48	—
1661	☉	Mar. 29	22 32	—
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	☉	Sep.	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	☉	April	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	—	—	1680	☉	Sept.	22	7	57	—	—
1664	☉	July	22	14	48	—	—	1680	☽	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.	25	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	4	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	9	—	—
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.	27	6	43	—	—	1689	☽	Apr.	4	7	42	Total	
1672	☽	Sept.	6	18	54	—	—	1689	☽	Sept.	28	15	46	Total	
1673	☉	Feb.	6	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

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	☽	June 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	84 5
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	6 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.
1732	☽	Dec.	1	10 A. T.
1733	☉	May	13	7 A.
1733	☽	May	28	7 A.
1735	☽	Oct.	2	1 M.
1736	☽	Mar.	26	12 A. T.
1736	☽	Sept.	20	3 M. T.
1736	☉	Oct.	4	6 A.
1737	☉	Mar.	1	4 A.
1737	☽	Sept.	9	4 M.
1738	☉	Aug.	15	11 M.
1739	☽	Jan.	24	11 A.
1739	☉	Aug.	4	5 A.
1739	☉	Dec.	30	9 M.
1740	☽	Jan.	13	11 A. T.
1741	☽	Jan.	1	12 A.
1743	☽	Nov.	2	3 M. T.
1744	☽	Aug.	26	9 A.
1746	☽	Aug.	30	12 A.
1747	☽	Feb.	14	5 M. T.
1748	☉	July	25	11 M.
1748	☽	Aug.	8	12 A.
1749	☽	Dec.	23	8 A.
1750	☉	Jan.	8	9 M.
1750	☽	June	19	9 A. T.
1750	☽	Dec.	13	7 M.
1751	☽	June	9	2 M.
1751	☽	Dec.	2	10 A.
1752	☉	May	13	8 A.
1753	☽	Apr.	17	7 A.
1753	☉	Oct.	26	10 M.
1755	☽	Mar.	28	1 M.
1757	☽	Feb.	4	5 M.
1757	☽	July	30	12 A.
1758	☽	Jan.	24	7 M. T.
1758	☉	Dec.	30	7 M.
1759	☉	June	24	7 A.
1759	☉	Dec.	19	2 A.
1760	☽	May	29	9 A.
1760	☉	June	13	7 M.
1760	☽	Nov.	22	9 A.
1761	☽	May	18	11 A. T.
1762	☽	May	8	4 M.
1762	☉	Oct.	17	8 M.
1762	☽	Nov.	1	8 A.
1763	☉	Apr.	13	8 M.

Aft. Chr.		Months and Days.		Time of the Day or Night.
1764	☉	Apr.	1	10 M.
1764	☽	Apr.	16	1 M.
1765	☉	Mar.	21	2 A.
1765	☉	Aug.	16	5 A.
1766	☽	Feb.	24	7 A.
1766	☉	Aug.	5	7 A.
1768	☽	Jan.	4	5 M.
1768	☽	June	30	4 M. T.
1768	☽	Dec.	23	4 A. T.
1769	☉	June	4	8 M.
1769	☽	Dec.	13	7 M.
1770	☉	Nov.	17	10 M.
1771	☽	Apr.	28	2 M.
1771	☽	Oct.	23	5 A.
1772	☽	Oct.	11	6 A. T.
1772	☉	Oct.	26	10 M.
1773	☉	Mar.	23	5 M.
1773	☽	Sept.	30	7 A.
1774	☉	Mar.	12	10 M.
1776	☽	July	31	1 M. T.
1776	☉	Aug.	14	5 M.
1777	☉	Jan.	9	5 A.
1778	☉	June	24	4 A.
1778	☽	Dec.	4	6 M.
1779	☽	May	30	5 M. T.
1779	☉	June	14	8 M.
1779	☽	Nov.	23	8 A.
1780	☉	Oct.	27	6 A.
1780	☽	Nov.	12	4 M.
1781	☉	Apr.	23	6 A.
1782	☉	Oct.	17	8 M.
1782	☽	Apr.	12	7 A.
1783	☽	Mar.	18	9 A. T.
1783	☽	Sept.	10	11 A. T.
1784	☽	Mar.	7	3 M.
1785	☉	Feb.	9	1 A.
1787	☽	Jan.	3	12 A. T.
1787	☉	Jan.	19	10 M.
1787	☉	June	15	5 A.
1787	☽	Dec.	24	3 A.
1788	☉	June	4	9 M.
2789	☽	Nov.	2	12 A.
1790	☽	Apr.	28	12 A. T.
790	☽	Oct.	23	1 M. T.
1791	☉	Apr.	3	1 A.

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.
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*	6	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*,

431.

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.

Plate XI.

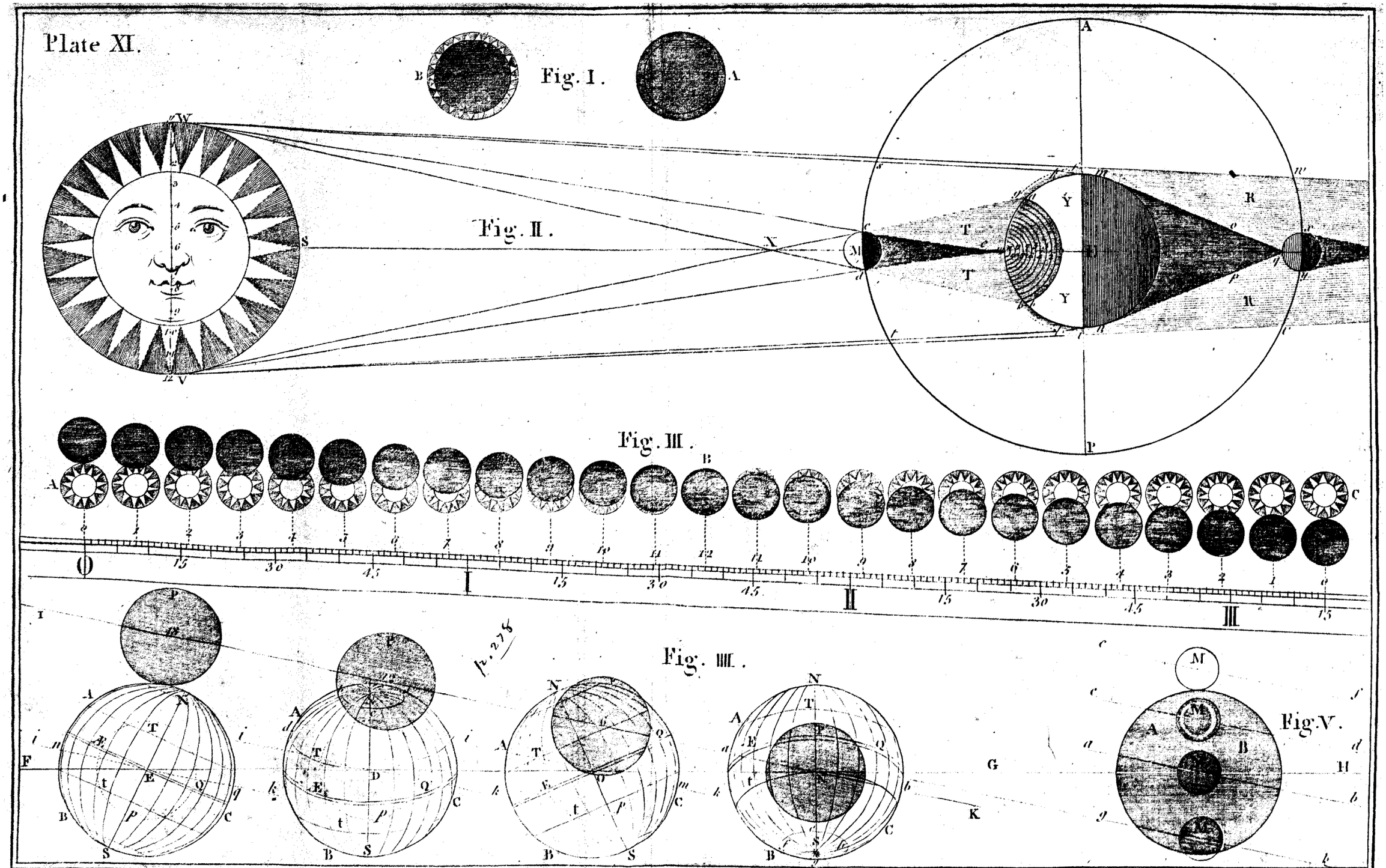


Fig. I.
Fig. II.
Fig. III.
Fig. IIII.
Fig. V.
Spring Equinox April
Summer Solstice July
Fall Equinox Sept.
Winter Solstice Dec.

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 ancients 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 ancients 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 its focuses, she is once at her

PLATE XI. Fig. I.

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 toward 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 eclipses 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 while 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.

and

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 centre 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 *AMP* 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.

and the Earth at 12: the dark space *c e* 12 *d* included between those lines in 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 Perigee, 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 *SXM*, 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 its 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 mo-

* 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 a 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 its 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 its 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 its 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 30½ minutes of a degree every hour at a mean rate; but so much of the Moon's Orbit is equal to 30½ degrees of a great Circle on the Earth, § 320; and therefore the Moon's shadow goes 30½ degrees or 1830 geographical miles on the Earth in an hour, or 30½ 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 its parallelism throughout its annual course. Let *E*, *D*, *O*, *N* be the Earth at the two Equinoxes and the two Solstices, *NS* its Axis, *N* the North Pole, *S* the South Pole, *Æ Q* the Equator, *T* the Tropic of Cancer, *t* the 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 toward the right hand, as seen from the Sun or New Moon; its Poles *N* and *S* being then in the Circumference of the Disc; and the Equator and all its 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

Fig. IV.

Phenomena of the Earth as seen from the Sun or New Moon at different times of the year.

Moon directly over *E*, where the Ecliptic *F G* intersects the Equator *Æ*. At the summer Solstice, the Earth's Axis has the position *N D S*; and that part of the Ecliptic F G, in which the Moon is then New, touches the Tropic of Cancer ♋ at *D*. The North Pole *N* at that time inclining 23½ degrees toward the Sun, falls so many degrees within the Earth's enlightened Disc, because the Sun is then vertical to *D*, 23½ degrees north of the Equator *Æ Q*; and the Equator with all its parallels seem elliptic curves bending downward, or toward the South Pole, as seen from the Sun: which Pole, together with 23½ degrees all around 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 its 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 its South Pole *S* inclining 23½ degrees toward the Sun, falls 23½ degrees within the enlightened Disc, as seen from the Sun or New Moon, which are then vertical to the Tropic of Capricorn ♑, 23½ degrees south of the Equator *Æ Q*; and the Equator with all its 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-

PLATE XI. Various positions of the Earth's Axis are seen from the Sun at different times of the year.

ed; and the Equator and all its 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 downward, or toward 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 toward the Sun at the Summer Solstice; from the Sun at the Winter Solstice; and Sidewise to the Sun at the Equinoxes; but toward the right hand, as seen from the Sun at the Vernal Equinox; and toward 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 Nodes 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 its 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 ☋. 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 its center at *D*, on the Tropic of Cancer ☋, 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 ☋ 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 *NES*: but in the former of these two last cases, the Penumbra enters the Earth at *A*, north of the Tropic of Cancer ☋, and leaves it at *m*, south of the Tropic of Capricorn *t*; having gone over the Earth obliquely southward, as its center described the line *A O m*: whereas, in the latter case, the Penumbra touches the Earth at *n*, south of the Equator *Æ Q*, and describing the line *nEq* (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 part 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; its center falling on the middle of it, 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 proportion 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 its 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) while the point *b* in the polar Circle *a b c d* is carried from *b*

to *c* by the Earth's diurnal motion, the point *d* on the Tropic of Cancer ☋ 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 while 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 toward *d*, but *a* moves the contrary way toward *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 its disappearing on 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 of

The Moon has no Atmosphere.

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 said so much about 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 its 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; and those which pass nearest the Earth's surface, are bent more than those rays which go through higher parts of the Atmosphere, where it is less dense, until it be so thin or rare as to lose its refractive power. Let the Circle *f g h i*, concentric to the Earth, include the Atmosphere, whose refractive power vanishes at the heights *f* and

Why the Moon is visible in a total Eclipse.

and *i*; so that the rays *W f w* and *V i v* 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 *W k* and *V l* 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 *m o q p n*, 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 its dark shadow, suppose about *p o*, she would be invisible during her stay in it; but visible before and after in the fainter shadow *RR*. PLATE XL.

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 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 *G H* be the Ecliptic, *e f* the Moon's Orbit where she is 12 degrees from the Node at her Full; *c d* her Orbit where she is 6 degrees from the Node, *a b* her Orbit where she is Full in the Node, *A B* the Earth's Fig. V.

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 *ab*, 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 several 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 broken 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 shew in the Eleventh Chapter. 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 its 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.

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 complete 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 complete 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 its orbit, is reckoned

koned 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 of it in coming round again, though ever so little.

The distance of the Sun or Moon from its Apogee at any given time is called its *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 its Apogee or its Perigee, its place is the same as it would be, if its motion were equable in all parts of its 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 *, while the Luminary is moving from its Apogee to its Perigee; and the true place is always forwarder than the mean, while the Luminary is moving from its Perigee to its 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 *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 $3\frac{1}{10}$ 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 Luna-

* 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 ancient Eclipses, than *Mayer*'s do, without allowing for the Moon's acceleration,

tions

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 complete Julian years; which accordingly we find

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, while the Anomaly is less than six signs; and their true places are forwarder than the mean, while the Anomaly is more.

Hence it is evident, that while 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 while 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 while the Sun is moving from his Apogee to his Perigee, and decreasing in length while 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* to *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 29 seconds, on account of the dilitation 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, 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 its greatest excentricity, her apogeal distance from the Earth's center is to her perigeal distance from it, 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 all the various inequalities depending on the different excentricities of the Moon's Orbit in the syzygies; and called *The second equation of*

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 its 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 its Aphelion, the Sun appears to be in its Apogee; and when the Earth is in its Perihelion, the Sun appears to be in its Perigee.

As the Earth moves from its Aphelion to its 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 its Perihelion to its 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 its 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 while 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

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.

Every 49th Lunation (or Course of the Moon from Change to Change) returns very nearly to the same time of the day as before. For, in 49 mean Lunations there are 1446 days 23 hours 58 minutes 29 seconds 25 thirds, which wants but 1 minute 30 seconds 34 thirds of 1477 days.

In 29530590851 08 days, there are 10000000000 mean Lunations exactly: and this is the smallest number of natural days in which any exact number of mean Lunations are completed.

