invented the mood we call *imperative;* which has no firft perfon in the fingular, becaufe a man, properly fpeaking, cannot command himfelf; in fome languages it has no third perfon, becaufe, in ftrictnefs, a man cannot command any perfon, but him to whom he fpeaks and addreffes himfelf. And becaufe the command or prayer always relates to what is to come, it happens that the imperative mood, and the future tenfe, are frequently ufed for each other (efpecially in the Hebrew): as, *non occides, thou fhalt not kill,* for *do not kill.* Hence fome grammarians place the imperative among the number of futures.

Of all the moods we have mentioned, the oriental languages have none but the laft, which is the imperative; and, on the contrary, none of the modern languages have any particular inflexion for the imperative. The method we take for it in Englifh, is either to omit the pronoun, or tranfpofe it: thus, I love, is a fimple affirmation; love, an imperative; we love, an affirmation; love we, an imperative. An infinitive verb is fometimes ufed by the poets to exprefs a command; the imperative verb being underftood.

In explaining the origin of moods, the ingenious Mr. Harris obferves, that the foul's leading powers are thofe of perception and volition; and that all fpeech or difcourfe is a publifhing either a certain perception or volition. Hence then, according as we exhibit it either in a different part, or after a different manner, the variety of moods. If we fimply declare or indicate fomething to be, or not to be, whether a perception or volition, this conftitutes the *declarative* or *indicative* mood. If we affert of fomething poffible only, and in the number of contingents, this makes the *potential* mood. When this is fubjoined to the indicative, and ufed, as it moftly is, to denote the end or final caufe, it is the *fubjunctive.* When we addrefs others, in order to have fome perception informed, or fome volition gratified, we form new modes of fpeaking: if we interrogate, it is the *interrogative* mood: if we require, it is the *requifitive,* which, with refpect to inferiors, is *imperative;* and, with refpect to equals and fuperiors, *precative* or *optative.* The indicative, potential, interrogative, and requifitive moods, have their foundation in nature; and, therefore, certain marks or figns of them have been introduced into language, that we may be enabled by our difcourfe to fignify them to one another; fo that moods are, in fact, no more than fo many literal forms, intended to exprefs thefe natural diftinctions. All thefe moods, with their refpective tenfes, the verb being confidered as denoting an attribute, have always reference to fome perfon or fubftance. But there is another mood or form, under which verbs fometimes appear, where they have no reference at all to perfons or fubftances: thefe, from their indefinite nature, are called *infinitives.* Hermes, p. 140, &c.

Mood, or *Mode,* in our old *Mufic,* was a term only applied to the divifions of time or meafure, which was fo embarraffing a ftudy, that a very confiderable portion of Morley's treatife is beftowed on that fubject. Previous to the ufe of bars, all meafures, however complicated, were determined by the modal figns placed after the clef of every compofition. Thefe figns were circles, femicircles, pointed, or without points, followed by the figures 2 or 3 differently combined. See Mode, Modal, and Prolation.

Rouffeau gives twelve examples of ancient characters of quantity; but as thefe were characters referred to notes now out of ufe, as the *maxima,* the *long,* and the *breve,* thefe explanations can be of little confequence but to thofe who are ambitious of knowing the ftate of meafured mufic at every period of its cultivation.

Mood, in *Philofophy* and *Mufic.* See Mode.

MOODUL, in *Geography,* a town of Hindooftan, in Vifiapour; 13 miles S.S.W. of Galgala.

MOODYPOUR, a town of Hindooftan, in Bengal; 28 miles N. of Pucculoe.

MOOGONG, a town of Hindooftan, in Goondwanah; 50 miles N. of Nagpour.

MOOGPOUR, a town of Hindooftan, in Guzerat; 31 miles E.N.E. of Janagur.

MOOGRY, a town of Hindooftan, in Vifiapour; 31 miles W. of Poonah.

MOOKANOOR, a town of Hindooftan, in Baramaul; 18 miles S.S.W. of Darempoory.

MOOKER, a town of Cabuliftan; 40 miles from Ghizni. —Alfo, a town of Hindooftan, in Madura; 40 miles E. of Coilpetta.

MOOKI, a fea-port town of Japan, in a bay on the S.E. coaft of the ifland of Niphon; 80 miles S.E. of Jedo. N. lat. 35° 30′. E. long. 40° 40′.

MOOLA, a town of Hindooftan, in Vifiapour; 10 miles E. of Poonah.

MOOLILLY, a town of Hindooftan, in Myfore; 20 miles W.N.W. of Allumbaddy.

MOON, Luna, ☾, in *Aftronomy,* one of the heavenly bodies belonging to that clafs of planets, accounted fatellites or fecondary planets.

The moon is an attendant of our earth, which fhe refpects as a centre, and in whofe neighbourhood fhe is conftantly found; infomuch as, if viewed from the fun, fhe would never appear to depart from us by an angle greater than ten minutes.

As all the other planets move primarily round the fun, fo does the moon round the earth: her orbit is an ellipfis, in which fhe is retained by the force of gravity; performing her revolution round the earth, from change to change, in 29 days, 12 hours, 44 minutes, and round the fun with it every year; fhe goes round her orbit in 27 days, 7 hours, 43 minutes, 5 feconds, moving about 2290 miles every hour; and turns round her axis in the time that fhe goes round the earth, which is the reafon of her keeping always the fame fide towards us; and that her day and night taken together are as long as our lunar month. See Libration *of the Moon.*

The mean diftance of the moon from the earth is $60\frac{1}{2}$ femi-diameters of the earth; which is equivalent to 240,000 miles.

The diameter of the earth is to that of the moon as 11 : 3, or as 1 : 0.2727 (fee Parallax); therefore, the magnitude of the earth is to that of the moon as 1 : .02028, or very nearly as 49 : 1; and the denfity of the moon being to that of the fun as 2.44 : 1, and the denfity of the fun being to that of the earth as 0.252 : 1, it follows that the denfity of the earth is to that of the moon as 1 : 0.6149; therefore, the quantity of matter in the earth is to that of the moon as 1 : 0.1245. But if, with fome authors, we affume the denfity of the moon to that of the fun as 2.5 : 1, the quantity of matter in the earth is to that in the moon as 78 : 1, or 1 : .0128. Alfo, the gravity of a body upon the earth is to that upon the moon as 1 : 0.1677. The apparent diameter of the moon, as feen from the earth, varies, according to M. de la Lande, from 29′ 22″ when the moon is in apogee and conjunction, to 33′ 31″ when in perigee and oppofition: its mean diameter being nearly equal to the leaft apparent diameter of the fun, it may be taken at 31′ 8″, and that of the fun at 32′ 2″. M. de la Lande makes it to be 31′ 26″. (See Declination and Diameter.) Its mean diameter, as feen from the fun, is 4″.6. The mean diameter, in Englifh miles, is 2180. The mean diameter, as above ſtated from M. de la Lande, is the arithmetic mean between the greateſt and leaſt diameters: the diameter at the mean diſtance is $31'\ 7''$. When the moon is at different altitudes above the horizon, it is at different diſtances from the ſpectator, and, therefore, there is a change of the apparent diameter; which is inverſely as the moon's diſtance. The diameter of the moon may be meaſured, at the time of its full, by a micrometer; or it may be meaſured by the time of its paſſing over the vertical wire of a tranſit teleſcope, which muſt be done when the moon paſſes within an hour or two of the time of the full, before the viſible diſc is ſenſibly changed from a circle. The moon's ſurface contains 14,898,750 ſquare miles, and its ſolidity 5,408,246,000 cubical miles. The mean excentricity of the moon's orbit is 0.05503568 of her mean diſtance, which is equal to about 13,200 miles; and this makes a conſiderable variation in that mean diſtance. This excentricity, however, is ſubject to a variation, the greateſt variation from the mean being 0.00986; the excentricity being increaſed whilſt the apſides move from quadratures to ſyzygies, and decreaſed whilſt they move from ſyzygies to quadratures. (See the annexed table.) The correſponding greateſt equation is $6°\ 18'\ 31''.6$, which Mayer makes to be $6°\ 18'\ 32''$ in his laſt Tables, publiſhed by Mr. Maſon, under the direction of Dr. Maſkelyne. The inclination of the moon's orbit is alſo ſubject to a variation. When the moon is in ſyzygies, the variation ($= 2'\ 40''.7$) is the diminution of the inclination in the tranſit of the moon from the nodes (in quadratures) to ſyzygies; the half of which ($1'\ 20''$) is the variation from the mean inclination in that time. Hence, in the tranſit of the nodes from ſyzygies to quadratures, when the moon is in quadratures, the variation of the inclination has been $16'\ 10'' - 1'\ 20'' = 14'\ 50''$, and when the moon is in ſyzygies, the variation has been $16'\ 10'' + 1'\ 20'' = 17'\ 30''$; therefore, if the inclination be $5°\ 17'\ 20''$, when the nodes are in ſyzygies, the leaſt inclination becomes $4°\ 59'\ 50''$, and the mean $= 5°\ 8'\ 35''$.

In order to determine the inclination of the moon's orbit to the plane of the ecliptic, obſerve the moon's right aſcenſion and declination when it is 90° from its nodes, and thence compute its latitude; which will be the inclination at that time. Repeat this obſervation for every diſtance of the ſun from the earth, and for every poſition of the ſun in reſpect to the moon's nodes, and the inclination at thoſe times will be thus found. Hence it will appear, that the inclination of the orbit to the ecliptic is variable, as we have already ſtated, the leaſt inclination occurring when the nodes are in quadratures, and the greateſt when they are in ſyzygies. This inclination partly depends upon the ſun's diſtance from the earth. As the axis of the moon is nearly perpendicular to the plane of the ecliptic, this planet has ſcarcely any difference of ſeaſons. The place of the moon's nodes may be determined in the manner ſtated under *Nodes*; which ſee. To determine the mean motion of the nodes, find the place of the nodes at different times, and thus will be obtained their motion in the interval; and the greater this interval, the more accurate will be the reſult.

The mean motion of the moon is found by obſerving its place at two different times, and thus we obtain the mean motion in that interval, ſuppoſing that the moon has had the ſame ſituation in reſpect to its apſides at each obſervation; if not, provided there be a great interval of the time, it will be ſufficiently exact. For determining this, we muſt compare together the moon's places, firſt at a ſmall interval of time from each other, in order to get nearly the mean time of a revolution; and then at a greater interval, in order to obtain it more exactly. The moon's place may be determined directly from obſervation, or deduced from an eclipſe. The mean time of a revolution of the moon was found from eclipſes at a diſtant interval to be $27^d\ 7^h\ 43'\ 5''$, which may be conſidered as very exact. Hence, the mean *diurnal* motion is $13°\ 10'\ 35''$, and the mean *hourly* motion $32'\ 56''\ 27'''\frac{1}{2}$. M. de la Lande makes the mean *diurnal* motion $13°\ 10'\ 35''.02784394$. This is the mean time of a revolution in reſpect to the equinoxes. But, as the preceſſion of the equinoxes is $50''.25$ in a year, or about $4''$ in a month, the mean revolution of the moon in reſpect to the fixed ſtars muſt be greater than that in reſpect to the equinox, by the time which the moon takes to deſcribe $4''$ with its mean motion, *i. e.* about $7''$. Hence the time of a ſidereal revolution of the moon is $27^d\ 7^h\ 43'\ 12''$.

The mean *horary* motion of the nodes of the moon's orbit in one ſynodic revolution is equal to half their horary motion when the moon is in ſyzygies, whatever be the poſition of the nodes. When the nodes are in quadratures and the moon is in ſyzygies, their horary motion is $32'\ 42''\ 7'''$; hence the mean horary motion of the nodes when in quadratures is $16'\ 21''\ 3\frac{1}{2}'''$, in an elliptic orbit, and in a circular orbit $16''\ 35'''\ 16''''\ 36'''''$. The mean *annual* regreſſion of the nodes is $19°\ 23'$. Allowing for the inclination of the orbit, this motion will be about $4'$ leſs; and we may, therefore, ſuppoſe the mean annual motion to be $19°\ 19'$. Mayer makes the mean annual motion of the nodes to be $12°\ 19'\ 43''.1$. The motion of the nodes is not affected by the excentricity of the orbit, as ſir Iſaac Newton ſuppoſed.

The motion of the apogee in one mean periodic revolution of the moon is $3°\ 2'\ 32''.3916$; hence, $27^d\ 7^h\ 43'$: $365^d\ 6^h\ 9'$ :: $3°\ 2'\ 32''.3916$: $40°\ 40'\ 20''$ the mean progreſſive motion of the apogee in a year. According to Mayer's Tables, it is $40\ 41'\ 33''$.

To determine the mean motion of the apogee, find its place at different times, and compare the difference of the places with the interval of the time that had elapſed between them. For this purpoſe, compare, firſt, obſervations at a ſmall diſtance from each other, in order to prevent being deceived in a whole revolution, and then we may compare thoſe at a greater diſtance. The mean annual motion of the apogee in a year of 365 days, is thus found to be $40°\ 39'\ 50''$, according to Mayer. Horrox, long ago, from obſerving the diameter of the moon, found the apogee ſubject to an annual equation of $12°.5$. The following table ſhews the times of the revolutions of the moon, of its apogee and nodes, as determined by M. de la Lande.

Tropical revolution - -		27^d	7^h	$43'$	$4''.6795$
Sidereal revolution - -		27	7	43	11.5259
Synodic revolution - -		29	12	44	2.8283
Anomaliſtic revolution -		27	13	18	33.9499
Revolution in reſpect to the node - - -		27	5	5	35.603
Tropical revolution of the apogee - - -	8^y	311	8	34	57.6177
Sidereal revolution of the apogee - - -	8	312	11	11	39.4089
Tropical revolution of the node - - -	18	228	4	52	52.0296
Sidereal revolution of the node - - -	18	223	7	13	17.744
Diurnal motion of the moon in reſpect to the equinox		-	13°	10'	$35.''02784394$
Diurnal motion of the apogee - -		-	0	6	41.069815195
Diurnal motion of the node		-	0	3	10.638603696

The years here taken are the common years of 365 days.

A Table

A TABLE of the great Equation of the Moon's Apogee, and of the Excentricity of its Orbit.

