The Project Gutenberg EBook of Astronomy Explained Upon Sir Isaac Newton's Principles, by James Ferguson

This eBook is for the use of anyone anywhere in the United States and most other parts of the world at no cost and with almost no restrictions whatsoever. You may copy it, give it away or re-use it under the terms of the Project Gutenberg License included with this eBook or online at www.gutenberg.org. If you are not located in the United States, you'll have to check the laws of the country where you are located before using this ebook.

Title: Astronomy Explained Upon Sir Isaac Newton's Principles
And made easy to those who have not studied mathematics

Author: James Ferguson

Release Date: November 3, 2019 [EBook #60619]

Language: English

Character set encoding: UTF-8

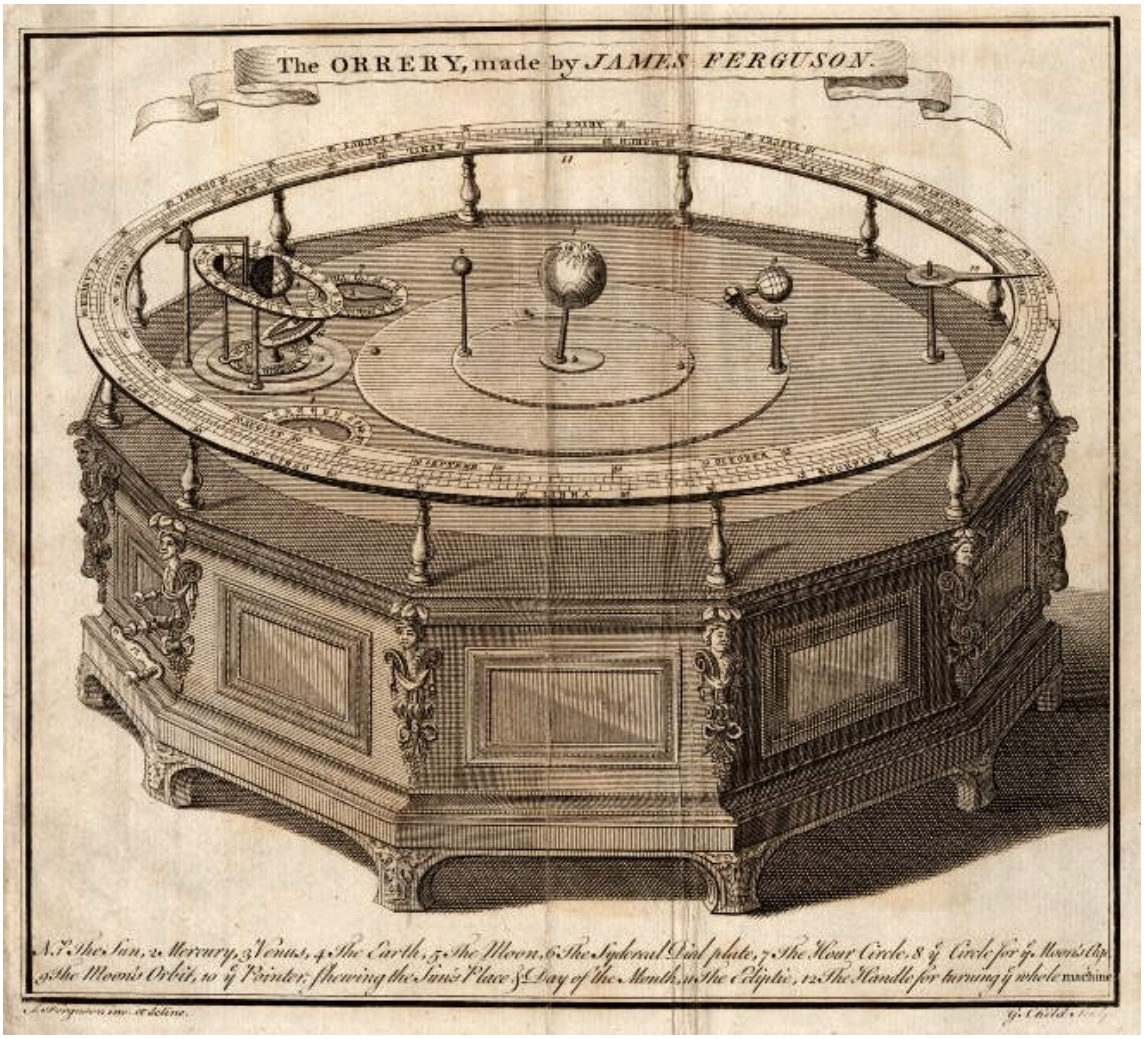
*** START OF THIS PROJECT GUTENBERG EBOOK ASTRONOMY EXPLAINED ***

Produced by MFR, Sonya Schermann, and the Online Distributed Proofreading Team at http://www.pgdp.net (This file was produced from images generously made available by The Internet Archive)

Transcriber's Note

This book uses a number of astronomical symbols, including signs of the Zodiac (♈, ♉, ♊, ♋, ♌, ♍, ♎, ♏, ♐, ♑, ♒, ♓), and symbols for planets (☿, ♀, ⊕, ♂, ♃, ♄). If these characters do not display correctly, you may have to use an alternative font, such as Arial Unicode MS or DejaVu.

The ORRERY, made by *JAMES FERGUSON*.



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

J. Ferguson inv. et delin.

G. Child. Sculp.

ASTRONOMY

EXPLAINED UPON

Sir ISAAC NEWTON's

PRINCIPLES,

AND MADE EASY

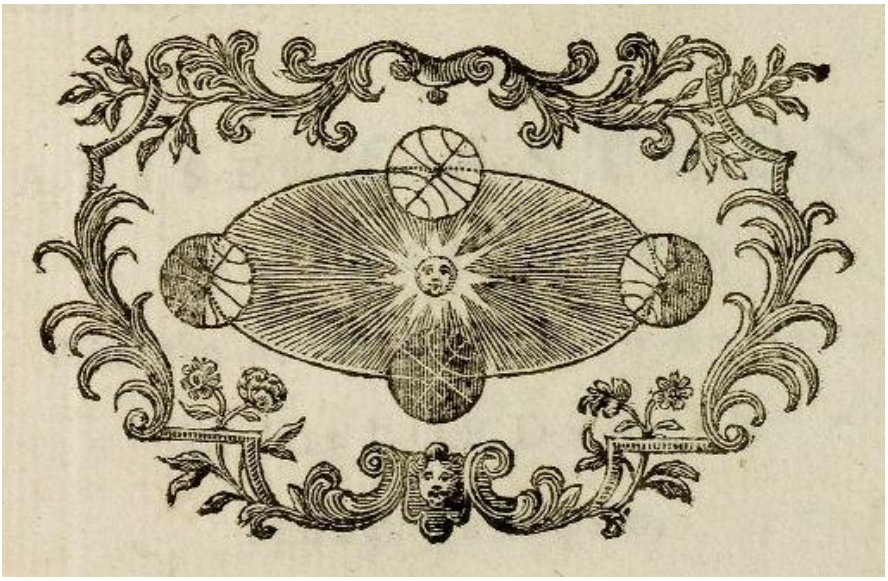
TO THOSE WHO HAVE NOT STUDIED

MATHEMATICS.

By JAMES FERGUSON.

HEB. XI. 3. *The Worlds were framed by the Word of* GOD.
JOB XXVI. 13. *By his Spirit he hath garnished the Heavens.*

THE SECOND EDITION.



LONDON:

Printed for, and sold by the AUTHOR, at the GLOBE,
opposite *Cecil-Street* in the *Strand*.
MDCCLVII.

TO

THE RIGHT HONOURABLE

GEORGE EARL of MACCLESFIELD,

VISCOUNT *PARKER* of EWELME in OXFORDSHIRE,

AND

BARON of MACCLESFIELD in CHESHIRE;

PRESIDENT of the ROYAL SOCIETY of *LONDON*,

MEMBER of the ROYAL ACADEMY OF SCIENCES at *PARIS*,

OF THE

IMPERIAL ACADEMY OF SCIENCES at *Petersburg*,

AND ONE OF THE

TRUSTEES of the BRITISH MUSEUM;

DISTINGUISHED

By his GENEROUS ZEAL for promoting every
BRANCH of USEFUL KNOWLEDGE;

THIS

TREATISE of ASTRONOMY

IS INSCRIBED,

With the MOST PROFOUND RESPECT,

By HIS LORDSHIP's

MOST OBLIGED,

And

MOST HUMBLE SERVANT,

JAMES FERGUSON.

THE

CONTENTS.

CHAP. I.

Of Astronomy in general Page 1

CHAP. II.

A brief Description of the SOLAR SYSTEM 5

CHAP. III.

The COPERNICAN *or* SOLAR SYSTEM *demonstrated to be true* 31

CHAP. IV.

The Phenomena of the Heavens as seen from different parts of the Earth 39

CHAP. V.

The Phenomena of the Heavens as seen from different parts of the Solar System 45

CHAP. VI.

The Ptolemean *System refuted. The Motions and Phases of Mercury and Venus explained* 50

CHAP. VII.

The physical Causes of the Motions of the Planets. The Excentricities of their Orbits. The times in which the Action of Gravity would bring them to the Sun. ARCHIMEDES'S *ideal Problem for moving the Earth. The world not eternal* 54

CHAP. VIII.

Of Light. It's proportional quantities on the different Planets. It's Refractions in Water and Air. The Atmosphere, it's Weight and Properties. The Horizontal Moon 62

CHAP. IX.

The Method of finding the Distances of the Sun, Moon and Planets 73

CHAP. X.

The Circles of the Globe described. The different lengths of days and nights, and the vicissitude of Seasons, explained. The explanation of the Phenomena of Saturn's Ring concluded 78

CHAP. XI.

The Method of finding the Longitude by the Eclipses of Jupiter's Satellites: The amazing velocity of Light demonstrated by these Eclipses 87

CHAP. XII.

Of Solar and Sidereal Time 93

CHAP. XIII.

Of the Equation of Time 97

CHAP. XIV.

Of the Precession of the Equinoxes 108

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 124

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 Page 136

CHAP. XVII.

Of the ebbing and flowing of the Sea 147

CHAP. XVIII.

Of Eclipses: Their Number and Period. A large Catalogue of Ancient and Modern Eclipses 156

CHAP. XIX.

The Calculation of New and Full Moons and Eclipses. The geometrical Construction of Solar and Lunar Eclipses. The examination of ancient Eclipses 189

CHAP. XX.

Of the fixed Stars 230

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* 248

CHAP. XXII.

A Description of the Astronomical Machinery serving to explain and illustrate the foregoing part of this Treatise 260

ERRATA.

In the Table facing Page 31, the Sun's quantity of matter should be 227500. Page 40, l. last, for infinite *read* indefinite. *Page 97, l. 20, for* this *read* the next. *Page 164, l. 2 from the bottom, for* without any acceleration *read* as above, without any acceleration. *Page 199, l. 16 for* XIV *read* XV. *Page 238, l. 16, for* 40 *read* 406. *Page 240, l. 15 from the bottom, for* Tifri *read* Tisri, *Page 249 l. 13; from the bottom for* XVII *read* V.

ASTRONOMY

EXPLAINED UPON

Sir ISAAC NEWTON's PRINCIPLES.

CHAP. I.

Of Astronomy in general.

The general use of Astronomy.

1. Of all the sciences cultivated by mankind, Astronomy is acknowledged to be, and undoubtedly is, the most sublime, the most interesting, and the most useful. For, by knowledge derived from this science, not only the bulk of the Earth is discovered, the situation and extent of the countries and kingdoms upon it ascertained, trade and commerce carried on to the remotest parts of the world, and the various products of several countries distributed for the health, comfort, and conveniency of 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, and superintendency of the SUPREME BEING! So that without an hyperbole,

"*An undevout Astronomer is mad*[1]."

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

The Earth but a point as seen from the Sun.

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

The Stars are Suns.

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

And innumerable.

5. By the help of telescopes we discover thousands of Stars which are invisible to the naked eye; and the better our glasses are, still the more become visible: so that we can set no limits either to their number or their distances. The celebrated HUYGENS carries his thoughts so far, as to believe it not impossible that there may be Stars at such inconceivable distances, that their light has not yet reached the Earth since it's creation; although the velocity of light be a million of times greater than the velocity of a cannon bullet, as shall be demonstrated afterwards § 197, 216: and, as Mr. ADDISON very justly observes, this thought is far from being extravagant, when we consider that the Universe is the work of infinite power, prompted by infinite goodness; having an infinite space to exert itself in; so that our imaginations can set no bounds to it.

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. 3

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, 'tis plain that the Stars are of the same nature with the Sun.

They are probably surrounded by Planets.

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.

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 out of the Creation than a grain of sand from the sea-shore. The space they possess being comparatively so small, that it would scarce be a sensible blank in the Universe; although Saturn, the outermost of our planets, revolves about the Sun in an Orbit of 4884 millions of miles in circumference, and some of our Comets make excursions upwards of ten thousand millions of miles beyond Saturn's Orbit; and yet, at that amazing distance, they are incomparably nearer to the Sun than to any of the Stars; as is evident from their keeping clear of the attractive Power of all the Stars, and returning periodically by virtue of the Sun's attraction.

The stellar Planets may be habitable.

10. From what we know of our own System it may be reasonably concluded that all the rest are with equal wisdom contrived, situated, and provided with accommodations for rational inhabitants. Let us therefore take a survey of the System to which we belong; the only one accessible to us; and from thence we shall be the better enabled to judge of the nature and end of the other Systems of the Universe. For although there is almost an infinite variety in all 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! 4

As our Solar Planets are.

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.

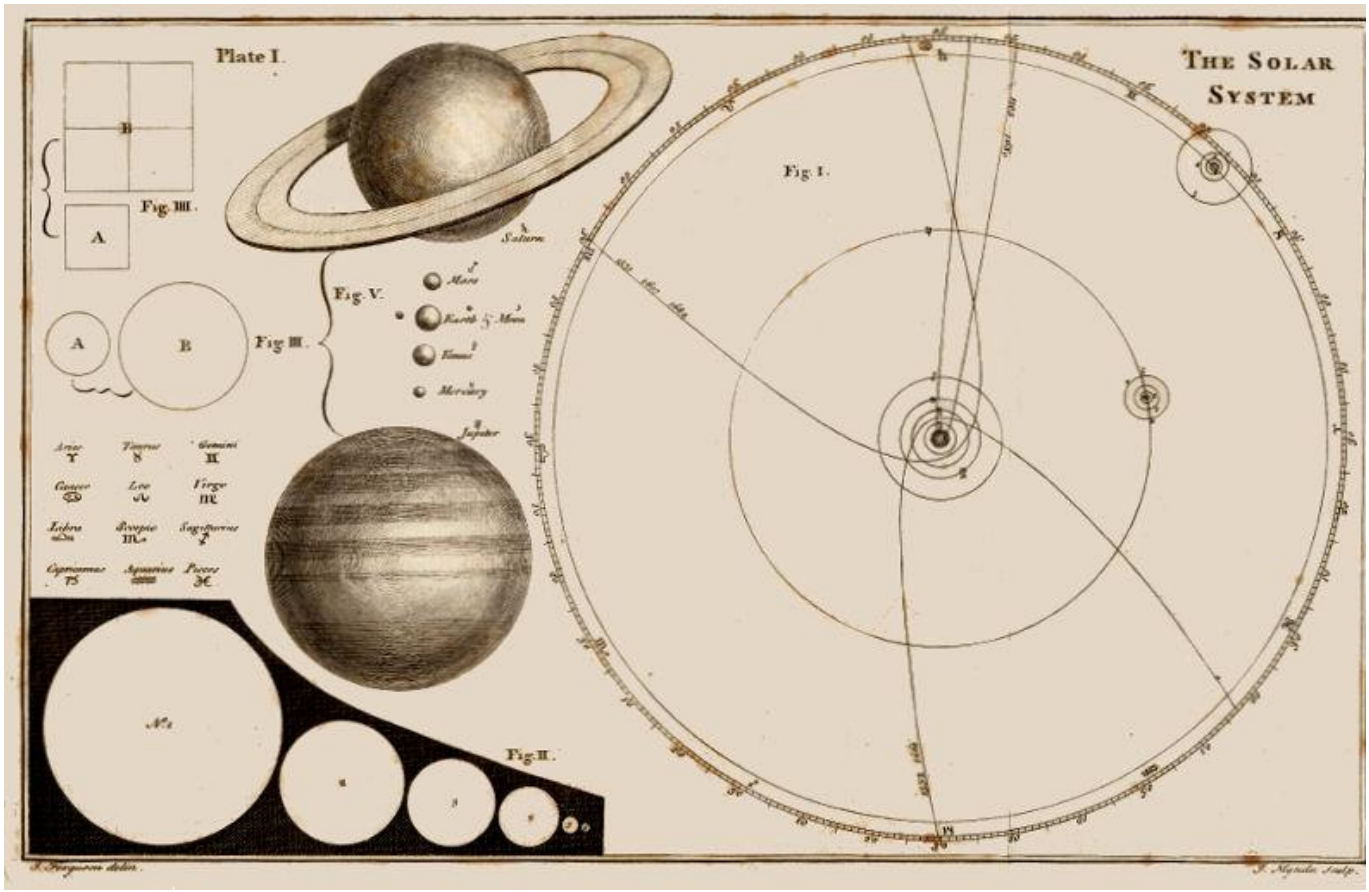
The farthest from the Sun have most Moons to enlighten their nights.

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 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 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.

The Solar System



J. Ferguson delin.

J. Mynde Sculp.

14. Since the Fixed Stars are prodigious spheres of fire, like our Sun, and at inconceivable distances from one another, as well as from us, it is reasonable to conclude they are made for the same purposes that the Sun is; each to bestow light, heat, and vegetation on a certain number of inhabited Planets, kept by gravitation within the sphere of it's activity. 5

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. II.

A brief Description of the SOLAR SYSTEM.

PLATE I. Fig. 1.

The Solar System.

17. The Planets and Comets which move round the Sun as their center, constitute the Solar System. Those Planets which are nearer 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 follows.

The Sun.

18. The SUN ☉, an immense globe of fire, is placed near the common center, or rather in the lower[2] focus, of the Orbits of all the Planets and Comets[3]; and turns round his axis in 25 days 6 hours, as is evident by the motion of spots seen on his surface. His diameter is computed to be 763,000 miles; and, by the various attractions of the circumvolving Planets, he is agitated by a small motion round the center of gravity of the System. All the Planets, as seen from him, move the same way, and according to the order of Signs in the graduated Circle ♈ ♉ ♎ ♋ &c. which represents the great Ecliptic in the Heavens: but, as seen from any one Planet, the rest appear sometimes to go backward, sometimes forward, and sometimes to stand still; not in circles nor ellipses, but in[4] looped curves which never return into themselves. The Comets come from all parts of the Heavens, and move in all sorts of directions. 6

PLATE I. Fig. I. The Sun.

The Axes of the Planets, what.

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

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

PLATE I.

Their Nodes.

Where situated.

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 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 rutts of waggon-wheels crossing one another in different parts, but never going far asunder. That Node, or Intersection of the Orbit of any Planet with the Earth's Orbit, from which the Planet ascends northward above the Ecliptic, is called the *Ascending Node* of the Planet; and the other, which is directly opposite thereto, is called it's *Descending Node*. Saturn's Ascending Node is in 21 deg. 13 min. of Cancer ♋, Jupiter's in 7 deg. 29 min. of the same Sign, Mars's in 17 deg. 17 min. of Taurus ♉, Venus's in 13 deg. 59 min. of Gemini ♊, and Mercury's in 14 deg. 43 min. of Taurus. Here we consider the Earth's Orbit as the standard, and the Orbits of all the other Planets as oblique to it. 7

The Planets Orbits, what.

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 without any solid Orbits to confine the

Planets, they keep their courses, and at the end of every revolution find the points from whence they first set out, much more truly than can be imitated in the best machines made by human art.

Mercury.

Fig. I.

May be inhabited.

PLATE I.

22. MERCURY, the nearest Planet to the Sun, goes round him (as 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 it's being inhabited; since the Almighty could as easily suit the bodies and constitutions of it's inhabitants to the heat of their dwelling, as he has done ours to the temperature of our Earth. And it is very probable that the people there have such an opinion of us, as we have of the inhabitants of Jupiter and Saturn; namely, that we must be intolerably cold, and have very little light at so great a distance from the Sun.

8

Has like phases with the Moon.

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

His Orbit and Nodes.

24. His Orbit is inclined seven degrees to the Ecliptic; and *that* Node § 20, from which he ascends northward above the Ecliptic is in the 14th degree of Taurus; the opposite, in the 14th degree of Scorpio. The Earth is in these points on the 5th of *November* and 4th of *May*, new style; and when Mercury comes to either of his Nodes at his[5] 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.

When he will be seen as if upon the Sun.

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

Fig. I.

Venus.

26. VENUS, the next Planet in order, is computed to be 59 millions of miles from the Sun; and by moving at the rate of 69 thousand miles every hour in her Orbit (as in the circle marked ♀), she goes round the Sun in 224 days 17 hours of our time nearly; in which, though it be the full length of her year, she has only $9\frac{1}{4}$ days, according to BIANCHINI's observations; so that in her, every day and night together is as long as $24\frac{1}{3}$ days and nights with us. This odd quarter of a day in every year makes every fourth year a leap-year to Venus; as the like does to our Earth. Her diameter is 7906 miles; and by her diurnal motion the inhabitants about her Equator are carried 43 miles every hour: besides the 69,000 above-mentioned.

9

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

She is our morning and evening Star by turns.

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

29. The Axis of Venus is inclined 75 degrees to the Axis of her Orbit; which is $51\frac{1}{2}$ degrees more than our Earth's Axis is inclined to the Axis of the Ecliptic: and therefore the variation of her seasons is much greater

than of ours. The North Pole of her Axis inclines toward the 20th degree of Aquarius, our Earth's to the beginning of Cancer; and therefore the northern parts of Venus have summer in the Signs where those of our Earth have winter, and *vice versâ*.

Remarkable appearances.

30. The [6]artificial day at each Pole of Venus is as long as 112½ [7]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[8] Tropics are only 15 degrees from her Poles; and her [9]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 Sign, or twelfth Part of her Orbit, in little more that three quarters of her natural day, or nearly in 18¾ 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 by that means, 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 remarkables.

Surprising appearances at her Poles;

The Sun will rise 22½ degrees[10] north of the East, and going on 112½ degrees, as measured on the plane of the [11]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 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 48½ degrees; next at the altitude of 12½ degrees; and going on thence 112½ degrees, he will set 22½ degrees north of the West; so that, after having been 4⅝ revolutions above the Horizon, he descends below it to exhibit the like appearances at the South Pole.

35. At each Pole, the Sun continues half a year without setting in summer, and as long without rising in winter; consequently the polar inhabitants of Venus have only one day and one night in the year; as it is at the Poles of our Earth. But the difference between the heat of summer and cold of winter, or of mid-day and mid-night, on Venus, is much greater than on the Earth: because in Venus, as the Sun is for half a year together above the Horizon of each Pole in it's turn, so he is for a considerable part of that time near the Zenith; and during the other half of the year, always below the Horizon, and for a great part of that time at least 70 degrees from it. Whereas, at the Poles of our Earth, although the Sun is for half a year together above the Horizon, yet he never ascends above, nor descends below it, more than 23½ degrees. When the Sun is in the Equinoctial, or in that Circle which divides the northern half of the Heavens from the southern, he is seen with one half of his Disc above the Horizon of the North Pole, and the other half above the Horizon of the South Pole; so that his center is in the Horizon of both Poles: and then descending below the Horizon of one, he ascends gradually above that of the other. Hence, in a year, each Pole has one spring, one harvest, a summer as long as them both, and a winter equal in length to the other three seasons.

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 betwixt them, § 31; only the winters are not quite so long, nor the summers so short: but the four seasons come twice round every year.

At her 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. Whilst he is more than 15 degrees from the Equator, he neither rises to the inhabitants of the one Tropic, nor sets to those of the other: whereas, at our terrestrial Tropics he rises and sets every day of the year.

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. 12

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

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

41. From the quick change of the Sun's declination it happens, that when 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.

The longitude of places easily found in Venus.

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

Her Equinoxes shift a quarter of a day forward every year.

43. On this Planet, wherever 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 (almost equal to 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.

Every fourth year a leap-year to Venus.

PLATE I.

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. 13

When she will appear on the Sun.

45. Venus's Orbit is inclined 3½ degrees to the Earth's; and crosses it in the 14th degree of Gemini and of Sagittarius; and therefore, when the Earth is about these points of the Ecliptic at the time that Venus is in her inferiour conjunction, she will appear like a spot on the Sun, and afford a more certain method of finding the distances of all the Planets from the Sun than any other yet known. But these appearances happen very seldom; and will only be thrice visible at *London* for three hundred years to come. The first time will be in the year 1761, *June* the 6th, at 5 hours 55 minutes in the morning. The second 1996, *June* the 9th, at 2 hours 13 minutes in the afternoon. And the third in the year 2004, *June* the 6th, at 7 hours 18 minutes in the forenoon. 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 it's enlightened side can never be fully turned towards us but when Venus is beyond the Sun; and then, as Venus appears little bigger than an ordinary Star, her Moon may be too small to be perceptible at such a distance. When she is between us and the Sun, her full Moon has it's dark side towards us; and then, we cannot see it any more than we can our own Moon at the time of Change. When Venus is at her greatest Elongation, we have but one half of the enlightened side of her Full Moon towards us; and even then it may be too far distant to be seen by us. But if she has a Moon, it may certainly be seen with her upon the Sun, in the year 1761, unless it's Orbit be considerably inclined to the Ecliptic: for if it should be in conjunction or opposition at that time, we can hardly imagine that it moves so slow as to be hid by Venus all the six hours that she will appear on the Sun's Disc.

The Earth.

Fig. I.

It's diurnal and annual motion.

47. The EARTH is the next Planet above Venus in the System. It is 81 millions of miles from the Sun, and goes round him (as in the circle ⊕) in 365 days 5 hours 49 minutes, from any Equinox or Solstice to the same again: but from any fixed Star to the same again, as seen from the Sun, in 365 days 6 hours and 9 minutes; 14 the former being the length of the Tropical year, and the latter the length of the Sidereal. 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 it's Axis every 24 hours from West to East, it causes an apparent diurnal motion of all the heavenly Bodies from East to West. By this rapid motion of the Earth on it's Axis, the inhabitants about the Equator are carried 1042 miles every hour, whilst those on the parallel of *London* are carried only about 580, besides the 58 thousand miles by the annual motion above-mentioned, which is common to all places whatever.

Inclination of it's Axis.

48. The Earth's Axis makes an angle of $23\frac{1}{2}$ degrees with the Axis of it's Orbit; and keeps always the same oblique direction; inclining towards the same fixed Stars[12] throughout it's annual course; which causes the returns of spring, summer, autumn, and winter; as will be explained at large in the tenth Chapter.

A proof of it's being round.

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

It's 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 million 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.

PLATE I.

51. Dr. LONG, in the first volume of his Astronomy, pag. 168, mentions an ingenious and easy method of finding nearly what proportion the land bears to the sea; which is, to take the papers of a large terrestrial globe, and after separating the land from the sea with a pair of scissars, to weigh them carefully in scales. This supposes the globe to be exactly delineated, and the papers all of equal thickness. The Doctor made the 15 experiment on the papers of Mr. SENEX's seventeen inch globe; and found that the sea papers weighed 349 grains, and the land only 124: by which it appears that almost three fourth parts of the surface of our Earth between the Polar Circles are covered with water, and that little more than one fourth is dry land. The Doctor omitted weighing all within the Polar Circles; because there is no certain measurement of the land there, so as to know what proportion it bears to the sea.

The Moon.

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

Her Phases.

53. The Moon is an opaque Globe like the Earth, and shines only by reflecting the light of the Sun: therefore whilst that half of her which is toward 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 towards the Earth, and she appears with a round, illumined Orb; which we call the *Full Moon*: her dark side being then turned away from the Earth. From the Full she seems to decrease gradually as she goes through the other half of her course; shewing us less and less of her enlightened side every day, till her next change or conjunction with the Sun, and then she disappears as before.

A proof that she shines not by her own light.

Fig. I.

54. The continual changing of the Moon's phases or shapes 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.

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 it's third quarter to her; and *vice versâ*. 16

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 line which limits our view of the Moon, or all round what we call her edges, only one half of the Earth's side next her is seen; the other half being hid below the Horizon. 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 such Atmosphere, or body of air 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 round her, which would make the Stars look fainter, when they were seen through it. But observation proves, that the Stars which disappear behind the Moon retain their full lustre until they seem to touch her very edge, and then vanish in a moment. This has been often observed by Astronomers, but particularly by Cassini[13] of the Star γ in the breast of Virgo, which appears single and round to the bare eye; but through a refracting Telescope of 16 feet appears to be two Stars so near together, that the distance between them seems to be but equal to one of their apparent diameters. The Moon was observed to pass over them on the 21st of *April* 1720, *N. S.* and as her dark edge drew near to them, it caused no change in their colour or Situation. At 25 min. 14 sec. past 12 at night, the most westerly of these Stars was hid by the dark edge of the Moon; and in 30 seconds afterward, the most easterly Star was hid: each of them disappearing behind the Moon in an instant, without any preceding diminution of magnitude or brightness; which by no means could have been the case if there were an Atmosphere round the Moon; for then, one of the Stars falling obliquely into it before the other, ought by refraction to have suffered some change in its colour, or in it's distance from the other Star which was not yet entered into the Atmosphere. But no such alteration could be perceived though the observation was performed with the utmost attention to that particular; and was very proper to have made such a discovery. The faint light, which has been seen all around the Moon, in total Eclipses of the Sun, has been observed, during the time of darkness, to have it's center coincident with the center of the Sun; and is therefore much more likely to arise from the Atmosphere of the Sun than from that of the Moon; for if it were the latter, it's center would have gone along with the Moon's. 17

Nor Seas.

She is full of caverns and deep pits.

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

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

The Earth a Dial to the Moon.

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

PLATE I.

How the Lunarians may know the length of their year.

62. The Moon's Axis is so nearly perpendicular to the Ecliptic, that the Sun never removes sensibly from her Equator: and the[14] obliquity of her Orbit, which is next to nothing as seen from the Sun, cannot cause any sensible declination of the Sun from her Equator. Yet her inhabitants are not destitute of means for determining the length of their year, though their method and ours must differ. For 18

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 the Poles of our Earth; as one always begins to be enlightened, and the other disappears, 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 $365\frac{1}{4}$ natural days, and the Lunarians only $12\frac{7}{19}$; every day and night in the Moon being as long as $29\frac{1}{2}$ on the Earth.

And the longitudes of their places.

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.

Mars.

Fig. I.

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 123 millions of miles; and by travelling at the rate of 47 thousand miles every hour, as in the circle ♂, he goes round the Sun in 687 of our days and 17 hours; which is the length of his year, and contains $667\frac{1}{4}$ 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.

His Atmosphere and Phases.

65. This Planet being but a fifth part so big as the Earth, if any Moon attends him, she must be very small, and has not yet been discovered by our best telescopes. He is of a fiery red colour, and by his Appulses to some of the fixed Stars, seems to be surrounded 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.

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 a quarter of a degree from each other, although they are 240 thousand miles asunder.

PLATE I.

How the other Planets appear to Mars.

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

Jupiter.

Fig. I.

68. JUPITER, the biggest of all the Planets, is still higher in the System, being about 424 millions of miles from the Sun: and going at the rate of 25 thousand miles every hour in his Orbit, as in the circle ♃ finishes his annual period in eleven of our years 314 days and 18 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.

The number of days in his year.

69. Jupiter turns round his Axis in 9 hours 56 minutes; so that his year contains 10 thousand 464 days; and the diurnal velocity of his equatoreal parts is greater than the swiftness with which he moves in his annual Orbit; a singular circumstance, as far as we know. By this prodigious quick Rotation, his equatoreal inhabitants are carried 25 thousand 920 miles every hour (which is 920 miles an hour more than an inhabitant of our Earth moves in twenty-four hours) besides the 25 thousand above-mentioned, which is common to all parts of his surface, by his annual motion.

His Belts and spots.

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

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

But has four Moons.

72. The Sun appears but $\frac{1}{28}$ 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 their light is not wanted, because the Sun constantly circulates in or near the Horizon, and is very probably kept in view of both Poles by the Refraction of Jupiter's Atmosphere, which, if it be like ours, has certainly refractive power enough for that purpose.

Their periods round Jupiter.

Their grand period.

73. The Orbits of these Moons are represented in the Scheme of the Solar System by four small circles marked 1. 2. 3. 4. on Jupiter's Orbit ♃; but are drawn fifty times too large in proportion to it. The first Moon, or that nearest to Jupiter, goes round him in 1 day 18 hours and 36 minutes of our time; and is 229 thousand miles distant from his center: The second performs it's revolution in three days 13 hours and 15 minutes, at 364 thousand miles distance: The third in 7 days three hours and 59 minutes, at the distance of 580 thousand miles: And the fourth, or outermost, in 16 days 18 hours and 30 minutes, at the distance of one million of miles from his center. The Periods of these Moons are so incommensurate to one another, that if ever they were all in a right line between Jupiter and the Sun, it will require more than 3,000,000,000,000 years from that time to bring them all into the same right line again, as any one will find who reduces all their periods into seconds, then multiplies them into one another, and divides the product by 432; which is the highest number that will divide the product of all their periodical times, namely 42,085,303,376,931,994,955,904 seconds, without a remainder.

Parallax of their Orbits, and distances from Jupiter.

PLATE I.

How he appears to his nearest Moon.

74. The Angles under which the Orbits of Jupiter's Moons are seen from the Earth, at it's mean distance from Jupiter, are as follow: The first, 3′ 55″; the second, 6′ 14″; the third, 9′ 58″; and the fourth, 17′ 30″. And their distances from Jupiter, measured by his semidiameters, are thus: The first, $5\frac{2}{3}$; the second, 9; the third. $14\frac{23}{60}$; and the fourth, $25\frac{18}{60}$ [15]. This Planet, seen from it's nearest Moon, appears 1000 times as large as our Moon does to us; waxing and waneing in all her monthly shapes, every $42\frac{1}{2}$ hours.

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

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

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

The difference little in those of our Earth.

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

Place of his Nodes.

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

Saturn.

Fig. I.

78. SATURN, the remotest of all the Planets, is about 777 millions of miles from the Sun; and, travelling at the rate of 18 thousand miles every hour, as in the circle marked ♄, performs his annual circuit in 29 years 167 days and 5 hours of our

time; which makes only one year to that Planet. His diameter is 67,000 miles; and therefore he is near 600 times as big as the Earth.

Fig. V.

His Ring.

PLATE I.

79. He is surrounded by a thin broad Ring, as an artificial Globe is by its Horizon. This 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 it's distance from Saturn on all sides. There is reason to believe that the Ring turns round it's Axis, because, when it is almost edge-wise to us, it appears somewhat thicker on one side of the Planet than on the other; and the thickest edge has been seen on different sides at different times. But Saturn having no visible spots on his body, whereby to determine the time of his turning round his Axis, the length of his days and nights, and the position of his Axis, are unknown to us.

22

His five Moons.

Fig. I.

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 sun-light, he has five Moons, all going round him on the outside of his Ring, and nearly in the same plane with it. The first, or nearest Moon to Saturn, goes round him in 1 day 21 hours 19 minutes; and is 140 thousand miles from his center: The second, in two 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 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 it's turn. So that the Ring is visible to the inhabitants of that Planet for almost fifteen of our years, and as long invisible by turns, if it's Axis has no Inclination to it's Ring: but if the Axis of the Planet be inclined to the Ring, suppose about 30 degrees, the Ring will appear and disappear once every natural day to all the inhabitants within 30 degrees of the Equator, on both sides, frequently eclipsing the Sun in a Saturnian day. Moreover, if Saturn's Axis be so inclined to his Ring, it is perpendicular to his Orbit; and thereby the inconvenience of different seasons to that Planet is avoided. For considering the length of Saturn's year, which is almost equal to thirty of ours, what a dreadful condition must the inhabitants of his Polar regions be in, if they be half of that time deprived of the light and heat of the Sun? which must not be their case alone, if the Axis of the Planet be perpendicular to the Ring, but also the Ring must hide the Sun from vast tracks of land on each side of the Equator for 13 or 14 of our years together, on the south side and north side by turns, as the Axis inclines to or from the Sun: the reverse of which inconvenience is another good presumptive proof of the Inclination of Saturn's Axis to it's Ring, and also of his Axis being perpendicular to his Orbit.

23

How the Ring appears to Saturn and to us.

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

82. This Ring, seen from Saturn, appears like a vast luminous Arch in the Heavens, as if it did not belong to the Planet. When we see the Ring most open, it's shadow upon the Planet is broadest; and from that time the shadow grows narrower, as the Ring appears to do to us; until, by Saturn's annual motion, the Sun comes to the plane of the Ring, or even with it's edge; which being then directed towards us, becomes invisible on account of it's thinness; as shall be explained more largely in the tenth Chapter, and illustrated by a figure. The Ring disappears twice in every annual Revolution of Saturn, namely, when he is in the 19th degree both of Pisces and of Virgo. And when Saturn is in the middle between these points, or in the 19th degree either of Gemini or of Sagittarius, his Ring appears most open to us; and then it's longest diameter is to it's shortest as 9 to 4.

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

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

Place of Saturn's Nodes.

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

The Sun's light much stronger on Jupiter

and Saturn than is generally believed.

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

85. The quantity of light, afforded by the Sun of Jupiter, being but $\frac{1}{28}$th part, and to Saturn only $\frac{1}{90}$th part, of what we enjoy; may at first thought induce us to believe that these two Planets are entirely unfit for rational beings to dwell upon. But, that their light is not so weak as we imagine, is evident from their brightness in the night-time; and also, that 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 24
at the end of darkness in Total Eclipses, when his western limb begins to be visible, and seems no bigger than a bit of fine silver wire, every one is surprised at the brightness wherewith that small part of him shines. The Moon when Full affords travellers light enough to keep them from mistaking their way; and yet, according to Dr. SMITH[16], it is equal to no more than a 90 thousandth part of the light of the Sun: that is, the Sun's light is 90 thousand times as strong as the light of the Moon when Full. Consequently, the Sun gives a thousand times as much light to Saturn as the Full Moon does to us; and above three thousand times as much to Jupiter. So that these two Planets, even without any Moons, would be much more enlightened than we at first imagine; and by having so many, they may be very comfortable places of residence. Their heat, so far as it depends on the force of the Sun's rays, is certainly much less than ours; to which no doubt the bodies of their inhabitants are as well adapted as ours are to the seasons we enjoy. And if we consider, that Jupiter never has any winter, even at his Poles; which probably is also the case with Saturn, the cold cannot be so intense on these two Planets as is generally imagined. Besides, there may be something in their nature or soil much warmer than in that of our Earth: and we find that all our heat depends not on the rays of the Sun; for if it did, we should always have the same months equally hot or cold at their annual returns. But it is far otherwise, for *February* is sometimes warmer than *May*, which must be owing to vapours and exhalations from the Earth.

It is highly probable that all the Planets are inhabited.

PLATE I.

86. Every person who looks upon, and compares the Systems of Moons together, which belong to Jupiter and Saturn, must be amazed at the vast magnitude of these two Planets, and the noble attendance they have in respect of our little Earth: and can never bring himself to think, that an infinitely wise Creator should dispose of all his animals and vegetables here, leaving the other Planets bare and destitute of rational creatures. To suppose that he had any view to our Benefit, in creating these Moons and giving them their motions round Jupiter and Saturn; to imagine that he intended these vast Bodies for any advantage to us, when he well knew that they could never be seen but by a few Astronomers peeping through telescopes; and that he gave to the Planets regular returns of days and nights, and different seasons to all where they would be convenient; but of no manner of service to us, except only what 25
immediately regards our own Planet the Earth; to imagine, I say, that he did all this on our account, would be charging him impiously with having done much in vain: and as absurd, as to imagine that he has created a little Sun and a Planetary System within the shell of our Earth, and intended them for our use. These considerations amount to little less than a positive proof that all the Planets are inhabited: for if they are not, why all this care in furnishing them with so many Moons, to supply those with light which are at the greater distances from the Sun? Do we not see, that the farther a Planet is from the Sun, the greater Apparatus it has for that purpose? save only Mars, which being but a small Planet, may have Moons too small to be seen by us. We know that the Earth goes round the Sun, and turns round it's own Axis, to produce the vicissitudes of summer and winter by the former, and of day and night by the latter motion, for the benefit of 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 that beautiful harmony which reigns over the Universe? 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!

Fig. II.

How the Sun appears to the different Planets.

Fig. III.

Fig. IV.

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

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, 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. V.

88. In Fig. 5th, we have a view of the bulks of the Planets in proportion to each other, and to a supposed globe of two foot diameter for the Sun. The Earth is 27

Proportional bulks and distances of the Planets.

PLATE I.

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 proportional bulks, as in our System, Mercury would be 28 yards from the Sun's center; Venus 51 yards 1 foot; the Earth 70 yards 2 feet; Mars 107 yards 2 feet; Jupiter 370 yards 2 feet; and Saturn 760 yards two feet. The Comet of the year 1680, at it's greatest distance, 10 thousand 760 yards. In this proportion, the Moon's distance from the center of the Earth would be only $7\frac{1}{2}$ inches. 26

An idea of their distances.

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

Why the Planets appear bigger and less at different times.

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

Fig. I.

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

The Comets.

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

PLATE I.

Fig. I.

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.

93. Part of the Paths of three Comets are delineated in the Scheme of the Solar System, and the years marked in which they made their appearance. It is believed, that there are at least 21 Comets belonging to our System, moving in all sorts of directions: and all those which have been observed, have moved through the ethereal Regions and the Orbits of the 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 afterwards. The second of them appeared in 1532 and 1661, and may be expected to return in 1789 and every 129th year afterwards. The third, having last appeared in 1680, and it's Period being no less than 575 years, cannot return until the year 2225. This Comet, at it's greatest distance, is about 11 thousand two hundred millions of miles from the Sun; and at it's least distance from the Sun's center, which is 490,000 miles, is within less than a third part of the Sun's semi-diameter from his surface. In that part of it's Orbit which is nearest the Sun, it flies with the amazing swiftness of 880,000 miles in an hour; and the Sun, as seen from it, appears an hundred degrees in breadth; consequently, 40 thousand times as large as he appears to us. The astonishing length that this Comet runs out into empty Space, suggests to our minds an idea of the vast distance between the Sun and the nearest fixed Stars; of whose Attractions all the Comets must keep clear, to return periodically, and go round the Sun; and it shews us also, that the nearest Stars, which are probably those that seem the largest, are as big as our Sun, and of the same nature with him; otherwise, they could not appear so large and bright to us as they do at such an immense distance. 27

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 [17]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, and the former enabling him to make creatures suited to all states and circumstances; that matter exists only for the sake of intelligence; 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, 28
air, water, and even on other animals; every blade of grass, every tender leaf, every natural fluid, swarming with life; and every one of these enjoying such gratifications as the nature and state of each requires: when we reflect moreover that some centuries ago, till experience undeceived us, a great part of the Earth was judged uninhabitable; the Torrid Zone by reason of excessive heat, and the two Frigid Zones because of their intollerable cold; it seems highly probable, that such numerous and large masses of durable matter as the Comets are, however unlike they be to our Earth, are not destitute of beings capable of contemplating with wonder, and acknowledging with gratitude the wisdom, symmetry, and beauty of the Creation; which is more plainly to be observed in their extensive Tour through the Heavens, than in our more confined Circuit. If farther conjecture is permitted, may we not suppose them instrumental in recruiting the expended fuel of the Sun; and supplying the exhausted moisture of the Planets? However difficult it may be, circumstanced as we are, to find out their particular destination, this is an undoubted truth, that wherever the Deity exerts his power, there he also manifests his wisdom and goodness.

This System very ancient, and demonstrable.

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.

The Ptolemean System absurd.

96. In the *Ptolemean System* the Earth was supposed to be fixed in the Center of the Universe; and that the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn moved round the Earth: above the Planets, this Hypothesis placed the Firmament of Stars, and then the two Crystalline Spheres; all which were included in and received motion from the *Primum Mobile*, which constantly revolved about the Earth in 24 hours, from East to West. But as this rude Scheme was found incapable to stand the test of art and observation, it was soon rejected by all true philosophers; notwithstanding the opposition and violence of blind and zealous bigots.

The Tychonic System, partly true and partly false.

97. The *Tychonic System* succeeded the *Ptolemean*, but was never so generally 29
received. In this the Earth was supposed to stand still in the Center of the Universe or Firmament of Stars, and the Sun to revolve about it every 24 hours; the Planets, Mercury, Venus, Mars, Jupiter, and Saturn, going round the Sun in the times already mentioned. But some of TYCHO's disciples supposed the Earth to have a diurnal motion round it's Axis, and the Sun with all the above Planets to go round the Earth in a year; the Planets moving round the Sun in the foresaid times. This hypothesis, being partly true and partly false, was embraced by few; and soon gave way to the only true and rational System, restored by COPERNICUS and demonstrated by Sir ISAAC NEWTON.

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

A TABLE 30

Of the PERIODS, REVOLUTIONS, MAGNITUDES, &c. of the PLANETS.

Sun and Planets.	Annual period round the Sun.	Diurnal rotation on it's Axis.	Diameter in English miles.	Mean diam. as seen fr. the Sun.	Mean distance from the Sun in English miles.
Sun	----	25d. 6h.	763000	----	----
Mercury	$87^d\ 23^h$	Unknown.	2600	20″	32,000,000
Venus	$224^d\ 17^h$	24d. 8h.	7906	30″	59,000,000
Earth	$365^d\ 6^h$	1d. 0h.	7970	21″	81,000,000
Moon	$365^d\ 6^h$	29d. $12\frac{3}{4}$h.	2180	6″	81,000,000
Mars	$686^d\ 23^h$	24h. 40m.	4444	11″	123,000,000
Jupiter	$4332^d\ 12^h$	9h. 56m.	81000	37″	424,000,000
Saturn	$10759^d\ 7^h$	Unknown.	67000	16″	777,000,000

Sun and Planets.	Excentricity of it's Orbit in miles.	Axis inclined to	Orbit inclined to Ecliptic.	Place of it's Aphelion.	Place of it's Ascending	Proportion of Diameters.

		Orbit.			Node.	
Sun	----	8° 0′	----	----	----	10000
Mercury	6,720,000	Unkn.	6° 54′	♐ 13° 8′	♉ 14° 43′	34 1/10
Venus	413,000	75° 0′	3° 20′	♒ 4° 20′	♊ 13° 59′	103 1/2
Earth	1,377,000	23° 29′	0° 0′	♑ 8° 1′	----	104 1/2
Moon	13,000	2° 10′	5° 8′	----	Variable.	28 1/2
Mars	11,439,000	0° 0′	1° 52′	♏ 0° 32′	♉ 17° 17′	58 1/6
Jupiter	20,352,000	0° 0′	1° 20′	♎ 9° 10′	♋ 7° 29′	1061 2/3
Saturn	42,735,000	Unkn.	2° 30′	♐ 27° 50′	♋ 21° 13′	878 1/9

Sun and Planets.	Proportion of Bulk.	Prop. of Gravity on the surface.	Proportion of Density.	Proportion of Light & Heat.	Propor. quantity of Matter.	Hourly motion in it's Orbit.	Hourly motion of it's Equator.
Sun	877650	24	25 1/2	45000	227500	----	3818
Mercury	1/27	Unkn.	Unkn.	6 1/2	Unkn.	95000	Unkn.
Venus	1	Unkn.	Unkn.	1 3/4	Unkn.	69000	43
Earth	1	1	100	1	1	58000	1042
Moon	1/50	34/100	123 1/2	1 ±	1/40	2290	9 1/2
Mars	1/5	Unkn.	Unkn.	3/7	Unkn.	47000	556
Jupiter	1049	2	19	1/28	220	25000	25920
Saturn	586	1 1/2	15	1/90	94	18000	Unkn.

Sun and Planets.	Square miles in surface.	Cubic miles in solidity.	Would fall to the Sun in
Sun	1,828,911,000,000	232,577,115,137,000,000	days h.
Mercury	21,236,800	9,195,534,500	15 13
Venus	691,361,300	258,507,832,200	39 17
Earth	199,852,860	265,404,598,080	14 10
Moon	14,898,750	5,408,246,000	64 10
Mars	62,038,240	45,969,335,840	121 0
Jupiter	20,603,970,000	278,153,595,000,000	290 0
Saturn	14,102,562,000	155,128,182,000,000	767 0
			If the projectile force was destroyed.

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

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

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

CHAP. III.

The COPERNICAN SYSTEM *demonstrated to be true*.

Of matter and motion.

99. Matter is of 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 nor 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 towards 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 it's surface. On opposite parts of the Earth bodies fall in opposite directions, all towards the centre where the 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 an horizontal direction, with so great a velocity that it would move more than a semidiameter of the Earth, in the time it would take to fall to the Earth by gravity; in that case, if there were no resisting medium in the way, the body would not fall to the Earth at all; but continue to circulate round the Earth, keeping always the same path, and returning to the point from whence it was projected, with the same velocity as at first.

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 such a power as gravity in these Planets. All the Planets move round the Sun, and respect it for their centre of motion: therefore the Sun must be endowed with attracting force, as well as the Earth and Planets. The like may be proved of the Comets. So that all the bodies or matter in the Solar System are possessed of this power; and perhaps so is all matter whatsoever.

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

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

33

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.

The absurdity of supposing the Earth at rest.

For, if the Sun moves about the Earth, the Earth's attractive power must draw the Sun towards it from the line of projection so, as to bend it's motion into a curve; and the Earth being at least 169 thousand times lighter than the Sun, by being so much less as to it's quantity of matter, must move 169 thousand times faster toward the Sun than the Sun does toward the Earth; and consequently 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 into the Sun. To say, that gravitation retains all the other Planets in their Orbits without affecting the Earth, which is placed between the Orbits of Mars and Venus, is as absurd as to suppose that six cannon bullets might be projected upwards to different heights in the Air, and that five of them should fall down to the ground; but the sixth, which is neither the highest nor the lowest, should remain suspended in the Air without falling; and the Earth move round about it.

34

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

110. The Sun is so immensely bigger and heavier than the Earth[18], 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.

The harmony of the celestial motions.

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

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 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 centre 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 is 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 centres of the several Orbits: that is, of the several parallel

35

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 axe of the Earth produced to the Poles of the Heavens, is an hypothesis too absurd to be allowed of by any rational creature. And it is still more absurd to imagine that these forces should increase exactly in proportion to the distances from this axe; for this is an indication of an increase to infinity: whereas the force of attraction is found to decrease in receding from the fountain from whence it flows. But, the farther that 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 to the Earth's motion round the Sun; which is, that in opposite points of the Earth's Orbit, it's Axis which always keeps a parallel direction would point to different fixed Stars; which is not found to be fact. But this objection is easily removed by considering the immense distance of the Stars in respect of the diameter of the Earth's Orbit; the latter being no more than a point when compared to the former. If we lay a ruler on the side of a table, and along the edge of the ruler view the top of a spire at ten miles distance; then lay the ruler on the opposite side of the table in a parallel situation to what it had before, and the spire will still appear along the edge of the ruler; because our eyes, even when assisted by the best instruments are incapable of distinguishing so small a change.

113. Dr. Bradley, our present Astronomer Royal, has found by a long series of the most accurate observations, that there is a small apparent motion of the fixed Stars, occasioned by the aberration of their light, and so exactly answering to an 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[19], Long[20], Desaguliers[21], Rutherfurth, Mr. Maclaurin[22], and M. de la Caille[23]. 36

Why the Sun appears to change his place.

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 Earth or Sun 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.

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 it's motion.

The Earth's motion on it's Axis demonstrated.

116. We find that the Sun, and those Planets on which there are visible spots, turn round their Axes: for the spots move regularly over their Disks[24]. From hence we may reasonably conclude that the other Planets on which we see no spots, and the Earth which is likewise a Planet, have such rotations. But being incapable of leaving the Earth, and viewing it at a distance; and it's rotation being smooth and uniform, we can neither see it move on it's Axis as we do the Planets, nor feel ourselves affected by it's motion. Yet there is one effect of such a motion which will enable us to judge with certainty whether the Earth revolves on it's Axis or not. All Globes which do not turn round their Axes will be perfect spheres, on account of the equality of the weight of bodies on their surfaces; especially of the fluid parts. But all Globes which turn on their Axes will be oblate spheroids; that is, their surfaces will be higher, or farther from the centre, in the equatoreal than in the polar Regions: for, as the equatoreal parts move quickest, they will recede farther from the Axis of motion, and enlarge the equatoreal diameter. That our Earth is really of this figure is demonstrable from the unequal vibrations of a pendulum, and the unequal lengths of degrees in different latitudes. Since then, the Earth is higher at the Equator than at the Poles, the sea, which naturally runs downward, or towards the places which are nearest the centre, would run towards the polar Regions, and leave the equatoreal parts dry, if the centrifugal force of these parts did not raise and carry the waters thither. The Earth's equatoreal diameter is 35 miles longer than its Axis. 37

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

117. Bodies near the Poles are heavier than those towards the Equator, because they are nearer the Earth's centre, 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, 'tis found necessary to diminish it's length. By comparing the different lengths of pendulums swinging seconds at the Equator and at *London*, it is found that a pendulum must be $2^{169}/_{1000}$ lines shorter at the Equator than at the Poles. A line is a twelfth part of an inch.

How they might lose all their weight.

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

The Earth's motion cannot be felt.

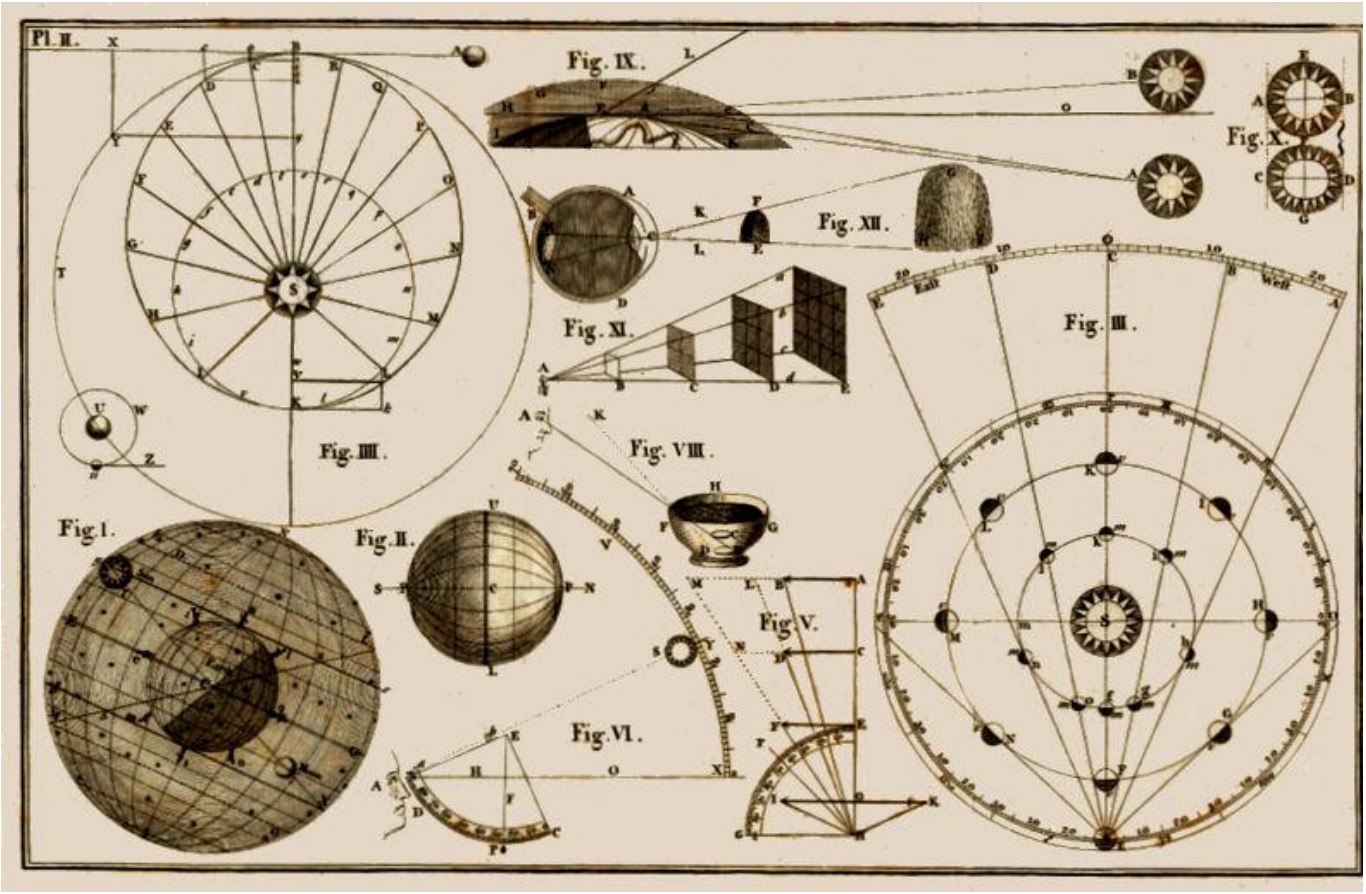
119. One on the Earth can no more be sensible of it's undisturbed motion on it's Axis, than one in the cabin of a ship on smooth Water can be sensible of her motion when she turns gently and uniformly round. It is therefore no argument against the Earth's diurnal motion that we do not feel it: nor is the apparent revolutions of the celestial bodies every day a proof of the reality of these motions; for whether we or they revolve, the appearance is the very same. A person looking through the 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.

To the different Planets the Heavens appear to turn round on different Axes.

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 to us on Earth would be at rest as seen from any other Planet. Thus, the Axis of Venus, which lies almost at right Angles to the Axis of the Earth, would have it's motionless Poles in two opposite points of the Heavens lying almost in our Equinoctial, where the motion appears quickest because it is 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 $23^1/_2$ 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 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 a day, he must travel upwards of 300,000 miles in a minute: but the Stars being at least 10,000 times as far as the Sun from us, those about the Equator must move 10,000 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 motion of the Sun westward, and bringing about the alternate returns of day and night.

38

Pl. II.



Objections against the Earth's diurnal motion answered.

121. As to the common objections against the Earth's motion on it's Axis, they are all easily answered and set aside. That it may turn without being seen or felt 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. This 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 again 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. And 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, this general answer may be made to them all, *viz.* 'tis plain from many instances that the Scriptures were never intended to instruct us in Philosophy or Astronomy; and therefore, on those subjects, expressions are not always to be taken in the strictest sense; but for the most part as accommodated to the common apprehensions of mankind. Men of sense in all ages, when not treating of the sciences purposely, have followed this method: and it would be in vain to follow any other in addressing ourselves to the vulgar, or bulk of any community. *Moses* calls the Moon A GREAT LUMINARY (as it is in the Hebrew) as well as the Sun: but the Moon is known to be an opaque body, and the smallest that Astronomers have observed in the Heavens and shines upon us not by any inherent light of it's own, but by reflecting the light of the Sun. If *Moses* had known this, and told the *Israelites* so, they would have stared at him; and considered him rather as a madman than as a person commissioned by the Almighty to be their leader.

39

CHAP. IV.

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

We are kept to the Earth by gravity.

PLATE II. Fig. I.

Antipodes.

Axis of the World. It's Poles. Fig. II.

122. We are kept to the Earth's surface on all sides by the power of it's central attraction; which, laying hold of all bodies according to their densities or quantities of matter without regard to their bulks, constitutes what we call their *weight*. And having the sky over our heads, go where we will, and our feet towards the centre 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 centre *C*; and have the same figure of sky *N*, *l*, *E*, *M*, *S*, *O*, *Q*, *L* over their heads. Therefore, the point *S* is as directly upward to the inhabitant *s* on the south Pole as *N* is to the inhabitant *n* on the North Pole: so is *E* to the inhabitant *e*, supposed to be on the north end of *Peru*; and *Q* to the opposite inhabitant *q* on the middle of the island *Sumatra*. Each of these observers is surprised that his opposite or *Antipode* can stand with his head hanging downwards. But let either 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 him.

40

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

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 persons 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 too strong for 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 it's Attraction, would pull away every thing from the side of the Earth next to it; and only those on the top of the opposite or upper side could keep upon it. But there is no larger Globe near enough our Earth to overcome it's central attraction; and therefore it has no such thing as an upper and an under side: for all bodies on or near it's surface, even to the Moon, gravitate towards it's center.

PLATE II.

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

41

Fig. I.

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

Phenomena at the Poles.

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 one half of the Heavens. The inhabitant *n*, on the North Pole of the Earth, constantly sees the Hemisphere *ENQ*; and having the North Pole *N* of the Heavens just over his head, his [25]Horizon coincides with the Celestial Equator *ECQ*. Therefore all the Stars in the Northern Hemisphere *ENC*, between the Equator and North Pole, appear to turn round the line *NC*, moving parallel to the Horizon. The Equatoreal Stars keep in the Horizon, and all those in the Southern Hemisphere *ESQ* are invisible. The like Phenomena are seen by the observer *s* on the South

PLATE II.

Pole, with respect to the Hemisphere *ESQ*; and to him the opposite Hemisphere is always invisible. Hence, under either Pole, only one 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 *YCX* or Orbit which the Sun appears to describe once a year by the Earth's annual motion, has the half *YC* constantly above the Horizon *ECQ* of the North Pole *n*; and the other half *CX* always below it. Therefore whilst the Sun describes the northern half *YC* of the Ecliptic he neither sets to the North Pole nor rises to the South; and whilst he describes the southern half *CX* he neither sets to the South Pole nor rises to the North. The same things are true with respect to the Moon; only with this difference, that as the Sun describes the Ecliptic but once a year, he is for half that time visible to each Pole in it's turn, and as long invisible; but as the Moon goes round the Ecliptic in 27 days 8 hours, she is only visible for 13 days 16 hours, and as long invisible to each Pole by turns. All the Planets likewise rise and set to the Poles, because their Orbits are cut obliquely in halves by the Horizon of the Poles. When the Sun (in his apparent way from *X*) arrives at *C*, which is on the 20th of *March*, he is just rising to an observer at *n* on the North Pole, and setting to another at *s* on the South Pole. From *C* he rises higher and higher in every apparent Diurnal revolution 'till he comes to 42
the highest point of the Ecliptic *y*, on the 21st of *June*, and then he is at his greatest Altitude, which is $23\frac{1}{2}$ degrees, or the Arc *Ey*, equal to his greatest North declination; and from thence he seems to descend gradually in every apparent Circumvolution, 'till he sets at *C* on the 23d of *September*; and then he goes to exhibit the like Appearances at the South Pole for the other half of the year. Hence the Sun's apparent motion round the Earth is not in parallel Circles, but in Spirals; such as might be represented by a thread wound round a Globe from Tropic to Tropic; the Spirals being at some distance from one another about the Equator, but gradually nearer to each other as they approach nearer to the Tropics.

Phenomena at the Equator.

Fig. I.

126. If the observer be any where on the Terrestrial Equator *eCq*, as suppose at *e*, he is in the Plane of the Celestial Equator; or under the Equinoctial *ECQ*; and the Axis of the Earth *nCs* is coincident with the Plane of his Horizon, extended out to *N* and *S*, the North and South Poles of the Heavens. As the Earth turns round the line *NCS*, the whole Heavens *MOLl* seem to turn round the same line, but the contrary way. It is plain that this observer has the Poles constantly in his Horizon, and that his Horizon cuts the Diurnal paths of all the Celestial bodies perpendicularly and in halves. Therefore the Sun, Planets, and Stars rise every day, and ascend perpendicularly above the Horizon for six hours, and passing over the Meridian, descend in the same manner for the six following hours; then set in the Horizon, and continue twelve hours below it. Consequently at the Equator the days and nights are equally long throughout the year. When the observer is in the situation *e*, he sees the Hemisphere *SEN*; but in twelve hours after, he is carried half round the Earth's Axis to *q*, and then the Hemisphere *SQN* becomes visible to him; and *SEN* disappears, being hid by the Convexity of the Earth. 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.

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

Remark.

127. If a Globe be held sidewise to the eye, at some distance, and so that neither of it's Poles can be seen, the Equator *ECQ* and all Circles parallel to it, as *DL*, *yzx*, *abX*, *MO*, &c. will appear to be straight lines, as projected in this Figure; which is requisite to be mentioned 43
here, because we shall have occasion to call them Circles in the following Article[26].

Phenomena between the Equator and Poles.

The Circles of perpetual Apparition and Occultation.

128. Let us now suppose that the observer has gone from the Equator e towards the North Pole *n*, and that he stops at *i*, from which place he then sees the Hemisphere *MElNL*; his Horizon *MCL* having shifted as many [27]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 as far from the North Pole *N* as the observer is from under, the Equinoctial, namely the Stars north of the dotted parallel *DL*, never set below the Horizon; and those which are south of the dotted parallel *MO* never rise above it. Hence, the former of these two parallel Circles is called *the Circle of perpetual Apparition*, and the latter *the Circle of perpetual Occultation*: but all the Stars between these two Circles rise and set every day. Let us imagine many Circles to be drawn between these two, and parallel to them; those which are on the north side of the Equinoctial will be unequally cut by the Horizon *MCL*, having larger portions above the Horizon than below it; and the more so, as they are nearer to the Circle of perpetual Apparition; but the reverse happens to those on the south side of the Equinoctial, whilst the Equinoctial is divided in two equal parts by the Horizon. Hence, by the apparent turning of the Heavens, the northern Stars describe greater Arcs or Portions of Circles above the Horizon than below it; and the greater as they are farther from the Equinoctial towards the Circle of perpetual Apparition; whilst the contrary 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.