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	25	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	16	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	34	8	24	30	47	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	31	20	3	50	9	2	8	50	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	30
1714	4	11	12	13	8	15	12	35	6	18	48	52	3	10	31	17
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	32	2	14	2	8	5	5	19	52
1718	19	23	54	45	9	0	28	44	1	19	39	13	6	14	2	54
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	43
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	54
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	46	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	33	8	25	42	34	6	15	57	28	3	10	3	4

TABLE

For the Meridian of London

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	51
1734	23	1	16	49	9	3	20	38	4	1	22	39	4	26	48	53
1735	12	10	3	25	8	22	36	30	2	11	10	44	5	4	51	40
1736	0	18	54	2	8	11	52	22	0	20	58	49	5	12	54	27
1737	19	16	26	42	9	0	14	34	11	26	35	55	6	21	37	29
1738	9	1	15	18	8	19	30	26	10	6	24	0	6	29	40	16
1739	27	22	47	58	9	7	52	38	9	12	1	6	8	8	23	18
1740	16	7	36	34	8	27	8	30	7	21	49	11	8	16	26	5
1741	5	16	25	11	8	16	24	22	6	1	37	16	8	24	28	52
1742	24	13	57	52	9	4	46	34	5	7	14	22	10	3	11	54
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	28
1745	21	5	7	44	9	1	40	32	1	2	27	38	11	28	0	30
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	19
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	52
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	40
1752	3	20	16	0	8	14	44	16	3	2	42	15	3	35	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	50
1758	27	15	19	54	9	7	38	28	7	18	57	48	8	15	57	52
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	0	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	49
1766	29	4	0	56	9	9	4	20	8	24	49	32	1	22	20	51

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 Dist. from the Node.			
	D.	H.	M.	S.	s	o	′	″	s	o	′	″	s	o	′	″
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	53	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	43	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	50
1774	1	3	57	55	8	11	24	1	9	4	52	14	5	28	3	37
1775	20	1	30	25	8	29	46	13	8	10	29	20	7	6	49	38
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	28	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	57	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	23	41	9	4	4	3	11	28	4	31	10	25	55	37
1800	13	0	22	17	8	23	19	55	10	7	52	36	11	3	58	22

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	38	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	17	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	4	3	15	1
1772	3	21	36	39	8	3	45	57	11	19	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	29	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	o	′	″	s	o	′	″	s	o	′	″
1787	18	14	10	6	8	17	21	59	3	21	22	24	2	16	9	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	31	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	57	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.*

No.	Mean Lunations.				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	′	″
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	14	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	30	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	30	0	15	20	7

TABLE

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	295.305908851080	295	7	20	30	29	43
20	590.611817021 60	590	14	41	0	59	26
30	885.917725532 40	885	22	1	31	29	10
40	1181.223634043 20	1181	5	22	1	58	53
50	1476.529542554 01	1476	12	42	32	28	36
60	1771.835451064 81	1771	20	3	2	58	19
70	2067.141359575 61	2067	3	23	33	28	2
80	2362.447268086 41	2362	10	44	3	57	46
90	2657.753176597 22	2657	18	4	34	27	29
100	2953.059085108 0	2953	1	25	4	57	12
200	5906.118170216 0	5906	2	50	9	54	24
300	8859.177255324 0	8859	4	15	14	51	36
400	11812.236340432 0	11812	5	40	19	48	48
500	14765.295425540 1	14765	7	5	24	46	0
600	17718.354510648 1	17718	8	30	29	43	12
700	20671.413595756 1	20671	9	55	34	40	24
800	23624.472680864 1	23624	11	20	39	37	36
900	26577.531765972 2	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	88591.772553140	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	236244.726801641	236244	17	26	36	16	0
9000	265775.317659722	265775	7	37	25	48	0
10000	295305.908510 80	295305	21	48	15	20	0
20000	590611.817021 60	590611	19	36	30	40	0
30000	885917.725532 40	885917	17	24	46	0	0
40000	1188223 63404320	1188223	15	13	1	20	0
50000	1476529.542554 01	1476529	13	1	16	40	0
60000	1771835.451064 81	1771835	10	49	32	0	0
70000	2067141.359575 61	2067141	8	37	47	20	0
80000	2362447.268086 41	2362447	6	25	2	40	0
90000	2657753.176597 22	2657753	4	14	18	0	0
100000	2953959.085108 0	2953959	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 complete 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
8658	700	0	20	32	3	11	24	22	10	21	45	7	15	31
9895	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	76	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	3200	20	18	51	40	11	20	51	4	28	27	0	19	52

TABLE

TABLE VI. *concluded.*

Lunations.	Julian years.	First New Moon.				Sun's mean Anomaly.			Moon's mean Anomaly.			Sun's mean Dif. from Node.		
		D.	H.	M.	S.	s	°	′	s	°	′	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	27	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	6	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
65354	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	56

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 Sign.	1 Sign.	2 Signs.	3 Signs.	4 Signs.	5 Signs.	Degrees.
	H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S	
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 51	2 14 14	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	3 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 10	1 10 33	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 0	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 1	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 35	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 54	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 5	0 13 23	3
28	1 55 37	3 30 26	4 10 33	3 43 45	2 15 20	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
Deg.	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 Sign.	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	
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	
15	0 24 10	1 6 18	1 31 19	1 32 14	1 8 8	0 25 3	
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 40	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 47 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 IX. *The second Equation of the mean to the true Syzygy.*

Argument. Moon's equated Anomaly.

Add

Degrees.	0 Sign.	1 Signs.	2 Signs.	3 Signs.	4 Signs.	5 Signs.	Degrees.
	H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S.	
0	0 0 0	5 12 48	8 47 8	9 46 44	8 8 59	4 34 33	30
1	0 10 58	5 21 56	8 51 45	9 45 3	8 3 12	4 26 1	29
2	0 21 56	5 30 57	8 56 10	9 45 12	7 57 23	4 17 25	28
3	0 32 54	5 39 51	9 0 25	9 44 11	7 51 33	4 8 47	27
4	0 42 52	5 48 37	9 4 31	9 42 59	7 45 46	4 0 7	26
5	0 54 50	5 57 17	9 8 25	9 41 36	7 39 46	3 51 23	25
6	1 5 48	6 5 51	9 12 9	9 40 3	7 33 36	3 42 32	24
7	1 16 46	6 14 19	9 15 43	9 38 19	7 27 22	3 33 38	23
8	1 27 44	6 22 41	9 19 5	9 36 24	7 21 2	3 24 42	22
9	1 38 40	6 30 57	9 22 14	9 34 18	7 14 30	3 15 44	21
10	1 49 33	6 39 4	9 25 12	9 32 1	7 7 50	3 6 45	20
11	2 0 23	6 47 0	9 27 58	9 29 33	7 1 2	2 57 43	19
12	2 11 10	6 54 46	9 30 32	9 26 54	6 54 8	2 48 39	18
13	2 21 54	7 2 24	9 32 58	9 24 4	6 47 9	2 39 34	17
14	2 32 34	7 9 52	9 35 12	9 21 3	6 40 6	2 30 28	16
15	2 43 9	7 17 9	9 37 14	9 17 51	6 32 56	2 21 19	15
16	2 53 38	7 24 19	9 39 8	9 14 28	6 25 40	2 12 8	14
17	3 4 8	7 31 18	9 40 51	9 10 54	6 18 18	2 2 53	13
18	3 14 24	7 38 9	9 42 21	9 7 9	6 10 49	1 53 36	12
19	3 24 42	7 44 51	9 43 42	9 3 13	6 3 16	1 44 16	11
20	3 34 58	7 51 24	9 44 53	8 59 6	5 55 38	1 34 54	10
21	3 45 11	7 57 45	9 45 52	8 54 50	5 47 54	1 25 31	9
22	3 55 21	8 3 56	9 46 38	8 50 24	5 40 4	1 16 7	8
23	4 5 26	8 9 57	9 47 13	8 45 48	5 32 9	1 6 41	7
24	4 25 26	8 15 46	9 47 36	8 41 2	5 24 9	0 57 13	6
25	4 25 20	8 21 24	9 47 49	8 36 6	5 16 5	0 47 44	5
26	4 35 6	8 26 53	9 47 54	8 31 0	5 7 56	0 38 13	4
27	4 44 42	8 32 11	9 47 46	8 25 44	4 59 42	0 28 41	3
28	4 54 11	8 37 19	9 47 33	8 20 18	4 51 15	0 19 8	2
29	5 3 33	8 42 18	9 47 14	8 14 33	4 43 2	0 9 34	1
30	5 12 48	8 47 8	9 46 44	8 8 59	4 34 33	0 0 0	0
Deg.	11 Signs.	10 Signs.	9 Signs	8 Signs.	7 Signs.	6 Signs.	Deg.

Subtract

TABLE

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		Signs. 1 Sub. 7 Add		Signs. 2 Sub. 8 Add		Degrees.
	M.	S.	M.	S.	M.	S.	
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

Degrees.	0, 6 Sig. (Add)		1, 7 Sig. (Add)		2, 8 Sig. (Add)		Degrees.
	M.	S.	M.	S.	M.	S.	
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. (Subtract)		4, 10 Sig. (Subtract)		3, 9 Sig. (Subtract)		Deg.

TABLE XII. *The Sun's mean Longitude, Motion, and Anomaly: Old Stile.*

Years beginning	Sun's mean Longitude.				Sun's mean Anomaly.		
	s	°	′	″	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 complete	Sun's mean Motion.				Sun's mean Anomaly.		
	s	°	′	″	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

Years complete	Sun's mean Motion.				Sun's mean Anomaly.		
	s	°	′	″	s	°	′
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.				Sun's mean Anomaly.		
	s	°	′	″	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
Sep.	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

TABLE XII. *concluded.*

Days.	Sun's mean Motion and Anomaly.				Sun's mean Motion and Anomaly.				Sun's mean Dist. from Node.				Sun's mean Motion and Anomaly.				Sun's mean Dist. from Node.			
	s	°	′	″	H M S	° ′ ″ ″ ‴ ⁗			° ′ ″ ″ ‴ ⁗				H M 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	44	8		47	1	55	49	2	2	3	
19	0	18	43	38	18	0	44	21	0	46	44		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	56		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	55	2	30	38	
30	0	29	34	10	29	1	11	28	1	15	19		59	2	25	23	2	33	14	
31	1	30	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

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 Sign.	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 53	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

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 21	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 Sign. ° ′	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

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	22	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.		Anomaly of Sun and Moon.	
s	°	′	″	′	″	′	″	′	″	′	″	s	°
0	0	54	29	15	50	14	54	30	10	2	23	12	0
	6	54	31	15	50	14	55	30	12	2	23		24
	12	54	34	15	50	14	56	30	15	2	23		18
	18	54	40	15	51	14	57	30	19	2	23		12
	24	54	47	15	51	14	58	30	26	2	23		6
1	0	54	56	15	52	14	59	30	34	2	24	11	0
	6	55	6	15	53	15	1	30	44	2	24		24
	12	55	17	15	54	15	4	30	55	2	24		18
	18	55	29	15	55	15	8	31	9	2	24		12
	24	55	42	15	56	15	12	31	23	2	25		6
2	0	55	56	15	58	15	17	31	40	2	25	10	0
	6	56	12	15	59	15	22	31	56	2	26		24
	12	56	29	16	1	15	26	32	17	2	27		18
	18	56	48	16	2	15	30	32	39	2	27		12
	24	57	8	16	4	15	36	33	11	2	28		6
3	0	57	30	16	6	15	41	33	23	2	28	9	0
	6	57	52	16	8	15	46	33	47	2	29		24
	12	58	12	16	10	15	52	34	11	2	29		18
	18	58	31	16	11	15	58	34	34	2	29		12
	24	58	49	16	13	16	3	34	58	2	30		6
4	0	59	6	16	14	16	9	35	22	2	30	8	0
	6	59	21	16	15	16	14	35	45	2	31		24
	12	59	35	16	17	16	19	36	0	2	31		18
	18	59	48	16	19	16	24	36	20	2	32		12
	24	60	0	16	20	16	28	36	40	2	32		6
5	0	60	11	16	21	16	31	37	0	2	32	7	0
	6	60	21	16	21	16	32	37	10	2	33		24
	12	60	30	16	22	16	37	37	19	2	33		18
	18	60	38	16	22	16	38	37	28	2	33		12
	24	60	45	16	23	16	39	37	36	2	33		6
6	0	60	45	16	23	16	39	37	40	2	33	6	0

To

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 propoſed 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 Diſtance from the Moon's aſcending Node.—If you want the time of Full Moon in *March*, add the half Lunation at the foot of Table III. with its Anomalies, &c. to the former numbers, if the New Moon falls before the 15th of *March*; but if it falls after, ſubtract the half Lunation, with the Anomalies, &c. belonging to it, from the former numbers, and write down the reſpective ſums or remainders.

II. In theſe additions or ſubtractions, obſerve, that 60 ſeconds make a minute, 60 minutes make a degree, 30 degrees make a ſign, and 12 ſigns make a circle. When you exceed 12 ſigns in addition, reject 12, and ſet down the remainder.—When the number of ſigns to be ſubtracted is greater than the number you ſubtract from, add 12 ſigns to the leſſer number, and then you will have a remainder to ſet down.—In the Tables, ſigns are marked thus ^{s}, degrees thus $^{\circ}$, minutes thus $'$, and ſeconds 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 diſtance from the Node, from Table III. as the given month is after *March*; ſetting them in order below the numbers taken out for *March*.

IV. Add all theſe together, and they will give the mean time of the required New or Full Moon, with the mean Anomalies and Sun's mean diſtance from the aſcending 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 fall short of any in the column under the given month, add one Lunation and its 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 downward; 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 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, found in the Table (from page 163 to page 175) 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.

EXAM-

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 fro. 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 22 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	Sun fro. Node, and Arg. 4th equation.
Time once equated,	32 1 50 19	9 20 27 1	11 10 59 18	
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 mean 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.

EXAM-

EXAMPLE II.

Qu. *The true mean time of Full Moon in* May 1762, [redacted] Stile?

By the Precepts.	New Moon.	Sun's Anom.	Moon's Anom.	Sun fro. Node.
	D. H. M. S.	s ° ′ ″	s ° ′ ″	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 6	1 28 12 39	1 21 38 1	2 1 20 28
New Moon, *May*,	22 16 46 30	10 22 0 55	3 15 37 12	0 20 9 42
Sub. 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 15	× 1 14 33	Sun fro. Node,
Time once equat.	8 1 41 4	1 3 30 30	9 3 57 15	and Arg. fourth
Second Equation,	— 9 47 53	Arg. 3d equat.	Arg. 2d equat.	equation.
Time twice equat.	7 15 53 11	Anſ. *May* 7th at 15 h. 50 m. 50 ſec. paſt		
Third Equation,	— 2 36	noon, viz. *May* 8th at III h. 50 min. 50 ſec.		
Time thrice equat.	7 15 50 35	in the morning.		
Fourth Equation,	× 15			
The Full Moon,	7 15 50 50			

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 complete centuries of years from Table VI. as, when ſubtracted from the above ſaid year in the 18th century, will anſwer to the given year; and take out the firſt mean New Moon and its Anomalies, &c. be-

 longing

longing 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 its 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 mean 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.	Sun's Anom.	Moon's Anom.	Sun fro. Node.
	D. H. M. S.	s ° ′ ″	s ° ′ ″	s ° ′ ″
March 1730.	7 12 34 16	8 18 4 31	9 0 32 17	1 23 17 16
Add ½ Lunation,	4 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	13 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 fro. Node
Time once equat.	6 5 31 43	4 21 59 20	5 10 58 40	and Arg. 4th
Second Equation,	+ 2 57 55	Arg. 3d equat.	Arg. 2d equat.	equation.
Time twice equat.	6 8 29 38			
Third Equation,	— 2 54			
Time thrice equat.	6 8 26 44			
Fourth Equation,	— 1 33			
Tr. Full Moon, *Apr.*	6 8 25 11			

Hence it appears, that the mean time of Full Moon in *April*, *A. D.* 30 Old Stile, was on the 6th day, at 25 m. 11 sec. 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 Christ diminished by one, shall make a number of complete centuries.

II. Find this number of centuries in Table VI. and subtract the Time and Anomalies belonging to it from those 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 the mean New Moon in *March*, the given year before Christ.—Then, for the true time of that New Moon, in any month of that year, proceed in the manner taught above.

EXAMPLE IV.

Required the mean time of New Moon in May, *Old Stile, the year before Christ* 585?

The years 584 added to 1716, make 2300, or 23 centuries.

By the Precepts.	New Moon.	Sun's Anom.	Moon's Anom.	Sun fro. 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 subtr.	11 5 57 53	11 19 47 0	1 5 59 0	7 25 27 0
Mar. bef. Chr. 585	0 11 35 36	9 3 3 39	2 28 15 2	9 1 50 5
Add 3 Lunations,	38 14 12 9	2 27 18 58	2 17 27 1	3 2 0 42
May bef. Chr. 585,	28 1 47 45	0 0 22 37	5 15 42 3	0 3 50 47
First Equation,	— 1 37	5 15 41 27	— 36	
Time once equat.	28 1 46 8	6 14 41 10	5 15 41 27	Sun fro. Node, and Arg. fourth equation.
Second Equation,	+ 2 14 58	Arg. 3d equat.	Arg. 2d equat.	
Time twice equat.	28 4 1 6			
Third Equation,	+ 1 13			
Time thrice equat.	28 4 2 19			
Fourth Equation,	+ 12			
True New Moon,	28 4 2 31			

So the mean time was *May* 28th, at 2 minutes 31 seconds past 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 mean time of Full Moon at Alexandria *in* Ægypt, *long.* 30°, 21′, 45″ E. *in* September, *Old Stile, the year before Christ* 201?

The years 200 added to 1800, make 2000, or 20 centuries.

By the Precepts.	New Moon.				Sun's Anom.				Moon's Anom.				Sun fro. Node.			
	D.	H.	M.	S.	s	°	′	″	s	°	′	″	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	54	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	53	9	10	4	19	52	—	1	28	17	Sun fro. Node, and Arg. 4th equation.			
Time once equat.	22	13	50	12	5	18	27	28	10	4	19	52				
Second Equation,	—	8	25	4	Arg. 3d equat.				Arg. 2d equat.							
Time twice equat.	22	5	25	8												
Third Equation,			—	58												
Time thrice equat.	22	5	24	10												
Fourth Equation,			—	12												
Tr. time at *London*,	22	5	23	58												
Add for *Alexandria*,		2	1	27												
True time there.	22	7	25	25												

Thus it appears, that the true mean time of Full Moon at *Alexandria*, in *September*, Old Stile, the year before Christ 201, was the 22d day, at 25 min. 25 sec. after VII in the evening.