	Sig. O. VI. +		Sig. I. VII. +		Sig. II. VIII. +		
Ann. Arg.	Equation of ☽'s Apogee.	Excentricity of the Moon's Orbit.	Equation of ☽'s Apogee.	Excentricity of the Moon's Orbit.	Equation of ☽'s Apogee.	Excentricity of the Moon's Orbit.	Ann. Arg.
Deg.	D. M. S.		D. M. S.		D. M. S.		Deg.
0	0 0 0	.066777	9 27 57	.061754	11 40 0	.050224	30
1	0 21 4	.066771	9 42 12	.061434	11 30 39	.049838	29
2	0 42 8	.066754	9 55 58	.061107	11 20 14	.049457	28
3	1 3 10	.066724	10 9 14	.060772	11 8 44	.049082	27
4	1 24 9	.066683	10 21 58	.060429	10 56 8	.048714	26
5	1 45 5	.066630	10 34 9	.060080	10 42 26	.048354	25
6	2 5 57	.066566	10 45 47	.059725	10 27 38	.048001	24
7	2 26 44	.066489	10 56 49	.059363	10 11 45	.047656	23
8	2 47 25	.066402	11 7 15	.058995	9 54 47	.047321	22
9	3 8 0	.066302	11 17 4	.058621	9 36 44	.046995	21
10	3 28 27	.066192	11 26 14	.058243	9 17 37	.046679	20
11	3 48 46	.066070	11 34 43	.057860	8 57 25	.046374	19
12	4 8 55	.065936	11 42 31	.057472	8 36 11	.046081	18
13	4 28 54	.065792	11 49 36	.057080	8 13 56	.045800	17
14	4 48 42	.065636	11 55 57	.056684	7 50 42	.045531	16
15	5 8 19	.065469	12 1 33	.056285	7 26 29	.045275	15
16	5 27 43	.065292	12 6 22	.055884	7 1 21	.045033	14
17	5 46 53	.065103	12 10 23	.055479	6 35 19	.044805	13
18	6 5 48	.064905	12 13 35	.055073	6 8 26	.044592	12
19	6 24 27	.064695	12 15 56	.054666	5 40 45	.044394	11
20	6 42 50	.064476	12 17 24	.054257	5 12 18	.044212	10
21	7 0 56	.064246	12 17 59	.053848	4 43 10	.044046	9
22	7 18 44	.064006	12 17 40	.053438	4 13 23	.043896	8
23	7 36 12	.063757	12 16 25	.053030	3 43 1	.043763	7
24	7 53 20	.063498	12 14 13	.052622	3 12 9	.043647	6
25	8 10 6	.063230	12 11 2	.052215	2 40 49	.043548	5
26	8 26 29	.062952	12 6 52	.051811	2 9 7	.043467	4
27	8 42 29	.062665	12 1 42	.051409	1 37 6	.043404	3
28	8 58 5	.062370	11 55 31	.051010	1 4 52	.043359	2
29	9 13 15	.062066	11 48 17	.050615	0 32 28	.043332	1
30	9 27 57	.061754	11 40 0	.050224	0 0 0	.043323	0
	Sig. V. XI. −		Sig. IV. X. −		Sig. III. IX. −		

N B. The preceding table is taken from Dr. Halley's " Aftronomical Tables ;" the argument, called the " annual argument," is the diftance of the fun from the mean place of the apogee corrected by its annual equation.

The full moon appears to the naked eye broader than a circular object subtending an equal angle seen by perfect vision. In a moon of three or four days old, the illuminated part appears too broad, in proportion to the obscure part, and likewise seems to extend more outwards, or to have a greater diameter than the obscure part. Also, in an eclipse of the sun or moon, the bright part appears too broad in proportion to the dark part, and the eclipse appears less than it really is.

This observation was made by Horrox, and is accounted for by Dr. Jurin, in his Essay upon distinct and indistinct Vision. Appendix to Smith's Optics. See *Phases of the* Moon.

Moon, *Phenomena of the.* The different appearances of the moon are very numerous; sometimes she is increasing, then waning; sometimes horned, then semicircular; sometimes gibbous, then full and round.

Sometimes, again, she illumines us the whole night; sometimes only a part of it; sometimes she is found in the southern hemisphere, sometimes in the northern; all which variations having been first observed by Endymion, an ancient Grecian, who watched her motions, she was fabled to have fallen in love with him.

The source of most of these appearances is, that the moon is a dark, opaque, and spherical body, and only shines with the light she receives from the sun; whence only that half turned towards him, at any instant, can be illuminated, the opposite half remaining in its native darkness. The face of the moon visible on our earth, is that part of her body turned towards the earth; whence according to the various positions of the moon with regard to the sun and earth, we observe different degrees of illumination; sometimes a large, and sometimes a less portion of the enlightened surface being visible.

If we look at the moon with an ordinary telescope, we shall perceive that her surface is diversified with long tracts of mountains and cavities; 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. The moon's surface being so uneven, many have been surprised that her edge should not appear 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 its roughness be very discernible on the side next the eye, especially if the sun or a candle shines obliquely on that side, yet the line terminating the visible part still appears smooth and even. If the moon have no atmosphere, the lunar inhabitants must have an immediate transition from the brightest sunshine to the blackest darkness; and thus must be totally destitute of the benefit of twilight. See the sequel of this article.

Moon, *Phases of the.* To conceive the lunar phases, let S (*Plate* XVII. *Astronomy, fig.* 5.) represent the sun, T the earth, R T S a portion of the earth's orbit, and A B C D E F G the orbit of the moon, in which she revolves round the earth in the space of a month, advancing from west to east: connect the centres of the sun and moon by the right line S L, and through the centre of the moon imagine a plane M L N to pass perpendicular to the line S L; the section of that plane, with the surface of the moon, will give the line that bounds light and darkness, and separates the illumined face from the dark one.

Connect the centres of the earth and moon by T L, perpendicular to a plane P L O, passing through the centre of the moon: that plane will give on the surface of the moon the circle that distinguishes the visible hemisphere, or that towards us, from the invisible one, and therefore called *the circle of vision.* Whence it appears, that whenever the moon is in A, the circle bounding light and darkness, and the circle of vision coincide; so that all the illuminated face of the moon will be turned towards the earth: in which case the moon is, with respect to us, full, and shines the whole night: with respect to the sun, she is in opposition; because the sun and moon are then seen in opposite parts of the heavens, the one rising when the other sets. But it is to be observed, that the moon's disc is not perfectly round when she is full, in the highest or lowest part of her orbit, because we have not a full view of her enlightened side at the 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.

When the moon arrives at B, the whole illuminated disc M P N is not turned towards the earth; so that the visible illumination will be short of a circle; and the moon will appear gibbous, as in B.

When she reaches C, where the angle C T S is nearly right, there only one-half of the illumined disc is turned towards the earth, and then we observe a half moon, as in C; and she is said to be *dichotomized,* or *bisected.*

In this situation, the sun and moon are a fourth part of a circle removed from each other; and the moon is said to be in a *quadrate aspect,* or to be in her *quadrature.*

The moon arriving at D, only a small part of the illumined face M P N is turned towards the earth: for which reason the small part that shines upon us will be seen falcated, or bent into narrow angles, or horns, as in D.

The inclination of that part of the ecliptic to the horizon, in which the moon is at any time when horned, may be known by the position of her horns; for a right line touching their points is perpendicular to the ecliptic. And as the angle, which the moon's orbit makes with the ecliptic, can never raise her above, nor depress her below the ecliptic, more than two minutes of a degree, as seen from the sun; it can have no sensible effect upon the position of her horns. Therefore, if a quadrant be held up, so that one of its edges may be seen 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 the edge of the quadrant, which seems to touch the moon's horns, will shew the inclination of that part of the ecliptic to the horizon. And the arc, between the other edge of the quadrant and the plumb-line, will shew the inclination of a line touching the moon's horns to the horizon.

At last, the moon arriving at E, shews no part of her illumined face at all to the earth, as in E; this position we call the *new* moon, and she is then said to be in conjunction with the sun; the sun and moon being in the same point of the ecliptic.

As the moon advances towards F, she resumes her horns: and as before the new moon the horns were turned westward, so now they change their position, and look eastward: when she comes to G, she is again in a quadrate aspect with the sun; in H she is gibbous; and in A she is again full.

Here

Here the arc E L, or the angle S T L, contained under lines drawn from the centres of the ſun and moon to that of the earth, is called *the elongation of the moon* from the ſun: and the arc M O, which is the portion of the illumined circle M O N, that is turned towards us, and which is the meaſure of the angle that the circle bounding light and darkneſs, and the circle of viſion, make with each other, is every where nearly ſimilar to the arc of elongation E L; or, which is the ſame thing, the angle S T L is nearly equal to the angle M L O: as is demonſtrated by geometers.

To delineate the Moon's Phaſes for any Time.—Let the circle C O B P (*fig.* 6.) repreſent the moon's diſc turned towards the earth, and let O P be the line in which the ſemicircle O C P is projected, which ſuppoſe cut at right angles by the diameter B C; then making L P the radius, take L F equal to the co-ſine of the elongation of the moon; and upon B C, as the greater axis, and L F the leſs, deſcribe the ſemi-ellipſis B F C; this ellipſis will cut off from the moon's diſc the portion B F C P, of the illumined face viſible on the earth. In other words, the viſible illumined part varies as F P, the verſed ſine of elongation; and we ſhall have the viſible illumined part to the whole, as the verſed ſine of elongation is to the diameter.

As the moon illumines the earth by a light reflected from the ſun, ſo ſhe is reciprocally illumined by the earth, which reflects the ſun's rays to the ſurface of the moon, and that much more abundantly than ſhe receives them from the moon. For the ſurface of the earth is above thirteen times greater than that of the moon; and, therefore, ſuppoſing the texture of each body alike as to the power of reflecting, the earth muſt return thirteen times more light to the moon than ſhe receives from it. In new moons, the illumined ſide of the earth is turned fully towards the moon, and will, therefore, at that time, illumine the dark ſide of the moon; and then the lunar inhabitants (if ſuch there be) will have a full earth, as we, in a ſimilar poſition, have a full moon: and hence ariſes that dim light obſerved in the old and new moons; by which, beſides the bright horns, we perceive ſomewhat more of her body behind them, though very obſcurely.

It is well known, that when the moon is about three or four days old, the part of her diſc which is not enlightened by the ſun appears to an obſerver, in ſerene weather, to be faintly illuminated by light reflected from the earth; and the horns of the enlightened part ſeem to project beyond the old moon, as if they were part of a ſphere conſiderably larger in diameter than the unenlightened part. This phenomenon is vulgarly called "the old moon in the new moon's arms." For the explication of this phenomenon, Dr. Jurin, in his "Eſſay on diſtinct and indiſtinct Viſion," (Smith's Optics, vol. ii. Rem. p. 113.), ſuppoſes, that the eye cannot accommodate itſelf, with ſufficient diſtinctneſs, to view objects at ſuch a diſtance as the moon. Hence it happens, that the pencils of rays unite before they reach the retina, and form an indiſtinct and enlarged image of the moon. Nothing can be more demonſtrable than this principle; and it may be evinced by the ſimple experiment of looking at the figure of the moon cut out of white paper, and placed upon a dark ground; for when this luminous body is covered, either at a diſtance too remote, or too near, for perfect viſion, its image upon the retina will be enlarged, and the illuminated part will encroach upon that which is obſcure, and appear to embrace it, in the ſame manner as it is ſeen in the heavens.

That the illuminated portion of the moon's diſc, when ſhe is three or four days old, receives its light from the earth, which will then appear to the lunar inhabitants, like a full moon, is univerſally allowed; and as the age of the moon increaſes, this ſecondary light is gradually enfeebled, partly on account of the diminution of the luminous part of the earth, and partly by the increaſe of the enlightened part of the moon. This ſecondary light, which in favourable circumſtances has been obſerved, even when the moon was nine days and fourteen hours old, has been aſcribed by Riccioli, and more lately by profeſſor Leſlie (Inquiry into the Nature and Propagation of Heat), to the ſuppoſed phoſphorency of the moon. Upon this hypotheſis Leſlie explains the thread of light, or lucid bow, that ſeems to connect the two horns of the moon. After emerging from conjunction with the ſun, ſays this ingenious philoſopher, her ſharp horns are ſeen, connected by a ſilver thread, or lucid bow, which completes the circle; and a faint light ſeems to be ſuffuſed over the included ſpace. This bright arc, however, becomes always leſs vivid; aud before the moon is five or ſix days old, it has almoſt totally vaniſhed. The pale outline of the old moon is commonly aſcribed to the reflection, or ſecondary illumination upon the earth. But if it were derived from that ſource, it would appear denſeſt near the centre, and gradually more dilute towards the edge. "I ſhould rather refer it," ſays our author, "to the ſpontaneous light which the moon may continue to emit for ſome time after the phoſphoreſcent ſubſtance has been excited by the action of the ſolar beams. The lunar diſc is viſible, although completely covered by the ſhadow of the earth; nor can this fact be explained by the inflection of the ſun's rays in paſſing through our atmoſphere; for why does the rim appear ſo brilliant? Any ſuch inflection could only produce a diffuſe light, obſcurely tinging the boundaries of the lunar orb; and in this caſe the earth, preſenting its dark ſide to the moon, would have no power to heighten the effect by reflection. But even when this reflection is greateſt about the time of conjunction, its influence ſeems extremely feeble. The lucid bounding arc is occaſioned by the narrow ***lunula***, which, having recently felt the ſolar impreſſion, ſtill continues to ſhine, and, from its extreme obliquity, glows with concentrated effect." Dr. Brewſter, diſſatisfied with the profeſſor's explanation of the phenomenon above ſtated, propoſes another, which, in his opinion, is ſo ſimple and convincing, as to claim an implicit reception. By looking at any map of the moon, which exhibits even a tolerable repreſentation of the lunar ſurface, we ſhall find that the eaſtern limb of the moon is ſeparated from the central parts of her diſc by darker regions, and that the luminous portion, comprehended between theſe darker regions and the circular line which bounds her eaſtern limb, has actually the form of a bow, which is broadeſt towards her ſouthern limb, and gradually diminiſhes in breadth towards her northern horn. The immediate cauſe, therefore, of the lucid bow is to be ſought for in the accidental circumſtance of the moon's eaſtern limb being more luminous than the adjacent regions towards the centre. The central parts of the moon, indeed, are equally luminous with her eaſtern limb; but their brilliancy is impaired by their proximity to the illuminated portion. It is obvious, that this explanation of the phenomenon may be equally juſt, whether the ſecondary light of the moon is cauſed by phoſphorence or by reflection from the earth. Brewſter's edition of Ferguſon's Aſtronomy, vol. ii. But to return from this digreſſion to the farther progreſs of the moon in her orbit.

When the moon comes to be in oppoſition to the ſun, the earth, ſeen from the moon, will appear in conjunction with him, and its dark ſide will be turned towards the moon; in which poſition the earth will diſappear to the moon as that does to us at the time of the new moon, or in her conjunction with the ſun. After this, the lunar inhabitants will ſee the earth in an horned figure. In fine, the earth will preſent all the ſame phaſes to the moon, as the moon does to the earth. But from one-half of the moon, the earth is never ſeen at all; from the middle of the other half it is always ſeen over head, turning round almoſt thirty times as quick as the moon does. From the circle which limits our view of the moon, only one-half of the earth's ſide next her is ſeen; the other half being hid below the horizon of all places on that circle. To her the earth ſeems to be the biggeſt body in the univerſe; for it appears thirteen times as big as ſhe does to us. As the earth turns round its axis, the ſeveral continents, ſeas, and iſlands appear to the moon's inhabitants like ſo many ſpots of different forms and brightneſs, moving over its ſurface; but much fainter at ſome times than others, as our clouds cover 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.

Dr. Hooke, accounting for the reaſon why the moon's light affords no viſible heat, obſerves that the quantity of light, which falls on the hemiſphere of the full moon, is rarefied into a ſphere 288 times greater in diameter than the moon, before it arrives at us; and, conſequently, that the moon's light is 104,368 times weaker than that of the ſun. It would, therefore, require 104,368 full moons to give a light and heat equal to that of the ſun at noon. The light of the moon, condenſed by the beſt mirrors, produces no ſenſible heat upon the thermometer.

Dr. Smith has endeavoured to ſhew, in his book on Optics, that the light of the full moon is but equal to a 90900dth part of the common light of the day, when the ſun is hidden by a cloud. For other obſervations on this ſubject, ſee LIGHT.

