

**The cyclopædia; or, Universal dictionary of arts, sciences, and literature.  
by Abraham Rees ... with the assistance of eminent professional  
gentlemen ...**

Rees, Abraham, 1743-1825.

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invented the mood we call *imperative*; which has no first person in the singular, because a man, properly speaking, cannot command himself; in some languages it has no third person, because, in strictness, a man cannot command any person, but him to whom he speaks and addresses himself. And because the command or prayer always relates to what is to come, it happens that the imperative mood, and the future tense, are frequently used for each other (especially in the Hebrew); as, *non occides, thou shalt not kill, for do not kill*. Hence some grammarians place the imperative among the number of futures.

Of all the moods we have mentioned, the oriental languages have none but the last, 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 English, is either to omit the pronoun, or transpose it: thus, I love, is a simple affirmation; love, an imperative; we love, an affirmation; love we, an imperative. An infinitive verb is sometimes used by the poets to express a command; the imperative verb being understood.

In explaining the origin of moods, the ingenious Mr. Harris observes, that the soul's leading powers are those of perception and volition; and that all speech or discourse is a publishing 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 simply declare or indicate something to be, or not to be, whether a perception or volition, this constitutes the *declarative* or *indicative* mood. If we assert of something possible only, and in the number of contingents, this makes the *potential* mood. When this is subjoined to the indicative, and used, as it mostly is, to denote the end or final cause, it is the *subjunctive*. When we address others, in order to have some perception informed, or some volition gratified, we form new modes of speaking: if we interrogate, it is the *interrogative* mood: if we require, it is the *requisitive*, which, with respect to inferiors, is *imperative*; and, with respect to equals and superiors, *precative* or *optative*. The indicative, potential, interrogative, and requisitive moods, have their foundation in nature; and, therefore, certain marks or signs of them have been introduced into language, that we may be enabled by our discourse to signify them to one another; so that moods are, in fact, no more than so many literal forms, intended to express these natural distinctions. All these moods, with their respective tenses, the verb being considered as denoting an attribute, have always reference to some person or substance. But there is another mood or form, under which verbs sometimes appear, where they have no reference at all to persons or substances: these, from their indefinite nature, are called *infinitives*. Hermes, p. 140, &c.

MOOD, or *Mode*, in our old *Musical*, was a term only applied to the divisions of time or measure, which was so embarrassing a study, that a very considerable portion of Morley's treatise is bestowed on that subject. Previous to the use of bars, all measures, however complicated, were determined by the modal signs placed after the clef of every composition. These signs were circles, semicircles, pointed, or without points, followed by the figures 2 or 3 differently combined. See *MODE*, *MODAL*, and *PROLATION*.

Rouffseau gives twelve examples of ancient characters of quantity; but as these were characters referred to notes now out of use, as the *maxima*, the *long*, and the *breve*, these explanations can be of little consequence but to those who are ambitious of knowing the state of measured music at every period of its cultivation.

MOOD, in *Philosophy* and *Musical*. See *MODE*.  
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MOODUL, in *Geography*, a town of Hindoostan, in Vifapour; 13 miles S.S.W. of Galgala.

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

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

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

MOOGRY, a town of Hindoostan, in Vifapour; 31 miles W. of Poonah.

MOOKANOR, a town of Hindoostan, in Baramaul; 18 miles S.S.W. of Darempoor.

MOOKER, a town of Cabulistan; 40 miles from Ghizni. —Also, a town of Hindoostan, in Madura; 40 miles E. of Coilpetta.

MOOKI, a sea-port town of Japan, in a bay on the S.E. coast of the island of Nippon; 80 miles S.E. of Jedo. N. lat. 35° 30'. E. long. 40° 40'.

MOOLA, a town of Hindoostan, in Vifapour; 10 miles E. of Poonah.

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

MOON, LUNA, ☾, in *Astronomy*, one of the heavenly bodies belonging to that class of planets, accounted satellites or secondary planets.

The moon is an attendant of our earth, which she respects as a centre, and in whose neighbourhood she is constantly found; inasmuch as, if viewed from the sun, she would never appear to depart from us by an angle greater than ten minutes.