EXAMPLE

EXAMPLE VI.

Required the true mean time of Full Moon at Babylon, *long.* 36°, 25′, 15″ E. *in* October, *Old Stile, the* 4008*th year before the first year of Christ, or* 4007 *before the year of his birth?*

The years 4007 added to 1793, makes 5800, or 58 centuries.

By the Precepts.	New Moon.				Sun's Anom.				Moon's Anom.				Sun fro. Node.			
	D.	H.	M.	S.	s	°	′	″	s	°	′	″	s	°	′	″
March 1793,	30	9	13	55	9	10	16	11	8	7	37	58	7	6	18	26
Subtr. 5800 years.	15	12	38	7	10	21	35	0	6	24	43	0	9	3	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	
Add { 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	28	1	26	27	26		—	5	5	Sun fro. Node,			
Time once equat.	22	7	52	43	4	0	31	10	1	26	27	26	and Arg. fourth			
Second Equation,	+	8	29	20	Arg. 3d equat.				Arg. 2d equat.				equation.			
Time twice equat.	22	16	22	3												
Third Equation,		—	4	10												
Time thrice equat.	22	16	17	53												
Fourth Equation.			—	51												
Full Moon at *London*	22	16	17	2												
Add for *Babylon*,		2	25	41												
True time there,	22	18	42	43												

So that, on the meridian of *London*, the true time was *October* 23d, at 17 min. 2 sec. past IV in the morning; but at *Babylon*, the true time was *October* 23d, at 42 min. 43 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 18*th 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 complete centuries.

III. Add all these together, and then work in all respects as shewn above, only remember to subtract a Lunation and its Anomalies, when the above-mentioned addition carries the New Moon beyond the 31st of *March*; as in the following example:

EXAMPLE VII.

Required the true mean time of New Moon in July, *Old Stile*, A. D. 2180?

Four centuries (or 400 years) added to *A. D.* 1780, makes 2180.

By the Precepts.	New Moon.	Sun's Anom.	Moon's Anom.	Sun fro. Node.
	D. H. M. S	s ° ′ ″	s ° ′ ″	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 2	0 29 6 19	0 25 49 0	1 0 40 14
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
New ☽ *July* 2180,	7 21 57 22	0 15 1 11	2 10 2 49	8 8 10 43
First Equation,	— 1 3 41	3 9 38 38	— 24 11	Sun fro. Node,
Time once equated,	7 20 53 41	10 5 22 33	2 9 38 38	and Arg. 4th
Second Equation,	+ 9 24 8	Arg. 3d equat	Arg. 2d equat.	equation.
Time twice equat.	8 6 17 49			
Third Equation,	+ 3 56	True mean time, *July* 8, at 22 minutes 53		
Time thrice equat.	8 6 21 45	seconds past VI in the evening.		
Fourth Equation,	+ 1 8			
True time, *July*,	8 6 22 53			

In keeping by the Old Stile, 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 53 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 complete 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 complete 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 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 complete 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	31	Mean Anomaly.			
Sun's true place at the same time		0.	12.	10.	7 or ♈	12	10	7.	

EXAMPLE

EXAMPLE II.

Required the Sun's true Place, October *23d 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	2	′	″	s	o	′	″
From the radical numbers after Christ – –	1	9	7	53	10	6	28	48	0
Subtract those for 5000 complete 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: complete 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 4 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

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 of these Phenomena.—Thus, at the time of mean New Moon in *April* 1764, the Sun's mean Distance from the ascending Node, is 0ˢ 5° 35′ 2″. *See Example* I. p. 320.

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 0ˢ 5° 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 9ˢ 1° 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. ° ′ ″
At the mean time of New Moon in *April* 1764 — —		0 5 35 2
Sun's motion from the Node for —	50 minutes 46 seconds	2 10 2
Sun's mean distance from Node at true New Moon — —		0 5 37 14
Equation of mean distance from Node, add — —		2 5 0
Sun's true distance from the ascending Node — —		0 7 42 14

which, being far within the above limit of 17 degrees, shews that the Sun must then be eclipsed.

And now we shall shew how to project this, or any other eclipse, either of the Sun or Moon.

To project an Eclipse of the Sun.

In order to this, we must 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 semidiameter of the Earth's disc, as seen from the Moon, which is equal to the Moon's horizontal parallax. 3. The Sun's distance from the solstitial Colure to which he is then nearest. 4. The Sun's declination. 5. The angle of the Moon's visible path with the Ecliptic. 6. The Moon's latitude. 7. The Moon's true horary motion from the Sun. 8. The Sun's semidiameter. 9. The Moon's. 10. The semidiameter of the Penumbra.

We shall now proceed to find these Elements for the Sun's Eclipse in *April* 1764.

To find the true time of New Moon. This, by Example I. p. 320, is found to be on the first day of the said month, at 30 minutes 25 seconds after X in the morning.

2. *To*

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 11ˢ 9° 24′ 21″, is 54′ 43″.

3. *To find the Sun's distance from the nearest Solstice, viz. the beginning of Cancer, which is 3ˢ or 90° from the beginning of Aries.* It appears by the Example on page 328 (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 0ˢ 12° 10′ 7″, that is, the Sun's place at that time is ♈ Aries, 12° 10′ 7″.

	s	°	′	″
Therefore from — — —	3	0	0	0
Subtract the Sun's longitude or place	0	12	10	7
Remains the Sun's distance from the Solstice ♋ — =	2	17	49	53

Or 77° 49′ 53″; 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. 0ˢ 12°, and making proportion for the 10′ 7″, take out the Sun's declination answering to his true place, and it will be found to be 4° 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 with this the Moon's Latitude is found in Table XVI.

Now we have already found, that the Sun's equated distance from the ascending Node, at the time of New Moon in *April* 1764, is 0ˢ 7° 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 proportion 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. 11ˢ 9° 24′ 21″, enter Table XVII. and take out the Moon's horary motion; which, by making proportion in that Table, will be found to be 30′ 22″. Then, with the Sun's Anomaly, 9ˢ 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.

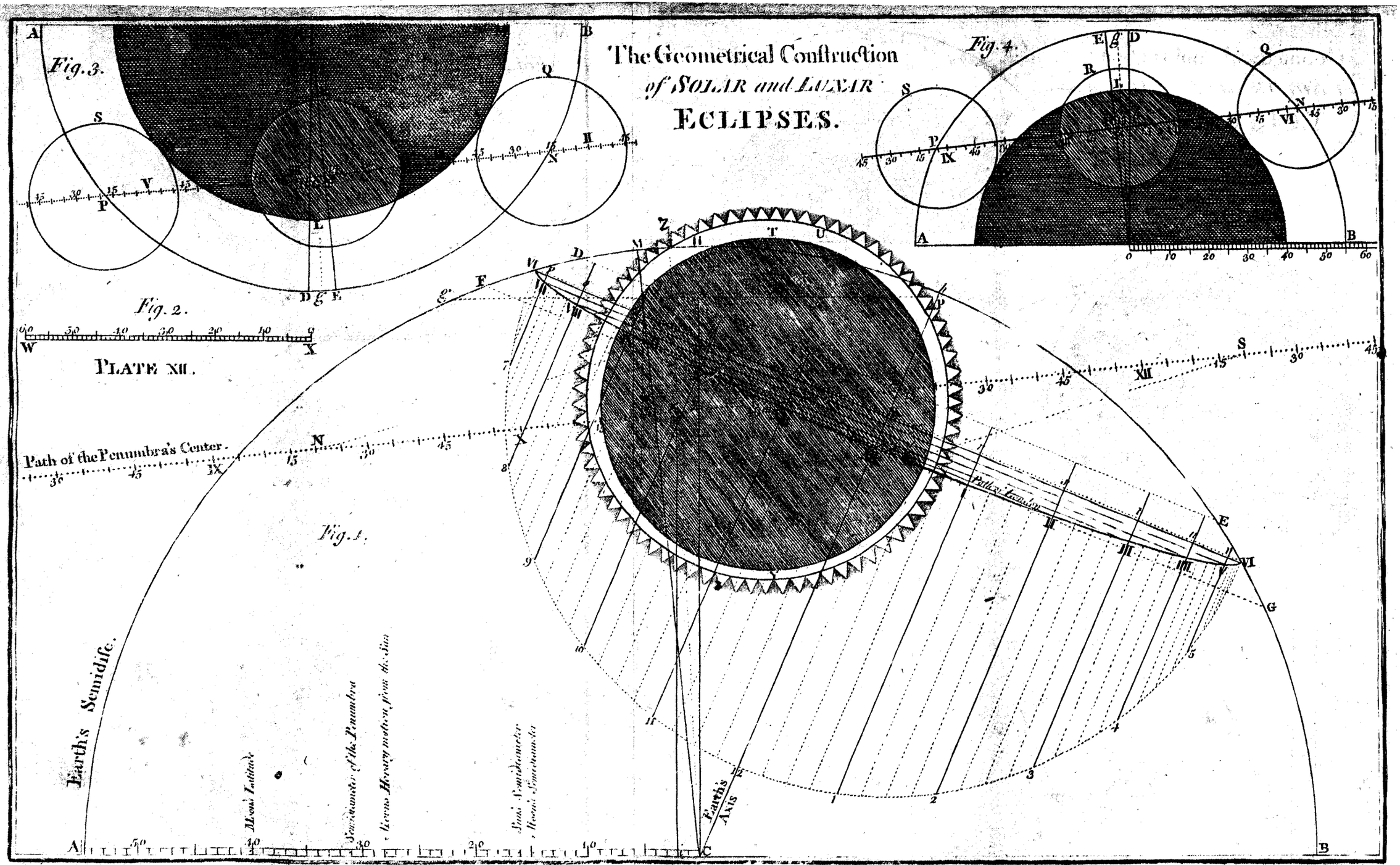
8, 9. *To find the semidiameters of the Sun and Moon.* These are found in the same Table, and by the same Arguments, as their horary Motions. —In the present case the Sun's Anomaly gives his semidiameter 16′ 6″, and the Moon's Anomaly gives her semidiameter 14′ 57″.

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	43
3. Sun's dist. from the nearest Solst.	77	49	53
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.
PLATE XII.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Path of the Penumbra's Center.
Path of the Lunar Orbit
Earth's Semidisc.
Moon's Latitude
Semidiameter of the Penumbra
Horizontal Parallax
Sun's Semidiameter
Moon's Semidiameter
Earth's Axis
J. Lagrion 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

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To project an Eclipse of the Sun geometrically.

Make a scale of any convenient length, as *A C*, 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′ 43″. Then, with the whole length of the scale as a radius, describe the semicircle *A M B* 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. 1.

Upon the center *C* raise the straight line *C H*, perpendicular to the diameter *ACB*; so *ACB* shall be a part of the Ecliptic, and *C H* its Axis.

Being provided with a good sector, open it to the radius *C A* in the line of chords; and taking from thence the chord of 23½ 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 while 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, while the Sun is in the other six Signs.

Open

Open the sector till the radius (or distance of the two 90's) of the Signs be equal to the length of *V h*, and take the sine of the Sun's distance from the Solstice (77° 49′ 53″) 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* toward *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*, 51½° from 90° and the remainder 38½° 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*.

So Bowditch.

take the length of the dotted line and set it each way from K to VI. on the bisecting line K M.

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* 38½° 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 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 its rising to its 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.

See Brackich or Clemmow – Relating to drawing the moon's orbit & using the Hourly motion in longitude & annual latitude
M. Cophill

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 *C z*, making *i x* parallel to *Cy*: and through *x*, at right-angles,* to the Axis of the Moon's Orbit *C M*, draw the ſtraight line *N w x y S* 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 ſixty 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 its tranſit over the Earth.

Apply one ſide of a ſquare to the line of the Penumbra's path, and move the ſquare backward and forward, until the other ſide of it cuts the ſame hour and minute (as at *m* and *n*) 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

* See Dummore or Burdett's — find the moon's latitude at the Ecliptic conjunction and lay it off on the axis of the Ecliptic from C, & on the line CH. — M. Conjunction

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*, 47½ minutes 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 backward and forward till both the points of the compaſſes fall into the ſame inſtant in both the paths: and that inſtant 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 inſtant in both the paths, that inſtant will be the time when 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 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 rectilinear 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 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 spheroid. 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 *Mayer*'s Tables, this Eclipse will be about a quarter of an hour sooner than either these Tables, or Mr. *Flamstead*'s, or Dr. *Halley*'s make it:

it: and *Mayer*'s Tables do not make it annular at *London*.

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 321, 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 321,) 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 proportion, will be found to be 57′ 20″.

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′ 39″.

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′ 20″, the ſum will be 57′ 30″, from which ſubtract the Sun's ſemidiameter 15′ 56″, and there will remain 41′ 34″ 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 331) at the true time of Full Moon; and this diſtnace, 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 333.

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 312) 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 proportion 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 316; 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	20
3. Sun's ſemidiameter	0	15	56
4. Moon's ſemidiameter	0	15	39
5. Semidiameter of the Earth's ſhadow at the Moon	0	41	34

	°	′	″
6. Moon's true latitude, south descending	0	32	21
7. Angle of her visible 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 construction of the Moon's Eclipse in *May*, 1762, proceed as follows:

Fig. II. Make a scale of any convenient length, as *W X*, and divide it into 60 equal parts, each part standing for a minute of a degree.

Draw the right line *A C B* (Fig 3.) for part of the Ecliptic, and *C D* perpendicular to it for the southern part of its Axis; the Moon having south latitude.

Add the semidiameters of the Moon and Earth's shadow together, which, in this Eclipse, will make 57′ 13″; and take this from the scale in your compasses, and setting one foot in the point *C*, as a center, with the other foot describe the semicircle *ADB*; in one point of which the Moon's center will be at the beginning of the Eclipse, and in another at the end of it.

Take the semidiameter of the Earth's shadow, 41′ 34″, in your compasses from the scale, and setting one foot in the center *C*, with the other foot describe the semicircle *K L M* for the southern half of the Earth's shadow, because the Moon's latitude is south in this Eclipse.

Make *C D* the radius of a line of chords on the sector, and set off the angle of the Moon's visible path with the Ecliptic, 5° 35′, from *D* to *E*, and draw the right line *C F E* for the southern half of the Axis of the Moon's Orbit, lying to the right hand from the Axis of the Ecliptic *C D*, because the Moon's latitude is south descending.—It would have been the same way (on the other side of the Ecliptic) if her latitude had been north descending; but contrary in both cases, if her

her latitude had been either north ascending or south ascending.

Bisect the angle *D C E* by the right line *C g*, 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 *C G g*; and through the point *G*, at right angles to *C F E*, draw the right line *P H G F N* 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 *P G N*: 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 *D C E*.

Take the Moon's semidiameter, 15′ 39″, 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 ancient 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 the Eclipse in his Chronology as follows, among several other ancient ones, recorded by different authors:

Jul. Per. 4513. *Sept.* 22.	Ecl. * *Per. Calip.* 2 *An.* 54. *Hor.* 7. *P. M. Alexandr. Dig. eccl.* 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 *Calipic* 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 324) 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 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. 10ˢ 6° 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 30½′ 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 its quantity was almost 10 digits, and its 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. XXIX.

Of the fixed Stars.

Why the fixed Stars appear bigger when viewed by the bare eye, than when seen through 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 revolution being caused solely by the Earth's turning on its 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 aerial 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 appears 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 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-ball 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 plurality 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 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 ancients divided the starry Sphere into particular Constellations, or Systems of Stars, according as they lay near one another, so as to occupy those spaces with 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 ancient 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* (ζωδιακος) from ζωδιον *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, 3d, That on the south side, 15. The *Zodiac*.

361. The ancients divided the *Zodiac* into the above 12 Constellations or Signs in the following manner. They took a vessel with a small hole 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 its 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 ob- The manner of dividing it by the ancients.

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 ancient 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
Cassiopea	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 ancient Constellations.		*Ptolemy.*	*Tycho.*	*Hevel.*	*Flamst.*
Argo	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
Piſcis Auſtralis	The Southern Fiſh	18			24

The New Southern Conſtellations.

Columba Naochi	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.	*Flamst.*
Lynx	The Lynx	19	44
Leo minor	The Little Lion		53
Aſteron and Chara	The Greyhounds	23	25
Cerberus	Cerberus	4	
Vulpecula and Anſer	The Fox and Gooſe	27	35
Scutum Sobieſki	Sobieſki's Shield	7	
Lacerta	The Lizard		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 its peculiar whiteneſs, which is found, by means of the teleſcope, to be owing to a vaſt number of very ſmall Stars that are ſituated in that part of the heavens. The *Milky Way.*

heavens. 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 its 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 forty in that of the *Crab*. Two are visible in the eye of *Sagittarius* without a telescope, and several more with it. *Flamstead* 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 *Flamstead* 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 ancient Astronomers, which are not now to be found; and others are now visible to the bare eye which are not recorded in the ancient 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 ancient 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 *Cassiopea*. 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 its 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 its 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, beſide 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

ſlow rotations on their Axes; 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 ſplendour for ſome time: which indeed appears to be the greateſt uſe of the cometary part of any ſyſtem*.