MOON, *Courſe and Motion of the.* Though the moon finiſhes its courſe in $27^d\ 7^h\ 43'\ 5''$, which interval we call a *periodical* month, yet ſhe is longer in paſſing from one conjunction to another; which ſpace we call a *ſynodical* month, or a *lunation*. The reaſon is, that while the moon is performing its courſe round the earth in its own orbit, the earth and moon are making their progreſs round the ſun; and both are advanced almoſt a whole ſign towards the eaſt; ſo that the point of the orbit, which in the former poſition was in a right line paſſing through the centres of the earth and ſun, is now more weſterly than the ſun; and, therefore, when the moon is arrived again at that point, it will not yet be ſeen in conjunction with the ſun; nor will the lunation be completed in leſs than 29 days and a half, or $29^d\ 12^h\ 44'\ 2''.\ 8$.

The moon's periodical and ſynodical revolution may be familiarly repreſented by the motions of the hour and minute hands of a watch round its dial-plate, which is divided into 12 equal parts or hours, as the ecliptic is divided into 12 ſigns, and the year into 12 months.

Let us ſuppoſe theſe 12 hours to be 12 ſigns, the hour-hand the ſun, and the minute-hand the moon; then the former will go round once in a year, and the latter once in a month; but the moon, or minute-hand, muſt go more than round from any point of the circle where it was laſt conjoined with 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 each conjunction. Thus, ſuppoſe the two hands to be in conjunction at XII, as they always are; then, at the firſt following conjunction it is 5 minutes 27 ſeconds 16 thirds 21 fourths $49\frac{1}{11}$ fifths paſt I, where they meet; at the ſecond conjunction it is 10 minutes 54 ſeconds 32 thirds 43 fourths $38\frac{2}{11}$ fifths paſt II; and ſo on. This, though an eaſy illuſtration of the motions of the ſun and moon, is not preciſe as to the times of their conjunctions; becauſe, while the ſun goes round the ecliptic, the moon makes $12\frac{1}{3}$ conjunctions with him; but the minute-hand of a watch or clock makes only 11 conjunctions with the hour-hand in one period round the dial-plate. But if, inſtead of the common wheel-work at the back of the dial-plate, the axis of the minute-hand had a pinion of 6 leaves turning a wheel of 74, and this laſt turning the hour-hand, in every revolution it makes round the dial-plate, the minute-hand would make $12\frac{1}{3}$ conjunctions with it; and ſo would be a pretty device for ſhewing the motions of the ſun and moon; eſpecially as the floweſt moving hand might have a little ſun fixed on its point, and the quickeſt a little moon.

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

Were the plane of the moon's orbit coincident with the plane of the ecliptic, *i. e.* were the earth and moon both moved in the ſame plane, the moon's way in the heavens, viewed from the earth, would appear juſt the ſame with that of the ſun; with this only difference, that the ſun would be found to deſcribe his circle in the ſpace of a year, and the moon her's in a month. But this is not the caſe; for the orbits of the two planets cut each other in a right line, paſſing through the centre of the earth, and are inclined to each other in an angle of about five degrees eighteen minutes.

Suppoſe, *e. g.* A B (*fig.* 7.) a portion of the earth's orbit, T the earth, and C E D F the moon's orbit, in which is the centre of the earth; from the ſame centre T, in the plane of the ecliptic, deſcribe another circle C G D H, whoſe ſemi-diameter is equal to that of the moon's orbit. Now theſe two circles, being in ſeparate planes, and having the ſame centre, will interſect each other in a line D C, paſſing through the centre of the earth. Conſequently, C E D, one-half of the orbit of the moon, will be raiſed above the plane of the circle C G H, towards the north; and D F C, the other half, will be ſunk below towards the ſouth. The right line D C, in which the two circles interſect each other, is called *the line of the nodes*, and the points of the angles C and D, *the nodes*: of which that where the moon aſcends above the plane of the ecliptic, northwards, is called *the aſcending node*, and *the head of the dragon*; and the other D, *the deſcending node*, and *the dragon's tail*;

tail; and the interval of time between the moon's going from the afcending node, and returning to it, a *dracontic month.*

If the line of the nodes were immoveable, that is, if it had no other motion but that by which it is carried round the fun, it would ftill look towards the fame point of the ecliptic; *i. e.* it would always keep parallel to itfelf; but it is found by obfervation, that the line of the nodes conftantly changes place, and fhifts in fituation from eaft to weft, contrary to the order of the figns; and, by a retrograde motion, finifhes its circuit in about nineteen years; in which time each of the nodes returns to that point of the ecliptic whence it before receded.

Hence it follows, that the moon is never precifely in the ecliptic, but twice each period; *viz.* when fhe is in the nodes. Throughout the reft of her courfe fhe deviates from it, being nearer or farther from the ecliptic, as fhe is nearer or farther from the nodes. In the points F and E fhe is at her greateft diftance from the nodes; which points are therefore called her *limits of north and fouth latitude.*

The moon's diftance from the nodes, or rather from the ecliptic, is called her *latitude*, which is meafured by an arc of a circle drawn through the moon, perpendicular to the ecliptic, and intercepted between the moon and the ecliptic. The moon's latitude, when at the greateft, as in E or F, never exceeds 5 degrees and about 18 minutes; which latitude is the meafure of the angles at the nodes.

It appears by obfervation, that the moon's diftance from the earth is continually changing; and that fhe is always either drawing nearer, or going farther from us. The reafon is, that the moon does not move in a circular orbit, which has the earth for its centre; but in an elliptic orbit (as reprefented in *fig.* 8.), one of whofe foci is the centre of the earth: A P reprefents the greater axis of the ellipfis, and the line of the apfides; and T C the excentricity; the point A, which is the higheft apfis, is called the *apogee* of the moon; and P, the lower apfis, is the moon's *perigee*, or the point in which fhe comes neareft the earth.

Befides, there is reafon to believe, that the moon is fomewhat nearer the earth now than fhe was formerly; her periodical month being fhorter than it was in former ages. For our aftronomical tables, which in the prefent age fhew the time of folar and lunar eclipfes to great precifion, do not anfwer fo well for ancient eclipfes.

The fpace of time in which the moon, going from the apogee, returns to it again, is called the *anomaliftic month.*

If the moon's orbit had no other motion but that with which it is carried round the fun, it would ftill retain a pofition parallel to itfelf, and always point the fame way, and be obferved in the fame point of the ecliptic; but the line of the apfides is likewife obferved to be moveable, and to have an angular motion round the earth, from weft to eaft, according to the order of the figns, returning to the fame fituation in the fpace of about nine years.

The irregularities of the moon's motion, and that of her orbit, are very confiderable. For, 1. When the earth is in her aphelion, the moon is in her aphelion likewife; in which cafe fhe quickens her pace, and performs her circuit in a fhorter time: on the contrary, when the earth is in its perihelion, the moon is fo too, and then fhe flackens her motion: and thus fhe revolves round the earth, in a fhorter fpace, when the earth is in her aphelion than when in her perihelion; fo that the periodical months are not all equal.

2. When the moon is in her fyzygies, *i. e.* in the line that joins the centres of the earth and fun, which is either in her conjunction or oppofition, fhe moves fwifter, *ceteris paribus*, than when in the quadratures.

3. According to the different diftances of the moon from the fyzygies, *i. e.* from oppofition to conjunction, fhe changes her motion: in the firft quarter, that is, from the conjunction to her firft quadrature, fhe abates fomewhat of her velocity; which in the fecond quarter fhe recovers; in the third quarter fhe again lofes; and in the laft fhe again recovers. Hence the areas defcribed are accelerated and retarded; and the mean place differs from the true. This inequality was firft difcovered by Tycho Brahe, who called it *the moon's variation.* At different diftances of the earth from the fun, the difturbing forces vary, and, therefore, the equation, called the "variation," being firft calculated for the mean diftance of the earth from the fun, will be fubject to a variation from the variation of that diftance; and hence fome new equations will arife.

4. The moon moves in an ellipfis, one of whofe foci is in the centre of the earth, round which fhe defcribes areas proportionable to the times, as the primary planets do round the fun; whence the motion in her perigee muft be quickeft, and it muft be floweft in the apogee.

5. The very orbit of the moon is changeable, and does not always preferve the fame figure; its excentricity being fometimes increafed, and fometimes diminifhed: it is greateft, when the line of the apfides coincides with that of the fyzygies; and leaft, when the line of the apfides cuts the other at right angles.

The moon's orbit being dilated or contracted as the earth approaches to or recedes from the fun, its motion will accordingly be diminifhed or increafed; and hence arifes an annual equation, affigning the difference between the mean motion at the mean diftance of the earth from the fun, and the mean motion at any other diftance of the fun. The variation depending on the true diftance of the fun from the moon, will produce feveral other equations, arifing from the different corrections that are made. The change of the excentricity caufes a change of the *equation of the centre*, called the *evection*, and hence new equations muft be applied. See thefe terms refpectively and EXCENTRICITY.

6. Nor is the apogee of the moon without an irregularity; being found to move forward, when it coincides with the line of the fyzygies; and backward, when it cuts that line at right angles. Nor are this progrefs and regrefs in any meafure equal; in the conjunction or oppofition, it goes brifkly forward; and in the quadratures it moves either flowly forward, ftands ftill, or goes backwards. Upon the whole, however, the motion of the apogee is progreffive. Hence arifes an equation of the motion of the apogee, which depends upon its diftance from the fun; and there is alfo a fmaller annual equation, arifing from the difturbing forces being different at different times of the year.

7. The motion of the nodes is not uniform; but when the line of the nodes coincides with that of the fyzygies at right angles, they go backward, from eaft to weft; and this, fir Ifaac Newton fhews, is at the rate of $16'' \; 19''' \; 24''''$ in an hour. See the preceding part of this article, and NODES.

The only equable motion the moon has, is that with which fhe turns round her axis exactly in the fame fpace of time in which fhe revolves round us in her orbit; whence it happens, that fhe always turns the fame face towards us.

For as the moon's motion round its axis is equal, and yet its motion, or velocity, in its orbit, is unequal, it follows, that when the moon is in its perigee, where it moves fwifteft in its orbit, that part of its furface, which, on account of

its

its motion in the orbit, would be turned from the earth, is not ſo entirely; by reaſon of its motion round its axis. Thus ſome parts in the limb or margin of the moon, ſometimes recede from the centre of the diſc, and ſometimes approach towards it; and ſome parts, that were before inviſible, become conſpicuous; which is called the moon's *libration*.

Yet this equability of rotation occaſions an apparent irregularity; for the axis of the moon not being perpendicular to the plane of her orbit, but a little inclined to it; and this axis, maintaining its paralleliſm, in its motion round the earth; it muſt neceſſarily change its ſituation, in reſpect of an obſerver on the earth; to whom ſometimes the one, and ſometimes the other pole of the moon becomes viſible; whence it appears to have a kind of wavering, or vacillation. See LIBRATION.

The irregularities above enumerated, and ſome others of a ſimilar kind, have been urged as objections to the Newtonian theory of gravity, though they were anticipated by the illuſtrious author, who not only evinced their conſiſtency with it, but ſuggeſted the explication of them which might be deduced from that theory, properly underſtood and applied. Sir Iſaac Newton having found, in the manner which we ſhall preſently explain, that the moon was retained in its orbit by a force, which, at different diſtances from the earth, varied inverſely as the ſquares of the diſtances, and concluding from analogy that the ſame law of attraction might take place between all the bodies in the ſyſtem, applied this theory to compute the effect of the ſun's attraction upon the earth and moon, ſo far as it might affect the relative ſituation of the latter as ſeen from the former; and hence he diſcovered, beſides the irregularities already mentioned, other ſmaller inequalities of the moon's motion, which were alſo found to agree with obſervations. From this, and other applications of his theory, he was confirmed in his conjectures concerning the principle of univerſal gravitation; and the farther inveſtigation of the ſame principle, and the diſcovery that it produced concluſions conformable to obſervation, ſerved firmly to eſtabliſh his theory. M. Clairaut, indeed, in the year 1747, publiſhed a memoir which was read before the Academy of Sciences at Paris, and urged as an objection againſt it, that it would not account for the motion of the moon's apogee, but that this motion, deduced from it by his calculations, was only one-half of what it was found to be by obſervations. But ſoon after diſcovering his miſtake, and poſſeſſing candour enough to acknowledge it, he was the firſt who gave a complete theory of the moon, in which he ſhewed that ſir I. Newton's law of gravity would not only account for the motion of the moon's apogee, but alſo for all the other irregularities of the moon. M. Euler alſo retracted his own erroneus opinion, in deference to the judgment of M. Clairaut; and concurs with him in doing ample juſtice to the Newtonian theory. "After moſt tedious calculations," ſays Euler, "I have at length found, to my ſatiſfaction, that M. Clairaut was in the right, and that this theory is entirely ſufficient to explain the motion of the apogee of the moon. As this enquiry is of the greateſt difficulty, and as thoſe, who hitherto pretended to have proved this nice agreement of the theory with the truth, have been much deceived, it is to M. Clairaut that we are obliged for this important diſcovery, which gives quite a new luſtre to the theory of the GREAT NEWTON; and it is but now that we can expect good aſtronomical tables of the moon." Others, and particularly Mr. Machin and M. Friſe, have proſecuted a ſimilar inveſtigation of this theory, and contributed to eſtabliſh it. What Euler led aſtronomers to expect, they have now actually obtained in Mayer's tables, as corrected by Dr. Maſkelyne, which, founded upon a very elegant theory conformable to obſervations, are the moſt correct, and do not err more than half a minute in longitude. See LONGITUDE and LUNAR *Obſervations*.

MOON'S *Motions*, *Phyſical Cauſe of the*. The moon, we have obſerved, moves round the earth by the ſame laws, and in the ſame manner, as the earth and other planets move round the ſun. The ſolution, therefore, of the lunar motions, in general, comes under thoſe of the earth and other planets.

As for the particular irregularities in the moon's motion, to which the earth, and other planets, are not ſubject, they ariſe from the ſun, which acts on, and diſturbs her in her ordinary courſe through her orbit; and are all mechanically deducible from the ſame great law by which her general motion is directed; *viz.* the *law of gravitation* and *attraction*.

Other ſecondary planets, *v.g.* the ſatellites of Jupiter and Saturn, are, doubtleſs, ſubject to the like irregularities with the moon; as being expoſed to the ſame perturbating or diſturbing force of the ſun; but their diſtance ſecures them from our obſervation.

The laws of the ſeveral irregularities in the ſyzygies, quadratures, &c. ſee under SYZYGIES, QUADRATURES, &c.

It would not be conſiſtent with the limits or nature of this work to inveſtigate, by tedious and elaborate proceſſes of an analytical and geometrical kind, the various equations that have been explored for the illuſtration of theſe laws, and for furniſhing a complete theory of the moon. Much has been done in this way by ſeveral learned mathematicians, and of late by profeſſor Vince, who is eminently qualified for the undertaking: and we ſhall therefore refer the reader, who may be deſirous of farther information, and who has no acceſs to a variety of other publications, to the ſecond volume of Vince's Complete Syſtem of Aſtronomy, chap. xxxii.

We ſhall, however, in this place, introduce a general view of the Newtonian theory of gravity, as it is applied to the ſolution of the irregularities of the moon's motion.

We have already, under the article GRAVITATION, illuſtrated and confirmed the Newtonian theory of gravity, as it regards the moon and the other planets; but as the ſubject is of importance, and as it is immediately connected with what follows, we ſhall here give a conciſe ſtatement of the leading fact by which the identity of the centripetal force, as it reſpects the moon, and that of gravity, was originally explained and eſtabliſhed, referring for a more detailed account to the article juſt cited.