PLATE II.

129. An observer on the Equator has no Circle of perpetual Apparition or Occultation, because all the Stars, together with the Sun and Moon, rise and set to him every day. But, as a bare view of the Figure is sufficient to shew that these two Circles *DL* and *MO* are just as far from the Poles *N* and *S* as the observer at *i* (or one opposite to him at *o*) is from the Equator *ECQ*; it is plain, that if an observer begins to travel from the Equator towards either Pole, his Circle of perpetual Apparition rises from that Pole as from a Point, and his Circle of perpetual Occultation from the other. As the observer advances toward the nearer Pole, these two Circles enlarge their diameters, and come nearer one another, until he comes to the Pole; and then they meet and coincide in the Equator. 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. 44

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

130. Because the Stars never vary their distances from the Equinoctial, so as to be sensible in an age, the lengths of their diurnal and nocturnal Arcs are always the same to the same places on the Earth. But as the Earth goes round the Sun every year in the Ecliptic, one half of which is on the north side of the Equinoctial and the other half on it's south side, the Sun appears to change his place every day, so as to go once round the Circle *YCX* every year § 114. Therefore whilst the Sun appears to advance northward, from having described the Parallel *abX* touching the Ecliptic in *X* the days continually lengthen and the nights shorten, until he comes to *y* and describes the Parallel *yzx*, when the days are at the longest and the nights at the shortest: for then, as the Sun goes no farther northward, the greatest portion that is possible of the diurnal Arc *yz* is above the Horizon of the inhabitant *i*; and the smallest portion *zx* below it. As the Sun declines southward from *y* he describes smaller diurnal and greater nocturnal Arcs, or Portions of Circles, every day; which causeth the days to shorten and nights to lengthen, until he arrives again at the Parallel *abX*; which having only the small part *ab* above the Horizon *MCL*, and the great part *bX* below it, the days are at the shortest and the nights at the longest; because the Sun recedes no farther south, but returns northward as before. It is easy to see that the Sun must be in the Equinoctial *ECQ* twice every year, and then the days and nights are equally long; that is, 12 hours each. These hints serve at present to give an idea of some of the Appearances resulting from the motions of the Earth; which will be more particularly described in the tenth Chapter.

Fig. I.

Parallel, Oblique, and Right sphere, what.

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 the Poles 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. 45

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, its 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 centre. 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 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 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 retrograde or stationary.

134. Next, let a spectator in motion view 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 it's Axis, not being sensible of his own motion he will imagine the whole Heavens, Sun, Planets, and Stars to revolve 46
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 will appear in the motions of the Planets: only, the times of their being direct, stationary and retrograde will be accelerated or retarded as they concur with, or are contrary to his motion: and the Sun will seem to move among the fixed Stars or Signs, directly opposite to those in which his Planet moves; changing it's place every day as he does. In a word, whether our observer be in motion or at rest, whether within or without the Orbits of the Planets, their motions will seem irregular, intricate and perplexed, unless he is in the center of the System; and from thence, the most beautiful order and harmony will be observed.

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

135. The Sun being the center of all the Planets motions, the only place from which their motions could be truly seen, is the Sun's center; where the observer being supposed not to turn round with the Sun (which, in this case, we must imagine to be a transparent body) would see all the Stars at rest, and seemingly equidistant from him. To such an observer the Planets would appear to move among the fixed Stars, in a simple, regular, and uniform manner; only, that as in equal times they describe equal Areas, they would describe spaces somewhat unequal, because they move in elliptic Orbits § 155. Their motions would also appear to be what they are in fact, the same way round the Heavens; in 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 one 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 it's 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[28]; 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 is much faster than 47
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

136. But as our solar Astronomer could have no idea of measuring the courses of the Planets by our days, he would very 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

distances and bulks of the Planets.

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

The Planetary motions very irregular as seen from the Earth.

PLATE III.

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

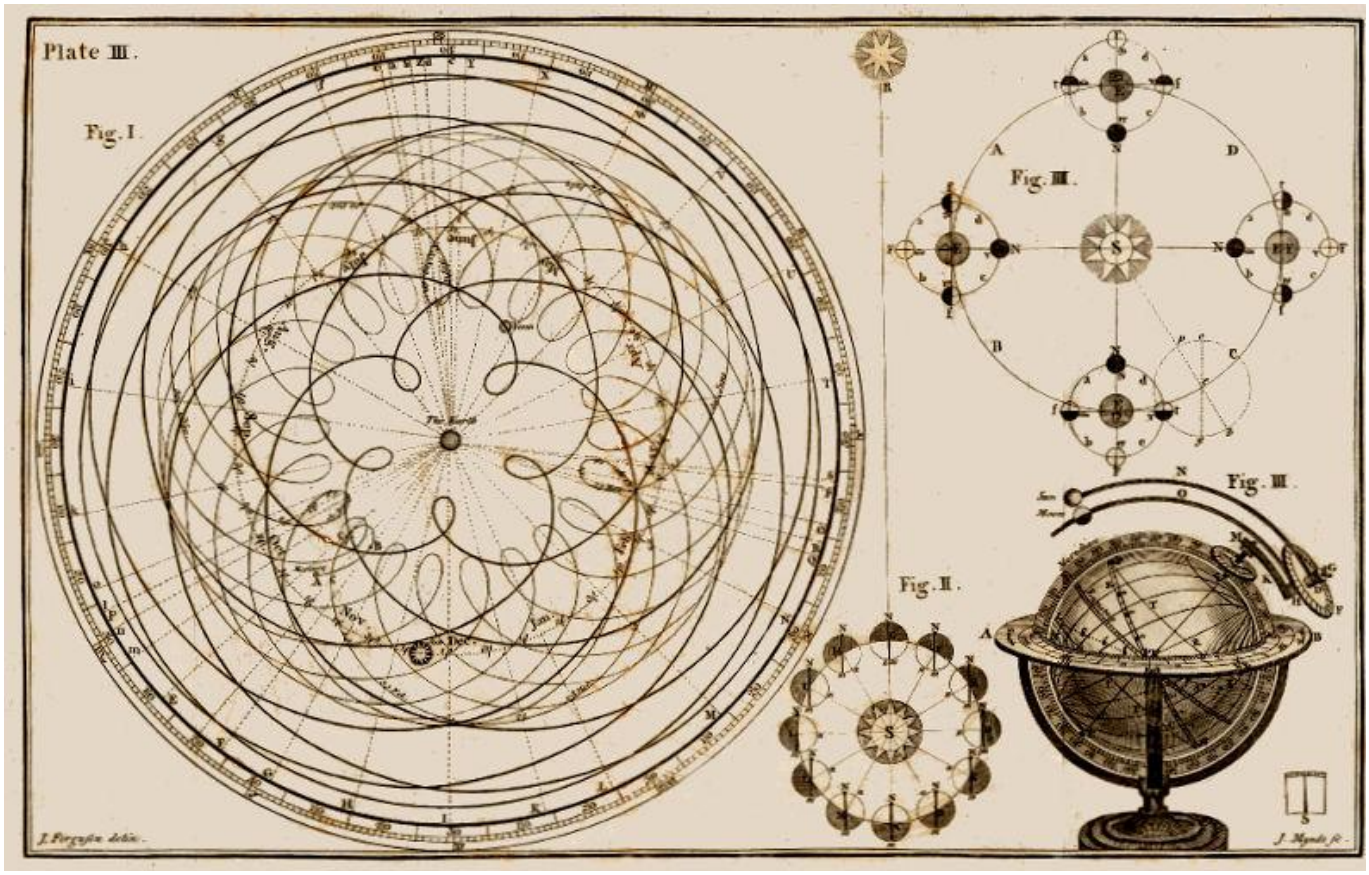
48

Those of Mercury and Venus represented.

Fig. I.

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[29] that shews the motions of the Sun, Mercury, Venus, the Earth and Moon, according to the *Copernican System*. Having taken off the Sun, Mercury, and Venus, I put black-lead pencils in their places, with the points turned upward; and fixed a circular sheet of paste-board so, that the Earth kept constantly under it's center in going round the Sun; and the paste-board kept 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 which 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 inferiour 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 superiour conjunctions. On each side of the loops they appear Stationary; in that part of each loop next the Earth retrograde; and in all rest of their paths direct.

Plate III.



J. Ferguson delin.

J. Mynde Sc.

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 49
which time his path makes three loops, and goes on a little farther; which shews that he has three inferiour, and as many superiour conjunctions with the Sun in that time, and also that he is six times Stationary, and thrice Retrograde. Let us now trace out his motion for one year in the Figure.

Fig. I. Suppose Mercury to be setting out from *A* towards *B* (between the Earth and left-hand corner of the Plate) and as seen from the Earth his motion will then be direct, or according to the order of the Signs. But when he comes to *B*, he appears to stand still in the 23d degree of ♏ at *F*, as shewn by the line *BF*. Whilst he goes from *B* to *C*, the line *BF* 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 $11\frac{1}{2}$ degrees. Now, suppose him Stationary on the first of *January* at *C*, on the tenth thereof he will appear in the Heavens 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 *Q* having gone back $11\frac{1}{2}$ degrees. Thus Mercury seems to go forward 4 Signs 11 Degrees, or 131 Degrees; and to go back only 11 or 12 Degrees, at a mean rate. From the 30th of *April* to the 10th of *May*, he seems to move from *Q* to *R*; and on the 20th he is seen at *S*, going forward in the same manner again, according to the order of letters; and backward when they go back; which, 'tis 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.

50

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 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 backwards as forwards, 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.

Appearances of Mercury and Venus.

141. These two Planets, when viewed 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.

Experiment to prove they are round.

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, it's enlightened side will be towards you, and appear round like the Full Moon: When the ball is between you and the candle, it's 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 circular plate which has a flat surface, you may make it appear fully enlightened, or not enlightened at all; but can never make it seem either horned or gibbous.

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 it's 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 rather 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 tolerably 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.

51

Fig. III.

The elongations or digressions of Mercury from the Sun.

PLATE II.

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 no nearer to us than the Sun and Stars are. Let the circle *fghiklmno* be the Orbit in which Mercury *m* moves round the Sun *S*, according to the order of 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 of the Sun *S*, which is seen at *C*: when at *h*, he appears at *A*, at his greatest western elongation or distance from the Sun; and then seems to stand still. But, as he moves from *h* to *i*, he appears to go from *A* to *B*; and seems to be in the same place when at *i* as when he was at *g*, only not near so big: at *k* he is hid from the Earth *E* by the Sun *S*; being then in his superiour Conjunction. In going from *k* to *l*, he appears to move from *C* to *D*; and when he is at *n*, he appears stationary at *E*; being seen as far east from the Sun then, as he was west from him at *A*. In going

from *n* to *o* in his Orbit, he seems to go back again in the Heavens, from *E* to *D*; and is seen in the same place (with respect to the Sun) at *o* as when he was at *l*; but of a larger diameter at *o*, because he is then nearer the Earth *E*: and when he comes to *f*, he again passes by the Sun, and disappears as before. In going from *n* to *h* in his Orbit, he seems to go backward in the Heavens from *E* to *A*; and in going from *h* to *n*, he seems to go forward from *A* to *E*. As he goes on from *f* a little of his enlightened side at *g* is seen from *E*; at *h* he appears half full, because half of his enlightened side is seen; at *i*, gibbous, or more than half full; and at *k* he would appear quite full, were he not hid from the Earth *E* by the Sun *S*. At *l* he appears gibbous again; at *n* half decreased, at *o* horned, and at *f* new like the Moon at her Change. He goes sooner from his eastern station at *n* to his western station at *h* than from *h* to *n* again; because he goes through less than half his Orbit in the former case, and more in the latter. 52

Fig. III.

The Elongations and Phases of Venus.

The greatest Elongations of Mercury and Venus.

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

Morning and Evening Star, what.

145. Venus, from her superiour Conjunction at *K* to her inferiour 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 inferiour Conjunction to her superiour, 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.

PLATE II.

The stationary places of the Planets variable.

146. If the Earth kept always at *E*, it is evident that the Stationary places of Mercury and Venus would always be in the same points of the Heavens where they were before. For example; whilst Mercury *m* goes from *h* to *n*, according to the order of the letters, he appears to describe the arc *ABCDE* in the Heavens, direct: and whilst he goes from *n* to *h*, he seems to describe the same arc back again, from *E* to *A*, retrograde: always at *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 it's Orbit from *E* to *t*. Venus also differs every time in the places of her Conjunctions and Stations; but much more than Mercury; because, as Venus describes a much larger Orbit than Mercury does, the Earth advances so much the farther in it's annual path before Venus comes round again. 53

The Elongations of all Saturn's inferiour 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 superiour Planet, all the inferiour ones have their Stations and Elongations; as Venus and Mercury have to the Earth. As seen from Saturn, Mercury never goes above $2\frac{1}{2}$ 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.

Fig. III.

PLATE II.

General Phenomena

149. As Venus and the Earth are superiour 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 54

of a superiour Planet to an inferiour.

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

CHAP. VII.

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

Gravitation and Projection.

Fig. IV.

PLATE II.

Circular Orbits.

Fig. IV.

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

55

151. If a Planet at *B* gravitates, or is attracted, toward the Sun, so as to fall from *B* to *y* in the time that the projectile force would have carried it from *B* to *X*, it will describe the curve *BY* by the combined action of these two forces, in the same time that the projectile force singly would have carried it from *B* to *X*, or the gravitating power singly have caused it to descend from *B* to *y*; and these two forces being duly proportioned, and perpendicular to one another, the Planet obeying them both, will move in the circle *BYTU*[30].

Elliptical Orbits.

PLATE II.

152. But if, whilst the projectile force carries the Planet from *B* to *b*, the Sun's attraction (which constitutes the Planet's gravitation) should bring it down from *B* to I, 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 it's motion thus accelerated, it gains so much centrifugal force, or tendency to fly off at *K* in the line *Kk*, as overcomes the Sun's attraction: and the centrifugal force being too great to allow the Planet to be brought nearer the Sun, or even to move round him in the Circle *Klmn*, &c. it goes off, and ascends in the curve *KLMN*, &c. it's motion decreasing as gradually from *K* to *B* as it increased from *B* to *K*, because the Sun's attraction acts now against the Planet's projectile motion just as much as it acted with it before. When the Planet has got round to *B*, it's projectile force is as much diminished from it's mean state about *G* or *N*, as it was augmented at *K*; and so, the Sun's attraction being more than sufficient to keep the Planet from going off at *B*, it describes the same Orbit over again, by virtue of the same forces or laws.

56

Fig. IV.

The Planets describe equal Areas in equal times.

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

A difficulty removed.

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. Suppose a Planet at *B* to be carried by the projectile force as far as from *B* to *b*, in the time that gravity would have brought it down from *B* to 1: by these two forces it will describe the curve *BC*. When the Planet comes down to *K*, it will be but half as far from the Sun *S* as it was at *B*; and therefore, by gravitating four times as strongly towards him, it would fall from *K* to *V* in the same length of time that it would have fallen from *B* to 1 in the higher part of it's Orbit, that is, through four times as much space; but it's projectile force is then so much increased at *K*, as would carry it from *K* to *k* in the same time; being double of what it was at *B*, and is therefore too strong for the tendency of the gravitating power, either to draw the Planet to the Sun, or cause it to go round him in the circle *Klmn*, &c. which would require it's falling from *K* to *w*, through a greater space than gravity can draw it whilst the projectile force is such as would carry it from *K* to *k*: and therefore the Planet ascends in it's Orbit *KLMN*, decreasing in it's velocity for the cause already assigned in § 152. 57

The Planetary Orbits elliptical.

Their Excentricities.

155. The Orbits of all the Planets are Ellipses, very little different from Circles: but the Orbits of the Comets are very long Ellipses; the lower focus of them all being in the Sun. If we suppose the mean distance (or middle between the greatest and least) of every Planet and Comet from the Sun to be divided into 1000 equal parts, the Excentricities of their Orbits, both in such parts and in *English* miles, will be as follows. 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.

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

156. By the above-mentioned laws § 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.

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

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 the fifth in 336. A stone would fall to the Earth's center, if there were an hollow passage, in 21 minutes 9 seconds. Mr. WHISTON gives the following Rule for such Computations. "[31]It is demonstrable, that half the Period of any Planet, when it is diminished in the sesquialteral proportion of the number 1 to the number 2, or nearly in the proportion of 1000 to 2828, is the time that it would fall to the Center of it's Orbit." This proportion is, when a quantity or number contains another once and a half as much more. 58

The prodigious attraction of the Sun and Planets.

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

ARCHIMEDES's Problem for raising the Earth.

159. The celebrated ARCHIMEDES affirmed he could move the Earth if he had a place to stand on to manage his machinery[32]. 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 will raise a great weight on the short one. But then, the small weight must move as much quicker than the great weight as the latter is heavier than the former; and the length of the long arm of the lever to the length of the short arm must be in the same proportion. Now, suppose a man pulls or presses the end of the long arm with the force of 200 pound weight, and that the Earth contains in round Numbers 4,000,000,000,000,000,000,000 or 4000 Trillions of cubic feet, each at a mean rate weighing 100 pound; and that the prop or center of motion of the lever is 6000 miles from the Earth's center: in this case, the length of the lever from the *Fulcrum* or center of motion to the moving power or weight ought to be 12,000,000,000,000,000,000,000,000 or 12 Quadrillions of miles; and so many miles must the power move, in order to raise the Earth but one mile, whence 'tis 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. 59

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.

Hard to determine what Gravity is.

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. We are certain 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. Hence Gravity should seem to arise from the agency of some subtile matter pressing towards the Sun and Planets, and acting, like all mechanical causes, by contact. But on the other hand, when we consider that the degree or force of Gravity is exactly in proportion to the quantities of matter in those bodies, without any regard to their bulks or quantity 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 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, (and why should not one as well as another?) it seems to me no greater absurdity, to suppose the Deity capable of superadding a Law, or what Laws he pleases, to 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. Do we not see that a human creature can prepare a bar of steel so as to make it attract needles and filings of iron; and that he can put a stop to that power or virtue, and again call it forth again as often as he pleases? To say that the workman infuses any new power into the bar, is saying too much; since the needle and filings, to which he has done nothing, re-attract the bar. And from this it appears that the power was originally imprest on the matter of which the bar, needle, and filings are composed; but does not seem to act until the bar be properly prepared by the artificer: somewhat like a rope coiled up in a ship, which will never draw a boat or any other thing towards the ship, unless one end be tied to it, and the other end to that which is to be hauled up; and then it is no matter which end of the rope the sailors pull at, for the rope will be equally stretched throughout, and the ship and boat will move towards one another. To say that the Almighty has infused no such virtue or power into the materials which compose the bar, but that he waits till the operator be pleased to prepare it by due position and friction, and then, when the needle or filings are brought pretty near the bar, the Deity presses them towards it, and withdraws his hand whenever the workman either for use, curiosity or whim, does what appears to him to destroy the action of the bar, seems quite ridiculous and trifling; as it supposes God not only to be subservient to our inconstant wills, but also to do what would be below the dignity of any rational man to be employed about. 60

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

162. Whatever Gravity be, 'tis plain that it acts every moment of time: for should it's action cease, the projectile force would instantly carry off the Planets in straight lines from those parts of their Orbits where Gravity left them. But, the Planets being once put into motion, there is no occasion for any new projectile force, unless they meet with some resistance in their Orbits; nor for any mending hand, unless they disturb one another too much by their mutual attractions. 61

The Planets disturb one another's motion.

The consequences thereof.

163. It is found that there are disturbances among the Planets in their motions, arising from their mutual attractions when they are in the same quarter of the Heavens; and that our years are not always precisely of the same length[33]. Besides, there is reason to believe that the Moon is somewhat nearer the Earth now than she was formerly; her periodical month being shorter than it was in former ages. For, our Astronomical Tables, which in the present Age shew the times of Solar and Lunar Eclipses to great precision, do not answer so well for very ancient Eclipses. Hence it appears, that the Moon does not move in a medium void of all resistance, § 174; and therefore her projectile force being a little weakened, whilst there is nothing to diminish her gravity, she must be gradually approaching nearer the Earth, describing smaller and smaller Circles round it in every revolution, and finishing her Period sooner, although her absolute motion with regard to space be not so quick now as it was formerly: and therefore, she must come to the Earth at last; unless that Being, which gave her a sufficient projectile force at the beginning, adds a little more to it in due time. And, as all the Planets move in spaces full of æther and light, which are material substances, they too must meet with some resistance. And therefore, if their gravities are not diminished, nor their projectile forces increased, they must necessarily approach nearer and nearer the Sun, and at length fall upon and unite with him.

The World not eternal.

164. Here we have a strong philosophical argument against the eternity of the World. For, had it existed from eternity, and been left by the Deity to be governed by the combined actions of the above forces or powers, generally called Laws, it had been at an end long ago. And if it be left to them it must come to an end. But we may be certain that it will last as long as was intended by it's Author, who ought no more to be found fault with for framing so perishable a work, than for making man mortal.

CHAP. VIII.

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

The amazing smallness of the particles of light.

165. Light consists of exceeding small particles of matter issuing from a luminous body; as from a lighted candle such particles of matter continually flow in all directions. Dr. NIEWENTYT[34] computes, that in one second of time there flows 418,660,000,000,000,000,000,000,000,000,000,000,000,000,000 particles of light out of a burning candle; which number contains at least 6,337,242,000,000 times the number of grains of sand in the whole Earth; supposing 100 grains of sand to be equal in length to an inch, and consequently, every cubic inch of the Earth to contain one million of such grains.

The dreadful effects that would ensue from their being larger.

166. These amazingly small particles, by striking upon our eyes, excite in our minds the idea of light: and, if they were so large as the smallest particles of matter discernible by our best microscopes, instead of being serviceable to us, they would soon deprive us of sight by the force arising from their immense velocity, which is above 164 thousand miles every second[35], 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 land, 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.

PLATE II.

167. When these small particles, flowing from the Sun or from a candle, fall upon bodies, and are thereby reflected to our eyes, they excite in us the idea of that body by forming it's picture on the retina[36]. And since bodies are visible on all sides, light must be reflected from them in all directions. 63

The rays of Light naturally move in straight lines.

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

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

Fig. XI.

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

PLATE II.

169. Light, and therefore heat so far as it depends on the Sun's rays (§ 85, towards the end) decreases in proportion to the squares of the distances of the Planets from the Sun. This is easily demonstrated by a Figure which, together with it's description, I have taken from Dr. SMITH's Optics[37]. 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 thinner in every part of that space, and at a treble distance it will be nine times thinner, and at a quadruple distance sixteen times thinner, than it was at first; and so on, according to the increase of the square surfaces *B*, *C*, *D*, *E*, built upon the distances *AB*, *AC*, *AD*, *AE*. Consequently, the quantities of this rarefied light received upon a surface of any given size and shape whatever, removed successively to these several distances, will be but one quarter, one ninth, one 64

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.

Why the Planets appear dimmer when viewed thro' telescopes than by the bare eye.

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.

Fig. VIII.

Refraction of the rays of light.

171. When a ray of light passes out of one medium[38] into another, it is refracted, or turned out of it's first course, more or less, as it falls more or less obliquely on the refracting surface which divides the two mediums. This may be proved by several experiments; of which we shall only give three for example's sake. 1. In a bason *FGH* put a piece of money as *DB*, and then retire from it as to *A*, till the edge of the bason at *E* just hides the money from your sight: then, keeping your head steady, let another person fill the bason gently with water. As he fills it, you will see more and more of the piece *DB*; which will be all in view when the bason is full, and appear as if lifted up to *C*. For, the ray *AEB*, which was straight whilst the bason was empty, is now bent at the surface of the water in *E*, and turned out of it's rectilineal course into the direction *ED*. Or, in other words, the ray *DEK*, that proceeded in a straight line from the edge *D* whilst the bason was empty, and went above the eye at *A*, is now bent at *E*; and instead of going on in the rectilineal direction *DEK*, goes in the angled direction *DEA*, and by entering the eye at *A* renders the object *DB* visible. Or, 2dly, place the bason where the Sun shines obliquely, and observe where the shadow of the rim *E* falls on the bottom, as at *B*: then fill it with water, and the shadow will fall at *D*; which proves, that the rays of light, 65
falling obliquely on the surface of the water, are refracted, or bent downwards into it.

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

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

The Atmosphere.

The Air's compression and rarity at different heights.

174. The Earth is surrounded by a thin fluid mass of matter, called the *Air*, or *Atmosphere*, which gravitates to the Earth, revolves with it in it's diurnal motion, and goes round the Sun with it every year. This fluid is of an elastic or springy nature, and it's lowermost parts being pressed by the weight of all the Air above them, are squeezed the closer together; and are therefore densest of all at the Earth's surface, and gradually rarer the higher up. "It is well known[39] that the Air near the surface of our Earth possesses a space about 1200 times greater than water of the same weight. And therefore, a cylindric column of Air 1200 foot 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 foot high[40]; and therefore if from the whole cylinder of Air, the lower part of 1200 foot high is taken away, the remaining upper part will be of equal weight with a cylinder of water 32 foot high; wherefore, at the height of 1200 feet or two furlongs, the weight of the incumbent Air is less, and consequently the rarity of the compressed Air is greater than near the Earth's surface in the ratio of 33 to 32. And having this ratio we may compute the rarity of the Air at all heights whatsoever, supposing the expansion thereof to be reciprocally proportional to 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 it's rarity or 66
expansion, supposing gravity to decrease in the duplicate ratio of the distances from the Earth's center. And the small numeral figures are here used to shew what number of cyphers must be joined to the numbers expressed by the larger figures, as $0.^{17}1224$ for 0.00000000000000001224, and 26956^{15} for 26956000000000000000.

Air's		
Height.	**Compression.**	**Expansion.**
0	33	1
5	17.8515	1.8486
10	9.6717	3.4151

20	2.852	11.571
40	0.2525	136.83
400	$0.^{17}1224$	26956^{15}
4000	$0.^{105}4465$	73907^{102}
40000	$0.^{192}1628$	26263^{189}
400000	$0.^{210}7895$	41798^{207}
4000000	$0.^{212}9878$	33414^{209}
Infinite.	$0.^{212}6041$	54622^{209}

From this Table it appears that the Air in proceeding upwards is rarefied in such manner, that a sphere of that Air which is nearest the Earth but of one inch diameter, if dilated to an equal rarefaction with that of the Air at the height of ten semi-diameters of the Earth, would fill up more space than is contained in the whole Heavens on this side the fixed Stars, according to the preceding computation of their distance[41]." And it likewise appears that the Moon does not move in a perfectly free and un-resisting medium; although the air at a height equal to her distance, is at least 34000^{190} times thinner than at the Earth's surface; and therefore cannot resist her motion so as to be sensible in many ages.

It's weight how found.

PLATE II.

175. The weight of the Air, at the Earth's surface, is found by experiments made with the air-pump; and also by the quantity of mercury that the Atmosphere balances in the barometer; in which, at a mean state; the mercury stands $29\frac{1}{2}$ inches high. And if the tube were a square inch wide, it would at that height contain $29\frac{1}{2}$ cubic inches of mercury, which is just 15 pound weight; and 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 about 199,409,400 square miles, it must be of no less than 5,559,215,016,960,000 square feet; which, multiplied by 2016, the number of pounds on every foot, amounts to 11,207,377,474,191,360,000; or 11 trillion 207 thousand 377 billion 474 thousand 191 million and 360 thousand pounds, for the weight of the whole Atmosphere. At this rate, a middle sized man, whose surface may be about 14 square feet, is pressed by 28,224 pound weight of Air all round; 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 internal Air in our blood vessels, it is not felt. 67

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, the Air is more elastic and weighty about us, by which means it balances the internal spring of the Air within us, braces up our blood-vessels and nerves, and makes us brisk and lively.

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

177. According to [42]Dr. KEILL, and other astronomical writers, it is entirely owing to the Atmosphere that the Heavens appear bright in the day-time. For, without an Atmosphere, only that part of the Heavens would shine in which the Sun was placed: and if an observer could live without Air, and should turn his back towards the Sun, the whole Heavens would appear as dark as in the 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, before he rises and after he sets. For, when the Earth by its rotation has withdrawn the Sun from our sight, the Atmosphere being still higher than we, has his light imparted to it; which gradually decreases until he has got 18 degrees below the Horizon; and then, all that part of the Atmosphere which is above us is dark. From the length of twilight, the Doctor has calculated the height of the Atmosphere (so far as it is dense enough to reflect any light) to be about 44 miles. But it is seldom dense enough at two miles height to bear up the Clouds.

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

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

Fig. IX.

179. To illustrate this, let *IEK* be a part of the Earth's surface, covered with the Atmosphere *HGFC*; and let *HEO* be the[43] sensible Horizon of an observer at *E*. 68

PLATE II.

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

Fig. IX.

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

The quantity of refraction.

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 33¾ min. which being more than his whole diameter, brings all his Disc in view, when his uppermost edge rises in the Horizon. At ten deg. height the refraction is not quite 5 min. at 20 deg. only 2 min. 26 sec.; at 30 deg. but 1 min. 32 sec.; between which and the Zenith, it is scarce sensible: the quantity throughout, is shewn by the annexed table, calculated by Sir ISAAC NEWTON.

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

Appar. Alt.		Refraction.		Ap. Alt.	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	0	32
1	0	23	7	25	1	54	60	0	31
1	15	21	20	26	1	49	61	0	30
1	30	19	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	1	1
20	0	2	26	55	0	38	90	0	0

PLATE II.

The inconstancy of Refractions.

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

69

A very remarkable case concerning refraction.

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 surprised to find, that after a continual night of three months, the Sun began to rise seventeen days sooner than according to computation, deduced from the Altitude of the Pole observed to be 76°: which cannot otherwise be accounted for, than by an extraordinary quantity of refraction of the Sun's rays, passing thro' 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."

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

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 as in both cases they are seen under the same angle[44], our imagination naturally suggests an idea of a greater distance between us and 70
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.

Nor always of those which are accessible.

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.

The reason assigned.

PLATE II.

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 71
have been deceived, by taking a red coat of arms, fixed upon the iron gate in *Clare-Hall* walks at *Cambridge*, for a brick house at a much greater distance[45].

Fig. XII.

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

Fig. IX.

Why the Sun and Moon appear biggest in the Horizon.

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

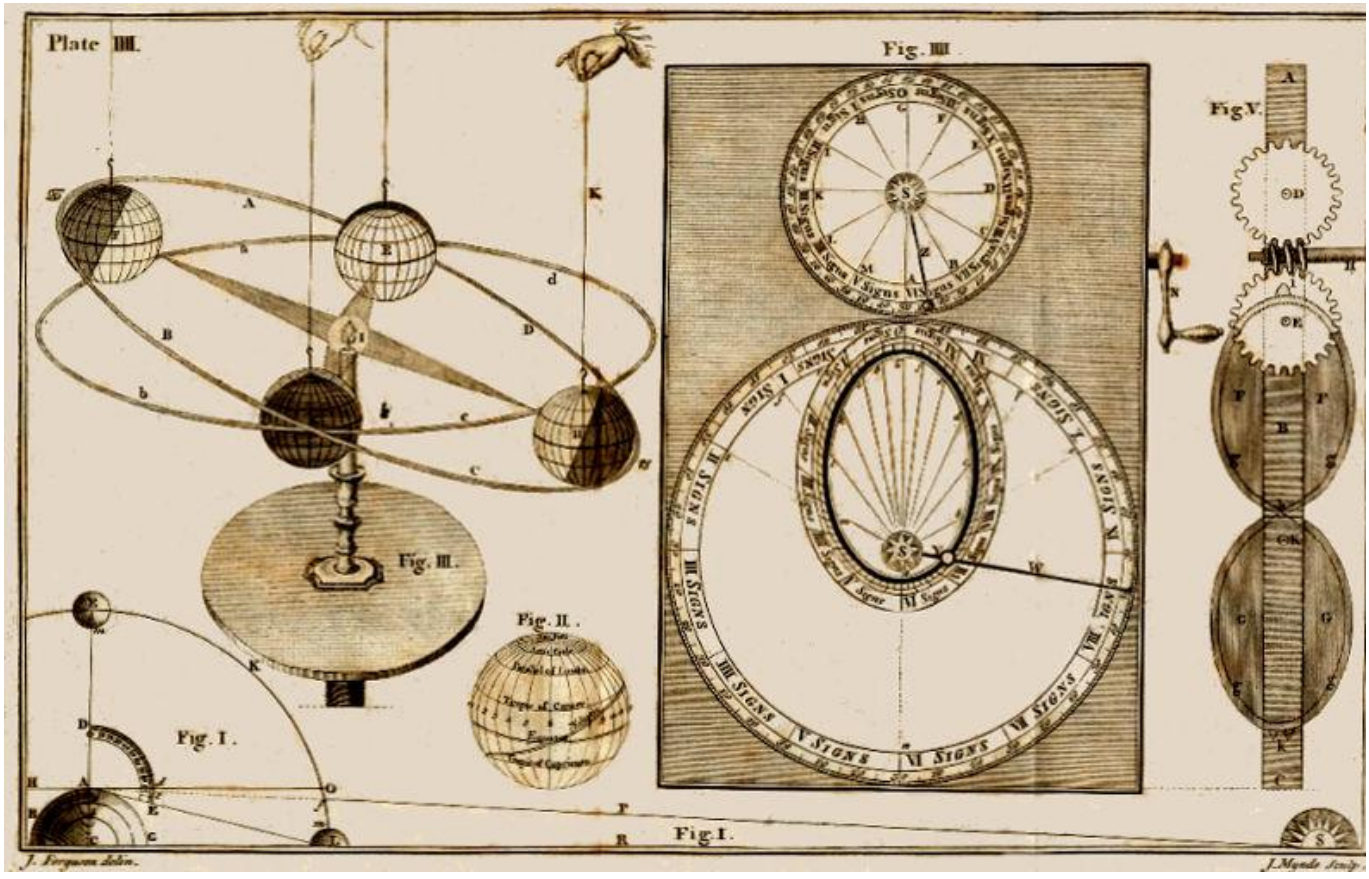
nearer us than those about *H* or *e* in the Horizon *HEe*. Therefore, when the Sun or Moon appear in the Horizon at *e*, they are not only seen in a part of the Sky which is really farther from us than if they were at any considerable Altitude, as about *f*; but they are also seen through a greater 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[46] 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.

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

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

Plate IIII.



J. Ferguson delin.

J. Mynde Sculp.

CHAP. IX.

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

PLATE IV.

190. Those who have not learnt how to take the [47]Altitude of any Celestial Phenomenon by a common Quadrant, nor know any thing of Plain Trigonometry, may pass over the first Article of this short Chapter, and take the Astronomer's word for it, that the distances of the Sun and Planets are as stated in the first Chapter of this Book. But, to every one who knows how to take the Altitude of the Sun, the Moon, or a Star, and can solve a plain right-angled Triangle, the following method of finding the distances of the Sun and Moon will be easily understood.

Fig I.

Let *BAG* be one half of the Earth, *AC* it's semi-diameter, *S* the Sun, *m* the Moon, and *EKOL* a quarter of the Circle described by the Moon in revolving from the Meridian to the Meridian again. Let *CRS* be the rational Horizon of an observer at *A*, extended to the Sun in the Heavens, and *HAO* his sensible Horizon; extended to the Moon's Orbit. *ALC* is the Angle under which the Earth's semi-diameter *AC* is seen from the Moon at *L*, which is equal to the Angle *OAL*, because the right lines *AO* and *CL* which include both these Angles are parallel. *ASC* is the Angle 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[48]. The Quantities of these Angles are determined by observation in the following manner.

The Moon's horizontal Parallax, what.

The Moon's distance determined.

Let a graduated instrument as *DAE*, (the larger the better) having a moveable Index and Sight-holes, be fixed in such a manner, that it's plane surface may be parallel to the Plan of the Equator, and it's edge *AD* in the Meridian: so that when the Moon is in the Equinoctial, and on the Meridian at *E*, she may be seen through the sight-holes when the edge of the moveable index cuts the beginning of the divisions at o, on the graduated limb *DE*; and when she is so seen, let the *precise* time be noted. Now, as the Moon revolves about the Earth from the Meridian to the Meridian again in 24 hours 48 minutes, she will go a fourth part round it in a fourth part of that time, *viz.* in 6 hours 12 minutes, as seen from *C*, that is, from the Earth's center or Pole. But as seen from *A*, the observer's place on the Earth's surface, the Moon will seem to have gone a quarter round the Earth when she comes to the sensible Horizon at *O*; for the Index through the sights of which she is then viewed will be at *d*, 90 degrees from *D*, where it was when she was seen at *E*. Now, let the exact moment when the Moon is seen at *O* (which will be when she is in or near the sensible Horizon) be carefully noted[49], that it may be known in what time she has gone from *E* to *O*; which time subtracted from 6 hours 12 minutes (the time of her going from *E* to *L*) leaves the time of her going from *O* to *L*, and affords an easy method for finding the Angle *OAL* (called *the Moon's horizontal Parallax*, which is equal to the Angle *ALC*) by the following Analogy: As the time of the Moon's describing the arc *EO* is to 90 degrees, so is 6 hours 12 minutes to the degrees of the Arc *DdE*, which measures the Angle *EAL*; from which subtract 90 degrees, and there remains the Angle *OAL*, equal to the Angle *ALC*, under which the Earth's Semi-diameter *AC* is seen from the Moon. Now, since all the Angles of a right-lined Triangle are equal to 180 degrees, or to two right Angles, and the sides of a Triangle are always proportional to the Sines of the opposite Angles, say, by the *Rule of Three*, as the Sine of the Angle *ALC* at the Moon *L* is to it's opposite side *AC* the Earth's Semi-diameter, which is known to be 3985 miles, so is Radius, *viz.* the Sine of 90 degrees, or of the right Angle *ACL* to it's opposite side *AL*, which is the Moon's distance at *L* from the observer's place at *A* on the Earth's surface; or, so is the Sine of the Angle *CAL* to its opposite side *CL*, which is the Moon's distance from the Earth's centre, 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 Sun's distance cannot be yet so exactly determined as the Moon's;

How near the truth it may soon be determined.

191. The Sun's distance from the Earth is found the same way, but with much greater difficulty; because his horizontal Parallax, or the Angle *OAS* equal to the Angle *ASC*, is so small as, to be hardly perceptible, being only 10 seconds of a minute, or the 360th part of a degree. But the Moon's horizontal Parallax, or Angle *OAL* equal to the Angle *ALC*, is very discernible; being 57′ 49″, or 3469″ at it's mean state; which is more than 340 times as great as the Sun's: and therefore, the distances of the heavenly bodies being inversely as the Tangents of their horizontal Parallaxes, the Sun's distance from the Earth is at least 340 times as great as the

Moon's; and is rather understated 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; and much more in the distances of the superiour Planets. 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. 76

The Sun proved to be much bigger than the Moon.

192. The Sun and Moon appear much about the same bulk: And every one who understands Geometry knows how their true bulks may be deduced from the apparent, when their real distances are known. Spheres are to one another as the Cubes of their Diameters; whence, if the Sun be 81 millions of miles from the Earth, to appear as big as the Moon, whose distance does not exceed 240 thousand miles, he must, in solid bulk, be 42 millions 875 thousand times as big as the Moon.

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

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

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

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

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

Relative mean distances from the Sun.

38710	72333	100000	152369	520096	954006

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

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

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

29,032,500	54,238,570	75,000,000	114,276,750	390,034,500	715,504,500

Errors in distance a rising from the mistake of 1″ in the Sun's Parallax

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

195. These last numbers shew, that although we have the relative distances of the Planets from the Sun to the greatest nicety, yet the best observers have not hitherto been able to ascertain their true distances to within less than a twelfth part of what they really are. And therefore, we must wait with patience till the 6th of *June*, A. D. 1761; wishing that the Sky may then be clear to all places where there are good Astronomers and accurate instruments for observing the Transit of Venus over the Sun's Disc at that time: as it will not happen again, so as to be visible in Europe, in less than 235 years after. 77

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

196. The Earth's Axis produced to the Stars, being carried [50]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 in itself, if viewed from the Stars, would appear no bigger than a point; and consequently, the circle described in the Sphere of the Stars by the Axis of the Earth produced, if viewed from the Earth, must appear but as a point; that is, it's diameter appears too little to be measured by observation: for Dr. BRADLEY has assured us, that if it had amounted to a single second, or two at most, he should have perceived it in the great number of observations he has made, especially upon γ *Dragonis*; and that it seemed to him very probable that the annual Parallax of this Star is not so great as a single second: and consequently, that it is above 400 thousand times farther from us than the Sun. Hence the celestial poles seem to continue in the same points of the Heavens throughout the year; which by no means disproves the Earth's annual motion, but plainly proves the distance of the Stars to be exceeding great.

The amazing velocity of light.

PLATE IV.

197. The small apparent motion of the Stars § 113, discovered by that great Astronomer, he found to be no ways owing to their annual Parallax (for it came out contrary thereto) but to the Aberration of their light, which can result from no known cause besides that of the Earth's annual motion; and as it agrees so exactly therewith, it proves beyond dispute that the Earth has such a motion: for this Aberration compleats all it's various Phenomena every year; and proves that the velocity of star-light is such as carries it through a space equal to the Sun's distance from us in 8 minutes 13 seconds of time. Hence, the velocity of light is [51]10 thousand 210 times as great as the Earth's velocity in it's Orbit; which velocity (from what we know already of the Earth's distance from the Sun) may be affected to be at least between 57 and 58 thousand miles every hour: and supposing it to be 58000, this number multiplied by the above 10210, gives 592 million 180 thousand miles for the hourly motion of light: which last number divided by 3600, the number of seconds in an hour, shews that light flies at the rate of more than 164 thousand miles every second of time, or swing of a common clock pendulum. 78

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.

Fig. II

Equator, Tropics, Polar Circles, and Poles.

Fig. II.

Earth's Axis.

PLATE IV.

Meridians.

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 it's center, and is just as far from the north Pole as the Tropics are from the Equator: and the *Antarctic Circle* (hid by the supposed convexity of the Figure) is just as far from the *South Pole*, every way round it. These Poles are the very north and south points of the Globe: and all other places are denominated *northward* or *southward* according to the side of the Equator they lie on, and the Pole to which they are nearest. The Earth's *Axis* is a straight line passing through the center of the Earth, perpendicular to the Equator, and terminating in the Poles at it's surface. This, in the real Earth and Planets is only an imaginary line; but in artificial Globes or Planets it is a wire by which they are supported, and turned round in *Orreries*, or such like machines, by wheel-work. The circles 12. 1. 2. 3. 4, *&c.* are Meridians to all places they pass through; and we must suppose thousands more to be drawn, because every place that is ever so little to the east or west of any other place, has a different Meridian from that other place. All the Meridians meet in the Poles; and whenever the Sun's center is passing over any Meridian, in his apparent motion round the Earth, it is mid-day or noon to all places on that Meridian.

79

Zones.

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

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.

Fig. III.

A pleasant experiment shewing the different lengths of days and nights, and the variety of seasons.

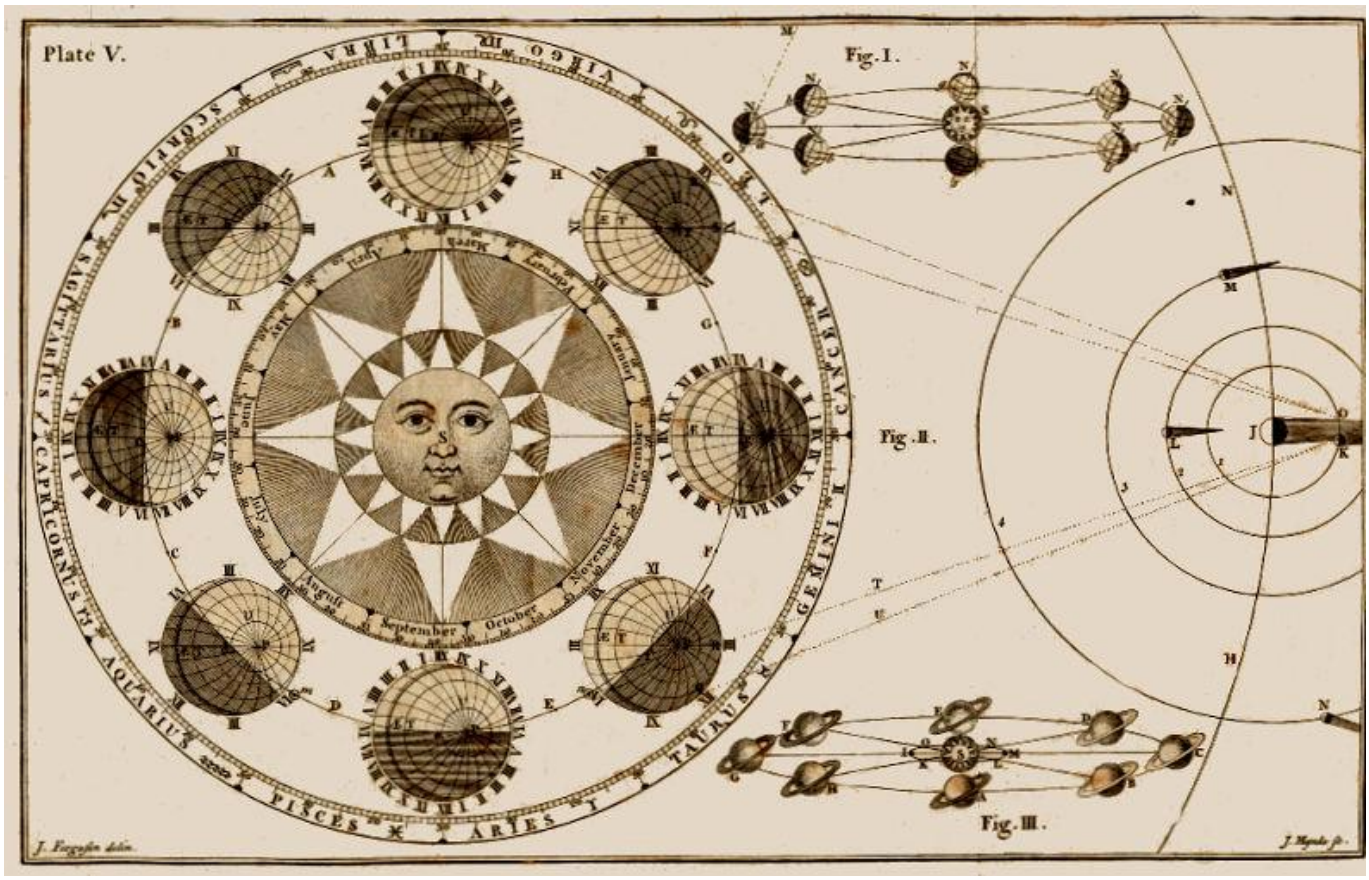
Summer Solstice.

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 in or near the center. Then, having twisted the thread as towards the left hand, that by untwisting it may turn the Globe round eastward, or contrary to the way that the hands of a watch move; hang the Globe by the thread within this circle, almost contiguous to it; and as the thread untwists, the Globe (which is enlightened half round by the candle as the Earth is by the Sun) will turn round it's Axis, and the different places upon it will be carried through the light and dark Hemispheres, and have the appearance of a regular succession of days and nights, as our Earth has in reality by such a motion. As the Globe turns, move your hand slowly so as to carry the Globe round the candle according to the order of the letters *abcd*, keeping it's center even with the wire circle; and you will perceive, that the candle being still perpendicular to the Equator will enlighten the Globe from pole to pole in it's 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

80

of the thread, and therefore has a perpetual Equinox. The Globe thus turning round represents the Earth turning round it's Axis; and the motion of the Globe round the candle represents the Earth's annual motion round the Sun, and shews, that if the Earth's Orbit had no inclination to it's Axis, all the days and nights of the year would be equally long, and there would be no different seasons. But now, desire the person who holds the wire to hold it obliquely in the position *ABCD*, raising the side ♋ just as much as he depresses the side ♑, that the flame may be still in the plane of the circle; and twisting the thread as before, that the Globe may turn round it's Axis the same way as you carry it round the candle; that is, from west to east, let the Globe down into the lowermost part of the wire circle at ♑, and if the circles be properly inclined, the candle will shine perpendicularly on the Tropic of Cancer, and the *frigid Zone*, lying within the *arctic* or *north polar Circle*, will be all in the light, as in the Figure; and will keep in the light let the Globe turn round it's Axis ever so often. From the Equator to the north polar Circle all the places have longer days and shorter nights; but from the Equator to the south polar Circle just the reverse. The Sun does not set to any part of the north frigid Zone, as shewn by the candle's shining on it so that the motion of the Globe can carry no place of that Zone into the dark: and at the same time the *south frigid Zone* is involved in darkness, and the turning of the Globe brings none of it's places into the light. If the Earth were to continue in the like part of it's Orbit, the Sun would never set to the inhabitants of the north frigid Zone, nor rise to those of the south. At the Equator it would be always equal day and night; and as the places are gradually more and more distant from the Equator, towards the arctic Circle, they would have longer days and shorter nights, whilst those on the south side of the Equator would have their nights longer than their days. In this case there would be continual summer on the north side of the Equator, and continual winter on the south side of it.

Plate V.



J. Ferguson delin.

J. Mynde Sc.

PLATE IV.

Autumnal Equinox.

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

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

Winter Solstice.

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 antarctic Circle; within which Circles it is dark to the north frigid Zone and light to the south.

Vernal Equinox.

Continue both motions, and as the Globe moves through the quarter *B*, the north Pole advances toward the light, and the south Pole recedes as fast from it; 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.

Thus we see the reason why the days lengthen and shorten from the Equator to the polar Circles every year; why there is no day or night for several 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.

Remark.

Fig. III.

PLATE V.

201. The inclination of an Axis or Orbit is merely relative, because we compare it with some other Axis or Orbit which we consider as not inclined at all. Thus, our Horizon being level to us whatever place of the Earth we are upon, we consider it as having no inclination; and yet, if we travel 90 degrees from that place, we shall then have an Horizon perpendicular to the former; but it will still be level to us. And, if this Book be held so that the [52]Circle *ABCD* be parallel to the Horizon, both the Circle *abcd*, and the Thread or Axis *K* will be inclined to it. But if 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. 82

202. Let us now take a view of the Earth in it's annual course round the Sun, considering it's Orbit as having no inclination; and it's Axis as inclining 23½ degrees from a line perpendicular to it's Orbit, and keeping the same oblique direction in all parts of it's annual course; or, as commonly termed, keeping always parallel to itself § 196.

Fig. I.

A concise view of the seasons.

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

Fig. II.

PLATE V.

The Ecliptic.

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

203. From this oblique view of the Earth's Orbit, let us suppose ourselves to be raised far above it, and placed just over it's center *S*, looking down upon it from it's north pole; and as the Earth's Orbit differs but very little from a Circle, we shall have it's figure in such a view represented by the Circle *ABCDEFGH*. Let us suppose this Circle to be divided into 12 equal parts called *Signs*, having their names affixed to them; and each Sign into 30 equal parts called *Degrees*, numbered 10, 20, 30, as in the outermost Circle of the Figure, which represents the great Ecliptic in the Heavens. The Earth is shewn in eight different positions in this Circle, and in each position *Æ* is the Equator, *T* the Tropic of Cancer, the 83

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

Vernal Equinox.

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[53], the north Pole is just coming into the light, the Sun is vertical to the Equator; which, together with the Tropic of Cancer, parallel of *London*, and arctic Circle, are all equally cut by the Circle bounding light and darkness, coinciding with the six o'clock hour Circle, and therefore the days and nights are equally long at all places: for every part of the Meridian *ÆTLa* comes into the light at six in the morning, and revolving with the Earth according to the order of the hour-letters, goes into the dark at six in the evening. There are 24 Meridians or hour-Circles drawn on the Earth in this Figure, to shew the time of Sun rising and setting at different Seasons of the Year.

Fig. II.

As the Earth moves in the Ecliptic according to the order of the letters *ABCD*, &c. through the Signs Libra, Scorpio, and Sagittarius, the north Pole comes more and more into the light; the days increase as the nights decrease in length, at all places north of the Equator *Æ*; which is plain by viewing the Earth at *b* on the 5th of *May*, when it is in the 15th degree of Scorpio[54], and the Sun as seen from the Earth appears in the 15th degree of Taurus. For then, the Tropic of Cancer *T* is in the light from a little after five in the morning till almost seven in the evening; the parallel of *London* from half an hour past four till half an hour past seven; the polar Circle *U* from three till nine; and a large track round the north Pole *P* has day all the 24 hours, for many rotations of the Earth on it's Axis.

Summer Solstice.

When the Earth comes to *c*, at the beginning of Capricorn, and the Sun as seen 84
from the Earth appears at the beginning of Cancer, on the 21st of *June*, as in this Figure, it is in the position *a* in Fig. I; and it's north Pole inclines 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 Circles; 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.

Autumnal Equinox.

Winter 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 recedes toward the dark, which causes the days to decrease, and the nights to increase in length, till the Earth comes to Aries, and then they are equal as before; for the boundary of light and darkness cut the Equator and all it's parallels equally, or in halves. The north pole then goes into the dark, and continues therein until the Earth goes half way round it's Orbit; or, from the 23d of *September* till the 20th of *March*. In the middle 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 it's Orbit: and then, the northern parallels are as much in the dark as they were in the light on the 21 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 multiply words on this subject, as we shall have occasion to mention the seasons again in describing the *Orrery*, § 439. Only this must be noted, that all that has been said of the northern Hemisphere, the contrary must be understood of the southern; for on different sides of the Equator the seasons are contrary, because, when the northern Hemisphere inclines toward the Sun the southern declines from him.

The Phenomena of Saturn's Ring.

PLATE V.

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 when it is turned round edgewise to the Sun, at which time it is also edgewise to the Earth; and therefore it disappears once in every fifteen 85
years to us. As the Sun shines half a year on the north pole of our earth, then disappears to it, and shines as long on the south pole; so, during one half of Saturn's year the Sun shines on the north side of his ring, then disappears to it, and shines as long on it's south side. When the Earth's Axis inclines neither to nor from the Sun, but sidewise to him, he instantly ceases to shine on one pole, and begins to enlighten the other; and when Saturn's Ring inclines neither to nor from the Sun, but sidewise to him, he ceases to shine on the one side of it, and begins to shine upon the other.

Fig. III.

Let *S* be the Sun, *ABCDEFGH* Saturn's Orbit, and *IKLMNO* the Earth's Orbit. Both Saturn and the Earth move according to the order of the letters, and when Saturn is at *A* his ring is turned edgewise to the Sun *S*, and he is then seen from the Earth as if he had lost his ring, let the Earth be in any part of it's Orbit whatever, except between *N* and *O*; for whilst it describes that space, Saturn is apparently so near the Sun as to be hid in his beams. As Saturn goes from *A* to *C* his ring

appears more and more open to the Earth: at *C* the ring appears most open of all; and seems to grow narrower and narrower as Saturn goes from *C* to *E*; and when he comes to *E*, the ring is again turned edgewise both to the Sun and Earth: and as neither of it's sides are illuminated, it is invisible to us, because it's edge is too thin to be perceptible: and Saturn appears again as if he had lost his ring. But as he goes from *E* to *G*, his ring opens more and more to our view on the under side; and seems just as open at *G* as it was at *C*; and may be seen in the night-time from the Earth in any part of it's Orbit, except about *M*, when the Sun hides the Planet from our view. As Saturn goes from *G* to *A* his ring turns more and more edgewise to us, and therefore it seems to grow narrower and narrower; and at *A* it disappears as before. Hence, while Saturn goes from *A* to *E* the Sun shines on the upper side of his ring, and the under side is dark; but whilst he goes from *E* to *A* the Sun shines on the under side of his ring, and the upper side is dark.

Fig. I and III.

It may perhaps be imagined that this Article might have been placed more properly after § 81 than here: but when the candid reader considers that all the various Phenomena of Saturn's Ring depend upon a cause similar to that of our Earth's seasons, he will readily allow that they are best explained together; and that the two Figures serve to illustrate each other.

PLATE VI.

The Earth nearer the Sun in winter than in summer.

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

205. The Earth's Orbit being elliptical, and the Sun constantly keeping in it's lower Focus, which is 1,377,000 miles from the middle point of the longer Axis, the Earth comes twice so much, or 2,754,000 miles nearer the Sun at one time of the year than at another: for the Sun appearing under a larger Angle in our winter than summer, proves that the Earth is nearer the Sun in winter, (*see the Note on Art. 185*.) But here, this natural question will arise, Why have we not the hottest weather when the Earth is nearest the Sun? In answer it must be observed, that the excentricity of the Earth's Orbit, or 1 million 377 miles bears no greater proportion to the Earth's mean distance from the Sun than 17 does to 1000; and therefore, this small difference of distance cannot occasion any great difference of heat or cold. But the principal cause of this difference is, that in winter the Sun's rays fall so obliquely upon us, that any given number of them is spread over a much greater portion of the Earth's surface where we live; and therefore each point must then have fewer rays than in summer. Moreover, there comes a greater degree of cold in the long winter nights, than there can return of heat in so short days; and on both these accounts the cold must increase. But in summer the Sun's rays fall more perpendicularly upon us, and therefore come with greater force, and in greater numbers on the same place; and by their long continuance, a much greater degree of heat is imparted by day than can fly off by night. 86

Fig. II.

206. That a greater number of rays fall on the same place, when they come perpendicularly, than when they come obliquely on it, will appear by the Figure. For, let *AB* be a certain number of the Sun's rays falling on *CD* (which, let us suppose to be *London*) on the 22d of *June*: but, on the 22d of *December*, the line *CD*, or *London*; has the oblique position *Cd* to the same rays; and therefore scarce a third part of them falls upon it, or only those between *A* and *e*; all the rest *eB* being expended on the space *dP*, which is more than double the length of *CD* or *Cd*. Besides, those parts which are once heated, retain the heat for some time; which, with the additional heat daily imparted, makes it continue to increase, though the Sun declines 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 *CF*. An iron bar is not heated immediately upon being put into the fire, nor grows cold till some time after it has been taken out. 87

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 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.

Fig. II.

Hour Circles.

An hour of time equal to 15 degrees of motion.

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

209. Because the Sun enlightens only one half of the Earth at once, as it turns round it's Axis he rises to some places at the same moments of absolute Time that he sets to others; and when it is mid-day to some places, it is mid-night to others. The XII on the middle of the Earth's enlightened side, next the Sun, stands for mid-day; and the opposite XII on the middle of the dark side, for mid-night. If we suppose this Circle of hours to be fixed in the plane of the Equinoctial, and the Earth to turn round within it, any particular Meridian will come to the different hours so, as to shew the true time of the day or night at all places on that Meridian. Therefore, 88

And consequently to 15 degrees of Longitude.

Lunar Eclipses useful in finding the Longitude.

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

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

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

How to solve this important problem.

PLATE V.

212. The *English* Astronomers have made 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 89

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 before or after 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.

Fig. II.

Illustrated by an example.

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

Fig. II.

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

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

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

PLATE VI.

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

215. In whatever month of the year Jupiter is in conjunction with the Sun, or in opposition to him, in the next year it will be a month later at least. For whilst the Earth goes once round the Sun, Jupiter describes a twelfth part of his Orbit. And therefore, when the Earth has finished it's annual period from being in a line with the Sun and Jupiter, it must go as much forwarder as Jupiter has moved in that time, to overtake him again: just like the minute hand of a watch, which must, from any conjunction with the hour hand, go once round the dial-plate and somewhat above a twelfth part more, to overtake the hour hand again. 90

The surprising velocity of light.

216. It is found by observation, that when the Earth is between the Sun and Jupiter, as at *g*, his 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 162 millions of miles in length: and consequently the particles of light fly about 164 thousand 494 miles every second of time, which is above a million of times swifter than the motion of a cannon bullet. And as light is $16\frac{1}{2}$ 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.

Fig. V.

Illustrated by a Figure.

217. To illustrate this progressive motion of light, let *A* and *B* be the Earth in two different parts of it's Orbit, whose distance is 81 millions of miles, equal to the Earth's distance from the Sun *S*. It is plain, that if the motion of light were instantaneous, the Satellite 1 would appear to enter into Jupiter's shadow *FF* at the same moment of time to a spectator in *A* as to another in *B*. But by many years observations it has been found, that the immersion of the Satellite into the shadow is seen $8\frac{1}{4}$ minutes sooner when the Earth is at *B*, than when it is at *A*. And so, as Mr. ROMER first discovered, the motion of light is thereby proved to be progressive, and not instantaneous, as was formerly believed. It is easy to compute in what time the Earth moves from *A* to *B*; for the chord of 60 degrees of any Circle is equal to the Semidiameter of that Circle; and as the Earth goes through all the 360 degrees of it's Orbit in a year, it goes through 60 of those degrees in about 61 days. Therefore, if on any given day, suppose the first of *June*, the Earth is at *A*, on the first of 91

August it will be at *B*: the chord, or straight line *AB*, being equal to *DS* the Radius of the Earth's Orbit, the same with *AS* it's distance from the Sun.

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

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

220. TABLES 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. 92

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

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

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

*Deg. Min. Sec.	Hours Min. Min. Sec. Thirds	*Deg. Min. Sec.	Hours Min. Min. Sec. Thirds	Degrees	Hours	Minutes
1	0 4	31	2 4	70	4	40

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

These are the Tables mentioned in the 208th Article, and are so easy that they scarce require any farther explanation than to inform the reader, that if, in Table I. he reckons the columns marked with Asterisks to be minutes of time, the other columns give the equatoreal parts or motion in degrees and minutes; if he reckons the Asterisk columns to be seconds, the others give the motion in minutes and seconds of the Equator; if thirds, in seconds and thirds: And if in Table II. he reckons the Asterisk columns to be degrees of motion, the others give the time answering thereto in hours and minutes; if minutes of motion, the time is minutes and seconds; if seconds of motion, the corresponding time is given in seconds and thirds. An example in each case will make the whole very plain. 93

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 Sidereal Time.

Sidereal days shorter than solar days, and why.

221. The fixed 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 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 *Sidereal*.

PLATE III.

The diameter of the Earth's Orbit is but a physical point in proportion to the distance of the Stars; for which reason, and the Earth's uniform motion on it's Axis, any given Meridian will revolve from any Star to the same Star again in every absolute turn of the Earth on it's Axis, without the least perceptible difference of time shewn by a clock which goes exactly true. 94

If the Earth had only a diurnal motion, without an annual, any given Meridian would revolve from the Sun to the Sun again in the same quantity of time as from any Star to the same Star again; because the Sun would never change his place with respect to the Stars. But, as the Earth advances almost a degree eastward in it's Orbit in the time that it turns eastward round 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 sidereal days would be just four minutes shorter than the solar.

Fig. II.

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 it's Axis the same way from the Sun to the Sun again every 24 hours. Let *S* be the Sun, and *R* a fixed Star at such an immense distance that the diameter of the Earth's Orbit bears no sensible proportion to that distance. Let *Nm* be any particular Meridian of the Earth, and *N* a given point or place upon that Meridian. When the Earth is at *A*, the Sun *S* hides the Star *R*, which would always be hid if the Earth never removed from *A*; and consequently, as the Earth turns round it's Axis, the point *N* would always come round to the Sun and Star at the same time. But when the Earth has advanced, suppose a twelfth part of it's Orbit from *A* to *B*, it's motion round it's Axis will bring the point *N* a twelfth part of a day or two hours sooner to the Star than to the Sun; for the Angle *NBn* is equal to the Angle *ASB*: and therefore, any Star which comes to the Meridian at noon with the Sun when the Earth is at *A*, will come to the Meridian at 10 in the forenoon when the Earth is at *B*. When the Earth comes to *C* the point *N* will have the Star on it's Meridian at 8 in the morning, or four hours sooner than it comes round to the Sun; for it must revolve from *N* to *n*, before it has the Sun in it's Meridian. When the Earth comes to *D*, the point *N* will have the Star on it's Meridian at six in the morning, but that point must revolve six hours more from *N* to *n*, before it has mid-day by the Sun: for now the Angle *ASD* is a right Angle, and so is *NDn*; that is, the Earth has advanced 90 degrees in it's Orbit, and must turn 90 degrees on its Axis to carry the point *N* from the Star to the Sun: for the Star always comes to the Meridian when *Nm* is parallel to *RSA*; because *DS* is but a point in respect of *RS*. When the Earth is at *E*, the Star comes to the Meridian at 4 in the morning; at *F*, at two in the morning; and at *G*, the Earth having gone half round it's Orbit, *N* points to the Star *R* at midnight, 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. 95

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.		
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.		
							″″				″″
1	15	2	28	1	0	15	2	31	7	46	16
2	30	4	56	2	0	30	5	32	8	1	19
3	45	7	24	3	0	45	7	33	8	16	21
4	60	9	51	4	1	0	10	34	8	31	24
5	75	12	19	5	1	15	12	35	8	46	26

6	90	14	47	6	1	30	15	36	9	1	29
7	105	17	15	7	1	45	17	37	9	16	31
8	120	19	43	8	2	0	20	38	9	31	34
9	135	22	11	9	2	15	22	39	9	46	36
10	150	24	38	10	2	30	25	40	10	1	39
11	165	27	6	11	2	45	27	41	10	16	41
12	180	29	34	12	3	0	30	42	10	31	43
13	195	32	2	13	3	15	32	43	10	46	46
14	210	34	30	14	3	30	34	44	11	1	48
15	225	36	58	15	3	45	37	45	11	16	51
16	240	39	26	16	4	0	39	46	11	31	53
17	255	41	53	17	4	15	41	47	11	46	56
18	270	44	21	18	4	30	44	48	12	1	58
19	285	46	49	19	4	45	47	49	12	17	1
20	300	49	17	20	5	0	49	50	12	32	3
21	315	51	45	21	5	15	52	51	12	47	6
22	330	54	13	22	5	30	54	52	13	2	8
23	345	56	40	23	5	45	57	53	13	17	11
24	360	59	8	24	6	0	59	54	13	32	13
25	376	1	36	25	6	16	2	55	13	47	16
26	391	4	4	26	6	31	4	56	14	2	18
27	406	6	32	27	6	46	7	57	14	17	21
28	421	9	0	28	7	1	9	58	14	32	23
29	436	11	28	29	7	16	11	59	14	47	26
30	451	13	56	30	7	31	14	60	15	2	28

Accelerations of the Fixed Stars.