Some Stars change their places.

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 changes its 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

* 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 toward us; as Saturn's Ring is in ſuch poſitions. But when any eccentric Planets or Comets go round any flat Star, in Orbits much inclined to its 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 its broadſide is more or leſs turned toward 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 perception.

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 ancients, because of the incorrectness of their Instruments; we have to answer that both *Tycho* and *Flamstead* are allowed to have been very good observers; and yet we find that *Flamstead* makes this obliquity 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 its Axis shorter than its 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 toward 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 standard, or integral measure of time, is a Year; which is determined by the Revolution of some Celestial Body in its Orbit, viz. the *Sun* or *Moon.* A Year.

371. The Time measured by the Sun's Revolution in the Ecliptic, from any Equinox or Solstice to the same again, is called the *Solar* or *Tropical Year,* which contains 365 days, 5 hours, 48 minutes, 57 seconds; and is the only proper or natural year, because it always keeps the same seasons to the same months. Tropical Year.

372. The quantity of time measured by the Sun's Revolution as from any fixed Star to the same Star again, is called the *Sydereal Year*; which contains 365 days, 6 hours, 9 minutes, 14½ seconds; and is 20 minutes 17½ seconds longer than the true Solar Year. Sydereal Year.

373. The time measured 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 seconds; and is therefore 10 days, 21 hours, 0 minutes, 21 seconds shorter than the Solar Year. This is the foundation of the Epact. Lunar Year.

374. The *Civil Year* is that which is in common use among the different nations of the world; of which, some reckon by the Lunar, but most 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 *Bissex-* Civil Year.

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 Style*. 377. The year thus settled, is what was used in *Britain* till *A. D.* 1752: 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 XIII. 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 the 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 of Months.

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 — — —	Apr.—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.

N°

N°	The ancient *Grecian* year.			Days
1	Hecatombæon	— —	June — July	30
2	Metagitnion	— —	July—Aug.	29
3	Boëdromion	— —	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	Municheon	— —	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 Sunset. 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 ancient *Greeks*, *Jews*, *Bohemians*, *Silesians*, with the modern *Italians* and *Chinese*, begin it at Sun-setting: and the ancient *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.

Minutes, Seconds, Thirds, and Scruples.

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.

Cycles of the Sun, Moon, and Indiction.

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.

To find the Years of these Cycles.

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 of

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 remain, 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 remain, 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 remain, the Indiction is 15.

The deficiency of the Lunar Cycle, and consequence thereof.

385. Although the above deficiency in the Lunar Cycle 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	Aug.	Sept.	Oct.	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		9				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.

A perpetual Table of the time of New Moon to the nearest hour for the *Old Stile*.

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 the case 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 nearest 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: because in that time the changes of the Moon anticipate almost a complete natural day. And if the like number of hours be added for so many years past, we shall have the mean time of any New Moon already elapsed. Suppose, for example, the mean time of Change was required for *January*, 1802; deduct 76 years, and there remains 1726, against which, in the following Table, under *January* I find the time of New Moon was on the 21st day, at 11 in the evening: from which take 6 hours, and there remains the 21st 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 against 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. For this addition for time past, or subtraction for time to come, the Table will not vary 24 hours from the truth in less than 14592 years. And if, instead of 6 hours for every 76 years, we add or subtract 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 Cycles 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* — —	$5^d\ 8^h\ 16^m$
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* —	$18^d\ 8^h\ 16^m$ Morn. *N. S.*

So the mean time of New Moon in *June* 1909, *New Stile*, is the 18th day, at 16 minutes past 8 in the Morning.

If 11 days be added to the time of any New Moon in this Table, it will give the time of that New Moon 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 neurest Hour, through four Lunar Periods, or 76 years.* M *signifies morning;* A *afternoon.*

Years of the Cyc.	A.D.	January		February		March		April	
		D.	H.	D.	H.	D.	H.	D.	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	15	11M
9	1732	16	5M	14	6 A	15	7M	23	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	1M	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

Yrs. of the Cyc.	A.D.	*May*		*June*		*July*		*August*	
		D.	H.	D.	H.	D.	H.	D.	H.
1	1724	11	8 A	10	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
26	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*		*October*		*November*		*December*	
		D.	H.	D.	H.	D.	H.	D.	H.
1	1724	6	10 A	6	11 M	4	12 A	4	1 A
2	1725	25	8 A	25	9 M	23	10 A	23	11 M
3	1726	15	5 M	14	5 A	13	6 M	12	7 A
4	1727	4	1 A	4	2 M	2	3 A	2 31	4 M 5 A
5	1728	22	11 M	21	12 A	20	1 A	20	2 M
6	1729	11	8 A	11	9 M	9	10 A	9	11 M
7	1730	2 30	5 M 6 A	30	7 M	28	8 A	28	9 M
8	1731	20	2 M	19	3 A	18	4 M	17	5 A
9	1732	8	11 M	7	12 A	6	1 A	6	2 M
10	1733	27	9 M	26	10 A	25	11 M	24	11 A
11	1734	16	5 A	16	6 M	14	7 A	14	8 M
12	1735	6	2 M	5	3 A	4	4 M	3	5 A
13	1736	23	12 A	23	1 A	22	2 M	21	3 A
14	1737	13	8 M	12	9 A	11	10 M	10	11 A
15	1738	2	5 A	2 31	6 M 7 A	30	8 M	29	8 A
16	1739	21	3 A	21	4 M	19	5 A	19	6 M
17	1740	9	12 A	9	1 A	8	2 M	7	3 A
18	1741	28	9 A	28	10 M	26	11 A	26	11 M
19	1742	18	6 M	17	7 A	16	8 M	15	9 A
20	1743	7	3 A	7	4 M	5	5 A	5	6 M
21	1744	25	1 A	25	2 M	23	3 A	23	3 M
22	1745	14	9 A	14	10 M	12	11 A	12	0 A
23	1746	4	6 M	3	7 A	2	8 M	1 31	9 A 10 M
24	1747	23	3 M	22	4 A	21	5 M	20	6 A
25	1748	11	0 A	11	1 M	9	2 A	9	3 M
26	1749	30	10 M	29	11 A	28	0 A	27	12 A

A TABLE *of the mean New Moons continued.*

Yrs. of the Cyc.	A.D.	*January*		*February*		*March*		*April*	
		D.	H.	D.	H.	D	H.	D.	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	3 A	29	4A	28	5M
44	1767	18	11 A	17	12 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 New Moons continued.*

Yrs. of the Cyc.	A.D.	*May*		*June*		*July*		*August*	
		D.	H.	D.	H.	D.	H.	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 M	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	2M
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 the Cyc.	A.D.	September		October		November		December	
		D.	H.	D.	H.	D.	H.	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	6	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	8M
45	1768	30	3M	29	4 A	28	5M	27	5 A
46	1769	19	1M	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	32	2M	1 1	3 A 4M	29	5 A	29	5M

Yrs. of the Cyc.	A.D.	*January*		*February*		*March*		*April*	
		D.	H.	D.	H.	D.	H.	D.	H.
54	1777	27	6 A	26	7M	27	8 A	26	9M
55	1778	17	3M	15	4 A	17	5M	15	6 A
56	1779	6	0 A	5	1M	6	2 A	5	3M
57	1780	25	10M	23	11 A	24	11M	22	12 A
58	1781	13	6 A	12	7M	13	8 A	12	9M
59	1782	3	3M	1	4 A	3	5M	1	6 A
60	1783	22	1M	20	2 A	22	2M	20	3 A
61	1784	11	9M	9	10 A	10	11M	8	12 A
62	1785	29	7M	27	8 A	29	9M	27	10 A
63	1786	18	4 A	17	5M	18	5 A	17	6M
64	1787	7	12 A	6	1 A	8	2M	6	3 A
65	1788	26	10 A	25	11M	25	12 A	24	1 A
66	1789	15	7M	13	8 A	15	9M	13	10 A
67	1790	4	4 A	3	5M	4	5 A	3	6M
68	1791	23	1 A	22	2M	23	3 A	22	4M
69	1792	12	10 A	11	11M	11	12 A	10	1 A
70	1793	1 30	7M 8 A			1 30	9M 10 A	29	10M
71	1794	20	5M	18	6 A	20	6M	18	7 A
72	1795	9	1 A	8	2M	9	3 A	8	4M
73	1796	28	11M	26	12 A	27	0 A	26	1M
74	1797	16	7 A	15	8M	16	9 A	15	10M
75	1798	6	4M	4	5 A	6	6M	4	7 A
76	1799	25	2M	23	3 A	25	4M	23	5 A
1	1800	14	11M	12	12 A	13	0 A	12	1M

A TABLE *of the mean New Moons concluded.*

The year 1800 begins a new Cycle.

A TABLE *of the mean New Moons concluded.*

Yrs. of the Cyc.	A.D.	*May*		*June*		*July*		*August*	
		D.	H.	D.	H	D.	H.	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	3A	3	4M	2	5 A	1 30	6M 6 A
57	1780	22	0 A	21	1M	20	2 A	19	3 A
58	1781	11	9 A	10	10M	9	11 A	8	0M
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*		*October*		*November*		*December*	
		D.	H.	D.	H.	D.	H.	D.	H.
54	1777	20	12 A	10	1 A	19	2M	18	3 A
55	1778	10	9M	9	10 A	8	11M	7	12 A
56	1779	29	7M	28	8 A	27	9M	26	9 A
57	1780	17	3 A	17	4M	15	5 A	15	6M
58	1781	6	12 A	6	1 A	5	2M	4	3 A
59	1782	25	10 A	25	11M	23	12 A	23	0 A
60	1783	15	6M	14	7 A	13	8M	12	9 A
61	1784	3	3 A	3	4M	1	5 A	1 30	6M 6 A
62	1785	22	1 A	22	2M	20	3 A	20	3M
63	1786	11	9 A	11	10M	9	11 A	9	0 A
64	1787	1 30	6M 7 A	30	8M	28	9 A	28	9M
65	1788	19	4M	18	5 A	17	6M	16	7 A
66	1789	8	1 A	8	2M	6	3 A	6	4M
67	1790	29	10M	26	11 A	25	0 A	24	12 A
68	1791	16	7 A	16	8M	14	9 A	14	10M
69	1792	5	4 A	4	5 A	3	6M	2	7 A
70	1793	24	2M	23	3 A	22	4M	21	4 A
71	1794	13	10M	12	11 A	11	0 A	11	1M
72	1795	2	7 A	2 31	8M 9 A	30	10M	29	10 A
73	1796	20	4 A	20	5M	18	6 A	18	7M
74	1797	0	1M	9	2 A	8	3M	7	4 A
75	1798	28	11 A	28	0 A	27	1M	26	1 A
76	1799	18	8M	17	9 A	16	10M	15	11 A
1	1800	6	4 A	6	5M	4	6 A	4	7M

388. The

Easter Cycl: 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.

Number of Direction.

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. To find the number of Direction, according to the *New Stile*, enter Table V. following this Chapter, with the complete hundreds of any given year at the top, and the years thereof (if any) below a hundred at the left hand; and where the columns meet is the Dominical Letter for the given year. Then enter Table I. with the complete hundreds of the same year at the left hand, and the years below a 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

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 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 Almanacs, 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 a 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 wanting 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 *F E*, 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 toward 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* are *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 *F E*, § 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 year before *Strauchius*'s supposed year of the Creation (for no later could all the three Cycles begin together), and it is not yet completed: 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 *Dyonysian* 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 unto 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 afterwards 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.

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 came upon *Jerusalem* as a torrent, with their idolatrous images, which were an abomination to the *Jews*, and under which they marched against them, invaded their land, and besieged their holy City, and by a calamitous war, brought such utter destruction upon both, that the *Jews* have never been able to recover themselves, even to this day.

Now, both by the undoubted Canon of *Ptolemy*, and the famous *Æra* of *Nabonassar*, the beginning of the seventh year of the reign of *Artaxerxes Longimanus*, King of *Persia*, (who is called *Ahasuerus* in the book of *Esther*,) is pinned down to the 4256th year of the *Julian* Period, in which year he gave *Ezra* the above-mentioned ample Commission: from which count 490 years to the death of CHRIST, and it will carry the same to the 4746th year of the *Julian* Period.

Our *Saturday* is the *Jewish* 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*, seeing the Crucifixion was on the day next before the *Jewish* Sabbath.—And according to St. *John*, ch. xviii. ver. 28. on the day that the Passover was to be eaten, at least by many of the *Jews*.

The *Jews* reckoned their months by the Moon, and their years by the apparent revolution of the Sun: and they ate the Passover on the 14th day of the month of *Nisan*, which was the first month of their year, reckoning from the first 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 sky was clear. So that their 14th day of the month answers to our fifteenth day of the Moon, on which she is full.—Consequently, the Passover 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 *Josephus* expressly says (*Antiq.* B. iii. ch. 10.) "The Passover was kept on the 14th day

" of the month of *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 Pascal 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 nominal 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 3d 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 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 Yesdegird:* 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 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 *Argonautic* Expedition	3420	2714	1293
10. The Destruction of *Troy*	3504	2798	1209
11. The Beginning of King *David*'s Reign	3650	2944	1063
12. The Foundation of *Solomon*'s Temple	3701	2995	1012
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. *Attica*, 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	1352	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	3542	464
35. The Beginning of *Daniel*'s seventy Weeks of Years	4256	3550	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 100,000 *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	3861	146
45. *Julius Cæsar* invades *Britain*	4659	3953	54
46. He corrects the Calendar	4677	3961	46
47. Is killed in the Senate-House	4671	3965	42

48. *Herod*

	Julian Period.	Y. of the World.	Before Christ.
48. *Herod* made King of *Judea*	4673	3967	40
49. *Anthony* defeated at the Battle of *Actium*	4683	3977	30
50. *Agrippa* builds the *Pantheon* at *Rome*	4688	3982	25
51. The true Æra of CHRIST's Birth	4709	4003	4
52. The Death of *Herod*	4710	4004	3
			After Christ.
53. The *Dionysian* or vulgar ÆRA of CHRIST's Birth	4713	4007	0
54. The true year of his Crucifixion	4746	4040	33
55. The Destruction of *Jerusalem*	4783	4077	70
56. *Adrian* builds the Long Wall in *Britain*	4833	4127	120
57. *Constantius* defeats the *Picts* in *Britain*	5019	4313	306
58. The Council of *Nice*	5038	4332	325
59. The Death of *Constantine the Great*	5050	4344	337
60. The *Saxons* invited into *Britain*	5158	4452	445
61. The *Arabian Hegira*	5335	4629	622
62. The Death of *Mahommed* the pretended Prophet	5343	4637	630
63. The *Persian Yesdegird*	5344	4638	631
64. The Sun, Moon, and all the Planets in *Libra*, *Sept.* 14, as seen from the Earth	5899	5193	1186
65. The Art of Printing discovered	6153	5447	1440
66. The Reformation begun by *Martin Luther*	6230	5524	1517

In fixing the year of the Creation to the 706th year of the *Julian* Period, which was the 4007th year before the year of CHRIST's Birth, I have followed Mr. *Bedford* in his Scripture Chronology, printed A. D. 1730, and Mr. *Kennedy*, in a work of the same kind, printed A. D. 1762.—Mr. *Bedford* takes it only for granted that the World was created at the time of the Autumnal Equinox; but Mr. *Kennedy* affirms that the said Equinox was at the noon of the fourth day of the Creation-week, and that the Moon was then 24 hours past her opposition to the Sun.—If *Moses* had told us the same things, we should have had sufficient *data* for fixing the *Æra* of the Creation: but as he has been silent on these points, we must consider the best accounts of Chronologers as entirely hypothetical and uncertain.

Age of the World uncertain.

TABLE

TABLE I. *Shewing the Golden Number (which is the same both in the Old and New Stile) from the Christian Æra to A. D.* 380.

Years less than an Hundred.