It is well known, and univerſally allowed, that the planets are retained in their orbits by ſome power which is continually acting upon them; that this power is directed towards the centres of their orbits; that the efficacy of this power increaſes upon an approach to the centre, and diminiſhes by its receſs from the ſame; and that it increaſes according to a certain law, *viz.* that of the ſquares of the diſtances, as the diſtance diminiſhes; and that diminiſhes in the ſame manner as the diſtance increaſes. Now by comparing this centripetal force of the planets with the force of gravity on earth, they will be found perfectly alike. This we ſhall illuſtrate in the caſe of the moon, the neareſt to us of all the planets. The rectilinear ſpaces deſcribed in any given time by a falling body, urged by any powers, reckoning from the beginning of its deſcent, are proportionable to thoſe powers. Conſequently the centripetal force of the moon, revolving in its orbit, will be to the force of gravity on the ſurface of the earth, as the ſpace which the moon would deſcribe in falling any little time, by her centripetal force towards the earth, if ſhe had no circular motion at all, to the ſpace which a body near the earth would deſcribe in falling, by its gravity towards the ſame. By a very eaſy and obvious calculation of theſe two ſpaces it will appear, that the firſt of them is to the ſecond, *i. e.* the centripetal force of the moon revolving in her orbit is to the force of gravity on the ſurface of the earth, as the ſquare of the earth's ſemidiameter to the ſquare of the ſemidiameter of her orbit, which is the ſame ratio as that of the moon's centripetal force in her orbit to the ſame force near the ſurface of the earth. The moon's centripetal force is, therefore, equal to the force of gravity. Theſe forces, conſequently, are not different, but they are one and the ſame; for if they were different, bodies acted upon by the two powers conjointly, would fall towards the earth with a velocity double to that ariſing from the ſole power of gravity. It is evident, therefore, that the moon's centripetal force, by which ſhe is retained in her orbit, and prevented from running off in tangents, is the very power of gravity of the earth, extended thither. This reaſoning may be farther illuſtrated and confirmed in the following manner. Let R A E (*Plate* XVII. *Aſtronomy, fig.* 9.) repreſent the earth, T its centre, V L the orbit of the moon, and L C a part of it deſcribed by the moon in a minute, which is equal to $\frac{1}{39343}$ of the whole periphery, or 33 ſeconds of a degree; becauſe the moon completes her whole courſe in 27 days, ſeven hours, 43 minutes, or in 39343 minutes. Moreover, the circumference of the earth, according to M. Picart's menſuration, is 123249600 Paris feet, and therefore its ſemidiameter T A = 19615800 feet; and T L, the ſemidiameter of the moon's orbit, will be 1176948000 feet, or = 60 times T A; and the verſed ſine L D of the arc L C = 33″, computed by means of tables, or B C, will be $15\frac{1}{12}$ feet, nearly: or L D may be found without tables thus; the whole circumference of the moon's orbit, or 60 × 123249600, is equal to 7394976000, which divided by 39343, will give the arc L C = 187961 feet; but by a well-known theorem in geometry, ſuppoſing the arc L C, which is a very ſmall part of the moon's orbit, to be rectilinear, $LC^2 = LD \times 2LT$, *i. e.* $LD = \frac{LC^2}{2LT}$, or the ſquare of 187961, which is 35329337521, divided by 2353896000, will give 15.013, &c. It may be here obſerved, that a diſtance of the moon ſomewhat greater than 60 times the diameter of the earth would afford a more exact reſult; and the force by which the moon is reſtrained in its orbit ſhould alſo be increaſed in the proportion of $177\frac{29}{40}$ to $178\frac{29}{40}$, in order to have the exact centripetal force of the moon, ſuch as it would be undiminiſhed by the action of the ſun, and with this correction the above number 15.013, &c. will become 15.097, &c. or $15\frac{1}{12}$ very nearly. (See Newton's Principia, lib. i. prop. 45. cor. 2. and lib. iii. prop. 3.) In either way of calculation it appears that the force, by which the moon is drawn off from the tangent L B, or retained in its orbit, impels it towards the centre of the earth about $15\frac{1}{12}$ Paris feet in one minute: but this force, being known from the elliptic figure of her orbit to be reciprocally proportional to the ſquare of the diſtance, would impel the moon, ſuppoſed to be at the ſurface of the earth, through a ſpace equal to 60 × 60 × $15\frac{1}{12}$ feet in one minute. But bodies, impelled by the force of gravity, fall near the ſurface of the earth through the ſpace of $15\frac{1}{12}$ Paris feet in one ſecond, and the ſpaces being as the ſquares of the times, through 60 × 60 × $15\frac{1}{12}$ in a minute. Conſequently, as the force by which the moon is retained in its orbit, and the force of gravity, produce the ſame effects in the ſame circumſtances, and tend towards the ſame point, they are the ſame forces. The moon, therefore, gravitates towards the earth, and the earth reciprocally towards the moon; and this law is further confirmed by the phenomena of the tides. See TIDES.

The like reaſoning might be applied to the other planets. For, as the revolutions of the primary planets round the ſun, and thoſe of the ſatellites of Jupiter, Saturn, and the Georgium Sidus, round their primaries, are phenomena of the ſame kind as the revolution of the moon round the earth; as the centripetal powers of the primary are directed towards the centre of the ſun, and thoſe of the ſatellites towards the centres of their primaries; and, laſtly, as all theſe powers are reciprocally as the ſquares of the diſtances from the centres; it may ſafely be concluded, that the power and cauſe are the ſame in all. Therefore, as the moon gravitates towards the earth, and the earth towards the moon, ſo do all the ſecondaries to their reſpective primaries; the primaries to their ſecondaries; and ſo do, alſo, the primaries to the ſun, and the ſun to the primaries, &c. Newton's Princ. lib. iii. prop. 4, 5, 6. Gregory's Aſt. lib. i. § .7. prop. 46 and 47.

In ſolving the irregularities of the moon's motion, agreeably to the theory of gravity, previouſly eſtabliſhed, it muſt firſt be conſidered, that if the ſun acted equally on the earth and moon, and always in parallel lines, this action would ſerve only to reſtrain them in their annual motions round the ſun, and no way affect their actions on each other, or their motions about their common centre of gravity. But becauſe the moon is nearer the ſun, in one half of her orbit, than the earth is, and farther in the other half of her orbit, and the power of gravity is always greater at a leſs diſtance, it follows, that, in one half of her orbit the moon is more attracted than the earth towards the ſun, and in the other half leſs attracted than the earth: and hence irregularities neceſſarily ariſe in the motions of the moon; the exceſs, in the firſt caſe, and the defect, in the ſecond, of the attraction, becoming a force that diſturbs her motion: and beſides, the action of the ſun on the earth and moon, is not directed in parallel lines, but in lines that meet in the centre of the ſun.

In order to underſtand the effects of theſe powers, let us ſuppoſe that the projectile motions of the earth and moon were deſtroyed, and that they were allowed to fall freely towards the ſun. If the moon was in conjunction with the ſun, or in that part of her orbit which is neareſt to him, the moon would be more attracted than the earth, and fall with greater velocity towards the ſun; ſo that the diſtance of the moon from the earth would be increaſed in the fall. If the moon was in oppoſition, or in the part of her orbit which is fartheſt from the ſun, ſhe would be leſs attracted than the earth by the ſun, and would fall with leſs velocity towards the ſun than the earth, and the moon would be left behind by the earth; ſo that the diſtance of the moon from the earth would be increaſed, in this caſe alſo. If the moon was in one of the quarters, then the earth and moon being both attracted towards the centre of the ſun, they would both directly deſcend towards that centre, and, by approaching to the ſame centre, they would neceſſarily approach at the ſame time to each other, and their diſtance from one another would be diminiſhed, in this caſe. Now, wherever the action of the ſun would increaſe their diſtance, if they were allowed to fall towards the ſun, there we may be ſure the ſun's action, by endeavouring to ſeparate them, diminiſhes their gravity to each other; wherever the action of the ſun would diminiſh their diſtance, there the ſun's action, by endeavouring to make them approach to one

one another, increases their gravity to each other: that is, in the conjunction and opposition, their gravity towards each other is diminished by the action of the sun; but in the two quarters it is increased by the action of the sun. To prevent mistaking this matter, it must be remembered, it is not the total action of the sun on them that disturbs their motions, it is only that part of its action, by which it tends to separate them, in the first case, to a greater distance from each other; and that part of its action, by which it tends to bring them nearer to each other, in the second case, that has any effect on their motions, with respect to each other. The other, and the far more considerable part, has no other effect but to retain them in their annual course, which they perform together about the sun.

In considering, therefore, the effects of the sun's action on the motions of the earth and moon, with respect to each other, we need only attend to the excess of its action on the moon above its action on the earth, in their conjunction; and we must consider this excess as drawing the moon from the earth towards the sun in that place. In the opposition, we need only consider the excess of the action of the sun, on the earth, above its action on the moon, and we must consider this excess as drawing the moon from the earth, in this place, in a direction opposite to the former, that is, towards the place opposite to where the sun is; because we consider the earth as quiescent, and refer the motion, and all its irregularities to the moon. In the quarters, we consider the actions of the sun as adding something to the gravity of the moon towards the earth.

Suppose the moon setting out from the quarter that precedes the conjunction, with a velocity that would make her describe an exact circle round the earth, if the sun's action had no effect on her; and because her gravity is increased by that action, she must descend towards the earth, and move within that circle: her orbit, there, will be more curve than otherwise it would have been; because this addition to her gravity will make her fall farther at the end of an arc below the tangent drawn at the other end of it; her motion will be accelerated by it, and will continue to be accelerated, till she arrives at the ensuing conjunction; because the direction of the action of the sun upon her, during that time, makes an acute angle with the direction of her motion. At the conjunction, her gravity towards the earth being diminished by the action of the sun, her orbit will be less curve there for that reason; and she will be carried farther from the earth, as she moves to the next quarter; and because the action of the sun makes then an obtuse angle with the direction of her motion, she will be retarded by the same degrees by which she was accelerated before.

Thus she will descend a little towards the earth, as she moves from the first quarter towards the conjunction, and ascend from it, as she moves from the conjunction to the next quarter. The action which disturbs her motion will have a like, and almost equal effect upon her, while she moves in the other half of her orbit, that is, that half of it which is farthest from the sun: she will proceed from the quarter that follows the conjunction with an accelerated motion to the opposition, approaching a little towards the earth, because of the addition made to her gravity, at that quarter, from the action of the sun; and receding from it again, as she goes on from the opposition to the quarter, from which we supposed her to set out. The areas described in equal times, by a ray drawn from the moon to the earth, will not be equal, but will be accelerated by the conspiring action of the sun, as she moves towards the conjunction or opposition from the quarters that precede them; and will be retarded by the same action, as she moves from the conjunction or opposition to the quarters that succeed them. Newton has computed the quantities of these irregularities from their causes. He finds, that the force added to the gravity of the moon, in her quarters, is to the gravity with which she would revolve in a circle about the earth, at her present mean distance, if the sun had no effect on her, as 1 to $178\frac{29}{40}$. He finds the force subducted from her gravity, in the conjunctions and oppositions, to be double of this quantity, and the area described in a given time in the quarters, to be to the area described in the same time in the conjunctions and oppositions, as 10973 to 11073. He finds, that in such an orbit, her distance from the earth in her quarters, would be to her distance in the conjunctions and oppositions, as 70 to 69. This is the variation of the form of the orbit arising from the force of the sun, supposing that the orbit would have been a circle without that disturbing force. And as the orbit of the moon is an ellipse, having the earth in its focus, and approaching nearly to a circle, the same cause must produce very nearly the same effect in the moon's orbit. Dr. Halley first took notice of this contraction of the lunar orbit in syzygies, from the phenomena of the moon's motion, and made the ratio of the diameter as 44.5 : 45.5, from observation.

From the alteration of the form of the orbit and from the acceleration of the areas, there will arise two corrections to be applied to the mean motion of the moon, in order to give the true motion; and the joint effect of these two constitutes an equation, called the "variation."

As to the effect of the action of the sun on the nodes, and, consequently, on the inclination of the moon's orbit to the ecliptic, see NODES, and the preceding part of this article.

Moreover, the action of the sun diminishes the gravity of the moon towards the earth, in the conjunctions and oppositions, more than it adds to it in the quarters, and, by diminishing the force, which retains the moon in her orbit, increases her distance from the earth and her periodic time: and because the earth and moon are nearer the sun in their perihelion than in their aphelion, and the sun acts with a greater force there, so as to subduct more form the moon's gravity towards the earth; it follows, that the moon must revolve at a greater distance, and take a longer time to finish her revolution in the perihelion of the earth, when her orbit is dilated, and she moves slower, than in the aphelion, when the moon's orbit is contracted, and she moves faster. The annual equation, by which this inequality is compensated, is nothing in aphelion and perihelion; and at the mean distance of the sun it is 12′ 55″, according to professor Vince's determination. Sir Isaac Newton makes it 11′ 50″: according to Mayer, it is 11′ 16″: M. d'Alembert makes it 12′ 57″: Halley makes it about 13′: according to M. de la Lande, it is 11′ 8″.6; and this also is conformable to observation.

There is another remarkable irregularity in the moon's motion, that also arises from the action of the sun: which is the progressive motion of the apsides. The moon describes an ellipse about the centre of the earth, having one of the foci in that centre. Her greatest and least distances from the earth are in the apsides, or extremities of the longer axis of the ellipse. This is not found to point always to the same place in the heavens, but to move with a progressive motion forwards, so as to finish a revolution round the earth's centre in about nine years.

To understand the reason of this motion of the apsides, we must consider, that, if the gravity of a body decreased less as the distance increases, then according to the regular course,

course of gravity, the body would descend sooner from the higher to the lower apsis, than in half a revolution; and therefore the apsis would recede in that case, for it would move in a contrary direction to the motion of the body, meeting it in its motion. But if the gravity of the body should decrease more, as the distance increases, than according to the regular course of gravity, that is, in a higher proportion than as the square of the distance increases, the body would take more than half a revolution to move from the higher to the lower apsis; and, therefore, in that case, the apsides would have a progressive motion in the same direction as the body.

In the quarters, the sun's action adds to the gravity of the moon, and the force it adds is greater, as the distance of the moon from the earth is greater; so that the action of the sun hinders her gravity towards the earth from decreasing as much while the distance increases, as it ought to do according to the regular course of gravity; and, therefore, while the moon is in the quarters, her apsides must recede. In the conjunction and opposition, the action of the sun subducts from the gravity of the moon towards the earth, and subducts the more the greater her distance from the earth is, so as to make her gravity decrease more as her distance increases, than according to the regular course of gravity; and, therefore, in this case, the apsides are in a progressive motion. Because the action of the sun subducts more in the conjunctions and oppositions from her gravity, than it adds to it in the quarters, and, in general, diminishes more than it augments her gravity; hence it is that the progressive motion of the apsides exceeds the retrograde motion; and, therefore, the apsides are carried round according to the order of the signs. The annual equation of the apsides, according to sir Isaac Newton, is 19′ 43″. See Maclaurin's Account of sir Isaac Newton's Phil. Disc. lib. iv. c. 4. We have some observations and tables concerning the moon's motion, by Mr. Richard Dunthorn, in the Philosophical Transactions, N° 482. sect. 13, where he gives 100 observed longitudes of the moon compared with the tables, *viz.* 25 eclipses of the moon, taken (except the first) from Flamsteed's Historia Cœlestis, the Philosophical Transactions, and the Memoirs of the Royal Academy of Sciences; the two great eclipses of the sun in 1706 and 1715; 25 select places of the moon, from Flamsteed's Historia Cœlestis; and 48 of those longitudes of the moon, computed from Flamsteed's Observations by Dr. Halley, and printed in the first edition of the Historia Cœlestis.