D.	H.	M.	S.
1	0	3	56
2	0	7	52
3	0	11	48
4	0	15	44
5	0	19	39
6	0	23	35
7	0	27	31
8	0	31	27
9	0	35	23
10	0	39	19
11	0	43	15
12	0	47	11
13	0	51	7
14	0	55	3
15	0	58	58
16	1	2	54
17	1	6	50
18	1	10	46
19	1	14	42
20	1	18	38
21	1	22	34
22	1	26	30
23	1	30	26
24	1	34	22
25	1	38	17
26	1	42	13
27	1	46	9
28	1	50	5

29	1	54	1
30	1	57	57

PLATE III.

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

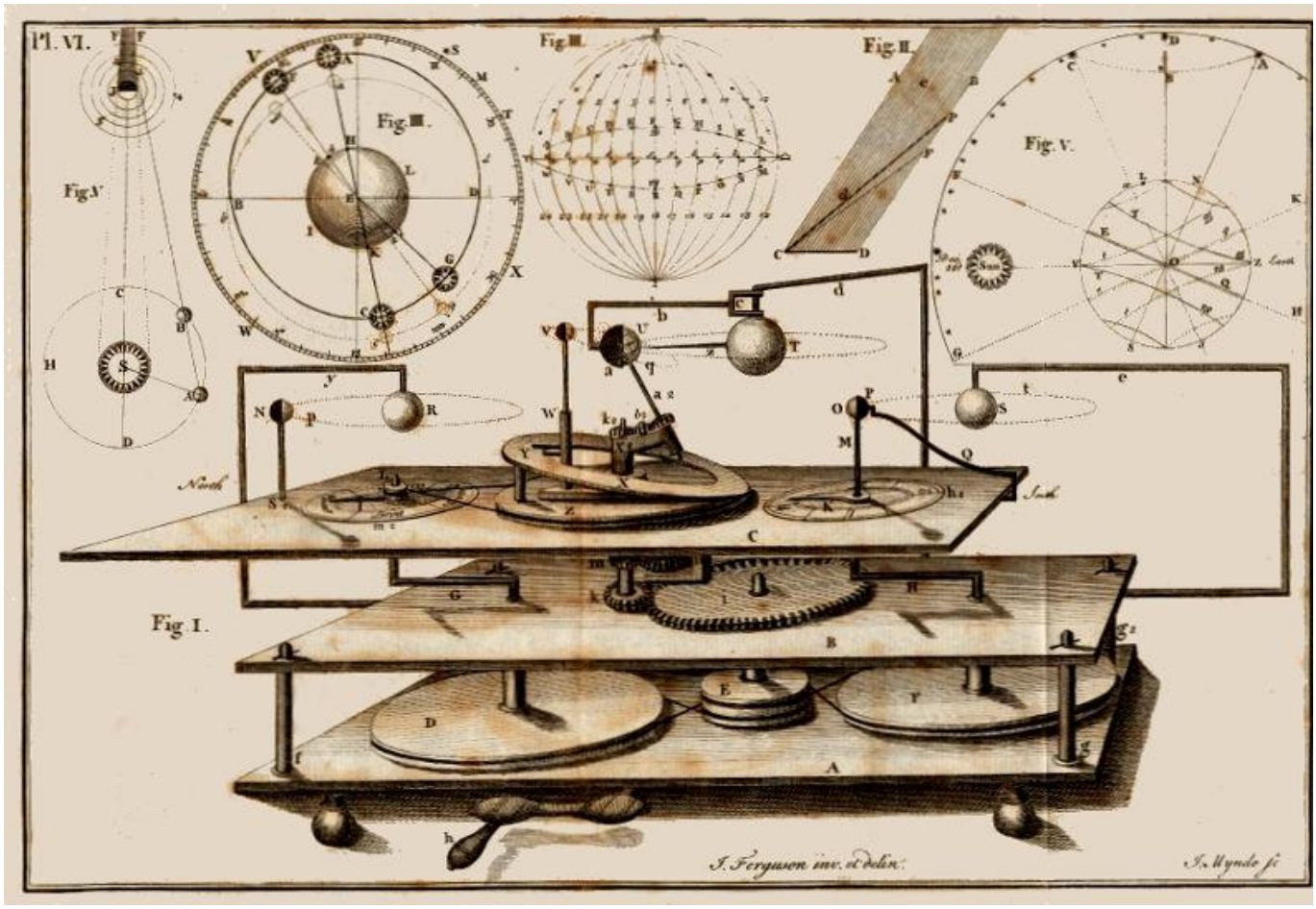
Fig. II.

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

To know by the Stars whether a Clock goes true or not.

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

Pl. VI.



J. Ferguson inv. et delin.

J. Mynde Sc.

CHAP. XIII.

97

Of the Equation of Time.

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

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

Use of the Equation Table.

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

How to draw a Meridian Line.

226. The easiest and most expeditious way of drawing a Meridian Line is this: Make four or five concentric Circles, about a quarter of an inch from one another, on a flat board about a foot in breadth; and let the outmost Circle be but little less than the board will contain. Fix a pin perpendicularly in the center, and of such a length that it's whole shadow may fall within the innermost Circle for at least four hours in the middle of the day. The pin ought to be about an eighth part of an inch thick, with 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 the Circles; watch the times in the forenoon, when the extremity of the shortening shadow just touches the several Circles, and *there* make marks. Then, in the afternoon of the same day, watch the lengthening shadow, and where it's end touches the several Circles in going over them, make marks also. Lastly, with a pair of compasses, find exactly the middle point between the two marks on any Circle, and draw a straight line from the center to that point; which Line will be covered at noon by the shadow of a small upright wire, which should be put in the place of the pin. The reason for drawing several Circles is, that in case one part of the day should prove clear, and the other part somewhat cloudy, if you miss the time when the point of the shadow should touch one Circle, you may perhaps catch it in touching another. The best time for drawing a Meridian Line in this manner is about the middle of summer; because the Sun changes his Declination slowest and his Altitude fastest in the longest days.

98

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

Equation of natural days explained.

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

PLATE VI.

The first part of the Equation of time.

228. The Earth's motion on it's Axis being perfectly equable, or always at the same rate, and the [55]plane of the Equator being perpendicular to it's Axis, 'tis evident that in equal times equal portions of the Equator pass over the Meridian; and so would equal portions of the Ecliptic if it were parallel to or coincident with the Equator. But, as the Ecliptic is oblique to the Equator, the equable motion of the Earth carries unequal portions of the Ecliptic over the Meridian in equal times, the difference being proportionate to the obliquity; and as some parts of the Ecliptic are much more oblique than others, those differences are unequal among themselves. Therefore, if two Suns should start either from the beginning of Aries or Libra, and continue to move through equal arcs in equal times, one in the Equator, and the other in the Ecliptic, the equatoreal Sun would always return to the Meridian in 24 hours time, as measured by a well regulated clock; but the Sun in the Ecliptic would return to the Meridian sometimes sooner, and sometimes later than the equatoreal Sun; and only at the same moments with him on four days of the year; namely, the 20th of *March*, when the Sun enters Aries; the 21st of *June*, when he enters Cancer; the 23d of *September*, when he enters Libra; and the 21st of *December*, when he enters Capricorn. But, as there is only one Sun, and his apparent motion is always in the Ecliptic, let us henceforth call him the real Sun, and the other which is supposed to move in the Equator the fictitious; to which last, the motion of a well regulated clock always answers. 99

Fig. III.

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

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 $Z\Upsilon z$, 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 whilst he is in the quadrant ♈ *F*, than the fictitious Sun does in the quadrant ♈ *f*; for which reason, the solar noon precedes noon by the Clock, until the real Sun comes to *F*, and the fictitious to *f*; which two points, being equidistant from the Meridian, both Suns will come to it precisely at noon by the Clock. 100

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

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

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

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

PLATE VI.

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 49 seconds faster than the clock; and when his place is ♋ Cancer 18 degrees, he is 6 minutes 2 seconds slower. 101

Sun faster than the Clock in				

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

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; 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 also on the Equator, shew that the two Suns meet there, and come to the Meridian together.

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

PLATE VI.

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

102

way of shewing the reason why any given Star, which, on a certain day of the year, comes to the Meridian with the Sun, passes over it so much sooner every following day, as on that day twelvemonth to come to the Meridian with the Sun again; and also to shew the reason why the real Sun comes to the Meridian sometimes sooner, sometimes later, than it is noon by the clock; and, on four days of the year, at the same time; whilst the fictitious Sun always comes to the Meridian when it is twelve at noon by the clock. This would be no difficult task for an artist to perform; for the gold ball might be carried round the Ecliptic by a wire from it's north Pole, and the silver ball round the Equator by a wire from it's south Pole, with 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 3d Figure of the 3d plate.

Fig. III.

232. 'Tis plain that if the Ecliptic were more obliquely posited to the Equator, as the dotted Circle ♈*x*♎, the equal divisions from ♈ to *x* would come still sooner to the Meridian *Z0*♈ than those marked *A*, *B*, *C*, *D*, and *E* do: for two divisions containing 30 degrees, from ♈ to the second dott, a little short of the figure 1, come sooner to the Meridian than one division containing only 15 degrees from ♈ to *A* does, as the Ecliptic now stands; and those of the second quadrant from *x* to ♎ would be so much later. The third quadrant would be as the first, and the fourth as the second. And it is likewise plain, that where the Ecliptic is most oblique, namely about Aries and Libra, the difference would be greatest: and least about Cancer and Capricorn, where the obliquity is least.

The second part of the Equation of Time.

PLATE VI.

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 it's Axis is equable all the year round, and is performed from west to east; which is the way that the Sun appears to change his place in the Ecliptic. 103

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

236. Now, if there were two Suns moving in the plane of the Ecliptic, so as to go round it in a year; the one describing an equal arc every 24 hours, and the other describing sometimes a less arc in 24 hours, and at other times a larger; gaining at one time of the year what it lost at the opposite; 'tis 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.

Fig. IV.

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

PLATE VI.

As the real Sun moves from *A* towards *C*, the swiftness of his motion increases all the way to *C*, where it is at the quickest. But notwithstanding this, the fictitious Sun gains so much upon the real, soon after his departing from *A*, that the increasing velocity of the real Sun does not bring him up with the equally moving fictitious Sun till the former comes to *C*, and the latter to *c*, when each has gone half round it's respective orbit; and then being in conjunction, the Meridian *EH* revolving to *EK* comes to both Suns at the same time, and therefore it is noon by them both at the same moment. 104

But the increased velocity of the real Sun, now being at the quickest, carries him before the fictitious; and therefore, the same Meridian will come to the fictitious Sun sooner than to the real: for whilst the fictitious Sun moves from *c* to *g*, the real Sun moves through a greater arc from *C* to *G*: consequently the point *K* has it's fictitious noon when it comes to *k*, but not it's real noon 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.

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

Apogee, Perigee, and Apsides, what.

Fig. IV.

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

Mean Anomaly, what.

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

240. From what was said above it appears, that when the Sun's Anomaly is less than 6 Signs, that is, when he is any where between *A* and *C*, in the half *ABC* of his orbit, the true noon precedes the fictitious; but when his Anomaly is more than 6 Signs, that is, when he is any where between *C* and *A*, in the half *CDA* of his Orbit, the fictitious noon precedes the true. 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. 105

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

	11 Signs	10	9	8	7	6	D.
Sun slower than the Clock if his Anomaly be							

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

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

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 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 beginning of these Signs, nor at any time of the year, except when the swiftness or slowness of Equation resulting from one cause just balances the slowness or swiftness arising from the other. 106

243. The last Table but one, at the end of this 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 a degree. Their use is only to assist in shewing 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 following Tables are such as might be made from these two; and shew the absolute Equation of Time resulting from the combination of both it's 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.

Examples for making Equation Tables.

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

EXAMPLE II. On the 16th of *June*, the Sun is in the 25th degree of ♊ Gemini, and his Anomaly is 11 Signs 16 Degrees; the Equation arising from the former is 1 minute 48 seconds too fast; and from the latter 1 minute 50 seconds too slow; which balancing one another at noon to 2 seconds, the Sun and Clocks are again equal on that day. 107

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

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

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

Remark.

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 Solsticial points § 242.

The reason why Equation Tables are but temporary.

245. If the line of the Apsides, together with the Equinoctial and Solsticial points, were immoveable, a general Equation Table might be made from the preceding Equation Tables, which would always keep true, because these Tables themselves are permanent. But, with respect to the fixed Stars, the line of the Apsides moves forwards 12 seconds of a degree every year, and the above points 50 seconds backward. So that if in any given year, the Equinoctial points, and line of the Apsides were coincident, in 100 years afterward they would be separated 1 degree 43 minutes 20 seconds; and consequently in 5225.8 years they would be separated 90 degrees, and could not meet again, so that the same Equinoctial point should fall again into the Apogee in less than 20,903 years: and this is the shortest Period in which the Equation of Time can be restored to the same state again, with respect to the same seasons of the year.

CHAP. XIV.

Of the Precession of the Equinoxes.

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

The Sun and Moon, by attracting this redundancy of matter, bring the Equator sooner under them in every return towards it than if there was no such accumulation. Therefore, if the Sun sets out, as from any Star, or other fixed point in the Heavens, the moment he is departing from the Equinoctial or either Tropic, he will come to the same again before he compleats his annual course, so as to arrive at the same fixed Star or Point from whence he set out.

When the Sun arrives at the same [56]Equinoctial or Solstitial Point, he finishes what we call the *Tropical Year*, which, by long observation, is found to contain 365 days 5 hours 48 minutes 57 seconds: and when he arrives at the same fixed Star again, as seen from the Earth, he compleats the *Sidereal Year*; which is found to contain 365 days 6 hours 9 minutes 14½ seconds. The *Sidereal 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 Sidereal and Tropical.

PLATE VI.

247. As the Sun describes the whole Ecliptic, or 360 degrees, in a Tropical year, he moves 59′ 8″ of a degree every day; 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. 109

A* TABLE *shewing the Precession of the Equinoctial Points in the Heavens, both in Motion and Time; and the Anticipation of the Equinoxes on 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	26	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	29	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	46	40	30	16	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

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 20th day of *May* 1756. Then, making 2160 revolutions through the Ecliptic *VWX*, at the end of so many Sidereal years, he will be found again at *S*: but at the end of so many Julian years, he will be found at *M*, short of *S*: and at the end of so many Tropical years, he will be found short of *M*, in the 30th deg. of Taurus at *T*, which has receded back from *S* to *T* in that time, by the Precession of the Equinoctial points ♈ *Aries* and ♎ *Libra*. The Arc *ST* will be equal to the amount of the Precession of the Equinox in 2160 years, at the rate of 50″ of a degree, or 20 min. 17½ sec. of time, annually: this, in so many years, makes 30 days, 10½ hours; which is the difference between 2160 Sidereal 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.

110

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 time of Hesiod, Eudoxus, Virgil, Pliny, &c. by no means answer at this time to their descriptions. The preceding table shews the quantity of this shifting both in the heavens and on the earth, for any number of years to 25,920; which compleats the grand celestial period: within which any number and 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 $2^{s}\ 20°\ 2'\ 30''$ 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 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.* 12th, it appears that the Autumnal Equinox at the creation was on the 26th of *October*.

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

The anticipation of the Equinoxes and Seasons.

PLATE VI.

249. The anticipation of the Equinoxes, and consequently of the seasons, is by no means owing to the Precession of the Equinoctial and Solsticial 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

111

365 days 5 hours 48 minutes 57 seconds. The following table shews the length, and consequently the difference of any number of Sidereal, Civil, and Solar years from 1 to 10,000.

The reason for altering the Style.

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

The Precession of the Equinoctial Points.

251. Having already mentioned the cause of the Precession of the Equinoctial points in the heavens, § 246, which occasions a slow deviation of the earth's axis from 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 describe the Phenomena by a Diagram.

Fig. V.

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 *BO* its Axis, both which are immoveable among the Stars. But, as [57]the Equinoctial points recede in the Ecliptic, the Earth's Axis *SON* is in motion upon the Earth's center *O*, in such 112
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 $23\frac{1}{2}$ 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, the point *A*, which at present is the North Pole of the Heavens, and near to a Star of the second magnitude in the tail of the constellation called *the Little Bear*, must be deserted by the Earth's Axis; which moving backwards a degree every 72 years, will be directed towards the Star or Point *B* in 6480 years hence: and in double of that time, or 12,960 years, it will be directed towards the Star or Point *C*; which will then be the North Pole of the Heavens, although it is at present $8\frac{1}{2}$ degrees south of the Zenith of *London L*. The present position of the Equator *EOQ* will then be changed into *eOq*, the Tropic of Cancer *T*♋*Z* into *Vt*♋, and the Tropic of Capricorn *VT*♑ into *t*♑*Z*; as is evident by the Figure. And the Sun, in the same part of the Heavens where he is now over the earthly Tropic of Capricorn, and makes the shortest days and longest nights in the Northern Hemisphere, will then be over the earthly Tropic of Cancer, and make the days longest, and nights shortest. So that it will require 12,960 years yet more, or 25,920 from the 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, polar Circles, and Poles, by the Earth's diurnal motion, will describe them over again.

A TABLE *shewing the Time contained in any number of Sidereal, Julian, and Solar Years, from 1 to 10000.* 113

Sidereal Years.					Julian Years.		Solar Years.			
Years	Days	H.	M.	S.	Days	H.	Days	H.	M.	S.
1	Contain 365	6	9	$14\frac{1}{2}$	Contain 365	6	Contain 365	5	48	57
2	730	12	18	29	730	12	370	11	37	54
3	1095	18	27	$43\frac{1}{2}$	1095	18	1095	17	26	51
4	1461	0	36	58	1461	0	1460	23	15	48
5	1826	6	46	$12\frac{1}{2}$	1826	6	1826	5	4	45
6	2191	12	55	27	2191	12	2191	10	53	42
7	2556	19	5	$41\frac{1}{2}$	2556	18	2556	16	42	39
8	2922	1	13	56	2922	0	2921	22	31	36

9	3287	7	23	10½	3287	6	3287	4	20	33
10	3652	13	32	25	3652	12	3652	10	9	30
20	7305	3	4	50	7305	0	7304	20	19	0
30	10957	16	37	15	10957	12	10957	6	28	30
40	14610	6	9	40	14610	0	14609	16	38	0
50	18262	19	42	5	18262	12	18262	2	47	30
60	21915	9	14	30	21915	0	21914	12	57	0
70	25567	22	46	55	25567	12	25566	23	6	30
80	29220	12	19	20	25220	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	10	
900	328730	18	37	30	328725		328718	2	15	
1000	365256	10	1	40	365250		365242	7	50	
2000	730512	20	3	20	730500		730484	15	40	
3000	1095769	6	5		1095750		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	14	40	
7000	2556794	22	11	40	2556750		2556696	6	50	
8000	2922051	8	13	20	2922000		2921938	14	40	
9000	3287037	18	15		3287250		3287180	22	30	
10000	3652564	4	16	40	3652500		3652423	6	20	

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

Days	January				February				March				April				May				June			
	Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom.		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.	D.	M.	S.	D.	D.	M.	S.	D.
1	11♑	7	6	2	12♒	39	7	3	10♓	53	8	0	11♈	40	9	1	10♉	57	10	0	10♊	46	11	1
2	12	8	6	3	13	40	7	4	11	53	8	1	12	39	9	2	11	55	10	1	11	44	11	2
3	13	9	6	4	14	41	7	5	12	53	8	2	13	38	9	3	12	53	10	2	12	41	11	3
4	14	10	6	5	15	42	7	6	13	53	8	3	14	37	9	4	13	51	10	3	13	38	11	4
5	15	11	6	6	16	43	7	7	14	53	8	4	15	36	9	5	14	49	10	4	14	35	11	5
6	16	12	6	7	17	43	7	8	5	53	8	5	16	35	9	6	15	47	10	5	15	33	11	6
7	17	14	6	8	18	44	7	9	16	53	8	6	17	34	9	7	16	45	10	6	16	30	11	7
8	18	15	6	9	19	45	7	10	17	53	8	7	18	33	9	8	17	43	10	7	17	28	11	8
9	19	16	6	10	20	46	7	11	18	53	8	8	19	32	9	9	18	41	10	8	18	25	11	9
10	20	17	6	11	21	46	7	12	19	53	8	9	20	30	9	10	19	39	10	9	19	22	11	10
11	21	18	6	12	22	47	7	13	20	52	8	10	21	29	9	11	20	37	10	10	20	20	11	11
12	22	19	6	13	23	47	7	14	21	52	8	11	22	28	9	12	21	34	10	11	21	17	11	12
13	23	21	6	14	24	48	7	15	22	52	8	12	23	26	9	13	22	32	10	12	22	14	11	13
14	24	22	6	15	25	48	7	16	23	52	8	13	24	25	9	14	23	30	10	13	23	11	11	14
15	25	23	6	16	26	49	7	17	24	51	8	14	25	24	9	15	24	28	10	14	24	8	11	15
16	26	24	6	17	27	49	7	18	25	51	8	15	26	22	9	16	25	26	10	15	25	6	11	16
17	27	25	6	18	28	50	7	19	26	51	8	16	27	21	9	17	26	23	10	16	26	3	11	17
18	28	26	6	19	29	50	7	20	27	50	8	17	28	19	9	18	27	21	10	17	27	0	11	18
19	29	27	6	20	♓	51	7	21	28	50	8	18	29	18	9	19	28	19	10	18	27	58	11	18
20		28	6	21	1	51	7	22	29	49	8	19		16	9	20	29	16	10	19	28	55	11	19

	♒						♈		♉				♊					
21	1	29	6	22	2	51	7	23	♈ 49	8	20	1	15	9	21	♊ 15	10	20	29	52	11	20
22	2	30	6	23	3	52	7	24	1	48	8	21	2	13	9	22	1	11	10	21	♋ 49	11	21
23	3	31	6	24	4	52	7	25	2	47	8	22	3	11	9	23	2	9	10	22	1	46	11	22
24	4	32	6	25	5	52	7	26	3	47	8	23	4	10	9	24	3	6	10	23	2	44	11	23
25	5	33	6	26	6	52	7	27	4	46	8	24	5	8	9	25	4	4	10	24	3	41	11	24
26	6	34	6	27	7	53	7	28	5	45	8	25	6	6	9	26	5	2	10	25	4	38	11	25
27	7	35	6	28	8	53	7	29	6	45	8	26	7	4	9	27	5	59	10	26	5	35	11	26
28	8	36	6	29	9	53	8	0	7	44	8	27	8	3	9	28	6	56	10	27	6	32	11	27
29	9	37	7	0					8	43	8	28	9	1	9	29	7	54	10	28	7	30	11	28
30	10	38	7	1					9	42	8	29	9	59	9	29	8	51	10	29	8	27	11	29
31	11	39	7	2					10	41	9	0					9	48	11	0				

115

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

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

116

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

The Bissextile, or Leap-year.

Days	January	Dif.	February	Dif.	March	Dif.	April	Dif.	May	Dif.	June	Dif.

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

28	12 13 27		12 13 0		12 5 2		11 57 12		11 56 49		12 2 43	
		11		12		18		9		7		12
29	12 13 38		12 12 48		12 4 44		11 57 3		11 56 56		12 2 55	
		10		12		19		8		8		12
30	12 13 48				12 4 25		11 56 55		11 57 4		12 3 7	
		9				19		8		9		11
31	12 13 57				12 4 6				11 57 13			
		8				18				9		
	Incr. 9′ 57″		Incr. 0′ 39″		Decr. 8′ 30″		Decr. 6′ 53″		Decr. 0′ 50″		Incr. 5′ 45″	
			Decr. 1 56						Incr. 1 17			

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

The first after Leap-year.

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

20	12	11	44	17	12	14	7	7	12	7	36	18	11	58	44	13	11	56	5	3	12	0	58	13
21	12	12	1	16	12	14	0	8	12	7	18	19	11	58	31	12	11	56	8	4	12	1	11	13
22	12	12	17	15	12	13	52	9	12	6	59	19	11	58	19	12	11	56	12	4	12	1	24	13
23	12	12	32	14	12	13	43	9	12	6	40	19	11	58	7	12	11	56	16	5	12	1	37	13
24	12	12	46	13	12	13	34	10	12	6	21	19	11	57	55	11	11	56	21	6	12	1	50	13
25	12	12	59	13	12	13	24	10	12	6	2	19	11	57	44	10	11	56	27	6	12	2	3	13
26	12	13	12	12	12	13	14	11	12	5	43	19	11	57	34	10	11	56	33	6	12	2	16	12
27	12	13	24	11	12	13	3	12	12	5	24	19	11	57	24	10	11	56	39	7	12	2	28	12
28	12	13	35	10	12	12	51	12	12	5	5	19	11	57	14	9	11	56	46	7	12	2	40	12
29	12	13	45					9	12	4	46	18	11	57	5	8	11	56	53	8	12	2	52	12
30	12	13	54					9	12	4	28	18	11	56	57	8	11	57	1	8	12	3	4	11
31	12	14	3	8					12	4	10	18					11	57	9	9				

Incr. 9′ 42″ Incr. 0′ 33″ Decr. 8′ 29″ Decr. 6′ 55″ Decr. 0′ 53″ Incr. 5′ 46″

Decr. 1 53 Incr. 1 12

119

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

The first after Leap-year.

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

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

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

The second after Leap-year.

Days	January	Dif.	February	Dif.	March	Dif.	April	Dif.	May	Dif.	June	Dif.
	H. M. S.	S.	H. M. S.	S.	H. M. S.	S.	H. M. S.	S.	H. M. S.	S.	H. M. S.	S.
		Inc.		Dec.		Inc.		Dec.		Dec.		Inc.
1	12 4 14	28	12 14 9	7	12 12 42	13	12 3 56	18	11 56 50	8	11 57 16	9
2	12 4 42	28	12 14 16	6	12 12 20	13	12 3 38	18	11 56 42	7	11 57 25	10
3	12 5 10	27	12 14 22	5	12 12 16	13	12 3 20	18	11 56 35	6	11 57 35	10
4	12 5 37		12 14 27		12 12 3		12 3 2		11 56 29		11 57 45	

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

Incr. 9′ 47″ Incr. 0′ 35″ Decr. 8′ 27″ Decr. 6′ 58″ Decr. 0′ 54″ Incr. 5′ 45″
Decr. 1 50 Incr. 1 12

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

The second after Leap-year.

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

25	12 5 58		1	12 1 45		16	11 51 34		20	11 44 15		6	11 47 25		19	12 0 41		30
26	12 5 59			12 1 29			11 51 14			11 44 9			11 47 44			12 1 11		
		Dec.				17			20			5			20			30
27	12 5 58		1	12 1 12			11 50 54			11 44 4			11 48 4			12 1 41		
						17			20			5			21			30
28	12 5 57		1	12 0 55			11 50 34			11 43 59			11 48 25			12 2 11		
						18			19			4			21			29
29	12 5 56		2	12 0 37			11 50 15			11 43 55			11 48 46			12 2 40		
						18			19			3			22			29
30	12 5 54		3	12 0 19			11 49 56			11 43 52			11 49 8			12 3 9		
						18			19			2			22			29
31	12 5 51		3	12 0 1						11 43 50						12 3 38		
						18						1						29
	Incr. 2′ 46″			Decr. 5′ 47″			Decr. 9′ 47″			Decr. 5′ 47″			Decr. 0′ 1″			Incr. 14′ 8″		
	Decr. 0 8												Incr. 5 19					

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

The third after Leap-year.

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

17	12 10 39	19		12 14 28	5		12 8 39	18		11 59 32	14		11 55 58	1		12 0 13	13					
18	12 10 58	18		12 14 23	6		12 8 21	18		11 59 18	14		11 55 59	2		12 0 26	13					
19	12 11 16	18		12 14 17	7		12 8 3	18		11 59 4	14		11 56 1	2		12 0 39	13					
20	12 11 34	17		12 14 10	7		12 7 45	18		11 58 50	13		11 56 3	3		12 0 52	13					
21	12 11 51	16		12 14 3	8		12 7 27	19		11 58 37	13		11 56 6	4		12 1 5	12					
22	12 12 7	16		12 13 55	8		12 7 8	19		11 58 24	12		11 56 10	4		12 1 17	13					
23	12 12 23	15		12 13 47	9		12 6 49	19		11 58 12	12		11 56 14	5		12 1 30	13					
24	12 12 38	14		12 13 38	9		12 6 30	19		11 58 0	11		11 56 19	5		12 1 43	13					
25	12 12 52	13		12 13 29	10		12 6 11	18		11 57 49	11		11 56 24	6		12 1 56	13					
26	12 13 5	12		12 13 19	11		12 5 53	19		11 57 38	10		11 56 30	6		12 2 9	13					
27	12 13 17	11		12 13 8	12		12 5 34	19		11 57 28	10		11 56 36	7		12 2 22	12					
28	12 13 28	11		12 12 56	12		12 5 15	18		11 57 18	9		11 56 43	7		12 2 34	12					
29	12 13 39	10					12 4 57	19		11 57 9	9		11 56 50	8		12 2 46	12					
30	12 13 49	9					12 4 38	19		11 57 0	8		11 56 58	8		12 2 58	12					
31	12 13 58	8					12 4 19	18					11 57 6	9									

Incr. 9′ 51″ Incr. 0′ 38″ Decr. 8′ 25″ Decr. 7′ 1″ Decr. 0′ 56″ Incr. 5′ 43″

Decr. 1 48 Incr. 1 10

123

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

The third after Leap-year.

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

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

Incr. 2′ 48″ Decr. 5′ 43″ Decr. 9′ 46″ Decr. 5′ 51″ Decr. 0′ 1″ Incr. 14′ 6″

Decr. 0 7 Incr. 5 14

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.

PL. VII.

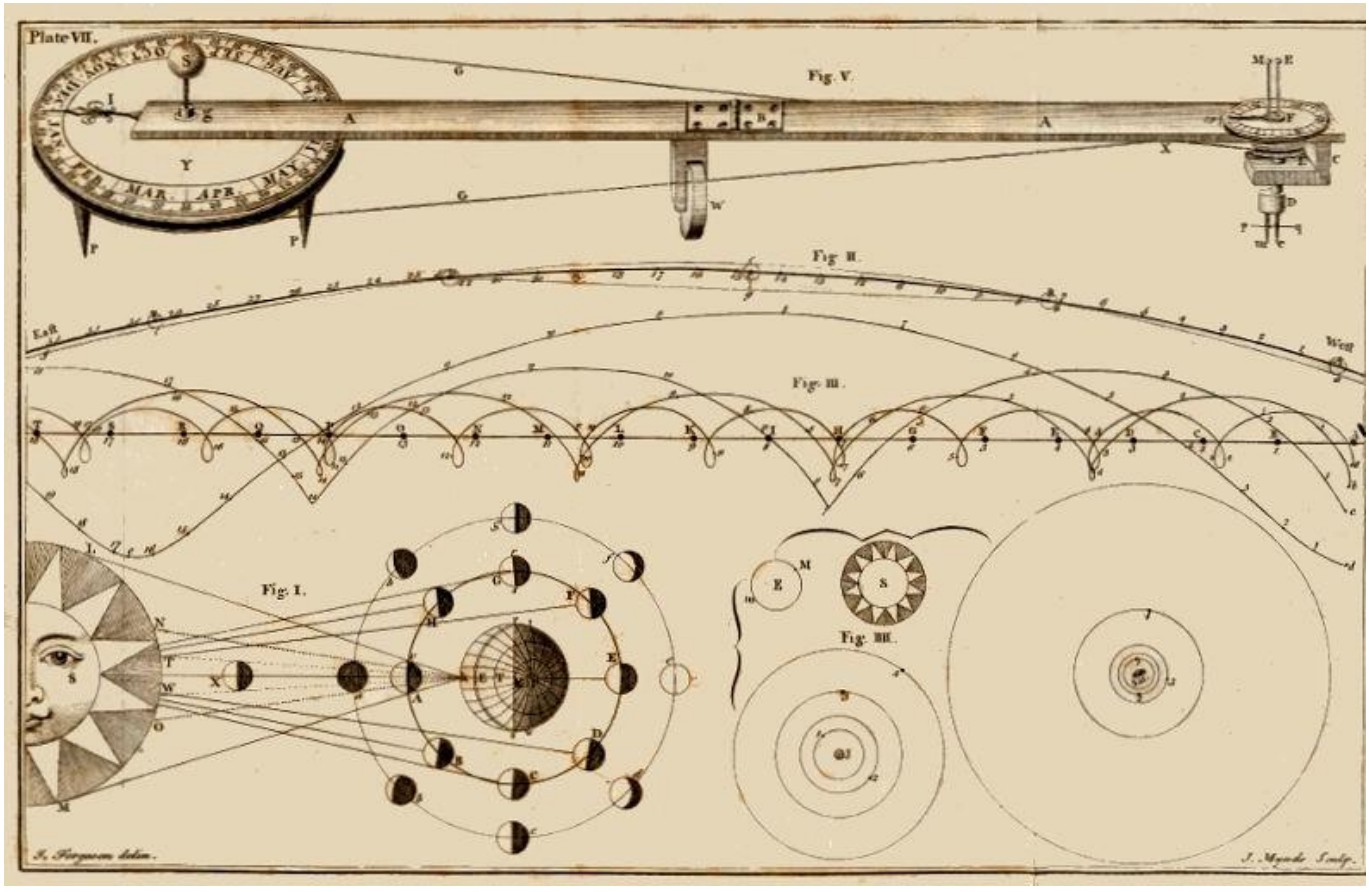
The Moon's surface mountainous.

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.

Why no hills appear on her edge.

253. The Moon's surface being so uneven, many have wondered why her edge appears not jagged, as well as the curve bounding the light and dark places. But if we consider, that what we call the edge of the Moon's Disc is not a single line set round with mountains, in which case it would appear irregularly indented, but a large Zone having many mountains lying behind one another from the observer's eye, we shall find that the mountains in some rows will be opposite to the vales in others; and so fill up the inequalities as to make her appear quite round: just as when one looks at an orange, although it's roughness be very discernible on the side next the eye, especially if the Sun or a Candle shines obliquely on that side, yet the line terminating the visible part still appears smooth and even.

Plate VII.



J. Ferguson delin.

J. Mynde Sculp.

The Moon has no twilight.

Fig. I.

254. As the Sun can only enlighten that half of the Earth which is at any moment turned towards him, and being withdrawn from the opposite half leaves it in darkness; so he likewise doth to the Moon: only with this difference, that the Earth being surrounded by an Atmosphere, and the Moon having none, we have twilight after the Sun sets; but the Lunar Inhabitants have an immediate transition from the brightest Sunshine to the blackest darkness § 177. For, let *tkrsw* be the Earth, and *A*, *B*, *C*, *D*, *E*, *F*, *G*, *H* the Moon in eight 125
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.

The Moon's Phases.

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

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

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

The Phases of the Earth and Moon contrary.

257. 'Tis plain by the Figure, that when the Moon changes to the Earth, the 126
Earth appears Full to the Moon; and *vice versâ*. For when the Moon is at *A*, *New* to the Earth, the whole enlightened side of the Earth is towards the Moon: and when the Moon is at *E*, *Full* to the Earth, it's dark side is towards her. Hence a *New Moon* answers to a *Full Earth*, and a *Full Moon* to a *New Earth*. The *Quarters* are also reversed to each other.

An agreeable Phenomenon.

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

The nonagesimal Degree, what.

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

How the inclination of the Ecliptic may be found by the position of the Moon

260. The inclination of that part of the Ecliptic to the Horizon in which the Moon is at any time when horned, may be known by the position of her horns; for a right line touching their points is perpendicular to the Ecliptic. And as the Angle that the Moon's orbit makes with the Ecliptic can never raise her above, nor

horns.

PL. VII.

depress her below the Ecliptic, more than two minutes of a degree, as seen from the Sun; it can have no sensible effect upon the position of her horns. Therefore, if a Quadrant be held up, so as one of it's edges may seem to touch the Moon's horns, the graduated side being kept towards the eye, and as far from the eye as it can be conveniently held, the arc between the Plumb-line and that edge of the Quadrant which seems to touch the Moon's horns will 127 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 the Moon's horns to the Horizon at that time also.

Fig. I.

Why the Moon appears as big as the Sun.

261. The Moon generally appears as large as the Sun; for the Angle *vkA*, under which the Moon is 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 afterwards. If the Moon were farther from the Earth as at *a*, she could never hide the whole of the Sun from us; for then she would appear under the Angle *NkO*, 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 *TW* from our sight.

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

262. The Moon turns round her Axis in the time that she goes round her orbit; which is evident from hence, that a spectator at rest, without the periphery of the Moon's orbit, would see all her sides turned regularly towards 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 sidereal 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 it's Axis; the same as if it had kept all the while at rest, and the Sun moved round it: but without turning round it's Axis it could never have one sidereal day, because it would always keep the same side towards any given Star.

Her periodical and synodical Revolution.

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

Familiarly represented.

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

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

PL. VII.

264. The Moon's periodical and synodical revolution may be familiarly represented by the motions of the hour and minute hands of a watch round it's dial-plate, which is divided into 12 equal parts or hours, as the Ecliptic is divided 128 into 12 Signs, and the year into 12 months. Let us suppose these 12 hours to be 12 months, the hour hand the Sun, and the minute hand the Moon; then will the former 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 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 annexed Table shews the number of conjunctions which the hour and minute hand make whilst the hour hand goes once round the dial-plate; and the other columns shew the times when the two hands meet at every conjunction. Thus, suppose the two hands to be in conjunction at XII, as they always are; then, at the first following conjunction it is 5 minutes 27 seconds 16 thirds 21 fourths 49$^{1}/_{11}$ fifths past I where they meet; at the second conjunction it is 10 minutes 54 seconds 32 thirds 43 fourths 38½ 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 12⅓ 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 40, and this last turning the hour hand, in every revolution it makes round the dial-plate the minute hand would make 12⅓ conjunctions with it; and so would be a pretty device for shewing the motions of the Sun and Moon; especially, as the slowest moving hand might have a little Sun fixed on it's point, and the quickest a little Moon. Besides, the plate, instead of hours and quarters, might have a Circle of months, with the 12 Signs and their Degrees; and if a plate of 29½ equal parts for the days of the Moon's age were fixed to the Axis of the Sun-hand, and below it, so as the Sun always kept at the ½ day of that plate, the Moon-hand 129 would shew the Moon's age upon that plate for every day pointed out by the Sun-hand in the Circle of months; and both Sun and Moon would shew their places in the Ecliptic: for the Sun would go round the

Ecliptic in 365 Days and the Moon in 27⅓ days, which is her periodical revolution; but from the Sun to the Sun again, or from Change to Change, in 29½ days, which is her synodical revolution.

Conj.	H.	M.	S.	‴	⁗	v pts.
1	I	5	27	16	21	49 1/11
2	II	10	54	32	43	38 2/11
3	III	16	21	49	5	27 3/11
4	IIII	21	49	5	27	16 4/11
5	V	27	16	21	49	5 5/11
6	VI	32	43	38	10	54 6/11
7	VII	38	10	54	32	43 7/11
8	VIII	43	38	10	54	32 8/11
9	IX	49	5	27	16	21 9/11
10	X	54	32	43	38	10 10/11
11	XII	0	0	0	0	0

The Moon's motion thro' open space described.

265. If the Earth had no annual motion, the Moon's motion round the Earth, and her track in absolute space, would be always the same[58]. But as the Earth and Moon move round the Sun, the Moon's real path in the Heavens is very different from her path round the Earth: the latter being in a progressive Circle, and the former in a curve of different degrees of concavity, which would always be the same in the same parts of the Heavens, if the Moon performed a compleat number of Lunations in a year.

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

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

Fig. II.

PL. VII.

Let us now suppose that the Radius of the circular curve described by the nail in the axle is to the Radius of the Circle which the pin in the nave describes round the axle as 337½ to 1; which is the proportion of the Radius or Semidiameter of the Earth's Orbit to that of the Moon's; or of the circular curve *A* 1 2 3 4 5 6 7 *B* &c. to the little Circle *a*; and then, whilst the progressive nail describes the said curve from *A* to *E*, the pin will go once round the nail with regard to the center of it's path, and in doing so, will describe the curve *abcde*. 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 Moon, and also the Earth's moving round it's common center of gravity and the Moon's: all which, if they were truly copied in this experiment, would not sensibly alter the figure of the paths described by the nail and pin, even though they should rub against a plain upright surface all the way, and leave their tracks visible. And if the chariot should be 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.

130

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

In this Diagram, the thickest curve line *ABCD*, 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 *abcdef* represents the line of the Moon's path in the Heavens for 32 days, accounted from any particular New Moon at *a*. The machine, Fig. 5th is for delineating the Moon's path, and will be described, with the rest of my Astronomical machinery, in the last Chapter. The Sun is supposed to be in the center of the curve *A 1 2 3 4 5 6 7 B* &c. and the small dotted Circles upon it represent the Moon's Orbit, of which the Radius is in the same proportion to the Earth's path in this scheme, that the Radius of the Moon's Orbit in the Heavens bears to the Radius of the Earth's annual path round the Sun; that is, as 240,000 to 81,000,000, or as 1 to 337½.

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 *ab*; 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 *bc*; and is opposite to the Sun at *c*, when the Earth is at *C*. Whilst the Earth describes the curve *C 15 16 17 18 19 20 21 22* the Moon describes the curve *cd*; and is in her third Quarter at *d* when the Earth is at *D*. Once more, whilst the Earth describes the curve *D 23 24 25 26 27 28 29* the Moon describes the curve *de*; 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 *abcde*, the Moon goes round the progressive Earth as really as if she had kept in the dotted Circle *A*, and the Earth continued immoveable in the center of that Circle.

The Moon's motion always concave towards the Sun.

And thus we see, that although the Moon goes round the Earth in a Circle, with respect to the Earth's center, her real path in the Heavens is not very different in appearance from the Earth's path. To 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*. 131

How her motion is alternately retarded and accelerated.

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

A difficulty removed.

PL. VII.

268. The Moon's path being concave to the Sun throughout, demonstrates that her gravity towards the Sun, at her conjunction, exceeds her gravity towards the Earth. And if we consider that the quantity of matter in the Sun is almost 230 thousand times as great as the quantity of matter in the Earth, and that the attraction of each body diminishes as the square of the distance from it increases, we shall soon find, that the point of equal attraction where these two powers would be equally strong, is about 70 thousand miles nearer the Earth than the Moon is at her Change. It may now appear surprising that the Moon does not abandon the Earth when she is between it and the Sun, because she is considerably more attracted by the Sun than by the Earth at that time. But this difficulty vanishes when we consider, that the Moon is so near the Earth in proportion to the Earth's distance from the Sun, that she is but very little more attracted by the Sun at that time than the Earth is; and whilst the Earth's attraction is greater upon the Moon than the difference of the Sun's attraction upon the Earth and her (and that it is always much greater is demonstrable) there is no danger of the Moon's leaving the Earth; for if she should fall towards the Sun, the Earth would follow her almost with equal speed. The absolute attraction of the Earth upon a drop of falling rain is much greater than the absolute attraction of the particles of that drop upon each other, or of it's center upon all parts of it's circumference; but then the side of the drop next the Earth is attracted with so very little more force than it's center, or even it's opposite side; that the attraction of the center of the drop upon it's side next the Earth is much greater than the difference of force by which the Earth attracts it's nearer surface and center: on which account the drop preserves it's round figure, and might be projected about the Earth by a strong circulating wind so as to be kept from falling to the Earth. It is much the same with the Earth and Moon in respect to the Sun; for if we should suppose the Moon's Orbit to be filled with a fluid Globe, of which all the parts would be attracted towards the Earth in it's center, but the whole of it much more attracted by the Sun; one part of it could not fall to the Sun without the other, and a sufficient projectile force would carry the whole fluid Globe round the Sun. A ship, at the distance of the Moon, sailing round the Earth on the surface of the fluid Globe, could no more be taken away by the Sun when it is on the side next him, than the Earth could be taken away from it when it is on the opposite side; which could never happen unless the Earth's projectile motion were stopt; and if it were stopt, the Ship with the whole fluid Globe, Earth and all together, would as naturally fall to the Sun as a drop of rain in calm air 132

falls to the Earth. Hence we may see, that the Earth is in no more danger of being left by the Moon at the Change, than the Moon is of being left by the Earth at the Full: the diameter of the Moon's Orbit being so small in comparison of the Sun's distance, that the Moon is but little more or less attracted than the Earth at any time. And as the Moon's projectile force keeps her from falling to the Earth, so the Earth's projectile force keeps it from falling to the Sun. 133

Fig. III.

269. All the curves which Jupiter's Satellites describe, are different from the path described by our Moon, although these Satellites go round Jupiter, as the Moon goes round the Earth. 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.

The absolute Path of Jupiter and his Satellites delineated.

Fig. III.

Now let us suppose all these Moons to set out from a conjunction with the Sun, as seen from Jupiter. When Jupiter is at *A* 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 *a1*, his second the curve *b1*, his third *c1*, and his fourth *d1*. The next day when Jupiter is at *C*, his first Satellite has described the curve *a2* from its conjunction, his second the curve *b2*, his third the curve *c2*, and his fourth the curve *d2*, 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 Satellites, shew where they are at the like times. The first Satellite, almost under *C*, is stationary at + as seen from the Sun; and retrograde from + to *2*: at *2* it appears stationary again, and thence it moves forward until it has past *3*, being twice stationary, and once retrograde between *3* and *4*. The path of this Satellite intersects itself every $42\frac{1}{2}$ hours of our time, 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 it's path every 3 days 13 hours; as at *4. 7. 11. 14. 18*, making only five loops and as many conjunctions in the time that the first makes ten. The third Satellite *c* moving still slower, and having described the curve *c 1. 2. 3. 4. 5. 6. 7*, comes to an Angle at *7* in conjunction with the Sun at the end of 7 days 4 hours; and so goes on to describe such another curve *7. 8. 9. 10. 11. 12. 13. 14*, and is at *14* in it's next conjunction. The fourth Satellite *d* is always progressive, making neither loops nor angles in the Heavens; but comes to it's next conjunction at *e* between the numeral figures *16* and *17*, or in 16 days 18 hours. In order to have a tolerably good figure of the paths of these Satellites, I took the following method.

Fig. IV.

PL. VII.

How to delineate the paths of Jupiter's Moons.

And Saturn's.

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 a tenth part; 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 $466\frac{4}{10}$ 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 an half thereon, from *A* to *T*; because Jupiter moves only so much, whilst his outermost Satellite goes once round him, and somewhat more; so that this small portion of so large a circle differs but very little from a straight line. This done, I divided the space *AT* into 18 equal parts, as *AB*, *BC*, &c. for the daily progress of Jupiter; and each part into 24 for his hourly progress. The Orbit of each Satellite was also divided into as many equal parts as the Satellite is hours in finishing it's synodical period round Jupiter. Then drawing a right line through the center of the Card, as a diameter to all the 4 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 said 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 *ABCD* etc. 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. And in the same manner might those for Saturn's Satellites be delineated. 134

The grand Period of Jupiter's Moons.

270. It appears by the scheme, that the three first Satellites come almost into the same line or 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 a conjunction again: See § 73.

Fig. IV. The proportions of the

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*;) *J* Jupiter;

Orbits of the Planets and Satellites.

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 21¼ yards, of Jupiter's orbit 11⅔, and of the Earth's 2¼, taking them in round numbers.

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

The Satellites		Proportion of the Radius of the Planet's Orbit to the Radius of the Orbit of each Satellite.		Proportion of the Time of the Planet's Revolution to the Revolution of each Satellite.		Proportion of the Velocity of each Satellite to the Velocity of 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 337½	to 1	As 12⅓	to 1	As 12⅓	to 337½

CHAP. XVI.

136

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.

No Harvest-Moon at the Equator.

273. It is generally believed that the Moon rises about 48 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.

But remarkable according to the distance of places from it.

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 48 minutes later every day or night than on the former. At considerable distances from the Equator, where the weather and seasons are more uncertain, the autumnal Full Moons rise very soon after sun-set for several evenings together. At the polar circles, where the mild season is of very short duration, the autumnal Full Moon rises at Sun-set from the first to the third quarter. And at the Poles, where the Sun is for half a year absent, the winter Full moons shine constantly without setting from the first to the third quarter.

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.

PLATE III.

137

274. The [59]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 from the Sun every day, as it is in her orbit, she would rise and set 48 minutes later every day than on the preceding: for 12 degrees of the Equinoctial rise or set in 48 minutes of time in all Latitudes.

Fig. III.

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 versâ*. In equal times, whenever this Angle is least, a greater portion of the Ecliptic rises than when the Angle is larger; as may be seen by elevating the pole of a Globe to any considerable Latitude, and then turning it round its Axis in the Horizon. Consequently, when the Moon is in those Signs which rise or set with the smallest Angles, she rises or sets with the least difference of time; and with the greatest difference in those Signs which rise or set with the greatest Angles.

Fig. III.

The different Angles made by the Ecliptic and Horizon.

But, because all who read this Treatise may not be provided with Globes, though in this case it is requisite to know how to use them, we shall substitute the Figure of a Globe; in which *FUP* is the Axis, ♋*TR* the Tropic of Cancer, *LT*♑ the Tropic of Capricorn, ♋*EU*♑ the Ecliptic touching both the Tropics which are 47 degrees from each other, and *AB* the Horizon. The Equator, being in the middle between the Tropics, is cut by the Ecliptic in two opposite points, which are the beginnings of ♈ Aries and ♎ Libra. *K* is the Hour circle with its Index, *F* the North pole of the Globe elevated to the Latitude of *London*[60], namely 51½ degrees above the Horizon; and *P* the South Pole depressed as much below it. 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 62 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 *NL* above the Horizon making only an Angle *NUL* of 15 degrees, with it; which is 47 degrees less than the former Angle, equal to the distance between the Tropics. 138

Least and greatest, when.

276. 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 [61]Sidereal 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.

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

Quantity of this Angle at London.

277. On the Parallel of *London*, as much of the Ecliptic rises about Pisces and Aries in two hours as the Moon goes through in six days: and therefore whilst the Moon is in these Signs, she differs but two hours in rising for six days together; that is, 20 minutes later every day or night than on the preceding. But in fourteen days afterwards, the Moon comes to Virgo and Libra; which are the opposite Signs to Pisces and Aries; and then she differs almost four times as much in rising; namely, one hour and about fifteen minutes later every day or night than the former, whilst she is in these Signs; for by § 275 their rising Angle is at least four times as great as that of Pisces and Aries. The annexed Table shews the daily mean difference of the Moon's 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 while the Moon is in ♍ and ♎ she rises an hour and a quarter later every day than the former; and differs only 24, 20, 18 or 17 minutes in setting. But, when she comes to ♓ and ♈, she is only 20 or 17 minutes later of rising; and an hour and a quarter later in setting. 139

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 [62] $13\frac{1}{6}$ 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 *LUI* 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 *EU*♎: 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*.

279. Having rectified the Globe, turn it until the patch at *0*, about the beginning of ♓ Pisces on the half *LUI* 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 remembred than any other. Then, turn the Globe round westward, and in that time, suppose the patch *0* to have moved thence to *1*, $13\frac{1}{6}$ degrees, whilst 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 of setting on the western side of the Horizon, which shews that the Moon will be so much later of setting in that week in which she moves through these two Signs. The cause of this difference is evident; for Pisces and Aries make only an Angle of 15 degrees with the Horizon when they rise; but they make an Angle of 62 degrees with it when they set § 275. As the Signs Taurus, Gemini, Cancer, Leo, Virgo, and Libra rise successively, the Angle increases gradually which they make with the Horizon; and decreases in the same proportion as they set. And for that reason, the Moon differs gradually more in the time of her rising every day whilst she is in these Signs, and less in her setting: After which, through the other six Signs, *viz.* Scorpio, Sagittary, Capricorn, Aquarius, Pisces, and Aries, the rising difference becomes less every day, until it be at the least of all, namely, in Pisces and Aries. 140

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.

Why the Moon is always Full in different Signs.

Her periodical and synodical Revolution exemplified.

281. If the Earth had no annual motion, the Sun would never appear to shift his place in the Ecliptic. And then every New Moon would fall in the same Sign and degree of the Ecliptic, and every Full Moon in the opposite: for the Moon would go precisely round the Ecliptic from Change to Change. So that if the Moon was once Full in Pisces, or Aries, she would always be Full when she came round to the same Sign and Degree again. And as the Full Moon rises at Sun-set (because when any point of the Ecliptic sets the opposite point rises) she would constantly rise within two hours of Sun-set 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 $2\frac{1}{15}$ degrees, before she can be in conjunction with, or opposite to the Sun again. Hence it is evident, that there can be but one conjunction or opposition of the Sun and Moon in a year in any particular part of the Ecliptic. This may be familiarly exemplified by the hour and minute hands of a watch, which are never in conjunction or opposition in that part of the dial-plate where they were so last before. And indeed if we compare the twelve hours on the dial-plate to the twelve Signs of the Ecliptic, the hour-hand to the Sun and the minute-hand to the Moon, we shall have a tolerably near resemblance in miniature to the motions of our great celestial Luminaries. The only difference is, that whilst the Sun goes once round the Ecliptic the Moon makes $12\frac{1}{3}$ conjunctions with him: but whilst the hour-hand goes round the dial-plate the minute-hand makes only 11 conjunctions with it; because the minute hand moves slower in respect of the hour-hand than the Moon does with regard to the Sun. 141

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

Why the Moon's regular rising is never perceived but in Harvest.

283. Here it will probably be asked, why we never observe this remarkable rising of the Moon but in harvest, since she is in Pisces and Aries at least 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 mid-night, 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 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 48 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 sidereal hour (or 3 minutes 56 seconds sooner every day than the former) and the very next moment one half of the Ecliptic containing Capricorn, Aquarius, Pisces, Aries, Taurus, and Gemini rises, and the opposite half sets. Therefore, whilst the Moon is going from the beginning of Capricorn to the beginning of Cancer, which is almost 14 days, she rises at the same sidereal hour; and in autumn just at Sun-set, because all that half of the Ecliptic in which the Sun is at that time sets at the same sidereal hour, and the opposite half rises: that is, 3 minutes 56 seconds, of mean solar time, sooner every day than on the day before. So whilst the Moon is going from Capricorn to Cancer she rises earlier every day than on the preceding; contrary to what she does at all places between the polar Circles. But during the above fourteen days, the Moon is 24 sidereal 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 $66\frac{1}{2}$ degrees, turn the Globe slowly round it's Axis, and observe the rising and setting of the Ecliptic. As the beginning of Aries is equally distant from the beginning of Cancer and of Capricorn, it is in the middle of that half of the Ecliptic which rises all at once. And when the Sun is at the beginning of Libra, he is in the middle of the other half. Therefore, when the Sun is in Libra and the Moon in Capricorn, the Moon is a Quarter of a Circle before the Sun; opposite to him, and consequently full in Aries, and a Quarter of a Circle behind him when in Cancer. But when Libra rises Aries sets, and all that half of the Ecliptic of which Aries is the middle. And therefore, at that time of the year the Moon rises at Sun-set from her first to her third Quarter. 142

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.

The Moon's Nodes.

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 $5\frac{1}{3}$ degrees above it, and the other half as much depressed 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. 143

289. The Moon's oblique motion with regard to the Ecliptic causes some difference in the times of her rising and setting from what is already mentioned. For whilst she is northward of the Ecliptic, she rises sooner and sets later than if she moved in the Ecliptic: and when she is southward of the Ecliptic she rises later and sets sooner. This difference is variable even in the same Signs, because the Nodes shift backward about $19\frac{2}{3}$ 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 whilst she is in Pisces and Aries than there would be if she kept in the Ecliptic. But in 9 years and 112 days afterward, the Descending Node comes to Aries; and then the Moon's Orbit makes an Angle $5\frac{1}{3}$ degrees greater with the Horizon when Aries rises, than the Ecliptic does at that time; which causes the Moon to rise with greater difference of time in Pisces and Aries than if she moved in the Ecliptic.

291. To be a little more particular, when the Ascending Node is in Aries, the Angle is only $9\frac{2}{3}$ degrees on the parallel of *London* when Aries rises. But when the Descending Node comes to Aries, the Angle is $20\frac{1}{3}$ degrees; this occasions as great a difference of the Moon's rising in the same Signs every 9 years, on the parallel of *London*, 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. 144

Moon's Age	Full in her Ascending node.				In the highest part of her Orbit.				Full in her Descending node.				In the lowest part of her Orbit.			
	Rises at		Sets at		Rises at		Sets at		Rises at		Sets at		Rises at		Sets at	
	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	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
Dif.	1	39	7	10	2	30	7	25	3	28	6	40	2	36	7	0

This Table was not computed, but only estimated as near as could be done from a common Globe, on which the Moon's Orbit was delineated with a black lead pencil. It may at first sight appear erroneous; since as we have supposed the Moon to be full in either Node at the autumnal Equinox, she ought by the Table to rise just at six o'clock, or at Sun-set, on the 15th day of her age; being in the Ecliptic at that time. But it must be considered, that the Moon is only $14\frac{1}{4}$ days old when she is Full; and therefore in both cases she is a little past the Node on the 15th day, being above it at one time, and below it at the other.

The period of the Harvest Moons.

292. As there is a compleat revolution of the Nodes in $18\frac{2}{3}$ years, there must be a regular period of all the Varieties which can happen in the rising and setting of the Moon during that time. But this shifting of the Nodes never affects the Moon's rising so much, even in her quickest descending Latitude, as not to allow us still the benefit of her rising nearer the time of Sun-set for a few days together about the Full in Harvest, than when she is Full at any other time of the year. The following Table shews in what years the Harvest-Moons are least beneficial as to the times of their rising, and in what years most, from 1751 to 1861. The column of years under the letter *L* are those in which the Harvest-Moons are least of all beneficial, because they fall about the Descending Node: and those under *M* are the most of all beneficial, because they fall about the Ascending Node. In all the columns from *N* to *S* the Harvest-Moons descend gradually in the Lunar Orbit, and rise to less heights above the Horizon. From *S* to *N* they ascend in the same proportion, and rise to greater heights above the Horizon. In both the columns under *S* the Harvest-Moons are in the lowest part of the Moon's Orbit, that is, farthest South of the Ecliptic; and therefore stay shortest of all above the Horizon: in the columns under *N* just the reverse. And in both cases, their rising, though not at the same times, are nearly the same with regard to difference of time, as if the Moon's Orbit were coincident with the Ecliptic. 145

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	

PL. VIII.

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. 146

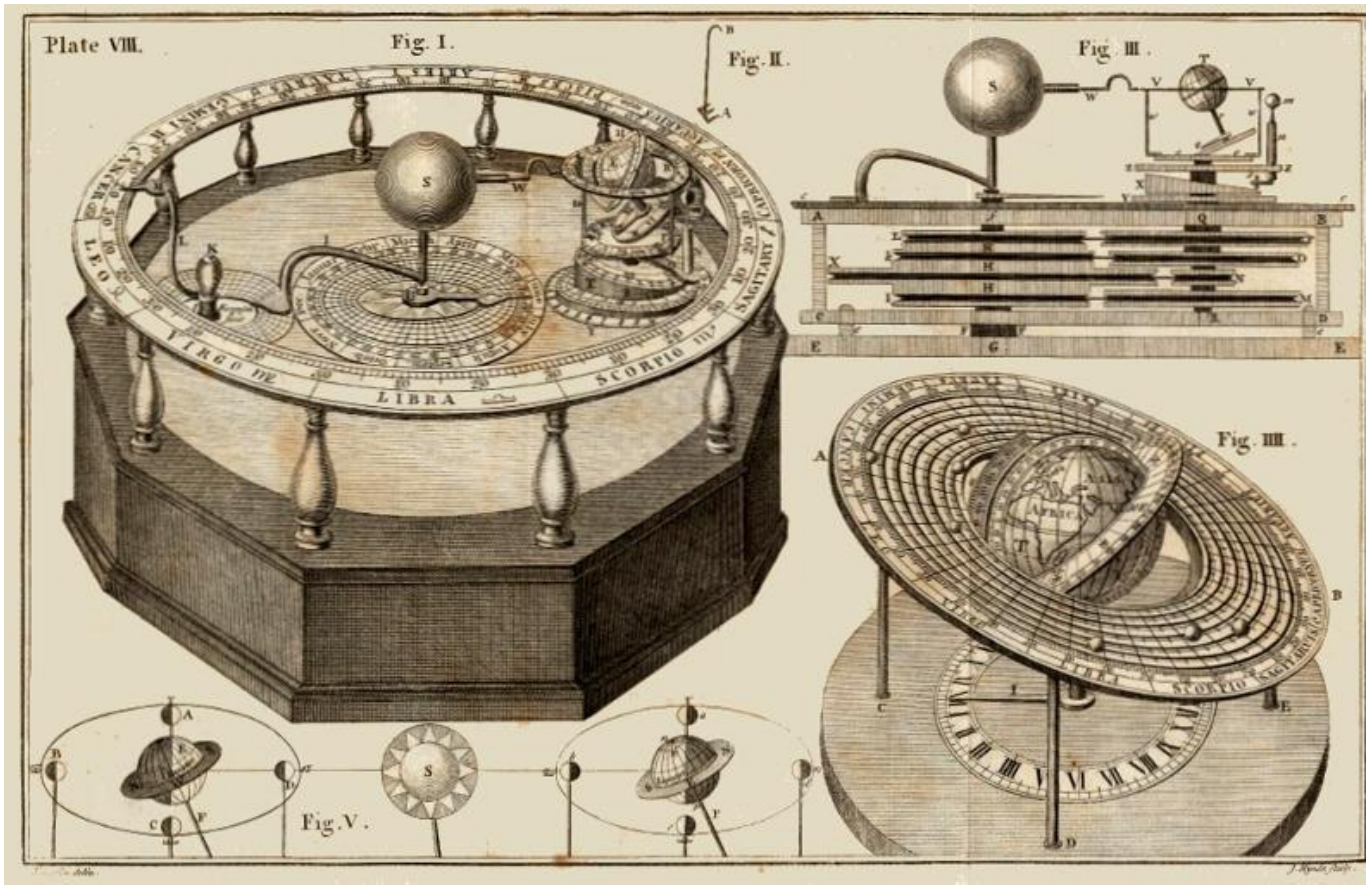
The long continuance of Moon-light at the Poles.

Fig. V.

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, 'tis natural to imagine that the Sun continues half a year together above the Horizon of each Pole in it's turn, and as long below it; rising to one Pole when he sets to the other. This would be exactly the case if there were no refraction: but by the Atmosphere's refracting the Sun's rays, he becomes visible some days sooner § 183, and continues some days longer in sight than he would otherwise do: so that he appears above the Horizon of either Pole before he has got below the Horizon of the other. And, as he never goes more than $23\frac{1}{2}$ degrees below the Horizon of the Poles, they have very little dark night: it being twilight there as well as at all other places till the Sun be 18 degrees below the Horizon, § 177. The Full Moon being always opposite to the Sun, can never be seen while the Sun is above the Horizon, except when the Moon falls in the northern half of her Orbit; for whenever any point of the Ecliptic rises the opposite point sets. Therefore, as the Sun is above the Horizon of the north Pole from the 20th of *March* till the 23d of *September*, it is plain that the Moon, when Full, being opposite to the Sun, must be below the Horizon during that half of the year. But when the Sun is in the southern half of the Ecliptic he never rises to the north Pole, during which half of the year, every Full Moon happens in some part of the northern half of the Ecliptic, which never sets. Consequently, as the polar Inhabitants never see the Full Moon in Summer, they have her always in the Winter, before, at, and after the Full, shining for 14 of our days and nights. And when the Sun is at his greatest depression below the Horizon, being then in Capricorn, the Moon is at her First Quarter in Aries, Full in Cancer, and at her Third Quarter in Libra. And as the beginning of Aries is the rising point of the Ecliptic, Cancer the highest, and Libra the setting point, the Moon rises at her First Quarter in Aries, is most elevated above the Horizon, 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 it's north Pole *n* inclines toward the Sun, and *E* the Earth in Winter, when it's north Pole declines from him. *SEN* and *NWS* 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 *abcd*, *ABCD*. When the Moon is at *a* she is in her Third Quarter to the Earth at *e*, and just rising to the north Pole *n*; at *b* she changes, and is at the greatest height above the Horizon, as the Sun likewise is; at *c* she is in her First Quarter, setting below the Horizon; and is lowest of all under it at *d*, when opposite to the Sun, and her enlightened side toward the Earth. But then she is full in view to the south Pole *p*; which is as much turned from the Sun as the north Pole inclines towards him. Thus in our Summer, the Moon is above the Horizon of the north Pole whilst she describes the northern half of the Ecliptic ♈♋♎, or from her Third Quarter to her First; and below the Horizon during the progress through the southern half ♎♑♈; highest at the Change, most depressed at the Full. But in winter, when the Earth is at *E*, and it's north Pole declines from the Sun, the New Moon at *D* is at her greatest depression below the Horizon *NWS*, and the Full Moon at *B* at her greatest height above it; rising at her First Quarter *A*, 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 147

as much below it at *D* and *d*, equal to the inclination of the Earth's Axis *F*. *S*♋ and *S*♑ are, as it were, a ray of light proceeding from the Sun to the Earth; and shews that when the Earth is at *e*, the Sun is above the Horizon, vertical to the Tropic of Cancer; and when the Earth is at *E*, he is below the Horizon, vertical to the Tropic of Capricorn.

