Since the Publication of the New Chart and Directions of the Entrance into Liverpool, by Lieut. Evans, several alterations have been made in the situation of the Floating Light and Buoys, altho' no change has yet taken place in either Banks or Channels, so that it is necessary to make the following Alterations, &c. in the Directions.

Page.	Line.	
23	8	*for* keep Bidston lighthouse, &c. *read* lead in with the sea lights in one until you pass the two first red buoys on your starboard hand, called the N. W. and N. W. Spit buoys, which have been removed, the former farther out on the same line of bearing, and the latter more to the eastward, then haul to the southward, and keep Bidston lighthouse open to the southward of the Lezza lighthouse, &c.—The N. E. red buoy has been also removed farther northward, and the Gut buoy farther westward.—The N. W. buoy in Formby channel has been removed farther out on the same line of bearing. The sailing directions will be the same.
23	2	*for* Rock & Horse Channels, *read* Horse & Rock Channels—ditto in p. 27, l. 2.
28	2	*for* White house, *read* Seaforth house.
33	22	FLOATING LIGHT, *for* bearing two masts, *read* three masts.
33	24	*for* on this mast the light, &c. *read* a white light is now suspended on each mast.
34	1	*for* is moored under the following angles, 93° 40′ & 46° 30′, *read* it has been removed, and is now moored by the following angles, 92° 34′ and 48° 0′
34	3	*for* the light, &c. *read* Bidston light a little open to the northward of the Lezza light, bearing S. E. ¼ S.
35	1	*for* keep the Floating Light, &c. *read* keep her astern due north.
36	9	*for* take Bidston light a sail's length, &c. *read* steer in with the two sea lights in one, until you open the second Lake light, when haul to the southward to clear the S. W. end of the flats, and anchor according to the directions.
37	13	*for* with a westerly wind, *read* with a leading wind.
38	10	*for* should the wind be even at west, *read* even at W. N. W.
40	9	*for* wind must be nothing to the southward of west, *read* the wind must be nothing to the westward of W. N. W.—Refer to the Chart for the course through the Narrows S. W. by S. on a flood tide.

N. B. The entrance into the Ribble and the north end of the Lytham banks, have been buoy'd since the author's survey.

A

PRACTICAL INTRODUCTION

TO

FINDING THE LONGITUDE AT SEA

BY

LUNAR OBSERVATIONS;

ALSO TO

Spherics and Nautical Astronomy;

IN WHICH ARE CONTAINED

THE BEST METHODS OF ADJUSTING THE SEXTANT,

AND OF OBTAINING THE

LATITUDE OF A SHIP AT SEA BY SUN, MOON AND STAR;

being an improved method of

Taking the Moon's distance from the Sun or Star,

AS ALSO OF

CLEARING THE EFFECT OF PARALLAX AND REFRACTION,

SHEWING BY PROJECTION HOW THE LATTER OPERATE

On the distance from the Ship on the Surface and the Earth's centre:

LIKEWISE,

NEW PARALLECTIC TABLES,

FOR

CLEARING THE EFFECT OF THE THIRD & FOURTH CORRECTIONS.

BY

LIEUT. THOMAS EVANS, ROYAL NAVY.

Liverpool:

PRINTED AND SOLD BY NEVETTS, CASTLE STREET,

And may also be had at the different Navigation Shops.

1814.

Entered at Stationer's Hall.

TO THE

RIGHT HONORABLE

LORD VISCOUNT MELVILLE,

FIRST LORD OF THE ADMIRALTY.

My Lord,

As your Lordship presides over the first Navy in the universe, in a Country eminent for its discoveries both in Arts and Sciences, any work that has for its object the improvement of Navigation, will, doubtless, be favorably received by your Lordship. The high compliment which your Lordship was pleased to pay my feeble talent in the Surveying Department, induced me to present your Lordship with this Introduction to Nautical Astronomy: it is my researches of twenty years' practice on the Lunar Observations, wherein new precepts are given for clearing the effect of parallax and refraction on the distance; likewise a fresh birth to the understanding through projection, which serves to simplify the calculations on the Lunar; and it is to be wished that the Longitude per Chronometer, so much of late resorted to, would again be hailed for per Lunar Observation. Such delicate and complicated pieces of mechanism, my Lord, like all other productions of human invention, are liable to accident, disorder, and decay; whereas the heavenly bodies are unchangeable, and the only true and unerring time-keepers. Indeed, of all the methods hitherto attempted to find the Longitude at sea, the moon's distance from the sun or a star, stands the first both in theory and practice; therefore my object in this work is to keep alive a science so beneficial to the great scale of Navigation; and should my endeavours be so successful as to meet your Lordship's further approbation, it will be my highest and most gratifying reward.