Theory of the Moon's Motions and Irregularities.—The tables of equation, which serve to solve the irregularities of the sun, do likewise serve for those of the moon.

But then these equations must be corrected for the moon, otherwise they will not exhibit the true motions in the syzygies. The method is thus: Suppose the moon's place in the zodiac, required in longitude, for any given time; here, we first find, in the tables, the place where it would be, supposing its motion uniform, which we call *mean*, and which is sometimes faster, and sometimes slower, than the true motion: then, to find where the *true* motion will place her, which is also the *apparent*, we are to find in another table at what distance it is from its apogee; for, according to this distance, the difference between her true and mean motion, and the two places which correspond thereto, is the greater. The true place thus found, is not yet the *true* place; but varies from it, as the moon is more or less remote both from the sun, and the sun's apogee: which variation respecting, at the same time, those two different distances, they are to be both considered and combined together, as in a table apart. Which table gives the correction to be made of the true places first found That place, thus corrected, is not yet the *true* place, unless the moon be either in conjunction, or opposition: if she be out of these, there must be another correction, which depends on two things taken together, and compared, *viz.* the distance of the moon's corrected place from the sun; and of that at which she is with regard to her own apogee; this last distance having been changed by the first correction.

By all these operations and corrections, we at length arrive at the moon's true place for that instant. In this, it must be owned, there occur prodigious difficulties: the lunar equalities are so many, that it was in vain the astronomers laboured to bring them under any rule, before the great sir Isaac Newton; to whom we are indebted both for the mechanical causes of these inequalities, and for the method of computing and ascertaining them: so that he has given us a world, in a great measure, of his own discovering, or rather subduing.

From the theory of gravity he shews, that the larger planets, revolving round the sun, may carry along with them smaller planets, revolving round themselves; and shews also, *à priori*, that these smaller must move in ellipses having their umbilici in the centres of the larger; and must have their motion in their orbits variously disturbed by the motion of the sun; and in a word, must be affected with those inequalities which we actually observe in the moon. And from this theory, he argues analogous irregularities in the satellites of Saturn.

From the same theory he examines the force which the sun has to disturb the moon's motion, determines the horary increase of the area which the moon would describe in a circular orbit by radii drawn to the earth—her distance from the earth—the horary motion in a circular and elliptic orbit—the mean motion of the nodes—the true motion of the nodes—the horary variation of the inclination of the moon's orbit to the plane of the ecliptic. Lastly, from the same theory he has found the annual equation of the moon's mean motion to arise from the various dilatation of her orbit; and that variation to arise from the sun's force, which being greater in the perigee, distends the orbit; and, being less in the apogee, suffers it to be again contracted. In the dilating orbit she moves more slowly; in the contracted, more swiftly; and the annual equation, whereby this inequality is compensated, in the apogee and perigee, is nothing at all; at a moderate distance from the sun, it amounts to 11′ 50″; and in other places it is proportional to the equation of the sun's centre, and is added to the mean motion of the moon, when the earth proceeds from its aphelion to its perihelion; and subtracted when in the opposite part.

Thus, supposing the radius of the *orbis magnus* 1000, and the earth's excentricity 16 ; this equation, when greatest, according to the theory of gravity, comes out 11′ 49″.

He adds, that in the earth's perihelion, the nodes move swifter than in the aphelion, and that in a triplicate ratio of the earth's distance from the sun, inversely. Whence arise annual equations of their motions, proportionable to that of the centre of the sun. Now the sun's motion is in a duplicate ratio of the earth's distance from the sun inversely, and the greatest equation of the centre which this inequality occasions, is 1° 56′ 26″, agreeable to the sun's excentricity 16$\frac{11}{12}$. If the sun's motion were in a triplicate ratio of its distance inversely, this inequality would generate the greatest equation 2° 56′ 9″; and therefore the greatest equations which the inequalities of the motions of the moon's apogee

and

and nodes occasion, are to 2° 56′ 9″, as the mean diurnal motion of the moon's apogee, and the mean diurnal motion of her nodes, are to the mean diurnal motion of the sun. Whence the greatest equation of the mean motion of the apogee comes out 19′ 42″; and the greatest equation of the mean motion of the nodes 9′ 27″. The former equation is added, and the latter subtracted, when the earth proceeds from its perihelion to its aphelion, and the contrary in the opposite part of its orbit.

From the same theory of gravity, it also appears that the sun's action on the moon must be somewhat greater when the transverse diameter of the lunar orbit passes through the sun, than when it is at right angles with the line that joins the earth and sun; and, therefore, that the lunar orbit is somewhat greater in the first case than in the second. Hence arises another equation of the mean lunar motion, depending on the situation of the moon's apogee with regard to the sun, which is greatest when the moon's apogee is in an octant with the sun; and none, when she arrives at the quadrature, or syzygies; and is added to the mean motion, in the passage of the moon's apogee from the quadrature to the syzygies, and subtracted in the passage of the apogee from the syzygies to the quadrature.

This equation, which sir Isaac calls *semestris*, when greatest, *viz.* in the octants of the apogee, rises to 3′ 45″, at a mean distance of the earth from the sun; but it increases and diminishes in a triplicate ratio of the sun's distance inversely; and therefore, in the sun's greatest distance, is 3′ 34″; in the smallest, 3′ 56″, nearly. But when the apogee of the moon is without the octants, it becomes less, and is to the greatest equation, as the sine of double the distance of the moon's apogee from the next syzygy, or quadrature, to the radius.

From the same theory of gravity it follows, that the sun's action on the moon is somewhat greater when a right line, drawn through the moon's nodes, passes through the sun, than when that line is at right angles with another joining the sun and earth: and hence arises another equation of the moon's mean motion, which he calls *secunda semestris*, and which is greatest when the nodes are in the sun's octants, and vanishes when they are in the syzygies, or quadratures; and in other situations of the nodes, is proportionable to the sine of double the distances of either node from the next syzygy, or quadrature.

It is added to the moon's mean motion while the nodes are in their passage from the sun's quadratures to the next syzygy, and subtracted in their passage from the syzygies to the quadratures in the octants.

When it is greatest, it amounts to 47″, at a mean distance of the earth from the sun; as it appears from the theory of gravity; at other distances of the sun, this equation in the octants of the nodes is reciprocally as the cube of the sun's distance from the earth; and therefore in the sun's perigee is 45″; in his apogee nearly 49″.

By the same theory of gravity the moon's apogee proceeds the fastest when either in conjunction with the sun, or in opposition to it; and is retrograde when in quadrature with the sun. In the former case, the excentricity is greatest, and in the latter smallest. These inequalities are very considerable, and generate the principal equation of the apogee, which he calls *semestris*, or *semimenstrual*. The greatest semimenstrual equation is about 12° 18′.

Horrox first observed the moon to revolve in an ellipsis round the earth placed in the lower umbilicus: and Halley placed the centre of the ellipsis in an epicycle, whose centre revolves uniformly about the earth: and from the motion in the epicycle arise the inequalities now observed in the progress and regress of the apogee, and the quantity of the excentricity.

Suppose the mean distance of the moon from the earth divided into 100,000; and let T (*Plate* XVII. *Astronomy, fig.* 12.) represent the earth, and TC the mean excentricity of the moon 5505 parts; produce TC to B, that CB may be the sine of the greatest semimenstrual equation 12° 18′, to the radius TC; the circle BDA, described on the centre C, with the interval CB, will be the epicycle wherein the centre of the lunar orb is placed, and wherein it revolves according to the order of the letters BDA. Take the angle BCD equal to double the annual argument, or double the distance of the true place of the sun from the moon's apogee once equated, and CTD will be the semimenstrual equation of the moon's apogee; and TD the excentricity of its orbit tending to the apogee equated a second time. From hence the moon's mean motion, apogee, and excentricity, as also the greater axis of its orbit 200,000, the moon's true place, as also her distance from the earth, are found, and that by the most common methods. In the earth's perihelion, by reason of the greater force of the sun, the centre of the moon's orbit will move more swiftly about the centre C than in the aphelion, and that in a triplicate ratio of the earth's distance from the sun inversely. By reason of the equation of the centre of the sun, comprehended in the annual argument, the centre of the moon's orbit will move more swiftly in the epicycle BDA, in a duplicate ratio of the distance of the earth from the sun inversely.

That the same may still move more swiftly in a simple ratio of the distance inversely from the centre of the orbit D, draw DE towards the moon's apogee, or parallel to TC; and take the angle EDC equal to the excess of the annual argument, above the distance of the moon's apogee from the sun's perigee in consequentia; or, which is the same thing, take the angle CDF equal to the complement of the true anomaly of the sun to 360°; and let DF be to DC as double the excentricity of the *orbis magnus* to the mean distance of the sun from the earth, and the mean diurnal motion of the sun from the moon's apogee, to the mean diurnal motion of the sun from it own apogee, conjunctly, *i. e.* as $33\frac{7}{8}$ is to 1000, and 52′ 27″ 16‴ to 59′ 8″ 10‴, conjunctly; or as 3 to 100. Conceive the centre of the moon's orbit placed in the point F, and to revolve in an epicycle, whose centre is D, and its radius DF, while the point D proceeds in the circumference of the circle DABD: thus the velocity, with which the centre of the moon's orbit moves in a certain curve, described about the centre C, will be reciprocally as the cube of the sun's distance from the earth.

The computation of this motion is difficult; but it will be made easy by the following approximation: if the moon's mean distance from the earth be 100,000 parts, and its excentricity TC 5505 of those parts, the right line CB or CD will be found $1172\frac{3}{4}$, and the right line DF $35\frac{1}{5}$. This right line, at the distance TC, subtends an angle to the earth, which the transferring of the centre of the orbit from the place D to F generates in the motion of this centre; and the same right line doubled, in a parallel situation, at the distance of the upper umbilicus of the moon's orbit from the earth, subtends the same angle, generated by that translation in the motion of the umbilicus; and at the distance of the moon from the earth subtends an angle, which the same translation generates in the motion of the moon; and which may therefore be called *the second equation of the centre*.

This equation of a mean distance of the moon from the earth, is as the sine of the angle contained between the right

line

line DF, and a right line drawn from the point F to the moon, nearly; and when greateſt, amounts to 2′ 25″. Now the angle comprehended between the right line DF and a line from the point D, is found either by ſubtracting the angle EDF from the mean anomaly of the moon, or by adding the moon's diſtance from the ſun to the diſtance of the moon's apogee from the apogee of the ſun. And as radius is to the ſine of the angle thus found, ſo is 2′ 25″ to the ſecond equation of the centre; which is to be added, if that ſine be leſs than a ſemicircle; and ſubtracted, if greater: thus we have its longitude in the very ſyzygies of the luminaries.

If a more accurate computation be required, the moon's place thus found muſt be corrected by a ſecond variation. The firſt and principal variation we have already conſidered, and have obſerved it to be greateſt in the octants. The ſecond is greateſt in the quadrants, and ariſes from the different action of the ſun on the moon's orbit, according to the different poſition of the moon's apogee to the ſun, and is thus computed; as radius is to the verſed ſine of the diſtance of the moon's apogee from the ſun's perigee, in conſequentia, ſo is a certain angle P to a fourth proportional. And as radius is to the ſine of the moon's diſtance from the ſun, ſo is the ſum of this fourth proportional and another angle Q to the ſecond variation; which is to be ſubtracted, if the moon's light be increaſing; and added, if diminiſhing.

Thus we have the moon's true place in her orbit; and by reduction of this place to the ecliptic, we have the moon's longitude. The angles P and Q are to be determined by obſervation in the mean time, if for P be aſſumed 2, and for Q 1′, we ſhall be near the truth.

The reſults of computations of this kind are rendered more accurate, in conſequence of modern diſcoveries; and the labour of them is in a great meaſure ſuperſeded by the valuable lunar tables, which the aſtronomer has now in his poſſeſſion. We ſhall therefore refer for theſe tables to the Nautical Almanack, and to Vince's Complete Aſtronomy, vol. iii.

MOON's *Path with reſpect to the Sun, Figure of the.* The path of the moon is concave towards the ſun throughout.

In other ſecondary planets, as the ſatellites of the ſuperior planets, that part of the path of theſe ſatellites which is neareſt the ſun, is convex towards the ſun, and the reſt is concave. And we often find in elementary treatiſes of aſtronomy, the moon's path repreſented in the ſame manner; that is, as partly convex and partly concave towards the ſun: but this is a miſtake. For it is to be obſerved, in general, that the force which bends the courſe of the ſatellite into a curve, when the motion is referred to an immoveable plane, is, at the conjunction, the difference of its gravity towards the ſun, and of its gravity towards the primary. When the former prevails over the latter, the force that bends the courſe of the ſatellite tends towards the ſun; and, conſequently, the concavity of the path is towards the ſun; and this is the caſe of the moon. When the gravity towards the primary exceeds the gravity towards the ſun, at the conjunction, then the force which bends the courſe of the ſatellite tends towards the primary, and therefore towards the oppoſition of the ſun; conſequently the path is there convex toward the ſun; and this is the caſe of the ſatellites of Jupiter. When theſe two forces are equal, the path has, at the conjunction, what mathematicians call a point of rectitude; in which caſe, however, the path is concave towards the ſun throughout.

If, indeed, the earth had no annual motion, the moon's motion round the earth, and her track in open ſpace, would be always the ſame. But as the earth and moon move round the ſun, the moon's real path in the heavens is very different from her viſible path round the earth; the latter being in a progreſſive circle, and the former in a curve of different degrees of concavity, which would be always the ſame in the ſame parts of the heavens, if the moon performed a complete number of lunations in a year, without any fractions.

Mr. Ferguſon has ſuggeſted the following familiar idea of the earth's and moon's path. Let a nail in the end 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 to the moon's path during ſo many lunations.

Let us now ſuppoſe that the radius of the circular curve, deſcribed by the nail in the axle, is to the radius of the circle, which the pin in the nave deſcribes round the axle, as $337\frac{1}{2}$ to 1; which is the proportion of the radius or 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. (*Plate* XVII. *Aſtronomy, fig.* 10.) 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 centre of its path, and, in ſo doing, will deſcribe the curve *a b c d e.* The former will be a true repreſentation of the earth's path for one lunation, and the latter of the moon's for that time. Here we may ſet aſide the inequalities of the moon's motion, and alſo the earth's moving round its common centre of gravity, and the moon's: all which, if they were truly copied in this experiment, would not ſenſibly alter the figure of the paths deſcribed by the nail and pin, even though they ſhould rub againſt a plain upright ſurface all the way, and leave their tracks viſible upon it. And if the chariot was driven forward on ſuch a convex piece of ground, ſo as to turn the wheel ſeveral times round, the track of the pin in the nave would ſtill be concave toward the centre of the circular curve deſcribed by the pin in the axle; as the moon's path is always concave to the ſun in the centre of the earth's annual orbit.

In this diagram, the thickeſt curve line ABCDE, with the numeral figures ſet to it, repreſents as much of the earth's annual orbit as it deſcribes in 32 days from weſt to eaſt; the little circles at *a*, *b*, *c*, *d*, *e*, ſhew the moon's orbit in due proportion to the earth's; and the ſmalleſt curve *a b c d e f* repreſents the line of the moon's path in the heavens for 32 days, accounted from any particular new moon at *a*.