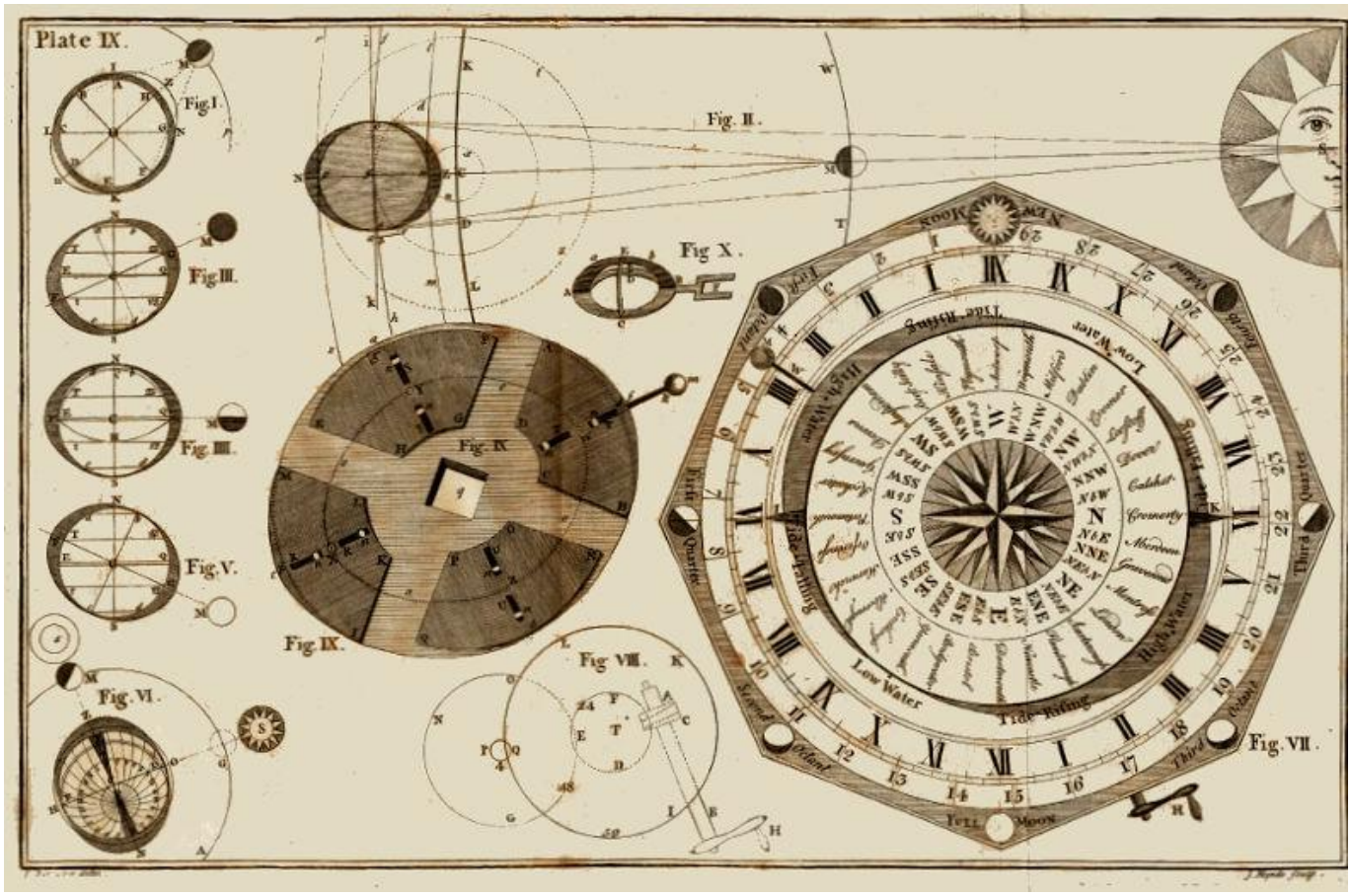
Plate VIII.



J. Ferguson delin.

J. Mynde Sculp.

Plate IX.



J. Ferguson delin.

J. Mynde Sculp.

CHAP. XVII.

Of the ebbing and flowing of the Sea.

The cause of the Tides discovered by KEPLER.

PLATE IX.

Their Theory improved by Sir ISAAC NEWTON.

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 148
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.

Explained on the Newtonian principles.

Fig. I.

Fig. I.

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

PLATE IX.

297. Suppose now there is a number of bodies, as *A*, *B*, *C*, *D*, *E*, *F*, *G*, *H* placed round *O*, so as to form a flexible or fluid ring: then, as the whole is attracted towards *M*, the parts at *H* and *D* will have their distance from *O* increased; whilst the parts at *B* and *F*, being nearly at the same distance from *M* as *O* is, these parts will not recede from one another; but rather, by the oblique attraction of *M*, they will approach nearer to *O*. Hence, the fluid ring will form itself into an ellipse *ZIBLnKFNZ*, whose longer Axis *nOZ* produced will pass through *M*, and it's shorter Axis *BOF* will terminate in *B* and *F*. Let the ring be filled with bodies, so as to form a flexible or fluid sphere round *O*; then, as the whole moves toward *M*, the fluid sphere being lengthned at *Z* and *n*, will assume an oblong or oval form. If *M* 149
is the Moon, *O* the Earth's center, *ABCDEFGH* the Sea covering the Earth's surface, 'tis evident by the above reasoning, that whilst the Earth by it's gravity falls toward the Moon, the Water directly below her at *B* will swell and rise gradually towards her: also, the Water at *D* will recede from the center [strictly speaking, the center recedes from *D*] and rise on the opposite side of the Earth: whilst the Water at *B* and *F* is depressed, and falls below the former level. Hence, as the Earth turns round it's Axis from the Moon to the Moon again in $24\frac{3}{4}$ hours, there will be two tides of flood and two of ebb in that time, as we find by experience.

Fig. II.

298. As this explanation of the ebbing and flowing of the Sea is deduced from the Earth's constantly falling toward the Moon by the power of gravity, some may find a difficulty in conceiving how this is possible when the Moon is Full, or in opposition to the Sun; since the Earth revolves about the Sun, and must continually fall towards it, and therefore cannot fall contrary ways at the same time: or if the Earth is constantly falling towards the Moon, they must come together at last. To remove this difficulty, let it be considered, that it is not the center of the Earth that describes the annual orbit round the Sun; but the [63]common center of gravity of the Earth and Moon together: and that whilst the Earth is moving round the Sun, it also describes a Circle round that centre of gravity; going as many times round it in one revolution about the Sun as there are Lunations or courses of the Moon round the Earth in a year: and therefore, the Earth is constantly falling towards the Moon from a tangent to the Circle it describes round the said common center of gravity. Let *M* be the Moon, *TW* part of the Moon's Orbit, and *C* the center of gravity

of the Earth and Moon: whilst the Moon goes round her Orbit, the center of the Earth describes the Circle *ged* round *C*, to which Circle *gak* is a tangent: and therefore, when the Moon has gone from *M* to a little past *W*, the Earth has moved from *g* to *e*; and in that time has fallen towards the Moon, from the tangent at *a* to *e*; and so round the whole Circle.

PLATE IX.

299. The Sun's influence in raising the Tides is but small in comparison of the Moon's: For though the Earth's diameter bears a considerable proportion to it's distance from the Moon, it is next to nothing when compared with the distance of the Sun. And therefore, the difference of the Sun's attraction on the sides of the Earth under and opposite to him, is much less than the difference of the Moon's attraction on the sides of the Earth under and opposite to her: and therefore the Moon must raise the Tides much higher than they can be raised by the Sun. 150

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

Fig. I.

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 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 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 increment made to the heat already imparted.

Nor always answer to her being at the same distance from it.

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.

Spring and neap Tides.

PLATE IX.

Fig. VI.

302. The Moon goes round the Earth in an elliptic Orbit, and therefore she approaches nearer to the Earth than her mean distance, and recedes farther from it, in every Lunar Month. When she is nearest: she attracts strongest, and so rises the Tides most; the contrary happens when she is farthest, because of her weaker attraction. When both Luminaries are in the Equator, and the Moon in *Perigeo*, or at her least distance from the Earth, she raises the Tides highest of all, especially at her Conjunction and opposition; both because the equatoreal parts have the greatest centrifugal force from their describing the largest Circle, and from the concurring actions of the Sun and Moon. At the Change, the 151 attractive forces of the Sun and Moon being united, they diminish the gravity of the waters under the Moon, which is also diminished on the other side, by means of a greater centrifugal force. At the full, whilst the Moon raises the Tide under and opposite to her, the Sun acting in the same line, raises the Tide 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 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

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 48 minutes. But as the Moon declines from the

same day, and why.

PLATE IX.

Fig. III, IV, V.

Fig. III.

Fig. IV.

Fig. V.

Equator towards either Pole, the Tides are alternately higher and lower at places having north or south Latitude. For one of the highest elevations, which is that under the Moon, follows her towards the same Pole, and the other declines towards the opposite; each 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 towards 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 it's opposite elevation described before. Whilst the Moon has north declination, the greatest Tides in the northern Hemisphere are when she is above the Horizon; and the reverse whilst her declination is south. Let *NESQ* be the Earth, *NCS* it's Axis, *EQ* the Equator, *T*♋ the Tropic of Cancer, *t*♑ the Tropic of Capricorn, *ab* the arctic Circle, *cd* 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 *ENQ* have the highest Tides when they come into the position *b*♋*Q*, under the Moon; and the lowest Tides when the Earth's diurnal rotation carries them into the position *aTE*, on the side opposite to the Moon; the reverse happens at the same time in the southern Hemisphere *ESQ*, as is evident to sight. The Axis of the Tides *aCd* has now it's Poles *a* and *d* (being always 90 degrees from the highest elevations) in the arctic and antarctic Circles; and therefore 'tis 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, it has the lowest ebb. In seven days afterward, the Moon *M* comes to the equinoctial Circle, and is over the Equator *EQ*, 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 has south declination to what they were when her declination was north, require no farther description.

Fig. VI.

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

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 *HZON* be the Earth and Sea, *FED* 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; *AGM* 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 *HCO* touches the polar Circles at *C*; and the high-water Circle *ETP6* 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 both parts of the lunar day: for a place at *1* (under *D*) revolving as formerly, goes sooner from *1* to *11* (under *F*) than from *11* to *1*, because the parallel it describes is cut into unequal segments by the high-water Circle *HCO*: but the points 1 and 11 being equidistant from the Pole of the Tides at *C*, which is directly under the Pole of the Moon's orbit *MGA*, the Elevations are equally high in both parts of the day.

306. And thus it appears, that as the Tides are governed by the Moon, they must turn on the Axis of the Moon's orbit, which is inclined $23\frac{1}{2}$ degrees to the Earth's Axis at a mean state: and therefore the Poles of the Tides must be so many degrees from the Poles of the Earth, or in opposite points of the polar Circles, going round these Circles in every lunar day. 'Tis true that according to Fig. IV. when the Moon is vertical to the Equator *ECQ*, the Poles of the Tides seem to fall in with the Poles of the World *N* and *S*: but when we consider that *FHG* is under the Moon's orbit, it will appear, that when the Moon is over *H*, in the Tropic of Capricorn, the north Pole of the Tides, (which can be no more than 90 degrees from under the Moon) must be at *c* in the arctic Circle, not at *N*; the north Pole of the Earth; and as the Moon ascends from *H* to *G* in her

orbit, the north Pole of the Tides must shift from *c* to *a* in the arctic Circle; and the South Pole as much in the antarctic.

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

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

307. Those who have opportunity to make observations, and choose to satisfy themselves whether the Tides are really affected in the above manner by the different positions of the Moon; especially as to the unequal times of their returns, may take this general rule for knowing, when they ought to be so affected. When the Earth's Axis inclines to the Moon, the northern Tides, if not retarded in their passage through Shoals and Channels, nor affected by the Winds, ought to be greatest when the Moon is above the Horizon, least when she is below it; and quite the reverse when the Earth's Axis declines from her: but in both cases, at equal intervals of time. When the Earth's Axis inclines sidewise to the Moon, both Tides are equally high, but they happen at unequal intervals of time. In every Lunation the Earth's Axis inclines once to the Moon, once from her, and twice sidewise to her, as it does to the Sun every year; because the Moon goes round the Ecliptic every month, and the Sun but once in a year. In Summer, the Earth's Axis inclines towards the Moon when New; and therefore the day-tides in the north ought to be highest, and night-tides lowest about the Change: at the Full the reverse. At the Quarters they ought to be equally high, but unequal in their returns; because the Earth's Axis then inclines sidewise to the Moon. In winter the Phenomena are the same at Full-Moon as in Summer at New. In Autumn the Earth's Axis inclines sidewise to the Moon when New and Full; therefore the Tides ought to be equally high, and unequal in their returns at these times. At the first Quarter the Tides of Flood should be least when the Moon is above the Horizon, greatest when she is below it; and the reverse at her third Quarter. In Spring, Phenomena of the first Quarter answer to those of the third Quarter in Autumn; and *vice versa*. 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.

155

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

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

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

309. The Tides are so retarded in their passage through different Shoals and Channels, and otherwise so variously affected by striking against Capes and Headlands, that to different places they happen at all distances of the Moon from the Meridian; 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 'tis high water three hours before the Moon comes to the Meridian; but that Tide which the Moon pushes as it were before her, is only the Tide opposite to that which was raised by her when she was nine hours past the opposite Meridian.

The Water never rises in Lakes.

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

The Moon raises Tides in the Air.

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

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

156

the column; and then there is an *equilibrium*, and consequently 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.

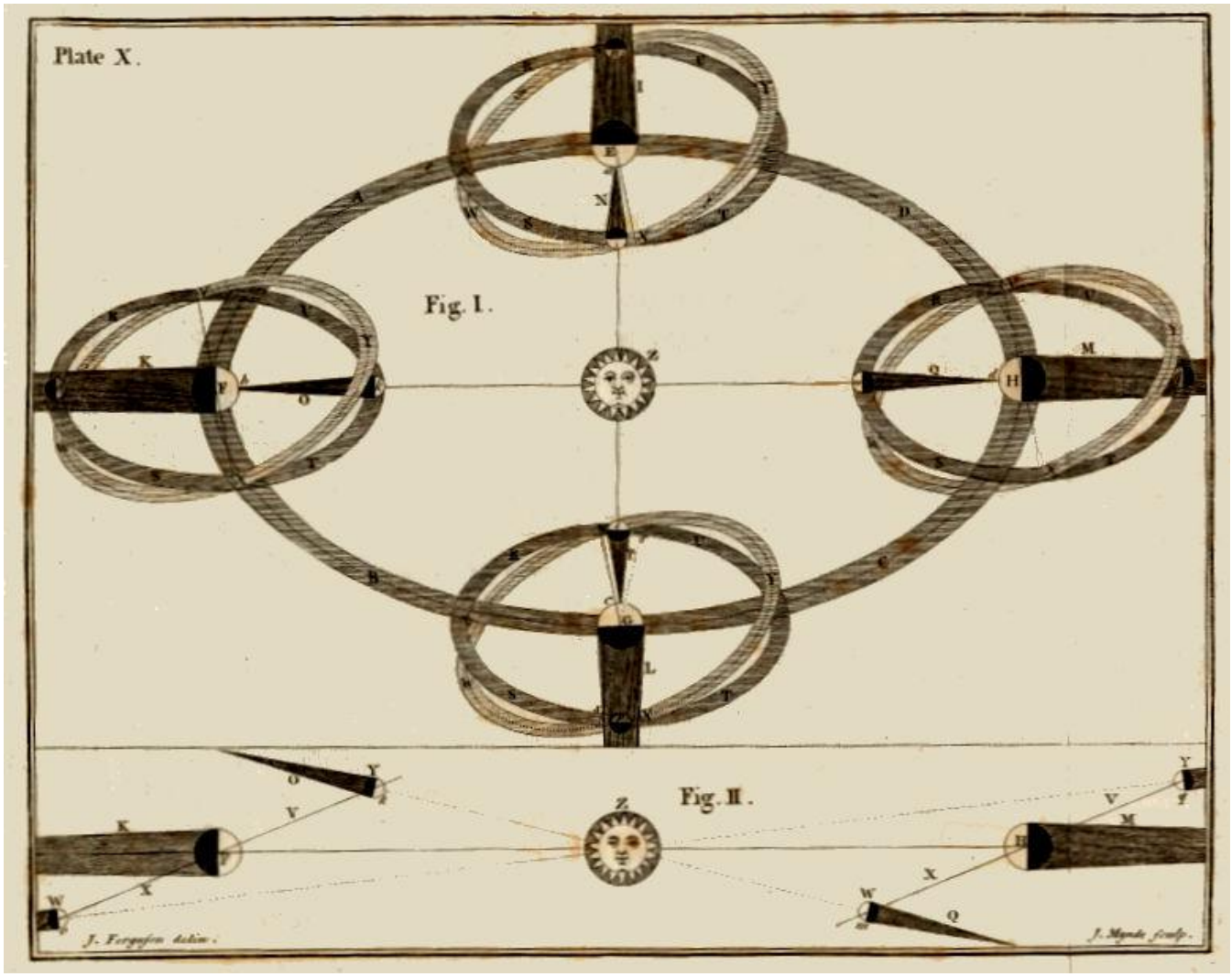
A shadow, what.

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

Eclipses of the Sun and Moon, 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, 'tis only an Eclipse of that part of the Earth where the Moon's shadow or [64]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 equatoreal parts move, and the same way as they move. When the Moon is in an Eclipse, the Sun appears eclipsed to her, total to all those parts on which the Earth's shadow falls, and of as long continuance as they are in the shadow.

Plate X.



J. Ferguson delin.

J. Mynde Sculp.

A proof that the Earth and Moon are globular bodies.

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 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 157 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 towards the Moon when she is eclipsed. The Moon's different Phases prove her to be round § 254; for, as she keeps still the same side towards the earth, if that side were flat, as it appears to be, she would never be visible from the third Quarter to the first; and from the first Quarter to the third, she would appear as round as when we say she is Full: because at the end of her first Quarter the Sun's light would come as suddenly on all her side next the Earth, as it does on a flat wall, and go off as abruptly at the end of her third Quarter.

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

315. If the Earth and Sun were equally big, the Earth's shadow would be infinitely extended, and all of the same breadth; 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, it's shadow would increase in breadth the farther it was 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, 'tis plain that the Earth is much less than the Sun; for otherwise it's shadow could not end in a point at so small a distance. If the Sun and Moon were equally big, the Moon's shadow would go on to the Earth with an equal breadth, and cover a portion of the Earth's surface more than 2000 miles broad, even if it fell directly against the Earth's center, as seen from the Moon: and much more if it fell obliquely on the Earth: but the Moon's shadow is seldom 150 miles broad at the Earth, unless when it falls very obliquely on the Earth, in total Eclipses of the Sun. In annular Eclipses, the Moon's real shadow ends in a point at some distance from the Earth. The Moon's small distance from the Earth, and the shortness of her shadow, prove her to be less than the Sun. And, as the Earth's shadow is large enough to cover the Moon, if her diameter was three times as large as it is (which is evident from her long continuance in the shadow when she goes through it's center) 'tis plain, that the Earth is much bigger than the Moon.

The primary Planets never eclipse one another.

PLATE X.

316. Though all opake bodies on which the Sun shines have their shadows, yet such is the bulk of the Sun, and the distances of the Planets, that the primary Planets can never eclipse one another. A Primary can eclipse only it's secondary, or be eclipsed by it; and never but when in opposition or conjunction with the Sun. 158 The primary Planets are very seldom in these positions, but the Sun and Moon are so every month: whence one may imagine that these two Luminaries should be eclipsed every month. But there are few Eclipses in respect of the number of New and Full Moons; the reason of which we shall now explain.

Why there are so few Eclipses.

The Moon's Nodes.

Limits of Eclipses.

317. If the Moon's Orbit were coincident with the Plane of the Ecliptic, in which the Earth always moves and the Sun appears to move, the Moon's shadow would fall upon the Earth at every Change, and eclipse the Sun to some parts of the Earth. In like manner the Moon would go through the middle of the Earth's shadow, and be eclipsed at every Full; but with this difference, that she would be totally darkened for above an hour and half; whereas the Sun never was above four minutes totally eclipsed by the interposition of 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 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 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 we have so many New and Full Moons without Eclipses.

Fig. I.

PLATE X.

Line of the Nodes.

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 the *Line of the Nodes*, which is carried almost parallel to itself round the Sun in a year. 159

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 of 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 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.

Fig. I and II.

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

PLATE X.

When the Earth has gone half round the Ecliptic from *E* to *G*, the line of the Nodes *VGX* 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*. 160

When the Earth comes to *H* the New Moon falls not at *m* in a plane coincident with the Ecliptic *CD*, 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 *CD*; 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.

The Moon's ascending and descending Node.

Her North and South Latitude.

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

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.

319. If the line of the Nodes, like the Earth's Axis, was carried parallel to itself round the Sun, there would be just half a year between the conjunctions of the Sun and Nodes. But the Nodes shift backward, or contrary to the Earth's annual motion, $19\frac{1}{3}$ degrees every year; and therefore the same Node comes round to the Sun 19 days sooner every year than on the year before. Consequently, from the time that the ascending Node *X* (when the Earth is at *E*) passes by the Sun as seen from the Earth, it is only 173 days (not half a year) till the descending Node *V* passes by him. Therefore, in whatever time of the year we have Eclipses of the Luminaries about either Node, we may be sure that in 173 days afterward we shall have Eclipses about the other Node. And when at any time of the year the line of the Nodes is in the situation *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 compleat number of Lunations were finished without a fraction. But this never happens, for if the Sun and Moon should start from a conjunction with 161

either of the Nodes in any point of the Ecliptic, whilst the same Node is going round to that point again the Earth performs 18 annual revolutions about the Sun and 222 Degrees (or 7 Signs 12 Degrees) over; and the Moon 230 Lunations or Courses from Change to Change and 85 Degrees (or 2 Signs 25 Degrees) over; so that the Sun will be 138 Degrees from the same Node when it comes round, and the Moon 85 Degrees from the Sun. Hence, the period of Eclipses and revolution of the Nodes are completed in different times.

A period of Eclipses.

The defects of it.

320. In 18 years 10 days 7 hours 43 minutes after the Sun Moon and Nodes have been in a line of conjunction, they come very near to a conjunction again: only, if the conjunction from which you reckon falls in a leap-year, the return of the conjunction will be one day later. Therefore, if to the [65]mean time of any Eclipse of the Sun or Moon in leap-year, you add 18 years 11 days 7 hours 43 minutes; or in a common year a day less, you will have the mean time of that Eclipse returned again for some ages; though not always visible, because the 7 hours 43 minutes may shift a solar Eclipse into the night, and a lunar Eclipse into the day. In this period there are just 223 Lunations, and the Sun is again within half a degree of the same Node, but short of it. Therefore, although this period will serve tolerably well for some ages to examine Eclipses by, it cannot hold long; because half a degree from the Node sets the Moon 2½ minutes of a degree from the Ecliptic. And as the Moon's mean distance from the Earth is equal to 60 Semidiameters of the Earth, every minute of a degree at that distance is equal to 60 geographical miles, or one degree on the Earth; consequently 2½ minutes of declination from the Ecliptic in the Moon's Orbit, is equal to 150 such miles, or 2½ degrees on the Earth. Consequently, if the Moon be passing by her ascending Node at the end of this period, her shadow will go 150 miles more southward on the Earth than it did at the beginning thereof. If the Moon be passing by her descending Node, her shadow will go 150 miles more northward: and in either case, in 500 years the shadow will have too great a Latitude to touch the Earth. So that any Eclipse of the Sun, which begins (for example) to touch the Earth at the south Pole (and that must be when the Moon is 17 degrees past her descending Node) will advance gradually northward in every return for about a thousand years, and then go off at the north Pole; and cannot take such another course again in less than 11,683 years.

This falling back of the Sun and Moon in every period, with respect to the Nodes, will occasion those 162
Eclipses which happen about the ascending Node to go more southerly in each return; and those which happen about the descending Node to go more northerly: for the farther the Moon is short of the ascending Node, within the limits of Eclipses, the farther she is south of the Ecliptic; and on the contrary, the more she is short of the descending Node, the farther she is northward of the Ecliptic.

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

321. "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 [66]*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 *Æthiopian* 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 [67]Digits eclipsed on the under limb; and setting in the gulf of *Cochinchina* in the *East-Indies*.

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

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

"The next visible return will happen on *July 25, 1766*, in the evening, about four Digits eclipsed; and after two periods more, on *August* 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 10 163
Digits; but happening so near the Equinox, the center will leave every part of *Britain* to the West, and enter *Germany* at *Embden*, passing by *Venice*, *Naples*, *Grand Cairo*, and set in the gulf of *Bassora* near that city.

"It will be no more visible till 1874, when five Digits will be obscured, the center being now about to leave the Earth on *September 28*. In 1892 the Sun will go down eclipsed at *London*, and again in 1928 the passage of the center will be in the *expansum*, though there will be two Digits eclipsed at *London*, *October* the 31st of that year; and about the year 2090 the whole Penumbra will be wore off; whence no more returns of this Eclipse can happen till after a revolution 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 irregularities that may protract or lengthen this period 100 years) complete the whole

terrestrial Phenomena of any single Eclipse: and since 20 periods of 54 years each, and about 33 days, comprehend the intire extent of their revolution, 'tis 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 *September*, had its center in the *expansum*, and set about the middle 164
of its obscurity in *Britain*; it will wear in at the north Pole, and in the year 2600, or thereabouts, go off into 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 etherial circuit; and will be 4000 years before they enter the Earth any more. This grand revolution seems to have been entirely unknown to the antients.

Why our present Tables agree not with antient 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 exactly with antient 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 confirmed by undeniable proofs, that the Moon now finishes her period in less time than formerly, and will continue by the centripetal law to approach nearer and nearer the Earth, and to go sooner and sooner round it: nor will the centrifugal power be sufficient to compensate the different gravitations of such an assemblage of bodies as constitute the solar system, which would come to ruin of itself, without some new regulation and adjustment of their original motions[68].

THALES's Eclipse.

"323. We are credibly informed from the testimony of the antients, that there 165
was a total Eclipse of the Sun predicted by THALES to happen in the fourth year of the 48th [69]*Olympiad*, 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[70], 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 before it past *Sardis* and the *Asiatic* towns, where the predictor lived; because an invisible Eclipse could have been of no service to demonstrate his ability in Astronomical Sciences to his countrymen, as it could give no proof of its reality.

THUCYDIDES's Eclipse.

"324. For a farther illustration, THUCYDIDES relates, that a solar Eclipse happened on a Summer's day in the afternoon, in the first year of the *Peloponnesian* war, so great that the Stars appeared. *Rhodius* was victor in the *Olympic* games the fourth year of the said war, being also the fourth of the 87th *Olympiad*, on the 428th year 166
before CHRIST. So that the Eclipse must have happened in the 431st year before CHRIST; and by computation it appears, that on the 3d of *August* there was a signal Eclipse which would have past over *Athens*, central about 6 in the evening, but which our present Tables bring no farther than the antient *Syrtes* on the *African* coast, above 400 miles from *Athens*; which suffering in that case but 9 Digits, could by no means exhibit the remarkable darkness recited by this historian; the center therefore seems to have past *Athens* about 6 in the evening, and probably might go down about *Jerusalem*, or near it, contrary to the construction of the present Tables. I have only obviated these things by way of caution to the present Astronomers, in re-computing antient Eclipses; and refer them to examine the Eclipse of *Nicias*, so fatal to the *Athenian* fleet[71]; that which overthrew the *Macedonian* Army[72] *&c.*" So far Mr. SMITH.

The number of Eclipses.

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 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 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.

Two periods of Eclipses.

326. A longer, and consequently more exact period than the above-mentioned § 320, for comparing and examining Eclipses which happen at long intervals of time, is 57 *Julian* years 324 days 21 hours 41 minutes and 35 seconds; in which time there are just 716 mean Lunations, and the Sun is again within 5 minutes of the same Node as before. 167
But a still better period is 557 years 21 days 18 hours 30 minutes 12 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.

An account of the following catalogue of Eclipses.

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 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*[73]. 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.

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 Pflaumen* and *Jo. Stæflerinus*, to the Meridian of *Ulm*, from 1507 to 1534: *Lucas Gauricus*, to the Latitude of 45 degrees, from 1534 to 1551: *Peter Appian*, to the Meridian of *Leysing*, from 1538 to 1578: *Jo. Stæflerus* to the Meridian of *Tubing*, from 1543 to 1554: *Petrus Pitatus*, to the Meridian of *Venice* from 1544 to 1556: *Georgius-Joachimus Rheticus*, for the year 1551: *Nicholaus Simus*, to the Meridian of *Bologna*, from 1552 to 1568: *Michael Mæstlin*, to the Meridian of *Tubing*, from 1557 to 1590: *Jo. Stadius*, to the Meridian of *Antwerp*, from 1554 to 1574: *Jo. Antoninus Maginus*, to the Meridian of *Venice*, from 1581 to 1630: *David Origan*, to the Meridian of *Franckfort* on the *Oder*, from 1595 to 1664: *Andrew Argol*, to the Meridian of *Rome*, from 1630 to 1700: *Franciscus Montebrunus*, to the Meridian of *Bologna*, from 1461 to 1660: Among which, *Stadius*, *Mæstlin*, and *Maginus*, used the *Prutenic* Tables; 168
Origan the *Prutenic* and *Tychonic*; *Montebrunus* the *Lansbergian*, as likewise those of *Duret*. Almost all the rest the *Alphonsine*.

But, that the places may readily be known for which these Eclipses were computed, and from what Tables, consult the following list, in which the years *inclusive* are also set down.

From 1485	to	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 *Oder*, from the *Prutenic*.
1601		1640	*Franckfort* on *Oder*, from the *Tychonic*.
1641		1660	*Bologna*, from the *Lansbergian*.
1661		1700	*Rome*, from the *Tychonic*.

So far RICCIOLUS.

N. B. The Eclipses marked with an Asterisk are not in RICCIOLUS's catalogue; but are supplied from *L'art de verifier les Dates*.

From the beginning of the catalogue to *A. D.* 1700, the time is reckoned from the noon of the day mentioned to the noon of the following day; but from 1700 to 1800 the time is set down according to our common way of reckoning. Those marked *Pekin* and *Canton* are Eclipses from the *Chinese* chronology according to STRUYK; and throughout the Table this mark ☉ signifies *Sun*, and this ☽ *Moon*.

STRUYK's Catalogue of ECLIPSES. 169

Bef. Chr.	Eclipses of the Sun and Moon seen at		M. & D.	Middle	Digits eclipsed

				H.	M.		
721	Babylon	●	Mar. 19	10	34	Total	
720	Babylon	●	Mar. 8	11	56	1	5
720	Babylon	●	Sept. 1	10	18	5	4
621	Babylon	●	Apr. 21	18	22	2	36
523	Babylon	●	July 16	12	47	7	24
502	Babylon	●	Nov. 19	12	21	1	52
491	Babylon	●	Apr. 25	12	12	1	44
431	Athens	○	Aug. 3	6	35	11	0
425	Athens	●	Oct. 9	6	45	Total	
424	Athens	○	Mar. 20	20	17	9	0
413	Athens	●	Aug. 27	10	15	Total	
406	Athens	●	Apr. 15	8	50	Total	
404	Athens	○	Sept. 2	21	12	8	40
403	Pekin	○	Aug. 28	5	53	10	40
394	Gnide	○	Aug. 13	22	17	11	0
383	Athens	●	Dec. 22	19	6	2	1
382	Athens	●	June 18	8	54	6	15
382	Athens	●	Dec. 12	10	21	Total	
364	Thebes	○	July 12	23	51	6	10
357	Syracuse	○	Feb. 28	22	--	3	33
357	Zant	●	Aug. 29	7	29	4	21
340	Zant	○	Sept. 14	18	--	9	0
331	Arbela	●	Sept. 20	10	9	Total	
310	Sicily Island	○	Aug. 14	20	5	10	22
219	Mysia	●	Mar. 19	14	5	Total	
218	Pergamos	●	Sept. 1	rising		Total	
217	Sardinia	○	Feb. 11	1	57	9	6
203	Frusini	○	May 6	2	52	5	40
202	Cumis	○	Oct. 18	22	24	1	0
201	Athens	●	Sept. 22	7	14	8	58
200	Athens	●	Mar. 19	13	9	Total	
200	Athens	●	Sept. 11	14	48	Total	
198	Rome	○	Aug. 6	----		----	
190	Rome	○	Mar. 13	18	--	11	0
188	Rome	○	July 16	20	38	10	48
174	Athens	●	Apr. 30	14	33	7	1
168	Macedonia		June	8	2	Total	

		●	21				
141	Rhodes	●	Jan. 27	10	8	3	26
104	Rome	☼	July 18	22	0	11	52
63	Rome	●	Oct. 27	6	22	Total	
60	Gibralter	☼	Mar. 16	setting		Central	
54	Canton	☼	May 9	3	41	Total	
51	Rome	☼	Mar. 7	2	12	9	0
48	Rome	●	Jan. 18	10	0	Total	
45	Rome	●	Nov. 6	14	--	Total	
36	Rome	☼	May 19	3	52	6	47
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.	Eclipses of the Sun and Moon seen at		M. & D.	Middle H.	Middle M.	Digits eclipsed	
1	Pekin	☼	June 10	1	10	11	43
5	Rome	☼	Mar. 28	4	13	4	45
14	Panonia	●	Sept. 26	17	15	Total	
27	Canton	☼	July 22	8	56	Total	
30	Canton	☼	Nov. 13	19	20	10	30
40	Pekin	☼	Apr. 30	5	50	7	34
45	Rome	☼	July 31	22	1	5	17
46	Pekin	☼	July 21	22	25	2	10
46	Rome	●	Dec. 31	9	52	Total	
49	Pekin	☼	May 20	7	16	10	8
53	Canton	☼	Mar. 8	20	42	11	6
55	Pekin	☼	July 12	21	50	6	40
56	Canton	☼	Dec. 25	0	28	9	20
59	Rome	☼	Apr. 30	3	8	10	38
60	Canton	☼	Oct. 13	3	31	10	30
65	Canton	☼	Dec. 15	21	50	10	23
69	Rome	●	Oct. 18	10	43	10	49
70	Canton	☼	Sept. 22	21	13	8	26
71	Rome	●	Mar. 4	8	32	6	0
95	Ephesus	☼	May 21	----		1	0
125	Alexandria	●	April 5	9	16	1	44

133	Alexandria	●	May 6	11	44	Total	
134	Alexandria	●	Oct. 20	11	5	10	19
136	Alexandria	●	Mar. 5	15	56	5	17
237	Bologna	○	Apr. 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
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	●	Mar. 1	13	2	11	11
464	Chaves	○	July 19	19	1	10	15
484	Constantinople	○	Jan. 13	19	53	0	0
486	Constantinople	○	May 19	1	10	5	15
497	Constantinople	○	Apr. 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	○	Mar. 18	22	6	10	0
603	Paris	○	Aug. 12	3	3	11	20
622	Constantinople	●	Febr. 1	11	28	Total	
644	Paris	○	Nov. 5	0	30	9	53
680	Paris	●	June 17	12	30	Total	
683	Paris	●	April	11	30	Total	

			16				
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	●	Mar. 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	
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	55
820	Paris	●	Nov. 23	6	26	Total	
824	Paris	●	Mar. 18	7	55	Total	
828	Paris	●	June 30	15	--	Total	
828	Paris	●	Dec. 24	13	45	Total	
831	Paris	●	April 30	6	19	11	8
831	Paris	☼	May 15	23	--	4	24
831	Paris	●	Oct. 24	11	18	Total	

832	Fulda	●	Apr. 18	9	0	Total	
840	Paris	◎	May 4	23	22	9	20
841	Paris	◎	Oct. 17	18	58	5	24
842	Paris	●	Mar. 29	14	38	Total	
843	Paris	●	Mar. 19	7	1	Total	
861	Paris	●	Mar. 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	●	Mar. 31	15	17	Total	
934	Paris	◎	Apr. 16	4	30	11	36
939	Paris	◎	July 18	19	45	10	7
955	Paris	●	Sept. 4	11	18	Total	
961	R pl prhemes	◎	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	●	Apr. 12	10	22	9	5
990	Fulda	●	Oct. 6	15	4	11	10
990	Constantinople	◎	Oct. 21	0	45	10	5
995	Augsburgh	●	July 14	11	27	Total	
1009	Ferrara	●	Oct. 6	11	38	Total	
1010	Messina	◎	Mar. 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	
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	Gemblours	Feb. 10	16	4	Total		
1096	Augsburgh	Aug. 6	8	21	Total		
1098	Augsburgh	Dec. 25	1	25	10	12	
1099	Naples	Nov. 30	4	58	Total		
1103	Rome	Sept. 17	10	18	Total		
1106	Erfurd	July 17	11	28	11	54	
1107	Naples	Jan. 10	13	16	Total		
1109	Erfurd	May 31	1	30	10	20	
1110	London	May 5	10	51	Total		
1113	Jerusalem	Mar. 18	19	0	9	12	
1114	London	Aug. 17	15	5	Total		
1117	Trier	June 15	13	26	Total		
1117	Trier	Dec. 10	12	51	Total		
1118	Naples	Nov. 29	15	46	4	11	171
1121	Trier	Sept. 27	16	47	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	March 3	8	14	Total		
1133	Prague	Feb. 20	16	41	3	23	
1135	London	Dec. 22	20	11	Total		
1142	Rome	Feb. 11	14	17	8	30	
1143	Rome	Feb. 1	6	36	Total		
1147	Auranches	Oct. 25	22	38	7	20	
1149	Bary	Mar. 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	
1154	Paris	●	Dec. 21	8	30	4	42
1155	Auranches	●	June 10	8	45	0	53
1160	Rome	●	Aug. 18	7	53	6	49
1161	Rome	●	Aug. 7	8	15	Total	
1162	Erfurd	●	Feb. 1	6	40	5	56
1162	Erfurd	●	July 27	12	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	●	April 25	7	2	8	6
1176	Auranches	●	Oct. 19	11	20	8	53
1178	Cologne	●	March 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	Mar. 16	15	35	Total	
1216	Acre	Feb. 18	21	15	11	36
1216	Acre	March 5	9	38	7	4
1218	Damietta	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
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	Mar. 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	Mar. 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	Apr. 12	6	55	10	6
1280	London	Mar. 17	12	12	Total	
1284	Reggio	Dec.	16	11	9	13

1290	Wittemburg	☼	Sept. 4	19	37	10	30
1291	London	●	Feb. 14	10	2	Total	
1302	Constantinople	●	Jan. 14	10	25	Total	
1307	Ferrara	☼	April 2	22	18	0	54
1309	London	●	Feb. 24	17	44	Total	
1309	Lucca	●	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	☼	Apr. 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	--
1333	Wittemburg	☼	May 14	3	--	10	18
1334	Cesena	●	Apr. 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	In China	●	Jan. 16	8	27	Total	
1389	Eugibin	●	Nov. 3	17	5	Total	
1396	Augsburg	☼	Jan. 11	0	16	6	22
1396	Augsburg	●	June 21	11	10	Total	

172

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	☼	Apr. 15	3	1	10	48
1410	Vienna	●	Mar. 20	13	13	Total	
1415	Wittemburg	☼	June 6	6	43	Total	
1419	Franckfort	☼	Mar. 25	22	5	1	45
1421	Forli	●	Feb. 17	8	2	Total	
1422	Forli	●	Feb. 6	8	26	11	7
1424	Wittemburg	☼	June 26	3	57	11	20
1431	Forli	☼	Feb. 12	2	4	1	39
1433	Wittemburg	☼	June 17	5	--	Total	
1438	Wittemburg	☼	Sept. 18	20	59	8	7
1442	Rome	●	Dec. 17	3	56	Total	
1448	Tubing	☼	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	●	Apr. 21	12	43	Total	
1465	Rome	☼	Sept. 20	5	15	8	46
1465	Rome	●	Oct. 4	5	12	Total	
1469	Rome	●	Jan. 27	7	9	Total	
1485	Norimburg	☼	Mar. 16	3	53	11	--

The following ECLIPSES are all taken from RICCIOLUS, except those marked with an Asterisk, which are from *L'Art de verifier les Dates*.

Aft. Chr.		M. & D.	Middle H.	Middle M.	Digits eclipsed	
1486	●	Feb. 18	5	41	Total	
1486	☼	Mar. 5	17	43	9	0
1487	●	Feb. 7	15	49	Total	
1487	☼	July 20	2	6	7	0
1488	●	Jan. 28	6	--	*	

1488	☼	July 8	17	30	4	0
1489	●	Dec. 7	17	41	Total	
1490	☼	May 19	Noon		*	
1490	●	June 2	10	6	Total	
1490	●	Nov. 26	18	25	Total	
1491	☼	May 8	2	19	9	0
1491	●	Nov. 15	18	--	*	
1492	☼	Apr. 26	7	--	*	
1492	☼	Oct. 20	23	--	*	
1493	●	April 1	14	0	Total	
1493	☼	Oct. 10	2	40	8	0
1494	☼	Mar. 7	4	12	4	0
1494	●	Mar. 21	14	38	Total	
1494	●	Sept. 14	19	45	Total	
1495	●	Mar. 10	16	--	*	
1495	☼	Aug. 19	17	--	*	
1496	●	Jan. 29	14	--	*	
1497	●	Jan. 18	6	38	Total	
1497	☼	July 29	3	2	3	0
1499	●	June 22	17	--	*	
1499	☼	Aug. 23	18	--	*	
1499	●	Nov. 17	10	--	*	
1500	☼	Mar. 27	In the Night			
1500	●	Apr. 11	At Noon			
1500	●	Oct. 5	14	2	10	0
1501	●	May 2	17	49	Total	
1502	☼	Sept. 30	19	45	10	0
1502	●	Oct. 15	12	20	2	0
1503	●	Mar. 12	9	--	*	
1503	☼	Sept. 19	22	--	*	
1504	●	Feb. 29	13	36	Total	
1504	☼	Mar. 16	3	--	*	
1505	●	Aug. 14	8	18	Total	
1506	●	Feb. 7	15	--	*	
1506	☼	July 20	3	11	2	0
1506	●	Aug. 3	10	--	*	
1507	☼	Jan. 12	19	--	*	
1508	☼	Jan. 2	4	--	*	
1508	☼	May 29	6	--	*	
1508	●	June 12	17	40	Total	
1509	●	June 2	11	11	7	0
1509	☼	Nov. 11	22	--	*	
1510	●	Oct. 16	19	--	*	
1511	●	Oct. 6	11	50	Total	
1512	●	Sept. 25	3	56	Total	
1513	☼	Mar. 7	0	30	6	0
1513	☼	Aug. 30	1	--	*	
1515	●	Jan. 29	15	18	Total	
1516		Jan. 19	6	0	Total	

	●					
1516	●	July 13	11	37	Total	
1516	☼	Dec. 23	3	47	3	0
1517	☼	June 18	16	--	*	
1517	●	Nov. 27	19	--	*	
1518	●	May 24	11	19	9	11
1518	☼	June 7	17	56	11	0
1519	☼	May 28	1	--	*	
1519	☼	Oct. 23	4	33	6	0
1519	●	Nov. 6	6	24	Total	
1520	●	May 2	7	--	*	
1520	☼	Oct. 11	5	22	3	
1520	●	Oct. 25	19	--	*	
1520	●	Mar. 21	17	--	*	
1521	☼	April 6	19	--	*	
1521	☼	Sept. 30	3	--	*	
1522	●	Sept. 5	12	17	Total	
1523	●	Mar. 1	8	26	Total	
1523	●	Aug. 25	15	24	Total	
1524	☼	Feb. 4	1	--	*	
1524	●	Aug. 16	16	--	*	
1525	☼	Jan. 23	4	--	*	
1525	●	July 4	10	10	Total	
1525	●	Dec. 29	10	46	Total	
1526	●	Dec. 18	10	30	Total	
1527	☼	Jan. 2	3	--	*	
1527	●	Dec. 7	10	--	*	
1528	☼	May 17	20	--	*	
1529	●	Oct. 16	20	23	11	55
1530	☼	Mar. 28	18	23	8	24
1530	●	Oct. 6	12	11	Total	
1531	●	April 1	7	--	*	
1532	☼	Aug. 30	0	49	3	35
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	
1537	☼	June 7	7	--	*	
1537	●	Nov. 16	14	56	Total	
1538	●	May 13	14	24	3	0
1538	●	Nov. 6	5	31	3	37
1539	☼	Apr. 18	4	33	9	0
1540	☼	April 6	17	15	Total	

1541	●	Mar. 11	16	34	Total	
1541	☼	Aug. 21	0	56	3	0
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	☼	April 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	--	*	
1556	☼	Nov. 1	18	0	9	41
1556	●	Nov. 16	12	44	6	55
1557	☼	Oct. 20	20	--	*	
1558	●	April 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. 4	7	--	*	
1561	☼	Feb. 13	19	--	*	
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	☼	April 8	23	4	9	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	--	*	
1575	☼	Nov. 2	5	--	*	
1576	●	Oct. 7	9	45	------	
1577	●	April 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 19	17	5	7	5
1583	●	Nov. 28	21	51	Total	
1584	☼	May 9	18	20	3	36
1584	●	Nov. 17	14	15	Total	
1585	☼	Apr. 29	7	53	11	7
1585	●	May 13	5	2	6	54
1586	●	Sept. 27	8	--	*	
1586	☼	Oct. 12	Noon		*	
1587	●	Sept. 16	9	28	10	2
1588	☼	Feb. 26	1	23	1	3
1588	●	Mar. 12	14	14	Total	
1588	●	Sept. 4	17	30	Total	
1589	☼	Aug. 10	18	--	*	
1589	☼	Aug. 25	8	1	3	54
1590	☼	Feb. 4	5	--	*	
1590	●	July 16	17	4	3	54
1590	☼	July 30	19	57	10	27
1591	●	Jan. 9	6	21	9	40
1591	●	July 6	5	8	Total	
1591	☼	July 20	4	2	1	0
1591	●	Dec. 29	16	11	Total	
1592	●	June 24	10	13	8	58
1592	●	Dec. 18	7	24	5	54
1593	☼	May 30	2	30	2	38

1594	☼	May 19	14	58	10	23
1594	●	Oct. 28	19	15	9	40
1595	☼	April 9	Ter. de Fuego			
1595	●	Apr. 24	4	12	Total	
1595	☼	May 7	22	--	*	
1595	☼	Oct. 3	2	4	5	18
1595	●	Oct. 18	20	47	Total	
1596	☼	Mar. 28	In Chili			
1596	●	Apr. 12	8	52	6	4
1596	☼	Sept. 21	In China			
1596	●	Oct. 6	21	15	3	33
1597	☼	Mar. 17	St. Pet. Isle			
1597	☼	Sept. 11	Picora		9	49
1598	●	Feb. 20	18	12	10	55
1598	☼	Mar. 6	22	12	11	57
1598	●	Aug. 16	8	15	Total	
1598	☼	Aug. 31	Magel.		8	34
1599	●	Feb. 10	17	21	Total	
1599	☼	July 22	4	31	4	18
1599	●	Aug. 6	------		Total	
1600	☼	Jan. 15	Java		11	48
1600	●	Jan. 30	6	40	2	58
1600	☼	July 10	2	10	5	39
1601	☼	Jan. 4	Ethiop.		9	40
1601	●	June 15	6	18	4	52
1601	☼	June 29	China		4	29
1601	●	Dec. 9	7	6	10	53
1601	☼	Dec. 24	2	46	9	52
1602	☼	May 21	Greenl.		2	41
1602	●	June 4	7	18	Total	
1602	☼	June 19	N. Gra.		5	43
1602	☼	Nov. 13	Magel.		3	--
1602	●	Nov. 28	10	2	Total	
1603	☼	May 10	China		11	21
1603	●	May 24	11	41	7	59
1603	☼	Nov. 3	Rom. I.		11	17
1603	●	Nov. 18	7	31	3	26
1604	☼	Apr. 29	Arabia		9	32
1604	☼	Oct. 22	Peru		6	49
1605	●	April 3	9	19	11	49
1605	☼	Apr. 18	Madag.		5	31
1605	●	Sept. 27	4	27	9	26
1605	☼	Oct. 12	2	32	9	24
1606	☼	Mar. 8	Mexico		6	0
1606	●	Mar. 24	11	17	Total	
1606	☼	Sept. 2	Magel.		6	40
1606	●	Sept. 16	15	6	Total	
1607	☼	Feb. 25	21	48	1	13
1607	●	Mar. 13	6	36	1	22
1607	☼	Sept. 5	15	40	4	7

174

1608	☼	Feb. 15	at the Antipo.			
1608	●	July 27	0	30	1	53
1608	☼	Aug. 9	4	39	0	40
1609	●	Jan. 19	15	21	10	32
1609	☼	Feb. 4	Fuego		5	22
1609	●	July 16	12	8	Total	
1609	☼	July 30	Canada		4	10
1609	☼	Dec. 26	19	--	5	50
1610	●	Jan. 9	1	31	Total	
1610	☼	June 20	Java		10	46
1610	●	July 5	16	58	11	13
1610	☼	Dec. 15	Cyprus		4	50
1610	●	Dec. 29	16	47	4	23
1611	☼	June 10	Califor.		11	30
1612	●	May 14	10	38	7	22
1612	☼	May 29	23	38	7	14
1612	●	Nov. 8	3	22	9	49
1612	☼	Nov. 22	Magel.		9	0
1613	☼	Apr. 20	Magellanica			
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	●	Apr. 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			
1616	●	Mar. 3	1	58	Total	
1616	☼	Mar. 17	Mexico		6	47
1616	●	Aug. 26	15	33	Total	
1616	☼	Sept. 10	Magel.		10	33
1617	☼	Feb. 5	Magellanica			
1617	●	Feb. 20	1	49	Total	
1617	☼	Mar 6	22	--	*	
1617	☼	Aug. 1	Biarmia			
1617	●	Aug. 16	8	22	Total	
1618	☼	Jan. 26	Magellanica			
1618	●	Feb. 9	3	29	2	57
1618	☼	July 21	Mexico		------	
1619	☼	Jan. 15	California			
1619	●	June 26	12	40	3	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	Magellanica			

1621	☼	May 20	14	54	10	44
1621	●	June 3	19	42	9	53
1621	☼	Nov. 13	Magellanica			
1621	●	Nov. 28	15	43	3	38
1622	☼	May 10	C. Verd		11	52
1622	☼	Nov. 2	Malacca 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	Magellanica			
1624	●	Sept. 26	8	55	Total	
1625	☼	Mar. 8	Florida			
1625	●	Mar. 23	14	11	2	11
1625	☼	Sept. 1	St. Peter's Isl.			
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
1627	☼	Feb. 15	Magellanica			
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	C Good Hope			
1628	●	July 16	11	26	Total	
1628	☼	Dec. 25	In England			
1629	●	Jan. 9	1	36	4	27
1629	☼	June 21	Ganges		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	C Good Hope			
1631	●	Nov. 8	12	0	Total	
1632	☼	Apr. 19	C Good Hope			
1632	●	May 4	1	24	6	35
1632	☼	Oct. 13	Mexico		8	37
1632	●	Oct. 27	12	23	5	31
1633	☼	April 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	C.G.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
1637	☼	Jan. 26	Camboya			
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	Magellan		9	5
1638	☼	Dec. 5	Magellan		2	10
1638	●	Dec. 20	15	16	Total	
1639	☼	Jan. 4	Tartary		0	30
1639	☼	June 1	5	59	10	40
1639	●	June 15	2	41	11	9
1639	☼	Nov. 24	Magel.		11	0
1639	●	Dec. 9	11	57	3	46
1640	☼	May 20	N. Spa.		10	30
1640	☼	Nov. 13	Peru		10	36
1641	●	Apr. 25	1	2	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	Magellan			
1642	●	Oct. 7	16	45	Total	
1643	☼	Mar. 19	13	53	------	
1643	●	April 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

175

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	5	19
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	☼	April 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	49	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	21	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	------	
1661	○	Sept. 23	1	36	11	19
1661	●	Oct. 7	14	51	7	4
1662	○	Mar. 19	15	8	------	
1662	○	Apr. 12	1	8	------	
1663	○	Feb. 21	16	11	3	14
1663	○	Mar. 9	5	47	------	
1663	●	Aug. 18	8	45	Total	
1663	○	Sept. 1	8	8	------	
1664	○	Jan. 27	20	40	------	
1664	●	Feb. 11	3	16	------	
1664	○	July 22	14	48	------	
1664	○	Aug. 20	22	10	------	
1665	●	Jan. 30	18	47	4	34
1665	○	July 12	7	48	------	
1665	●	July 26	13	31	0	10
1666	○	Jan. 4	21	33	------	
1666	○	July 1	19	0	11	10
1667	●	June 5	Noon		------	
1667	○	July 21	2	32	------	
1667	○	Nov. 15	11	30	------	
1668	○	May 10	Setting		------	
1668	●	May 25	16	26	9	32
1668	○	Nov. 4	2	53	9	50
1668	●	Nov. 18	3	54	6	45
1669	○	Apr. 29	18	18	------	
1669	○	Oct. 24	10	13	------	
1670	○	Apr. 19	7	0	------	
1670	○	Sept. 10	19	0	------	
1670	●	Sept. 28	15	43	9	7
1670	○	Oct. 13	12	5	------	
1671	○	April 8	23	29	------	
1671	○	Sept. 2	21	25	------	
1671	●	Sept. 18	7	44	Total	
1672	○	Feb. 28	3	38	------	
1672	●	Mar. 13	3	17	------	
1672	○	Aug. 22	6	43	------	
1672	●	Sept. 6	18	54	------	
1673	○	Feb. 16	7	29	------	
1673	○	Aug. 11	21	44	------	
1674	●	Jan. 21	18	22	11	21
1674	○	Feb. 5	9	4	------	
1674	●	July 17	9	40	Total	
1675	●	Jan. 11	8	29	Total	
1675	○	Jan. 25	10	36	------	
1675	●	July 6	16	31	Total	
1676	○	June 10	21	26	4	34

1676	●	June 25	6	26	------	
1676	☼	Dec. 4	20	52	------	
1677	☼	Nov. 24	12	5	------	
1677	●	May 16	16	25	8	15
1678	●	May 6	5	30	------	
1678	●	Oct. 29	9	17	Total	
1679	☼	Apr. 10	21	0	------	
1679	●	Apr. 25	11	53	5	47
1680	☼	Mar. 29	23	22	------	
1680	☼	Sept. 22	7	57	------	
1681	●	Mar. 4	Noon		------	
1681	☼	Mar. 10	13	43	------	
1681	●	Aug. 28	15	22	10	35
1681	☼	Sept. 11	15	43	------	
1682	●	Feb. 21	12	28	Total	
1682	●	Aug. 17	18	56	Total	
1683	☼	Jan. 27	1	35	10	30
1683	●	Feb. 9	3	39	------	
1683	●	Aug. 6	20	36	------	
1684	☼	Jan. 16	6	34	------	
1684	●	June 26	15	18	1	35
1684	☼	July 12	3	26	Total	
1684	●	Dec. 21	11	18	9	45
1685	☼	Jan. 4	16	0	------	
1685	●	June 16	6	0	------	
1685	●	Dec. 10	11	26	Total	
1686	☼	May 21	17	9	------	
1686	●	June 6	Noon		------	
1686	●	Nov. 29	12	22	Total	
1687	☼	May 11	1	--	*	
1687	●	May 26	14	--	*	
1687	●	Apr. 15	7	4	6	49
1688	☼	Apr. 29	16	27	------	
1688	●	Oct. 9	Noon		------	
1688	☼	Oct. 25	19	40	------	
1689	●	April 4	7	42	Total	
1689	●	Sept. 28	15	46	Total	
1690	☼	Mar. 10	--	--	------	
1690	●	Mar. 24	11	14	5	43
1690	☼	Sept. 3	--	--	------	
1690	●	Sept. 18	2	42	------	
1691	☼	Feb. 27	17	30	------	
1691	☼	Aug. 23	5	51	------	
1692	●	Feb. 2	3	20	------	
1692	☼	Feb. 16	17	31	------	
1692	●	July 27	16	9	Total	
1693	●	Jan. 21	17	25	Total	
1693	●	July 17	Noon		------	

1694	●	Jan. 11	Noon		------	
1694	☼	June 22	4	22	6	22
1694	●	July 6	13	51	0	47
1695	☼	May 11	6	3	------	
1695	●	May 28	Noon		------	
1695	●	Nov. 20	8	0	6	55
1695	☼	Dec. 5	17	7	------	
1696	●	May 16	12	45	Total	
1696	☼	May 30	12	56	------	
1696	●	Nov. 8	17	30	Total	
1696	☼	Nov. 23	17	32	------	
1697	☼	Apr. 20	14	32	------	
1697	●	May 5	18	27	------	
1697	●	Oct. 29	8	44	8	54
1698	☼	Apr. 10	9	13	------	
1698	☼	Oct. 3	15	29	------	
1699	●	Mar. 15	8	14	9	7
1699	☼	Mar. 30	22	0	------	
1699	●	Sept. 8	23	22	------	
1699	☼	Sept. 23	22	38	9	58
1700	●	Mar. 4	20	11	------	
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.	
1701	●	Feb. 22	11 A.	
1703	●	Jan. 3	7 M.	
1703	●	June 29	1 M.	*T.*
1703	●	Dec. 23	7 M.	*T.*
1704	●	Dec. 11	7 M.	
1706	●	Apr. 28	2 M.	
1706	☼	May 12	10 M.	
1706	●	Oct. 21	7 A.	
1707	●	Apr. 17	2 M.	*T.*
1708	●	April 5	6 M.	
1708	☼	Dec. 14	8 M.	
1708	●	Sept. 29	9 A.	
1709	☼	Mar. 11	2 A.	
1710	●	Feb. 13	11 A.	
1710	☼	Feb. 28	1 A.	
1711	☼	July 15	8 A.	
1711	●	July 29	6 A.	*T.*
1712	●	Jan. 23	8 A.	
1713	●	June 8	6 A.	
1713	●	Dec. 2	4 M.	
1715	☼	May 3	9 M.	*T.*

1715	●	Nov. 11	5 M.	
1717	●	Mar. 27	3 M.	
1717	●	May 20	6 A.	
1718	●	Sept. 9	8 A.	*T.*
1719	●	Aug. 29	9 A.	
1721	●	Jan. 13	3 A.	
1722	●	June 29	3 M.	
1722	☼	Dec. 8	3 A.	
1722	●	Dec. 22	4 A.	
1724	☼	May 22	7 A.	*T.*
1724	●	Nov. 1	4 M.	
1725	●	Oct. 21	7 A.	
1726	☼	Sept. 25	6 A.	
1726	●	Oct. 11	5 M.	
1727	☼	Sept. 15	7 M.	
1729	●	Feb. 13	9 A.	*T.*
1729	●	Aug. 9	1 M.	
1730	●	Feb. 4	4 M.	
1731	●	June 20	2 M.	
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	6 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.	
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.	
1781	☼	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.	
1789	●	Nov. 2	12 A.	
1790	●	Apr. 28	12 A.	*T.*
1790	●	Oct. 23	1 M.	*T.*
1791	○	April 3	1 A.	
1791	●	Oct. 12	3 M.	
1792	○	Sept. 16	11 M.	
1793	●	Feb. 25	10 A.	
1793	○	Sept. 5	3 A.	
1794	○	Jan. 31	4 A.	
1794	●	Feb. 14	11 A.	*T.*
1794	○	Aug. 25	5 A.	
1795	●	Feb. 4	1 M.	
1795	○	July 16	9 M.	
1795	●	July 31	8 A.	
1797	○	June 25	8 A.	
1797	●	Dec. 4	6 M.	
1798	●	May 27	7 A.	*T.*
1800	●	Oct. 2	11 A.	

328. *A List of Eclipses, and historical Events, which happened about the same Times, from* RICCIOLUS.

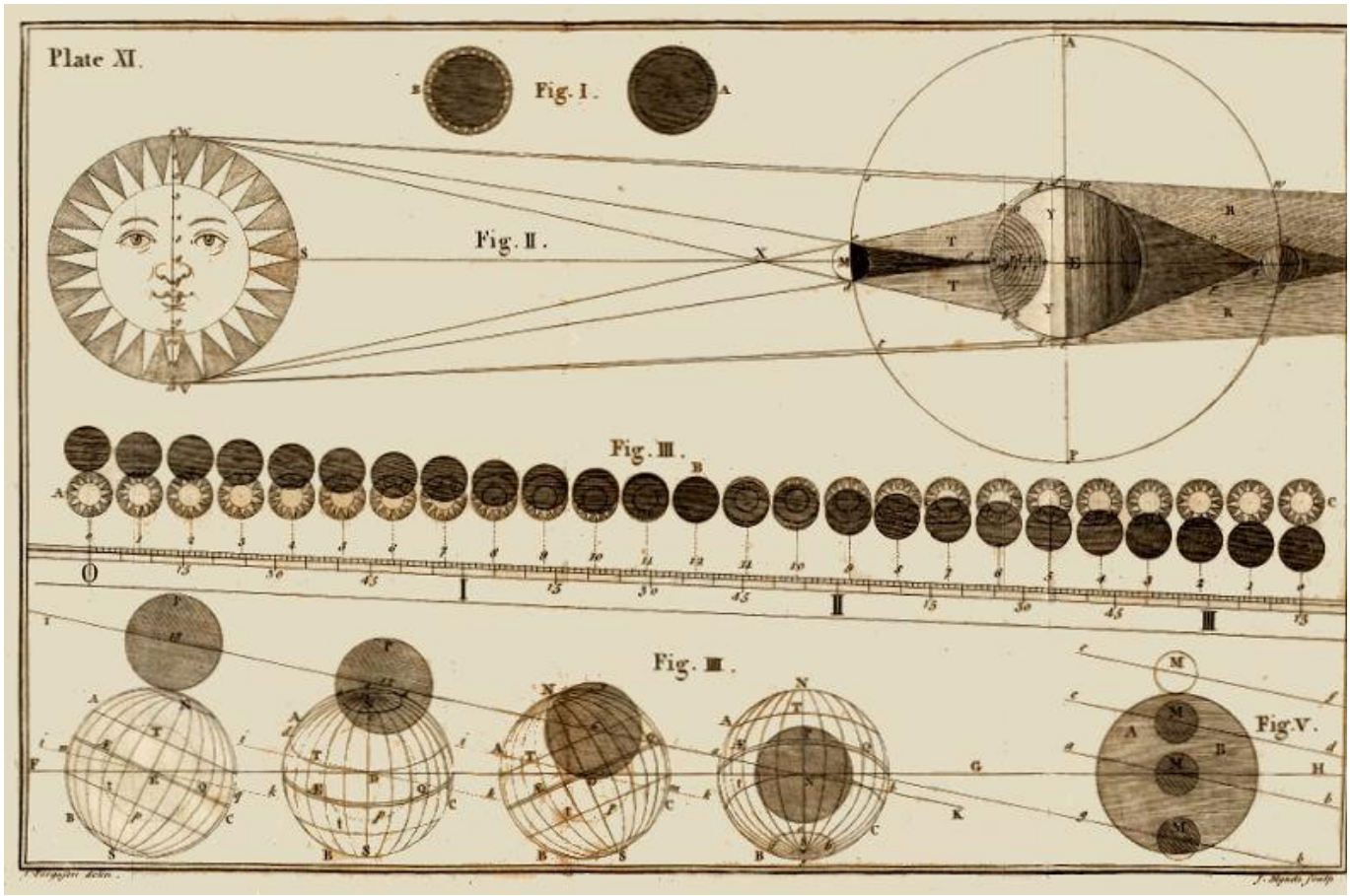
Historical Eclipses.

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*.
523	*July* 16	An Eclipse of the Moon, which was followed by the death of CAMBYSES.
502	*Nov.* 19	An Eclipse of the Moon, which was followed by the slaughter of the *Sabines*, and death of *Valerius Publicola*.
463	*April* 30	An Eclipse of the Sun. The *Persian* war, and the falling off of the *Persians* from the *Egyptians*.
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*[74].

413	*Aug.* 27	A total Eclipse of the Moon. *Nicias* with his ship destroyed at *Syracuse*.
394	*Aug.* 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 murther 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	*Aug.* 2	A terrible Eclipse of the Sun. The Stars were seen. A schism in the church, occasioned by there being three Popes at once.

Plate XI.



J. Ferguson delin.

J. Mynde Sculp.

The superstitious notions of the antients with regard to Eclipses.

PLATE XI.

329. I have not cited one half of RICCIOLUS's list of potentous Eclipses; and for the same reason that he declines giving any more of them than what that list contains: namely, that 'tis most disagreeable to dwell any longer on such nonsense, and as much as possible to avoid tiring the reader: the superstition of the antients may be seen by the few here copied. My author farther says, that there were treatises written to shew against what regions the malevolent effects of any particular Eclipse was aimed: and the writers affirmed, that the effects of an Eclipse of the Sun continued as many years as the Eclipse lasted hours; and that of the Moon as many months. 179

Very fortunate once for CHRISTOPHER COLUMBUS.

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 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. 1. v. c. ii.

Why there are more visible Eclipses of the Moon than of the Sun.

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 equally great to each of these 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.

Fig. I.

Total and annular Eclipses of the Sun.

PLATE XI.