I have the honor to be,

My Lord,

Your Lordship's most obedient

humble servant,

THOMAS EVANS,

Liverpool, 12th August, 1814. *Lieut. R. N.*

PREFACE.

Of all the sciences cultivated by mankind, astronomy is acknowledged to be the most sublime, and the most useful; for by knowledge derived from this science, not only the bulk of the earth is discovered, and the situation and extent of the different countries and kingdoms ascertained; but also trade and commerce are carried on with the remotest parts of the world, and the various productions of the several countries distributed for the health, comfort, and convenience of the inhabitants: even our very faculties are expanded by the grandeur it conveys to our minds, and are elevated above the low, contracted prejudices of the vulgar; and our understandings are clearly convinced of the existence, wisdom, power, goodness, infiniteness, and superintendance of a Supreme Being.

It is a task of no small difficulty to express the precepts of any art or science, and to arrange its examples, so as to facilitate its attainment without an instructor. Having this object in view, the author trusts his aim will not be entirely missed; and he flatters himself, that there is no subject in this small volume, which expert mariners will not be able to comprehend without any other assistance; aided as they are by the practical directions for knowing the stars, and the clear precepts laid down both in taking and working a lunar observation, which will doubtless smooth the way to a more general application. Indeed, hitherto the calculations on all lunar observations have been very abstruse, the principle comprehended being only within the reach of a few, as not one out of fifty understand spherical trigonometry, on which all lunar observations are founded; and recourse is had to watches for the longitude, instead of following up astronomical observations, which is both the first and safest method to be depended upon, and will ever stand the foremost in the great scale of navigation. The author has therefore endeavoured to render all observations of the sun, moon, and stars, better understood, and to open by projection the whole nature and properties of a lunar observation, whereby that part of the Nautical Almanac, as far as relates to a lunar, is fully explained at one view of the figure, and how the parallax and refraction of both objects operate on the distance from the surface and the earth's centre; a criterion materially instructive in all lunar observations.

Navigators, into whose hands this treatise may come, will be the best judges of its utility, and their own experience on its simplification, will ultimately prove the truth.

A PRACTICAL INTRODUCTION

TO

NAUTICAL ASTRONOMY, &c.

Most seafaring men are acquainted with the rules, and comprehend a problem in plane trigonometry: as triangles in spheric trigonometry bear a relation to the former, it will be necessary before entering on the projection of either latitude or longitude on the sphere, to set down the most useful and requisite definitions, for the better instruction of the learner.

Astronomy in general comprehends the theory of the universe, and the primary laws of nature, and is consequently a mixed science, composed of physics and mathematics. The mathematical part of astronomy determines the quantity of either matter, space, or motion, such as magnitudes, periods, eclipses, and other particulars of the heavenly bodies.

Astronomy is distinguished into solar and terrestrial, according to the supposed situation of the spectator. The sun being the centre of all the planetary motions, the only place from which their motions could be truly seen is the sun's centre; but terrestrial astronomy explains the celestial appearances as seen from the earth, and although the sun is the fountain of all calculations yet from the earth, the sun and all the heavenly bodies seem to make an entire revolution from east to west in one day; but this apparent motion arises from the real motion of the earth round its axis; therefore terrestrial astronomy teaches the projection and computation of the whole or any part of that spherical surface, in which the heavenly bodies appear to describe great and lesser circles in every diurnal revolution.

Definition of the Sphere.

The Centre of the sphere is a point equidistant from all parts of its surface.

Zenith is the vertical point of the sphere, that is, the point directly over head.

Naider is opposite to the Zenith, or that under point of the sphere.

Poles are two immoveable points, round which the sphere is supposed to move. A right line drawn from pole to pole is called the Axis; as for a similitude, the earth's axis may be compared to a small pin driven thro' a shot, or any round ball, when the pin would represent the poles of the earth's axis, on which the shot or ball turned round.