The ſun is ſuppoſed to be in the centre of the curve A 1 2 3 4 5 6 7 B, &c. and the ſmall dotted circles upon it repreſent the moon's orbit, of which the radius is in the ſame proportion to the earth's path, in this ſcheme, that the radius of the moon's orbit, in the heavens, bears to the radius of the earth's annual path round the ſun; that is, as 240,000 to 81,000,000, or as 1 to $337\frac{1}{2}$.

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

the moon, in accompanying the earth, deſcribes the curve *a b*; and is in her firſt quarter at *b*, when the earth is at B. As the earth deſcribes the curve B 8 9 10 11 12 13 14, the moon deſcribes the curve *b c*; and is at *c*, oppoſite to the ſun, when the earth is at C. Whilſt the earth deſcribes the curve 15 16 17 18 19 20 21 22, the moon deſcribes the curve *c d*; and is in her third quarter at *d*, when the earth is at D. And, laſtly, whilſt the earth deſcribes the curve D 23 24 25 26 27 28 29, the moon deſcribes the curve *d e*; and is again in conjunction at *e* with the ſun, when the earth is at E, between the 29th and 30th day of the moon's age, accounted by the numeral figures from the new moon at A. In deſcribing the curve *a b c d e*, the moon goes round the progreſſive earth as really as if ſhe had kept in the dotted circle A, and the earth continued immoveable in the centre of that circle.

And thus we ſee, that although the moon goes round the earth in a circle, with reſpect to the earth's centre, 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*.

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 240,000 miles, (equal to the ſemi-diameter 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 ſo retarded, that ſhe loſes as much with reſpect to the earth, as is equal to her diſtance from it, or to the ſemi-diameter of her orbit; and by that means ſhe comes to *e*, and is then in conjunction with the ſun, as ſeen from the earth at E. Hence we find, that the moon's abſolute motion is ſlower than the earth's, from her third quarter to her firſt; and ſwifter than the earth's, from her firſt quarter to her third: her path being leſs curved than the earth's in the former caſe, and more in the latter. Yet it is ſtill bent the ſame way towards the ſun; for if we imagine the concavity of the earth's orbit to be meaſured by the length of a perpendicular line C *g*, let down from the earth's place upon the ſtraight line *b g d*, at the full of the moon, and connecting the places of the earth at the end of the moon's firſt and third quarters, that length will be about 640,000 miles; and the moon, when new, only approaching nearer to the ſun, by 240,000 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 400,000 miles.

The gravity of the moon towards the ſun has been found to be greater, at her conjunction, than her gravity towards the earth, ſo that the point of equal attraction, where thoſe two powers would ſuſtain each other, falls then between the moon and earth; and ſince the quantity of matter in the ſun is almoſt 230,000 times as great as the quantity of matter in the earth, and the attraction of each body diminiſhes as the ſquare of the diſtance from it increaſes, it may be eaſily found, that this point of equal attraction between the earth and the ſun, is about 70,000 times nearer the earth than the moon is at her change: whence ſome, and particularly Mr. Baxter, author of Matho, have apprehended, that either the parallax of the ſun is very different from that which is aſſigned by aſtronomers, or that the moon ought neceſſarily to abandon the earth; becauſe ſhe is conſiderably more attracted by the ſun than by the earth at that time. This apprehenſion may be removed eaſily, by attending to what has been ſhewn by ſir Iſaac Newton, and is illuſtrated by vulgar experiments concerning the motions of bodies about one another, that are all acted upon by a third force in the ſame direction. Their relative motions not being in the leaſt diſturbed by this third force, if it act equally upon them in parallel lines; as the relative motions of the ſhips in a fleet, carried away by a current, are no way affected by it, if it act equally upon them; or as the rotation of a bullet or bomb, about its axis, while it is projected in the air; or the figure of a drop of falling rain, are not at all affected by the gravity of the particles of which they are made up towards the earth. The moon is ſo near the earth, and both of them ſo far from the ſun, that the attractive power of the ſun may be conſidered as equal on both; and, therefore, the moon will continue to circulate round the earth in the ſame manner as if the ſun did not attract them at all. It is to the inequality of the action of the ſun upon the earth and moon, and the want of paralleliſm in the directions of theſe actions, only, that we are to aſcribe the irregularities in the motion of the moon.

But it may contribute farther towards removing this difficulty to obſerve, that if the abſolute velocity of the moon, at the conjunction, was leſs than that which is requiſite to carry a body in a circle there around the ſun, ſuppoſing this body to be acted on by the ſame force which acts there on the moon, (*i. e.* by the exceſs of her gravity towards the ſun, above her gravity towards the earth,) then the moon would, indeed, abandon the earth. For, in that caſe, the moon having leſs velocity than would be neceſſary to prevent her from deſcending within that circle, ſhe would approach to the ſun, and recede from the earth. But though the abſolute velocity of the moon, at the conjunction, be leſs than the velocity of the earth in the annual orbit, yet her gravity towards the ſun is ſo much diminiſhed, by her gravity towards the earth, that her abſolute velocity is ſtill much ſuperior to that which is requiſite to carry a body in a circle there about the ſun, that is acted on by the remaining force only. Therefore, from the moment of the conjunction, the moon is carried without ſuch a circle, receding continually from the ſun to greater and greater diſtances, till ſhe arrives at the oppoſition; where, being acted on by the ſum of thoſe two gravities, and her velocity being now leſs than what is requiſite to carry a body in a circle there about the ſun, that is acted on by a force equal to that ſum, the moon thence begins to approach to the ſun again. Thus ſhe recedes from the ſun, and approaches to it by turns, and in every month her path hath two apſides, a perihelion at the conjunction, and an aphelion at the oppoſition; between which ſhe is always carried in a manner ſimilar to that in which the primary planets revolve between their apſides. The planet recedes from the ſun at the perihelion, becauſe its velocity there is greater than that with which a circle could be deſcribed about the ſun, at the ſame diſtance, by the ſame centripetal force; and approaches towards the ſun from the aphelion, becauſe its velocity there is leſs than is requiſite to carry it in a circle, at that diſtance, about the ſun.

If we ſuppoſe the earth to revolve in a circular orbit round the ſun as its centre, and the moon to revolve round the earth in the ſame manner; the planes of their orbits to coincide; the diameters of their orbits to be as 340 to 1; and the moon to perform 13,368 revolutions to every ſingle revolution of the earth; it is eaſy to inveſtigate the nature and

and defcription of the curve generated by the centre of the moon; and to determine whether this curve, in one lunation, be any where convex towards the fun.

Let S (*fig.* 11.) reprefent the fun; E the earth; E ε an arc of the orbit of the earth paffed over by its centre, in one lunation of the moon; the circumference of the circle E A F = the concentric arc A α; then, (becaufe 13,368 − 1 = 12,368 = the number of lunations in the year, or one revolution of the earth, and therefore S A : E A :: 12,368 : 1,) when the moon is in conjunction with the fun, the diftance between the fun and moon will be greater than the diftance or radius S A. Now the curve, defcribed by the centre of the moon, is the fame as that defcribed by a point M (E M being the femi-diameter of the moon's orbit), carried round by the rotation of the circle E A F on the arc A α: it is therefore of the cycloidal kind, having a point of inflexion, if every cycloid, defcribed by a point within the generating circle, is inflected, as well upon a circular as upon a rectilinear bafe. To determine which,

Put S *b* A or S R = *a*, E A or *e* R = *b*, E M or *e m* = *c*, R *m* = *r*, R *d* = *s*; and let *m* C be the radius of curvature at any point *m*, which, it is evident, muft pafs through the point of contact R. Suppofe the point *n* indefinitely near to *m*; then, R *r* and R *r* being the indefinitely fmall contemporary arcs with *m n*, and, confequently, the triangles R *m r* and R *n r* equal in all refpects; if we confider the faid little arcs R *r* and R *r* as little right lines perpendicular to the radii *e r* and S *r*, we fhall have the $< m R n = < r R r =$ (becaufe the angles *e* R *r* and S R *r*, added to either fide of the equation, make it two right angles) $< R e r + < R S r$. Now $S R : e R :: < R e r : < R S r$, and $S R : S R + R e :: < R e r : R e r + < R S r$, that is, $a : a + b :: < R e r : < m R n = \frac{a+b}{a} < R e r$. Again, in any triangle, as *d m r*, if the angles *m d r*, *m r d*, and R *m r*, the complement of the obtufe angle to two right angles, be indefinitely fmall, they will be proportional to the oppofite fides *m r*, *m d*, and *d r*; that is, $d r : m d :: < R m r : < m r d$; and $d r - m d : d r :: < R m r - < m r d : < R m r$, that is, $m R : d R :: < R d r : < R n r$, or, $r : s :: \frac{1}{2} < R e r : < R n r = \frac{s}{2r} < R e r$. And again, $< R C n : < R n C :: R n : R C$, that is, $< m R n - < R n r : < R n r :: R m : R C$, or $\overline{\frac{a+b}{a} - \frac{s}{2r}} < R e r : \frac{s}{2r} < R e r :: r : R C = \frac{a r s}{2ar + 2br - s}$. Confequently, $m R + R C = m C = \frac{2ar^2 + 2br^2}{2ar + 2br - as} = \frac{r^2}{r - \frac{as}{2a+2b}}$ = the radius of curvature at any point *m*.

Now, it is evident, that, at the point of inflexion, the radius of curvature muft be infinite: or that, on one fide of the faid point, the expreffion for the radius of curvature muft be affirmative, and on the other negative; therefore, *r* muft be more than $\frac{as}{2a+2b}$ on one fide of the faid point, and on the other lefs; and, confequently, at the point of inflexion, $r = \frac{as}{2a+2b}$; which, fubftituted for *r*, makes $(d m \times m R =)\ r s - r^2 = \frac{2abs^2 + a^2 s^2}{\overline{2a+2b}|^2}$ = (becaufe $d m \times m R = f m \times m a =)\ b^2 - c^2$; from which equation we have $s = \frac{\overline{2a+2b}\sqrt{b^2 - c^2}}{\sqrt{2ab + a^2}}$. Or, to find *r*, fay $2ar + 2br = as$, or $s = \frac{2ar + 2br}{a}$; then $(d m \times m R =)\ r s - r^2 = \frac{ar^2 + 2br^2}{a} = (f m \times m a =)\ b^2 - c^2$; which equation gives $r = \sqrt{\frac{ab^2 - ac^2}{a + 2b}}$, when the point *m* becomes a point of inflexion.

Now, as *m* R (*r*) muft, by the nature of the circle, always be greater than *m a*; that is, as $\sqrt{\frac{ab^2 - ac^2}{a+2b}}$ muft always be more than $b - c$; and, confequently, $\frac{ab^2 - ac^2}{a+2b}$ be more than $\overline{b-c}|^2$, that is, $\frac{ab + ac}{a+2b} \times \overline{b-c}$ be more than $\overline{b-c} \times \overline{b-c}$; therefore, *c* muft always be more than $\frac{b^2}{a+b}$; that is, E M muft be more than a third proportional to E S and E A, in order to have a point of inflexion take place in the curve: but in the prefent cafe, E S, E A, and E M, being as 13.368.1, and $\frac{13.368}{340}$, or .039; therefore EM is lefs than the faid third proportional; and, confequently, the curve M *m* μ, generated by the centre of the moon, has not a point of inflexion, or is no where convex towards the fun. See Ferguson's Aftronomy, p. 129, &c. Maclaurin's Account of Sir Ifaac Newton's Phil. Difc. book iv. ch. 5. p. 336, &c. 4to. Rowe's Fluxions, p. 127, &c.

MOON, *Aftronomy of the.* 1. To determine the period of the moon's revolution round the earth, or the *periodical* month; and the time between one oppofition and another, or the *fynodical* month.

Since in the middle of a lunar eclipfe the moon is oppofite to the fun, compute the time between two eclipfes, or oppofitions, between which there is a great interval of time; and divide this by the number of lunations that have paffed in the mean time; the quotient will be the quantity of the fynodical month. Compute the fun's mean motion, during the time of the fynodical month, and add this to the entire circle defcribed by the moon. Then, as the fum is to 360°, fo is the quantity of the fynodical month to the periodical.

Thus, Copernicus, in the year 1500, November 6, at twelve at night, obferved an eclipfe of the moon at Rome; and Auguft 1, 1523, at $4^h\ 25'$, another at Cracow: hence the quantity of the fynodical month is thus determined:

Obf. 2 An.	1523^d	237^h	$4.25'$
Obf. 1 An.	1500	310	2.20
Interval of time An.	22^d	292^h	$2.5'$
Add the intercalary days		5	
Exact interval An.	22^d	297^h	$2.5'$
or			$11991005'$

Which, divided by 282 months, elapfed in the mean time, gives the quantity of the fynodical month $42521'\ 9''\ 9'''$; that is, $29^d\ 12^h\ 41'$.

From.

From two other obſervations of eclipſes, the one at Cracow, the other at Babylon, the ſame author determines more accurately the quantity of the ſynodical month to be

$$42524' \; 3'' \; 10''' \; 9''''.$$

That is, $29^d \; 11^h \; 43' \; 3'' \; 10'''$. But this is leſs than the true ſynodical month, which is $29^d \; 12^h \; 44' \; 3''$.

The ſun's mean motion in the time $29^{\circ} \; 6' \; 24'' \; 18'''$
The moon's motion - - $389 \; 6 \; 24 \; 18$
Quantity of the periodical month $27^d \; 7^h \; 43' \; 5''$

Hence, 1. The quantity of the periodical month being given, by the rule of three we may find the moon's diurnal and horary motion, &c. And thus may tables of the mean motion of the moon be conſtructed.

2. If the ſun's mean diurnal motion be ſubtracted from the moon's mean diurnal motion, the remainder will give the moon's diurnal motion from the ſun: and thus may a table thereof be conſtructed.

3. Since, in the middle of a total eclipſe, the moon is in the node, if the ſun's place be found for that time, and to this be added ſix ſigns, the ſum will give *the place of that node*.

4. From comparing the ancient obſervations with the modern, it appears, that the nodes have a motion, and that they proceed *in antecedentia*, *i. e.* from Taurus to Aries, from Aries to Piſces, &c. If, then, to the moon's mean diurnal motion be added the diurnal motion of the nodes, the ſame will be the motion of the moon from the node; and thence, by the rule of three, may be found in what time the moon goes 360° from the dragon's head, or in what time ſhe goes from, and returns to it: that is, the quantity of the *dracontic* month.

5. If the motion of the apogee be ſubtracted from the mean motion of the moon, the remainder will be the moon's mean motion from the apogee; and thence, by the rule of three, is determined the quantity of the *anomaliſtic* month. See the preceding part of this article.

To find the Moon's Age or Change.—The following canon, in which the twelve numbers anſwer to the twelve months, beginning with January, will ſerve for this purpoſe.

Janus 0, 2, 1, 2, 3, 4, 5, 6,
8, 8, 10, 10, theſe to the epact fix,
The ſum, bate 30, to the month's day add,
Or take from 30, age or change is had.