Hundreds of Years.		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
		38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
		57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
		76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
		95	96	97	98	99														
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 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	18	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

TABLE IV. *Shewing the Dominical Letters, Old Stile, for 4200 Years after the Christian Æra.*

After Chr.				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 Chr.				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	A B

TABLE VI. *Shewing the Days of the Months, for both Stiles, by the Dominical Letters.*

Week Days.	A	B	C	D	E	F	G
January 31 October 31	1 8 15 22 29	2 9 16 23 30	3 10 17 24 31	4 11 18 25	5 12 19 26	6 13 20 27	7 14 21 28
Feb. 28-29 March 31 November 30	5 12 19 26	6 13 20 27	7 14 21 28	1 8 15 22 29	2 9 16 23 30	3 10 17 24 31	4 11 18 25
April 30 July 31	2 9 16 23 30	3 10 17 24 31	4 11 18 25	5 12 19 26	6 13 20 27	7 14 21 28	1 8 15 22 29
August 31	6 13 20 27	7 14 21 28	1 8 15 22 29	2 9 16 23 30	3 10 17 24 31	4 11 18 25	5 12 19 26
September 30 December 31	3 10 17 24 31	4 11 18 25	5 12 19 26	6 13 20 27	7 14 21 28	1 8 15 22 29	2 9 16 23 30
May 31	7 14 21 28	1 8 15 22 29	2 9 16 23 30	3 10 17 24 31	4 11 18 25	5 12 19 26	6 13 20 27
June 30	4 11 18 25	5 12 19 26	6 13 20 27	7 14 21 28	1 8 15 22 29	2 9 16 23 30	3 10 17 24

CHAP.

CHAP. XXII.

A Description of the Astronomical Machinery serving to explain and illustrate the foregoing part of this Treatise.

Frontingthe 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 its 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 its Axis inclining almost 8 Degrees from the Axis of the Ecliptic; and turning round in $25\frac{1}{4}$ days on its 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 its Axis in the Machine, because the time of its 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 toward 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 its 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 its 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 its Parallelism throughout its annual Course, § 48, 202; so that in Summer the northern parts of the Earth incline toward 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 toward 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, *&c 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 its Signs and Degrees in $18\frac{2}{3}$ 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 o and o; and, as the Moon rises and falls in her Orbit according to its 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 toward 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 engraven 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 29½ 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 PLATE IX. Fig. X.

of Ebb, § 304, 305; the Index on the Hour-Circle (No. 7.) ſhewing the times of theſe Phenomena.

There is a jointed Wire, of which one end being put into a hole in the upright ſtem that holds the Earth's cap, and the Wire laid into a ſmall forked piece which may be occaſionally put upon Venus or Mercury, ſhews the direct and retrograde Motions of theſe two Planets, with their ſtationary Times and Places as ſeen from the Earth.

The whole Machinery is turned by a winch or handle (No. 12.) and is ſo eaſily moved, that a clock might turn it without any danger of ſtopping.

To give a Plate of the wheel-work of this Machine would anſwer no purpoſe, becauſe many of the wheels lie ſo behind others, as to hide them from ſight in any view whatſoever.

Another ORRERY. PLATE VI. Fig. I.

398. *Another* ORRERY. In this Machine, which is the ſimpleſt I ever ſaw, for ſhewing the diurnal and annual motions of the Earth, together with the motion of the Moon and her Nodes, *A* and *B* are two oblong ſquare plates held together by four upright pillars; of which three appear at *f*, *g*, and *g* 2. Under the Plate *A* is an endleſs ſcrew on the Axis of the handle *b*, which works in a wheel fixed on the ſame Axis with the double-grooved wheel *E*; and on the top of this Axis is fixed the toothed wheel *i*, which turns the pinion *k*, on the top of whoſe Axis is the pinion *k* 2, which turns another pinion *b* 2, and that turns a third, which being fixed on *a* 2, the Axis of the Earth *U*, turns it round, and the earth with it: this laſt Axis inclines in an angle of $23\frac{1}{2}$ Degrees. The ſupporter *X* 2, in which the Axis of the Earth turns, is fixed to the moveable Plate *C*.

In the fixed Plate *B*, beyond *H*, is fixed the ſtrong wire *d*, on which hangs the Sun *T*, ſo as it may turn round the wire. To this Sun is fixed the wire or ſolar ray *Z*, which (as the Earth *U* turns round its Axis) points to all the places that the Sun paſſes vertically over, every day of the year.

The

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 toward 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 *YX*, 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 *YX*; 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 toward 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 catgut string crossing between them; and by this means the Moon's inclined Plane *Y X*, with its Nodes, is turned backward, for shewing the times and returns of Eclipses, § 310, 320.

The following parts of this machine must be considered as distinct from those already described.

Toward 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 $29\frac{1}{2}$ 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 toward 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 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 its Parallelifm 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 its 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 its 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 centre 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 toward the centre of the Earth *E*, which is furniſhed with a moveable Horizon *H*, together with a brazen Meridian, and Quadrant of Altitude. *R* is a ſmall Ecliptic, whoſe Plane coincides 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 Plane *P P*, 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 PLATE VIII. Fig. I.

being rectified to any given Latitude, and the Earth turned round its 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 its Furniture round the Sun; for the Index *U* is fixed tight on the immoveable Axis in the Centre 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, its 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

the Nodes, one of which, viz. the Descending 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 distances, as in the other Orrery, the limits of Eclipses are marked, and all the solar and lunar Eclipses are shewn in the same manner, for any given year within the limits of 6000, either before or after the Christian Æra. On the plate that covers the wheel-work, under the Sun ☉, and round the knob *K*, are Astronomical Tables, by which the Machine may be rectified to the beginning of any given year within these limits, in three or four minutes of time; and when once set right, may be turned backward for 300 years past, or forward for as many to come, without requiring any new rectification. There is a method for its 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 Month-Circle, too long and intricate to be described here, I shall only shew how these Motions may be performed near enough for common use, by wheels with grooves and cat-gut strings round them; only here I must put the Operator in mind, that the grooves are to be made sharp (not round) bottomed, to keep the strings from slipping.

The Moon's Axis moves up and down in the socket *N* fixed into the bar *O* (which carries her round the Earth) as she rises above or sinks below the Ecliptic; and immediately below the inclined Plane ☊ is a flat circular plate (between ☋ and ☊) on which the different Eccentricities of the Moon's Orbit are laid down: and likewise her mean Anomaly and elliptic Equation, by which her true Place may be very nearly found at any time. Below this Apogee-plate, which shews the Anomaly, &c. is a Circle ☋ divided into 29½ equal parts,

which are the days of the Moon's age: and the forked end *A* of the Index *A B* (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 Agogee, and retrograde 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 Eccentricity 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 its 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

work of ſuch a Machine, is as follows: which is 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; two of which 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 *E E*, which ſupports the whole work. PLATE VIII. Fig. III.

In the centre of this laſt-mentioned Plate is fixed the upright Axis *G F f*, 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 *P P*, under the Earth, in Fig. 1.) and to this Plate is fixed, at an Angle of 23½ 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 Parallelifm 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

on the inclined Plane *X* (which is *T* in Fig. 1.) and so causes the Moon alternately to rise above and sink below the little Ecliptic *V V* (*R* in Fig. 1.) in every Lunation.

On the socket or hollow Axis of the Wheel *N*, there is another socket, on which the Wheel *O* is fixed; and the Moon's inclined Plane *X* is put tightly on the upper end of this socket, not on a square, but on a round, that it may be occasionally set by hand without wrenching the Wheel or Axle.

Lastly, on the hollow Axis of the Wheel *O* is another socket, on which is fixed the Wheel *P*, and on the upper end of this socket is put on tightly the Apogee-plate *Y* (*that* immediately below *T* in Fig. 1.) All these Axles turn in the upper Plate of the moveable frame at *Q*; which Plate is covered with the thin Plate *c c* (screwed to it), whereon are the fore-mentioned Tables and Month-Circle in Fig. 1.

The middle part of the thick fixed Wheel *H H H* is much broader than the rest of it, and comes out between the Wheels *M* and *O* almost to the Wheel *N*. To adjust the diameters of the Grooves of this fixed Wheel to the Grooves of the separate Wheels *M*, *N*, *O*, and *P*, so as they may perform their motions in the proper times, the following method must be observed.

The Groove of the Wheel *M*, which keeps the Parallelism of the Earth's Axis, must be precisely of the same Diameter as the lower Groove *I* of the fixed Wheel *H H H*; but, when this Groove is so well adjusted as to shew, that in ever so many annual revolutions of the Earth, its Axis keeps its Parallelism, as may be observed by the solar Ray *W* (Fig. 1.) always coming precisely to the same Degree of the small 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 small rub all round, and, by that means lessening

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 its Parallelifm, § 246, toward 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 its 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 its 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, *I M k*, *O*, and *L P*, without crossing.

The COMETARIUM. 400. The COMETARIUM. This curious Machine shews the Motion of a Comet, or eccentric 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 Eccentricity. 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 ♈: 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 *a S b*, *b S c*, *c S d*, &c. or contents of these several Triangles, are all equal: and in every turn of the Winch *N* the Comet ♈ 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 its Orbit continually decreases from the Perihelion *a* to the Aphelion *g*; and increases in the same proportion from *g* to *a*.

The elliptical 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*. While the Comet moves from *f* to *g* in its 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 *t n* or *n o* in the Heavens, either of which spaces contains 120 Degrees, or four Signs. Were the Eccentricity of

of its Orbit greater, the greater ſtill would be the difference of its motion, and *vice verſâ.*

ABCDEFGHIKLMA is a circular Orbit for ſhewing the equal Motion of a Body round the Sun *S*, deſcribing equal Areas *A S B*, *B S C*, &c. in equal times with thoſe of the Body *Y* in its elliptical Orbit above-mentioned; but with this difference, that the circular motion deſcribes the equal Arcs *A B*, *B C*, &c. in the ſame equal times that the elliptical Motion deſcribes the unequal Arcs *a b*, *b c*, &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 its reſpective Orbit, to arrive at theſe Points again at the ſame inſtant, the Body *Y* will be forwarder in its 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 its 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. *A B C* 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 *F F* and *G G*; each Plate being fixed on an Axis in one of its Focuſes, at *E* and *K*: and the Wheel *E* is fixed on the ſame Axis with the Plate *F F*. PLATE IV. Fig. V.

F F. These Plates have Grooves round their edges precisely of equal diameters to one another, and in these Grooves is the cat-gut string *g g*, *g g* 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 *F F*, being fixed on the same Axis with the Wheel *E*, and the Plate *F F* turning the equally big Plate *G G* 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 *F F* being farther from its 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 Centre *E*. But then, the quick-moving end *h* of the Plate *F F* leads about the short end *h K* of the Plate *GG* with the same velocity; and the slow moving end *i* of the Plate *F F* coming half round, as to *B*, must then lead the long end *k* of the Plate *G G* as slowly about: So that the elliptical Plate *F F* and its Axis *E* move uniformly and equally quick in every part of its revolution; but the elliptical Plate *G G*, together with its Axis *K*, must move very unequally in different parts of its revolution: the difference being always inversely as the distance of any points of the Circumference of *G G* from its Axis at *K*; or in other words, to instance in two points, if the distance *K k*, be four, five, or six times as great as the distance *K h*, the Point *h* will move in that position four, five, or six times

times as fast as the point *k* does: when the Plate *G G* has gone half round: and so on for any other Eccentricity or Difference of the Distances *K k* and *K h*. The tooth *i* on the Plate *F F* falls in between the two teeth at *k* on the Plate *G G*, by which means the revolution of the latter is so adjusted to that of the former, that they can never vary from one another.

On the top of the Axis of the equally moving Wheel *D*, in Fig. 5th, is the Sun *S* in Fig. 4th; which Sun, by the Wire *Z* fixed to it, carries the Ball 1 round the Circle *A B C D*, &c. with an equable Motion according to the order of the letters: and on the top of the Axis *K* of the unequally-moving Ellipsis *G G*, in Fig. 5th, is the Sun *S* in Fig. 4th, carrying the Ball *Y* unequally round in the elliptical Groove *a b c d*, &c. *N. B.* This elliptical Groove must be precisely equal and similar to the verge of the Plate *G G*, which is also equal to that of *F F*.

In this manner, Machines may be made to shew the true motion of the Moon about the Earth, or of any Planet about the Sun; by making the elliptical Plates of the same eccentricities, in proportion to the Radius, as the Orbits of the Planets are, whose Motions they represent; and so, their different Equations, in different parts of their Orbits, may be made plain to the sight: and clearer ideas of these Motions and Equations will be acquired in half an hour, than could be gained from reading half a day about them.

401. The IMPROVED CELESTIAL GLOBE. On the north Pole of the Axis, above the Hour-Circle, is fixed an Arch *M K H* of 23½ Degrees; and at the end *H* is fixed an upright pin *H G*, which stands directly over the North pole of the Ecliptic, and perpendicular to that part of the surface of the Globe. On this pin are two moveable Collets at *D* and *H*, to which are fixed the quadrantal Wires *N* and

The improved CELESTIAL GLOBE.

PLATE III. Fig. III.

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, on which the $29\frac{1}{2}$ 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 that when the Globe is turned, the Wires with the Sun and Moon may 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 $5\frac{1}{3}$ 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 $5\frac{1}{3}$ Degrees of the Moon's Latitude on both sides of the Ecliptic; and when this piece is set upright on the Globe, its 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 brass Meridian, and set the Hour-Index to XII at noon, that

that is, to the upper XII on the Hour-Circle, keeping the Globe in that situation; slacken the screw *G*, and set the Sun directly over his place on the Meridian; which being done, set the Moon's Wire under the number that expresses her age for that day on the Plate *F*, and she will then stand over her place in the Ecliptic, and shew what Constellation she is in. Lastly, fasten the screw *G*, and laying the curved edge of the pasteboard *S* over the Ecliptic, below the Moon, adjust the Moon to her latitude over the graduated edge of the pasteboard; and the Globe will be rectified.

Having thus rectified the Globe, turn it round, and observe on what points of the Horizon the Sun and Moon Balls rise and set, for these agree with the points of the Compass on which the Sun and Moon rise and set in the Heavens on the given day: and the Hour-Index shews the times of their rising and setting; and likewise the time of the Moon's passing over the Meridian. Its use.

This simple Apparatus shews all the varieties that can happen in the rising and setting of the Sun and Moon; and makes the forementioned Phenomena of the Harvest Moon (Chap. xvi.) plain to the eye. It is also very useful in reading Lectures on the Globes, because a large company can see this Sun and Moon go round, rising above and setting below the Horizon at different times, according to the seasons of the year; and making their appulses to different fixed Stars. But in the usual way, where there is only the places of the Sun and Moon in the Ecliptic to keep the eye upon, they are easily lost sight of, unless they be covered with patches.

402. The PLANETARY GLOBES. In this Machine, *T* is a terestrial Globe fixed on its Axis standing upright on the Pedestal *C D E*, on which is an Hour-Circle, having its Index fixed on the Axis, which turns somewhat tightly in the Pedestal, The PLANETARY GLOBE. PL. VIII. Fig. IV.

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 brazen Meridian, much in the uſual way; and the thin Plate *N*, *NE*, *E* is a moveable Horizon, graduated round the outer edge, for ſhewing the Bearings and Amplitudes of the Sun, Moon, and Planets. The brazen 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 *AB* 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 its 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 23½ 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 brazen 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.

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 the Signs; and when the eaſtern edge of the Horizon comes right againſt the Sun, Moon, or any Planet, the Hour-Index will ſhew the time of its riſing; and the inner edge of the Ecliptic will cut its riſing Amplitude in the Horizon. Turn on, and when the Quadrant of Altitude comes right againſt the Sun, Moon, or any Planet, the Ecliptic will cut their Meridian Altitudes on the Quadrant and the Hour-Index will ſhew the times of their coming to the Meridian. Continue turning, and when the weſtern edge of the Horizon comes right againſt the Sun, Moon, or any Planet, their ſetting Amplitudes will be cut on the Horizon by the Ecliptic; and the times of their ſetting will be ſhewn by the Index on the Hour-Circle. Its 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, is 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. *A A* 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 *G G* 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 its Limb; and in the Bar *A A* 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 its spiked feet (of which two appear at *P* and *P*, the third being supposed to be hid from sight by the Wheel) to 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- Its use.

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 $29\frac{1}{2}$ equal parts. And as this last Index points to the different days in its Circle, the like numeral Figures may be set to those parts of the curves of the Earth's path and Moons, 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 toward *e* to bring them to the same distance 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 its head toward that of the Pin *q* in the Pencil *e*, the head of the former will always keep to the head of the latter as *m* goes round *e*, and shews that the same side of the Moon is continually turned 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 its 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 $29\frac{1}{2}$ 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

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 its 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 elliptical 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*.