As all the other planets move primarily round the sun, so does the moon round the earth: her orbit is an ellipse, in which she 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 sun with it every year; she goes round her orbit in 27 days, 7 hours, 43 minutes, 5 seconds, moving about 2290 miles every hour; and turns round her axis in the time that she goes round the earth, which is the reason of her keeping always the same side towards us; and that her day and night taken together are as long as our lunar month. See *LIBRATION of the Moon*.

The mean distance of the moon from the earth is 60½ semi-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 (see *PARALLAX*); therefore, the magnitude of the earth is to that of the moon as 1 : 0.02028, or very nearly as 49 : 1; and the density of the moon being to that of the sun as 2.44 : 1, and the density of the sun being to that of the earth as 0.252 : 1, it follows that the density 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 some authors, we assume the density of the moon to that of the sun as 2.5 : 1, the quantity of matter in the earth is to that in the moon as 78 : 1, or 1 : 0.128. Also, 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 seen 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 opposition: its mean diameter being nearly equal to the least apparent diameter of the sun, it may be taken at 31' 8", and that of the sun at 32' 2". M. de la Lande makes it to be 31' 26". (See *DECLINATION* and *DIAMETER*.) Its mean diameter, as seen from the sun, is 4".6. The mean diameter, in English miles, is 2180. The mean diameter,  
H as

# MOON.

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 apses 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  $90^\circ$  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 apses 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  $13^\circ 10' 35''$ , and the mean hourly motion  $32' 56'' 27''' \frac{1}{2}$ . M. de la Lande makes the mean diurnal motion  $13^\circ 10' 35''.02784394$ . 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  $19^\circ 23'$ . 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  $19^\circ 19'$ . Mayer makes the mean annual motion of the nodes to be  $12^\circ 19' 43''.1$ . 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  $3^\circ 2' 32''.3916$ ; hence,  $27^d 7^h 43' : 365^d 6^h 9' :: 3^\circ 2' 32''.3916 : 40^\circ 40' 20''$  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  $40^\circ 39' 50''$ , 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	-	-	$8^s 311 8 34 57.6177$
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	-	-	$13^\circ 10' 35''.02784394$
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

# MOON.

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

Sig. O. VI. +			Sig. I. VII. +		Sig. II. VIII. +		
Ann. Arg.	Equation of D's Apogee.	Eccentricity of the Moon's Orbit.	Equation of D's Apogee.	Eccentricity of the Moon's Orbit.	Equation of D's Apogee.	Eccentricity 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 35	.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 "Astronomical Tables;" the argument, called the "annual argument," is the distance of the sun from the mean place of the apogee corrected by its annual equation.

## MOON.

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 illumined 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 illumined 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 *quadrate*.

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

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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 illuminated 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 semi-circle  $O C P$  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-ellipse  $B F C$ ; this ellipse will cut off from the moon's disc the portion  $B F C P$ , of the illuminated face visible on the earth. In other words, the visible illuminated part varies as  $F P$ , the versed sine of elongation; and we shall have the visible illuminated 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 illuminated 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; and 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 phosphorenc 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 phosphorency 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

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tion 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 goodly 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  $49\frac{21}{100}$  fifths past I, where they meet; at the second conjunction it is 10 minutes 54 seconds 32 thirds 43 fourths  $38\frac{43}{100}$  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  $12\frac{1}{2}$  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  $12\frac{1}{2}$  conjunctions with it; and so would be a pretty device for shewing the motions of the sun and moon; especially as the slowest moving hand might have a little sun fixed on its point, and the quickest a little moon.

Conj.	H.	M.	S.	'''	''''	v p <sup>ts</sup> .
1	I	5	27	16	21	$49\frac{21}{100}$
2	II	10	54	32	43	$38\frac{43}{100}$
3	III	16	21	49	5	$27\frac{3}{100}$
4	IV	21	49	5	27	$16\frac{21}{100}$
5	V	27	10	21	49	$5\frac{27}{100}$
6	VI	32	43	38	10	$54\frac{6}{100}$
7	VII	38	10	54	32	$43\frac{7}{100}$
8	VIII	43	38	10	54	$32\frac{10}{100}$
9	IX	49	5	27	16	$21\frac{49}{100}$
10	X	54	32	43	38	$10\frac{54}{100}$
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*;

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

If the line of the nodes were immovable, that is, if it had no other motion but that by which it is carried round the sun, it would still look towards the same point of the ecliptic; *i. e.* it would always keep parallel to itself; but it is found by observation, that the line of the nodes constantly changes place, and shifts in situation from east to west, contrary to the order of the signs; and, by a retrograde motion, finishes 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 precisely in the ecliptic, but twice each period; *viz.* when she is in the nodes. Throughout the rest of her course she deviates from it, being nearer or farther from the ecliptic, as she is nearer or farther from the nodes. In the points F and E she is at her greatest distance from the nodes; which points are therefore called her *limits of north and south latitude*.