332. The Moon's Orbit being elliptical, and the Earth in one of its focuses, she is once at her 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 on the Earth, she appears big enough to cover the whole [75]Disc of the Sun from that part on which her shadow falls; and the Sun appears totally eclipsed there, as at *A*, for some minutes: But when the Moon changes at her greatest distance from the Earth, and so near the Node that her dark shadow is directed towards the Earth, her diameter subtends a less angle than the Sun's; and therefore she cannot hide his whole Disc from any part of the Earth, nor does her shadow reach it at that time; and to the place over which the point of her shadow hangs, the Eclipse is annular as at *B*; the Sun's edge appearing like a luminous ring all around the body of the Moon. When the Change happens within 17 degrees of the Node, and the Moon at her mean distance from the Earth, the point of her shadow just touches the Earth, and she eclipseth the Sun totally to that small spot whereon her shadow falls; but the darkness is not of a moment's continuance. 180

The longest duration of total Eclipses of the Sun.

333. The Moon's apparent diameter when largest exceeds the Sun's when least only 1 minute 38 seconds of a degree: And in the greatest Eclipse of the Sun that can happen at any time and place, the total darkness continues no longer than whilst the Moon is going 1 minute 38 seconds from the Sun in her Orbit; which is about 3 minutes and 13 seconds of an hour.

To how much of the Earth the Sun may be totally or partially eclipsed at once.

334. The Moon's dark shadow covers only a spot on the Earth's surface, about 180 *English* miles broad, when the Moon's diameter appears largest 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 in 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.

Duration of general and particular Eclipses.

The Moon's dark shadow.

And Penumbra.

335. When the Penumbra first touches the Earth the general Eclipse begins: when it leaves the Earth the general Eclipse ends: from the beginning to the end the Sun appears eclipsed in some part of the Earth or other. When the Penumbra touches any place the Eclipse begins at that place, and ends when the Penumbra leaves it. When the Moon changes in the Node, the Penumbra goes over the center of the Earth's Disc as seen from the Moon; and consequently, by describing the longest line possible on the Earth, continues the longest upon it; namely, at a mean

rate, 5 hours 50 minutes: more, if the Moon be at her greatest distance from the Earth, because she then moves slowest; less, if she be at her least distance, because of her quicker motion.

Fig. II.

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 181
Wc 12 from the western edge of the Sun at *W*, touching the western edge of the Moon at *c* and the Earth at *12*: draw also the right line *Vd 12* from the eastern edge of the Sun at *V*, touching the eastern edge of the Moon at *d* and the Earth at *12*: the dark space *ce 12 d* included between those lines is the Moon's shadow, ending in a point at *12* where it touches the Earth; because in this case the Moon is supposed to change at *M* in the middle between *A* the Apogee, or farthest point of her Orbit from the Earth, and *P* the 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 *WXdh* and *VXcg*, touching the contrary sides of the Sun and Moon, and ending on the Earth at *a* and *b*: draw also the right line *SXM 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 *WXdh* and *VXcg* to revolve on the line *SXM 12* as an Axis, and their points *a* and *b* will describe the limits of the Penumbra *TT* on the Earth's surface, including the large space *a0b12a*; within which the Sun appears more or less eclipsed as the places are more or less distant from the verge of the Penumbra *a0b*.

Digits, what.

Draw the right line *y 12* across the Sun's Disc, and parallel to the plane of the Moon's Orbit; divide this line into twelve equal parts, as in the Figure, for the twelve [76]Digits of the Sun's diameter: and at equal distances from the center of the Penumbra *TT* to its edge on the Earth, or from *12* to *0*, draw twelve concentric Circles, as marked with the numeral Figures *1 2 3 4* &c. and remember that the Moon's motion in her Orbit *AMP* is from west to east, as from *s* to *t*. Then,

The different phases of a solar Eclipse.

PLATE XI.

Fig. III.

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 182
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 state 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, 8 Digits; and in an hour and thirty-seven minutes, 12 Digits.

Fig. II.

The Velocity of the Moon's shadow on the Earth.

Fig. IV.

337. By Fig. II it is plain, that the Sun is totally or centrally eclipsed but to a small part of the Earth at any time; because the dark conical shadow *e* of the Moon *M* falls but on a small part of the Earth: and that the partial Eclipse is confined at that time to the space included by the Circle *a 0 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* of the Earth, because the Moon is not between the Sun and 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, altho' 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 3 minutes and 13 seconds of time, 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 $30\frac{1}{2}$ minutes of a degree every hour at a mean rate; but so much of the Moon's Orbit is equal to $30\frac{1}{2}$ degrees of a great Circle on the Earth, § 320; and therefore the Moon's shadow goes $30\frac{1}{2}$ degrees or 1830 geographical miles on the Earth in an hour, or $30\frac{1}{2}$ miles in a minute, which is almost four times as swift as the motion of a cannon-ball.

PLATE XI.

Fig. IV.

Phenomena of the Earth as seen from the Sun or New Moon

338. As seen from the Sun or Moon, the Earth's Axis appears differently 183
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; *N S* its Axis, *N* the North Pole, *S* the South Pole, *Æ Q* the Equator, *T* the Tropic of Cancer, *t* the Tropick of Capricorn, and *ABC* the Circumference of the Earth's enlightened Disc as seen from the Sun or New Moon at these times. The

at different times of the year.

Earth's Axis has the position *NES* at the vernal Equinox, lying towards 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 directly over *E*, where the Ecliptic *FG* intersects the Equator *Æ*. At the Summer Solstice, the Earth's Axis has the position *NDS*; and that part of the Ecliptic *FG* in which the Moon is then New, touches the Tropic of Cancer *T* at *D*. The North Pole *N* at that time inclining $23\frac{1}{2}$ degrees towards the Sun, falls so many degrees within the Earth's enlightened Disc, because the Sun is then vertical to *D*, $23\frac{1}{2}$ degrees north of the Equator *ÆQ*; and the Equator with all its parallels seem elliptic curves bending downward, or towards the South Pole as seen from the Sun: which Pole, together with $23\frac{1}{2}$ degrees all round it, is hid behind the Disc in the dark Hemisphere of the Earth. At the autumnal Equinox the Earth's Axis has the position *NOS*, 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 *ÆQ*. 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 *NNS*; when its South Pole *S* inclining $23\frac{1}{2}$ degrees toward the Sun falls $23\frac{1}{2}$ degrees within the enlightened Disc, as seen from the Sun or New Moon which are then vertical to the Tropic of Capricorn *t*, $23\frac{1}{2}$ degrees south of the Equator *ÆQ*; and the Equator with all its parallels seem elliptic curves bending upward; the North Pole being as far hid 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.

PLATE XI.

Various positions of the Earth's Axis, as seen from the Sun at different times of the year.

339. Thus it appears, that from the vernal equinox to the autumnal, the North Pole is enlightened; and the Equator and all its parallels appear Semi-ellipses as seen from the Sun, more or less curved as the time is nearer to or farther from the Summer Solstice; and bending downwards or towards the South Pole; the reverse of which happens from the autumnal Equinox to the vernal. A little consideration will be sufficient to convince the reader, that the Earth's Axis inclines towards the Sun at the Summer Solstice; from the Sun at the Winter Solstice; and sidewise to the Sun at the Equinoxes; but towards the right hand, as seen from the Sun at the vernal Equinox; and towards the left hand at the autumnal. From the Winter to the Summer Solstice, the Earth's Axis inclines more or less to the right hand, as seen from the Sun; and the contrary from the Summer to the Winter Solstice. 184

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 fell at another, even though the Moon should always change in the Nodes and at the same hour of the day: of which indefinitely various affections, we shall only give Examples for the times of the Equinoxes and Solstices.

Fig. IV.

In the same Diagram, let *FG* be part of the Ecliptic, and *IK ik ik ik* part of the Moon's Orbit; both seen edgewise, and therefore projected into right lines; and let the intersections *N*, *O*, *D*, *E* be one and the same Node at the above times, when the Earth has the forementioned different positions; and let the spaces 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 the Penumbra touches the Tropic of Cancer *T*. At the Summer Solstice, when the Earth's Axis has the position *NDS* (*iDk* being then part of the Moon's Orbit whose Node is at *D*) the Penumbra *p* has its center on the Tropic of Cancer *T* at the middle of the general Eclipse, and then no part of it touches the Tropic of Capricorn *t*. At the autumnal Equinox the Earth's Axis has the position *NOS* (*iOk* being then part of the Moon's Orbit) and the Penumbra equally includes part of both Tropics *T* and *t* at the middle of the general Eclipse: at the vernal Equinox it does the same, because the Earth's Axis has the position *NES*: But, in the former of these two last cases, the Penumbra enters the Earth at *A*, north of the Tropic of Cancer *T*, and leaves it at *m*, south of the Tropic of Capricorn *t*; having gone over the Earth obliquely southward, as its center described the line *AOm*: whereas in the latter case the Penumbra touches the Earth at *n*, south of the Equator *ÆQ*, and describing the line *nEq* (similar to the former line *AOm* in open space) goes obliquely northward over the Earth, and leaves it at *q*, north of the Equator. 185

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 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 that Eclipses happen.

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 *P6* falls on the Earth at the middle of the general Eclipse. And lastly, when the Moon changes in the Node, the Penumbra *PN* takes the longest course possible on the Earth's Disc; its center falling on the middle thereof, at the middle of the general Eclipse. The farther the Moon changes from either Node within 17 degrees of it, the shorter is the Penumbra's continuance on the Earth, because it goes over a less portion of the Disc, as is evident by the Figure.

The Earth's diurnal motion lengthens the duration of solar Eclipses, which fall without the polar Circles.

342. The nearer that the Penumbra's center is to the Equator at the middle of the general Eclipse, the longer is the duration of the Eclipse at all those places where it is central; because, the nearer that any place is to the Equator, the greater is the Circle it describes by the Earth's motion on its Axis: and so, the place moving quicker keeps longer in the Penumbra whose motion is the same way with that of the place, tho' faster as has been already mentioned § 337. Thus, (see the Earth at *D* and the Penumbra at *12*) whilst the point *b* in the polar Circle *abcd* is carried from *b* to *c* by the Earth's diurnal motion, the point *d* on the Tropick of Cancer *T* is carried a much greater length from *d* to *D*: and therefore, if the Penumbra's center goes one time over *c* and another time over *D*, the Penumbra will be longer in passing over the moving place *d* than it was in passing over the moving place *b*. Consequently, central Eclipses about the Poles are of the shortest duration; and about the Equator of the longest. 186

And shortens the duration of some which fall within these Circles.

343. In the middle of Summer the whole frigid Zone included by the polar Circle *abcd* is enlightened; and if it then happens that the Penumbra's center goes over the north Pole, the Sun will be eclipsed much the same number of Digits at *a* as at *c*; but whilst the Penumbra moves eastward over *c* it moves westward over *a*, because with respect to the Penumbra, the motions of *a* and *c* are contrary: for *c* moves the same way with the Penumbra towards *d*, but *a* moves the contrary way towards *b*; and therefore the Eclipse will be of longer duration at *c* than at *a*. At *a* the Eclipse begins on the Sun's eastern limb, but at *c* on his western: at all places lying without the polar Circles, the Sun's Eclipses begin on his western limb, or near it, and end on or near his eastern. At those places where the Penumbra touches the Earth, the Eclipse begins with the rising Sun, on the top of his western or uppermost edge; and at those places where the Penumbra leaves the Earth, the Eclipse ends with the setting Sun, on the top of his eastern edge which is then the uppermost, just at its disappearing in the Horizon.

The Moon has no Atmosphere.

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 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.

PLATE XI.

345. Having been so prolix concerning Eclipses of the Sun, we shall drop that subject at present, and proceed to the doctrine of lunar Eclipses; which, being more simple, may be explained in less time. 187

Eclipses of the Moon.

Fig. II.

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, have been shewn already § 316, 317. Let *S* be the Sun, *E* the Earth, *RR* 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.

Why the Moon is visible in a total Eclipse.

346. The Moon when totally eclipsed, is not invisible if she be above the Horizon and the Sky be clear; but appears generally of a dusky colour like tarnished copper, which some have thought to be the Moon's native light. But the true cause of her being visible is the scattered beams of the Sun, bent into the Earth's shadow by going through the Atmosphere; which, being more dense near the Earth than at considerable heights above it,

refracts or bends the Sun's rays more inward § 179, the nearer they are passing by the Earth's surface, than those rays which go through higher parts of the Atmosphere, where it is less dense according to its height, until it be so thin or rare as to lose its refractive power. Let the Circle *fghi*, concentric to the Earth, include the Atmosphere whose refractive power vanishes at the heights *f* and *i*; so that the rays *Wfw* and *Viv* go on straight without suffering the least refraction: But all those rays which enter the Atmosphere between *f* and *k*, and between *i* and *l*, on opposite sides of the Earth, are gradually more bent inward as they go through a greater portion of the Atmosphere, until the rays *Wk* and *Vl*, touching the Earth at *m* and *n*, are bent so as to meet at *q*, a little short of the Moon; and therefore the dark shadow of the Earth is contained in the space *moqpn* where none of the Sun's rays can enter: all the rest *RR*, being mixed by the scattered rays which are refracted as above, is in some measure enlightened by them; and some of those rays falling on the Moon give her the colour of tarnished copper, or of iron almost red hot. So that if the Earth had no Atmosphere, the Moon would be as invisible in total Eclipses as she is when New. If the Moon were so near the Earth as to go into its dark shadow, suppose about *po*, she would be invisible during her stay in it; but visible before and after in the fainter shadow *RR*.

PLATE XI.

Why the Sun and Moon are sometimes visible when the Moon is totally eclipsed.

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. 188

Fig. V.

Duration of central Eclipses of the Moon.

348. When the Moon is Full at 12 degrees from either of her Nodes, she just touches the Earth's shadow but enters not into it. Let *GH* be the Ecliptic, *ef* the Moon's Orbit where she is 12 degrees from the Node at her Full; *cd* her Orbit where she is 6 degrees from the Node, *ab* her Orbit where she is Full in the Node, *AB* the Earth's shadow, and *M* the Moon. When the Moon describes the line *ef* she just touches the shadow but does not enter into it; when she describes the line *cd* 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 slowest; and when nearest to it, quickest.

Digits.

349. The Moon's diameter, as well as the Sun's, is supposed to be divided into twelve equal parts called *Digits*; and so many of these parts as are darkened by the Earth's shadow, so many Digits is the Moon eclipsed. All that the Moon is eclipsed above 12 Digits, shew how far the shadow of the Earth is over the body of the Moon, on that edge to which she is nearest at the middle of the Eclipse.

Why the beginning and end of a lunar Eclipse is so difficult to be determined by observation.

350. It is difficult to observe exactly either the beginning or ending of a lunar Eclipse, even with a good Telescope; because the Earth's shadow is so faint, and ill defined about the edges, that when the Moon is either just touching or leaving it, the obscuration of her limb is scarce sensible; and therefore the nicest observers can hardly be certain to four or five seconds of time. But both the beginning and ending of solar Eclipses are visibly instantaneous; for the moment that the edge of the Moon's Disc touches the Sun's, his roundness seems a little broke on that part; and the moment she leaves it he appears perfectly round again.

The use of Eclipses in Astronomy, Geography, and Chronology.

351. In Astronomy, Eclipses of the Moon are of great use for ascertaining the periods of her motions; especially such Eclipses as are observed to be alike in all circumstances, and have long intervals of time between them. In Geography, the Longitudes of places are found by Eclipses, as already shewn in the eleventh chapter: but for this purpose Eclipses of the Moon are more useful than those of the Sun, because they are more frequently visible, and the same lunar Eclipse is of equal largeness and duration at all places where it is seen. In Chronology, both solar and lunar Eclipses serve to determine exactly the time of any past event: for there are so many particulars observable in every Eclipse, with respect to its quantity, the places where it is visible (if of the Sun) and the time of the day or night; that 'tis impossible there can be two Eclipses in the course of many ages which are alike in all circumstances. 189

The darkness at our SAVIOUR's crucifixion supernatural.

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 next day after eating his last Passover-Supper, 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 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*.

CHAP. XIX.

The Calculation of New and Full Moons and Eclipses. The geometrical Construction of Solar and Lunar Eclipses. The examination of antient Eclipses.

353. To construct an Eclipse of the Sun, we must collect these ten Elements or Requisites from the following Astronomical Tables.

Requisites for a solar Eclipse.

I. The true time of conjunction of the Sun and Moon: to know at what conjunctions the Sun must be eclipsed; and to the times of those conjunctions,

II. The Moon's horizontal parallax, or angle which the semi-diameter of the Earth subtends as seen from the Moon.

III. The Sun's true place, and distance from the solstitial colure to which he is then nearest, either in coming to it or going from it.

IV. The Sun's declination. 190

V. The angle of the Moon's visible path with the Ecliptic.

VI. The Moon's Latitude or Declination from the Ecliptic.

VII. The Moon's true hourly motion from the Sun.

VIII. The Angle of the Sun's semi-diameter as seen from the Earth.

IX. The Angle of the Moon's semi-diameter as seen from the Earth.

X. The semi-diameter of the Penumbra.

And for an Eclipse of the Moon, the following Elements.

Requisites for a lunar Eclipse.

I. The true time of opposition of the Sun and Moon; and for that time,

II. The Moon's horizontal parallax.

III. The Sun's semi-diameter.

IV. The semi-diameter of the Earth's shadow.

V. The Moon's semi-diameter.

VI. The Moon's Latitude.

VII. The Moon's true hourly motion from the Sun.

VIII. The Angle of the Moon's visible path with the Ecliptic.

These Elements are easily found from the following Tables and Precepts, by the common Rules of Arithmetic.

Note, 60 minutes make a Degree, 30 degrees a Sign, and 12 Signs a Circle. A Sign is marked thus ^{s}, a Degree thus °, and a Minute thus ′.

When you exceed 12 Signs, always reject them 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 that which you subtract from; and then you will have a remainder to set down.

How the Signs are reckoned.

354. As we fix arbitrarily upon the beginning of the Sign *Aries* to reckon from, when we speak of the places of the Sun, Moon, and Nodes; we call *Aries* 0 Signs, *Taurus* 1 Sign, *Gemini* 2 Signs, *Cancer* 3 Signs, *&c.* So, when the Sun is in the 10th degree of Aries, we say his Place or Longitude is 0 Signs 10 Degrees, because he is only 10 Degrees from the beginning of Aries: if he is in the 5th, 10th, *&c.* Degree of Taurus, we say his Place or Longitude is 1 Sign, 5, 10, *&c.* Degrees: and so on, till he comes quite round again. But in reckoning the Anomalies of the Sun and Moon, and their distance from the Nodes, we only consider the number of Signs and Degrees the 191 Luminaries are gone past their Apogee or Nodes; not how far they have to go to these points, were the distance ever so little. The Sun, Moon, and Apogee move according to the order of Signs, but the Nodes contrary. We shall now give the Precepts and Examples for the above Requisites in their due order.

To calculate the time of New and Full Moon.

First Element or Requisite.

355. PRECEPT I. For any proposed year in the 18th Century, take out the mean time of the New Moon in *March* from Table I., and the mean time of Full Moon from Table III., for the *Old Stile*; or from Tables II and IV for *New Stile*; with the mean Anomalies of the Sun and Moon for these times, and set them by themselves. Then, from Table VI, take out as many Lunations as the proposed Month is after *March*, with the days, hours, and minutes belonging to them; and also the mean Anomalies of the Sun and Moon for these Lunations.

II. Add the days, hours, and minutes of these Lunations to the time of New or Full Moon in *March*, and the Anomalies for the Lunations to the Anomalies for *March*: the sums give the hours and minutes of the mean New or Full Moon required, and the mean Anomalies of the Sun and Moon for that time.

III. Then, with the number of days enter Table VII, under the given Month, and right against this number, in the left hand column you have the day of New or Full Moon; which set before the hours and minutes above-mentioned.

IV. But, (as it will sometimes happen) if the number of days fall short of all those under the given Month, add one Lunation with its Anomalies from Table VI to the foresaid sums; so you will have a new sum of days wherewith to enter the 7th Table under the given Month, where you are sure to find that sum the second time, if the first falls short.

V. With the Signs and Degrees of the Sun's Anomaly enter Table VIII, *The Moon's annual Equation*, and take out the minutes of time of that Equation by the Anomaly; remembring, that if the Signs are at the head of the Table, the degrees are at the left hand, in which case the Equation found in the Angle of meeting must be subtracted from the mean time of New or Full Moon, as the title *Subtract*, at the head of the Table directs: but if the Signs are at the foot of the Table their degrees are in the right-hand column, and the Equation where the Signs and Degrees meet in the Table is to be added to the mean time, as the title *Add*, at the foot of the Table directs; which Equation, so applied, gives the mean time of New or Full Moon corrected. 192

VI. With the Signs and Degrees of the Sun's Anomaly enter Table IX, *Equation of the Moon's mean Anomaly*, and take out the Equation thereof; adding it to the mean Anomaly or subtracting it therefrom, as the titles at the head or foot of the Table direct; and it gives the mean Anomaly corrected. Then, with the Sun's Anomaly enter Table XII, *Equation of the Sun's mean Place*, and take out that Equation, applying it to the Moon's corrected Anomaly as the titles direct; and it will give the Moon's Anomaly equated[77]. *N. B.* In all these Equations, care must be taken to make proper allowance for the odd minutes of Anomaly; the Tables having the Equations only for compleat Degrees.

VII. With the Moon's equated Anomaly enter Table X, *The Moon's elliptic Equation*, and take out that Equation in the same manner as the preceding: adding it to the former corrected time if the Signs be at the head of the Table, or subtracting it if they be at the foot, as the Table directs; and this gives the mean time equated.

VIII. Lastly, enter Table XI, *The Sun's Equation at New and Full Moon*, with the Sun's Anomaly, and take out the Sun's Equation in the same manner as the others; adding it to, or subtracting it from the former equated time, as the titles direct: and by this last Equation you have the true time of New or Full Moon, agreeing with well regulated Clocks and Watches. But to make it agree with true Sun-Dials, the Equation of time must be applied as taught § 225.

EXAMPLE I.

To find the time of New Moon in April 1764, *N. S.*

	Days	Hours	Min.	Sun's Anom. s	°	′	Moon's Ano. s	°	′
Tab. II. Mean time of New Moon in *March*	2	8	57	8	2	23	10	13	32
Add, for Lunation, from Tab. VI.	29	12	44	0	29	6	0	25	49
Mean New Moon and Anomaly	31	21	41	0	1	29	11	9	21
To which Time add the Moon's Ann. Equ. Tab. VIII.	+	0	22	Equ. Moon's Anom.				- 20	
And it gives the Mean time corrected	31	22	3	Anom. cor.			11	9	1
From which subtract the Moon's elliptic Equ. Tab. X.	-	3	10	Sun's Equat.			+	1	56
				Moon's Ano.			11	10	57
And it gives the Mean time equated	31	18	53				**h.**	**m.**	
To which add the Sun's Equation, Tab. XI.	+	3	32	Moon's ann. Equ.			0	22	add
				Her ellipt. Equ.			3	10	sub.
And it gives the true time of Conjunction	31	22	25	Sun's Equation			3	32	add

Which true time answers to the first of *April*, at 25 minutes past 10 in the forenoon: for, as the Astronomical Day begins at Noon, then 22 hours 25 min. after the Noon of *March 31*, is *April 1*, at 10 hours 25 min. in the Forenoon.

EXAMPLE II.

To find the time of Full Moon in May 1761, *N. S.*

	Days	Hours	Min.	Sun's Anom. s	°	′	Moon's Ano. s	°	′
Mean time of Full Moon in *March*	20	12	9	8	20	2	9	1	13
Add, for two Lunations	59	1	28	1	28	13	1	21	38
The several sums are	79	13	37	10	18	15	10	22	51
The days, in Tab. VII, answer to *May 18*	18	13	37	Equ. Moon's Anom.			-		13
Moon's annual Equation add		+	14	Anom. cor.			10	22	38
Mean time corrected	18	13	51	Sun's Equat.			+	1	15
Moon's elliptic Equation subtract	-	5	38	Moon's Ano.			10	23	53
Mean time equated	18	8	13				h.	m.	
Sun's Equation add	+	2	19	Moon's ann. Equ.			0	14	add
				Her ellipt. Equ.			5	38	sub.
True time of Opposition, *May*	18	10	32	Sun's Equation			2	19	add

Namely, the 18th day, at 32 minutes past 10 at night.

The Leap-years are allowed for in the Tables, so as to give no Trouble in these Calculations.

194

To compute the time of New and Full Moon in a given year and month, of any particular Century, between the Christian Æra[78] and 18th Century.

PRECEPT I. Find the like year of the 18th Century in Table I., for New Moon, or Table III., for Full Moon; and take out the New or Full Moon in *March* for that year, with the Anomalies of the Sun and Moon.

II. From Table V, take as many compleat Centuries, as when subtracted from the above year of the 18th Century, will answer to the given year; and take out the Conjunctions and Anomalies of these Centuries.

III. Subtract the Conjunctions and Anomalies of these Centuries from those of the New or Full Moon in *March* above taken out, and the remainders will shew the mean time of New or Full Moon in *March* the given year, with the Anomalies of the Sun and Moon at that time. Then, work in all respects for the true time of the proposed New or Full Moon, as taught by the Precepts already given § 355.

EXAMPLE I.

To find the time of New Moon in July 1581, *O. S.*

From 1781 subtract 200 years, and there remains 1581.

	Days	Hours	Min.	Sun's Anom. s	°	′	Moon's Ano. s	°	′
Table I. Mean time of New Moon in *March 1781*	13	7	52	8	23	37	0	0	53
Tab. V. Conj. and Anom. for 200 years subtract	8	16	22	0	6	42	5	0	44
Remain the Conj. and Anom. for *March 1581*	4	15	30	8	16	55	7	0	9
Tab. VI. Add, for five Lunations, to bring it to *July*	147	15	40	4	25	32	4	9	5
The sums are	152	7	10	1	12	27	11	9	14
The Days in Tab. VII. answer to *July* 30th	30	7	10	Equ. Moon's Anom.				+	13
Sum of the three Equations subtract	-	7	9	Anom. cor.			11	9	27
				Sun's Equat.			-	1	16
True time of Conjunction, *July*	30	0	1	Moon's Ano.			11	8	11
Which is the 30th day, at one minute past noon, as shewn by well regulated Clocks or Watches				Moon's ann. Eq.			0^h	14^m	sub.
				Her ellipt. Equ.			3	35	sub.
				Sun's Equation			3	20	sub.
				Sum			7	9	sub.

EXAMPLE II.

195

To find the time of Full Moon in April *A. D. 30, O. S.*

From 1730 subtract 1700, and there remains 30.

	Days	Hours	Min.	Sun's Anom. s	°	′	Moon's Ano. s	°	′
Tab. III. Mean time of Full Moon in *March 1730*	22	6	58	9	2	40	3	13	23
Tab. V. Conj. and Anom. for 1700 years subtract	14	17	37	11	28	46	10	29	36
Rem. the Opposition and Anom. in *March* A. D. 30	7	13	21	9	3	54	4	13	47
Tab. V. Add, for one Lunation, to bring it into *April*	29	12	44	0	29	6	0	25	49
The sums are	37	2	5	10	3	0	5	9	36
The Days in Tab. VII. answer to *April 6*	6	2	5	Equ. Moon's Anom.				-	17
To which add the sum of the three Equations		6	1	Anom. cor.			5	9	19
				Sun's Equat.			+	1	35
True time of Opposition *April* A. D. 30	6	8	6	Moon's Ano.			5	10	54
Which is the 6th day, at 6 minutes past 8 in the Evening. And thus, the time of New or Full Moon may be found for any given year and month after the Christian Æra.				Moon's ann. Eq.			0^h	18^m	add
				Her ellipt. Equ.			2	46	add
				Sun's Equat.			2	57	add
				Sum			6	1	add

Remark.

N. B. Sometimes it happens that the days annexed to the Centuries in Table V are more in number than the days on which the New or Full Moon happens in *March* the year of the 18th Century, with which the computation begins; as in the third following Example, *viz.* for the Full Moon in *March* the year before CHRIST 721: in which case, a Lunation and it's Anomalies must be added, from Table VI, to the days and Anomalies of the New or Full Moon in *March*; and then, subtraction can be made: and having gained a remainder, work in all respects as taught in § 355.

To find the time of New or Full Moon in any given year and month before the Christian Æra.

356. PRECEPT I. Find a year of the 18th Century, which added to the given number of years before CHRIST, diminished by one, shall make a number of whole Centuries.

II. Find this number of Centuries in Table V, and subtract the Time and Anomalies answering to it from the Time and Anomalies answering to the mean New or Full Moon in *March* the year of the 18th Century thus found; and they will give the mean time of New or Full Moon in *March* the given year before CHRIST, with the Anomalies answering thereto. Whence the true time of that New or Full Moon may be had by the Precepts already delivered § 355. 196

III. The Tables are calculated for the Meridian of *London*: therefore, in computing for any place westward of *London*, four minutes of time must be subtracted from the time shewn by the Tables, for every degree the place is westward; and added for every degree it is eastward. See § 210.

EXAMPLE I.

To find the time of New Moon at London *and* Athens *in* March, *the year before Christ 424.*

The years 423 added to 1777 make 2200, or 22 Centuries.

	Days	Hours	Min.	Sun's Anom. s	°	′	Moon's Ano. s	°	′	
Tab. I. Mean New Moon in *March* A. D. 1777	27	7	53	9	7	27	5	25	51	
From which subtract 2200 years in Tab. V.	6	21	47	11	16	26	4	20	37	
Mean Conj. and Anom. in *March* before Chr. 424	20	10	6	9	21	1	1	5	14	
Which with, the total of the three Equations added		9	20	Equ. Moon's Anom.				-	19	
				Anom. cor.			1	4	55	
Gives the true time of Conjunction	20	19	26	Sun's Equat.			+	1	48	
				Moon's Ano.			1	6	43	
Which was the 21st day of *March*, at 26 minutes past 7 in the morning at *London*: and if 1 hour 35 minutes be added for *Athens*, which is 23° 52′ east of the meridian of *London*, we have the time at *Athens*; namely, 1 minute past 9 in the morning.				Moon's ann. Eq.			0^h	20^m	add	
				Her ellipt. Equ.			5	43	add	
				Sun's Equation			3	17	add	
				Total			9	20	add	

EXAMPLE II.

197

To find the time of Full Moon in October, *the year before Christ 4030.*

The years 1771 added to 4029 make 5800, or 58 Centuries.

		Days	Hours	Min.	Sun's Anom. s	°	′	Moon's Ano. s	°	′
Tab. III. From the mean Full Moon in *March 1771*		19	7	11	8	29	6	7	22	30
Tab. V. Subtr. the numbers for 5800 years	5000	10	7	56	10	23	56	0	17	36
	800	5	4	43	11	27	43	7	7	7
Which collected make		15	12	39	10	21	39	7	24	43
Rem. the mean Full Moon *&c. March* before Chr. 4030		3	18	32	10	7	27	11	27	47
To which add eight Lunations to carry it to *October*		236	5	52	7	22	50	6	26	32
And the several sums will be		240	0	24	6	0	17	6	24	19
Which, for Full Moon day, Tab. VII, is *October 26*		26	0	24				**h.**	**m.**	
Moon's ellipt. Equation subtr. there being none besides			3	28	Moon's Ann. Eq.			0	0	add
					Moon's ellipt. Eq.			3	28	sub.
Rem. the true time of Full Moon, *October*		25	20	56	Sun's Equation			0	0	add
Which is the 26th day, at 8 hours 26 minutes in the forenoon[79].					Total			3	28	sub.

Age of the world uncertain.

By the method prescribed § 248 it will be found, that the Autumnal Equinox in the year before CHRIST 4030, fell on the 26th of *October*; as this Example shews the Full Moon to have been on the same day: and by working as hereafter taught, it will appear that the Dominical Letter was then *G*, which shews the 26th of *that October* to have been on a *Friday*; namely our sixth day of the week, but the *Ante-Mosaic* fifth day. And as, according to *Genesis*, chap. i. ver. 14. the Sun and Moon were created on the fourth day of the week, those who are of opinion that the world was made at the time of the Autumnal Equinox, and that the Moon at her first appearance was in full lustre, opposite to the Sun, or nearly so, may perhaps look upon this as a Criterion for ascertaining the year of the creation; since it shews the Moon to have been Full the next day after she was made: and this is only 9 years sooner than *Rheinholt* makes it, and 11 years later than according to *Lange*. Whereas, they who maintain that the world was created in the 4007th year before CHRIST, with the Sun on the Autumnal Equinoctial Point, *October 26*, and the Moon then Full; will find, if they compute by the best Tables extant, that the Moon was New, instead of being Full, on that day.

198

If it could be proved from the writings of *Moses* that the Sun was created on the point of the Autumnal Equinox, and the Moon in opposition; as well as it can be proved that these Luminaries were made (or according to some, did not shine out till) on the fourth day of the creation-week, there would be *Data* enough for ascertaining the age of the world: for supposing the Moon to have been Full on an Equinoctial Day, which was the fourth day of the week, it would require many thousands of years to bring these three characters together again. For, the soonest in which the Moon returns to be New or Full on the same days of the Months as before, is 19 years wanting an hour and half, but then the days of the week return not to the same days of the months in less than 28 years, in which time the Moon has gone through one Course of Lunations, and 9 years over; therefore a co-incidence of the Full Moon and day of the Week and Month cannot happen in that time, and if we multiply 19 by 28, which is the nearest co-incidence of these three characters, namely 532 years; the Moon's falling back an hour and half every 19 years will amount to 42 hours in so many years; and the Equinox will have anticipated five days. From all which we may venture to say, that 200000 years would not be sufficient to bring all these circumstances together again.

EXAMPLE III.

To find the time of Full Moon at Babylon *in* March, *the year before Christ 721.*

The years 720 added to 1780 make 2500, or 25 Centuries.

	Days	Hours	Min.	Sun's Anom.			Moon's Ano.		
				s	°	′	s	°	′
Tab. I. To the mean F. Moon and Anom. in *Mar. 1780*	9	4	41	8	19	48	7	8	10
Add one Lunation and it's Anomalies from Tab. VI[80]	29	12	44	0	29	6	0	25	49
The several sums are	38	17	25	9	18	54	8	3	59
Fr. which subt. the Days & Anom. of 2500 years, Tab. V	19	22	20	11	26	19	6	6	43
Rem. the mean time and Anom. of F.M. in *Mar. b.C. 721*	18	19	5	9	22	25	1	27	16
To which add the sum of the three Equations	+	11	36	Equ. Moon's Anom.				-	18
And it gives the true time of Full Moon, *Mar. b.C. 721*	18	6	41	Anom. cor.			1	26	48
				Sun's Equat.			+	1	47
				Moon's Anom.			1	28	35
				Moon's ann. Eq.	0^h	20^m	add		
Which was the 19th day, at 41 minutes past 6 in the evening, at *London*; to which time, if[81] 2 hours 51 minutes be added, we shall have the time at *Babylon*, namely, 9 hours 51 minutes.				Her ellipt. Equ.	8	1	add		
				Sun's Equation	3	15	add		
				Sum	11	36	add		

357. To know whether the Sun will be eclipsed or no, at the time of any given New Moon; collect the Sun's distance from the Node at that time, and if it be less than 17 degrees he will be eclipsed, otherwise not. 199

EXAMPLE.

For the time of New Moon in April 1764.

	Sun from Node		
	s	**°**	**′**
Table II, mean New Moon in *March 1764, New Stile*,	11	4	57
Table VI, add for 1 Lunation to carry it to *April*	1	0	40
Sun's distance from the Node at New Moon in *April*	0	5	37

Which, being within the above limit, the Sun must be eclipsed: and therefore, we proceed to find the rest of the Elements for computing this Eclipse.

To find the Moons Horizontal Parallax, or the Angle of the Earth's semi-diameter as seen from the Moon.

Second Element.

358. PRECEPT. Having found the Moon's mean Anomaly for the above time, by the first and second Precepts of § 355, enter the XVth Table with the signs and degrees of that Anomaly, and thereby take out the Moon's Horizontal Parallax: only note, that this is given but to every 6th degree of Anomaly in the Table, because it is very easy to make proper allowance by sight. So the Moon's Horizontal Parallax *April* the 1st 1764, at 10 hours 25 minutes in the Forenoon, answering to her mean Anomaly at that time (namely 11^s 9° 21′) is 55′ 7″; which, diminished by 10″, the Sun's constant Horizontal Parallax, gives for the semi-diameter of the Earth's Disc 54′ 57″.

To find the Sun's true Place, and his distance from the nearest Solstice.

Third Element.

359. PRECEPT I. We are to consider, that the beginning of Aries and of Libra, which are the Equinoctial Points, are equidistant from the beginning of Cancer and of Capricorn, which are the Solstitial Points. Hence, when we know in what Sign and Degree the Sun is, we can easily find his distance from the nearest Solstice. Now, to find the Sun's Place, or Longitude from Aries, *April* the 1st, 1764, at 10 hours 21 minutes in the Forenoon; being the equated time of New Moon.

PRECEPT II. This being to the time of New Moon, take out the Sun's mean Place and Anomaly from Table II. for that time, and the Equation of his mean Place from Table XII by his Anomaly; adding the Equation to his mean Place or subtracting it from the same, as the Table directs, will give his true Place. 200

EXAMPLE.

	Sun's Long. from Aries.			Sun's mean Anomaly.		
	s	°	′	s	°	′
Table I. To the Sun's mean Place and Anomaly at the mean time of New Moon in *March 1764*, N. S.	11	17	7	8	2	23
Add the same from Tab. VI. for one Lunation, to carry it to *April*	0	29	6	0	29	6
Mean Place and Anomaly at the time of New Moon in *April*	0	10	13	9	1	29
To which place add the Sun's Equation from Tab. XII.		1	56	Equal	1°	56′
And it gives the Sun's true place	0	12	9	Additive.		
Which is Aries 12° 9′; and this, when taken from three Signs, or the beginning of Cancer, leaves 2 signs 17 deg. 51 min., or 77° 51′ for the Sun's distance from the then nearest Solstice.						

360. But because the Sun's true Place is often wanted when the Moon is neither New nor Full, we shall next shew how it may be found for any given moment of time: though this be digressing from our present purpose.

In Table XVI find the nearest lesser year to that in which the Sun's Place is sought; and take out the Sun's mean Longitude and Anomaly answering thereto; to which add his mean motion and Anomaly for the compleat residue of the years, with the month, day, hour, and minute, all taken from the same Table, and you have the Sun's mean Longitude and Anomaly for the given time. Then, from Table XII take out the Sun's Equation by means of his Anomaly (making proportions for the odd minutes of Anomaly) which Equation being added to or subtracted from the Sun's mean Longitude from Aries, as the titles in the Table direct, gives his true Place, or Longitude from the beginning of Aries, reckoned according to the order of the Signs § 354.

EXAMPLE.

To find the Sun's true Place April *30th, A. D. 1757, at 18 minutes 40 seconds past 10 in the morning*.

			Sun's Long.				Sun's Anom.		
			s	°	′	″	s	°	′
The year next less than 1757 in the Table is 1753, at the beginning of which, the Sun's mean Longitude from the beginning of Aries, and his mean Anomaly, is			9	10	16	52	6	1	38
To which add his mean Mot. and Anom. for four years to make 1757			0	0	1	49	11	29	58
And likewise his mean Mot. and Anom. for	*April*		2	28	42	30	2	28	42
	days	29	0	28	35	2	0	28	35
	hours	22		0	54	13		0	54
	min.	18			0	44			1
	sec.	49				2			0
Sun's mean Longitude and Anomaly for the given time is			1	8	31	12	9	29	48
To which add the Equation of the Sun's mean Place				1	40	14	Sun's Eq.		
And it gives his true Place, *viz.* ♉ Taurus 10° 11′ 26″			1	10	11	26	1°	40′	14″

N. B. *In leap-years after* February, *the Sun's mean Motion and Anomaly must be taken out for the day next after the given one.*

361. *To calculate the Sun's true Place for any time in a given year before the first year of* CHRIST: subtract the mean Motions and Anomalies for the compleat hundreds next above the given year; to the remainder add those for the residue of years, months, *&c.* and then work in all respects as above taught.

EXAMPLE.

To find the Suns true Place May *the 28th at 4 hours 3 min. 42 sec. in the afternoon, the year before Christ 585, which was a Leap year*[82].

				Sun's Long.				Sun's Anom.		
				s	°	′	″	s	°	′
From the Sun's mean Longitude and Anomaly at the beginning of the year Christ 1				9	7	53	10	6	29	54
Subtract his mean Motion and Anomaly for 600 years				0	4	32	0	11	24	2
And the remainder, or radix, is				9	3	21	10	7	5	52
To which add what 585 wants of 600, *viz.* 15 years				11	29	22	27	11	29	7
	May			3	28	16	40	3	28	17
	days	28	Bissextile	0	28	35	2	0	28	35
And also those of	hours	4			0	9	51		0	10
	min.	3				0	7			
	sec.	42					2	0	2	1
								Sun's Anom.		
Sun's mean Long. *May* 28th, at 4 hour 3 min. 24 sec. afternoon				1	29	45	19			
Equation of the Sun's mean Place subtract						2	2	2′ 22″		
								Sun's Equat.		
Rem. his true Place for the same time, *viz.* ♉ Taurus 29° 43′ 17″				1	29	43	17	subtract.		

N. B. As the Longitudes or Places of all the visible Stars in the Heavens are well known, we have an easy method of finding the Sun's true Place in the Ecliptic: for the Sun is directly opposite to that Point of the Ecliptic which comes to the Meridian at mid-night.

202

To find the Sun's Declination.

Fourth Element.

362. PRECEPT. Enter Table XVII with the Signs and Degrees of the Sun's Place; and making proportions, take out his Declination answering thereto. If the Signs are at the head of the Table, the Degrees are at the left hand; but if the Signs are at the foot of the Table, the Degrees are at the right hand. So, the Sun's Declination answering to his true Place (found by § 359 to be 0^s 12° 9′) is 4 degrees 48 minutes 54 seconds, making allowance for the 9′ that his Place exceeds 12°.

To find the Angle of the Moon's visible Path with the Ecliptic.

Fifth Element.

PRECEPT. This we may state at 5 degrees 38 minutes, as near enough for the purpose; since it is never above 8 minutes of a degree more or less.

To find the Moon's Latitude.

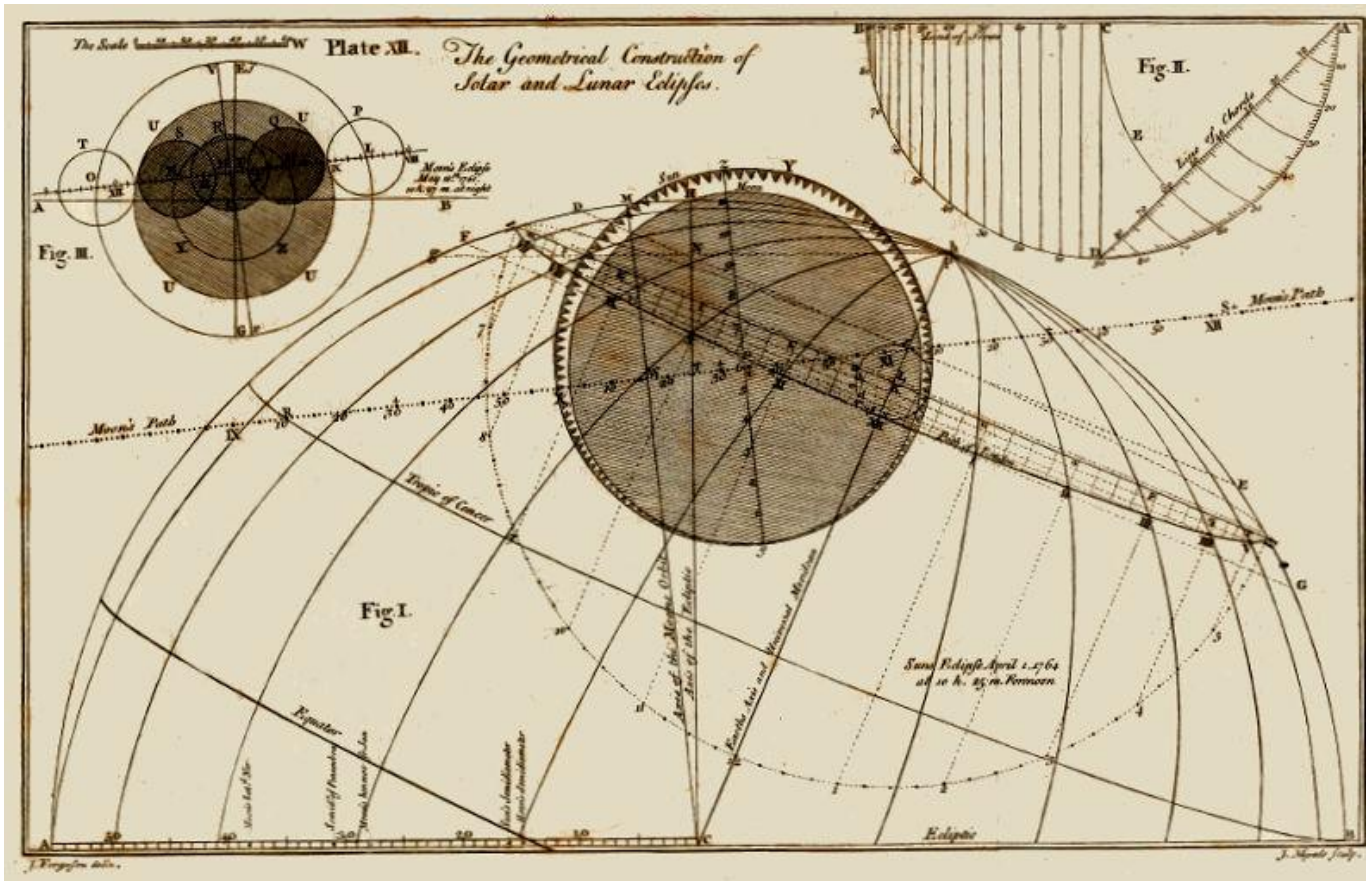
Sixth Element.

363. PRECEPT. Having found the Sun's distance from the Ascending Node by § 357, at the mean time of New Moon, and his Anomaly for that time by § 359, find the Equation of the Node in Table XIII, by the Sun's Anomaly, and the Equation of the Sun's mean Place in Table XII by his Anomaly: these two Equations applied (as the titles direct) to the Sun's mean distance from the Ascending Node, give his true distance from it, and also the Moon's true distance at the time of Change: but when the Moon is Full, this distance must be increased by the addition of 6 Signs, which will then be the Moon's true distance from the same Node.

The Moon's true distance from the Ascending Node is called the *Argument of the Moon's Latitude*; with the Signs of which, at the head of Table XIV, and Degrees at the left hand, or with the Signs at the foot of the Table and Degrees at the right hand, take out the Moon's Latitude: which is *North Ascending*, *North Descending*, *South Ascending*, or *South Descending*, according to the letters *NA*, *ND*, *SA* or *SD*, annexed to the Signs of the said Argument.

Plate XII.

The Geometrical Construction of Solar and Lunar Eclipses.



J. Ferguson delin.

J. Mynde Sculp.

EXAMPLE.

	s ° ′
Sun's mean Dist. from the [83]Node at New Moon in *April 1764*	0 5 37
To which add the Equation of the Node	+ 10
And it gives the Sun's corrected Distance from the Node	0 5 47
To which cor. Dist. add the Eq. of the Sun's mean Place	+ 1 56
And it gives the Sun's true Distance from the Node	0 7 43

Which, being at the time of New Moon, is the *Argument of Latitude*; and in Table XIV, (making proportions for the 43′) shews the Moon's Latitude to be 40′ 9″ *North Ascending*[84].

To find the Moon's true hourly Motion from the Sun.

Seventh Element.

364. PRECEPT. With the Moon's Anomaly enter Table XV, and thereby take out her true hourly Motion: then with the Sun's Anomaly take out his true hourly Motion from the same Table: which done, subtract the Sun's hourly Motion from the Moon's, and the remainder will be the Moon's true hourly Motion from the Sun; which, for the above time § 359, is 27′ 50″.

To find the Semi-diameters of the Sun and Moon as seen from the Earth at the above-mentioned time.

Eighth and Ninth Elements.

365. PRECEPT. Enter the XVth Table with the Sun's Anomaly, and thereby take out his Semi-diameter; and in the same manner take out the Moon's Semi-diameter by her Anomaly. The former of which for the above time will be found to be 16′ 6″; the latter 14′ 58″.

To find the Semi-diameter of the Penumbra.

Tenth Element.

366. PRECEPT. Add the Sun's semi-diameter to the Moon's, and their Sum will be the Semi-diameter of the Penumbra; namely, at the above time 31′ 4″.

Pl. XII.

366. Having found the proper Elements or Requisites for the Sun's Eclipse *April 1, 1764*, and intending to project this Eclipse Geometrically, we shall now collect them under the eye, that they may be the more readily found as they are wanted in order for the Projection. 204

The proper Elements collected.

	D	H	M
367. I. The true time of Conj. or New Moon *April*	1	10	25
	°	′	″
II. The Earth's Semi-Disc, which is equal to the Moon's Horizontal Parallax 55′ 7″ diminished by the Sun's Horizontal Parallax which is always 10″	0	54	57
III. The Sun's distance from the nearest Solstice, *viz.* ♋	77	51	0
IV. The Sun's Declination, North	4	48	54
V. The Angle of the Moon's vis. path with the Eclipt.	5	38	0
VI. The Moon's true Latitude, North Ascending		40	9
VII. The Moon's true Horary Motion from the Sun		27	50
VIII. The Sun's Semi-diameter		16	6
IX. The Moon's Semi-diameter		14	58
X. The Semi-diameter of the Penumbra		31	4

368. Having collected these Elements or Requisites, the following part of the work may be very much facilitated by means of a good Sector, with the use of which the reader should be so well acquainted, as to know how to open it to any given Radius, as far as it will go; and to take off the Chord or Sine of any Arc of that Radius. This is done by first taking the extent of the given Radius in your Compasses, and then opening the Sector so as the distance cross-wise between the ends of the lines of Sines or Chords at *S* or *C*, from Leg to Leg of the Sector, may be equal to that extent; then, without altering the Sector, take the Sine or Chord of the given Arc with your Compasses extended cross-wise from Leg to Leg of the Sector in these lines. But if the operator has not a Sector, he must construct these lines to such different lengths as he wants them in the projection. And lest this Treatise should fall into the hands of any person who would wish to project the Figure of a solar or lunar Eclipse, and has not a Sector to do it by, we shall shew how he may make a line of Sines or Chords to any Radius.

Fig. II.

How to make a line of Chords.

Pl. XII.

369. Draw the right line *BCA* at pleasure; and upon *C* as a Center, with the distance *CA* or *CB* as a Radius, describe the Semi-circle *BDA*; and from the Center *C* draw *AC* perpendicular to *BCA*. Then divide the Quadrants *AD* and *BD* each into 90 equal parts or degrees, and join the right line *AD* for the Chord of the Quadrant *AD*. This done, setting one foot of the Compasses in *A*, extend the other to the different divisions of the Quadrant *AD*; and so transfer them to the right line *AD* as in the Figure, and you have a line of Chords *AD* to the Radius *CA*. *N. B.* 60 Degrees on the Line of Chords is always equal to the Radius of the Circle it is made from; as is evident by the Figure, where the Arch *E*, whose Center is *A*, drawn from 60 on the Quadrant *AD*, cuts the Chord line in 60 degrees, and terminates in the Center *C*. 205

And of Sines.

Then, from the divisions or degrees of the Quadrant *BD*, draw lines parallel to *CD*, which will fall perpendicularly on the Radius *BC*, dividing it into a line of Sines; and it will be near enough for the present purpose, to have them to every fifth Degree, as in the Figure. And thus the young *Tyro* may supply himself with Chords and Sines, if he has not a Sector. But as the Sector

greatly shortens the work, we shall describe the projection as done by it, so far as Signs and Chords are required.

Fig. II.

Earth's Semi-Disc.

370. Make a Scale of any convenient length (six inches at least) as *AC*, and divide it into as many equal parts as the semi-diameter of the Earth's Disc contains minutes, which in this construction of the Eclipse for *London* in *April 1764*, is 54 minutes and 57 seconds; but as it wants only 3″ of 55′ the Scale may be divided into 55 equal parts, as in the Figure. Then, with the whole length of the Scale as a Radius, setting one foot of your Compasses in *C* as a center, describe the Semi-circle *AMB* for the northern Hemisphere or Semi-disc of the Earth, as seen from the Sun at that time. Had the Place for which the Construction is made been in South Latitude, this Semi-circle would have been the Southern Hemisphere of the Earth's Disc.

Axis of the Ecliptic.

371. Upon the center *C* raise the straight line *CH* for the Axis of the Ecliptic, perpendicular to *ACB*.

North Pole of the Earth.

372. Make a line of Chords to the Radius *AC*, and taking from thence the Chord of 23½ Degrees, set it off from *H* to *g* and to *h*, on the periphery of the Semi-disc; and draw the straight line *gNh*, in which the North Pole of the Disc is always found.

373. While the Sun is in Aries, Taurus, Gemini, Cancer, Leo, and Virgo, the North Pole of the Disc is illuminated; but while the Sun is in Libra, Scorpio, Sagittary, Capricorn, and Aquarius, the North Pole is hid in the obscure part behind the Disc.

374. And, whilst the Sun is in Capricorn, Aquarius, Pisces, Aries, Taurus, and Gemini, the Earth's Axis *CP* lies to the right hand of the Axis of the Ecliptic *CH* as seen from the Sun, and to the left hand while the Sun is in the other six Signs.

Earth's Axis.

Universal Meridian.

375. Make a line of Sines equal in length to *Ng* or *Nh*, and take off with your Compasses from it the Sine of the Sun's distance from the nearest Solstice, which in the present case is 77° 51′ § 367, and set that distance to the right hand, from *N* to *P*, on the line *gNh*, because the Sun being in Aries § 359, the Earth's Axis lies to the right hand of the Axis of the Ecliptic § 374: then draw the straight line *C*XII*P*, for the Earth's Axis and the Universal Meridian; of both which *P* is the North Pole. 206

Path of a given Place on the Disc as seen from the Sun.

376. To draw the parallel of Latitude of any given Place (suppose *London*) which parallel is the visible Path of the Place On the Disc, as seen from the Sun, from the time that the Sun rises till it sets; subtract the Latitude of the Place (*London*) 51½ degrees from 90 degrees, and there remains 38½; which take from the Line of Chords in your Compasses, and set it from *h* (where the Universal Meridian *CP* cuts the periphery of the Semi-disc) to VI and VI; and draw the occult Line VI*L*VI. Then, on the left hand of the Earth's Axis, set off the Chord of the Sun's Declination 4° 48′ 5″ § 367, from VI to *D* and to *F*; set off the same on the right hand from VI to *E* and to *G*; and draw the occult Lines *DsE* and *F*XII*G* parallel to VI *L* VI.

Situation of the Place on the Disk from Sun-rise to Sun-set.

377. Bisect *s* XII in *K*, and through the point *K* draw the black Line VI*K*V1 parallel to the occult or dotted Line VI*L*VI. Then, making *AC* the Radius or length of a Line of Lines, set off the Sine of 38½ degrees, the Co-Latitude of *London*, from *K* to VI and VI; and with that extent as a Radius, describe the Semi-Circle VI 7 8 9 &c. and divide it into 12 equal parts, beginning at VI. From these divisions, draw the occult Lines 7*m*, 8*l*, 9*k*, &c. all to the Line VI*K*VI, and parallel to *C*XII*P*. Then, with *K*XII as a Radius, describe the Circle *abcdef*, round the Center *K*, and divide the Quadrant *a*XII into six equal parts, as *ab*, *bc*, *cd*, *de*, &c. Then, through these points of division *b*, *c*, *d*, *e*, and *f*, draw the occult Lines VII*b*V, VIII*c*IIII, IX*d*III, &c. intersecting the former Lines 7*m*, 8*l*, 9*k*, 10*i*, &c. in the points VII, VIII, IX, X, XI, &c. which points mark the situation of *London* on the Earth's Disc as seen from the Sun at these hours respectively, from six in the morning till six at night: and if the elliptic Curve VI, VII, VIII, &c. be drawn through these points, it will represent the parallel of *London*, or the path it seems to describe as viewed from the Sun, from Sun-rise to Sun-set. *N.B.* When the Sun's Declination is North, the said Curve is the diurnal Path of *London*; and the opposite part VI*s*VI is it's nocturnal Path behind the Disc, or in the obscure part thereof, § 338, 339. But if the Sun's Declination had been South, the Curve VI*s*VI would have been the diurnal path of *London*; in which case the Lines 7*m*, 8*l*, &c. must have been continued thro' the right Line VI*K*VI, and their lengths beyond that line determined by dividing the Quadrant *s a* of the little Circle *abcd* into six equal parts, and drawing the parallels VII*b*, VIII*c* &c. through that division, in the same manner as done on the side *K* XII; and the Curve VII, VIII, IX, &c. would have been the nocturnal Path. It is requisite to divide the hours of the diurnal Path into quarters, as in the Diagram; and if possible into minutes also. 207

Axis of the Moon's Orbit.

378. From the Line of Chords § 372 take the Angle of the Moon's visible Path with the Ecliptic, *viz.* 5° 38′ § 367: and note, that when the Moon's Latitude is *North Ascending*, as in the present case, the Chord of this Angle must be set off to

the left hand of the Axis of the Ecliptic *CH*, as from *H* to *M*, and the right line *CM* drawn for the Axis of the Moon's Orbit: but when the Moon's Latitude is *North Descending*, this Angle and Axis must be set to the right hand, or from *H* toward *h*. When the Moon's Latitude *South Ascending*, the Axis of her Orbit lies the same way as when her Latitude is *North Ascending*; and when *South Descending*, the same way as when *North Descending*.

Path of the Penumbra's center over the Earth.

379. Take the Moon's Latitude, 40′ 9″ § 367, from the Scale *CA*, and set it from *C* to *T* on the Axis of the Ecliptic; and through *T*, at right Angles to the Axis of the Moon's Orbit *CM*, draw the straight Line *RTS*; which is the Moon's Path, or Line that the center of her shadow and Penumbra describes in going over the Earth's Disc. The Point *T* in the Axis of the Ecliptic is the Place where the true Conjunction of the Sun and Moon falls, according to the Tables; and the Point *W*, in the Axis of the Moon's Orbit, is that where the center of the Penumbra approaches nearest to the center of the Earth's Disc, and consequently the middle of the general Eclipse.

It's Place on the Earth's Disc shewn for every minute of it's Transit.

380. Take the Moon's true Horary Motion from the Sun 27′ 50″ § 367, from the Scale *CA* with your Compasses (every division of the Scale being a minute of a Degree) and with that extent make marks in the Line of the Moon's Path *RTS*: then divide each of these equal spaces by dots into 60 equal parts or horary minutes, and set the hours to every 60th minute, in such a manner that the dot; signifying the precise minute of New Moon by the Tables, may fall in the Point *T* where the Axis of the Ecliptic cuts the Line of the Moon's Path; which, in this Eclipse, is the 25th minute past ten in the Forenoon: and then the other marks will shew the places on the Earth's Disc where the center of the Penumbra is, at the hours and minutes denoted by them, during its transit over the Earth.

Middle of the Eclipse.

It's Phases.

381. Apply one side of a Square to the Line of the Moon's Path, and move the Square backward or forward until the other side cuts the same hour and minute both in the Path of the Place (*London*, in this Construction) and Path of the Moon; and *that* minute, cut at the same time in both Paths, will be the precise minute of visible Conjunction of the 208
Sun and Moon at *London*, and therefore the time of greatest obscuration, or middle of the Eclipse at *London*; which time, in this Projection, falls at *t*, 34 minutes past 10 in the Moon's Path; and at *u*, 34 minutes past 10 in the Path of *London*. Then, upon the Point *u* as a center, describe the Circle *zYy* whose Radius *uy* is equal to the Sun's semi-diameter 16′ 6″ § 367, taken from the Scale *CA*: And upon the Point *t* as a center, describe the Circle *Hy* whose Radius is equal to the Moon's semi-diameter 14′ 58″ § 367, taken from the same Scale. The Circle *zYy* represents the Disc of the Sun as seen from the Earth, and the Circle *Hy* the Disc of the Moon. The portion of the Sun's Disc cut off by the Moon's shews the Quantity of the Eclipse at the time of greatest obscuration: and if a right Line as *yz* be drawn across the Sun's Disc through *t* and *u*, the minute of greatest obscuration in both Paths, and divided into 12 equal parts, it will shew what number of Digits are then eclipsed. If these two Circles do not touch one another, the Eclipse will not be visible at the given Place.

It's beginning and ending.

382. Lastly, take the Semi-diameter of the Penumbra 31′ 4″ § 367, from the Scale *CA* with your Compasses; and setting one foot in the Moon's Path, to the left hand of the Axis of the Ecliptic, direct the other toward the Path of *London*; and carry this extent backwards or forwards until both Points of the Compasses fall into the same instants of time in both Paths: which will denote the time of the beginning of the Eclipse: then, do the same on the right hand of the Axis of the Ecliptic, and where both Points mark the same instants in both Paths, they will shew at what time the Eclipse ends. These trials give the Points *R* in the Moon's Path and *r* in the Path of *London*, namely 9 minutes past 9 in the Morning for the beginning of the Eclipse at *London*, *April 1, 1764*: *t* and *u* for the middle or greatest obscuration, at 35 minutes past 10; when the Eclipse will be barely annular on the Sun's lower-most edge, and only two thirds of a Digit left free on his upper-most edge: and for the end of the Eclipse, *S* in the Moon's Path and *x* in the Path of *London*, at 4 minutes past 12 at Noon.

In this Construction it is supposed that the Equator, Tropics, Parallel of *London*, and Meridians through every 15th degree of Longitude are projected in visible Lines on the Earth's Disc, as seen from the Sun at almost an infinite distance; that the Angle under which the Moon's diameter is seen, during the time of the Eclipse, continues invariably the same; that the Moon's motion is uniform, and her Path rectilineal, for that time. But all these suppositions do not exactly agree with the truth; and therefore, supposing the Elements § 209
367, given by the Tables to be perfectly accurate, yet the time and phases of the Eclipse deduced from it's Construction will not answer exactly to what passeth in the Heavens; but may be two or three minutes wrong though done with the utmost care. Moreover, the Paths of all Places of considerable Latitude go nearer the center of the Disc as seen from the Moon than these Constructions make them; because the Earth's 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 North in places of northern Latitude, and farther South in places of southern Latitude than these projections answer to. Hence we may venture to predict that this Eclipse will be more annular at *London* (that is, the annulus will be somewhat broader on the southern Limb of the Sun) than the Diagram shews it.

383. Having shewn how to compute the times and project the phases of a Solar Eclipse, we now proceed to those of the Lunar. And it has been already mentioned § 317, that when the Full Moon is within 12 degrees of either of her Nodes, she must be eclipsed. We shall now enquire whether or no the Moon will be eclipsed *May 18, 1761, N. S.* at 32 minutes past 10 at Night. See page 193.

Table IV.

Table VI.

	s	°	′
Sun from Node at Full Moon in *March 1761*	9	25	27
Add his distance for two Lunations, to bring it into *May*	2	1	20
And his distance at Full Moon in that month is	11	26	47

Subtract this from a Circle, or 12 Signs, and there will remain 3° 13′; which is all that the Sun wants of coming round to the Ascending Node; and the Moon being then opposite to the Sun, must be just as near the Descending Node: consequently, far within the limit of an Eclipse.

384. Knowing then that the Moon will be eclipsed in *May 1761*, we must find her true distance from the Node at that time, by applying the proper Equations as taught § 363, and then find her true Latitude as taught in that article.

Table IV.

Table XIII.

Table XII.

	s	°	′
Sun's mean distance from the Node at F. Moon in *May 1761*	11	26	47
Add the Equation of the Node, for the Sun's Anomaly 10^s 18° 15′[85]		+	6
Sun's mean distance from the Node corrected	11	26	53
Add the Equation of the Sun's mean Place		+ 1	15
Sun's true distance from the Ascending Node	11	28	8
To which add 6 Signs, See § 363	6		
The sum is the Moon's true distance from the same Node	5	28	8

Pl. XII.

Or the *Argument* of her *Latitude*; which in Table XIV, gives the Moon's true Latitude, *viz.* 9′ 56″ North Descending. 210

385. Having by the foregoing precepts § 355 found the true time of Opposition of the Sun and Moon in a lunar Eclipse, with the Moon's Anomaly enter Table XV and take out her horizontal Parallax, also her true horary Motion and Semi-diameter: and likewise those of the Sun by his Anomaly, as already taught § 364 & *seq.* Then add the Sun's horizontal Parallax, which is always 10 Seconds, to the Moon's horizontal Parallax, and from their sum subtract the Sun's Semi-diameter; the remainder will be the Semi-diameter of that part of the Earth's shadow which the Moon goes through.

386. From the Sum of the Semi-diameters of the Moon and Earth's Shadow, subtract the Moon's Latitude; the remainder is the parts deficient. Then, as the Semi-diameter of the Moon is to 6 Digits, so are the parts deficient to the Digits eclipsed.

387. If the parts deficient be more than the Moon's Diameter, the Eclipse will be total with continuance; if less, it will not be total; if equal, it will be total, but without continuance.

388. Now collect the Elements for projecting this Eclipse.

	′	″
Moon's horizontal Parallax	55	32
Sun's horizontal Parallax (always)		10
The Sum of both Parallaxes	55	42
From which subtract the Sun's Semi-diameter	15	54
Remains the Semi-diameter of the Earth's Shadow	39	48
Semidiameter of the Moon	15	2
Sum of the two last	54	50
Moon's Latitude subtract	9	56
Remains the parts deficient	45	0
Moon's horary motion	30	46
Sun's horary motion subtract	2	24
Remains the Moon's horary motion from the Sun	28	22

To project a lunar Eclipse.

Fig. III.