Poles of Ecliptic are two points cutting the equator 90 degrees from this great circle, and are each 23½ degrees nearly from the poles of the equinoctial, that is, the greater north and south declination.

Definition of the Great Circles.

Equator is equidistant from both poles dividing the earth into equal parts.

Equinoctial is a circle of the celestial sphere equidistant from both poles, and compared with the equator of the earth from east to west.

Meridians are circles perpendicular to the equator, passing thro' both poles; are also circles of right ascension and of terrestrial longitude; so that every point on the surface of the earth has its proper meridian, as the latitude begins at the equator where it is 0, so it ends at the poles where it is greatest, or 90 degrees; of these 24 divide the equator into equal parts of 15 degrees each, and are called hour circles, the whole making 360 degrees.

Ecliptic is that great circle through which the sun seems to move and perform in a year; it cuts the equinoctial at an angle of 23½ degrees nearly, and is divided into 12 equal parts, called Signs, marked and named in order thus:

Aries.	*Taurus.*	*Gemini.*	*Cancer.*	*Leo.*	*Virgo.*
♈	♉	♊	♋	♌	♍
Libra.	*Scorpio.*	*Sagittarlus.*	*Capriornus.*	*Aquanius.*	*Pisces.*
♎	♏	♐	♑	♒	♓

The first six signs are called the north, and the last south; the former laying to the north, and the latter to the south of the equator.

Circles of Celestial Longitude are great circles perpendicular to the ecliptic, passing through its poles.

Definition of Small Circles.

PARALLELS of LATITUDE are circles parallel to the equator on the earth.

PARALLELS of DECLINATION are straight lines to the equinoctial in the heavens.

CELESTIAL LONGITUDE are parallels to the ecliptic.

ALMACANTERAS or Parallels of Altitude, are circles parallel to the horizon; are some of the most useful circles in astronomy, as the celestial motions are refered to for the rising and setting of sun, moon, and star.

ALMACANTERAS or Crepuseulous is a parallel 18 degrees below the horizon, where the twilight begins and ends.

TROPICS are parallels 23½ degrees on each side of the equator, one to the north called Cancer, the other to the south Capricorn.

POLAR CIRCLES are 23½ degrees from the poles of the world, the Artic circle to the north, and the Antartic to the south.

EXAMPLE

For turning degrees and minutes into time, and the contrary.

	°	′	″	
Longitude east	88	25	00	motion.
Multiply by			4	
Divide by 60	353	0	40	
Answer	5h 53m 40s time.			

The Dip of the Horizon.

The observer's eye being raised above the level of the sea, he sees an horizon below the level of the true one, consequently the instrument gives too great an altitude: this error depends on the height of the eye above the water, and that on the size of the ship.

EXAMPLE.

Let it be required to find tbe dip of the horizon answering to an elevation of 60 feet above the surface of the sea.

	′	″		
Constant logarithm				0,4235
Given height 60 feet..............			Pro. Log.	2,2553
			Sum	2,6788
Dip of the horizon....	8	13¼	Pro. Log.	1,3394
Corr. for terrestrial refra.	0	48		
True dip of the horizon	7	25¼		

Of Refraction.

Celestial objects the nearer they are to the horizon, are consequently seen through a larger portion of atmosphere, and therefore have a greater quantity to be allowed for refraction than when they are seen with greater altitude, and the rule for finding the refraction is fitted to a mean warmth and weight of the atmosphere, to the height of 50 degrees in Fahrenheit's Thermometer, and to the height of 29 degrees of the Barometer for other states of the air. Dr. Bradly gave a rule for a further correction, but it is apprehended that neither of these are necessary for any purposes at sea.

EXAMPLE.

Let it be required to find the refraction at the apparent altitude of 30 degrees by logarithms.

	°	′	″		
Apparent zenith distance	60	0	0	———Log. tang.	0,23856
Mean refraction at altitude 45 deg.	0	0	57	———Log. tang.	0,21964
True refraction on altitude of 30 deg.	0	1	38	....	0,45820

By this method reject rad. in index, and take degrees for minutes, &c.—or thus: increase any given altitude by three times the refraction on that altitude, then to the log co-tang. of that sum add the log of 57s 1,75587—the sum less rad. in the index is the log number of seconds in the refraction. This rule is more correct than the tables.