The reaſon of adding theſe numbers to the epact in the ſeveral months, is becauſe the lunar ſynodical months fall ſhort of the calendar months; ſo that the epact, which expreſſes how much the lunar year falls ſhort of the ſolar, or calendar year, muſt be conſidered as continually increaſing; and, therefore, to find the new moons, which are the beginnings of the ſynodical months, an addition muſt be made to the epact in every month, and more and more as the year advances; which additional numbers are called the menſtrual epacts. Only nothing is to be added to the epact in January, becauſe the annual epact, together with the day of the month, does then expreſs the true age of the moon: but as January has 31 days, which is near 2 days more than a ſynodical month, therefore the beginning of the lunar month in February will fall 2 days ſooner than it did in January; conſequently 2 is the menſtrual epact of February; and then, as February has but 28, or at moſt 29 days, which may be accounted 1 day leſs than a ſynodical month, the next lunar month will begin 1 day later in March than it did in February; conſequently the menſtrual epact of March decreaſes inſtead of increaſing, and is but 1. If from thence you reckon the lunar months to conſiſt of 30 days and 29 interchangeably, the new moons will fall ſo much earlier in the following months than the new moon did in January, as is expreſſed by the menſtrual epacts in the canon, *viz.* 2 days in April, 3 in May, &c. until they amount to 11 days at the end of the year, which are then added to the annual epact.

TABLE I.—Epacts of Years.

Years.		Epacts.			Years.		Epacts.		
B.	1804	18d	13h	37′	B.	1844	10d	22h	14′
	1805	29	4	59		1845	21	13	26
	1806	10	7	16		1846	2	15	53
	1807	20	22	27		1847	13	7	4
B.	1808	3	0	55	B.	1848	24	22	16
	1809	13	16	6		1849	6	0	43
	1810	24	7	18		1850	16	15	55
	1811	5	9	45		1851	27	7	6
B.	1812	17	0	57	B.	1852	9	9	34
	1813	27	16	8		1853	20	0	45
	1814	8	18	35		1854	1	3	12
	1815	19	9	47		1855	11	18	24
B.	1816	1	12	14	B.	1856	23	9	35
	1817	12	3	26		1857	4	12	2
	1818	22	18	37		1858	15	3	14
	1819	3	21	4		1859	25	17	26
B.	1820	15	22	16	B.	1860	7	20	53
	1821	26	3	27		1861	18	12	4
	1822	7	5	55		1862	29	3	16
	1823	17	21	6		1863	10	5	43
B.	1824	29	12	18	B.	1864	21	20	55
	1825	10	14	45		1865	2	23	22
	1826	21	5	57		1866	13	14	33
	1827	2	8	24		1867	24	5	45
B.	1828	13	23	35	B.	1868	6	8	12
	1829	24	14	47		1869	16	23	24
	1830	5	17	14		1870	27	14	35
	1831	16	8	26		1871	8	17	3
B.	1832	27	23	37	B.	1872	20	8	14
	1833	9	2	4		1873	1	10	42
	1834	19	17	16		1874	12	1	53
	1835	0	19	43		1875	22	17	4
B.	1836	12	10	55	B.	1876	4	20	32
	1837	23	2	6		1877	15	10	43
	1838	4	4	34		1878	26	1	55
	1839	14	19	45		1879	7	4	22
B.	1840	26	10	56	B.	1880	18	19	33
	1841	7	13	24		1881	29	10	45
	1842	18	4	35		1882	10	13	12
	1843	28	19	47		1883	21	4	24

TABLE II.—Epacts of Months.

Months.	Epacts.			Months.	Epacts.		
January	0d	0h	0′	July	3d	19h	36′
February	1	11	16	Auguſt	5	6	52
March	29	11	16	September	6	18	8
April	1	9	48	October	7	5	24
May	1	21	4	November	8	16	40
June	3	8	20	December	9	3	55

In leap years, a day is to be ſubtracted from the ſum of the epacts, in the months of January and February.

Table III.—To find the Moon's Age by Inspection.

Months									Years.																		
Jan.	Feb. April.	Mar.	May.	June.	July.	Aug.	Sept. Oct.	Nov. Dec.	1800 1819 1838 1857 1876	1801 1820 1839 1858 1877	1802 1821 1840 1859 1878	1803 1822 1841 1860 1879	1804 1823 1842 1861 1880	1805 1824 1843 1862 1881	1806 1825 1844 1863 1882	1807 1826 1845 1864 1883	1808 1827 1846 1865 1884	1809 1828 1847 1866 1885	1810 1829 1848 1867 1886	1811 1830 1849 1868 1887	1812 1831 1850 1869 1888	1813 1832 1851 1870 1889	1814 1833 1852 1871 1890	1815 1834 1853 1872 1891	1816 1835 1854 1873 1892	1817 1836 1855 1874 1893	1818 1837 1856 1875 1894
Days.									Moon's Age.																		
1 31	29	30	28	27	26	25	23	22	5	16	27	8	19	1	12	23	4	F	26	7	18	29	10	21	2	13	24
2	30	1 31	29	28	27	26	24	22	6	17	28	9	20	2	13	24	5	16	27	8	19	N	11	22	3	14	25
3	1	2	30	29	28	27	25	23	7	18	29	10	21	3	14	25	6	17	28	9	20	1	12	23	4	F	26
4	2	3	1	30	29	28	26	24	8	19	N	11	22	4	F	26	7	18	29	10	21	2	13	24	5	16	27
5	3	4	2	1 31	30	29	27	25	9	20	1	12	23	5	16	27	8	19	N	11	22	3	14	25	6	17	28
6	4	5	3	2	1 31	30	28	26	10	21	2	13	24	6	17	28	9	20	1	12	23	4	F	26	7	18	29
7	5	6	4	3	2	1 31	29	27	11	22	3	14	25	7	18	29	10	21	2	13	24	5	16	27	8	19	N
8	6	7	5	4	3	2	30	28	12	23	4	F	26	8	19	N	11	22	3	14	25	6	17	28	9	20	1
9	7	8	6	5	4	3	1	29	13	24	5	16	27	9	20	1	12	23	4	F	26	7	18	29	10	21	2
10	8	9	7	6	5	4	2	30	14	25	6	17	28	10	21	2	13	24	5	16	27	8	19	N	11	22	3
11	9	10	8	7	6	5	3	1 31	F	26	7	18	29	11	22	3	14	25	6	17	28	9	20	1	12	23	4
12	10	11	9	8	7	6	4	2	16	27	8	19	N	12	23	4	F	26	7	18	29	10	21	2	13	24	5
13	11	12	10	9	8	7	5	3	17	28	9	20	1	13	24	5	16	27	8	19	N	11	22	3	14	25	6
14	12	13	11	10	9	8	6	4	18	29	10	21	2	14	25	6	17	28	9	20	1	12	23	4	F	26	7
15	13	14	12	11	10	9	7	5	19	N	11	22	3	F	26	7	18	29	10	21	2	13	24	5	16	27	8
16	14	15	13	12	11	10	8	6	20	1	12	23	4	16	27	8	19	N	11	22	3	14	25	6	17	28	9
17	15	16	14	13	12	11	9	7	21	2	13	24	5	17	28	9	20	1	12	23	4	F	26	7	18	29	10
18	16	17	15	14	13	12	10	8	22	3	14	25	6	18	29	10	21	2	13	24	5	16	27	8	19	N	11
19	17	18	16	15	14	13	11	9	23	4	F	26	7	19	N	11	22	3	14	25	6	17	28	9	20	1	12
20	18	19	17	16	15	14	12	10	24	5	16	27	8	20	1	12	23	4	F	26	7	18	29	10	21	2	13
21	19	20	18	17	16	15	13	11	25	6	17	28	9	21	2	13	24	5	16	27	8	19	N	11	22	3	14
22	20	21	19	18	17	16	14	12	26	7	18	29	10	22	3	14	25	6	17	28	9	20	1	12	23	4	F
23	21	22	20	19	18	17	15	13	27	8	19	N	11	23	4	F	26	7	18	29	10	21	2	13	24	5	16
24	22	23	21	20	19	18	16	14	28	9	20	1	12	24	5	16	27	8	19	N	11	22	3	14	25	6	17
25	23	24	22	21	20	19	17	15	29	10	21	2	13	25	6	17	28	9	20	1	12	23	4	F	26	7	18
26	24	25	23	22	21	20	18	16	N	11	22	3	14	26	7	18	29	10	21	2	13	24	5	16	27	8	19
27	25	26	24	23	22	21	19	17	1	12	23	4	F	27	8	19	N	11	22	3	14	25	6	17	28	9	20
28	26	27	25	24	23	22	20	18	2	13	24	5	16	28	9	20	1	12	23	4	F	26	7	18	29	10	21
29	27	28	26	25	24	23	21	19	3	14	25	6	17	29	10	21	2	13	24	5	16	27	8	19	N	11	22
30	28	29	27	26	25	24	22	20	4	F	26	7	18	N	11	22	3	14	25	6	17	28	9	20	1	12	23

Explanation of the Tables.—By Tables I. and II. the mean age of the moon, at any given time, may be found to the nearest minute, by adding the epacts of the given year and month, and the proposed time reduced to the meridian of Greenwich. If this sum exceeds a mean lunation, or 29^d 12^h 44′, deduct it therefrom. The mean time of new moon is found by subtracting the sum of the epacts of the given year and month, from 29^d 12^h 44′; but if greater than that quantity, subtract it from 59^d 1^h 29′, to which add the longitude, in time, if east, but subtract it if west. The mean time of the preceding, or following full moon, is found by subtracting, or adding 14^d 18^h 22′; and the quarters, by applying 7^d 9^h 11′. See Epact and *Metonic* Cycle.

By Table III. the moon's age is found by inspection only, from the year 1800 until 1894, inclusive; and the method of extending it a few years before or after the limits of the table is obvious.

This table is divided into two parts; the first of which contains the months and days, and the other the years, with the moon's age. In this last part, N stands for new moon, and F for full moon. In order, therefore, to find the moon's age on any given day of any given year, within the limits of the table, find the proposed day under the given month, then, on the same horizontal line, and under the given year, is the moon's age required. Thus, March 12th, 1869, it is a new moon, and on the 18th of the same month, in the year 1878, it is full moon.

The epact for any given year within the limits of the table, is found at the bottom of the column immediately under the given year. Thus the epact for the year 1850 is 17. Mackay's Complete Navigator.

To find the Time of the Moon's being in the Meridian, or Southing.—Multiply her age by 4, and divide the product by 5: the quotient gives the hour, and the remainder, multiplied by 12, the minute.

The reason of this rule is, that as the moon at the change comes to the south with the sun, or at twelve o'clock, and as there are thirty days, nearly, from one new moon to another, and twenty-four hours in a day; therefore she loses one day with another $\frac{24}{30}$ths, or $\frac{4}{5}$ths of an hour in the time of her southing: now the moon's age, a number of days from the change, being multiplied by four, the product is so many fifths of an hour as she has lost, which, divided by five, is reduced to hours, and the remainder, if any, multiplied by 12, will be minutes.

Moon, *For the Eclipses of the,* see Eclipses.

For the Moon's *Parallax,* see Parallax.

Moon, *Nature and Furniture of the.* 1. From the various phases of the moon: from her only shewing a little part illumined, when following the sun ready to set: from that part's increasing as she recedes from the sun, till at the distance of 180° she shines with a full face: and again wanes as she re-approaches that luminary, and loses all her light when she meets him: from the lucid parts being constantly turned towards the west, while the moon increases; and towards the east when she decreases: it is evident, that only that part shines on which the sun's rays fall. And, from the phenomena of eclipses happening when the moon should shine with a full face; *viz.* when she is 180° distant from the sun; and the darkened parts appearing the same in all places; it is evident she has no light of her own, but borrows whatever light she has from the sun; for if she did, being globular, we should always see her with a round full orb, like the sun.

2. The moon sometimes disappears in a clear heaven, so as not to be discoverable by the best glasses; little stars of the fifth and sixth magnitude all the time remaining visible. This phenomenon Kepler observed twice, anno 1580 and 1583, and Hevelius in 1620. Ricciolus, and other Jesuits at Bologna, and many people throughout Holland, observed the like April 14, 1642, yet at Venice and Vienna she was all the time conspicuous. December 23, 1703, there was another total obscuration. At Arles she first appeared of a yellowish-brown; at Avignon ruddy and transparent, as if the sun had shone through; at Marseilles, one part was reddish, the other very dusky; and, at length, though in a clear sky, she wholly disappeared. Here it is evident that the colours appearing different at the same time, do not belong to the moon; but they are probably occasioned by our atmosphere, which is variously disposed, at different times, for refracting of these or those coloured rays.

3. The eye, either naked, or armed with a telescope, sees some parts in the moon's face darker than others, which are called *maculæ*, or *spots*. Through the telescope, while the moon is either increasing or decreasing, the illuminated parts in the maculæ appear evenly terminated; but in the bright parts, the boundary of the light appears jagged and uneven, composed of dissimilar arches, convex and concave. (See *Plate* XVII. *Astron. fig.* 13.) There are also observed lucid parts dispersed among the darker; and illumined parts are seen beyond the limits of illumination; other intermediate ones remaining still in darkness; and near the maculæ, and even in them, are frequently seen such lucid specks. Beside the maculæ observed by the ancients, there are other variable ones, invisible to the naked eye, called *new maculæ*, always opposite to the sun; and which are hence found among those parts which are the soonest illumined in the increasing moon, and in the decreasing moon lose their light later than the intermediate ones; running round, and appearing sometimes longer sometimes smaller.

Hence, 1. As all parts are equally illumined by the sun, inasmuch as they are equally distant from him: if some appear brighter, and others darker; some reflect the sun's rays more copiously than others; and therefore they are of different natures. And, 2. Since the boundary of the illumined part is very smooth and equable in the maculæ, their surface must be so too. 3. The parts illumined by the sun sooner, and deserted later, than others that are nearer, are higher than the rest; *i. e.* they stand up above the other surface of the moon. 4. The new maculæ answer perfectly to the shadows of terrestrial bodies.

4. Hevelius writes, that he has several times found, in skies perfectly clear, when even stars of the sixth and seventh magnitude were conspicuous, that at the same altitude of the moon, and the same elongation from the earth, and with one and the same excellent telescope, the moon and its maculæ do not appear equally lucid, clear and perspicuous, at all times; but are much brighter, purer, and more distinct, at one time than another. From the circumstances of the observation, it is evident the reason of this phenomenon is not either in our air, in the tube, in the moon, or in the spectator's eye; but it must be looked for in something existing about the moon.

5. Cassini frequently observed Saturn, Jupiter, and the fixed stars, when hid by the moon, near her limb, whether the illumined or dark one, to have their circular figure changed into an oval one; and in other occultations he found no alteration of figure at all. In like manner, the sun and moon rising and setting in a vaporous horizon, do not appear circular, but elliptical.

Hence, as we know, by sure experience, that the circular figure of the sun and moon is only changed into an elliptical

tical one by means of the refraction in the vapoury atmosphere; some have concluded, that at the time when the circular figure of the stars is thus changed by the moon, there is a dense matter encompassing the moon, wherein the rays, emitted from the stars, are refracted; and that, at other times, when there is no change of figure, this matter is wanting.

This phenomenon is well illustrated by the following experiment.

To the inner bottom of any vessel, either plain, convex, or concave, with wax fasten a circle of paper; then pouring in water, that the rays, reflected from the circle in the air, may be refracted before they reach the eye; viewing the circle obliquely, the circular figure will appear changed into an ellipsis.