389. This done, make a Scale of any convenient length as *W*, whereof each division is a minute of a degree; and take from it in your Compasses 54 Minutes 50 Seconds, the Sum of Semi-diameters of the Moon and Earth's shadow; and with that extent as a Radius, describe that Circle *OVLG* round *C* as a Center.

From the same Scale take 39 Minutes 48 Seconds, the Semi-diameter of the Earth's shadow, and therewith as a Radius, describe the Circle *UUUU* for the Earth's shadow, round *C* as a Center. Subtract the Moon's Semi-diameter from the Semi-diameter of the Shadow, and with the difference 24 Minutes 46 seconds as a Radius, taken from the Scale *W*, describe the Circle *YZ* round the Center *C*. 211

Draw the right line *AB* through the Center *C* for the Ecliptic, and cross it at right Angles with the line *EG* for the Axis of the Ecliptic.

Because the Moon's Latitude in this Eclipse is North Descending, § 384, set off the Angle of her visible Path with the Ecliptic 5 Degrees 38 Minutes (Page 202.) from *E* to *V*; and draw *VCv* for the Axis of the Moon's Orbit. Had the Moon's Latitude been North Ascending, this Angle must have been set off from *E* to *f*. *N. B.* When the Moon's Latitude is South Ascending, the Axis of her Orbit lies the same way as when she has North Ascending Latitude; and when her Latitude is North Descending, the Axis of her Orbit lies the same way as when her Latitude is South Descending.

Take the Moon's true Latitude 9′ 56″ in your Compasses from the Scale *W*, and set it off from *C* to *F* on the Axis of the Ecliptic because the Moon is north of the Ecliptic; (had she been to the South of it, her Latitude must have been set off the contrary way, as from *C* towards *v*:) and through *F*, at right Angles to the Axis of the Moon's Orbit *VCv*, draw the right line *LMHNO* for the Moon's Orbit, or her Path through the Earth's shadow. *N. B.* When the Moon's Latitude is North Ascending, or North Descending, she is above the Ecliptic: but when her Latitude is South Ascending, or South Descending, she is below it.

Take the Moon's true horary motion from the Sun, *viz.* 28 Minutes 22 Seconds, from the Scale *W* in your Compasses; and with that extent make marks in the line of the Moon's Path *LMHNO*: then divide each of these equal spaces into 60 equal parts or minutes of time: and set the hours to them as in the Figure, in such a manner that the precise time of Full Moon, as shewn by the Tables, may fall in the Axis of the Ecliptic at *F*, where the line of the Moon Path cuts it.

Lastly, Take the Moon's Semi-diameter 15 Minutes 2 Seconds from the Scale *W* in your Compasses, and therewith as a Radius describe the Circles *P*, *Q*, *R*, *S*, and *T* on the Centers *L*, *M*, *H*, *N*, and *O*; the Circles *P* and *T* just touching the Earth's Shadow *UU*, but no part of them within it; the Circles *Q* and *S* all within it, but touching at its edges; and the Circle *R* in the middle of the Moon's Path through the shadow. So the Circle *P* shall be the Moon touching the shadow at the moment the Eclipse begins; the Circle *Q* the Moon just immersed into the shadow at the moment she is totally eclipsed; the Circle *R* the Moon at the greatest obscuration, in the middle of the Eclipse; the Circle *S* the Moon just beginning to be enlightened on her western limb at the end of total darkness; and the Circle *T* the Moon quite clear of the Earth's shadow at the moment the Eclipse ends. The moments of time marked at the points *L*, *M*, *H*, *N* and *O* answer to these Phenomena: and according to this small projection are as follow. The beginning of the Eclipse at 8 Hours 36 Minutes *P. M.* The total immersion at 9 Hours 42 Minutes. The middle of the Eclipse at 10 Hours 26 Minutes. The end of total darkness at 11 Hours 12 Minutes. And the end of the Eclipse at 12 Hours 18 Minutes; but the Figure is too small to admit of precision. 212

The examination of antient Eclipses.

390. By computing the times of New and Full Moons, together with the distance of the Sun and Moon from the Nodes; and knowing that when the Sun is within 17 Degrees of either Node at New Moon he must be eclipsed; and when the Moon is within 12 Degrees of either Node at Full she cannot escape an Eclipse; and that there can be no Eclipses without these limits; 'tis easy to examine whether the accounts of antient Eclipses recorded in history be true. I shall take the liberty to examine two of those mentioned in the foregoing catalogue, namely, that of the Moon at *Babylon* on the 19th of *March* in the 721st year before CHRIST; and that of the Sun at *Athens*, on the 20th of *March*, in the 424th year before CHRIST.

The time of Full Moon for the former of these Eclipses is already calculated, Page 198, and the time of New Moon for the latter, Page 196, both to the *Old Style*; so that we have nothing now to do but find the Sun's distance from the Nodes the same way as we did the Anomalies; and if the Full Moon in *March* 721 years before CHRIST was within 12 degrees of either Node, she was then eclipsed; and if the Sun, at the time of New Moon in *March* 424 years before CHRIST was within 17 degrees of either Node, he must have been eclipsed at that time.

EXAMPLE I.

To find the distance of the Sun and Moon from the Nodes, at the time of Full Moon in March, *the year before* CHRIST *721, O. S.*

The years 720 added to 1780 make 2500, or 25 Centuries.

213

	Sun from Node		
	s	°	′
To the mean time of Full Moon in *March 1780*, Table III.	10	3	1
Add the distance for 1 Lunation [See *N. B.* Page 195, and Example III, Page 198]	1	0	40
Sum	11	3	41
From which subtract the Sun's distance from the Node for 2500 years, Table V	5	4	11
Remains the Sun's distance from the Node, *March 19*, 721 years before CHRIST	5	29	30
To which add 6 Signs for the Moon's distance, because she was then in opposition to the Sun	6	0	0
The Sum is the Moon's dist. from the Ascend. Node	11	29	30

That is, she was within half a degree of coming round to it again; and therefore, being so near, she must have been totally, and almost centrally eclipsed.

EXAMPLE II

To find the Suns distance from the Node at the Time of New Moon in March, *the year before* CHRIST *424, O. S.*

The years 423 added to 1777 make 2200, or 22 Centuries.

	Sun from Node		
	s	°	′
At the mean time of New Moon in *March 1777*, Tab. I.	8	23	33
From which subtract the Sun's distance from the Node for 2200 years, Table V	3	6	0
Remains the Sun's distance from the Ascending Node, *March 21*, 424 years before CHRIST	5	17	33
Which, taken from 6 Signs, the distance of the Nodes from each other	6	0	0
Leaves the Sun's distance at that time from the Descending Node, Descending *viz.*	0	12	27

Which being less than 17 degrees, shews that the Sun was then eclipsed. And as from these short Calculations we find those two antient Eclipses taken at a venture, to be truly recorded; it is natural to imagine that so are all the rest in the catalogue.

Here follow ASTRONOMICAL TABLES, for calculating the Times of NEW and FULL MOONS and ECLIPSES.

TABLE I. *The mean time of New Moon in* March, *the mean Anomaly of the Sun and Moon, the Sun's mean Distance from the Ascending Node; with the mean Longitude of the Sun and Node from the beginning of the Sign Aries, at the times of all the New Moons in* March *for 100 years, Old Style*.

Years of CHRIST.	Mean time of New Moon in *March*.			The Sun's mean Anomaly.			The Moon's mean Anomaly.			The Sun's distance from the Node.			The Sun's Longitude from Aries.			The Node's Longitude from Aries.		
	D.	H.	M.	s	°	′	s	°	′	s	°	′	s	°	′	s	°	′
1701	27	13	45	9	8	23	0	28	5	7	23	15	0	16	3	4	22	48
1702	16	22	34	8	27	39	11	7	53	8	1	17	0	5	20	4	4	3
1703	6	7	23	8	16	55	9	17	41	8	9	20	11	24	37	3	15	17
1704	24	4	55	9	4	30	8	23	18	9	18	3	0	13	0	2	24	57
1705	13	13	44	8	23	54	7	3	6	9	26	6	0	2	17	2	6	11
1706	2	22	32	8	13	48	5	12	54	10	4	9	11	21	34	1	17	25
1707	21	20	5	9	2	17	4	18	31	11	12	52	0	9	57	0	27	5
1708	10	4	54	8	21	10	2	28	19	11	20	55	11	29	14	0	8	19
1709	29	2	26	9	9	48	2	3	56	0	29	38	0	17	37	11	17	59
1710	18	11	16	8	28	32	0	13	44	1	7	40	0	6	54	10	29	14
1711	7	20	5	8	17	27	10	23	33	1	15	43	11	26	11	10	10	28
1712	25	17	36	9	5	8	9	29	10	2	24	26	0	14	34	9	20	8
1713	15	2	25	8	25	48	8	8	58	3	2	29	0	3	50	9	1	21
1714	4	11	14	8	14	52	6	16	46	3	10	32	11	23	7	8	12	35
1715	23	8	46	9	3	37	5	24	22	4	19	15	0	11	30	7	22	15
1716	11	17	35	8	21	26	4	4	11	4	27	18	0	0	47	7	3	29
1717	1	2	23	8	11	58	2	13	59	5	5	20	11	20	4	6	14	44
1718	19	23	56	9	0	31	1	19	36	6	14	3	0	8	27	5	24	24
1719	9	8	45	8	19	47	11	29	24	6	22	6	11	27	43	5	5	37
1720	27	6	17	9	8	9	11	5	1	8	0	49	0	16	6	4	15	17
1721	16	15	6	8	27	25	9	14	49	8	8	52	0	5	23	3	26	31
1722	5	23	55	8	16	41	7	24	38	8	16	55	11	24	40	3	7	45
1723	24	21	27	9	5	3	7	0	15	9	25	38	0	13	4	2	17	26
1724	13	6	16	8	24	19	5	10	3	10	3	41	0	2	22	1	28	41
1725	2	15	4	8	13	45	3	19	51	10	11	43	11	21	39	1	9	56
1726	21	12	37	9	1	57	2	25	28	11	20	26	0	10	3	0	19	37
1727	10	21	26	8	21	13	1	5	16	11	28	29	11	29	20	0	0	51
1728	28	18	58	9	9	35	0	10	53	1	7	13	0	17	43	11	10	30
1729	18	3	47	8	28	51	10	20	41	1	15	15	0	7	0	10	21	45
1730	7	12	36	8	18	7	9	0	29	1	23	18	11	26	17	10	2	59
1731	26	10	8	9	6	29	8	6	6	3	2	1	0	14	40	9	12	39
1732	14	18	57	8	25	45	6	15	54	3	10	3	0	3	57	8	23	54
1733	4	3	45	8	14	49	4	25	43	3	18	6	11	23	14	8	5	7
1734	23	1	18	9	3	25	4	1	20	4	26	49	0	11	37	7	14	48
1735	12	10	7	8	22	39	2	11	8	5	4	52	0	0	54	6	26	1
1736	30	7	39	0	11	1	1	16	45	6	13	35	0	19	17	6	5	42
1737	19	16	28	9	0	1	11	26	33	6	21	38	0	8	34	5	16	56
1738	9	1	17	8	19	33	10	6	21	6	29	42	11	27	51	4	28	9
1739	27	22	49	9	7	55	9	11	58	8	8	24	0	16	14	4	7	50
1740	16	7	38	8	27	11	7	21	46	8	16	27	0	5	30	3	19	3
1741	5	16	26	8	16	27	6	1	34	8	24	30	11	24	47	3	0	16
1742	24	13	59	9	4	49	5	7	11	10	3	12	0	13	10	2	9	58
1743	13	22	48	8	24	5	3	16	59	10	11	15	0	2	27	1	21	12
1744	2	7	36	8	13	21	1	26	48	10	19	18	11	21	44	1	2	25
1745	21	5	9	9	1	43	1	2	25	11	28	0	0	10	7	0	12	7

1746	10	13	58	8	20	59	11	12	13	0	6	3	11	29	44	11	23	20
1747	29	11	30	9	9	21	10	17	50	1	14	45	0	17	47	11	3	2
1748	17	20	19	8	28	37	8	27	38	1	22	49	0	7	4	10	14	15
1749	7	5	8	8	17	53	7	7	26	2	0	53	11	26	21	9	25	28
1750	26	2	40	9	6	15	6	13	3	3	9	35	0	14	44	9	5	9
1751	15	11	29	8	25	32	4	22	51	3	17	38	0	4	1	8	16	23
1752	3	20	17	8	14	47	3	2	39	3	25	41	11	23	18	7	27	37
1753	22	17	50	9	3	10	2	8	16	5	4	24	0	11	41	7	7	17
1754	12	2	39	8	22	26	0	18	4	5	12	27	0	0	59	6	18	32
1755	1	11	27	8	11	41	10	27	52	5	20	30	11	20	16	5	29	45
1756	19	9	0	9	0	4	10	3	30	6	29	13	0	8	39	5	9	27
1757	8	17	49	8	19	20	8	13	18	7	10	15	11	27	56	4	20	41
1758	27	15	21	9	7	42	7	18	55	8	15	58	0	16	19	4	0	21
1759	17	0	10	8	26	58	5	28	43	8	24	1	0	5	36	3	11	36
1760	5	8	58	8	16	13	4	8	31	9	2	4	11	24	53	2	22	49
1761	24	6	31	9	4	35	3	14	8	10	10	47	0	13	16	2	2	29
1762	13	15	19	8	23	52	1	23	56	10	18	51	0	2	33	1	13	44
1763	3	0	8	8	13	7	0	3	44	10	26	53	11	21	50	0	24	57
1764	20	21	41	9	1	29	11	9	21	0	5	36	0	10	13	0	4	37
1765	10	6	30	8	20	46	9	19	9	0	13	38	11	29	30	11	15	52
1766	29	4	2	9	9	8	8	24	46	1	22	21	0	17	53	10	25	32
1767	18	12	51	8	28	24	7	4	35	2	0	24	0	7	10	10	6	47
1768	6	21	39	8	17	39	5	14	23	2	8	27	11	26	27	9	18	1
1769	25	19	12	9	6	2	4	20	0	3	17	0	0	14	50	8	27	41
1770	15	4	1	8	25	17	2	29	48	3	25	12	0	4	7	8	8	56
1771	4	12	49	8	14	33	1	9	36	4	3	16	11	23	24	7	20	8
1772	22	10	22	9	2	56	0	15	13	5	11	49	0	11	47	6	29	48
1773	11	19	10	8	22	11	10	25	1	5	20	1	0	1	4	6	11	3
1774	1	3	59	8	11	27	9	4	49	5	28	4	11	20	21	5	22	17
1775	20	1	32	8	29	50	8	10	26	7	6	4	0	8	44	5	1	57
1776	8	10	20	8	19	5	6	20	14	7	14	50	11	28	1	4	13	12
1777	27	7	53	9	7	27	5	25	51	8	23	23	0	16	24	3	22	52
1778	16	16	42	8	26	43	4	5	40	9	1	36	0	5	41	3	4	6
1779	6	1	30	8	15	59	2	15	28	9	9	39	11	24	58	2	15	19
1780	23	23	3	9	4	21	1	21	5	10	18	22	0	13	21	1	24	59
1781	13	7	52	8	23	37	0	0	53	10	26	24	0	2	38	1	6	14
1782	2	16	40	8	12	53	10	10	41	11	4	27	11	21	54	0	17	27
1783	21	14	13	9	1	15	9	16	18	0	13	10	0	10	17	11	27	7
1784	9	23	2	8	20	32	7	26	6	0	21	13	11	29	34	11	8	22
1785	28	20	35	9	8	54	7	1	43	1	29	56	0	17	57	10	18	2
1786	18	5	23	8	28	9	5	11	31	2	7	59	0	7	14	9	29	16
1787	7	14	11	8	17	25	3	21	19	2	16	2	11	26	31	9	10	29
1788	25	11	44	9	5	47	2	26	56	3	24	45	0	14	54	8	20	9
1789	14	20	33	8	25	3	1	6	45	4	2	47	0	4	11	8	1	25
1790	4	5	21	8	14	19	11	16	33	4	10	50	11	23	28	7	12	38
1791	23	2	54	9	2	41	10	22	10	5	19	33	0	11	51	6	22	18
1792	11	11	43	8	21	57	9	1	58	5	27	56	0	1	7	6	3	32
1793	0	20	31	8	11	12	7	11	45	6	5	39	11	20	24	5	14	45
1794	19	18	4	8	29	35	6	17	23	7	14	22	0	8	48	4	24	27
1795	9	2	52	8	18	51	4	27	11	7	22	25	11	28	6	4	5	41
1796	27	0	25	9	7	13	4	2	48	9	1	8	0	16	29	3	15	21
1797	16	9	14	8	26	29	2	12	36	9	9	10	0	5	46	2	26	36
1798	5	18	2	8	15	44	0	22	24	9	17	13	11	25	3	2	7	50
1799	24	15	35	9	4	6	11	28	1	10	25	56	0	13	26	1	17	30
1800	13	0	24	8	23	23	10	7	49	11	3	59	0	2	43	0	28	44

TABLE II. *The mean New Moons, &c. in* March *to the New Style.*

Years of CHRIST.	Mean time of New Moon in *March*.			The Sun's mean Anomaly.			The Moon's mean Anomaly.			The Sun's distance from the Node.			The Sun's Longitude from Aries.			The Node's Longitude from Aries.		
	D.	H.	M.	s	°	′	s	°	′	s	°	′	s	°	′	s	°	′
1753	4	5	6	7	4	2	1	12	27	4	3	44	11	12	35	7	8	50
1754	23	2	39	8	22	26	0	18	4	5	12	27	0	0	59	6	18	32
1755	12	11	27	8	11	41	10	27	52	5	20	29	11	20	16	5	29	45
1756	30	9	0	9	0	3	10	3	29	6	29	12	0	8	39	5	9	27
1757	19	17	49	8	19	19	8	13	17	7	7	15	11	27	56	4	20	41
1758	9	2	37	8	8	35	6	23	5	7	15	18	11	17	13	4	1	54
1759	28	0	9	8	26	58	5	28	43	8	24	1	0	5	36	3	11	36
1760	16	8	58	8	16	14	4	8	31	9	2	4	11	24	53	2	22	49
1761	5	7	47	8	5	29	2	18	19	9	10	9	11	14	10	2	4	1
1762	24	15	19	8	23	52	1	23	56	10	18	51	0	2	33	1	13	44
1763	14	0	8	8	13	7	0	3	44	10	26	53	11	21	50	0	24	57
1764	2	8	57	8	2	23	10	13	32	11	4	57	11	11	7	0	6	10
1765	21	6	30	8	20	46	9	19	9	0	13	38	11	29	30	11	15	52
1766	10	15	18	8	10	1	7	28	58	0	21	41	11	18	47	10	27	5
1767	29	12	51	8	28	23	7	4	35	2	0	23	0	7	10	10	6	47
1768	17	21	39	8	17	39	5	14	23	2	8	26	11	26	27	9	18	1
1769	7	6	28	8	6	55	3	24	11	2	16	29	11	15	44	8	29	15
1770	26	4	1	8	25	18	2	29	48	3	25	11	0	4	7	8	8	56
1771	15	12	49	8	14	33	1	9	36	4	3	16	11	23	24	7	20	8
1772	3	21	38	8	3	49	11	19	24	4	11	19	11	12	41	7	1	22
1773	22	19	10	8	22	11	10	25	1	5	20	1	0	1	4	6	11	3
1774	12	3	59	8	11	27	9	4	49	5	28	4	11	20	21	5	22	17
1775	1	12	48	8	0	43	7	14	37	6	6	7	11	9	38	5	3	30
1776	19	10	20	8	19	5	6	20	14	7	14	50	11	28	1	4	13	12
1777	8	19	9	8	8	21	5	0	2	7	22	53	11	17	18	3	24	25
1778	27	16	42	8	26	43	4	5	40	9	1	36	0	5	41	3	4	6
1779	17	1	30	8	15	59	2	15	28	9	9	39	11	24	58	2	15	19
1780	5	10	19	8	5	15	0	25	16	9	17	42	11	14	15	1	26	32
1781	24	7	52	8	23	37	0	0	53	10	26	24	0	2	38	1	6	14
1782	13	16	40	8	12	53	10	10	41	11	4	27	11	21	54	0	17	27
1783	3	1	29	8	2	8	8	20	29	11	12	30	11	11	11	11	28	40
1784	20	23	2	8	20	32	7	26	6	0	21	13	11	29	34	11	8	22
1785	10	7	50	8	9	47	6	5	54	0	29	16	11	18	51	10	19	35
1786	29	5	23	8	28	9	5	11	31	2	7	59	0	7	14	9	29	16
1787	18	14	11	8	17	25	3	21	19	2	16	2	11	26	31	9	10	29
1788	6	23	0	8	6	41	2	1	7	2	24	5	11	15	48	8	21	43
1789	25	20	33	8	25	3	1	6	45	4	2	47	0	4	11	8	1	25
1790	15	5	21	8	14	19	11	16	33	4	10	50	11	23	28	7	12	38
1791	4	14	10	8	3	34	9	26	21	4	18	53	11	12	44	6	23	51
1792	22	11	43	8	21	57	9	1	58	5	27	36	0	1	7	6	3	32
1793	11	20	31	8	11	12	7	11	45	6	5	39	11	20	24	5	14	45
1794	1	6	20	8	0	29	5	21	34	6	13	42	11	9	22	4	7	15
1795	20	2	52	8	18	51	4	27	11	7	22	25	11	28	6	4	5	41
1796	8	11	41	8	8	6	3	6	59	8	0	28	11	17	23	3	16	54
1797	27	9	14	8	26	29	2	12	36	9	9	10	0	5	46	2	26	36
1798	16	18	2	8	15	44	0	22	24	9	17	13	11	25	3	2	7	50
1799	6	2	51	8	5	0	11	2	12	9	25	16	11	14	20	1	19	3
1800	25	0	24	8	23	23	10	7	49	11	3	59	0	2	43	0	28	44

TABLE III. *The mean time of Full Moon in* March, *the mean Anomaly of the Sun and Moon, the Sun's mean Distance from the Ascending Node; with the mean Longitude of the Sun and Node from the beginning of the Sign Aries, at the time of all the Full Moons in* March *for 100 years, Old Style.*

Years of CHRIST.	Mean time of Full Moon in *March.*			The Sun's mean Anomaly.			The Moon's mean Anomaly.			The Sun's distance from the Node.			The Sun's Longitude from Aries.			The Node's Longitude from Aries.		
	D.	H.	M.	s	°	′	s	°	′	s	°	′	s	°	′	s	°	′
1701	12	19	23	8	23	56	6	15	11	7	7	55	0	1	30	4	23	35
1702	2	4	12	8	13	6	4	24	59	7	15	57	11	20	47	4	4	48
1703	21	1	45	9	1	28	4	0	35	8	24	40	0	9	10	3	14	30
1704	9	10	33	8	19	57	2	10	24	9	2	43	11	28	27	2	25	43
1705	28	8	6	9	8	27	1	16	0	10	11	26	0	16	50	2	5	25
1706	17	16	54	8	28	11	11	25	48	10	19	29	0	6	7	1	16	38s
1707	7	1	43	8	17	44	10	5	37	10	27	32	11	25	24	0	27	51
1708	24	23	16	9	5	43	9	11	14	0	6	15	0	13	47	0	7	33
1709	14	8	4	8	25	15	7	21	2	0	14	18	0	3	4	11	18	46
1710	3	16	54	8	13	59	6	0	50	0	22	21	11	22	21	11	0	0
1711	22	14	27	9	2	0	5	6	27	2	1	3	0	10	44	10	9	42
1712	10	23	14	8	20	35	3	16	16	2	9	6	0	0	1	9	20	55
1713	29	20	47	9	10	21	2	21	52	3	17	48	0	18	23	9	0	35
1714	19	5	36	8	29	25	1	1	40	3	25	53	0	7	40	8	11	48
1715	8	14	24	8	19	4	11	11	28	4	3	56	11	26	57	7	23	1
1716	26	11	57	9	5	59	0	17	5	5	12	38	0	15	20	7	2	43
1717	15	20	45	8	26	31	18	26	53	5	20	41	0	4	37	6	13	56
1718	5	5	34	8	15	58	7	6	42	5	28	44	11	23	54	5	25	10
1719	24	3	7	9	4	20	6	12	18	7	7	26	0	12	17	5	4	52
1720	12	11	55	8	23	36	4	22	7	7	15	29	0	1	34	4	16	5
1721	1	20	44	8	12	52	3	1	55	7	23	32	11	20	51	3	27	18
1722	20	18	17	9	1	14	2	7	32	9	2	15	0	9	14	3	6	59
1723	10	3	5	8	20	30	0	17	21	9	10	18	11	28	31	2	18	12
1724	28	0	38	9	8	52	11	22	57	10	19	0	0	16	55	1	27	55
1725	17	9	26	8	28	18	10	2	45	10	27	3	0	6	12	1	9	9
1726	6	18	15	8	17	24	8	12	34	11	5	6	11	25	30	0	20	23
1727	25	15	48	9	5	46	7	18	10	0	13	49	0	13	53	0	0	5
1728	14	0	36	8	25	2	5	27	59	0	21	52	0	3	10	11	11	18
1729	3	9	25	8	14	18	4	7	47	0	29	55	11	22	27	10	22	32
1730	22	6	58	9	2	40	3	13	23	2	8	38	0	10	50	10	2	13
1731	11	15	46	8	21	56	1	23	12	2	16	41	0	0	7	9	13	26
1732	29	13	19	9	10	18	0	28	48	3	25	23	0	18	30	8	23	8
1733	18	22	7	8	29	22	11	8	37	4	3	26	0	7	47	8	4	21
1734	8	6	56	8	18	50	9	18	26	4	11	29	11	27	4	7	15	34
1735	27	4	29	9	7	12	8	24	2	5	20	12	0	15	27	6	25	15
1736	15	13	17	8	26	29	7	3	51	5	28	15	0	4	44	6	6	29
1737	4	22	6	8	15	44	5	13	39	6	6	18	11	24	1	5	17	42
1738	23	19	39	9	4	6	4	19	15	7	15	1	0	12	24	4	27	24
1739	13	4	27	8	23	22	2	29	4	7	23	4	0	1	41	4	8	37
1740	1	13	16	8	12	38	1	8	52	8	1	7	11	20	57	3	19	50
1741	20	10	48	9	1	0	0	14	28	9	9	49	0	9	20	2	29	30
1742	9	19	37	8	20	16	10	24	17	9	17	52	11	28	37	2	10	44
1743	28	17	10	9	8	38	9	29	53	10	26	35	0	17	0	1	20	26
1744	17	1	58	8	27	54	8	9	42	11	4	38	0	6	17	1	1	39
1745	6	10	47	8	17	10	6	19	31	11	12	41	11	25	34	0	12	52

1746	25	8	19	9	5	32	5	25	7	0	21	24	0	13	57	11	22	34
1747	14	17	8	8	24	48	4	4	56	0	29	27	0	3	14	11	3	47
1748	3	1	57	8	14	4	2	14	44	1	7	30	11	22	31	10	15	0
1749	21	23	30	9	2	26	1	20	20	2	16	12	0	10	54	9	24	42
1750	11	8	18	8	21	42	0	0	9	2	24	15	0	0	11	9	5	59
1751	30	5	51	9	10	5	11	5	45	4	2	58	0	18	34	8	15	37
1752	18	14	39	8	29	20	9	15	33	4	11	1	0	7	51	7	26	50
1753	7	23	18	7	18	35	7	25	21	4	19	4	11	27	8	7	8	4
1754	26	21	1	9	6	59	7	0	58	7	27	47	0	15	32	6	17	45
1755	16	5	49	8	26	14	5	10	46	6	5	49	0	4	49	5	29	0
1756	4	14	38	8	15	30	3	20	35	6	13	52	11	24	6	5	10	14
1757	23	12	11	9	3	53	2	26	12	7	25	35	0	12	29	4	19	54
1758	12	20	59	8	23	8	1	5	59	8	0	38	0	1	46	4	1	9
1759	2	5	47	8	12	25	11	15	48	8	8	41	11	21	3	3	12	22
1760	20	3	20	9	0	46	10	21	25	9	17	24	0	9	26	2	22	2
1761	9	12	9	8	20	2	9	1	13	9	25	27	11	28	43	2	3	16
1762	28	9	41	9	8	25	8	6	50	11	4	11	0	17	6	1	12	57
1763	17	18	30	8	27	40	6	16	38	11	12	13	0	6	23	0	24	11
1764	6	3	19	8	16	56	4	26	26	11	20	16	11	25	40	0	5	24
1765	25	0	52	9	5	19	4	2	3	0	28	58	0	14	3	11	15	5
1766	14	9	40	8	24	34	2	11	52	1	7	1	0	3	20	10	26	20
1767	7	18	29	8	13	50	0	21	41	1	15	4	11	22	37	10	7	34
1768	21	16	1	9	2	12	11	27	17	2	23	47	0	11	0	9	17	14
1769	11	0	50	8	21	28	10	7	9	3	1	49	0	0	17	8	28	28
1770	0	9	39	8	10	44	8	16	57	3	9	52	11	19	54	8	9	42
1771	19	7	11	8	29	6	7	22	30	4	18	36	0	7	57	7	19	21
1772	7	16	0	8	18	22	6	2	18	4	26	39	11	27	14	7	0	35
1773	26	13	32	9	6	44	5	7	55	6	5	21	0	15	37	6	10	16
1774	15	22	21	8	26	0	3	17	43	6	13	24	0	4	54	5	21	31
1775	5	7	10	8	15	16	1	27	31	6	21	27	11	24	11	5	2	44
1776	23	4	42	9	3	38	1	3	8	8	0	10	0	12	34	4	12	25
1777	12	13	31	8	22	54	11	12	56	8	8	13	0	1	51	8	23	30
1778	1	22	20	8	12	10	9	22	45	8	16	16	11	21	8	3	4	52
1779	20	19	52	9	0	32	8	28	22	9	24	59	0	9	31	2	14	32
1780	9	4	41	8	19	48	7	8	10	10	3	1	11	28	48	1	25	47
1781	28	2	14	9	8	9	6	13	47	11	11	44	0	17	11	1	5	27
1782	19	11	2	8	27	28	4	23	34	11	19	47	0	6	27	0	6	41
1783	6	19	51	8	16	44	3	3	23	11	27	50	11	25	44	11	27	54
1784	24	17	24	9	5	4	2	9	0	1	6	35	0	14	7	11	7	35
1785	14	2	12	8	24	20	0	18	48	1	14	36	0	3	24	10	18	48
1786	3	11	1	8	13	36	10	28	37	1	22	39	11	22	41	10	0	2
1787	22	8	33	9	1	57	10	4	13	3	1	22	0	11	4	9	9	42
1788	10	17	22	8	21	14	8	14	2	3	9	25	0	0	21	8	20	57
1789	29	14	55	9	9	36	7	19	39	4	18	7	0	18	44	8	0	38
1790	18	23	43	8	28	52	5	29	27	4	26	10	0	8	1	7	11	51
1791	8	8	32	8	18	8	4	9	15	5	4	13	11	27	17	6	23	4
1792	26	6	5	9	6	20	3	14	52	6	12	56	0	15	40	6	2	45
1793	15	14	53	8	25	46	1	24	40	6	20	59	0	4	58	5	13	59
1794	4	23	42	8	15	2	0	4	29	6	29	2	11	24	15	4	25	13
1795	23	21	14	9	3	14	11	10	5	8	7	45	0	12	39	4	4	54
1796	12	6	3	8	22	39	9	19	53	8	15	48	0	1	56	3	16	8
1797	1	14	52	8	11	55	7	29	42	8	23	50	11	21	13	2	27	23
1798	20	12	24	9	0	7	7	5	18	10	2	33	0	9	36	2	7	3
1799	9	21	13	8	19	33	5	15	6	10	10	36	11	28	53	1	18	18
1800	27	18	46	9	7	46	4	20	43	11	19	19	0	17	16	0	27	57

220

TABLE IV. *The mean Full Moons, &c. in* March *to the New Style*.

Years of CHRIST.	Mean time of Full Moon in *March*.			The Sun's mean Anomaly.			The Moon's mean Anomaly.			The Sun's distance from the Node.			The Sun's Longitude from Aries.			The Node's Longitude from Aries.		
	D.	H.	M.	s	°	′	s	°	′	s	°	′	s	°	′	s	°	′
1753	18	23	18	7	18	35	7	25	21	4	19	4	11	27	8	7	8	4
1754	8	8	17	7	7	53	6	5	10	4	27	7	11	16	26	6	19	18
1755	27	5	49	8	26	14	5	10	46	6	5	49	0	4	49	5	29	0
1756	15	14	38	8	15	30	3	20	35	6	13	52	11	24	6	5	10	14
1757	4	23	27	8	4	36	2	0	23	6	21	55	11	13	23	4	21	27
1758	23	20	59	8	23	8	1	5	59	8	0	38	0	1	46	4	1	9
1759	13	5	47	8	12	25	11	15	48	8	8	41	11	21	3	3	12	22
1760	1	14	36	8	1	41	9	25	37	8	16	44	11	10	20	2	23	35
1761	20	12	9	8	20	2	9	1	13	9	25	27	11	28	43	2	3	16
1762	9	20	57	8	9	19	7	11	2	10	3	31	11	18	0	1	14	29
1763	28	18	30	8	27	40	6	16	38	11	12	13	0	6	23	0	24	11
1764	17	3	19	8	16	56	4	26	26	11	20	16	11	25	40	0	5	24
1765	6	12	8	8	6	13	3	6	15	11	28	19	11	14	57	11	16	38
1766	25	9	40	8	24	34	2	11	52	1	7	1	0	3	20	10	26	20
1767	18	18	29	8	13	50	0	21	41	1	15	4	11	22	37	10	7	33
1768	3	3	17	8	3	6	11	1	29	1	23	7	11	11	54	9	18	46
1769	22	0	50	8	21	28	10	7	5	3	1	49	0	0	17	8	28	28
1770	11	9	39	8	15	45	8	16	54	3	9	52	11	19	34	8	9	42
1771	30	7	11	8	29	6	7	22	30	4	18	36	0	7	57	7	19	21
1772	18	16	0	8	18	22	6	2	18	4	26	39	11	27	14	7	0	35
1773	8	0	48	8	7	38	4	12	7	5	4	42	11	16	31	6	11	49
1774	26	22	21	8	26	0	3	17	43	6	13	24	0	4	54	5	21	31
1775	16	7	10	8	15	16	1	27	31	6	21	27	11	24	11	5	2	44
1776	4	15	58	8	4	32	0	7	20	6	29	30	11	13	28	4	13	58
1777	23	13	31	8	22	54	11	12	56	8	8	13	0	1	51	3	23	39
1778	12	22	20	8	12	10	9	22	45	8	16	16	11	21	8	3	4	52
1779	2	7	8	8	1	26	8	2	34	8	24	19	11	10	25	2	16	5
1780	20	4	41	8	19	48	7	8	10	10	3	1	11	28	48	1	25	47
1781	9	13	30	8	9	4	5	17	59	10	11	4	11	18	5	1	7	0
1782	28	11	2	8	27	28	4	23	34	11	19	47	0	6	27	0	16	41
1783	17	19	51	8	16	44	3	3	23	11	27	50	11	25	44	11	27	54
1784	6	4	40	8	5	59	1	13	12	0	5	53	11	15	1	11	9	7
1785	25	2	12	8	24	20	0	18	48	1	14	36	0	3	24	10	18	48
1786	14	11	1	8	13	36	10	28	37	1	22	39	11	22	41	10	0	2
1787	3	19	49	8	2	52	9	8	25	2	0	42	11	11	58	9	11	15
1788	21	17	22	8	21	14	8	14	2	3	9	25	0	0	21	8	20	57
1789	11	2	11	8	10	30	6	23	51	3	17	28	11	19	38	8	2	10
1790	29	23	43	8	28	52	5	29	27	4	26	10	0	8	1	7	11	51
1791	19	8	32	8	18	8	4	9	15	5	4	13	11	27	17	6	23	4
1792	7	17	21	8	7	24	2	19	4	5	12	16	11	16	34	6	4	17
1793	26	14	53	8	25	46	1	24	40	6	20	59	0	4	58	5	13	59
1794	15	23	42	8	15	2	0	4	29	6	29	2	11	24	15	4	25	13
1795	5	8	30	8	4	18	10	14	17	7	7	5	0	13	32	4	6	26
1796	23	6	3	8	22	39	9	19	53	8	15	48	0	1	56	3	16	8
1797	12	14	52	8	11	55	7	29	42	8	23	50	11	21	13	2	27	23
1798	1	23	40	8	1	11	6	9	30	9	1	53	11	10	30	2	8	36
1799	20	21	13	8	19	33	5	15	6	10	10	36	11	28	53	1	18	18
1800	10	6	2	8	8	50	3	24	55	10	18	39	11	18	10	0	29	31

TAB. V. *The first mean Conjunction of the Sun and Moon after a compleat Century, beginning with* March, *for 5000 years 10 days 7 hours 56 minutes (in which time there are just 61843 mean Lunations) with the mean Anomaly of the Sun and Moon, the Sun's mean distance from the Ascending Node, and the mean Long. of the Sun and Node from the beginning of the sign Aries, at the times of all those mean Conjunctions.*

222

Centuries of *Julian* Years.	First Conjunction after a Century.			The Sun's mean Anomaly.			The Moon's mean Anomaly.			The Sun's distance from the Node.			The Sun's Longitude from Aries.			The Node's Longitude from Aries.		
	D.	H.	M.	s	°	′	s	°	′	s	°	′	s	°	′	s	°	′
100	4	8	11	0	3	21	8	15	22	4	19	27	0	5	2	4	14	25
200	8	16	22	0	6	42	5	0	44	9	8	55	0	10	4	8	28	51
300	13	0	33	0	10	3	1	16	6	1	28	22	0	15	6	1	13	16
400	17	8	43	0	13	24	10	1	28	6	17	49	0	20	8	5	27	41
500	21	16	54	0	16	46	6	16	50	11	7	16	0	25	10	10	12	6
600	26	1	5	0	20	7	3	2	12	3	26	44	1	0	12	2	26	32
700	0	20	32	11	24	22	10	21	45	7	15	31	0	6	7	7	9	24
800	5	4	43	11	27	43	7	7	7	0	4	58	0	11	9	11	23	49
900	9	12	54	0	1	4	3	22	29	4	24	25	0	16	12	4	8	13
1000	13	21	5	0	4	25	0	7	51	9	13	53	0	21	14	8	22	39
1100	18	5	16	0	7	46	8	23	13	2	3	20	0	26	16	1	7	4
1200	22	13	26	0	11	7	5	8	35	6	22	47	1	1	18	5	21	29
1300	26	21	37	0	14	28	1	23	57	11	12	15	1	6	20	10	5	55
1400	1	17	4	11	18	43	9	13	30	3	1	2	0	12	15	2	18	47
1500	6	1	15	11	22	4	5	28	52	7	20	29	0	17	17	7	3	12
1600	10	9	26	11	25	25	2	14	14	0	9	56	0	22	19	11	17	37
1700	14	17	37	11	28	46	10	29	36	4	29	23	0	27	22	4	2	2
1800	19	1	48	0	2	8	7	14	58	9	18	51	1	2	24	8	16	27
1900	23	9	58	0	5	29	4	0	20	2	8	18	1	7	26	1	0	52
2000	27	18	9	0	8	50	0	15	42	6	27	45	1	12	28	5	15	17
2100	2	13	36	11	13	5	8	5	15	10	16	32	0	18	24	9	28	8
2200	6	21	47	11	16	26	4	20	37	3	6	0	0	23	26	2	12	34
2300	11	5	58	11	19	47	1	5	59	7	25	27	0	28	28	6	26	59
2400	15	14	9	11	23	8	9	21	21	0	14	54	1	3	30	11	11	24
2500	19	22	20	11	26	29	6	6	43	5	4	11	1	8	32	3	25	49
2600	24	6	31	11	29	50	2	22	4	9	23	49	1	13	35	8	10	14
2700	28	14	41	0	3	11	11	17	26	2	13	16	1	18	37	0	24	39
2800	3	10	8	11	7	26	6	26	59	6	2	3	0	24	31	5	7	33
2900	7	18	19	11	10	47	3	12	21	10	21	30	0	29	33	9	21	58
3000	12	2	30	11	14	8	11	27	43	3	10	58	1	4	35	2	6	23
3100	16	10	41	11	17	30	8	13	5	8	10	25	1	9	37	6	20	48
3200	20	18	52	11	20	51	4	28	27	0	19	52	1	14	39	11	5	13
3300	25	3	3	11	24	11	1	13	49	5	9	20	1	19	41	3	19	39
3400	29	11	14	11	27	32	9	29	11	9	28	47	1	24	43	8	4	4
3500	4	6	41	11	1	47	5	18	44	1	17	34	1	0	41	0	16	53
3600	8	14	52	11	4	58	2	4	6	6	7	1	1	5	42	5	1	19
3700	12	23	3	11	8	9	10	19	28	10	26	28	1	10	43	9	15	45
3800	17	7	14	11	11	20	7	4	50	3	15	55	1	15	45	2	0	10
3900	21	15	25	11	14	31	4	20	12	8	5	22	1	20	47	6	14	35
4000	25	23	36	11	17	42	1	5	34	0	24	49	1	25	49	10	29	0
4100	0	19	3	10	22	56	8	25	7	4	13	36	1	0	45	3	12	51
4200	5	3	14	10	26	17	5	10	29	9	3	3	1	6	47	7	6	16
4300	9	11	25	10	29	37	1	25	51	1	12	30	1	11	48	11	25	39

223

4400	13	19	36	11	2	58	10	11	13	6	1	57	1	16	51	4	10	4
4500	18	3	46	11	6	18	6	26	35	10	21	24	1	21	53	8	29	31
4600	22	11	57	11	9	39	3	11	15	3	10	51	1	26	55	1	13	56
4700	26	20	7	11	12	59	11	27	19	8	0	16	2	1	57	5	28	19
4800	1	15	34	10	17	14	7	16	52	11	19	4	1	7	53	10	11	11
4900	5	23	45	10	20	35	4	2	14	4	8	30	1	12	55	2	25	35
5000	10	7	56	10	23	56	0	17	36	8	27	57	1	17	57	7	10	0

TABLE VI. *The mean Anomaly of the Sun and Moon, the Sun's mean distance from the Ascending Node, with the mean Longitude of the Sun and Node from the beginning of the Sign Aries, for 13 mean Lunations.*

Lunations.	Mean Lunations.			The Sun's mean Anomaly.			The Moon's mean Anomaly.			The Sun's motion from the Node.			The Sun's mean Motion.			The Node's retrograde Motion.		
	D.	H.	M.	s	°	′	s	°	′	s	°	′	s	°	′	s	°	′
1	29	12	44	0	29	6	0	25	49	1	0	40	0	29	6	0	1	34
2	59	1	28	1	28	13	1	21	38	2	1	20	1	28	13	0	3	8
3	88	14	12	2	27	19	2	17	27	3	2	1	2	27	19	0	4	41
4	118	2	56	3	26	26	3	13	16	4	2	41	3	26	26	0	6	15
5	147	15	4	4	25	32	4	9	5	5	3	21	4	25	32	0	7	49
6	177	4	24	5	24	38	5	4	54	6	4	1	5	24	38	0	9	23
7	206	17	8	6	23	44	6	0	43	7	4	42	6	23	45	0	10	57
8	236	5	52	7	22	50	6	26	32	8	5	22	7	22	51	0	12	31
9	265	18	36	8	21	57	7	22	21	9	6	2	8	21	58	0	14	4
10	295	7	21	9	21	3	8	18	10	10	6	42	9	21	4	0	15	38
11	324	20	5	10	20	9	9	13	59	11	7	22	10	20	10	0	17	12
12	354	8	49	11	19	16	10	9	48	0	8	3	11	19	17	0	18	46
13	383	21	33	0	18	22	11	5	37	1	8	43	0	18	23	0	20	20

The first, second, third, and fourth Tables may be continued, by means of the sixth, to any length of time: for, by adding 12 Lunations to the mean time of the New or Full Moon which happens next after the 11th day of *March*, and then, casting out 365 days in common years, and 366 days in leap-years, we have the mean time of New or Full Moon in *March* the following year. But when the mean New or Full Moon happens on or before the 11th of *March*, there must be 13 Lunations added to carry it to *March* again. The Anomalies, Sun's distance from the Node, and Longitude of the Sun, are found the same way, by adding them for 12 or 13 Lunations. But the retrograde Motion of the Node for these Lunations must be subtracted from it's longitude from Aries in *March*, to have it's Longitude or Place in the *March* following.

TABLE VII. *The number of Days, reckoned from the beginning of* March, *answering to the Days of all the mean New and Full Moons.*

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 VIII. *The Moon's annual Equation.*

Sun's Ano.	Subtract						Sun's Ano.
	0 S.	1 S.	2 S.	3 S.	4 S.	5 S.	
D.	M.	M.	M.	M.	M.	M.	D.
0	0	11	18	22	19	11	30
1	0	11	19	22	19	11	29
2	1	11	19	22	18	10	28
3	1	11	19	22	18	10	27
4	1	12	19	22	18	10	26
5	2	12	19	22	18	9	25
6	2	12	19	21	18	9	24
7	3	13	20	21	17	9	23
8	3	13	20	21	17	8	22
9	3	13	20	21	17	8	21
10	4	14	20	21	17	8	20
11	4	14	20	21	16	7	19
12	4	14	20	21	16	7	18
13	5	14	20	21	16	6	17
14	5	15	20	21	16	6	16
15	5	15	21	21	15	6	15
16	6	15	21	21	15	5	14
17	6	15	21	21	15	5	13
18	6	16	21	21	15	5	12
19	7	16	21	20	14	4	11
20	7	16	21	20	14	4	10
21	7	16	21	20	14	3	9
22	8	17	21	20	13	3	8
23	8	17	21	20	13	3	7
24	9	17	21	20	13	2	6
25	9	17	21	20	13	2	5
26	9	18	21	20	12	2	4
27	10	18	21	19	12	1	3
28	10	18	21	19	12	1	2
29	10	18	22	19	11	0	1
30	11	18	22	19	11	0	0
Sun's Ano.	11 S.	10 S.	9 S.	8 S.	7 S.	6 S.	Sun's Ano.
	Add						

TABLE IX. *Equation of the Moon's mean Anomaly.*

Sun's Anom.	Add						Sun's Anom.
	0 S.	1 S.	2 S.	3 S.	4 S.	5 S.	
°	′	′	′	′	′	′	°
0	0	10	17	20	17	10	30
1	0	10	17	20	17	10	29
2	1	11	17	20	17	9	28
3	1	11	18	20	17	9	27
4	1	11	18	20	17	9	26
5	2	12	18	20	17	9	25
6	2	12	18	20	16	8	24
7	2	12	18	20	16	8	23
8	3	12	18	20	16	8	22
9	3	12	19	20	16	7	21
10	3	13	19	20	16	7	20
11	4	13	19	20	15	7	19
12	4	13	19	20	15	6	18
13	4	13	19	19	15	6	17
14	5	14	19	19	15	6	16
15	5	14	19	19	14	5	15
16	5	14	19	19	14	5	14
17	6	14	19	19	14	5	13
18	6	15	19	19	14	4	12
19	6	15	20	19	13	4	11
20	7	15	20	19	13	4	10
21	7	15	20	19	13	3	9
22	7	16	20	19	13	3	8
23	8	16	20	19	12	3	7
24	8	16	20	18	12	2	6
25	8	16	20	18	12	2	5
26	9	16	20	18	11	1	4
27	9	17	20	18	11	1	3
28	9	17	20	18	11	1	2
29	10	17	20	18	10	0	1
30	10	17	20	17	10	0	0
Sun's Anom.	11 S.	10 S.	9 S.	8 S.	7 S.	6 S.	Sun's Anom.
	Subtract						

TABLE X. *The Moon's elliptic Equation.*

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

TABLE XI. *The Sun's Equation at the time of New and Full Moon.* 226

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

TABLE XII. *Equation of the Sun's mean Place.*

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

TABLE XIII. *Equation of the Moon's Nodes.*

Sun's Ano.	Subtract						Sun's Ano.
	0 S.	1 S.	2 S.	3 S.	4 S.	5 S.	
°	′	′	′	′	′	′	°
0	0	5	8	10	8	5	30
1	0	5	8	10	8	5	29
2	0	5	8	10	8	5	28
3	0	5	8	10	8	4	27
4	1	5	8	10	8	4	26
5	1	5	8	10	8	4	25
6	1	6	9	10	8	4	24
7	1	6	9	9	8	4	23
8	1	6	9	9	8	4	22
9	1	6	9	9	7	3	21
10	2	6	9	9	7	3	20
11	2	6	9	9	7	3	19
12	2	6	9	9	7	3	18
13	2	6	9	9	7	3	17
14	2	7	9	9	7	3	16
15	2	7	9	9	7	3	15
16	2	7	9	9	7	2	14
17	3	7	9	9	7	2	13
18	3	7	9	9	6	2	12
19	3	7	9	9	6	2	11
20	3	7	9	9	6	2	10
21	3	7	9	9	6	2	9
22	4	7	9	9	6	1	8
23	4	8	9	9	6	1	7
24	4	8	9	9	6	1	6
25	4	8	9	9	6	1	5
26	4	8	10	9	5	1	4
27	4	8	10	9	5	1	3
28	4	8	10	8	5	0	2
29	5	8	10	8	5	0	1
30	5	8	10	8	5	0	0
Sun's Ano.	11 S.	10 S.	9 S.	8 S.	7 S.	6 S.	Sun's Ano.
	Add						

The above titles, *Add* and *Subtract*, are right when the Equation is applied to the Sun's mean distance from the Node; but when it is applied to the mean place of the Node, the titles must be changed.

Tab. XIV. *The Moon's latitude in Eclipses.*

Argument of Latit.				
Moon fr. the Node.	**Sig. 0 N. A. Sig. 6 S. D.**			
°	°	′	″	°
0	0	0	0	30
1	0	5	15	29
2	0	10	30	28
3	0	15	44	27
4	0	20	59	26
5	0	26	13	25
6	0	31	26	24
7	0	36	39	23
8	0	41	51	22
9	0	47	2	21
10	0	52	13	20
11	0	57	23	19
12	1	2	31	18
13	1	7	38	17
14	1	12	44	16
15	1	17	49	15
16	1	22	52	14
17	1	27	53	13
18	1	32	54	12
N. D. Sig. 5 S. A. Sig. 11				**Moon fr. the Node.**
Argument of Latit.				

This Table extends no farther than the limits of Eclipses. N. A. signifies North Ascending Lat. S. A. South Ascending; N. D. North Descending; and S. D. South Descending.

TABLE XV. *The Moons Horizontal Parallax; the Semidiameters and true Horary motions of the Sun and Moon.*

Anomaly of the Sun and Moon.		Moon's Horizontal Parallax.		Sun's Semidiameter.		Moon's Semidiamet.		Moon's horary Mot.		Sun's horary Mot.		Anomaly of the Sun and Moon.	
s	°	′	″	′	″	′	″	′	″	′	″	s	°
0	0	54	59	15	50	14	54	30	10	2	23	12	0
	6	54	59	15	50	14	55	30	12	2	23		24
	12	55	0	15	50	14	56	30	15	2	23		18
	18	55	4	15	51	14	57	30	18	2	23		12
	24	55	11	15	51	14	58	30	26	2	23		6
1	0	55	20	15	52	14	59	30	34	2	23	11	0
	6	55	30	15	53	15	1	30	44	2	24		24
	12	55	40	13	54	15	4	30	55	2	24		18
	18	55	51	15	55	15	8	31	9	2	24		12
	24	56	0	15	56	15	12	31	23	2	25		6
2	0	56	11	15	58	15	17	31	40	2	25	10	0
	6	56	24	15	59	15	22	31	58	2	26		24
	12	56	41	16	1	15	26	32	17	2	27		18
	18	57	12	16	2	15	30	32	39	2	27		12
	24	57	30	16	4	15	36	33	11	2	28		6
3	0	57	49	16	6	15	41	33	23	2	28	9	0
	6	58	10	16	8	15	46	33	47	2	29		24
	12	58	31	16	9	15	52	34	11	2	29		18
	18	58	52	16	11	15	58	34	34	2	29		12
	24	59	11	16	13	16	3	34	58	2	30		6
4	0	59	30	16	14	16	9	35	22	2	30	8	0
	6	59	52	16	15	16	14	35	45	2	31		24
	12	60	9	16	17	16	19	36	0	2	31		18
	18	60	26	16	19	16	24	36	20	2	32		12
	24	60	40	16	20	16	28	36	40	2	32		6
5	0	60	54	16	21	16	31	37	0	2	32	7	0
	6	61	4	16	21	16	34	37	10	2	33		24
	12	61	11	16	22	16	37	37	19	2	33		18
	18	61	16	16	22	16	38	37	28	2	33		12
	24	61	20	16	23	16	39	37	36	2	33		6
6	0	61	24	16	23	16	39	37	40	2	33	6	0

The gradual increase or decrease of the above numbers being so small, it is sufficient to have them to every sixth degree; the proportions for the intermediate degrees being easily made by sight.

Table XVI. *The Sun's mean Motion and Anomaly.*

	Years of Christ beginning	Sun's mean Longitude from Aries.				Sun's mean Anomaly.		
		s	°	′	″	s	°	′
O.S.	1	9	7	53	10	6	29	54
	1301	9	17	42	30	6	16	58
	1401	9	18	27	50	6	15	59
	1501	9	19	13	10	6	14	59
	1601	9	19	58	30	6	13	59
	1701	9	20	43	50	6	12	59
N.S.	1753	9	10	16	52	6	1	38
	1801	9	9	39	39	6	0	10

Old Style to the beginning of A. D. 1753; then New Style

Years of Christ compleat	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
19	11	29	24	16	11	29	4
20	0	0	9	4	11	29	48
40	0	0	18	8	11	29	36
60	0	0	27	12	11	29	24
80	0	0	36	16	11	29	12
100	0	0	45	20	11	29	0
200	0	1	30	40	11	28	1
300	0	2	16	0	11	27	1
400	0	3	1	20	11	26	1
500	0	3	46	40	11	25	2
600	0	4	32	0	11	24	2
700	0	5	17	20	11	23	2
800	0	6	2	40	11	22	3
900	0	6	48	0	11	21	3
1000	0	7	33	20	11	20	3
2000	0	15	6	40	11	10	7
3000	0	22	40	0	11	0	10
4000	1	0	13	20	10	20	13

5000	1	7	46	40	10	10	16
6000	1	15	20	0	10	0	19

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

Days.	Sun's mean Motion and Anomaly.			
	s	°	′	″
1	0	0	59	8
2	0	1	58	17
3	0	2	57	25
4	0	3	56	33
5	0	4	55	42
6	0	5	54	50
7	0	5	53	58
8	0	7	53	7
9	0	8	52	15
10	0	9	51	23
11	0	10	50	32
12	0	11	49	40
13	0	12	48	48
14	0	13	47	57
15	0	14	47	5
16	0	15	46	13
17	0	16	45	22
18	0	17	44	30
19	0	18	43	38
20	0	19	42	47
21	0	20	41	55
22	0	21	41	3
23	0	22	40	12
24	0	23	39	20
25	0	24	38	28
26	0	25	37	37
27	0	26	36	45
28	0	27	35	53
29	0	28	35	2
30	0	29	34	10
31	1	0	33	18

In Leap-years, after *February*, add one Day and one Day's motion.

Sun's mean Motion and Anomaly.

Hours.	Mot. & Ano.		
′ ″	° ′ ″	′ ″ ‴	″ ‴ ⁗
1	0	2	28
2	0	4	56
3	0	7	24
4	0	9	51
5	0	12	19
6	0	14	47
7	0	17	15
8	0	19	43
9	0	22	11
10	0	24	38
11	0	27	6
12	0	29	34
13	0	32	2
14	0	34	30
15	0	36	58
16	0	39	26
17	0	41	53
18	0	44	21
19	0	46	49
20	0	49	17
21	0	51	45
22	0	54	13
23	0	56	40
24	0	59	8
25	1	1	36
26	1	4	4
27	1	6	32
28	1	9	0
29	1	11	28
30	1	13	55
31	1	16	23
32	1	18	51
33	1	21	19
34	1	23	47
35	1	26	15
36	1	28	42
37	1	31	10
38	1	33	38
39	1	36	6
40	1	38	34
41	1	41	2
42	1	43	30
43	1	45	57
44	1	48	25
45	1	50	53
46	1	53	21
47	1	55	49
48	1	58	17

49	2	0	44
50	2	3	12
51	2	5	40
52	2	8	8
53	2	10	36
54	2	13	4
55	2	15	32
56	2	17	59
57	2	20	27
58	2	22	55
59	2	25	23
60	2	27	51

In Leap-years, after *February*, add one Day and one Day's motion.

TABLE XVII. *The Sun's Declination in every Degree of the Ecliptic.*

Signs	♈ 0 Nor.	♎ 6 Sou.	♉ 1 Nor.	♏ 7 Sou.	♊ 2 Nor.	♐ 8 Sou.	
°	° ′ ″		° ′ ″		° ′ ″		°
0	0 0 0		11 29 33		20 11 16		30
1	0 23 54		11 50 35		20 23 49		29
2	0 47 48		12 11 26		20 36 0		28
3	1 11 42		12 32 5		20 47 48		27
4	1 35 34		12 52 31		20 59 13		26
5	1 59 25		13 12 44		21 10 15		25
6	2 23 14		13 32 54		21 20 53		24
7	2 47 1		13 52 32		21 31 7		23
8	3 10 45		14 12 5		21 40 58		22
9	3 34 26		14 31 24		21 50 24		21
10	3 58 4		14 50 28		21 59 25		20
11	4 21 38		15 9 17		22 8 2		19
12	4 45 8		15 27 51		22 16 14		18
13	5 8 34		15 46 9		22 24 0		17
14	5 31 55		16 4 11		22 31 21		16
15	5 55 11		16 21 57		22 38 16		15
16	6 18 21		16 39 26		22 44 45		14
17	6 41 25		16 56 37		22 50 49		13
18	7 4 23		17 13 31		22 56 26		12
19	7 27 15		17 30 7		23 1 36		11
20	7 50 0		17 46 15		23 6 20		10
21	8 12 36		18 2 24		23 10 38		9
22	8 35 5		18 18 3		23 14 29		8
23	8 57 26		18 33 24		23 17 52		7
24	9 19 39		18 48 25		23 20 49		6
25	9 41 43		19 3 5		23 23 19		5
26	10 3 37		19 17 26		23 25 22		4
27	10 25 21		19 31 25		23 26 57		3
28	10 46 56		19 45 3		23 28 5		2
29	11 8 20		19 58 20		23 28 46		1
30	11 29 33		20 11 16		23 29 0		0
Signs	♓ 1 Sou.	♍ 5 Nor.	♒ 10 Sou.	♌ 4 Nor.	♑ 9 Sou.	♋ 3 Nor.	

If the Sun's place be taken from the Tables on pag. 114 and 115, his declination may be had thereby, near enough for common use, from this Table, by entering it with the signs at the head and degrees at the left hand; or with the signs at the foot and degrees at the right hand. Thus, *March* the 5th, the Sun's place is ♓ 14° 53′ (call it 15°, being so near) to which answers 5° 55′ 11″ of the south declination.

TABLE XVIII. *Lunations from 1 to 100000.*

Lunat.	Days.	H.	M.	S.
1	Contain 29	12	44	3
2	59	1	28	6
3	88	14	12	9
4	118	2	56	13
5	147	15	40	16
6	177	4	24	19
7	206	17	8	22
8	236	5	52	25
9	265	18	36	28
10	295	7	20	31
20	590	14	41	3
30	885	22	1	34
40	1181	5	22	6
50	1476	12	42	37
60	1771	20	3	9
70	2067	3	23	40
80	2362	10	44	12
90	2657	18	4	43
100	2953	1	25	15
200	5906	2	50	30
300	8859	4	15	45
400	11812	5	41	0
500	14765	7	6	15
600	17718	8	31	30
700	20671	9	56	45
800	23624	11	22	0
900	26577	12	47	15
1000	29530	14	12	30
2000	59061	4	25	0
3000	88591	18	37	30
4000	118122	8	50	0
5000	147652	23	2	30
6000	177183	13	15	0
7000	206714	3	27	30
8000	236244	17	40	0
9000	265775	7	52	30
10000	295305	22	5	
20000	590611	20	10	
30000	885917	18	15	
40000	1181223	16	20	
50000	1476529	14	25	
60000	1771835	12	30	
70000	2067141	10	35	
80000	2362447	8	40	
90000	2657753	6	45	
100000	2953059	4	50	

By comparing this Table with the Table on page 113, it is easy to find how many Lunations are contained in any given number of Sidereal, Julian, and Solar years, from 1 to 8000.

CHAP. XX.

230

Of the fixed Stars.

Why the fixed Stars appear bigger when viewed by the bare eye than when seen through a telescope.

391. The Stars are said to be fixed, because they have been generally observed to keep at the same distance from each other: their apparent diurnal revolutions 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 eye-lids, 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, yet scarce renders that one visible.

A proof that they shine by their own light.

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. Now since the Stars appear less in a telescope which magnifies 200 times than they do to the bare eye, insomuch that they seem to be only indivisible points, it proves at once both 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.

Their number much less than is generally imagined.

392. 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, you will be surprised to find them so few. Or, 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 (the *Milky way* excepted) 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 231
which cannot be seen without the assistance of a telescope, contains no more than 3000, in both Hemispheres.

The absurdity of supposing the Stars were made only to enlighten our nights.

393. As we have incomparably more light from the Moon than from all the Stars together, it were 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 more than a cannon bullet would fly in 7,000,000 of years. Hence 'tis 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 a plurality of worlds is rational, and greatly manifests the Power, Wisdom, and Goodness of the great Creator.

Their different Magnitudes.

394. 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.

395. The antients divided the starry Sphere into particular Constellations, or Systems of Stars, according as they lay near one another, so as to occupy those spaces which the figures of different sorts of animals or things would take up, if they were there delineated. And those Stars which could not be brought into any particular Constellation were called *unformed Stars*.

The use of this division.

396. This division of the Stars into different Constellations or Asterisms, serves to distinguish them from one another, so that any particular Star may be readily

found in the Heavens by means of a Celestial Globe; on which the Constellations are so delineated as to put the most remarkable Stars into such parts of the figures as are most easily distinguished. The number of the antient Constellations is 48, and upon our present Globes about 70. On *Senex*'s Globes are inserted *Bayer*'s Letters; 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.

232

The *Zodiac*.

397. There is also a division of the Heavens into three parts. 1. The *Zodiac*, (ζωδιακὸς) from ζώδιον *Zodion* an Animal, because most of the Constellations in it, which are twelve in number, are the figures of Animals: as *Aries* the Ram, *Taurus* the Bull, *Gemini* the Twins, *Cancer* the Crab, *Leo* the Lion, *Virgo* the Virgin, *Libra* the Balance, *Scorpio* the Scorpion, *Sagittarius* the Archer, *Capricornus* the Goat, *Aquarius* the Water-bearer, and *Pisces* the Fishes. The Zodiac goes quite round the Heavens: it is about 16 degrees broad, so that it takes in the Orbits of all the Planets, and likewise the Orbit of the Moon. Along the middle of this Zone or Belt is the Ecliptic, or Circle which the Earth describes annually as seen from the Sun; and which the Sun appears to describe as seen from the Earth. 2. All that Region of the Heavens, which is on the north side of the Zodiac, containing 21 Constellations. And 3. that on the south side, containing 15.

The manner of dividing it by the antients.

398. The antients divided the *Zodiac* into the above 12 Constellations or Signs in the following manner. They took a vessel with a small hole in 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 strictly observing the rising of some Star in the *Zodiac*, they at the same time suffered the water to drop into one of the small vessels; and as soon as it was full, they shifted it and set an empty one in it's place. By this means, when each vessel was full, they observed what Star of the *Zodiac* rose; and though not possible in one night, yet in many, they observed the rising of twelve Stars, by which they divided the *Zodiac* into twelve parts.

399. The names of the Constellations, and the number of Stars observed in each of them by different Astronomers, are as follows.

The antient Constellations.

		Ptolemy.	*Tycho.*	*Hevelius.*	*Flamsteed.*
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
Argo Navis	The Ship	45	3	4	64
Hydra	The Hydra	27	19	31	60
Crater	The Cup	7	3	10	31
Corvus	The Crow	7	4		9
Centaurus	The Centaur	37			35
Lupus	The Wolf	19			24
Ara	The Altar	7			9
Corona Australis	The southern Crown	13			12
Pisces Australis	The southern Fish	18			24

The New Southern Constellations.

Columba Noachi	Noah's Dove	10
Robur Carolinum	The Royal Oak	12
Grus	The Crane	13
Phœnix	The Phenix	13
Indus	The Indian	12
Pavo	The Peacock	14
Apus, *Avis Indica*	The Bird of Paradise	11
Apis, *Musca*	The Bee or Fly	4
Chamæleon	The Chameleon	10
Triangulum Australis	The South Triangle	5
Piscis volans, *Passer*	The Flying Fish	8
Dorado, *Xiphias*	The Sword Fish	6
Toucan	The American Goose	9
Hydrus	The Water Snake	10

Hevelius's Constellations made out of the unformed Stars.

		Hevelius.	***Flamsteed.***
Lynx	The Lynx	19	44
Leo minor	The Little Lion		53
Asterion & Chara	The Greyhounds	23	25
Cerberus	Cerberus	4	
Vulpecula & Anser	The Fox and Goose	27	35
Scutum Sobieski	Sobieski's Shield	7	
Lacerta	The Lizard	10	16
Camelopardalus	The Camelopard	32	58
Monoceros	The Unicorn	19	31
Sextans	The Sextant	11	41

The *Milky Way*.