The moon's distance from the nodes, or rather from the ecliptic, is called her *latitude*, which is measured 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 greatest, as in E or F, never exceeds 5 degrees and about 18 minutes; which latitude is the measure of the angles at the nodes.

It appears by observation, that the moon's distance from the earth is continually changing; and that she is always either drawing nearer, or going farther from us. The reason is, that the moon does not move in a circular orbit, which has the earth for its centre; but in an elliptic orbit (as represented in *fig. 8.*), one of whose foci is the centre of the earth: A P represents the greater axis of the ellipsis, and the line of the apses; and T C the excentricity; the point A, which is the highest apsis, is called the *apogee* of the moon; and P, the lower apsis, is the moon's *perigee*, or the point in which she comes nearest the earth.

Besides, there is reason to believe, that the moon is somewhat nearer the earth now than she was formerly; her periodical month being shorter than it was in former ages. For our astronomical tables, which in the present age shew the time of solar and lunar eclipses to great precision, do not answer so well for ancient eclipses.

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

If the moon's orbit had no other motion but that with which it is carried round the sun, it would still retain a position parallel to itself, and always point the same way, and be observed in the same point of the ecliptic; but the line of the apses is likewise observed to be moveable, and to have an angular motion round the earth, from west to east, according to the order of the signs, returning to the same situation in the space of about nine years.

The *irregularities of the moon's motion*, and that of her orbit, are very considerable. For, 1. When the earth is in her aphelion, the moon is in her aphelion likewise; in which case she quickens her pace, and performs her circuit in a shorter time: on the contrary, when the earth is in its perihelion, the moon is so too, and then she slackens her motion: and thus she revolves round the earth, in a shorter space, when the earth is in her aphelion than when in her perihelion; so that the periodical months are not all equal.

2. When the moon is in her syzygies, *i. e.* in the line that joins the centres of the earth and sun, which is either in her

conjunction or opposition, she moves swifter, *ceteris paribus*, than when in the quadratures.

3. According to the different distances of the moon from the syzygies, *i. e.* from opposition to conjunction, she changes her motion: in the first quarter, that is, from the conjunction to her first quadrature, she abates somewhat of her velocity; which in the second quarter she recovers; in the third quarter she again loses; and in the last she again recovers. Hence the areas described are accelerated and retarded; and the mean place differs from the true. This inequality was first discovered by Tycho Brahe, who called it *the moon's variation*. At different distances of the earth from the sun, the disturbing forces vary, and, therefore, the equation, called the "variation," being first calculated for the mean distance of the earth from the sun, will be subject to a variation from the variation of that distance; and hence some new equations will arise.

4. The moon moves in an ellipsis, one of whose foci is in the centre of the earth, round which she describes areas proportionable to the times, as the primary planets do round the sun; whence the motion in her perigee must be quickest, and it must be slowest in the apogee.

5. The very orbit of the moon is changeable, and does not always preserve the same figure; its excentricity being sometimes increased, and sometimes diminished: it is greatest, when the line of the apses coincides with that of the syzygies; and least, when the line of the apses cuts the other at right angles.