Of the Moon's Parallax.

It is evident that the moon, when seen at the same time from the surface and centre of the earth, will not appear in the same place in the heavens;* this arises from the semi-diameter of the earth bearing a sensible proportion to the distance between the earth and moon, which is about $\frac{1}{60}$, a quantity that considerably affects the observation on that planet, and must be allowed for; but the distance of the moon from the earth constantly altering between the apogee and perigee, the parallax also will be continually altering, therefore the the moon's horizontal parallax, which lies between the limits of 53 and 62 seconds, is given in the Nautical Almanac for every 12 hours throughout the year.

* For the explanation, refer to the projection of a lunar in figure 2d on plate 1st.

Of Natural Sines and Co-Sines.

The natural number of any degrees is the natural sine and co-sine of that arc, answering to the logarithms sine and co-sine of their respective arcs.

EXAMPLE.

Let it be required to find the natural sine and co-sine of 26 degrees.

Log sn. less the index of	26 degrees—641842	Nat. num.—43837	Nat. sine.
Log co-sn. less index of	26 degrees—953660	Nat. num.—89879	Nat. sine.

As most seamen have been accustomed to work their day's works from logs, sines, and co-sines, it will not be necessary to introduce here the log versed sine, which is considered too complicated for seamen in general to understand.

Proportional Logarithms.

This is a very useful logarithm introduced into navigation, which will be found very ready in facilitating the computation of the effects of parallax and refraction upon the moon's distance from the sun or star, which before the invention of this log, were calculated by the long process of the Rule of Three. Any number in the tables may be found by the following rule.

EXAMPLE.

Let it be required to the proportional logarithm of 30 min. 20 sec.

Number of seconds in	3h. 0m. 0s.	10300......Com. log	4,03342
Number of seconds in	30 20	1820......Com. log	3,26007
		P. L.	0,77335

The roots of logarithms are in proportion to their respective squares and cubes, for example, the

Logarithm of 12 is	1,07918	Root——or thus	12
Multiply by	2		12
Logarithm of 144	2.15836	Square........	144
			12
Logarithm of 1728	3,23754	Cube	1728

Of the Equation of Time.

This important problem, so necessary to be understood in navigation, is useful both for regulating observations on shore and watches at sea; is the true difference between the mean and solar time, so that the time shewn by an equal going clock and a sun dial well fixed in the meridian, is never the same, but on certain days of the year, namely, 15th April, 15th June, 31st August, and 24th December; the cause of which is the difference of the obliquity to the equator, the sun performing his course through the former, and the earth's axis bending in the latter. This difference is given for every day throughout the year in the Nautical Almanac, and is used with observations to regulate time at sea.

EXAMPLE I.

At Madrass Roads, July 20th, 1812, what was the equation of time at noon, the longitude of Madrass Roads 80 deg. 28 min. E. in time 5h. 21m. 52s ?

Equation of time for noon at Greenwich, add	5′	55″,	4
Then as 24h. is to 5h. 21m. 52s. so is daily diff. 3s., 8 to			9
Equation of time for noon at Madrass	5	56	3

EXAMPLE II.

What was the equation of time for noon July 20th, 1814, at Liverpool, the longitude of Liverpool in time being 11m. 36s.?

Equation of time for noon at Greenwich, add	5′	53″,	8
Then as 24h. is to 11m. 36s. so is daily diff. 4s., 3 to			7
Equation of time for noon at Liverpool	5	54	5

N. B. In the like manner the equation may be reduced to any intermediate time.

Rewards offered for finding the Longitude.

THE first who offered a reward for the discovery of the longitude at sea was Phillip III. king of Spain, in the year 1598, and soon after the States of Holland followed his example. The reward offered by Phillip was 1000 crowns, and that by the States 10,000 florins. In the year 1714, the British Parliament offered a premium of £20,000 for any method by which the longitude at all times might be determined at sea within 30 miles; £15,000. if the proposed method gave the longitude within 40 miles; £10,000. if within one degree, or 60 geographical miles: this part of the Act was repealed, and a new one framed to take place after the 24th of June, 1774, of which there is an extract at the beginning of the Nautical Almanac; and in the year 1716, a reward of 100,000 livres was promised by the Duke of Orleans, who at that time was regent of France.