400. There is a remarkable track round the Heavens, called the *Milky Way* from its peculiar whiteness, which is owing to a great number of Stars scattered therein; none of which can be distinctly seen without telescopes. This track appears single in some parts, in others double.

Lucid Spots.

401. 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, first observed *A. D.* 1612, by *Simon Marius*; and which has some whitish rays near its middle: it 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 235
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.

Magellanic Clouds.

402. *Cloudy Stars* are so called from their misty appearance. They look like dim Stars to the naked eye; but through a telescope they appear broad illuminated parts of the sky; in some of which is one Star, in others more. Five of these are mentioned by *Ptolemy*. 1. One at the extremity of the right hand of *Perseus*. 2. One in the middle of the *Crab*. 3. One unformed, near the Sting of the *Scorpion*. 4. The eye of *Sagittarius*. 5. One in the head of *Orion*. In the first of these appear more Stars through the telescope than in any of the rest, although 21 have been counted in the head of *Orion*, and above 40 in that of the *Crab*. Two are visible in the eye of *Sagittarius* without a telescope, and several more with it. *Flamsteed* observed a cloudy Star in the bow of *Sagittarius*, containing many small Stars: and the Star *d* above *Sagittary*'s right shoulder is encompassed with several more. Both *Cassini* and *Flamsteed* discovered one between the *Great* and *Little Dog*, which is very full of Stars visible only by the telescope. 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.

Changes in the Heavens.

403. Several Stars are mentioned by antient Astronomers, which are not now to be found; and others are now visible to the bare eye which are not recorded in the antient catalogues. *Hipparchus* observed a new Star about 120 years before CHRIST; but he has not mentioned in what part of the Heavens it was seen, although it occasioned his making a catalogue of the Stars; which is the most antient that we have.

New Stars.

The first *New Star* that we have any good account of, was discovered by 236
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 even at mid-day: afterwards it decayed gradually both in magnitude and lustre, until *March* 1573, when it became invisible.

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 its 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 it by a steady light. 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.

404. Many Stars, besides those above-mentioned, have been observed to change their magnitudes: and as none of them could ever be perceived to have tails, 'tis plain they could not be Comets; especially as they had no parallax, even when largest and brightest. It would seem that the periodical Stars have vast clusters of dark spots, and very slow rotations on their Axis; by 237
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, 'tis by no means improbable that they are Suns whose Fuel is almost spent, and again supplied by some of their Comets falling upon them, and occasioning an uncommon blaze and splendor for some time: which indeed appears to be the greatest use of the cometary part of any system[86].

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 changeth 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 of 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 they are to us, or the 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.

405. The obliquity of the Ecliptic to the Equinoctial is found at present to be above a third part of a degree less than *Ptolemy* found it. And most of the observers after him found it to decrease gradually down to *Tycho*'s time. If it be objected, that we cannot depend on the observations of the antients, because of the incorrectness of their Instruments; we have to answer, that both *Tycho* and *Flamsteed* are allowed to have been very good observers: and yet we find that *Flamsteed* makes this obliquely $2\frac{1}{2}$ minutes of a degree less than *Tycho* did, about 100 years before him: and as *Ptolemy* was 1324 years before *Tycho*, so the gradual 238
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 Equatoreal diameter; and that the Sun and Moon are constantly acting obliquely upon the greater quantity of matter about the Equator, pulling it, as it were, towards a nearer and nearer co-incidence with the Ecliptic; it will not appear improbable that these actions should gradually diminish the Angle between those Planes. Nor is it less probable that the mutual attractions of all the Planets should have a tendency to bring the planes of all their Orbits to a co-incidence: but this change is too small to become sensible in many ages.

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.*

406. The parts of time are *Seconds*, *Minutes*, *Hours*, *Days*, *Years*, *Cycles*, *Ages*, and *Periods*.

A Year.

407. 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*.

Tropical Year.

408. 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.

Sidereal year.

409. The quantity of time, measured by the Sun's Revolution, as from any fixed Star to the same Star again, is called the *Sidereal Year*; which contains 365 days 6 hours 9 minutes $14\frac{1}{2}$ seconds; and is 20 minutes $17\frac{1}{2}$ seconds longer than the true Solar Year.

Lunar Year.

410. 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 37 seconds; and is therefore 10 days 21 hours 0 minutes 20 seconds shorter than the Solar Year. This is the foundation of the Epact.

Civil Year.

411. 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 239
what is called the *Bissextile* 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.

412. 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.

413. 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, § 411, 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*.

414. The year thus settled, is what we still make use of in *Britain*: but as it is somewhat more than 11 minutes longer than the *Solar Tropical Year*, the times of the Equinoxes go backward, and fall earlier by one day in about 130 years. In the time of the *Nicene Council* (A. D. 325.) which was 1431 years ago, the vernal Equinox fell on the 21st of *March*: and, if we divide 1431 by 130, it will quote 11, which is the number of days the Equinox has fallen back since the Council of *Nice*. This causing great disturbances, by unfixing the times of the celebration of *Easter*, and consequently of all the other moveable Feasts, Pope *Gregory* the 13th, in the year 1582 ordered ten days to be at once struck out of that year; and the next day after the fourth of *October* was called the fifteenth. By this means the vernal Equinox was restored to the 21st of *March*; and it was endeavoured, by the omission of three intercalary days in 400 years, to make the civil or political year keep pace with the Solar for 240
time to come. This new form of the year is called the *Gregorian Account* or *New Style*; which is received in all Countries where the Pope's Authority is acknowledged, and ought to be in all places where truth is regarded.

Months.

415. 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 compleat 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 in $29^d\ 12^h\ 44^m$. 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 Style; 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 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.

Nº	The Jewish year.		Days
1	Tisri	Aug.-Sept.	30
2	Marchesvan	Sept.-Oct.	29
3	Casleu	Oct.-Nov.	30
4	Tebeth	Nov.-Dec.	29
5	Shebat	Dec.-Jan.	30
6	Adar	Jan.-Feb.	29
7	Nisan *or* Abib	Feb.-Mar.	30
8	Jiar	Mar.-Apr.	29
9	Sivan	April-May	30
10	Tamuz	May-June	29
11	Ab	June-July	30
12	Elul	July-Aug.	29
Days in the year			354>
In the _*Embolimic* year after *Adar* they added a month called *Ve-Adar* of 30 days.			

Nº	The Egyptian year.		Days
1	Thoth	August 29	30
2	Paophi	Septemb. 28	30
3	Athir	October 28	30
4	Chojac	Novemb. 27	30
5	Tybi	Decemb. 27	30
6	Mechir	January 26	30
7	Phamenoth	Februar. 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

241

Nº	The *Arabic* and *Turkish* year.		Days
1	Muharram	July 16	30
2	Saphar	August 15	29
3	Rabia I.	Septemb. 13	30
4	Rabia II.	October 13	29
5	Jomada I.	Novemb. 11	30
6	Jomada II.	Decemb. 11	29
7	Rajab	January 9	30
8	Shasban	February 8	29
9	Ramadan	March 9	30
10	Shawal	April 8	29
11	Dulhaadah	May 7	30
12	Dulheggia	June 5	29
Days in the year			354

Nº	The ancient *Grecian* year.		Days
1	Hecatombæon	June-July	30
2	Metagitnion	July-Aug.	29
3	Boedromion	Aug.-Sept.	30
4	Pyanepsion	Sept.-Oct.	29
5	Mæmacterion	Oct.-Nov.	30
6	Posideon	Nov.-Dec.	29
7	Gamelion	Dec.-Jan.	30
8	Anthesterion	Jan.-Feb.	29
9	Elapheloblion	Feb.-Mar.	30
10	Munichion	Mar.-Apr.	29
11	Thargelion	April-May	30
12	Schirrophorion	May-June	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.

Weeks

416. 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*; and to the sixth, of *Saturn*.

Days

417. A Day is either *Natural* or *Artificial*. The Natural Day contains 24 hours; the Artificial the time from Sun-rise to Sun-set. The Natural Day is either *Astronomical* or *Civil*. The Astronomical Day begins at Noon, because the increase and decrease of Days

terminated by the Horizon are very unequal among themselves; which inequality is likewise augmented by the inconstancy of the horizontal Refractions § 183: and therefore the Astronomer takes the Meridian for the limit of diurnal Revolutions; reckoning Noon, that is the instant when the Sun's Center is on the Meridian, for the beginning of the Day. The *British*, *French*, *Dutch*, *Germans*, *Spaniards*, *Portuguese*, and *Egyptians*, begin the Civil Day at mid-night: the antient *Greeks*, *Jews*, *Bohemians*, *Silesians*, with the modern *Italians*, and *Chinese*, begin it at Sun-setting: And the antient *Babylonians*, *Persians*, *Syrians*, with the modern *Greeks*, at Sun-rising.

Hours

418. 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 by well regulated Clocks and Watches; but those 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. 242

Minutes, Seconds, Thirds, and Scruples.

419. 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.

420. 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.

421. 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 CHRIST, and divide the sum by 28, the Quotient is the number of Cycles elapsed since his birth, and the remainder is the Cycle for the given year: if nothing remains, the Cycle is 28. To find the Lunar Cycle, add 1 to the given year of CHRIST, and divide the sum by 19; the Quotient is the number of Cycles elapsed in the interval, and the remainder is the Cycle for the given year: if nothing remains, the Cycle is 19. Lastly, subtract 312 from the given year of CHRIST, and divide the remainder by 15; and what remains after this division is the Indiction for the given year: if nothing remains, the Indiction is 15.

The deficiency of the Lunar Cycle, and consequence thereof.

422. 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 rightly placed against the days of the month in the Calendar, as in our *Common Prayer Books*, for finding the days of 243
the mean Conjunctions or Oppositions of the Sun and Moon, and consequently the time of *Easter*; it will only serve for 310 years *Old Style*. 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 *O.S.* than they were at the time of the said Council; or six days lower for the *New Style*, because at present it differs 11 days from the *Old*.

Days	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octob.	Nov.	Dec.
1	9		9	17	17	6				11		19
2		17			6	14	14	3	11		19	
3	17	6	17	6			3	11		19	8	8
4	6		6	14	14	3			19	8		16
5		14			3	11	11	19	8		16	
6	14	3	14	3			19			16	5	5
7	3		3	11	11	19		8	16			13
8		11			19	8	8	16	5	5	13	
9	11	19	11	19						13		2
10			19	8	8	16	16	5	13		2	10
11	19	8					5	13	2	2	10	
12	8	16	8	16	16	5				10		18
13					5	13	13	2	10		18	7

14	16	5	16	5			2	10	18	18	7	
15	5		5	13	13	2				7		15
16		13			2	10	10	18	7		15	
17	13	2	13	2			18	7		15	4	4
18	2		2	10	10	18			15			12
19		10			18	7	7	15	4	4	12	
20	10	18	10	18			15			12	1	1
21			18	7	7	15		4	12			9
22	18	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

How to find the day of the New Moon by the Golden Number.

423. 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 Style*; 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 Style*) 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.

244

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

424. 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 Style*, 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 Style* 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. By 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.

245

Although this Table is calculated for 76 years only, and according to the *Old Style*, yet by means of two easy Equations it may be made to answer as exactly to the *New Style*, for any time to come. Thus, because the

year 1724 in this Table is the first year of the Cycle for which it is made; if from any year of CHRIST after 1800 you subtract 1723, and divide the overplus by 76, the Quotient will shew how many entire Cycles of 76 years are elapsed since the beginning of the Cycle here provided for; and the remainder will shew the year of the current Cycle answering to the given year of CHRIST. Hence, if the remainder be 0, you must instead thereof put 76, and lessen the Quotient by unity.

Then, look in the left hand column of the Table for the number in your remainder, and against it you will find the times of all the mean New Moons in that year of the present Cycle. And whereas in 76 *Julian* Years the Moon anticipates 5 hours 52 minutes, if therefore these 5 hours 52 minutes be multiplied by the above found Quotient, that is, by the number of entire Cycles past; the product subtracted from the times in the Table will leave the corrected times of the New Moons to the *Old Style*; which may be reduced to the *New Style* 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 Style*. The reason of this is, that every 400 years of the *New Style* gains 3 days upon the *Old Style*: one of which it gains in each of the centurial years succeeding that which is exactly divisible by 4 without 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 *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, *O. S.* for on that day begins the difference between the *Styles*; 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 rem.			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 Style*, *June*	5^d	9^h	16^m	Morning.
Entire hundred in 1909 are 19, which divided 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 Style*, gives *June*	18^d	9^h	16^m	Morn.*N.S.*

So the mean time of New Moon in *June* 1909 *New Style* is the 18th day at 16 minutes past 9 in the Morning.

If 11 days be added to the time of any New Moon in this Table, it will give the time thereof according to the *New Style* till the year 1800. And if 14 days 18 hours 22 minutes be added to the mean time of New Moon in either *Style*, it will give the mean time of the next Full Moon according to that *Style*.

A TABLE *shewing the times of all the mean Changes of the Moon, to the nearest Hour, through four Lunar Periods, or 76 years.* M *signifies morning*, A *afternoon*.

Yrs of the Cyc.	A.D.	January		February		March		April		May		June		July		August		Septemb.		October		Novemb.		Decemb.	
		D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.
1	1724	14	5A	13	5M	13	6A	12	7M	11	8A	10	8M	9	9A	8	10M	6	10A	6	11M	4	12A	4	1A
2	1725	3	2M	1	2A	3	3M	1	4A	1 30	4M 5A	29	6M	28	7A	27	8M	25	8A	25	9M	23	10A	23	11M
3	1726	21	11A	20	11M	21	12A	20	1A	20	1M	18	2A	18	3M	16	4A	15	5M	14	5A	13	6M	12	7A
4	1727	11	8M	9	9A	11	9M	9	10A	9	11M	7	12A	7	0A	6	1M	4	1A	4	2M	2	3A	2 31	4M 5A
5	1728	30	6M	28	7A	29	7M	27	8A	27	8M	25	9A	25	10M	23	11A	22	11M	21	12A	20	1A	20	2M
6	1729	18	2A	17	3M	18	4A	17	4M	16	5A	15	6M	14	7A	12	7M	11	8A	11	9M	9	0A	9	11M
7	1730	7	11A	6	0A	8	1M	6	1A	6	2M	4	3A	4	3M	2	4A	2 30	5M 6A	30	7M	28	8A	28	9M
8	1731	26	9A	25	10M	26	10A	25	11M	24	11A	23	0A	23	1M	21	2A	20	2M	19	3A	18	4M	17	5A
9	1732	16	5M	14	6A	15	7M	13	8A	13	8M	11	9A	11	10M	9	11A	8	11M	7	12A	6	1A	6	2M
10	1733	4	2A	3	3M	4	4A	3	4M	2	5A	1 30	6M 7A	30	8M	28	8A	27	9M	26	10A	25	11M	24	11A
11	1734	23	0A	22	1M	23	1A	22	2M	21	2A	20	3M	19	4A	18	5M	16	5A	16	6M	14	7A	14	8M
12	1735	12	9A	11	9M	12	10A	11	11M	10	11A	9	0A	9	1M	7	2A	6	2M	5	3A	4	4M	3	5A
13	1736	2 31	5M 6A	----		1 30	7M 8A	29	9M	28	9A	27	10M	26	11A	25	0A	23	12A	23	1A	22	2M	21	3A
14	1737	20	3M	18	4A	20	4M	18	5A	18	5M	16	6A	16	7M	14	8A	13	8M	12	9A	11	10M	10	11A
15	1738	9	11M	7	12A	9	1A	8	1M	7	2A	6	3M	5	4A	4	5M	2	5A	2 31	6M 7A	30	8M	29	8A
16	1739	28	9M	26	10A	28	11M	26	12A	26	0A	25	1M	24	2A	23	3M	21	3A	21	4M	19	5A	19	6M
17	1740	17	6A	16	7M	16	8A	15	9M	14	9A	13	10M	12	11A	11	0A	9	12A	9	1A	8	2M	7	3A
18	1741	6	3M	4	4A	6	4M	4	5A	4	5M	2	6A	2 31	7M 7A	30	8M	28	9A	28	10M	26	11A	26	11M
19	1742	24	12A	23	1A	25	2M	23	3A	23	3M	21	4A	21	5M	19	6A	18	6M	17	7A	16	8M	15	9A
20	1743	14	9M	12	10A	14	11M	12	12A	12	0A	11	1M	10	2A	9	3M	7	3A	7	4M	5	5A	5	6M
21	1744	3	6A	2	7M	2	8A	1 30	9M 9A	30	10M	28	11A	28	0A	26	12A	25	1A	25	2M	23	3A	23	3M
22	1745	21	4A	20	5M	21	5A	20	6M	19	6A	18	7M	17	8A	16	8M	14	9A	14	10M	12	11A	12	0A
23	1746	10	12A	9	1A	11	2M	9	3A	9	3M	7	4A	7	5M	5	6A	4	6M	3	7A	2	8M	1 31	9A 10M
24	1747	29	10A	28	11M	29	11A	28	0A	27	12A	26	1A	26	2M	24	3A	23	3M	22	4A	21	5M	20	6A
25	1748	19	6M	17	7A	18	8M	16	9A	16	9M	14	10A	14	11M	12	12A	11	0A	11	1M	9	2A	9	3M
26	1749	7	3A	6	4M	7	5A	6	6M	5	6A	4	7M	3	8A	2 31	9M 9A	30	10M	29	11A	28	0A	27	12A
27	1750	26	1A	25	2M	26	3A	25	4M	24	4A	23	5M	22	6A	21	7M	19	7A	19	8M	17	9A	17	10M
28	1751	15	10A	14	11M	15	11A	14	0A	13	12A	12	1A	12	2M	10	3A	9	3M	8	4A	7	5M	6	6A
29	1752	5	6M	3	7A	4	8M	2	9A	2 31	9M 10A	30	11M	29	12A	28	0A	27	1M	26	2A	25	3M	24	3A
30	1753	23	4M	21	5A	23	6M	21	7A	21	7M	19	8A	19	9M	17	10A	16	10M	15	11A	14	0A	14	1M
31	1754	12	1A	11	2M	12	3A	11	4M	10	4A	9	5M	8	6A	7	7M	5	7A	5	8M	3	9A	3	10M
32	1755	1 31	10A 11M	----		1 31	11A 0A	29	12A	29	1A	28	2M	27	3A	25	3M	24	4A	24	5M	22	6A	22	6M
33	1756	20	7A	19	8M	19	9A	18	9M	17	10A	16	11M	15	12A	14	1A	13	1M	12	2A	11	3M	10	4A
34	1757	9	4M	7	5A	9	6M	7	7A	7	7M	5	8A	5	9M	3	10A	2	10M	1 31	14A 0A	30	1M	29	1A
35	1758	28	2M	26	3A	28	3M	26	4A	26	4M	24	5A	24	6M	22	7A	21	7M	20	8A	19	9M	18	10A

36	1759	17	10M	15	11A	17	0A	16	1M	15	1A	14	2M	13	3A	12	2M	10	4A	10	5M	8	6A	8	7M
37	1760	6	7A	5	8M	5	9A	4	10M	3	10A	2	11M	1 31	12A 1A	30	1M	28	2A	28	3M	26	4A	26	4M
38	1761	24	5A	23	6M	24	7A	23	8M	22	9A	21	10M	20	10A	19	11M	17	11A	17	0A	16	1M	15	2A
39	1762	14	2M	12	3A	14	3M	12	4A	12	4M	10	5A	10	6M	8	7A	7	7M	6	8A	5	9M	4	10A
40	1763	3	11M	1	12A	3	0A	2	1M	1 31	1A 2M	29	3A	29	4M	27	4M	26	5M	25	6A	24	7M	23	7A
41	1764	22	8M	20	9A	21	10M	19	11A	19	11M	17	12A	17	1A	16	2M	14	2A	14	3M	12	4A	12	5M
42	1765	10	5A	9	6M	10	6A	9	7M	8	7A	7	8M	6	9A	5	10M	3	10A	3	11M	1	12A	1 31	1A 1M
43	1766	29	2A	28	3M	29	4A	28	5M	27	5A	26	6M	25	7A	24	8M	22	8A	22	9M	20	10A	20	11M
44	1767	18	11A	17	0A	19	1M	17	2A	17	2M	15	3A	15	4M	13	5A	12	6M	11	6A	10	7M	9	8A
45	1768	8	8M	6	9A	7	10M	5	11A	5	11M	3	12A	3	1A	2 31	2M 2A	30	3M	29	4A	28	5M	27	5A
46	1769	26	6M	24	7A	26	7M	24	8A	24	8M	22	9A	22	10M	20	11A	19	11M	18	12A	17	1A	17	2M
47	1770	15	2A	14	3M	15	4A	14	5M	13	5A	12	4M	11	7A	10	8M	8	8A	8	9M	6	10A	6	11M
48	1771	4	11M	3	0A	5	1M	3	2A	3	2M	1	3A	1 30	4M 5A	29	5M	27	6A	27	7M	25	8A	25	9M
49	1772	23	9A	22	10M	22	10A	21	11M	20	11A	19	0A	19	1M	17	2A	16	2M	15	3A	14	4M	13	5A
50	1773	12	5M	10	6A	12	7M	10	8A	10	8M	8	9A	8	9M	6	10A	5	11M	4	12A	3	1A	3	2M
51	1774	1 31	2A 3M	----		1 31	4A 5M	29	5A	29	6M	27	7A	27	8M	25	8A	24	9M	23	10A	22	11M	21	11A
52	1775	20	0A	19	1M	20	2A	19	3M	18	3A	17	4M	16	5A	15	6M	13	6A	13	7M	11	8A	11	9M
53	1776	9	9A	8	10M	8	10A	7	11M	6	12A	5	0A	5	1M	3	2A	2	2M	1 31	3A 4M	29	5A	29	5M
54	1777	27	6A	26	7M	27	8A	26	9M	25	9A	24	10M	23	11A	22	0A	20	12A	20	1A	19	2M	18	3A
55	1778	17	3M	15	4A	17	5M	15	6A	15	6M	13	7A	13	8M	11	9A	10	9M	9	10A	8	11M	7	12A
56	1779	6	0A	5	1M	6	2A	5	3M	4	3A	3	4M	2	5A	1 30	6M 6A	29	7M	28	8A	27	9M	26	9A
57	1780	25	10M	23	11A	24	11M	22	12A	22	0A	21	1M	20	2A	19	3M	17	3A	17	4M	15	5A	15	6M
58	1781	13	6A	12	7M	13	8A	12	9M	11	9A	10	10M	9	11A	8	0A	6	12A	6	1A	5	2M	4	3A
59	1782	3	3M	1	4A	3	5M	1	6A	1 30	6M 7A	29	8M	28	9A	27	9M	25	10A	25	11M	23	12A	23	0A
60	1783	22	1M	20	2A	22	2M	20	3A	20	3M	18	4A	18	5M	16	6A	15	6M	14	7A	13	8M	12	9A
61	1784	11	9M	9	10A	10	11M	8	12A	8	0A	7	1M	6	2A	5	3M	3	3A	3	4M	1	5A	1 30	6M 6A
62	1785	29	7M	27	8A	29	9M	27	10A	27	10M	25	11A	25	0A	24	1M	22	1A	22	2M	20	3A	20	3M
63	1786	18	4A	17	5M	18	5A	17	6M	16	6A	15	7M	14	8A	13	9M	11	9A	11	10M	9	11A	9	0A
64	1787	7	12A	6	1A	8	2M	6	3A	6	3M	4	4A	4	5M	2	6A	1 30	6M 7A	30	8M	28	9A	28	9M
65	1788	26	10A	25	11M	25	12A	24	1A	24	1M	22	2A	22	3M	20	4M	19	4M	18	5A	17	6M	16	7A
66	1789	15	7M	13	8A	15	9M	13	10A	13	10M	11	11A	11	0A	10	1M	8	1A	8	2M	6	3A	6	4M
67	1790	4	4A	3	5M	4	5A	3	6M	2	6A	1 30	7M 8A	30	9M	28	9A	27	10M	26	11A	25	0A	24	12A
68	1791	23	1A	22	2M	23	3A	22	4M	21	4A	20	5M	19	6A	18	7M	16	7A	16	8M	14	9A	14	10M
69	1792	12	10A	11	11M	11	12A	10	1A	10	1M	8	2A	8	3M	6	4A	5	4A	4	5A	3	6M	2	7A
70	1793	1 30	7M 8A	----		1 30	9M 10A	29	10M	28	11A	27	0A	27	1M	25	1A	24	2M	23	3A	22	4M	21	4A
71	1794	20	5M	18	6A	20	6M	18	7A	18	7M	16	8A	16	9M	14	10A	13	10M	12	11A	11	0A	11	1M
72	1795	9	1A	8	2M	9	3A	8	4M	7	4A	6	5M	5	6A	4	7M	2	7A	2 31	8M 9A	30	10M	29	10A
73	1796	28	11M	26	12A	27	0A	26	1M	25	1A	24	2M	23	3A	22	4M	20	4A	20	5M	18	6A	18	7M
74	1797	16	7A	15	8M	16	9A	15	10M	14	10A	13	11M	12	12A	11	1A	10	1M	9	2A	8	3M	7	4A
75	1798	6	4M	4	5A	6	6M	4	7A	4	7M	2	8A	2 31	9M 10A	30	10M	28	11A	28	0A	27	1M	26	1A
76	1799	25	2M	23	3A	25	4M	23	5A	23	5M	21	6A	21	6M	19	8A	18	8M	17	9A	16	10M	15	11A

1	1800	14	11A	12	12A	13	0A	12	1M	11	1A	10	2M	9	3A	8	4M	6	4A	6	5M	4	6A	4	7M

The year 1800 begins a new Cycle.

Easter Cycle, deficient.

425. 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 succeeds 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 *Style*, 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 Style* will admit of. 249

Number of Direction.

To find the true *Easter*.

426. 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 Style*, enter Table V following this Chapter, with the compleat hundreds of any given year at the top, and the years thereof (if any) below an hundred at the left hand; and where the columns meet is the Dominical Letter for the given year. Then, enter Table I, with the compleat hundreds of the same year at the left hand, and the years below an hundred at the top; and where the columns meet is the Golden Number for the same year. Lastly, enter Table II with the Dominical Letter at the left hand and Golden Number at the top; and where the columns meet is the Number of Direction for that year; which number, added to the 21st day of *March* shews on what day either of *March* or *April* Easter *Sunday* falls in that year. Thus, the Dominical Letter *New Style* for the year 1757 is *B* (Table V) and the Golden Number is 10, (Table I) by which in Table II, the Number of Direction is found to be 20; which, reckoned from the 21st of *March*, ends on the 10th of *April*, and *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.

Dominical Letter.

427. *The first seven Letters of the Alphabet* are commonly placed in the annual Almanacks to shew on what days of the week the days of the months fall throughout the year. And because one of those seven Letters must necessarily stand against *Sunday* it is printed in a capital form, and called the *Dominical Letter*: the other six being inserted in small characters to denote the other six days of the week. Now, since a common *Julian Year* contains 365 Days, if this number be 250
divided by 7 (the number of days in a week) there will remain one day. If there had been no remainder, 'tis plain the year would constantly begin on the same day of the week. But since one remains, 'tis 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 'tis 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 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 does not return to its first state till after four times seven, or 28 years: and then the same days of the month return in order to the same days of the week.

To find the Dominical Letter.

428. *To find the Dominical Letter for any year either before or after the Christian Æra*[87]: In Table III or IV for *Old Style*, or V for *New Style*, look for the hundreds of years at the head of the Table, and for the years below an hundred (to make up the given year) at the left hand: and where the columns meet you have the Dominical Letter for the year desired. Thus, suppose the Dominical Letter be required for the year of CHRIST 1758, *New Style*, I look for 1700 at the head of Table V, and for 58 at the left hand of the same Table; and in the angle of meeting, I find *A*, which is the Dominical Letter for that year. If it was wanted for the same year *Old Style*, 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 251
Dominical Letter be required for the 585th year before the first year of CHRIST, look for 500 at the head of Table III, and for 84 at the left hand; in the meeting of these columns is *FE*, which were the Dominical Letters for that year, and shews that it was a leap-year; because, leap-year has always two Dominical Letters.

To find the Days of the Months.

429. *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 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 to the right hand are *Sundays*, in the divisions of the months; the next column to the right are *Mondays*; the next, *Tuesdays*; and so on to the last column under *G*, from which go back to the column under *A*, and thence proceed towards the right hand as before. Thus, in the year 1757, the Dominical Letter *New Style* is *B*, in Table V, then in Table VI all the days under *B* are *Sundays* in that year, *viz.* the 2d, 9th, 16th, 23d, and 30th of *January* and *October*; the 6th, 13th, 20th, and 27th of *February*, *March* and *November*; the 3d, 10th, and 17th, of *April* and *July*, together with the 31st of *July*: and so on to the foot of the column. Then, of course, all the days under *C* on *Mondays*, namely the 3d, 10th, *&c.* of *January* and *October*; and so of all the rest in that column. If *the day of the week answering to any day of the month* be required, it is easily had from the same Table by the Letter that stands at the top of the column in which the given day of the month is found. Thus, the Letter that stands over the 28th of *May* is *A*; and in the year 585 before CHRIST the Dominical Letter was found to be *FE* § 428; 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*, *A* for *Wednesday*, *B* for *Thursday*, *C* for *Friday*, and *D* for *Saturday*. Hence, as it appears 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 certainly fell on a *Wednesday*.

Julian Period.

430. From the multiplication of the Solar Cycle of 28 years into the Lunar Cycle of 19 years, arises the great *Julian Period* consisting of 7980 years; which had its beginning 764 years before the supposed year of the creation (when all the three Cycles began together) and is not yet compleated, and therefore it comprehends all other Cycles, Periods and Æras. There is but one year in the whole Period which 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. 252

To find the year of this Period.

And the Cycles of that year.

431. The *Dionysian* or vulgar Æra of *Christ*'s birth was about the end of the year of the *Julian* Period 4713; and consequently the first year of his age, according to that account, was the 4714th year of the said Period. Therefore, if to the current year of *Christ* we add 4713, the Sum will be the year of the *Julian* Period. So the year 1757 will be found to be the 6470th year of that Period. Or, to find the year of the *Julian* Period answering to any given year before the first year of CHRIST, subtract the number of that given year from 4714, and the remainder will be the year of the *Julian* Period. Thus, the year 585 before the first year of CHRIST (which was the 584th before his birth) was the 4129th year of the said Period. Lastly, to find the Cycles of the Sun, Moon, and Indiction for any given year of this Period, divide the given year by 28, 19, and 15; the three remainders will be the Cycles sought, and the Quotients the numbers of Cycles run since the beginning of the Period. So in the above 4714th year of the *Julian* Period the Cycle of the Sun was 10, the Cycle of the Moon 2, and the Cycle of Indiction 4; the Solar Cycle having run through 168 courses, the Lunar 248, and the Indiction 314.

The true Æra of CHRIST's birth.

432. 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 certainly four years too late. For, our SAVIOUR was undoubtedly born before the Death of *Herod* the Great, who sought to kill him as soon as he heard of his birth. And, according to the testimony of *Josephus* (B. xvii. c. 8.) there was an eclipse of the Moon in the time of *Herod*'s last illness: which very eclipse our Astronomical Tables shew to have been in the year of the *Julian* Period 4710, *March* 13th, 3 hours 21 minutes after mid-night, at *Jerusalem*. Now, as our SAVIOUR must have been born some months before *Herod*'s death, since in the interval he was carried into *Ægypt*; the latest time in which we can possibly fix the true *Æra* of his birth is about the end of the 4709th year of the *Julian* Period. And this is four years before the vulgar *Æra* thereof.

The time of his crucifixion.

In the former edition of this book, I endeavoured to ascertain the time of CHRIST's death; by shewing in what year, about the reputed time of the Passion, there was a Passover Full Moon on a *Friday*: on which day of the week, and at the time of the Passover, it is evident from *Mark* xv. 42. that our SAVIOUR was crucified. And in computing the 253 times of all the Passover Full Moons from the 20th to the 40th year of CHRIST, after the *Jewish* manner, which was to add 14 days to the time when the New Moon next before the Passover was first visible at *Jerusalem*, in order to have their day of the Passover Full Moon, I found that the only Passover Full Moon which fell on a *Friday*, in all that time, was in the year of the *Julian* Period 4746, on the third day of *April*: which year was the 33d year of CHRIST's age, reckoning from the vulgar Æra of his birth, but the 37th counting from the true *Æra* thereof: and was also the last year of the 402d Olympiad[88], in which very year *Phlegon* an Heathen writer tells us, *there was the most extraordinary Eclipse of the Sun that ever was known*, and that *it was night at the sixth hour of the day*. Which agrees exactly with the time that the darkness at the crucifixion began, according to the three Evangelists who mention it[89]: and therefore must have been the very same darkness,

but mistaken by *Phlegon* for a natural Eclipse of the Sun; which was impossible on two accounts, 1. because it was at the time of Full Moon; and 2. because whoever takes the pains to calculate, will find that there could be no regular and total Eclipse of the Sun that year in any part of *Judea*, nor any where between *Jerusalem* and *Egypt*: so that this darkness must have been quite out of the common course of nature.

From the co-incidence of these characters, I made no doubt of having ascertained the true year and day of our SAVIOUR's death. But having very lately read what some eminent authors have wrote on the same subject, of which I was really ignorant before; and heard the opinions of other candid and ingenious enquirers after truth (which every honest man will follow wherever it leads him) and who think they have strong reasons for believing that the time of CHRIST's death was not in the year of the *Julian* Period 4746, but in the year 4743; I find difficulties on both sides, not easily got over: and shall therefore state the case both ways as fairly as I can; leaving the reader to take which side of the Question he pleases.

Both Dr. *Prideaux* and Sir *Isaac Newton* are of opinion that *Daniel*'s seventy weeks, consisting of 490 years (*Dan.* chap. ix. v. 23-26) began with the time when Ezra received his commission from *Artaxerxes* to go to *Jerusalem*, which was in the seventh year of that King's reign (*Ezra* ch. vii. v. 11-26) and ended with the death of CHRIST. For, by joining the accomplishment of that prophecy with the expiation of Sin, those weeks cannot well be supposed to end at any other time. And both these authors agree that this was 254
Artaxerxes Longimanus, not *Artaxerxes Mnemon*. The Doctor thinks that the last of those annual weeks was equally divided between *John*'s ministry and CHRIST's. And, as to the half week, mentioned by *Daniel* chap. ix. v. 27. Sir *Isaac* thinks it made no part of the above seventy; but only meant the three years and an half in which the *Romans* made war upon the *Jews* from spring in *A.D.* 67 to autumn in *A.D.* 70, when a final Period was put to their sacrifices and oblations by destroying their city and sanctuary, on which they were utterly dispersed. Now, both by the undoubted Canon of *Ptolemy*, and the famous Æra of *Nabonassar*, which is so well verified by Eclipses that it cannot deceive us, the beginning of these seventy weeks, or the seventh year of the reign of *Artaxerxes Longimanus*, is pinned down to the year of the *Julian* Period 4256: from which count 490 years to the death of CHRIST, and the same will fall in the above year of the *Julian* Period 4746: which would seem to ascertain the true year beyond dispute.

But as *Josephus*'s Eclipse of the Moon in a great measure fixes our SAVIOUR's birth to the end of the 4713th year of the *Julian* Period, and a *Friday* Passover Full Moon fixes the time of his death to the third of *April* in the 4746th year of that Period, the same as above by *Daniel*'s weeks, this supposes our SAVIOUR to have been crucified in the 37th year of his age. And as St. *Luke* chap. iii. ver. 23. fixes the time of CHRIST's baptism to the beginning of his 30th year, it would hence seem that his publick ministry, to which his baptism was the initiation, lasted seven years. But, as it would be very difficult to find account in all the Evangelists of more than four Passovers which he kept at *Jerusalem* during the time of his ministry, others think that he suffered in the vulgar 30th year of his age, which was really the 33d; namely in the year of the *Julian* Period 4743. And this opinion is farther strengthened by considering that our SAVIOUR eat his last Paschal Supper on a *Thursday* evening, the day immediately before his crucifixion: and that as he subjected himself to the law, he would not break the law by keeping the Passover on the day before the law prescribed; neither would the Priests have suffered the Lamb to be killed for him before the fourteenth day of *Nisan* when it was killed for all the people, *Exod.* xii. *ver.* 6. And hence they infer that he kept this Passover at the same time with the rest of the *Jews*, in the vulgar 30th year of his age: at which time it is evident by calculation that there was a Passover Full Moon on *Thursday April* the 6th. But this is pressed with two difficulties. 1. It drops the last half of *Daniel*'s seventieth week, as of no moment in the prophecy; and 2. it sets aside the testimony of 255
Phlegon, as if he had mistaken almost a whole *Olympiad*.

Others again endeavour to reconcile the whole difference, by supposing, that as CHRIST expressed himself only in round numbers concerning the time he was to lie in the grave, *Matt.* xii. 40. so might St. *Luke* possibly have done with regard to the year of his baptism: which would really seem to be the case when we consider, that the *Jews* told our SAVIOUR, sometime before his death, *Thou art not yet fifty years old*, John vii. 57. which indeed was more likely to be said to a person near forty than to one but just turned of thirty. And as to his eating the above Passover on *Thursday*, which must have been on the *Jewish* Full Moon day, they think it may be easily accommodated to the 37th year of his age; since, as the *Jews* always began their day in the evening, their *Friday* of course began on the evening of our *Thursday*. And it is evident, as above-mentioned, that the only *Jewish Friday* Full Moon, at the time of their Passover, was in the vulgar 33d, but the real 37th year of CHRIST's age; which was the 4746th year of the *Julian* Period, and the last year of the 202d *Olympiad*.

Æras or Epochas.

433. 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 *Epochas*. The most remarkable *Æras* are those of the *Creation*, the *Greek Olympiads*, the building of *Rome*, the *Æra* of *Nabonassar*, the death of *Alexander*, the birth of CHRIST, the *Arabian Hegira*, and the *Persian Jesdegird*: All which, together with several others of less note, have their beginnings in the following Table fixed to the years of the *Julian Period*, to the age of the world at those times, and to the years before and after the birth of CHRIST.

	Julian Period.	Y. of the World.	Before Christ.
1. The creation of the world, according to *Strauchius*	764	1	3949
2. The Deluge, or *Noah*'s Flood	2420	1656	2293
3. The *Assyrian* Monarchy by *Nimrod*	2537	1773	2176
4. The Birth of *Abraham*	2712	1948	2001
5. The beginning of the Kingdom of the *Argives*	2856	2092	1857
6. The begin. of the Kingdom of *Athens* by *Cecrops*	3157	2393	1556
7. The departure of the *Israelites* from *Egypt*	3216	2452	1497
8. Their entrance into *Canaan*, or the Jubilee	3256	2492	1457
9. The destruction of *Troy*	3529	2865	1184
10. The beginning of King *David*'s reign	3653	2889	1060
11. The foundation of *Solomon*'s Temple	3696	2932	1017
12. The *Argonautic* expedition	3776	3012	937
13. *Arbaces*, the first King of the *Medes*	3838	3074	175
14. *Mandaucus* the second	3865	3101	848
15. *Sosarmus* the third	3915	3151	798
16. *Artica* the fourth	3945	3181	768
17. *Cardica* the fifth	3996	3232	718
18. *Phraortes* the sixth	4057	3293	656
19. *Cyaxares* the seventh	4080	3316	633
20. The beginning of the *Olympiads*	3938	3174	775
21. The *Catonian* Epocha of the building of *Rome*	3961	3197	752
22. The Æra of *Nabonassar*	3967	3202	746
23. The destruction of *Samaria*	3990	3226	723
24. The *Babylonish* captivity	4133	3349	600
25. The destruction of *Solomon*'s Temple	4124	3360	589
26. The *Persian* monarchy founded by *Cyrus*	4154	3390	559
27. The battle of *Marathon*	4224	3460	489
28. The begin. of the reign of *Art. Longimanus*	4249	3485	464
29. The beginning of *Daniel*'s 70 weeks	4256	3492	457
30. The beginning of the *Peloponnesian* war	4282	3518	431
31. The death of *Alexander*	4390	3626	323
32. The restoration of the *Jews*	4548	3784	129
33. The corr. of the Calendar by *Julius Cæsar*	4669	3905	44
34. The beginning of the reign of *Herod*	4673	3909	40
35. The *Spanish* Æra	4675	3911	38
36. The battle at *Actium*	4683	3919	30
37. The taking of *Alexandria*	4683	3919	30
38. The Epoch of the title of *Augustus*	4686	3922	27
39. The true Æra of CHRIST's birth	4709	3945	4
40. The death of *Herod*	4710	3946	3
41. The *Diony*. or vulg. Æra of the birth of CHRIST	4713	3949	*AD*0
42. The true year of CHRIST's death	4746	3982	33
43. The destruction of *Jerusalem*	4783	4019	70
44. The *Dioclesian* persecution	5015	4251	302
45. The Epoch of *Constantine* the Great	5019	4255	306
46. The Council of *Nice*	5038	4274	325
47. The Epocha of the *Hegira*	5335	4571	622
48. The Epoch of *Yesdejerd*	5344	4580	631
49. The *Jellalæan* Epocha	5791	5027	1078
50. The Epocha of the reformation	6230	5466	1517

256

TAB. I. *Shewing the Golden Number (which is the same both in the Old and New Style) from the Christian Æra to A.D. 4000.*

Hundreds of Years.			**Years less than an Hundred.**																		
			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	3800	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
100	2000	3900	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5
200	2100	4000	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10
300	2200	&c.	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

TAB. 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 Style.

TAB. III. *Shewing the Dominical Letters, Old Style, for 4200 Years before the Christian Æra.*

Before Christ				**Hundreds of Years.**						
Years less than an Hundred.				0 700 1400 2100 2800 3500	100 800 1500 2200 2900 3600	200 900 1600 2300 3000 3700	300 1000 1700 2400 3100 3800	400 1100 1800 2500 3200 3900	500 1200 1900 2600 3300 4000	600 1300 2000 2700 3400 4100
0	28	56	84	D C	C B	B A	A G	G F	F E	E D
1	29	57	85	E	D	C	B	A	G	F
2	30	58	86	F	E	D	C	B	A	G
3	31	59	87	G	F	E	D	C	B	A
4	32	60	88	B A	A G	G F	F E	E D	D C	C B
5	33	61	89	C	B	A	G	F	E	D
6	34	62	90	D	C	B	A	G	F	E
7	35	63	91	E	D	C	B	A	G	F
8	36	64	92	G F	F E	E D	D C	C B	B A	A G
9	37	65	93	A	G	F	E	D	C	B
10	38	66	94	B	A	G	F	E	D	C
11	39	67	95	C	B	A	G	F	E	D
12	40	68	96	E D	D C	C B	B A	A G	G F	F E
13	41	69	97	F	E	D	C	B	A	G
14	42	70	98	G	F	E	D	C	B	A
15	43	71	99	A	G	F	E	D	C	B
16	44	72		C B	B A	A G	G F	F E	E D	D C
17	45	73		D	C	B	A	G	F	E
18	46	74		E	D	C	B	A	G	F
19	47	75		F	E	D	C	B	A	G
20	48	76		A G	G F	F E	E D	D C	C B	B A
21	49	77		B	A	G	F	E	D	C
22	50	78		C	B	A	G	F	E	D
23	51	79		D	C	B	A	G	F	E
24	52	80		F E	E D	D C	C B	B A	A G	G F
25	53	81		G	F	E	D	C	B	A
26	54	82		A	G	F	E	D	C	B
27	55	83		B	A	G	F	E	D	C

TAB. IV. *Shewing the Dominical Letters, Old Style, for 4200 Years after the Christian Æra.*

After Christ				**Hundreds of Years.**						
Years less than an Hundred.				0	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	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	D C	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

TAB. V. *The Dominical Letter, New Style, for 4000 Years after the Christian Æra.* 259

After Christ.				**Hundreds of Years.**			
Years less than an Hundred.				100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600 2700 2800 2900 3000 3100 3200 3300 3400 3500 3600 3700 3800 3900 4000			
				C	E	G	B A
1	29	57	85	B	D	F	G
2	30	58	86	A	C	E	F
3	31	59	87	G	B	D	E
4	32	60	88	F E	A G	C B	D C
5	33	61	89	D	F	A	B
6	34	62	90	C	E	G	A
7	35	63	91	B	D	F	G
8	36	64	92	A G	C B	C D	F E
9	37	65	93	F	A	C	D
10	38	66	94	E	G	B	C
11	39	67	95	D	F	A	B
12	40	68	96	C B	E D	G F	A G
13	41	69	97	A	C	E	F
14	42	70	98	G	B	D	E
15	43	71	99	F	A	C	D
16	44	72		E D	G F	B A	C B
17	45	73		C	E	G	A
18	46	74		B	D	F	G
19	47	75		A	C	E	F
20	48	76		G F	B A	D C	E D
21	49	77		E	G	B	C
22	50	78		D	F	A	B
23	51	79		C	E	G	A
24	52	80		B A	D C	F E	G F
25	53	81		G	B	D	E
26	54	82		F	A	C	D
27	55	83		E	G	B	C
28	56	84		D C	F E	A G	B A

TAB. VI. *Shewing the Days of the Months for both Styles by the Dominical Letters.*

Week Day.	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 Nov. 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
Septemb. 30 Decemb. 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. XXII.

260

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

Fronting the Title Page.

The ORRERY.

434. 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.

The Ecliptic.

In the Center, No 1. represents the SUN, supported by it's Axis inclining almost 8 Degrees from the Axis of the Ecliptic; and turning round in $25\frac{1}{4}$ days on 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.

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 towards the 20th Degree of Aquarius, according to the observations of *Bianchini*. She shews all the Phenomena described from the 30th to the 44th Article in Chap. I.

The Earth.

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 sidereal Dial-Plate under the Earth; and No. 7 a solar Dial-Plate on the cover of the Machine. The Index of the former shews sidereal, 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 sidereal days, or apparent revolutions of the Stars. In the time that the Earth makes $365\frac{1}{4}$ diurnal rotations on its Axis, it goes once round the Sun in the Plane of 261
the Ecliptic; and always keeps opposite to a moving Index (No. 10) which shews the Sun's daily change of place, and also the days of the months.

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 $23\frac{1}{2}$ 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 towards the Sun, and in the 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 Semi-circle 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. On the lower side of this thin Horizon Plate stand out four small Wires, to which is fixed a Twilight Circle 18 Degrees from the graduated side of the Horizon all round. This Horizon may be put upon the Earth (when the cap is taken away) and rectified to the Latitude of any place: and then, by a small Wire called *the Solar Ray*, which may be put on so as to proceed directly from the Sun's Center towards the Earth's, but to come no farther than almost to touch the Horizon, the beginning of Twilight, time of Sun-rising, with his Amplitude, Meridian Altitude, time of Setting, Amplitude, and end of Twilight, are shewn for every day of the year, at *that* place to which the Horizon is rectified.

The Moon.

The Moon (No. 5) goes round the Earth, from between it and any fixed point at a great distance, in 27 days 7 hours 43 minutes, or through all the Signs and Degrees of her Orbit; which is called *her Periodical Revolution*; but she goes round from the Sun to the Sun

again, or from Change to Change, in 29 days 12 hours 45 minutes, which is *her Synodical Revolution*; and in that time she exhibits all the Phases already described § 255.

When the above-mentioned Horizon is rectified to the Latitude of any given place, the times of the Moon's rising and setting, together with her Amplitude, are shewn to that place as well as the Sun's; and all the various Phenomena of the Harvest Moon § 273 & *seq.* made obvious to sight. 262

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 0 and 0 lie in the Plane of the Ecliptic, as described § 317, 318, and shift backward through all it's Signs and Degrees in $18\frac{2}{3}$ years. The Degrees of the Moon's Latitude, to the highest at *NL* (North Latitude) and lowest at *SL* (South Latitude) are engraven both ways from her Nodes at 0 and 0; 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 then point towards the Sun, all the Eclipses may be shewn for hundreds of years (without any new rectification) by turning the Machinery backward for time past, or forward for time to come. At 17 Degrees distance from each Node, on both Sides, is engraved a small Sun; and at 12 Degrees distance, a small Moon; which shew the limits of solar and lunar Eclipses § 317: and when, at any change, the Moon falls between either of these Suns and the Node, the Sun will be eclipsed on the day pointed to by the annual Index (No. 10,) and as the Moon has then North or South Latitude, one may easily judge whether that Eclipse will be visible in the Northern or Southern Hemisphere; especially as the Earth's Axis inclines towards the Sun or from him at that time. And when, at any Full, the Moon falls between either of the little Moon's and Node, she will be eclipsed, and the annual Index shews the day of that Eclipse. There is a Circle of $29\frac{1}{2}$ equal parts (No. 8.) on the cover of the Machine, on which an Index shews the days of the Moon's age.

PLATE IX. Fig. X.

There are two Semi-circles 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-circle *AaEbB*, they have Tides of Flood; and when they come to the Semicircle *CED* they have Tides 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. 263

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.

435. *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 other turns a third, on the Axis *a*2 of which is the Earth *U* turning round; this last Axis inclining $23\frac{1}{2}$ 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 Earth is half covered with a black cap *a*, as in the former Orrery, for dividing the day from the night; and, as the different places come out from below the edge of the cap, or go in below it, they shew the times of Sun-rising and setting every day of the year. This cap is fixed on the wire *b*, which has a forked piece *C* turning round the wire *d*: and, as the Earth goes round the Sun, it carries the Cap, Wire, and solar Ray round him; so that the solar Ray constantly points towards the Earth's Center.

On the Axis of the pinion *k* is the pinion *m*, which turns a wheel on the cock or supporter *n*, and on the Axis of this wheel nearest *n* is a pinion (hid from view) under the Plate *C*, which pinion turns a wheel that carries the Moon *V* round the Earth *U*; the Moon's Axis rising and falling in the socket *W*, which is fixed to the triangular piece above *Z*; and this piece is fixed to the top of the Axis of the last mentioned wheel. The socket *W* is slit on the outermost side; and in this slit the two pins near *Y*, fixed in the Moon's Axis, move up 264

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 Axis of these two wheels are cranked at *G* and *H*, above the Plate *B*. The upright stems of these cranks going through the Plate *C*, carry it over and over the fixed Plate *B*, with a motion which carries the Earth *U* round the Sun *T*, keeping the Earth's Axis always parallel to itself; or still inclining towards the left-hand of the Plate; and shewing the vicissitudes of seasons, as described in the tenth chapter. As the Earth goes round the Sun the pinion *k* goes round the wheel *i*, for the Axis of *k* never touches the fixed Plate *B*; but turns on a wire fixed into the Plate *C*.

On the top of the crank *G* is an Index *L*, which goes round the Circle *m*2 in the time that the Earth goes round the Sun; and points to the days of the months; which, together with the names of the seasons, are marked in this Circle.

This Index has a small grooved wheel *L* fixed upon it, round which, and the Plate *Z*, goes a cat-gut string crossing between them; and by this means the Moon's inclined Plane *YX* with its Nodes is turned backward, for shewing the times and returns of Eclipses § 319, 320.

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

Towards the right hand, let *S* be the Earth hung on the wire *e*, which is fixed into the Plate *B*; and let *O* be the Moon fixed on the Axis *M*, and turning round within the cap *P*, in which, and in the Plate *C* the crooked wire *Q* is fixed. On the Axis *M* is also fixed the Index *K*, which goes round a Circle *h*2, divided into 29½ equal parts, which are the days of the Moon's age: but to avoid confusion in the scheme, it is only marked with the numeral figures 1 2 3 4, for the Quarters. As the crank *H* carries this Moon round the Earth *S* in the Orbit *t*, she shews all her Phases by means of the cap *P* for the different days of her age, which are shewn by the Index *K*; this Index, turning just as the Moon *O* does, demonstrates her turning round her Axis as she still keeps the same side towards the Earth *S* § 262.

PL. VIII.

At the other end of the Plate *C*, a Moon *N* goes round an Earth *R* in the Orbit *p*; 265
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 parallelism round the Sun *T*, and shew all the seasons; as I sometimes make these Machines: and the Moon *O* would go round the Earth *S*, shewing her Phases as above; as likewise would the Moon *N* round the Earth *R*; but then, neither could the diurnal motion of the Earth *U* on its Axis be shewn, nor the motion of the Moon *V* round that Earth.

The CALCULATOR.

436. In the year 1746 I contrived a very simple Machine, and described it's performance in a small treatise upon the Phenomena of the Harvest Moon, published in the year 1747. I improved it soon after, by adding another wheel, and called it *the Calculator*. It may be easily made by any Gentleman who has a mechanical Genius.

Fig. I.

The great flat Ring supported by twelve pillars, and on which the twelve Signs with their respective Degrees are laid down, is the Ecliptic; nearly in the center of it is the Sun *S* supported by the strong crooked Wire *I*; and from the Sun proceeds a Wire *W*, called *the Solar Ray*, pointing towards the center of the Earth *E*, which is furnished with a moveable Horizon *H*, together with a brazen Meridian, and Quadrant of Altitude. *R* is a small Ecliptic, whose Plane co-incides with that of the great one, and has the like Signs and Degrees marked upon it; and is supported by two Wires *D* and *D*, which enter into the Plate *PP*, but may be taken off at pleasure. As the Earth goes round the Sun, the Signs of this small Circle keep parallel to themselves, and to those of the great Ecliptic. When it is taken off, and the solar Ray *W* drawn farther out, so as almost to touch the Horizon *H*, or the Quadrant of Altitude, the Horizon being 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 266
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 Center of the Machine. *K* is a knob or handle for moving the Earth round the Sun, and the Moon round the Earth.

As the Earth is carried round the Sun, 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 Nodes, one of which, *viz.* the Descending Node appears at 0, by *DN* above *B*; the other Node being hid from Sight on this Plane by the plate *PP*; 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 *S*, 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. 267

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 *T* is a flat circular plate (between *Y* and *T*) on which the different Excentricities 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 *Y* divided into $29\frac{1}{2}$ equal parts which are the days of the Moon's age: and the forked end *A* of the Index *AB* (Fig II) may be put into the Apogee-part of this plate; there being just such another Index to put into the inclined Plane *T* at the Ascending Node; and then the curved points *B* of these Indexes shew the direct motion of the Apogee, and 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 Excentricity of her Orbit, and her elliptic Equation, all on the Apogee Plate, and the day of her age in the Circle *Y* of $29\frac{1}{2}$ 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 9 Fig. 10. put upon the Earth and Moon, together with the solution of many problems not here related, are made conspicuous.

PL. VIII.

The easiest, though not the best way, that I can instruct any mechanical person to make the wheel-work of such a machine, is as follows; which is the way that I made it, before I thought of numbers exact enough to make it worth the trouble of cutting teeth in the wheels. 268

Fig. III.

Fig. 3d of Plate 8 is a section of this Machine; in which *ABCD* is a frame of wood held together by four pillars at the corners, whereof two appear at *AC* and *BD*. In the lower Plate *CD* of this Frame are three small friction-wheels, at equal distances from each other; two of them appearing at *e* and *e*. As the frame is moved round, these wheels run upon the fixed bottom Plate *EE* which supports the whole work.

In the Center of this last mentioned Plate is fixed the upright Axis *f FFG*, and on the same Axis is fixed the wheel *HHH* in which are four grooves *I*, *X*, *k*, *L* of different Diameters. In these grooves are cat-gut strings going also round the separate wheels *M*, *N*, *O* and *P*.

The wheel *M* is fixed on a solid Spindle or Axis, the lower pivot of which turns at *R* in the under Plate of the moveable frame *ABCD*; and on the upper end of this Axis is fixed the Plate *o o* (which is *PP*, under the Earth, in Fig. I.) and to this Plate is fixed, at an Angle of $23\frac{1}{2}$ Degrees inclination, the Dial-plate below the Earth *T*; on the Axis of which, the Index *q* is turned round by the Earth. This Axis, together with the Wheel *M*, and Plate *o o*, keep their parallelism in going round the Sun *S*.

On the Axis of the wheel *M* is a moveable socket on which the small wheel *N* is fixed, and on the upper end of this socket is put on tight (but so as it may be occasionally turned by hand) the bar *ZZ* (*viz.* the bar *O* in Fig. I.) which carries the Moon *m* round the Earth *T*, by the Socket *n*, fixed into the bar. As the Moon goes

round the Earth her Axis rises and falls in the Socket *n*; because, on the lower end of her Axis, which is turned inward, there is a small friction Wheel *s* running on the inclined Plane *X* (which is *T* in Fig. I.) and so causes the Moon alternately to rise above and sink below the little Ecliptic *VV* (*R* in Fig. I.) 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. I.) all these Axles turn in the upper Plate of the moveable frame at *Q* which Plate is covered with the thin Plate *cc* (screwed to it) whereon are the fore-mentioned Tables and month Circle in Fig. I. 269

The middle part of the thick fixed Wheel *HHH* 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 *HHH*; 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. I.) 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 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 slowly deviates from its parallelism § 246, towards the antecedent Signs of the Ecliptic.

The Diameter of the Groove of the Wheel *N*, which carries the Moon round the Earth, must be to the Diameter of the Groove *X* as a Lunation is to a year; that is, as $29\frac{1}{2}$ to $365\frac{1}{4}$.

The Diameter of the Groove of the Wheel *O*, which turns the inclined Plane *X* with the Moon's Nodes backward, must be to the Diameter of the Groove *k* as 20 to $18\frac{225}{365}$. And,

Lastly, the Diameter of the Groove of the Wheel *P*, which carries the Moon's Apogee forward, must be to the Diameter of the Groove *L* as 70 to 62.

PLATE IV. 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. 270

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 in their respective Grooves *IM*, *kO*, and *LP* without crossing.

The Cometarium. 437. The Cometarium. This curious Machine shews the Motion of a Comet or excentric Body moving round the Sun, describing equal Areas in equal times § 152, and may be so contrived as to shew such a Motion for any Degree of Excentricity. It was invented by the late Dr. *Desaguliers*.

Fig. IV. The dark elliptical Groove round the letters *abcdefghiklm* is the Orbit of the Comet *Y*: this Comet is carried round in the Groove according to the order of letters, by the Wire *W*, fixed in the Sun *S*, and slides on the Wire as it approaches nearer to or recedes farther from the Sun, being nearest of all in the Perihelion *a*, and farthest in the Aphelion *g*. The Areas *aSb*, *bSc*, *cSd* &c. or contents of these several Triangles are all equal; and in every turn of the Winch *N* the Comet *Y* is carried over one of these Areas; consequently in as much time as it moves, from *f* to *g*, or from *g* to *h*, it moves from *m* to *a*, or from *a* to *b*; and so of the rest, being quickest of all at *a*, and slowest at *g*. Thus, the Comet's velocity in its Orbit continually decreases from the Perihelion *a* to the Aphelion *g*; and increases in the same proportion from *g* to *a*.

PLATE IV. The elliptic Orbit is divided into 12 equal Parts or Signs with their respective Degrees, and so is the Circle *n o p q r s t n* which represents a great Circle in the Heavens, and to which all the fixed Stars in the Comet's way are referred. Whilst the Comet moves from *f* to

g in its Orbit it appears to move only about 5 Degrees in this Circle, as is shewn by the small knob on the end of the Wire *W*; but in as short time as the Comet moves from *m* to *a*, or from *a* to *b*, and it appears to describe the large space *tn* or *no* in the Heavens, either of which spaces contains 120 Degrees or four Signs. Were the Excentricity of its Orbit greater, the greater still would be the difference of its Motion, and *vice versâ*. 271

ABCDEFGHIKLMA is a circular Orbit for shewing the equable Motion of a Body round the Sun *S*, describing equal Areas *ASB*, *BSC*, &c. in equal times with those of the Body *Y* in its elliptical Orbit above mentioned; but with this difference, that the circular Motion describes the equal Arcs *AB*, *BC*, &c. in the same equal times that the elliptical Motion describes the unequal Arcs *ab*, *bc*, &c.

Now, suppose the two Bodies *Y* and I 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 I all the way from *a* to *g*, and from *A* to *G*; but I 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 355th 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*.

Fig. V.

This curious Motion is performed in the following manner. *ABC* is a wooden bar (in the box containing the wheel-work) above which are the wheels *D* and *E*; and below it the elliptic Plates *FF* and *GG*; each Plate being fixed on an Axis in one of its Focuses, at *E* and *K*; and the Wheel *E* is fixed on the same Axis with the Plate *FF*. These Plates have Grooves round their edges precisely of equal Diameters to one another, and in these Grooves is the cat-gut string *gg*, *gg* crossing between the Plates at *h*. On *H*, the Axis of the handle or winch *N* in Fig. 4th, is an endless screw in Fig. 5, working in the Wheels *D* and *E*, whose numbers of teeth being equal, and should be equal to the number of lines *aS*, *bS*, *cS*, &c. in Fig. 4, they turn round their Axes in equal times to one another, and to the Motion of the elliptic Plates. For, the Wheels *D* and *E* having equal numbers of teeth, the Plate *FF* being fixed on the same Axis with the Wheel *E*, and the Plate *FF* turning the equally big Plate *GG* by a cat-gut string round them both, they must all go round their Axes in as many turns of the handle *N* as either of the Wheels has teeth. 272

'Tis easy to see, that the end *h* of the elliptical Plate *FF* being farther from its Axis *E* than the opposite end *i* is, must describe a Circle so much the larger in proportion; and therefore move through so much more space in the same time; and for that reason the end *h* moves so much faster than the end *i*, although it goes no sooner round the Center *E*. But then, the quick-moving end *h* of the Plate *FF* leads about the short end *hK* of the Plate *GG* with the same velocity; and the slow moving end *i* of the Plate *FF* coming half round as to *B*, must then lead the long end *k* of the Plate *GG* as slowly about: So that the elliptical Plate *FF* and it's Axis *E* move uniformly and equally quick in every part of its revolution; but the elliptical Plate *GG*, 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 point of the Circumference of *GG* from its Axis at *K*: or in other words, to instance in two points, if the distance *Kk* be four, five, or six times as great as the distance *Kh*, the Point *h* will move in that position four, five, or six times as fast as the Point *k* does, when the Plate *GG* has gone half round: and so on for any other Excentricity or difference of the Distances *Kk* and *Kh*. The tooth *i* on the Plate *FF* falls in between the two teeth at *k* on the Plate *GG*, 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 I round the Circle *ABCD*, &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 *GG*, in Fig. 5th, is the Sun *S* in Fig. 4th, carrying the Ball *Y* unequably 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 *GG*, which is also equal to that of *FF*.

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 Excentricities, 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 sight; and clearer Ideas of these Motions and Equations acquired in half an hour, than could be gained from reading half a day about such Motions and Equations. 273

The improved Celestial Globe.

PLATE III. Fig. III.

438. The *Improved Celestial Globe*. On the North Pole of the Axis, above the Hour Circle, is fixed an Arch *MKH* of 23½ Degrees; and at the end *H* is fixed an upright pin *HG*, 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 *O*, having two little Balls on their ends for the Sun and Moon, as in the Figure. The Collet *D* is fixed to the circular Plate *F* whereon the 29½ days of the Moon's age are engraven, beginning just under the Sun's Wire *N*; and as this Wire is moved round the Globe, the Plate *F* turns round with it. These Wires are easily turned if the Screw *G* be slackened; and when they are set to their proper places, the Screw serves to fix them there so, as in turning the Ball of the Globe, the Wires with the Sun and Moon go round with it; and these two little Balls rise and set at the same times, and on the same points of the Horizon, for the day to which they are rectified, as the Sun and Moon do in the Heavens.

Because the Moon keeps not her course in the Ecliptic (as the Sun appears to do) but has a Declination of 5⅓ Degrees on each side from it in every Lunation § 317, her Ball may be screwed as many Degrees to either side of the Ecliptic as her Latitude or Declination from the Ecliptic amounts to at any given time; and for this purpose *S* is a small piece of pasteboard, of which the curved edge *S* is to be set upon the Globe at right Angles to the Ecliptic, and the dark line over *S* to stand upright upon it. From this line, on the convex edge, are drawn the 5⅓ Degrees of the Moon's Latitude on both sides of the Ecliptic; and when this piece is set upright on the Globe, it's graduated edge reaches to the Moon on the Wire *O*, by which means she is easily adjusted to her Latitude found by an Ephemeris.

The Horizon is supported by two semicircular Arches, because Pillars would stop the progress of the Balls when they go below the Horizon in an oblique sphere.

To rectify it.

To rectify the Globe. Elevate the Pole to the Latitude of the Place; then bring the Sun's place in the Ecliptic for the given day to the brasen Meridian, and set the Hour Index to XII at noon, that 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 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. 274

It's use.

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.

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 going 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 covered with Patches.

The Planetary Globe.

PL. VIII. Fig. IV.

439. The *Planetary Globe*. In this Machine, *T* is a terrestrial Globe fixed on its Axis standing upright on the Pedestal *CDE*, on which is an Hour Circle, having its Index fixed on the Axis, which turns somewhat tightly in the Pedestal, so that the Globe may not be liable to shake; to prevent which, the Pedestal is about two Inches thick, and the Axis goes quite through it, bearing on a shoulder. The Globe is hung in a graduated brasen Meridian, much in the usual way; and the thin Plate *N*, *NE*, *E*, is a moveable Horizon, graduated round the outer edge, for shewing the Bearings and Amplitudes of the Sun, Moon, and Planets. The brasen Meridian is grooved round the outer edge; and in this Groove is a slender Semi-circle of brass, the ends of which are fixed to the Horizon in its North and South Points: this Semi-circle 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 properly inclined to the Axis of the Globe which stands upright on the Pedestal. 275

To rectify it.