The moon's orbit being dilated or contracted as the earth approaches to or recedes from the sun, its motion will accordingly be diminished or increased; and hence arises an annual equation, assigning the difference between the mean motion at the mean distance of the earth from the sun, and the mean motion at any other distance of the sun. The variation depending on the true distance of the sun from the moon, will produce several other equations, arising from the different corrections that are made. The change of the excentricity causes a change of the *equation of the centre*, called the *evulsion*, and hence new equations must be applied. See these terms respectively 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 syzygies; and backward, when it cuts that line at right angles. Nor are this progress and regress in any measure equal; in the conjunction or opposition, it goes briskly forward; and in the quadratures it moves either slowly forward, stands still, or goes backwards. Upon the whole, however, the motion of the apogee is progressive. Hence arises an equation of the motion of the apogee, which depends upon its distance from the sun; and there is also a smaller annual equation, arising from the disturbing 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 syzygies at right angles, they go backward, from east to west; and thus, sir Isaac Newton shews, 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 she turns round her axis exactly in the same space of time in which she revolves round us in her orbit; whence it happens, that she always turns the same 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 swiftest in its orbit, that part of its surface, which, on account of its



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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 erroneous 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 perturbing 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

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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  $\frac{1}{33}$  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  $15\frac{1}{2}$  feet, nearly: or L D may be found without tables thus; the whole circumference of the moon's orbit, or  $60 \times 123249600$ , 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, L C = L D  $\times$  2 L T, *i. e.* L D =  $\frac{L C^2}{2 L T}$ , 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  $177\frac{1}{2}$  to  $178\frac{1}{2}$ , 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  $60 \times 60 \times 15\frac{1}{12}$  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  $60 \times 60 \times 15\frac{1}{12}$  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  $178\frac{2}{3}$ . 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 from 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

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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 apses 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 apses 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 apses 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 apses exceeds the retrograde motion; and, therefore, the apses are carried round according to the order of the signs. The annual equation of the apses, 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<sup>o</sup> 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, *a 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, dilates 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 eccentricity 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 eccentricity  $16\frac{1}{2}$ . 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

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and nodes occasion, are to  $2^{\circ} 56' 9''$ , 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 *femestris*, 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 femestris*, 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 *femestris*, or *femimenstrual*. The greatest semimenstrual equation is about  $12^{\circ} 18'$ .

Horrox first observed the moon to revolve in an ellipse round the earth placed in the lower umbilicus: and Halley placed the centre of the ellipse 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 regresses 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 (*Plat. 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 line of the greatest semimenstrual equation  $12^{\circ} 18'$ , 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  $365^{\circ}$ ; 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 its own apogee, conjunctly, i. e. as  $33\frac{1}{2}$  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 11723, and the right line DF 35. 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

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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  $abcde$ . The former will be a true representation of the earth's path for one lunation, and the latter of the moon's for that time. Here we may set aside the inequalities of the moon's 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  $A B C D E$ , with the numeral figures set to it, represents as much of the earth's annual orbit as it describes in 32 days from west to east; the little circles at  $a, b, c, d, e$ , shew the moon's orbit in due proportion to the earth's; and the smallest curve  $abcdef$  represents the line of the moon's path in the heavens for 32 days, accounted from any particular new moon at  $a$ .

The 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

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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, she 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

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and description 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 sun.

Let S (fig. 11.) represent the sun; E the earth; E s an arc of the orbit of the earth passed over by its centre, in one lunation of the moon; the circumference of the circle E A F = the concentric arc A a; then, (because 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 sun, the distance between the sun and moon will be greater than the distance or radius S A. Now the curve, described by the centre of the moon, is the same as that described by a point M (E M being the semi-diameter of the moon's orbit), carried round by the rotation of the circle E A F on the arc A a: it is therefore of the cycloidal kind, having a point of inflexion, if every cycloid, described by a point within the generating circle, is inflected, as well upon a circular as upon a rectilinear base. 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, must pass through the point of contact R. Suppose the point n indefinitely near to m; then, R r and R r being the indefinitely small contemporary arcs with m n, and, consequently, the triangles R m r and R n r equal in all respects; if we consider the said little arcs R r and R r as little right lines perpendicular to the radii e r and S r, we shall have the  $\angle m R n = \angle r R r$  (because the angles e R r and S R r, added to either side of the equation, make it two right angles)  $\angle R e r + \angle R S r$ . Now S R : e R ::  $\angle R e r$  :  $\angle R S r$ , and S R : S R + R e ::  $\angle R e r$  :  $\angle R S r$ , that is,  $a : a + b :: \angle R e r$  :  $\angle m R n = \frac{a + b}{a} \angle R e r$ . 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 obtuse angle to two right angles, be indefinitely small, they will be proportional to the opposite sides m r, m d, and d r; that is,  $d r : m d :: \angle R m r$  :  $\angle m r d$ ; and  $d r - m d : d r :: \angle R m r - \angle m r d$  :  $\angle R m r$ , that is,  $m R : d R :: \angle R d r$  :  $\angle R n r$ , or,  $r : s :: \frac{1}{2} \angle R e r$  :  $\angle R n r =$