Its 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 Midnight; then looking for the name of any given place on the round Plate

(which makes 29½ rotations while 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 toward 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 its Axis is the Pinion *PQ* of four leaves, which turns the Wheel *LKI* of 59 teeth round in 29½ turnings or rotations of the Wheel *FED*, or in 708 revolutions

PLATE IX. Fig. VIII.

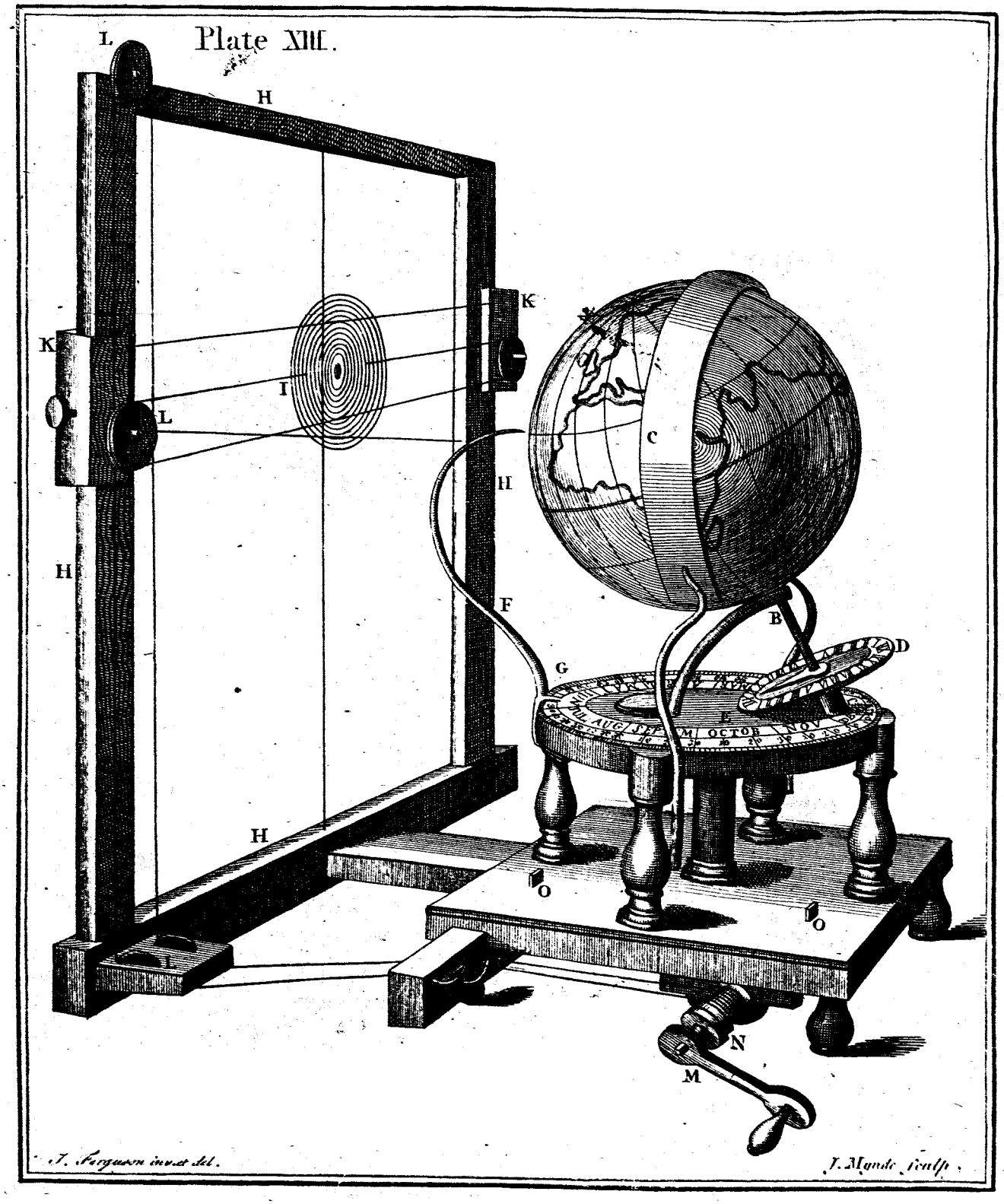
Plate XIII.
L
H
K
K
I
L
C
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D
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E
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H
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O
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M
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 *F E D*; and the Elliptical or Tide Plate with the Moon fixed to it is upon the Axis of the Wheel *L K I*; consequently, the former makes 29½ revolutions in the time that the latter makes one. The whole Wheel *F E D*, with the endless Screw *C*, and dotted part of the Axis of the Handle *A B*, together with the dotted part of the Wheel *O N G*, lie hid below the large Wheel *L K I*.

Fig. IXth represents the under side of the Elliptical or Tide-Plate *a b c d*, 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 *n m*, 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 *o o o o* 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 Elliptical Plate at *d* and *b*, to *f* and *e*; while the Pins *Y* and *Z* draw in the Plates *E F G H* 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 *E F G H* and *N O P Q* 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, being hid by 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 its Axis *B* by 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 its 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 its 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 *HHHH*, 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 its 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 its 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 its 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 its 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.

Its use. These things being done (and they may be done sooner than they can be expressed) turn the Handle backward, until the Penumbra almost touches the side *HF* of the frame; then turning gradually forward, observe the following Phænomena. 1. Where the eastern edge of the shadow of the Penumbral Plate *I* 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 its 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, its western edge at the solar Horizon touches and leaves the place where the Eclipse ends

ends at Sun-rise on the 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 its 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 its 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 its 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

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

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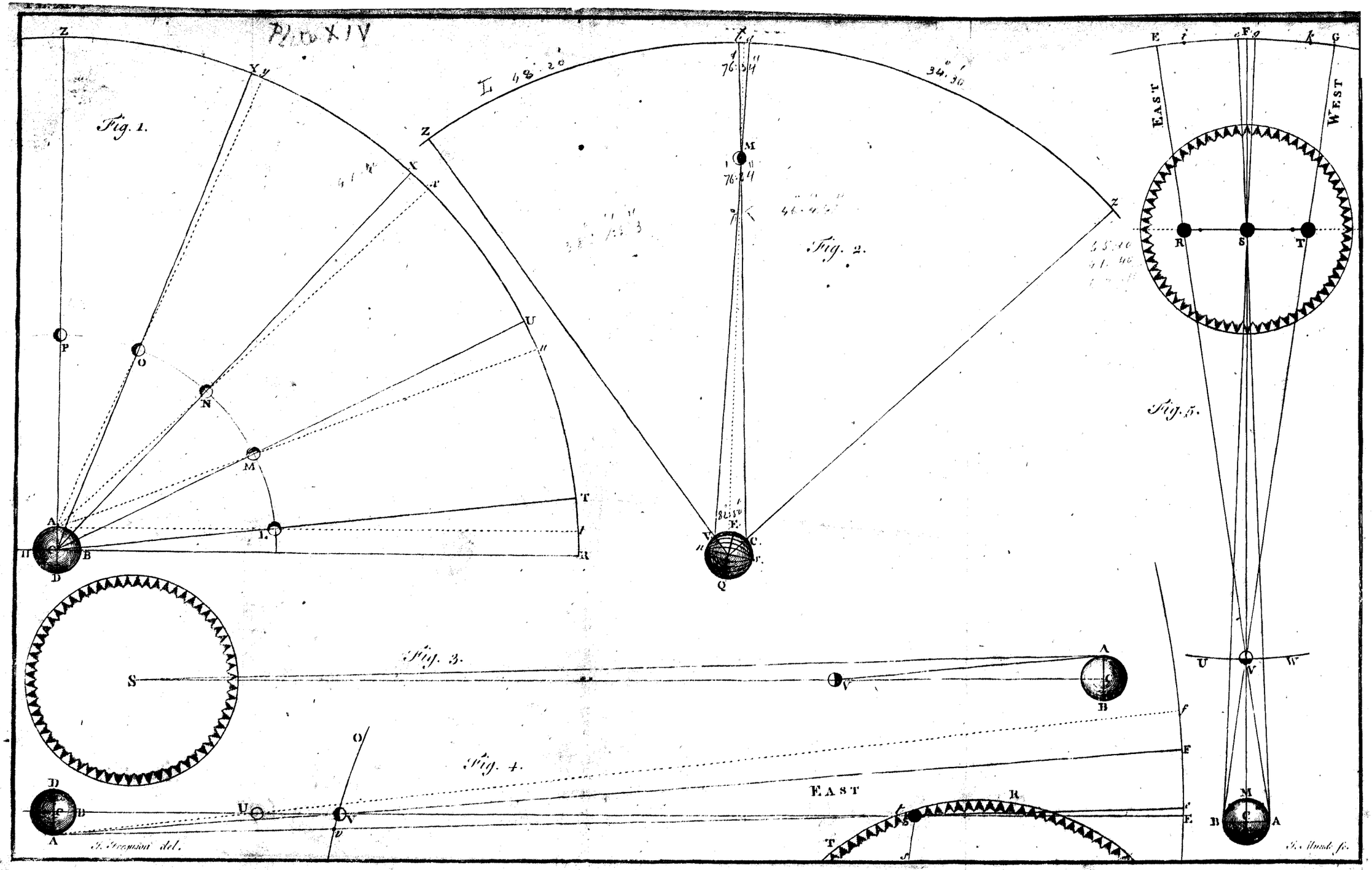

Pl. XIV
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
EAST
WEST
EAST
S. Freemson del.
S. Hunt sc.

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 its true and apparent place in the heavens. 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. I. of Plate XIV.), *C* its 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 among the ſtars.—The angle *A M C* is called the moon's parallax, and is equal to the oppoſite angle *U M u*, whoſe meaſure is the celeſtial arc *U u*.—The whole Earth is but a point if compared with its 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 its 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 *A L t* 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 *T t* 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 *U M u, X N x, Y o y* diminiſh, and ſo do the arcs *U u, X x, Y y*, 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 whether it be ſeen from *A* on the Earth's ſurface, or from *C* its center.

4. If the obſerver at *A* could take the true meaſure or quantity of the parallactic angle *ALC*, he might by that means find the Moon's diſtance from the center of the Earth. For, 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 *C A L*, would be given. Therefore, by trigonometry, as the tangent of the parallactic angle *ALC* is to radius, ſo is the Earth's ſemidiameter *A C* to the Moon's diſtance *C L* 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

tract the logarithmic tangent of the angle *ALC* from radius, and the remainder will be the logarithm of *C L*, and its corresponding number is the number of semidiameters of the Earth which the Moon is distant from the Earth's center.—Thus supposing the angle *ALC* of the Moon's horizontal parallax 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 59.99, the number of semidiameters of the Earth which are equal to the Moon's distance from the Earth's center. Then, 59.99 being multiplied by 3985, the number of miles contained in the Earth's semidiameter, will give 239060 miles for the Moon's distance from the center of the Earth, by this parallax.

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 as her parallax depresses 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 *EV* is 48° 20′ north; and *C* the *Cape of Good Hope*, whose latitude *EC* 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 (*Z a*+*z b*) 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 is

is to 10000000, so is 1° 16′ 34″ to 57′ 18″, which is the Moon's horizontal parallax.

If the two places of observation be not exactly under the same meridian, their difference of longitude must be accurately taken, that proper allowance may be made for the Moon's declination while she is passing from the meridian of the one to the meridian of the other.

6. The Earth's diameter, as seen from the Moon, subtends an angle of double the Moon's horizontal parallax; which being supposed (as above) to be 57′ 18″, or 3438″, the Earth's diameter must be 1° 54′ 36″, or 6876″. When the Moon's horizontal parallax (which is variable on account of the eccentricity of her orbit) is 57′ 18″, her diameter subtends an angle 31′ 2″, or 1862″: therefore the Earth's diameter is to the Moon's diameter, as 6876 is to 1862; that is, as 3.69 is to 1.

And since the relative bulks of spherical bodies are as the cubes of their diameters, the Earth's bulk is to the Moon's bulk, as 49.4 is to 1.

7. The parallax, and consequently the distance and bulk of any primary planet, might be found in the above manner, if the planet was near enough to the Earth, to make the difference of its two apparent places sufficiently sensible: but the nearest planet is too remote for the accuracy required. In order therefore to determine the distances and relative bulks of the planets with any tolerable degree of precision, we must have recourse to a method less liable to error: and this the approaching transit of Venus over the Sun's disc will afford us.

8. From the time of any inferior conjunction of the Sun and Venus to the next, is 583 days 22 hours 7 minutes. And, if the plane of Venus's orbit were coincident with the plane of the ecliptic, she would pass directly between the Earth and the Sun at each inferior conjunction, and would then appear like a dark round spot on the Sun for about

7 hours and 3 quarters. But Venus's orbit (like the Moon's) only intersects the ecliptic in two opposite points called its Nodes. And therefore one half of it is on the north side of the ecliptic, and the other on the south: on which account, Venus can never be seen on the Sun, but at those inferior conjunctions which happen in or near the nodes of her orbit. At all the other conjunctions, she either passes above or below the Sun; and her dark side being then toward the Earth, she is invisible.— The last time when this planet was seen like a spot 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 observation, and from thence, by analogy, the parallax and distance of the Sun, and of all the Planets from him.

9. In Fig. 4. of Plate XIV. let *D B A* be the Earth, *V* Venus, and *T S R* the eastern limb of the Sun. To an observer at *B* the point *t* of that limb will be on the meridian, its place referred to the heaven will be at *E*, and Venus will appear just within it at *S*. But, at the same instant, to an observer at *A*, Venus is east of the Sun, in the right line *A V F*; the point *t* of the Sun's limb appears at *e* in the heaven, and if Venus were then visible, she would appear at *F*. The angle *C V A* is the horizontal parallax of Venus, which we seek; and is equal to the opposite angle *F V E*, whose measure is the arc *FE*. *A S C* is the Sun's horizontal parallax, equal to the opposite angle *e S E*, whose measure is the arc *e E*: and *F A e* (the same as *V A v*) is Venus's horizontal parallax from the Sun, which may be found by observing how much later in absolute time her total ingress on the Sun is, as seen from *A*, than as seen from *B*, which is the time

time ſhe takes to move from *V* to *v* in her orbit *O V*.

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 6½ 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 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 on that day 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 from it on the

* To prove this, let *S* be the Sun (Fig. 3.) *V* Venus, *AB* the Earth, *C* its center, and *AC* its semidiameter. The angle *AVC* is the horizontal parallax of Venus, and *ASC* the horizontal parallax of the Sun. But by the property of plain triangles, as the sine of *AVC* (or of *SVA* its supplement to 180) is to the sine of *ASC*, so is *AS* to *AV*, and so is *CS* to *CV*.—*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 its true diſtance from it 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 its center, which number, being multiplied by 3985, the number of miles contained in the Earth's ſemidiameter, will give the number of miles 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 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 diſtance 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″.5, 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, its 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 toward, 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 $62\frac{1}{2}°$ from the meridian; at VI in the morning he is 90° from it: therefore, as the sine of $62\frac{1}{2}°$ 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 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 times 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 of the beginning as given by the tables.