6. The moon, then, is a dense opaque body, furnished with mountains and vallies. That the moon is dense and impervious to the light, has been shewn: but some parts sink below, and others rise above the surface; and that considerably, inasmuch as they are visible at so great a distance as that of the earth from the moon; whence it has been concluded that in the moon there are high mountains, and very deep vallies. Ricciolus measured the height of one of the mountains, called St. Catharine, and found it (as he conceived) nine miles high. The method of measuring the height of the lunar mountains is as follows. Suppose E D (*fig.* 14.) the moon's diameter, E C D the boundary of light and darkness, and A the top of a hill in the dark part beginning to be illumined: with a telescope and micrometer observe the proportion of A E, or the distance of A from the line where the light commences to the diameter E D; here we have two sides of a rectangled triangle A E, C E; the squares of which added together give the square of the third; whence the semi-diameter C B being subtracted, leaves A B, the height of the mountain.

Ricciolus, *v. gr.* found the top of the mount St. Catharine illumined at the distance of $\frac{1}{16}$th of the moon's diameter from the confines of light. Supposing, therefore, C E 8, and A E 1, the squares of the two will be 65, whose root is 8.062, the length of A C; subtracting, therefore, B C = 8, the remainder is A B = 0.062. The moon's semi-diameter, therefore, is to the mountain's height as 8 is to 0.062; *i. e.* as 8000 to 62. Supposing, therefore, the semi-diameter of the moon 1182 English miles, by the rule of three we find the height of the mountain 9 miles.

Galileo takes the distance of the top of a lunar mountain from the line that divides the illumined part of the disc from that which is in the shade to be equal to a 20th part of the moon's diameter; but Hevelius affirms, that it is only the 26th part of the same. If we calculate, in the manner above stated, the height of such a mountain, it will be found, in English measure, according to Galileo, almost $5\frac{1}{2}$ miles; and, according to Hevelius, somewhat more than $3\frac{1}{2}$ miles, admitting the moon's diameter to be 2180 miles. The observations of Hevelius have been always held in great esteem; and this is probably the reason why later astronomers have not repeated them. M. de la Lande, one of the most eminent modern astronomers, concurs in his sentiments. Mr. Ferguson says, that some of the mountains of the moon, by comparing their height with her diameter, are found to be three times higher than the highest hills on our earth; and Keill, in his "Astronomical Lectures," has calculated the height of St. Catharine's hill, according to the observations of Ricciolus, in the manner above stated, and finds it nine miles. Dr. Herschel, the most accurate as well as industrious observer of modern times, has directed his attention to this subject. He observes, with regard to the method pursued by Hevelius, that it will only avail when the moon is in her quadratures; for in all other positions, the projection of the hills must appear much shorter than it really is. Let S L M, or *s l m* (*fig.* 15.) be a line drawn from the sun to the mountain, touching the moon at L or *l*, and the mountain at M or *m*. Then to an observer at E or *e*, the lines L M, or *l m*, will not appear of the same length, though the mountains should be of an equal height; for L M will be projected into *o n*, and *l m* into O N. But these are the quantities that are taken by the micrometer, when we observe a mountain to project from the line of illumination. From the observed quantity *o n*, when the moon is not in her quadrature, to find L M we have the following analogy. The triangles *o* O L, *r* M L, are similar; therefore, $L\,o : L\,O :: L\,r : L\,M$, or $\frac{L\,O \times on}{L\,o} = L\,M$: but L O is the radius of the moon, and L *r*, or *o n*, is the observed distance of the moon's projection, and L *o* is the sine of the angle R O L = *o* L S, which we may take to be the distance of the sun from the moon, without any material error, and which, therefore, we may find at any given time from an ephemeris.

E.G. On June, 1780, at seven o'clock, Dr. Herschel found the angle under which L M, or L *r* appeared, to be 40″.625, for a mountain in the south-east quadrant; and the sun's distance from the moon was 125° 8′, whose sine is .8104; hence, 40″.625 divided by .8104, gives 50″.13, the angle under which L M would appear, if seen directly. Now the semi-diameter of the moon was 16′ 2″.6, and taking its length to be 1090 miles, we have 16′ 2″.6 : 50″.13 :: 1090 : L M = 56.73 miles; hence, M *p* = 1.47 miles.

The instrument used by Dr. Herschel in his observations was a Newtonian reflector of six feet eight inches focal length, to which a micrometer was adapted consisting of two parallel hairs, one of which was moveable by means of a fine screw. His observations were numerous, and from the result of all, he concludes, that the height of the lunar mountains in general is greatly overrated; and that, with the exception of a few, they do not generally exceed half a mile in their perpendicular elevation. Our author had not an opportunity of particularly observing the three mountains mentioned by Hevelius; nor that which Ricciolus found to project a sixteenth part of the moon's diameter. If Keill, he says, had calculated the height of this hill according to the theorem which he has given, he would have found (supposing the observation to have been made, as he says, on the fourth day after new moon) that its perpendicular height could not well be less than between 11 and 12 miles. Phil. Trans. vol. lxx. pt. 2. art. 29.

The heights, &c. of the lunar mountains being measurable, astronomers have taken occasion to give each its name. Ricciolus, whom most others now follow, distinguished them by the names of celebrated astronomers; and by these names they are still expressed in observations of the lunar eclipses, &c. (See *fig.* 16.) For an account of the VOLCANOS *in the Moon*, see that article. See also *Lunar* SPOTS.

Astronomers are now generally of opinion, that the moon has no atmosphere of any visible density surrounding her, as we have: for if she had, we could never see her edge so well defined as it appears: but there would be a sort of mist or haziness around her, which would make the stars look fainter, when they are seen through it. But observation proves, that the stars which disappear behind the moon retain their full lustre until they seem to touch her very edge, and then they vanish in a moment. This has been often observed by astronomers, but particularly by Cassini of the star γ in the breast of Virgo, which appears single and round to the bare

eye;

eye; but through a refracting teleſcope of fixteen 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 twelve at night, the moſt weſterly of theſe ſtars was hid by the dark edge of the moon; and in 30 ſeconds afterward, the moſt eaſterly ſtar was hid: each of them diſappearing behind the moon in an inſtant, without any preceding diminution of magnitude or brightneſs; which by no means could have been the caſe if there were an atmoſphere round the moon; for then, one of the ſtars falling obliquely into it before the other, ought by refraction to have ſuffered ſome change in its colour, or in its diſtance from the other ſtar, which was not yet entered into the atmoſphere. But no ſuch alteration could be perceived, though the obſervation was performed with the utmoſt attention to that particular; and was very proper to have made ſuch a diſcovery. The faint light, which has been ſeen all around the moon, in total eclipſes of the ſun, has been obſerved, during the time of darkneſs, to have its centre coincident with the centre of the ſun; and was therefore much more likely to ariſe from the atmoſphere of the ſun, than from that of the moon; for if it had been owing to the latter, its centre would have gone along with the moon's.

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.

There being no atmoſphere about the moon, the heavens in the day time have the appearance of night to a lunarian who turns his back towards the ſun; and when he does, the ſtars appear as bright to him as they do in the night to us. For it is entirely owing to our atmoſphere that the heavens are bright about us in the day. Some, however, have ſuſpected that at an occultation of a fixed ſtar by the moon, the ſtar did not vaniſh inſtantly; whilſt the general opinion has been that which we have above ſtated. Mr. Schroeter, of Lilienthal, in the duchy of Bremen, has endeavoured to eſtabliſh the exiſtence of an atmoſphere from the following obſervations. 1. He obſerved the moon when two days and an half old, in the evening ſoon after ſun-ſet, before the dark part was viſible, and continued to obſerve it till it became viſible. The two cuſps appeared tapering in a very ſharp, faint prolongation, each exhibiting its fartheſt extremity faintly illuminated by the ſolar rays, before any part of the dark hemiſphere was viſible. Soon after, the whole dark limb appeared illuminated. This prolongation of the cuſps beyond the ſemicircle, he thinks, muſt ariſe from the refraction of the ſun's rays by the moon's atmoſphere. He computes alſo the height of the atmoſphere, which refracts light enough into its dark hemiſphere to produce a twilight, more luminous than the light reflected from the earth when the moon is about 32° from the new, to be 1356 Paris feet; and that the greateſt height capable of refracting the ſolar rays is 5376 feet. 2. At an occultation of Jupiter's ſatellites, the third diſappeared, after having been about $1''$ or $2''$ of time indiſtinct; the fourth became indiſcernible near the limb; this was not obſerved of the other two. Phil. Tranſ. vol. lxxxii. pt. 2. art. 16.

MOON, *As to the Influence of the*, on the changes of our weather, and the conſtitution of the human body, we ſhall obſerve that the vulgar doctrine concerning it is very ancient, and has gained credit among the learned, without ſufficient examination; but it is now generally exploded by philoſophers, as equally deſtitute of all foundation in phyſical theory, and unſupported by any plauſible analogy. The common opinion is, that the lunar influence is exerted at the ſyzygies and quadratures, and for three days before and after each of thoſe epochs. There are twenty-four days, therefore, in each ſynodic month, over which the moon at this rate is ſuppoſed to preſide, and as the whole conſiſts but of 29 days, $12\frac{3}{4}$ hours, only $5\frac{1}{2}$ days are exempt from her pretended dominion. Hence, though the changes of the weather ſhould happen to have no connection whatever with the moon's aſpects, and they ſhould be diſtributed in an equal proportion through the whole ſynodic month; yet any one who ſhall predict, that a change ſhall happen on ſome one of the twenty-four days aſſigned, rather than in any of the remaining $5\frac{1}{2}$, will always have the chances 24 to $5\frac{1}{2}$ in his favour. Men may, therefore, eaſily deceive themſelves, eſpecially in ſo unſettled a climate as ours. Moreover, the writers who treat of the ſigns of the weather, derive their prognoſtics from circumſtances, which neither argue any real influence of the moon as a cauſe, nor any belief of ſuch an influence, but are merely indications of the ſtate of the air at the time of obſervation: ſuch are, the ſhape of the horns, the degree and colour of the light, and the number and quality of the luminous circles which ſometimes ſurround the moon, and the circumſtances attending their diſappearance. (See the Διοσημεια of Aratus, and the Scholia of Theon.) The vulgar ſoon began to conſider thoſe things as cauſes, which had been propoſed to them only as ſigns: and the notion of the moon's influence on all terreſtrial things was confirmed by her manifeſt effect upon the ocean. See on this ſubject, Phil. Tranſ. vol. lxv. part 2. p. 178, &c.

The famous Dr. Mead was a believer in the influence of the ſun and moon on the human body, and publiſhed a book to this purpoſe, intitled "De Imperio Solis ac Lunæ in Corpore humano:" but this opinion has been exploded by philoſophers, as equally unreaſonable in itſelf, and contrary to fact. As the moſt accurate and ſenſible barometer is not affected by the various poſitions of the moon, it is not likely that the human body ſhould be affected by them. See LUNATIC.

MOON, *Harveſt*. It is remarkable, that the moon, during the week in which ſhe is full in harveſt, riſes ſooner after ſun-ſetting than ſhe does in any other full-moon week in the year. By doing ſo, ſhe affords an immediate ſupply of light after ſun-ſet, which is very beneficial to the farmers for reaping and gathering in the fruits of the earth: and therefore they diſtinguiſh *this* full moon from all the others in the year, by calling it the *harveſt-moon*. Mr. Ferguſon has given a full account of the harveſt-moon in his Aſtronomy; the ſubſtance of which is as follows, in a problem on the common celeſtial globe.

Make

Make chalk-marks all round the globe, on the ecliptic, at 12$\frac{1}{6}$ degrees from each other (beginning at Capricorn) which is equal to the moon's daily mean motion from the ſun: then elevate the north pole of the globe to the latitude of any place in Europe; ſuppoſe London, whoſe latitude is 51$\frac{1}{4}$ degrees north.

This done, turn the ball of the globe round, weſtward, in its frame; and you will ſee that different parts of the ecliptic make very different angles with the horizon, as theſe parts riſe in the eaſt: and therefore, in equal times, very unequal portions of the ecliptic will riſe. About Piſces and Aries, ſeven of theſe chalk-marks will riſe in little more than two hours, as meaſured by the motion of the index on the horary circle: but, about the oppoſite ſigns, Virgo and Libra, the index will go over eight hours in the times that ſeven marks will riſe. The intermediate ſigns will more or leſs partake of theſe differences as they are more or leſs remote from thoſe above-mentioned.

Hence it is plain that when the moon is in Piſces and Aries, the difference of her riſing will be little more than two hours in ſeven days; but in Virgo and Libra it will be eight hours in ſeven days: and this happens every month of the year, becauſe the moon goes through all the ſigns of the ecliptic in a month, or rather in 27 days, 8 hours.

The moon is always oppoſite to the ſun when ſhe is full, and the ſun is never in Virgo and Libra but in our harveſt months; and, therefore, the moon is never full in Piſces and Aries (which are the ſigns oppoſite to Virgo and Libra) but in our harveſt months. Conſequently, when the moon is about her full in harveſt, ſhe riſes with leſs difference of time, or more immediately after ſun-ſet, than when ſhe is full in any other month of the year. In our winter, the moon is in Piſces and Aries about the time of her firſt quarter, and riſes about noon; but her riſing is not then taken notice of, becauſe the ſun is above the horizon.

In ſpring the moon is in Piſces and Aries about the time of her change; and then, as ſhe gives no light, and riſes with the ſun, her riſing cannot be perceived.

In ſummer, the moon is in Piſces and Aries about the time of her laſt quarter; and then, as ſhe is on the decreaſe, and riſes not till midnight, her riſing generally paſſes unobſerved.

But in harveſt, the moon is full in Piſces and Aries (theſe ſigns being oppoſite to the ſun in our autumnal months) and riſes ſoon after ſun-ſet for ſeveral evenings ſucceſſively; which makes her regular riſing very conſpicuous at that time of the year, as it is ſo beneficial then to the farmers in affording them an immediate ſupply of light after the going down of the ſun.

This would always be the caſe if the moon's orbit lay in the plane of the ecliptic. But as the moon moves in an orbit which makes an angle of 5 degrees 18 minutes with the ecliptic, and croſſes it only in the two oppoſite points called the nodes, her riſing when in Piſces and Aries, will ſometimes not differ above an hour and forty minutes through the whole of ſeven days; and at other times, in the ſame two ſigns, ſhe will differ three hours and a half in the time of her riſing in a week, according to the different poſitions of the nodes with reſpect to theſe ſigns; which poſitions are conſtantly changing, becauſe the nodes go backward through the whole ecliptic in 18 years and 225 days.

This revolution of the nodes will cauſe the harveſt moons to go through a whole courſe of the moſt and leaſt beneficial ſtates with reſpect to the farmers every nineteen years. 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 1807 to 1861. The columns 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 gradually deſcend in the lunar orbit, and riſe to leſs heights above the horizon. From S to N, they aſcend in the like 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 in the columns under N, the reverſe. And in both theſe caſes, their riſings, though not at the ſame time, are nearly the ſame with regard to the difference of time, as if the moon's orbit were coincident with the ecliptic.

Years in which the harveſt moons are leaſt beneficial.

N				L				S
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	
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	

We may obſerve farther, that in ſummer with us the full moons are low, and their ſtay is ſhort above the horizon, when the nights are ſhort and we have the 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. Moreover 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 fourteen 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 fourteen 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.

MOON, *Acceleration of the.* See ACCELERATION.

MOON-*Dial.* See DIAL.

MOON, *Horizontal.* See *Apparent* MAGNITUDE.

MOON, *Prime of the.* See PRIME.

MOON-*Eyes*, in the *Manege.* A horſe is ſaid to have moon-eyes when the weakneſs of his eyes increaſes or decreaſes according to the courſe of the moon; ſo that in the wane of the moon his eyes are muddy and troubled, and at new moon they clear up; but ſtill he is in danger of loſing his eye-ſight quite.

MOON-