$\frac{s}{2r} \angle R e r$ . And again,  $\angle R C n$  :  $\angle R n C :: R n$  : R C, that is,  $\angle m R n - \angle R n r$  :  $\angle R n r :: R m$  :

R C, or  $\frac{a + b}{a} - \frac{s}{2r} \angle R e r$  :  $\frac{s}{2r} \angle R e r :: r$  : R C  
 $= \frac{a r s}{2 a r + 2 b r - s}$ . Consequently,  $m R + R C = m C$   
 $= \frac{2 a r^2 + 2 b r^2}{2 a r + 2 b r - a s} = \frac{r^2}{r - \frac{a s}{2 a + 2 b}}$  = the radius of

curvature at any point m.

Now, it is evident, that, at the point of inflexion, the radius of curvature must be infinite: or that, on one side of the said point, the expression for the radius of curvature must be affirmative, and on the other negative; therefore,

r must be more than  $\frac{a s}{2 a + 2 b}$  on one side of the said point, and on the other less; and, consequently, at the point of inflexion,  $r = \frac{a s}{2 a + 2 b}$ ; which, substituted for r, makes

$(d m \times m R =) r s - r^2 = \frac{2 a b s^2 + a^2 s^2}{2 a + 2 b} =$  (because

$d m \times m R = f m \times m a =) b^2 - c^2$ ; from which equation we have  $s = \frac{2 a + 2 b \sqrt{b^2 - c^2}}{\sqrt{2 a b + a^2}}$ . Or, to find r, say

$2 a r + 2 b r = a s$ , or  $s = \frac{2 a r + 2 b r}{a}$ ; then  $(d m \times m R =) r s - r^2 = \frac{a r^2 + 2 b r^2}{a} = (f m \times m a =) b^2 - c^2$ ;

which equation gives  $r = \sqrt{\frac{a b^2 - a c^2}{a + 2 b}}$ , when the point m becomes a point of inflexion.

Now, as m R (r) must, by the nature of the circle, always be greater than m a; that is, as  $\sqrt{\frac{a b^2 - a c^2}{a + 2 b}}$  must always be

more than  $b - c$ ; and, consequently,  $\frac{a b^2 - a c^2}{a + 2 b}$  be more

than  $b^2 - c^2$ , that is,  $\frac{a b + a c}{a + 2 b} \times b - c$  be more than  $b^2 - c^2$ ; therefore, c must always be more than  $\frac{b^2}{a + b}$ ; that is, E M must 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 present case, E S, E A, and E M, being as 13.368.1, and  $\frac{13.368}{340}$ , or .039; therefore

E M is less than the said third proportional; and, consequently, the curve M m  $\mu$ , generated by the centre of the moon, has not a point of inflexion, or is no where convex towards the sun. See Fergufon's Astronomy, p. 129, &c. Maclaurin's Account of Sir Isaac Newton's Phil. Disc. book iv. ch. 5. p. 336, &c. 4to. Rowe's Fluxions, p. 127, &c.

MOON, Astronomy of the. 1. To determine the period of the moon's revolution round the earth, or the periodical month; and the time between one opposition and another, or the synodical month.

Since in the middle of a lunar eclipse the moon is opposite to the sun, compute the time between two eclipses, or oppositions, between which there is a great interval of time; and divide this by the number of lunations that have passed in the mean time; the quotient will be the quantity of the synodical month. Compute the sun's mean motion, during the time of the synodical month, and add this to the entire circle described by the moon. Then, as the sum is to 360°, so is the quantity of the synodical month: to the periodical.