When he perceives a dent (as it were) to be made in the Sun 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

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 its apparent path on the Sun, and consequently will then be at its least apparent distance from the Sun's center; at which time, the observer must take its distance from the Sun's center by means of a good micrometer, in order to ascertain its true latitude or declination from the ecliptic, and thereby find the places of its 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 must watch the planet carefully with his telescope: and his assistant must watch the clock, so as to denote 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 Fig. 5. of Plate XIV. let *B M A* be the Earth, *V* Venus, and *S* the Sun. The Earth's Motion on its axis from weſt to eaſt, or in the direction *A M B* carries an obſerver on that ſide contrary to the motion of Venus in her orbit, which is in the direction *U V W*, 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 its 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 *A M B*. 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 *R S T*: which being in the direction of her apparent motion on the Sun as ſhe moves in her orbit *U W*, 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 its 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 *Abridgement of the Philosophical Transactions, Vol. I. page* 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, a method by which 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 would 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, while the semidiameter of Mercury, at its 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 16,500 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 altar 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, while 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 its 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 fide-

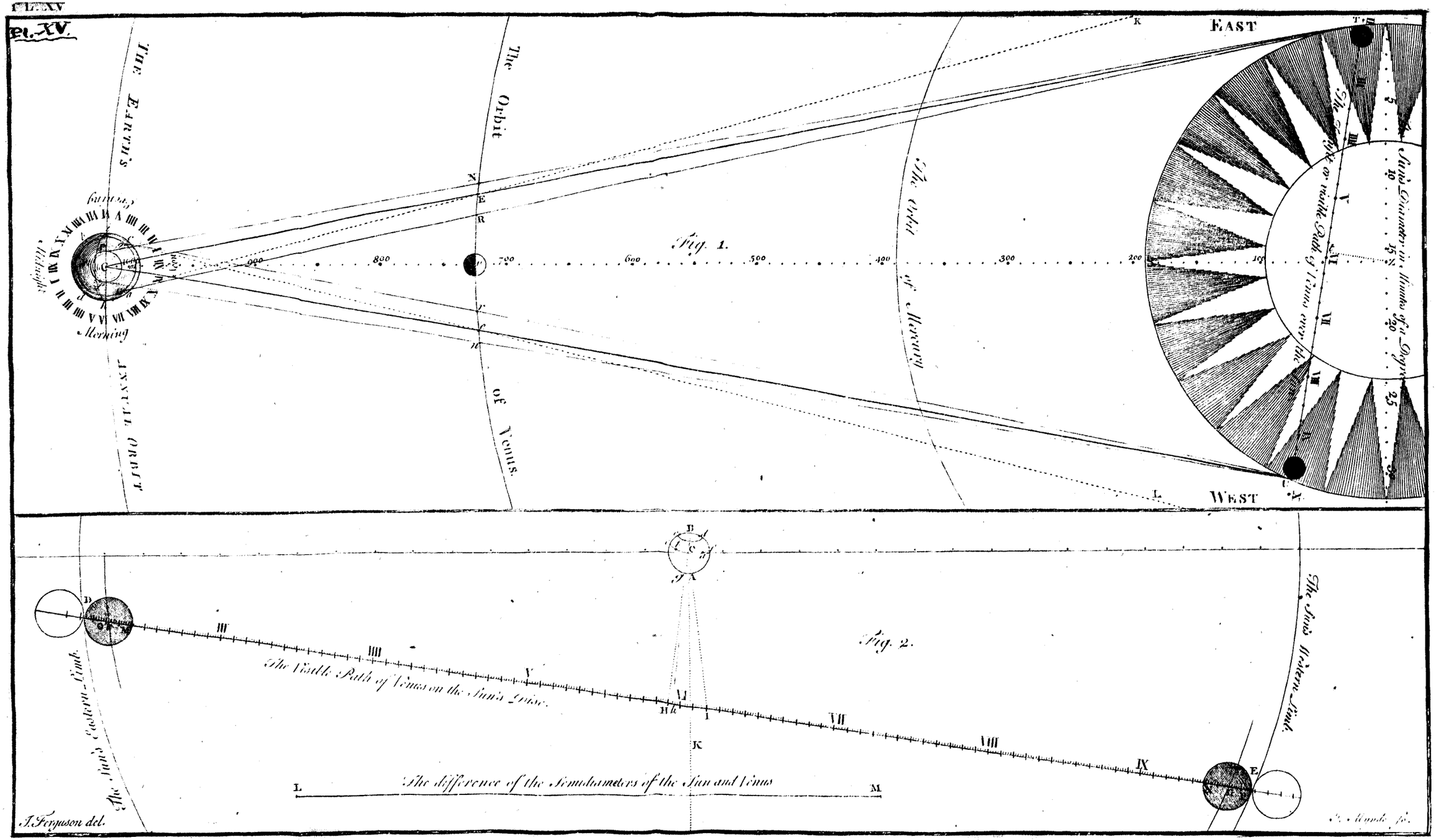
lity, diligence, and a moderate skill in Astronomy; For there is no need that the latitude of the place should be scrupulously observed, nor that the hours themselves should be accurately determined with respect to the meridian: it is sufficient that the clocks be regulated according to the motion of 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, *Horrox*, 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

* The sixth of *June*, according to the New Stile.

Sun's

Pl. XV.


The Earth's Annual Orbit
The Orbit of Venus.
The Orbit of Mercury
Fig. 1.
East
West
Midnight
Morning
Evening
Sun's Diameter in Minutes 32
The Path or visible Path of Venus over the Sun's Disc
The Sun's Eastern Limb.
The Sun's Western Limb.
The Visible Path of Venus on the Sun's Disc.
Fig. 2.
The difference of the Semidiameters of the Sun and Venus
J. Ferguson del.

Sun's disc; and perhaps the ingress of Venus upon 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 toward 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, while 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 CvZ, make vZ to CZ 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 conjunction with the Sun; and let TSU 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 its 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 its axis, while 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 its 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.

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, while 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 its 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

a degree; and by this ſpace of time, the duration of this eclipſe cauſed by Venus will, on account of the parallax, be ſhortened. And from this ſhortening of the time only, we might ſafely enough draw a concluſion concerning the parallax which we are in ſearch of, provided the diameter of the Sun, and the latitude of Venus, were accurately known. But we cannot expect an exact computation in a matter of ſuch ſubtilty.

We muſt endeavour therefore to obtain, if poſſible, another obſervation, to be taken in thoſe places where Venus will be in the middle of the Sun's diſc at midnight; that is, in places under the oppoſite meridian to the former, or about 6 hours or 90 degrees weſt of *London*; and where Venus enters upon the Sun a little before its ſet-

parallax from the Sun, as ſeen from the *Ganges* at *g*, when ſhe is but juſt beginning to leave the Sun at *U*, as ſeen from the Earth's center *C*.

Here it is plain, that the duration of the tranſit about the mouth of the *Ganges* (and alſo in the neighbouring places) will be diminiſhed by about double the quantity of Venus's parallax from the Sun at the beginning and ending of the tranſit. For Venus muſt be at *E* in her orbit when ſhe is wholly upon the Sun at *T*, as ſeen from the Earth's center *C*: but at that time ſhe is ſhort of the Sun, as ſeen from the *Ganges* at *G*, by the whole quantity of her eaſtern parallax from the Sun at that time, which is the angle *KET*. [This angle, in fact, is only 23″.; though it is repreſented much larger in the figure, becauſe the Earth therein is a vaſt deal too big.] Now, as Venus moves at the rate of 4′ in an hour, ſhe will move 23″ in five minutes 45 ſeconds: and therefore, the tranſit will begin later by 5 minutes 45 ſeconds at the banks of the *Ganges* than at the Earth's center.——When the tranſit is ending at *U*, as ſeen from the Earth's center at *C*, Venus will be quite clear of the Sun (by the whole quantity of her weſtern parallax from him) as ſeen from the *Ganges*, which is then at *g*: and this parallax will be 22″, equal to the ſpace through which Venus moves in 5 minutes 30 ſeconds of time: ſo that the tranſit will end $5\frac{1}{2}$ minutes ſooner as ſeen from the *Ganges*, than as ſeen from the Earth's center.

Hence the whole contraction of the duration of the tranſit at the mouth of the *Ganges* will be 11 minutes 15 ſeconds of time: for it is 5 minutes 45 ſeconds at the beginning, and 5 minutes 30 ſeconds at the end.

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ting, and goes off a little after its 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, while the Sun, from its setting to its 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. I. of Plate XV. let *a C* 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, while 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 *P n p*.——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 *T t U*, as seen from the Earth's Center *C*, it is plain that while 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 while 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 its duration 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* ſhould 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 leſt 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, while 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* while ſhe paſſes over the Sun, as ſeen from the banks of the *Ganges*.

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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 its 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 its 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 its 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 above said 4 minutes from the Sun's center. And the difference between the duration 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 chuse 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 its 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 37½″. 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 12½″. Then, on the center *C* (Plate XV. Fig. 2.) let the little circle *A B*, representing the Earth's disc, be described, and let is 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 *FHG*, 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 *CH*, perpendicular to *F G*; and suppose Venus to be at *H* at 55 minutes after V in the morning. Let the right line *FHG* be divided into the horary space III IV, IV V, V VI, &c. each equal to *CH*; 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 *BCg* (Fig. 2. of Plate XV.) and the Axis of Venus's orbit *CH* on the same side of the axis of the ecliptic *CK*; 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 8½°. Therefore, the sum of these angles, which is 14½° (and not their difference 2° 18′) is the inclination of Venus's visible path to the equator and parallels of declination.

apparent ſemidiameters of the Sun and Venus, which is 15′ 13½″; and a circle being deſcribed with the radius *L M*, on a center taking in any point within the little circle *A B* repreſenting the Earth's diſc, will meet the right line *FG* 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 *FG*, in the points *F* and *G*; and the ſpaces *FH* 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 its 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. 53½ degrees; as the poſnts *a* and *b* (repreſenting that place in the Earth's diſc *AB*) are, in the greater parallel, from the meridian *BCg*. 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 53½ and 68 degrees;

grees; 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 *FH* 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 here is 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 55½ and 34 degrees, so is *AB*, 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 *HG* 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; while, 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 its 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 its full success. For he tells us, that by means of this transit the Sun's parallax may only be determined within its five hundredth part, 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, by which he could determine, with certainty, whether the nodes of Venus's orbit have any motion; 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 of which 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 four 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 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 its 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 its 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 its 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 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 12½″; 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 its 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 its 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

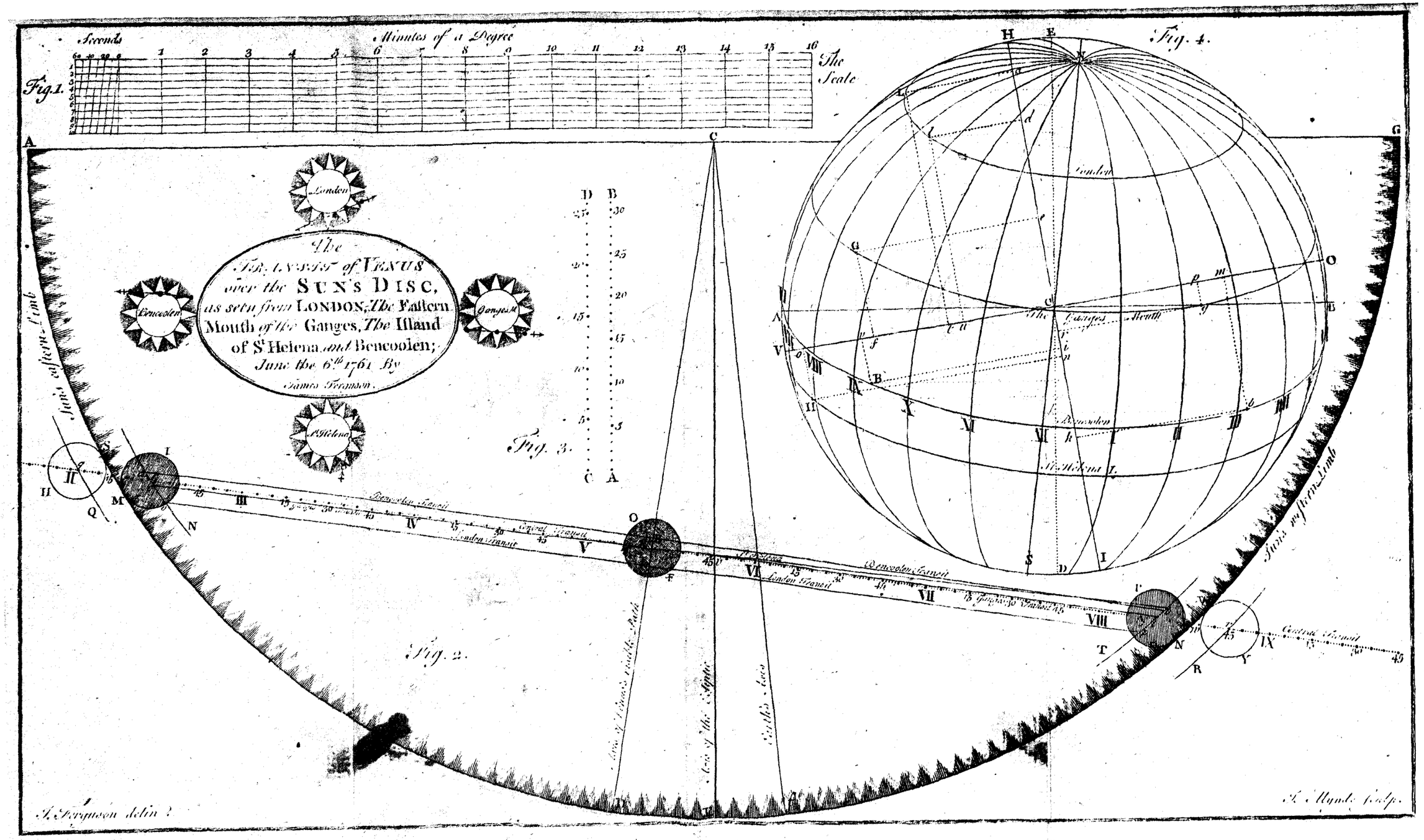


Fig. 1.
Seconds
Minutes of a Degree
The Scale
Fig. 4.
The TRANSIT of VENUS over the SUN'S DISC, as seen from LONDON, The Eastern Mouth of the Ganges, The Island of St Helena and Bencoolen; June the 6th 1761 By James Ferguson.
London
Bencoolen
Ganges
St Helena
Fig. 3.
Fig. 2.
Transit of Venus
Sun's eastern Limb
Sun's western Limb
Bencoolen Transit
Central Transit
London Transit
Ganges Transit
The Ganges Mouth
Bencoolen
St Helena
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), 37½″.

V. The difference of the semidiameters of the Sun and Venus, 15′ 12½″.

VI. Their sum, 16′ 27½″.

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 divided into 17 equal parts, each of which 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 to it 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 *q t* and *t r*.

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 *q t r*. 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, 46¾ 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′ 12½″, 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 two 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 morning, as seen from the Earth's center, and reckoned according to the time at *London*. The interval between these times is 6 hours 18 minutes.

42. Take the sum of the semidiameters of the Sun and Venus, 16′ 27½″, in your compasses from the scale; and with that extent, setting one foot in the Sun's center *C*, describe the arcs *Q* and *R* with the other, cutting the transit-line in the points *q* and *r*, which are the points in open space (clear of the Sun) where the center of Venus is, at the moments of her two external contacts with the Sun's limb at *S* and *W*; or the moments of the beginning and ending of the transit as seen from the Earth's center; the former of which is at 3 minutes after II in the morning at *London*, and the latter at 45 minutes after VIII. The interval between these moments is 6 hours 42 minutes.

43. Take the semidiameter of Venus 37½″, in your compasses from the scale: and with that extent as a radius, on the points *q*, *k*, *t*, *l*, *r*, as centers, describe the circles *H S*, *M I*, *O F*, *P N*, *W Y*, for the disc of Venus, at her first contact at *S*, her total ingress at *M*, her place on the Sun at the middle of her transit, her beginning of egress at *N*, and her last contact at *W*.

44. Those who have a mind to project the Earth's disc on the Sun, round the center *C*, and to lay down the parallels of latitude and situations of places thereon, according to Dr. HALLEY's method, may draw *Cf* for the axis of the Earth, produced to the southern edge of the Sun at *f*; and making an angle *E C f* of 6° with the axis of the ecliptic *C E*: but he will find it very difficult and uncertain to mark the places on that disc, unless he makes the Sun's semidiameter *A C* 15 inches at least: otherwise the line *Cf* is of no use at all in this projection.—The following method is better.

45. In Fig. 3. of Plate XVI. make the line *A B* of any convenient length, and divide it into 31 equal parts, each of which may be taken for a second of

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 *A E B D* for the Earth's enlightened disc, whose diameter is 62″, or double the horizontal parallax of Venus from the Sun. In this disc, draw *A C B* for a small part of the ecliptic, and at right angles to it draw *E C D* for the axis of the ecliptic. Draw also *N C S* 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; *H C I* for the axis of Venus's orbit, making an angle of 8° 31′ with *E C D*, the axis of the ecliptic; and lastly, *V C O* for a small part of Venus's orbit, at right angles to its 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 *N C S* by the Earth's rotation on its 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 these two places, reckoning one hour for every 15 degrees

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 the parallax of Venus from the Sun in the direction of her path; 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 orbit of Venus, as ſeen from the Sun; and weſtward when the place gets to the right hand of that axis. 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; 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, as ſeen from the given place on the Earth's ſurface: but when the parallax is weſtward, ſubtract the time anſwering to this parallax 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 parallax.—The reaſon of this is plain to every one

* In a *former* edition of this, I made a miſtake, in taking the parallax in longitude inſtead of the parallax in the direction of the orbit of Venus; and the parallax in latitude inſtead of the parallax in lines perpendicular to her orbit.—But in this edition, theſe errors are corrected; which make ſome ſmall differences in the quantities of the parallaxes, and in the times depending on them; as will appear by comparing them in this with thoſe in the former edition.

who

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 lines perpendicular to her path; 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 on it.