John Werner, of Nurenburg, appears to be the first who proposed the method of finding the longitude at sea, by observing the distance between the moon and a star. In his annotations on Ptolemy's Book of Geography in 1544, he recommends the cross staff as a very proper instrument for the purpose of observing the distances between the moon, sun, or star.

Kepler was fully persuaded of the utility of this method of finding the longitude at sea: in his tables he gave directions for observing the distance between the moon and a star, and for making the necessary computations; and a method for the above purpose was now much desired in England. In the year 1675, the Royal Observatory at Greenwich was founded by Charles II., and Mr. Flamstead appointed Astronomer Royal: the words of his commission were to apply himself, with the utmost care and diligence, to rectifying the tables of the motion of the heavens, and the places of the fixed stars, in order to find out the so much desired longitude at sea, for perfecting the art of navigation.

That celebrated astronomer and navigator, Dr. Edmund Hally, recommended observations of the moon, as the most certain method of ascertaining the longitude at sea. This eminent astronomer having by his own experience found the impracticability of all the other methods, he gave in an excellent paper on that subject, wherein he shews the defects of the lunar tables then extant, by comparing the place of the moon as given then by the tables, with that deduced from observations of ten years' practice on the moon's transit. He compared his observation of 1730 and 1731, with those he had made in 1721 and 1722; from the result of these observations he was able to compute the true place of the moon within two minutes of motion, and recommends Hadley's Quadrant as a perfect instrument for taking the necessary observations at sea. Dr. Hally again treats on this subject in his Astronomical Tables, in which are given two compleat examples of finding the longitude, from the observed distance between the moon and a star, and concludes by observing, that by a like method of computation, may the difference of the meridians be found from observations of the moon's distance from the sun in her first and last quarter.

Mr. Robert Wright, of Winwick in Lancashire, published his address to the Commissioners of longitude, in which he asserted, that Sir Isaac Newton's theory being freed from some errors of the press, and restored to its original exactness, the moon's place in the heavens will be so nearly given, that the longitude, if due care be taken in the observation, will be found within a few miles of certainty; and in 1732 he published his new and correct tables of the lunar motions, according to the Newtonian theory of gravitation.

It will be found that in 1755, Professor Mayer, of Gottingen, sent a manuscript copy of his lunar tables to the British Admiralty, at the same time claiming some of the reward promised by Parliament, which he might be thought to merit. The above tables were delivered to Dr. Bradly, then Astronomer Royal, to be examined, who having compared them with his own observations, was convinced of their worth, and sent his account of them to the Secretary of the Admiralty in a letter, dated Greenwich, February 10th, 1765, from which the following is an extract:

"In obedience to their Lordships' command, I have examined the same, and carefully compared several observations that have been made during the last 5 years, at the Royal Observatory at Greenwich, with the places of the moon computed by the said tables, in more than 230 comparisons which I have already made. I did not find any difference so great as 1½ minute between the observed longitude of the moon, and that which I computed by the tables; and altho' the greatest difference which occured is in fact but a small quantity, yet as it ought to be considered as partly arising from the error of observation, and partly from the error of the tables, it seems probable that during this interval of time, the tables generally gave the moon's place within one minute of a degree.

"A more general comparison may perhaps discover larger errors, but those which I have hitherto met with being so small, that even the biggest could occasion an error of but little more than half a degree in longitude; it may be hoped that the tables of the moon's motions are exact enough for the purpose of finding at sea the longitude of a ship, *provided that the observations that are necessary to be made on ship-board, can be taken with sufficient exactness.*"

Of Time-keepers.

In England, Mr. John Harrison was the first in note who applied himself further, with indefatigable industry, to the improvement of time-keepers, and his success therein greatly merited the attention of the public. In the year 1726 he made a pendulum clock, which kept time so exactly as not to err one second in a month during a period of ten years. In 1736 he made a trial of his first machine in a voyage to Lisbon, and found it to answer his expectation.

In his voyage to Jamaica in 1761 & 2, under the direction of the Board of Longitude, the error of his watch was found to be no more than 118 seconds in time, or 29 miles of Longitude, altho' it had passed through a variety of climates, and undergone violent agitations at sea, in a voyage of 147 days: it appears that several objections however were made to this trial. In consideration of the accuracy of the time-keeper in the above voyage, Mr. Harrison received £5000. and was ordered to make a second voyage to Barbadoes; and it was then proposed to him, that he should send the rate of going of his time-keeper, immediately before he sailed on his intended voyage, sealed up to the Secretary of the Admiralty, and abide thereby upon its trial, to which he consented.