To rectify this Machine. Set all the planetary Balls to their geocentric places in the Ecliptic for any given time by an Ephemeris: then, set the North Point of the

Horizon to the Latitude of your place on the brasen Meridian, and the Quadrant of Altitude to the South Point of the Horizon; which done, turn the Globe with its Furniture till the Quadrant of Altitude comes right against the Sun, *viz.* to his place in the Ecliptic; and keeping it there, set the Hour Index to the XII next the letter *C*; and the Machine will be rectified, not only for the following Problems, but for several others, which the Artist may easily find out.

PROBLEM I.

To find the Amplitudes, Meridian Altitudes, and times of Rising, Culminating, and Setting, of the Sun, Moon, and Planets.

It's use.

Turn the Globe round eastward, or according to the order of Signs; and as the eastern edge of the Horizon comes right against the Sun, Moon, or any Planet, the Hour Index will shew the time of it's rising; and the inner edge of the Ecliptic will cut it's rising Amplitude in the Horizon. Turn on, and as the Quadrant of Altitude comes right against the Sun, Moon, or Planets, the Ecliptic cuts their meridian Altitudes in the Quadrant, and the Hour Index shews the times of their coming to the Meridian. Continue turning, and as the western edge of the Horizon comes right against the Sun, Moon, or Planets, their setting Amplitudes are cut in the Horizon by the Ecliptic; and the times of their setting are shewn by the Index on the Hour Circle.

PROBLEM II.

To find the Altitude and Azimuth of the Sun, Moon, and Planets, at any time of their being above the Horizon.

Turn the Globe till the Index comes to the given time in the Hour Circle; then keep the Globe steady, and moving the Quadrant of Altitude to each Planet respectively, the edge of the Ecliptic will cut the Planet's mean Altitude on the Quadrant, and the Quadrant will cut the Planet's Azimuth, or Point of Bearing on the Horizon.

PROBLEM III.

The Sun's Altitude being given at any time either before or after Noon, to find the Hour of the Day, and the Variation of the Compass, in any known Latitude.

With one hand hold the edge of the Quadrant right against the Sun; and, with the other hand, turn the Globe westward, if it be in the forenoon, or eastward if it be in the afternoon, until the Sun's place at the inner edge of the Ecliptic cuts the Quadrant in the Sun's observed Altitude; and then the Hour Index will point out the time of the day, and the Quadrant will cut the true Azimuth, or Bearing of the Sun for that time: the difference between which, and the Bearing shewn by the Azimuth Compass, shews the variation of the Compass in that place of the Earth.

The TRAJECTORIUM LUNARE.

PL. VII. Fig. V.

440. The *Trajectorium Lunare*. This Machine is for delineating the paths of the Earth and Moon, shewing what sort of Curves they make in the etherial regions; and was just mentioned in 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 $^{24}/_{100}$ parts of an Inch from the Earth's in this Machine, this being in just proportion to the Moon's distance from the Earth § 52. *AA* is a Bar of Wood, to be moved by hand round the Axis *g* which is fixed in the Wheel *Y*. The Circumference of this Wheel is to the Circumference of the small Wheel *L* (below the other end of the Bar) as $365\frac{1}{4}$ days is to $29\frac{1}{2}$; or as a Year is to a Lunation. The Wheels are grooved round their edges, and in the Grooves is the cat-gut string *GG* crossing between the Wheels at *X*. On the Axis of the Wheel *L* is the Index *F*, in which is fixed the Moon's Axis *M* for carrying her round the Earth *E* (fixed on the Axis of the Wheel *L*) in the time that the Index goes round a Circle of $29\frac{1}{2}$ equal parts, which are the days of the Moon's age. The Wheel *Y* has the Months and Days of the year all round it's Limb; and in the Bar *AA* is fixed the Index *I*, which points out the Days of the Months answering to the Days of the Moon's age, shewn by the Index *F*, in the Circle of $29\frac{1}{2}$ equal parts at the other end of the Bar. On the Axis of the Wheel *L* is put the piece *D*, below the Cock *C*, in which this Axis turns round; and in *D* are put the Pencils *e* and *m*, directly under the Earth *E* and Moon *M*; so that *m* is carried round *e* as *M* is round *E*. 277

It's use.

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) enter a little into the Floor to secure the Wheel from turning. Then lay a paper about four foot 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 proportioned 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 it's Circle, the like numeral Figures may be set to those parts of the Curves of the Earth's Path and Moon's, where the Pencils *e* and *m* are at those times respectively, to shew the places of the Earth and Moon. If the Pencil *e* be pushed a very little off, as if from the Pencil *m*, to about $^1/_{40}$ part of their distance, and the Pencil *m* pushed as much towards *e*, to bring them to the same distances again, though not to the same points of space; then as *m* goes round *e*, *e* will go as it were round the Center of Gravity between the Earth *e* and Moon *m* § 298: but this Motion will not sensibly alter the Figure of the Earth's Path or the Moon's.

If a Pin as *p* be put through the Pencil *m*, with its head towards that of the Pin *q* in the Pencil *e*, its head will always keep thereto as *m* goes round *e*, or as the same side of the Moon is still obverted to the Earth. But the Pin *p*, which may be considered as an equatoreal 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. 278

The TIDE DIAL.

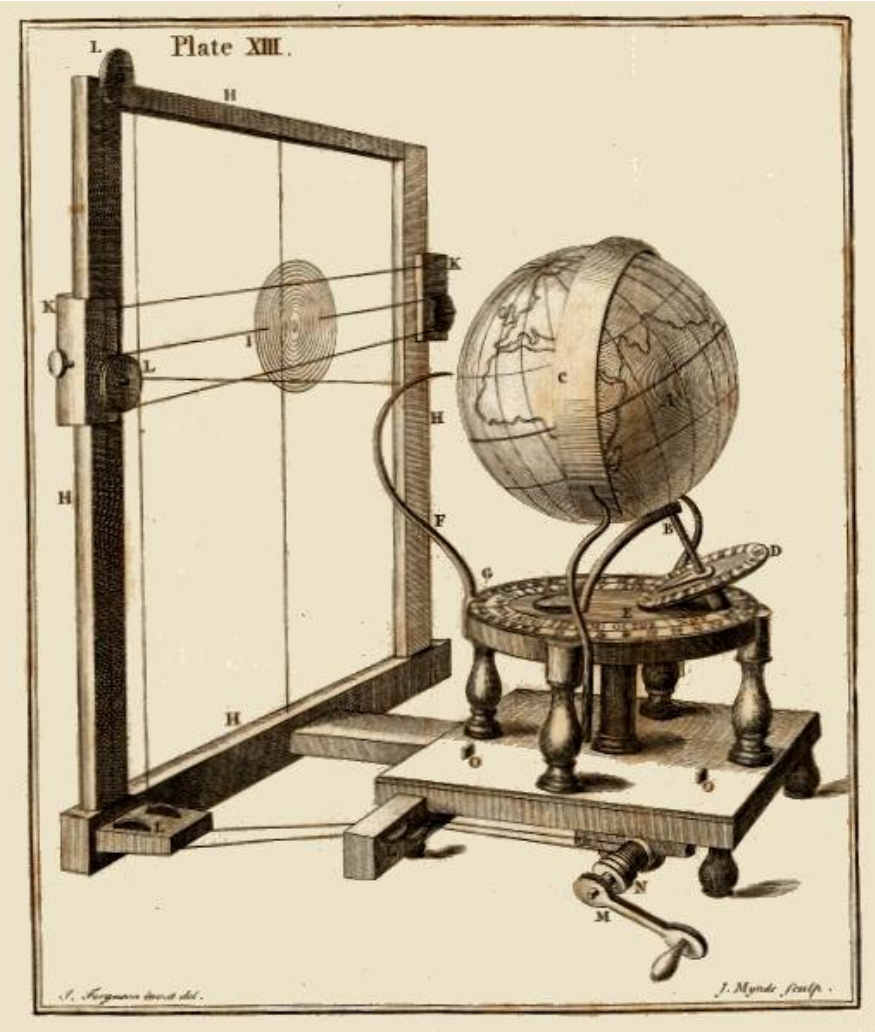
PLATE IX. Fig. VII.

It's use.

441. The TIDE-DIAL. The outside parts of this Machine consist of, 1. An eight-sided Box, on the top of which at the corner 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 same again. Within this Circle is one of 24 hours divided into their respective Halves and Quarters. 2. A moving elliptical Plate painted blue to represent the rising of the Tides under and

opposite to the Moon; and has the words, *High Water, Tide falling, Low Water, Tide rising*, marked upon it. To one end of this Plate is fixed the Moon *M* by the Wire *W*, and goes along with it. 3. Above this elliptical Plate is a round one, with the Points of the Compass upon it, and also the names of above 200 places in the large Machine (but only 32 in the Figure to avoid confusion) set over those Points on which the Moon bears when she raises the Tides to the greatest heights at these Places twice in every lunar day: and to the North and South Points of this Plate are fixed two Indexes *I* and *K*, which shew the times of High Water in the Hour Circle at all these places. 4. Below the elliptical Plate are four small Plates, two of which project out from below 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 elliptic Plate, to shew the Nepe 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 Nepe Tides at those times. Within the Box are a few Wheels for performing these Motions by the Handle or Winch *H*.

Plate XIII.



J. Ferguson inv. et del.

J. Mynde Sculp.

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 Mid-day, and the opposite XII Mid-night: then looking for the name of any given place on the round Plate (which makes 29½ rotations whilst the Moon *M* makes only one revolution from the Sun to the Sun again) turn the Handle till *that* place comes to the word *High Water* under the Moon, and the Index which falls among the Afternoon Hours will shew the time of high water at that place in the Afternoon of the given day: then turn the Plate half round, till the same place comes to the opposite High Water Mark, and the

279

Index will shew the time of High Water in the Forenoon 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 two days before and after the times of New and Full Moon, the two small Plates come out a little way from below the High Water Marks on the elliptical Plate, to shew that the Tides rise still higher about these times: and about the Quarters, the other two Plates come out a little from under the Low Water Marks towards the Sun and on the opposite side, shewing that the Tides of Flood rise not then so high, nor do the Tides of Ebb fall so low, as at other times.

By pulling the Handle a little way outward, it is disengaged from the Wheel-work, and then the upper Plate may be turned round quickly by hand so, as the Moon may be brought to any given day of her age in about a quarter of a minute.

The inside work described.

Fig. VIII.

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 of the Handle, which is the number of Hours in a synodical revolution of the Moon. The round Plate with the names of Places upon it is fixed on the Axis of the Wheel *FED*; and the Elliptical or Tide-Plate with the Moon fixed to it is upon the Axis of the Wheel *LKI*; consequently, the former makes 29½ revolutions in the time that the latter makes one. The whole Wheel *FED* with the endless Screw *C*, and dotted part of the Axis of the Handle *AB*, together with the dotted part of the Wheel *ONG*, lie hid below the large Wheel *LKI*. 280

Fig. 9th represents the under side of the Elliptical or Tide-Plate *abcd*, with the four small Plates *ABCD*, *EFGH*, *IKLM*, *NOPQ* upon it: each of which has two slits as *TT*, *SS*, *RR*, *UU* sliding on two Pins as *nn*, fixed in the elliptical Plate. In the four small Plates are fixed four Pins at *W*, *X*, *Y*, and *Z*; all of which work in an elliptic Groove *oooo* on the cover of the Box below the elliptical Plate; the longest Axis of this Groove being in a right line with the Sun and Full Moon. Consequently, when the Moon is in Conjunction or Opposition, the Pins *W* and *X* thrust out the Plates *ABCD* and *IKLM* a little beyond the ends of the elliptic Plate at *d* and *b*, to *f* and *e*; whilst the Pins *Y* and *Z* draw in the Plates *EFGH* and *NOPQ* quite under the elliptic Plate to *g* and *h*. But, when the Moon comes to her first or third Quarter, the elliptic Plate lies across the fixed elliptic Groove in which the Pins work; and therefore the end Plates *ABCD* and *IKLM* are drawn in below the great Plate, and the other two Plates *EFGH* and *NOPQ* are thrust out beyond it to *a* and *c*. When the Moon is in her Octants the Pins *V, X, Y, Z* are in the parts *o, o, o, o* of the elliptic Groove, which parts are at a mean between the greatest and least distances from the Center *q*, and then all the four small Plates disappear below the great one.

The Eclipsareon.

Pl. XIII.

442. 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 towards 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 281 the size of the Globe; so that the shadow of this Plate, formed by the Sun, or a candle placed at a convenient distance, with it's Rays transmitted through a convex Lens to make them fall parallel on the Globe, covers exactly all those places upon it that the Moon's Shadow and Penumbra do on the Earth: so that the Phenomena of any solar Eclipse may be shewn by this Machine with candle-light, almost as well as by the light of the Sun. 5. An upright frame *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 Globe from that which is in the dark at any given time, and shewing at what places the general Eclipse begins and ends with the rising or setting Sun. 7. A Handle *M*, which turns the Globe round it's Axis by wheel-work, and at the same time moves the Penumbra across the frame by threads over the Pullies *L, L, L*, with the 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 Pullies.

To rectify it.

To rectify the Machine for use. The true time of New Moon and her Latitude being known by the foregoing Precepts § 355, 363, 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 the Machine for performing by the Light of the Sun. 1. Move the Sliders *KK* till their Indexes point to the Moon's Latitude on the Scales, as it is North and 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 § 371. 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 282
Hour Circle *D* by Hand till XII at Noon comes to its Index. 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 the Candle-Light, proceed in every respect as above, except in that part of the last paragraph where the Sun is mentioned; instead of which place a Candle before the Machine, about four yards from it, so as the shadow of Intersection of the cross threads in the middle of the frame may fall precisely on that part of the Globe to which the crooked Wire *F* points: then, with a pair of Compasses take the distance between the Penumbra's Center and Intersection of the threads; and equal to that distance set the Candle higher or lower as the Penumbra's Center is above or below the said Intersection. Lastly, place a large convex Lens between the Machine and Candle, so as the Candle may be in the Focus of the Lens, and then the Rays will fall parallel, and cast a strong light on the Globe.

It's use.

These things done, which may be sooner than expressed, turn the Handle backward until the Penumbra almost touches the side *HF* of the frame; then turning it gradually forward, observe the following Phenomena. 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 at Sun-rise on his lowermost edge. Continue turning, and, 4. the cross lines in the Center of the Penumbra will go over all those places on the Globe where the Sun is centrally eclipsed. 5. When the eastern edge of the Shadow touches any place of the Globe, the Eclipse begins there: when the vertical line in the Penumbra comes to any place, then is the greatest obscuration at that place; and when the western edge of the Penumbra leaves the place, the Eclipse ends there; the times of all which are shewn on the Hour Circle: and from the beginning to the end, the Shadows of the concentric penumbral Circles shew the number 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 283
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 § 343.

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 that the evening Twilight ends to it. When the place has gone through the dark part *A*, and comes about so to touch under the back of the Hoop *C* on the other side, the Index shews the time that 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 that the Sun passes vertically over on that day.

FINIS.

INDEX.

The numeral Figures refer to the Articles, and the small *n* to the Notes on the Articles.

A.

Acceleration of the Stars, 221.

Angle, what, 185.

Annual Parallax of the Stars, 196.

Anomaly, what, 239.

Antients, their superstitious notions of Eclipses, 329.
Their method of dividing the Zodiac, 398.

Antipodes, what, 122.

Apsides, line of, 238.

ARCHIMEDES, his ideal Problem for moving the Earth, 159.

Areas described by the Planets, equal in times, 153.

Astronomy, the great advantages arising from it both in our religious and civil concerns, 1 Discovers the laws by which the Planets move, and are retained in their Orbits, 2

Atmosphere, the higher the thinner, 174.
It's prodigious expansion, *ib.*
It's whole weight on the Earth, 175.
Generally thought to be heaviest when it is lightest, 176.
Without it the Heavens would appear dark in the day-time, 177.
Is the cause of twilight, *ib.*
It's height, *ib.*
Refracts the Sun's rays, 178.
Causeth the Sun and Moon to appear above the Horizon when they are really below it, *ib.*
Foggy, deceives us in the bulk and distance of objects, 185.

Attraction, 101-105.
Decreases as the square of the distance increases, 106.
Greater in the larger than in the smaller Planets, 158.
Greater in the Sun than in all the Planets if put together, *ib.*

Axes of the Planets, what, 19.
Their different positions with respect to one another, 120.

Axis of the Earth, it's parallelism, 302.
It's position variable as seen from the Sun or Moon, 338.
the Phenomena thence arising, 340.

B.

Bodies, on the Earth, lose of their weight the nearer they are to the Equator, 117.
How they might lose all their weight, 118,
How they become visible, 167.

C.

Calculator, (an Instrument) described, 436.

Calendar, how to inscribe the Golden Numbers rightly in it for shewing the days of New Moons, 423.

Cannon-Ball, it's swiftness, 89.
In what times it would fly from the Sun to the different Planets and fixed Stars, *ib.*

CASSINI, his account of a double Star eclipsed by the Moon, 58.

His Diagrams of the Paths of the Planets, 138.

Catalogue of the Eclipses, 327.
Of the Constellations and Stars, 367.
Of remarkable *Æras* and events, 433.

Celestial Globe improved, 438.

Centripetal and centrifugal forces, how they alternately overcome each other in the motions of the Planets, 152-154.

Changes in the Heavens, 403.

Chords, line of, how to make, 369.

Circles, of perpetual Apparition and Occultation, 128.
Of the Sphere, 198.
Contain 360 Degrees whether they be great or small, 207.

Civil Year, what, 411.

COLUMBUS (CHRISTOPHER) his story concerning an Eclipse, 330.

Clocks and *Watches*, an easy method of knowing whether they go true or false, 223.
Why they seldom agree with the Sun if they go true, 228-245.
How to regulate them by Equation Tables and a Meridian line, 225, 226.

Cloudy Stars, 402.

Cometarium (an Instrument) described, 437.

Constellations, antient, their number, 396.
The number of Stars in each, according to different Astronomers, 399.

Cycle, Solar, Lunar, and *Romish*, 420.
Of *Easter*, 425.

D.

Darkness at our SAVIOUR's crucifixion supernatural, 352, 432.

Day, natural and artificial, what, 417.
And *Night*, always equally long at the Equator, 126.
Natural, not compleated in an absolute turn of the Earth on it's Axis, 222.

Degree, what, 207.

Digit, what, 321, *n.*

Direction, (Number of) 426.

Distances of the Planets from the Sun, an idea thereof, 89.
A Table thereof, 98.
How found, 190.

Diurnal and *annual Motions* of the Earth illustrated, 200, 202.

Dominical Letter, 427.

Double projectile force, a balance to a *Quadruple* Power of Gravity, 153.
Star covered by the Moon, 58.

E.

Earth, it's bulk but a point as seen from the Sun, 3 It's Diameter, annual Period, and Distance from the Sun, 47.
Turns round it's Axis, *ib.*
Velocity of it's equatoreal Parts, *ib.*
Velocity in it's annual Orbit, *ib.*
Inclination of it's Axis, 48.
Proof of it's being globular, or nearly so, 49, 314.
Measurement of it's surface, 50, 51.
Difference between it's Equatoreal and Polar Diameters, 76.
It's motion round the Sun demonstrated by gravity, 108, 111.

by Dr. BRADLEY's observations, 113.
by the Eclipses of Jupiter's Satellites, 219.
It's diurnal motion highly probable from the absurdity that must follow upon supposing it not to move, 111. 120.
and demonstrable from it's figure, 116.
this motion cannot be felt, 119.
Objections against it's motion answered, 112, 121.
It has no such thing as an upper or under side, 122.
in what case it might, 123.
The swiftness of it's motion in it's Orbit compared with the velocity of light, 197.
It's diurnal and annual motions illustrated by an easy experiment, 200.
Proved to be less than the Sun and bigger than the Moon, 315.

Easter Cycle, 425.

Eclipsareon (an Instrument) described, 442.

Eclipses, of Jupiter's Satellites, how the Longitude is found by them, 207-218.
they demonstrate the velocity of light, 216.
Of the Sun and Moon, 312-327.
Why they happen not in every month, 316.
When they must be, 317.
Their limits, *ib.*
Their Period, 320, 326.
A dissertation on their progress, 321-324.
A large catalogue of them, 327.
Historical ones, 328.
More of the Sun than of the Moon, and why, 331.
The proper Elements for their calculation and projection, 353-390.

Ecliptic, it's Signs, their names and characters, 91.
Makes different Angles with the Horizon every hour and minute, 275.
how these Angles may be estimated by the position of the Moon's horns, 260.
It's obliquity to the Equator less now than it was formerly, 405.
How it's Signs are numbered, 354.

Elongations, of the Planets, as seen by an observer at rest on the outside of all their Orbits, 133.
Of Mercury and Venus as seen from the Earth, illustrated, 142.
it's quantity, 143.
Of Mercury, Venus, the Earth, Mars, and Jupiter; it's quantity as seen from Saturn, 147.

Epochas or *Æras*, 433.

Equation of time, 224-245.
Of the Moon's Place, 355.
Of the Sun's Place, *ib.*
Of the Nodes, 363.

Equator, day and night always equal there, 126.
Makes always the same Angle with the Horizon of the same place; the Ecliptic not, 274, 275.

Equinoctial Points in the Heavens, their precession, 246,
a very different thing from the recession or anticipation of the Equinoxes on Earth, the one no ways occasioned by the other, 249.

Excentricities of the Planets Orbits, 155.

F.

Fallacies in judging of the bulk of objects by their apparent distance, 185;
applied to the solution of the horizontal Moon, 187.

First Meridian, what, 207.

Fixed Stars, why they appear of less magnitude when viewed through a telescope than by the bare eye, 391.
Their number, 392.
Their division into different Classes and Constellations, 395-399.

G.

General Phenomena of a superior Planet as seen from an inferior, 149.

Gravity, demonstrable, 101-104.
Keeps all bodies on the Earth to it's surface, or brings them back when thrown upward; and constitutes their weight, 101, 122.
Retains all the Planets in their Orbits, 103.
Decreases as the square of the distance increases, 106.
Proves the Earth's annual motion, 108.
Demonstrated to be greater in the larger Planets than in the smaller; and stronger in the Sun than in all the Planets together, 158.
Hard to understand what it is, 160.
Acts every moment, 162.

Globe, improved celestial, 438.

Great Year, 251.

H.

Harmony of the celestial motions, 111.

Harvest-Moon, 273-293.
None at the Equator, 273.
Remarkable at the Polar Circles, 285.
In what years most and least advantageous, 292.

Heat, decreases as the square of the distance from the Sun increases, 169.
Why not greatest when the Earth is nearest the Sun, 205.
Why greater about three o'Clock in the afternoon than when the Sun is on the Meridian, 300.

Heavens, seem to turn round with different velocities as seen from the different Planets; and on different Axes as seen from most of them, 120.
Only one Hemisphere of them seen at once from any one Planet's surface, 125.
The Sun's Center the only point from which their true Motions could be seen, 135.
Changes in them, 403.

Horizon, what, 125, *n.*

Horizontal-Moon explained, 187.

Horizontal Parallax, of the Moon, 190;
of the Sun, 191;
best observed at the Equator, 193.

Hour-Circles, what, 208.

Hour of time equal to 15 degrees of motion, *ib.*
How divided by the *Jews*, *Chaldeans*, and *Arabians*, 419.

HUYGENIUS, his thoughts concerning the distance of some Stars, 5

I. J.

Inclination of Venus's Axis, 29.
Of the Earth's, 48.
Of the Axis or Orbit of a Planet only relative, 201.

Inhabitants of the Earth (or any other Planet) stand on opposite sides with their feet toward one another, yet each thinks himself on the upper side, 122.

Julian Period, 430.

Jupiter, it's distance, diameter, diurnal and annual revolutions, 67-69.
The Phenomena of it's Belts, 70.
Has no difference of seasons, 71.
Has four Moons, 72,
their grand Period, 73,
the Angles which their Orbits subtend as seen from the Earth, 74,
most of them are eclipsed in every revolution, 75.
The great difference between it's equatoreal and polar Diameters, 76.

The inclination of it's Orbit, and place of it's Ascending Node, 77.
The Sun's light 3000 times as strong on it as Full Moon-light is on the Earth, 85.
Is probably inhabited, 86.
The amazing strength required to put it in motion, 158.
The figures of the Paths described by it's Satellites, 269.

L.

Light, the inconceivable smallness of it's particles, 165,
and the dreadful mischief they would do if they were larger, 166.
It's surprising velocity, 166,
compared with the swiftness of the Earth's annual motion, 197.
Decreases as the square of the distance from the luminous body increases, 169.
Is refracted in passing through different Mediums, 171-173.
Affords a proof of the Earth's annual motion, 197, 219.
In what time it comes from the Sun to the Earth, 216,
this explained by a figure, 217.

Limits of Eclipses, 317.

Line, of the Nodes, what, 317;
has a retrograde motion, 319.
Of Sines and Chords, how to make, 369.

Long (Rev. Dr.) his method of comparing the quantity of the surface of dry land with that of the Sea, 51.
His glass sphere, 126.

Longitude, how found, 207-213.

Lucid Spots in the Heavens, 401.

Lunar Cycle deficient, 422.

M.

Magellanic Clouds, 402.

Man, of a middle size, how much pressed by the weight of the Atmosphere, 175;
why this pressure is not felt, *ib.*

Mars, it's Diameter, Period, Distance, and other Phenomena, 64-67.

Matter, it's properties, 99.

Mean Anomaly, what, 239.

Mercury, it's Diameter, Period, Distance, &c. 22.
Appears in all the shapes of the Moon, 23.
When it will be seen on the Sun, 24.
The inclination of it's Orbit and Place of it's Ascending Node, *ib.*
It's Path delineated, 138.
Experiment to shew it's Phases and apparent Motion, 142.

Mercury (Quicksilver) in the Barometer, why not affected by the Moon's raising Tides in the Air, 311.

Meridian, first, 207.
Line, how to draw one, 226.

Milky Way, what, 400.

Months, *Jewish*, *Arabian*, *Egyptian*, and *Grecian*, 415.

Moon, her Diameter and Period, 52.
Her phases, 53, 255.
Shines not by her own light, 54.
Has no difference of seasons, 55.
The Earth is a Moon to her, 56.
Has no Atmosphere of any visible Density, 58;
nor Seas, 59.
How her inhabitants may be supposed to measure their year, 62.
Her light compared with day-light, 85.

The excentricity of her Orbit, 98.
Is nearer the Earth now than she was formerly, 163.
Appears bigger in the Horizon than at any considerable height above it, and why, 187;
yet is seen much under the same Angle in both cases, 188.
Her surface mountainous, 252:
if smooth she could give us no light, *ib.*
Why no hills appear round her edge, 253.
Has no Twilight, 254.
Appears not always quite round when full, 256.
Her phases agreeably represented by a globular Stone viewed in Sun-shine when she is above the Horizon, and the observer placed as if he saw her on the top of the Stone, 258.
Turns round her Axis, 262.
The length of her Solar and Sidereal Day, *ib.*
Her periodical and synodical revolution represented by the motions of the hour and minute hands of a Watch, 264.
Her Path delineated, and shewn to be always concave to the Sun, 265-268.
Her motion alternately retarded and accelerated, 267.
Her gravity toward the Sun greater than toward the Earth at her Conjunction, and why she does not then abandon the Earth on that account, 268.
Rises nearer the time of Sun-set when about the full in harvest for a whole week than when she is about the full at any other time of the year, and why, 273-284:
this rising goes through a course of increasing and decreasing benefit to the farmers every 19 years, 292.
Continues above the Horizon of the Poles for fourteen of our natural Days together, 293.
Proved to be globular, 314.
and to be less than the Earth, 315.
Her Nodes, 317.
ascending and descending, 318.
their retrograde motion, 319.
Her acceleration proved from antient Eclipses, 322, *n.*
Her Apogee and Perigee, 336.
Not invisible when she is totally eclipsed, and why, 346.
How to calculate her Conjunctions, Oppositions, and Eclipses, 355-390.
How to find her age in any Lunation by the Golden Number, 423.

Morning and *Evening Star*, what, 145.

Motion, naturally rectilineal, 100.
Apparent, of the Planets as seen by a spectator at rest on the outside of all their Orbits, 133;
and of the Heavens as seen from any Planet, 154.

N.

Natural Day, not compleated in the time that the Earth turns round it's Axis, 222.

New and *Full Moon*, to calculate the times of 355.

New Stars, 403,
cannot be Comets, 404.

New Style, it's original, 414.

NICIAS's Eclipse, 328.

Nodes, of the Planet's Orbits, their places in the Ecliptic, 20.
Of the Moon's Orbit, 317.
their retrograde motion, 319.

Nonagesimal Degree, what, 259.

Number of Direction, 426.

O.

Objects, we often mistake their bulk by mistaking their distance, 185.
Appear bigger when seen through a fog than through clear Air, and why, *ib.*
this applied to the solution of the Horizontal Moon, 187.

Oblique Sphere, what, 131.

Olympiads, what, 323. *n.*

Orbits of the Planets not solid, 21.

Orrery described, 434, 435, 436.

P.

Parallax, Horizontal, what, 190.

Parallel Sphere, what, 131.

Path of the Moon, 265, 266, 267.
Of Jupiter's Moons, 269.

Pendulums, their vibrating slower at the Equator than near the Poles proves that the Earth turns on it's Axis, 117.

Penumbra, what, 336.
It's velocity on the Earth in Solar Eclipses, 337.

Period of Eclipses, 320, 326.

Phases of the Moon, 252-268.

Planets, much of the same nature with the Earth, 11.
Some have Moons belonging to them, 12.
Move all the same way as seen from the Sun, but not as seen from one another, 18.
Their Moons denote them to be inhabited, 86.
The proportional breadth of the Sun's Disc as seen from each of them, 87.
Their proportional bulks as seen from the Sun, 88.
An idea of their distances from the Sun, 89.
Appear bigger and less by turns, and why, 90.
Are kept in their Orbits by the power of gravity, 101, 150-158.
Their motions very irregular as seen from the Earth, 137.
The apparent motions of Mercury and Venus delineated by Pencils in an Orrery, 138.
Elongations of all the rest as seen from Saturn, 147.
Describe equal areas in equal times, 153.
The excentricities of their Orbits, 155.
In what times they would fall to the Sun by the power of gravity, 157.
Disturb one another's motions, the consequence thereof, 163.
Appear dimmer when seen through telescopes than by the bare eye, the reason of this, 170.

Planetary Globe described, 439.

Polar Circles, 198.

Poles, of the Planets, what, 19.
Of the world, what, 122.
Celestial, seem to keep on the same points of the Heavens all the year, and why, 196.

Projectile Force, 150;
if doubled would require a quadruple power of gravity to retain the Planets in their Orbits, 153.
Is evidently an impulse from the hand of the ALMIGHTY, 161.

Precession of the Equinoxes, 246-251.

Ptolemean System absurd, 96, 140.

R.

Rays of Light, if not disturbed, move in straight lines, and hinder not one another's motions, 168.
Are refracted in passing through different mediums, 171.

Reflection of the Atmosphere causes the Twilight, 177.

Refraction of the Atmosphere bends the rays of light from straight lines, and keeps the Sun and Moon longer in sight than they would otherwise be, 178.
A surprising instance of this, 183.
Must be allowed for in taking the Altitudes of the celestial bodies, *ib.*

Right Sphere, 131.

S.

Satellites; the times of their revolutions round their primary Planets, 52, 73, 80.
Their Orbits compared with each other, with the Orbits of the primary Planets, and with the Sun's circumference, 271.
What sort of Curves they describe, 272.

Saturn, with his Ring and Moon's, their Phenomena, 78, 79, 82.
The Sun's light 1000 times as strong to him as the light of the Full Moon is to us, 85.
The Phenomena of his Ring farther explained, 204.

Our blessed SAVIOUR, the darkness at his crucifixion supernatural, 352.
The prophetic year of his crucifixion found to agree with an astronomical calculation, 432.

Seasons, different, illustrated by an easy experiment, 200;
by a figure, 202.

Shadow, what, 312.

Sidereal Time, what, 221;
the number of Sidereal Days in a year exceeds the number of Solar Days by one, and why, 222.
An easy method for regulating Clocks and Watches by it, 223.

Signs of the Zodiac, their names and characters, 91, 365.
How they are numbered by Astronomers, 354.

Sines, line of, how to make, 369.

SMITH, (Rev. Dr.) his companion between Moon-light and Day-light, 85.
His demonstration that light decreases as the square of the distance from the luminous body increases, 169.
(*Mr.* GEORGE) his Dissertation on the Progress of a Solar Eclipse, 321-324.

Solar Astronomer, the judgment he might be supposed to make concerning the Planets and Stars, 135, 136.

Sphere, parallel, oblique, and right, 131.
It's Circles, 198.

Spring and Neap Tides, 302.

Stars, their vast distance from the Earth, 3, 196.
Probably not all at the same distance, 4 Shine by their own light, and are therefore Suns 7,
probably to other worlds, 8 A demonstration that they do not move round the Earth, 111.
Have an apparent slow motion round the Poles of the Ecliptic, and why, 251.
A catalogue of them, 399.
Cloudy, 402.
New, 403.
Some of them change their places, 404.

Starry Heavens have the same appearance from any part of the Solar System, 132.

SUN appears bigger than the Stars, and why, 4 Turns round his Axis, 18.
His proportional breadth as seen from the different Planets, 87.
Describes unequal arcs above and below the Horizon at different times, and why, 130.
His Center the only place from which the true motions of the Planets could be seen, 135.
Is for half a year together visible at each Pole in it's turn, and as long in visible, 200, 294.
Is nearer the Earth in Winter than in Summer, 205.
Why his motion agrees so seldom with the motion of a well regulated Clock, 224-245.
Would more than fill the Moon's Orbit, 271.
Proved to be much bigger than the Earth, and the Earth to be bigger than the Moon, 315.
To calculate his true place, 360.

Systems, the Solar, 17-95;
the Ptolemean, 96;
the Tychonic, 97.

T.

Table, of the Periods, Revolutions, Magnitudes, Distances, *&c.* of the Planets, facing § 99.
Of the Air's rarity, compression, and expansion at different heights, 174.

Of refractions, 182.
For converting time into motion, and the reverse, 220.
For shewing how much of the celestial Equator passes over the Meridian in any part of a mean Solar Day; and how much the Stars accelerate upon the mean Solar time for a month, 221.
Of the first part of the Equation of time, 229;
of the second part, 241.
Of the precession of the Equinox, 247.
Of the length of Sidereal, Julian, and Tropical Years, 251.
Of the Sun's place and Anomaly, following 251.
Of the Equation of natural Days, following 251
Of the Conjunctions of the hour and minute hands of a Watch, 264.
Of the Curves described by the Satellites, 272.
Of the difference of time in the Moon's rising and setting on the parallel of *London* every day during her course round the Ecliptic, 277.
Of Eclipses, 327.
For calculating New and Full Moons and Eclipses, following 390.
Of the Constellations and number of the Stars, 399.
Of the *Jewish*, *Egyptian*, *Arabic*, and *Grecian* months, 415.
For inserting the Golden Numbers right in the Calendar, 423.
Of the times of all the New Moons for 76 years, 424.
Of remarkable Æras or Events, 433.
Of the Golden Number, Number of Direction, Dominical Letter and Days of the Months, following 433.

THALES's Eclipse, 323.

THUCYDIDES's Eclipse 324.

Tides, their Cause and Phenomena, 295-311.

Tide-Dial described, 441.

Trajectorium Lunare described, 440.

Tropics, 198.

Twilight, none in the Moon, 254.

Tychonic System absurd, 97.

U.

Universe, the Work of Almighty Power, 5, 161.

Up and *down*, only relative terms, 122.

Upper or *under side of the Earth* no such thing, 123.

V.

Velocity of Light compared with the velocity of the Earth in it's annual Orbit, 197.

Venus, her bulk, distance, period, length of days and nights, 26.
Shines not by her own light, *ib.*
Is our morning and evening Star, 28.
Her Axis, how situated, 29.
Her surprising Phenomena, 29-43.
The inclination of her Orbit, 45.
When she will be seen on the Sun, *ib.*
How it may probably be soon known if she has a Satellite, 46.
Appears in all the Shapes of the Moon, 23, 141.
An experiment to shew her phases and apparent motion, 141.

Vision, how caused, 167.

W.

Weather, not hottest when the Sun is nearest to us, and why, 205.

Weight, the cause of it, 122.

World not eternal, 164.

Y.

Year, 407,
Great, 251,
Tropical, 408,
Sidereal, 400,
Lunar, 410,
Civil, 411,
Bissextile, *ib.*
Roman, 413,
Jewish, *Egyptian*, *Arabic*, and *Grecian*, 415,
how long it would be if the Sun moved round the Earth, 111.

Z.

Zodiac, what, 397.
How divided by the antients, 398.

Zones, what, 199.

DIRECTIONS to the BOOKBINDER.

The ORRERY PLATE is to front the Title Page.

PLATE I	fronting Page 5
II	39
III	49
IV	73
V	81
VI	97
VII	125
VIII	147
IX	147
X	157
XI	179
XII	203
XIII	279

Footnotes

1. Dr. YOUNG's Night Thoughts.

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

3. Astronomers are not far from the truth, when they reckon the Sun's center 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.

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

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

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

7. One entire revolution, or 24 hours.

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

9. 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.

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

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

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

13. *Memoirs d'Acad. ann. 1720.*

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

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

16. Optics, Art. 95.

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

18. As will be demonstrated in the ninth Chapter.

19. Optics, B. I. § 1178.

20. Astronomy, B. II. §. 838.

21. Philosophy, Vol. I. p. 401.

22. Account of Sir Isaac Newton's *Philosophical Discoveries*, B. III. c. 2. § 3.

23. *Elements d'Astronomie*, § 381.

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

25. 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.

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

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

28. 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.

29. The ORRERY fronting the Title-page.

30. 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.

31. Astronomical Principles of Religion, p. 66.

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

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

34. Religious Philosopher, Vol. III. page 65.

35. This will be demonstrated in the eleventh Chapter.

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

37. Book I. Art. 57.

38. 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.

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

40. This is evident from pumps, since none can draw water higher than 33 foot.

41. Namely 10000 times the distance of Saturn from the Sun; p. 94.

42. See his Astronomy, p. 232.

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

44.

Fig. V.

An Angle is the inclination of two right lines, as *IH* and *KH*, meeting in a point at *H*; and in describing an Angle by three letters, the middle letter always denotes the angular point: thus, the above lines *IH* and *KH* meeting each other at *H*, make the Angle *IHK*. And the point *H* is supposed to be the center of a Circle, the circumference of which contains 360 equal parts called degrees. A fourth part of a Circle, called a Quadrant, as *GE*, contains 90 degrees; and every Angle is measured by the number of degrees in the arc it cuts off; as the angle *EHP* is 45 degrees, the Angle *EHF* 33,

&c: and so the Angle *EHF* is the same with the angle *CHN*, and also with the Angle *AHM*, because they all cut off the same arc or portion of the Quadrant *EG*; and so likewise the Angle *EHF* is greater than the Angle *CHD* or *AHL*, because it cuts off a greater arc.

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

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

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

46. The Sun and Moon subtend a greater Angle on the Meridian than in the Horizon, being nearer the Earth in the former case than the latter.

47. The Altitude of any celestial Phenomenon is an arc of the Sky intercepted between the Horizon and the Phenomenon. In Fig. VI. of Plate II. let *HOX* be a horizontal line, supposed to be extended from the eye at *A* to *X*, where the Sky and Earth seem to meet at the end of a long and level plain; and let *S* be the Sun. The arc *XY* will be the Sun's height above the Horizon at *X*, and is found by the instrument *EDC*, which is a quadrantal board, or plate of metal, divided into 90 equal parts or degrees on its limb *DPC*; and has a couple of little brass plates, as *a* and *b*, with a small hole in each of them, called *Sight-Holes*, for looking through, parallel to the edge of the Quadrant whereon they stand. To the center *E* is fixed one end of a thread *F*, called *the Plumb-Line*, which has a small weight or plummet *P* fixed to it's other end. Now, if an observer holds the Quadrant upright, without inclining it to either side, and so that the Horizon at *X* is seen through the sight-holes *a* and *b*, the plumb-line will cut or hang over the beginning of the degrees at *o*, in the edge *EC*; but if he elevates the Quadrant so as to look through the sight-holes at any part of the Heavens, suppose to the Sun at *S*; just so many degrees as he elevates the sight-hole *b* above the horizontal line *HOX*, so many degrees will the plumb-line cut in the limb *CP* of the Quadrant. For, let the observer's eye at *A* be in the center of the celestial arc *XYV* (and he may be said to be in the center of the Sun's apparent diurnal Orbit, let him be on what part of the Earth he will) in which arc the Sun is at that time, suppose 25 degrees high, and let the observer hold the Quadrant so that he may see the Sun through the sight-holes; the plumb-line freely playing on the quadrant will cut the 25th degree in the limb *CP* equal to the number of degrees of the Sun's Altitude at the time of observation. *N. B.* Whoever looks at the Sun, must have a smoaked glass before his eyes to save them from hurt. The better way is not to look at the Sun through the sight-holes, but to hold the Quadrant facing the eye, at a little distance, and so that the Sun shining through one hole, the ray may be seen to fall on the other.

48. See the Note on § 185.

49. 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.

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

51. Smith's Optics, § 1197.

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

53. 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.

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

55. 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.

56. 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*.

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

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

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

60. The Figure shews the Globe as if only elevated about 40 degrees, which was occasioned by an oversight in the drawing: but it is still sufficient to explain the Phenomena.

61. The Ecliptic, together with the fixed Stars, make $366\frac{1}{4}$ apparent diurnal revolutions about the Earth in a year; the Sun only $365\frac{1}{4}$. Therefore the Stars gain 3 minutes 56 seconds upon the Sun every day: so that a Sidereal day contains only 23 hours 56 minutes of mean Solar time; and a natural or Solar day 24 hours. Hence 12 Sidereal hours are 1 minute 58 seconds shorter than 12 Solar.

62. 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.

63. 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 *æquilibria*. 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.

64. 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.

65. Which is the time that the Eclipse would be at the greatest obscuration, if the motions of the Sun and Moon were equable, or the same in all parts of their Orbits.

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

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

68. There are two antient Eclipses of the Moon, recorded by *Ptolemy* from *Hipparchus*, which afford an undeniable proof of the Moon's acceleration. The first of these was observed at *Babylon*, *December* the 22d, in the year before CHRIST 383: when the Moon began to be eclipsed about half an hour before the Sun rose, and the Eclipse was not over before the Moon set: but by our best 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 our Tables the beginning of this Eclipse was not till about 10 minutes after the Moon rose at *Alexandria*. Had these Eclipses begun and ended while the Sun was below the Horizon, we might have imagined, that as the antients had no certain way of measuring time, they might have been so far mistaken in the hours, that we could not have laid any stress on the accounts given by them. But, as in the first Eclipse the Moon was set, and consequently the Sun risen, before it was over; and in the second Eclipse the Sun was set, and the Moon not risen, till some time after it began; these are such circumstances as the observers could not possibly be mistaken in. Mr. *Struyk* in the following Catalogue, notwithstanding the express words of *Ptolemy*, puts down these two Eclipses as observed at *Athens*; where they might have been seen as above, without any acceleration of the Moon's motion: *Athens* being 20 degrees West of *Babylon*, and 7 degrees West of *Alexandria*.

69. 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 after the Solstice, and at other times not till four weeks after it. The first *Olympiad* began in the year of the Julian Period 3938, which was 776 years before the first year of CHRIST, or 775 before the year of his birth; and the last *Olympiad*, which was the 293d, began *A. D.* 393. At the expiration of each *Olympiad*, the *Olympic Games* were celebrated in the *Elean* fields, near the river *Alpheus* in the *Peloponnesus* (now *Morea*) in honour of JUPITER OLYMPUS. See STRAUCHIUS's *Breviarium Chronologium*, p. 247-251.

70. The reader may probably find it difficult to understand why Mr. SMITH should reckon this Eclipse to have been in the 4th year of the 48th *Olympiad*; as it was only in the end of the third year: and also why the 28th of *May*, in the 585th year before CHRIST should answer to the present 10th of that month. But we hope the following explanation will remove these difficulties.

The month of *May* (when the Sun was eclipsed) in the 585th year before the first year of CHRIST, which was a leap-year, fell in the latter end of the third year of the 48th *Olympiad*; and the fourth year of that *Olympiad* began at the Summer Solstice following: but perhaps Mr. SMITH begins the years of the *Olympiad* from *January*, in order to make them correspond more readily with *Julian* years; and so reckons the month of *May*, when the Eclipse happened, to be in the fourth year of that *Olympiad*.

The Place or Longitude of the Sun at that time was ♉ 29° 43′ 17″, to which same place the Sun returned (after 2300 years, *viz.*) *A. D.* 1716, on *May*, 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.

71. Before CHRIST 413, *August 27*.

72. Before CHRIST 168, *June 20*.

73. STRUYK's Eclipses are to the *Old Style*, all the rest to the *New*.

74. This Eclipse happened in the first year of the *Peloponnesian* war.

75. Although the Sun and Moon are spherical bodies, as seen from the Earth they appear to be circular planes, and so would the Earth if it were seen from the Moon. The apparently flat surfaces of the Sun and Moon are called their *Disks* by Astronomers.

76. A Digit is a twelfth part of the diameter of the Sun and Moon.

77. This is the same with *the annual Argument of the Moon*.

78. When the *Romans* divided the Empire, which was about 38 years before CHRIST, *Spain* fell to *Augustus*'s share: in memory of which, the *Spaniards* dated all their memorable events *ab exordio Regni Augusti*; as Christians do from the birth of our SAVIOUR. But in process of time, only the initial letters *AERA* of these words were used instead of the words themselves. And thus, according to some, came the word *ÆRA*, which is made use of to signify a point of time from whence historians begin to reckon.

79. When the Sun's Anomaly is 0 signs 0 degrees, or 6 signs 0 degrees, neither the Sun nor the Moon's Anomaly have any Equation; which is the case in this Example.

80. See the Remark, p. 195.

81. *Babylon* is 42 deg. 46 min. east from the Meridian of *London*, which is equal to 2 hours 51 min. of time nearly. See § 220.

82. Our SAVIOUR was born in a leap-year, and therefore every fourth year both before and after is a leap-year in the *Old Stile*: but the Tables begin with the year *next after* that of his birth.

83. When only one of the Nodes is mentioned, it is the Ascending Node that is meant, to which the Descending Node is exactly opposite.

84. When the Moon is North of the Ecliptic and going farther from it, her Latitude or Declination from the Ecliptic is called *North Ascending*: when she is North of the Ecliptic and going toward it, her Latitude is *North Descending*: when she is South of the Ecliptic and going farther from it, her Latitude is *South Descending*: and lastly, when she is South of the Ecliptic and going toward it, her Latitude is *South Ascending*.

85. See Page 193, Example II.

86. M. *Maupertuis*, in his dissertation on the figures of the Celestial Bodies (p. 61-63) is of opinion that some Stars, by their prodigious quick rotations on their Axes, may not only assume the figures of oblate spheroids, but that by the great centrifugal force, arising from such rotations, they may become of the figures of mill-stones; or be reduced to flat circular planes, so thin as to be quite invisible when their edges are turned towards us; as Saturn's Ring is in such positions. But when very excentric Planets or Comets go round any flat Star, in Orbits much inclined to it's Equator, the attraction of the Planets or Comets in their perihelions must alter the inclination of the Star; on which account it will appear more or less large and luminous as it's broad side is more or less turned towards us. And thus he imagines we may account for the apparent changes of magnitude and lustre in those Stars, and likewise for their appearing and disappearing.

87. See this word explained in the note at the foot of page 194.

88. See the note on § 323.

89. *Matt.* xxvii. 45. *Mark* xv. 43. *Luke* xxiii. 44.

Transcriber's Note

This book uses inconsistent spelling and hyphenation, which were retained in the ebook version. Some corrections have been made to the text, including correcting the errata and normalizing punctuation. Further corrections are noted below:

Errata: l. 15 from botton -> l. 15 from bottom
p. 9: forward in the Eliptic -> forward in the Ecliptic
p. 31: is at it were -> is as it were
p. 36, Footnote 22 moved from referring to Rutherfurth to Maclaurin, additionally 'Isacc Newton' changed to 'Isaac Newton'. Footnote marker on Rutherfurth removed as there was no footnote associated with it.
p. 38: on the the same Axis -> on the same Axis
Footnote 32 κοσμὸν -> κόσμον
p. 69: who were suprised to find -> who were surprised to find
p. 69: than those whch -> than those which
p. 72: than tie a thread -> then tie a thread
p. 74: is is equal to -> is equal to
p. 74: the graduaded limb -> the graduated limb
Footnote 49: bove the horizon -> above the horizon
p. 78: different lenghts -> different lengths
p. 78: from the the Equator -> from the Equator
p. 90: is not instantaneons -> is not instantaneous
p. 92: Degreees and Parts of the Equtor-> Degrees and Parts of the Equator
p. 132: appear supprising -> appear surprising
p. 133: When Jupiter at -> When Jupiter is at
Sidenote p. 136: The reason of of this -> the reason of this
p. 140 the opposite points rises -> the opposite point rises
Sidenote p. 141: Harvest aad Hunter's -> Harvest and Hunter's
p. 154: espeically as to the -> especially as to the
Sidenote p. 155: aereal Tides -> aerial Tides
p. 158: the the Earth -> the Earth
p. 160: goes round him 87 days -> goes round him in 87 days
p. 161: Eclipses and revolulution -> Eclipses and revolution
p. 167: Jacobus Ptlaumen -> Jacobus Pflaumen
p. 168: set set down -> set down
p. 172 Table 2, 1st column, 6th row: 1388 -> 1488
p. 174: duplicate entry for 1606 Sept 2. removed
p. 177: foretold by Thalls -> foretold by Thales
p. 180: the Eclipse is annualar -> the Eclipse is annular
p. 193: EAAMPLE II. -> EXAMPLE II
p. 202: these two Fquations -> these two Equations
p. 203: their Sun will be -> their Sum will be
p. 210: the page number was printed as 110 and has been corrected
p. 210: Motion and Semi diameter -> Motion and Semi-diameter
p. 232: ζωδίακος -> ζωδιακὸς
p. 232: ζῶδιον -> ζώδιον
p. 238: oblate spheriod -> oblate spheroid
p. 261 18 Degres -> 18 Degrees
Index Mercury (Quicksiver) -> Mercury (Quicksilver)
List of Plates Page number for Plate IV corrected from 15 to 97

End of the Project Gutenberg EBook of Astronomy Explained Upon Sir Isaac Newton's Principles, by James Ferguson

*** END OF THIS PROJECT GUTENBERG EBOOK ASTRONOMY EXPLAINED ***

***** This file should be named 60619-h.htm or 60619-h.zip *****
This and all associated files of various formats will be found in:
http://www.gutenberg.org/6/0/6/1/60619/

Produced by MFR, Sonya Schermann, and the Online Distributed

Proofreading Team at http://www.pgdp.net (This file was
produced from images generously made available by The
Internet Archive)

Updated editions will replace the previous one--the old editions will
be renamed.

Creating the works from print editions not protected by U.S. copyright
law means that no one owns a United States copyright in these works,
so the Foundation (and you!) can copy and distribute it in the United
States without permission and without paying copyright
royalties. Special rules, set forth in the General Terms of Use part
of this license, apply to copying and distributing Project
Gutenberg-tm electronic works to protect the PROJECT GUTENBERG-tm
concept and trademark. Project Gutenberg is a registered trademark,
and may not be used if you charge for the eBooks, unless you receive
specific permission. If you do not charge anything for copies of this
eBook, complying with the rules is very easy. You may use this eBook
for nearly any purpose such as creation of derivative works, reports,
performances and research. They may be modified and printed and given
away--you may do practically ANYTHING in the United States with eBooks
not protected by U.S. copyright law. Redistribution is subject to the
trademark license, especially commercial redistribution.

START: FULL LICENSE

THE FULL PROJECT GUTENBERG LICENSE
PLEASE READ THIS BEFORE YOU DISTRIBUTE OR USE THIS WORK

To protect the Project Gutenberg-tm mission of promoting the free
distribution of electronic works, by using or distributing this work
(or any other work associated in any way with the phrase "Project
Gutenberg"), you agree to comply with all the terms of the Full
Project Gutenberg-tm License available with this file or online at
www.gutenberg.org/license.

Section 1. General Terms of Use and Redistributing Project
Gutenberg-tm electronic works

1.A. By reading or using any part of this Project Gutenberg-tm
electronic work, you indicate that you have read, understand, agree to
and accept all the terms of this license and intellectual property
(trademark/copyright) agreement. If you do not agree to abide by all
the terms of this agreement, you must cease using and return or
destroy all copies of Project Gutenberg-tm electronic works in your
possession. If you paid a fee for obtaining a copy of or access to a
Project Gutenberg-tm electronic work and you do not agree to be bound
by the terms of this agreement, you may obtain a refund from the
person or entity to whom you paid the fee as set forth in paragraph
1.E.8.

1.B. "Project Gutenberg" is a registered trademark. It may only be
used on or associated in any way with an electronic work by people who
agree to be bound by the terms of this agreement. There are a few
things that you can do with most Project Gutenberg-tm electronic works
even without complying with the full terms of this agreement. See
paragraph 1.C below. There are a lot of things you can do with Project
Gutenberg-tm electronic works if you follow the terms of this
agreement and help preserve free future access to Project Gutenberg-tm
electronic works. See paragraph 1.E below.

1.C. The Project Gutenberg Literary Archive Foundation ("the
Foundation" or PGLAF), owns a compilation copyright in the collection
of Project Gutenberg-tm electronic works. Nearly all the individual
works in the collection are in the public domain in the United
States. If an individual work is unprotected by copyright law in the
United States and you are located in the United States, we do not
claim a right to prevent you from copying, distributing, performing,
displaying or creating derivative works based on the work as long as
all references to Project Gutenberg are removed. Of course, we hope
that you will support the Project Gutenberg-tm mission of promoting
free access to electronic works by freely sharing Project Gutenberg-tm
works in compliance with the terms of this agreement for keeping the
Project Gutenberg-tm name associated with the work. You can easily

comply with the terms of this agreement by keeping this work in the same format with its attached full Project Gutenberg-tm License when you share it without charge with others.

1.D. The copyright laws of the place where you are located also govern what you can do with this work. Copyright laws in most countries are in a constant state of change. If you are outside the United States, check the laws of your country in addition to the terms of this agreement before downloading, copying, displaying, performing, distributing or creating derivative works based on this work or any other Project Gutenberg-tm work. The Foundation makes no representations concerning the copyright status of any work in any country outside the United States.

1.E. Unless you have removed all references to Project Gutenberg:

1.E.1. The following sentence, with active links to, or other immediate access to, the full Project Gutenberg-tm License must appear prominently whenever any copy of a Project Gutenberg-tm work (any work on which the phrase "Project Gutenberg" appears, or with which the phrase "Project Gutenberg" is associated) is accessed, displayed, performed, viewed, copied or distributed:

> This eBook is for the use of anyone anywhere in the United States and most other parts of the world at no cost and with almost no restrictions whatsoever. You may copy it, give it away or re-use it under the terms of the Project Gutenberg License included with this eBook or online at www.gutenberg.org. If you are not located in the United States, you'll have to check the laws of the country where you are located before using this ebook.

1.E.2. If an individual Project Gutenberg-tm electronic work is derived from texts not protected by U.S. copyright law (does not contain a notice indicating that it is posted with permission of the copyright holder), the work can be copied and distributed to anyone in the United States without paying any fees or charges. If you are redistributing or providing access to a work with the phrase "Project Gutenberg" associated with or appearing on the work, you must comply either with the requirements of paragraphs 1.E.1 through 1.E.7 or obtain permission for the use of the work and the Project Gutenberg-tm trademark as set forth in paragraphs 1.E.8 or 1.E.9.

1.E.3. If an individual Project Gutenberg-tm electronic work is posted with the permission of the copyright holder, your use and distribution must comply with both paragraphs 1.E.1 through 1.E.7 and any additional terms imposed by the copyright holder. Additional terms will be linked to the Project Gutenberg-tm License for all works posted with the permission of the copyright holder found at the beginning of this work.

1.E.4. Do not unlink or detach or remove the full Project Gutenberg-tm License terms from this work, or any files containing a part of this work or any other work associated with Project Gutenberg-tm.

1.E.5. Do not copy, display, perform, distribute or redistribute this electronic work, or any part of this electronic work, without prominently displaying the sentence set forth in paragraph 1.E.1 with active links or immediate access to the full terms of the Project Gutenberg-tm License.

1.E.6. You may convert to and distribute this work in any binary, compressed, marked up, nonproprietary or proprietary form, including any word processing or hypertext form. However, if you provide access to or distribute copies of a Project Gutenberg-tm work in a format other than "Plain Vanilla ASCII" or other format used in the official version posted on the official Project Gutenberg-tm web site (www.gutenberg.org), you must, at no additional cost, fee or expense to the user, provide a copy, a means of exporting a copy, or a means of obtaining a copy upon request, of the work in its original "Plain Vanilla ASCII" or other form. Any alternate format must include the full Project Gutenberg-tm License as specified in paragraph 1.E.1.

1.E.7. Do not charge a fee for access to, viewing, displaying, performing, copying or distributing any Project Gutenberg-tm works unless you comply with paragraph 1.E.8 or 1.E.9.

1.E.8. You may charge a reasonable fee for copies of or providing access to or distributing Project Gutenberg-tm electronic works provided that

* You pay a royalty fee of 20% of the gross profits you derive from the use of Project Gutenberg-tm works calculated using the method you already use to calculate your applicable taxes. The fee is owed to the owner of the Project Gutenberg-tm trademark, but he has agreed to donate royalties under this paragraph to the Project Gutenberg Literary Archive Foundation. Royalty payments must be paid within 60 days following each date on which you prepare (or are legally required to prepare) your periodic tax returns. Royalty payments should be clearly marked as such and sent to the Project Gutenberg Literary Archive Foundation at the address specified in Section 4, "Information about donations to the Project Gutenberg Literary Archive Foundation."

* You provide a full refund of any money paid by a user who notifies you in writing (or by e-mail) within 30 days of receipt that s/he does not agree to the terms of the full Project Gutenberg-tm License. You must require such a user to return or destroy all copies of the works possessed in a physical medium and discontinue all use of and all access to other copies of Project Gutenberg-tm works.

* You provide, in accordance with paragraph 1.F.3, a full refund of any money paid for a work or a replacement copy, if a defect in the electronic work is discovered and reported to you within 90 days of receipt of the work.

* You comply with all other terms of this agreement for free distribution of Project Gutenberg-tm works.

1.E.9. If you wish to charge a fee or distribute a Project Gutenberg-tm electronic work or group of works on different terms than are set forth in this agreement, you must obtain permission in writing from both the Project Gutenberg Literary Archive Foundation and The Project Gutenberg Trademark LLC, the owner of the Project Gutenberg-tm trademark. Contact the Foundation as set forth in Section 3 below.

1.F.

1.F.1. Project Gutenberg volunteers and employees expend considerable effort to identify, do copyright research on, transcribe and proofread works not protected by U.S. copyright law in creating the Project Gutenberg-tm collection. Despite these efforts, Project Gutenberg-tm electronic works, and the medium on which they may be stored, may contain "Defects," such as, but not limited to, incomplete, inaccurate or corrupt data, transcription errors, a copyright or other intellectual property infringement, a defective or damaged disk or other medium, a computer virus, or computer codes that damage or cannot be read by your equipment.

1.F.2. LIMITED WARRANTY, DISCLAIMER OF DAMAGES - Except for the "Right of Replacement or Refund" described in paragraph 1.F.3, the Project Gutenberg Literary Archive Foundation, the owner of the Project Gutenberg-tm trademark, and any other party distributing a Project Gutenberg-tm electronic work under this agreement, disclaim all liability to you for damages, costs and expenses, including legal fees. YOU AGREE THAT YOU HAVE NO REMEDIES FOR NEGLIGENCE, STRICT LIABILITY, BREACH OF WARRANTY OR BREACH OF CONTRACT EXCEPT THOSE PROVIDED IN PARAGRAPH 1.F.3. YOU AGREE THAT THE FOUNDATION, THE TRADEMARK OWNER, AND ANY DISTRIBUTOR UNDER THIS AGREEMENT WILL NOT BE LIABLE TO YOU FOR ACTUAL, DIRECT, INDIRECT, CONSEQUENTIAL, PUNITIVE OR INCIDENTAL DAMAGES EVEN IF YOU GIVE NOTICE OF THE POSSIBILITY OF SUCH DAMAGE.

1.F.3. LIMITED RIGHT OF REPLACEMENT OR REFUND - If you discover a defect in this electronic work within 90 days of receiving it, you can receive a refund of the money (if any) you paid for it by sending a written explanation to the person you received the work from. If you received the work on a physical medium, you must return the medium with your written explanation. The person or entity that provided you with the defective work may elect to provide a replacement copy in

lieu of a refund. If you received the work electronically, the person or entity providing it to you may choose to give you a second opportunity to receive the work electronically in lieu of a refund. If the second copy is also defective, you may demand a refund in writing without further opportunities to fix the problem.

1.F.4. Except for the limited right of replacement or refund set forth in paragraph 1.F.3, this work is provided to you 'AS-IS', WITH NO OTHER WARRANTIES OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY OR FITNESS FOR ANY PURPOSE.

1.F.5. Some states do not allow disclaimers of certain implied warranties or the exclusion or limitation of certain types of damages. If any disclaimer or limitation set forth in this agreement violates the law of the state applicable to this agreement, the agreement shall be interpreted to make the maximum disclaimer or limitation permitted by the applicable state law. The invalidity or unenforceability of any provision of this agreement shall not void the remaining provisions.

1.F.6. INDEMNITY - You agree to indemnify and hold the Foundation, the trademark owner, any agent or employee of the Foundation, anyone providing copies of Project Gutenberg-tm electronic works in accordance with this agreement, and any volunteers associated with the production, promotion and distribution of Project Gutenberg-tm electronic works, harmless from all liability, costs and expenses, including legal fees, that arise directly or indirectly from any of the following which you do or cause to occur: (a) distribution of this or any Project Gutenberg-tm work, (b) alteration, modification, or additions or deletions to any Project Gutenberg-tm work, and (c) any Defect you cause.

Section 2. Information about the Mission of Project Gutenberg-tm

Project Gutenberg-tm is synonymous with the free distribution of electronic works in formats readable by the widest variety of computers including obsolete, old, middle-aged and new computers. It exists because of the efforts of hundreds of volunteers and donations from people in all walks of life.

Volunteers and financial support to provide volunteers with the assistance they need are critical to reaching Project Gutenberg-tm's goals and ensuring that the Project Gutenberg-tm collection will remain freely available for generations to come. In 2001, the Project Gutenberg Literary Archive Foundation was created to provide a secure and permanent future for Project Gutenberg-tm and future generations. To learn more about the Project Gutenberg Literary Archive Foundation and how your efforts and donations can help, see Sections 3 and 4 and the Foundation information page at www.gutenberg.org Section 3. Information about the Project Gutenberg Literary Archive Foundation

The Project Gutenberg Literary Archive Foundation is a non profit 501(c)(3) educational corporation organized under the laws of the state of Mississippi and granted tax exempt status by the Internal Revenue Service. The Foundation's EIN or federal tax identification number is 64-6221541. Contributions to the Project Gutenberg Literary Archive Foundation are tax deductible to the full extent permitted by U.S. federal laws and your state's laws.

The Foundation's principal office is in Fairbanks, Alaska, with the mailing address: PO Box 750175, Fairbanks, AK 99775, but its volunteers and employees are scattered throughout numerous locations. Its business office is located at 809 North 1500 West, Salt Lake City, UT 84116, (801) 596-1887. Email contact links and up to date contact information can be found at the Foundation's web site and official page at www.gutenberg.org/contact

For additional contact information:

    Dr. Gregory B. Newby
    Chief Executive and Director
    gbnewby@pglaf.org

Section 4. Information about Donations to the Project Gutenberg

Literary Archive Foundation

Project Gutenberg-tm depends upon and cannot survive without wide spread public support and donations to carry out its mission of increasing the number of public domain and licensed works that can be freely distributed in machine readable form accessible by the widest array of equipment including outdated equipment. Many small donations ($1 to $5,000) are particularly important to maintaining tax exempt status with the IRS.

The Foundation is committed to complying with the laws regulating charities and charitable donations in all 50 states of the United States. Compliance requirements are not uniform and it takes a considerable effort, much paperwork and many fees to meet and keep up with these requirements. We do not solicit donations in locations where we have not received written confirmation of compliance. To SEND DONATIONS or determine the status of compliance for any particular state visit www.gutenberg.org/donate

While we cannot and do not solicit contributions from states where we have not met the solicitation requirements, we know of no prohibition against accepting unsolicited donations from donors in such states who approach us with offers to donate.

International donations are gratefully accepted, but we cannot make any statements concerning tax treatment of donations received from outside the United States. U.S. laws alone swamp our small staff.

Please check the Project Gutenberg Web pages for current donation methods and addresses. Donations are accepted in a number of other ways including checks, online payments and credit card donations. To donate, please visit: www.gutenberg.org/donate

Section 5. General Information About Project Gutenberg-tm electronic works.

Professor Michael S. Hart was the originator of the Project Gutenberg-tm concept of a library of electronic works that could be freely shared with anyone. For forty years, he produced and distributed Project Gutenberg-tm eBooks with only a loose network of volunteer support.

Project Gutenberg-tm eBooks are often created from several printed editions, all of which are confirmed as not protected by copyright in the U.S. unless a copyright notice is included. Thus, we do not necessarily keep eBooks in compliance with any particular paper edition.

Most people start at our Web site which has the main PG search facility: www.gutenberg.org

This Web site includes information about Project Gutenberg-tm, including how to make donations to the Project Gutenberg Literary Archive Foundation, how to help produce our new eBooks, and how to subscribe to our email newsletter to hear about new eBooks.