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 will cauſe her to deſcribe a longer line on the Sun, than ſhe would if ſhe had no ſuch parallax; and a ſouthern parallax 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 in lines perpendicular to her orbit is ſouth; and to all places ſituated on the ſouth ſide of the plane of her orbit, in the hemiſphere *VIO*, this parallax 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; 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 beginning of egreſs, as ſeen from the

Earth's center, in order to have the true time of total ingreſs and beginning of egreſs as ſeen from places in the hemiſphere *VHO*: and juſt the reverſe for places in the hemiſphere *VIO*.—It was proper to mention theſe circumſtances, for the reader's more eaſily conceiving the reaſon of applying the times anſwering to theſe parallaxes in the ſubſequent part of this article: for it is their ſum in ſome caſes, and their difference in others, which being applied to the times of total ingreſs and beginning of egreſs as ſeen from the Earth's center, that will give the times of theſe phenomena as ſeen from given places on the Earth's ſurface.

52. The angle which the Sun's ſemidiameter ſubtends, as ſeen from the Earth, at all times of the year, has been ſo well aſcertained by late obſervations, that we can make no doubt of its being 15′ 50″ on the day of the tranſit; and Venus's latitude has alſo been ſo well aſcertained at many different times of late, that we have very good reaſon to believe it will be 9′ 43″ ſouth of the Sun's center at the time of her conjunction with the Sun.—If then her ſemidiameter at that time be 37½″ (as mentioned by Dr. HALLEY) it appears by the projection (Fig. 2.) that her total ingreſs on the Sun, as ſeen from the Earth's center, will be at 28 minutes after two in the morning (§ 40.), and her beginning of egreſs from the Sun will be 20 minutes after VIII, according to the time reckoned at *London*.

53. As the total ingreſs will not be viſible at *London*, we ſhall not here trouble the reader about Venus's parallax at that time.—But by projecting the ſituation of *London* on the Earth's diſc (Fig. 4.) for the time when the egreſs begins, we find it will then be at *l*, as ſeen from the Sun.

Draw *l d* parallel to Venus's orbit *VCO*, and *l u* perpendicular to it: the former is Venus's eaſtern parallax in the direction of her path at the beginning of her egreſs from the ſun, and the latter is her

her ſouthern parallax in a direction at right angles to her path at the ſame time. Take theſe in your compaſſes, and meaſure them on the ſcale *A B* (Fig. 3.) and you will find the former parallax to be $10\frac{3}{4}''$, and the latter $21\frac{1}{2}''$.

54. As Venus's true motion on the Sun is at the rate of four minutes of a degree in 60 minutes of time (*See* N° XI. *of* § 31.) ſay, as 4 minutes of a degree is to 60 minutes of time, ſo is $10\frac{3}{4}''$ of a degree to 2 minutes 41 ſeconds of time; which being added to VIII hours 20 minutes (becauſe this parallax is eaſtward, § 49.) gives VIII hours 22 minutes 41 ſeconds, for the beginning of egreſs at *London*, as affected only by this parallax.—But as Venus has a ſouthern parallax at that time, her beginning of egreſs will be ſooner; for this parallax ſhortens the line of her viſible tranſit at *London*.

55. Take the diſtance *C t* (Fig. 2.), or neareſt approach of the centers of the Sun and Venus, in your compaſſes, and meaſure it on the ſcale (Fig. 1.), and it will be found to be $9' 36\frac{1}{2}''$; and as the parallax of Venus from the ſun in a direction which is at right angles to her path is $21\frac{1}{2}''$ ſouth, add it to $9' 36\frac{1}{2}''$, and the ſum will be $9' 58''$; which is to be taken from the ſcale in Fig. 1. and ſet from *C* to *L* in Fig. 2. And then, if a line be drawn parallel to *t l*, it will terminate at the point *p* in the arc *T*, where Venus's center will be at the beginning of her egreſs, as ſeen from *London* *.—But as her center is at *l* when her egreſs begins as ſeen from the Earth's center, take *L p* in your compaſſes, and ſetting that extent from *t* toward *l* on the central tranſit-line, you will find it to be 5 minutes ſhorter than *t l*: therefore ſubtract 5 minutes from VIII hours 22 minutes 41 ſeconds, and there will remain VIII

* The reaſon why the line *o L p*, *a B b*, *c t*, and *t h*, which are the viſible tranſits at *London*, the *Ganges* mouth, *Bencoolen*, and *St. Helena*, are not parallel to the central tranſit-line *k t l*, is, becauſe the parallaxes in latitude are different at the times of ingreſs and egreſs, as ſeen from each of theſe places. The method of drawing theſe lines will be ſhewn by and by.

hours

hours 17 minutes 41 seconds for the visible beginning of egress in the morning at *London*.

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 *L a* of Venus from the Sun in the direction of her path is then $12\frac{1}{2}''$; by which, working as above directed, we find the middle of the transit, as seen from *London*, will be at V hours 20 minutes 53 seconds.—This is not affected by *L t* the parallax at right angles to the path of Venus.—But *L t* 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 *G e* and *g r* parallel to the orbit of Venus *V C O*, and measure them on the scale *AB* in Fig. 3. the former will be 21″ for Venus's eastern parallax in the direction of her path, at the above-mentioned time of her total ingress, and the latter will be $16\frac{1}{4}''$ for her western parallax 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

hours 29 minutes 15 ſeconds, for the time of total ingreſs, as ſeen from the banks of the *Ganges*, and II 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″: take 10″ from the ſcale in Fig. 1. and find, by trials, a point *c*, in the arch *N*, where, if one foot of the compaſſes be placed, the other will juſt touch the central tranſit line *k l*. Take the neareſt diſtance from this point *c* to *C L*, the axis of Venus's orbit, and applying it from *t* toward *k*, you will find it fall a minute ſhort of *k*; which ſhews, that Venus's parallax in this direction 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 *g p* in the ſame direction is 2½″ (by meaſurement on the ſcale *A B*), 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 from the Earth's center; and at *b* when her egreſs begins.

Draw

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 the direction of her path at the time of her total ingress; and the latter to be 19½″ for her western parallax in the same direction 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 *VCO*, and measure them on the scale *A B:* the former will be 5″ for Venus's northern parallax in a direction perpendicular to her path, as seen from *Bencoolen*, at the time of her total ingress; and the latter will be 15½″ for her northern parallax in that direction when her egress begins. Take these parallaxes from the scale, Fig. 1. in your compasses, and find, by trials, two points in the arcs *N* and *T* (Fig. 2.) where if one foot of the compasses be placed, the other will touch the central transit line *k l:* draw a line from *a* to *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.—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:* and taking the extent *B b*

in

in your compasses, and setting it forward from *t* toward *w*, on the central transit-line, it will be found to reach 3 minutes beyond *l*. 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 afternoon, for the time when the egress begins, as seen from *Bencoolen*.

60. The whole duration of the transit, from the total ingress to the beginning of egress, as seen from the Earth's center, is 5 hours 52 minutes (by § 40.) but the whole duration from the total ingress to the 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 *H n* parallel to Venus's orbit *V C O*, and *H o* perpendicular to it; and by measuring them on the scale *A B* (Fig. 3.) the former will be found to amount to 29″ for Venus's eastern parallax in the

direction of her path, as ſeen from *St. Helena*, when her egreſs begins, as ſeen from the Earth's center; and the latter to be 6″ for her northern parallax in a direction at right angles to her path.

By the analogy in § 54, the parallax in the direction of the path of Venus gives 10 minutes 2 ſeconds of time; which being added (on account of its being eaſtward) to VII hours 56 minutes, gives VIII hours 6 minutes 2 ſeconds for the beginning of egreſs at *St. Helena*, as affected by this parallax. —But 6″ of parallax in a perpendicular direction to her path (applied as in the caſe of *Bencoolen*) lengthens out the end of the tranſit-line by one minute; which being added to VIII hours 6 minutes 2 ſeconds, gives VIII hours 7 minutes 2 ſeconds for the beginning of egreſs, as ſeen from *St. Helena*.

62. We ſhall now collect the above-mentioned times into a ſmall table, that they may be ſeen at once, as follows: *M* ſignifies morning, *A* afternoon.

		Total ingreſs. H. M. S.	Beg. of egreſs H. M. S.	Duration. H. M. S.
At	The Earth's center	II 28 0*M*	VIII 20 0*M*	5 52 0*
	London - - -	Inviſible *M*	VIII 17 41*M*	— — —
	The *Ganges* mouth	VIII 30 15*M*	II 12 19*A*	5 42 4
	Bencoolen - - -	IX 19 30*M*	III 6 8*A*	5 46 38
	St. Helena - -	Inviſible. *M*	VIII 7 2*M*	— — —

63. The times at the three laſt-mentioned places are reduced to the meridian of *London*, by ſubtracting 5 hours 56 minutes from the times of ingreſs and egreſs at the *Ganges*; 6 hours 48 minutes from the times at *Bencoolen*; and adding 24

* This duration as ſeen from the Earth's center, is on ſuppoſition that the ſemidiameter of Venus would be found equal to 37½″, on the Sun's diſc, as ſtated by Dr. *Halley* (ſee Art. V. § 31.) to which all the other durations are accommodated.—But, from later obſervations, it is highly probable, that the ſemidiameter of Venus will be found not to exceed 30″ on the Sun; and if ſo, the duration between the two internal contacts, as ſeen from the Earth's center, will be 5 hours 58 minutes; and the duration, as ſeen from the above-mentioned places, will be lengthened very nearly in the ſame proportion.

minutes

minutes to the time of beginning of egreſs at *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 0*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 12½″ that the true latitude of Venus is given, and that her ſemidiameter will ſubtend an angle of 37½″ 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 later than 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 24 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) for their difference or elapſe, in abſolute times, between the beginning of egreſs, as ſeen from theſe two places.

Divide 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 ſo ſmall an angle as that of the Sun's parallax, the arc is not ſenſibly different from either its ſine or its 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 its real time, the Sun's parallax may be then found within the 32d part of a ſecond of its true quantity; and conſequently, his diſtance may be found within a 400th part of the whole, provided his parallax be not leſs than $12\frac{1}{2}''$; 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, we may well imagine that the internal contacts of Venus with the Sun may be obſerved with as

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 its 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 its 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.

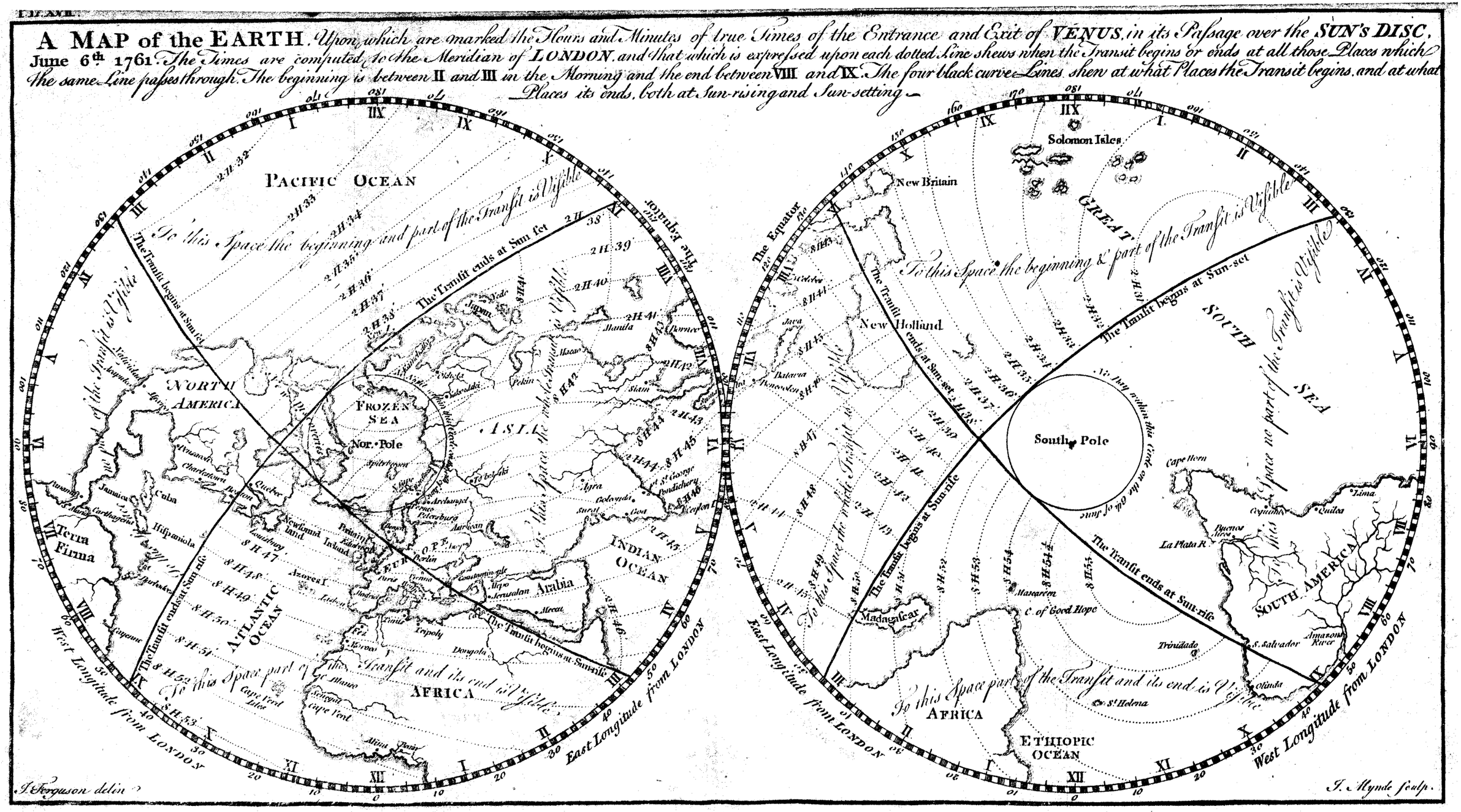
69. There will also be a great difference between the absolute times of egress at *St. Helena* and the northern parts of *Russia*, which would make these places very proper for observation. The difference between them at *Tobolsk* in *Siberia* and at *St. Helena* will be 11 minutes, according to DE L'ISLE's map: at *Archangel* it will be but about 40 seconds less than at *Tobolsk*; and only a minute and a quarter less at *Petersburg*, 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 M. 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 its 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 hozizontal 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,


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.
PACIFIC OCEAN
NORTH AMERICA
FROZEN SEA
Nor. Pole
ASIA
INDIAN OCEAN
ATLANTIC OCEAN
AFRICA
Terra Firma
Arabia
The Equator
The Transit begins at Sun-rise
The Transit ends at Sun-rise
The Transit begins at Sun-set
The Transit ends at Sun-set
To this Space the beginning and part of the Transit is Visible
To this Space part of the Transit and its end is Visible
Space not part of the Transit is Visible
Solomon Isles
New Britain
New Holland
GREAT SOUTH SEA
South Pole
Madagascar
C. of Good Hope
ETHIOPIC OCEAN
SOUTH AMERICA
West Longitude from LONDON
East Longitude from LONDON
J. Ferguson delin.
J. Mynde sculp.

§ 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 the ecliptic, 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 its ſurface, whoſe latitude is leſs than 90 degrees: then there is a parallax in latitude proportional to the perpendicular let fall upon the above ſaid 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 its being parallel to the central tranſit-line, unleſs when its 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 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 northernmost 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 that

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, & Venuc 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. Hence he foresaw when their conjunctions, their appulses to the fixed stars, and the most remarkable phænomena 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 mis-spent, 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 was 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 its 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 some what 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 on it 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 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, beaking 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 public; 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 Abridgment of the Philoſophical Tranſactions, page 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 52½ 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

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 ſtyle, 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 its 500dth part.—But ſeveral years after, he explained this affair 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 *6th, 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. Mr. *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 11′ 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 five 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 means of three good obſervations, the dia- of Venus on the Sun was 58″.

Mr.

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 its being ſeen at *Greenwich*.

Meſſrs. *Ellicott* and *Doland* obſerved the internal contact at *Hackney*, and their time of ſeeing it, reduced to the time at *Greenwich*, was at 8 hours 18 minutes 36 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° 20½′ 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 60° 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 *Conſtans*, 14½″ 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 20½ ſeconds after 12 at noon.—So that the whole duration of the tranſit between the internal contacts was 5 hours 48 minutes 52½ ſeconds, as ſeen at that place; which was 2 minutes 3½ 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 year 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 people's 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 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 95,173,127 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 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 is 190,346,000 miles. And ſince the diameter of a circle is to its circumference as 1 to 3.14159 the circumference of the Earth's orbit is 597,989,090 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 68,217 miles every hour, and conſequently 11,369 miles every minute; ſo that its velocity in its 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.

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

* Fronting page 42.

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 its 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 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

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.

Henry P. Harrison
S. Carolina

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