Thus, Copernicus, in the year 1500, November 6, at twelve at night, observed an eclipse of the moon at Rome; and August 1, 1523, at 4<sup>h</sup> 25', another at Cracow: hence the quantity of the synodical month is thus determined:

Obs. 2 An. 1523<sup>d</sup> 237<sup>n</sup> 4.25'  
 Obs. 1 An. 1500. 310 2.20

Interval of time An. 22<sup>d</sup> 292<sup>h</sup> 2.5'  
 Add the intercalary days 5

Exact interval An. 22<sup>d</sup> 297<sup>h</sup> 2.5'  
 or 11991005'

Which, divided by 282 months, elapsed in the mean time, gives the quantity of the synodical month 42521' 9'' 9''' ; that is, 29<sup>d</sup> 12<sup>h</sup> 41'.

From.



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

$425^{\text{d}} 24^{\text{h}} 3^{\text{m}} 10^{\text{s}} 9^{\text{m}}.$

That is,  $29^{\text{d}} 11^{\text{h}} 43^{\text{m}} 3^{\text{s}} 10^{\text{m}}.$  But this is less than the true synodical month, which is  $29^{\text{d}} 12^{\text{h}} 44^{\text{m}} 3^{\text{s}}.$

The sun's mean motion in the time  $29^{\text{d}} 6^{\text{h}} 24^{\text{m}} 18^{\text{s}}$

The moon's motion - - - - -  $389^{\text{d}} 6^{\text{h}} 24^{\text{m}} 18^{\text{s}}$

Quantity of the periodical month  $27^{\text{d}} 7^{\text{h}} 43^{\text{m}} 5^{\text{s}}$

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 sun 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  $360^{\circ}$  from the dragon's head, or in what time she goes from, and returns to it: that is, the quantity of the *draconic* 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 *anomalous* 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 mensural 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 mensural 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 mensural 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 mensural

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	18 <sup>d</sup> 13 <sup>h</sup> 37'	B. 1844	10 <sup>d</sup> 22 <sup>h</sup> 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	0 <sup>d</sup> 0 <sup>h</sup> 0'	July	3 <sup>d</sup> 19 <sup>h</sup> 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.



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*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  $\frac{2}{3}$ 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  $180^\circ$  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  $180^\circ$  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 *macule*, or *spots*. Through the telescope, while the moon is either increasing or decreasing, the illumined 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!

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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  $ED$  (*fig. 14.*) the moon's diameter,  $ECD$  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  $AE$ , or the distance of  $A$  from the line where the light commences to the diameter  $ED$ ; here we have two sides of a rectangled triangle  $AE$ ,  $CE$ ; the squares of which added together give the square of the third; whence the semi-diameter  $CB$  being subtracted, leaves  $AB$ , the height of the mountain.

Ricciolus, *v. gr.* found the top of the mount St. Catharine illumined at the distance of  $\frac{1}{7}$ th of the moon's diameter from the confines of light. Supposing, therefore,  $CE = 8$ , and  $AE = 1$ , the squares of the two will be 65, whose root is 8.062, the length of  $AC$ ; subtracting, therefore,  $BC = 8$ , the remainder is  $AB = 0.062$ . 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 26th 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  $SLM$ , or  $s/m$  (*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  $LM$ , or  $l/m$ , will not appear of the same length, though the mountains should be of an equal height; for  $LM$  will be projected into  $on$ , and  $l/m$  into  $ON$ . 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  $on$ , when the moon is not in her quadrature, to find  $LM$  we have the following analogy. The triangles  $oOL$ ,  $rML$ , are similar; there-

fore,  $Lo : LO :: Lr : LM$ , or  $\frac{LO \times on}{Lo} = LM$  :

but  $Lo$  is the radius of the moon, and  $Lr$ , or  $on$ , is the observed distance of the moon's projection, and  $LO$  is the sine of the angle  $ROL = oLS$ , 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  $LM$ , or  $Lr$  appeared, to be  $40''.625$ , for a mountain in the fourth-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  $LM$  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  $16' 2''.6 : 50''.13 :: 1090 : LM = 56.73$  miles; hence,  $Mp = 1.47$  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  $\gamma$  in the breast of Virgo, which appears single and round to the bare

eye; but through a refracting telescope of sixteen 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 com-

putes 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  $32^\circ$  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. Transf. 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,  $12\frac{2}{3}$  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 *Διοσημια* 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. Transf. vol. lxxv. 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  $12\frac{1}{2}$  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  $51\frac{1}{2}$  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-