The following in a copy of Mr. Harrison's declaration, dated Portsmouth, March 26th, 1764.

"In obedience to your instruction, dated August 9th, 1763, I humbly certify, that I do expect the rate of going of the time-keeper will be as followeth, viz.

When the Thermometer is	at 42°	it will gain	3″	in every	24 hours.
	at 52	do.	2	do.	do.
	at 62	do.	1	do.	do.
	at 72	it will neither gain nor lose.			
	at 82	it will loose	1″	in every	24 hours."

March 28th, 1764, Mr. Harrison sailed from Portsmouth, in His Majesty's ship Tartar, Sir John Lindsey, having previously ascertained the error of the time-keeper, from observations of equal altitude of the sun taken at Portsmouth between 29th February and 27th March. April 19th they made Madeira, exactly as given by the time-keeper, and arrived at Barbadoes the 13th of May, and for the four following days, the time-keeper was compared with the clock at the Observatory near Bridge Town, under the directions of Dr. Maskelyne, and the difference of longitude between Portsmouth and Barbadoes as given by the time-keeper was 3h. 35m. 3s. and that by the eclipses of Jupiter's Satellites being 3h. 54m. 20s. the error of the time-keeper was only 43 seconds. June the 4th, Mr. Harrison sailed from

Barbadoes, and on the 18th of July he landed at Surry Stairs; the time-keeper was found to have gained only 54 seconds in 156 days, the interval of time between its leaving London and its returning thither. In consequence of which, the Board of Longitude unanimously agreed, that Mr. Harrison's time-keeper had given the ship's longitude in these trials within the limits prescribed by Act of Parliament; and upon discovering the principle on which his time-keeper was constructed, he was therefore promised a part of the reward, and accordingly he was ordered £5000.

In the mean time the Board of Longitude, at their meeting in April 1766, resolved that Mr. Harrison's watch should again be tried at the Royal Observatory, under the inspection of Dr. Maskelyne, and accordingly his watch was delivered by Mr. Phillip Stephens, Secretary to the Admiralty, to Dr. Maskelyne on the 3d of May, 1766, that from a comparison of its rate, terminating March 4th, 1767, the watch being kept in an horizontal position with its face upwards, Dr. Maskelyne stated as follows:

"That Mr. Harrison's watch can not be depended upon to keep the longitude within a degree in a West India voyage of six weeks, nor to keep the longitude within half a degree for more than a fortnight, and then it must be kept in a place where the Thermometer is always some degrees above freezing; that in case the cold amounts to freezing, the watch can not be depended upon to keep the longitude within half a degree for more than a few days, and perhaps not so long if the cold be very intense. Nevertheless it is an useful and valuable invention, and in conjunction with the observation of the moon from the sun and fixed star, may be of considerable advantage to Navigation."

To find the Latitude of a Ship at Sea from the observed Meridian Altitude of the Moon's Limb.

RULE.

To the longitude of the given place in time, add the number from Table XX. corresponding to that longitude, and daily variation of the moon's passage over the meridian, and take the sum from the time of the moon's passing over the same on the given day, (Nautical Almanac page 6,) if the longitude be east; but add it to the time of her passage if the longitude be west; the sum or difference will be the time at Greenwich, when the moon was on the meridian of the given place. To this time take the moon's horizontal parallax and semidiameter, from page 7 of the Nautical Almanac, and her declination from page 6, noting whether it be north or south.

Correct the observed altitude of the moon's limb by substracting the dip of the horizon (Table II.) from it, and by adding the correction of the altitude, (taken out of Table VIII. with the moon's horizontal parallax, and the altitude of her limb corrected for dip,) and also her semidiameter, if her lower limb was observed, or substracting her semidiameter from it if the upper limb was observed, will give the true altitude of her centre; taken from 90 degrees it will leave her distance from the zenith, which will be north or south according as the zenith was north or south of the moon at the time of observation. Then if the zenith distance and declination be both north or both south, add them together; but if one be north and the other south, substract the less from the greater; the sum or difference will be the latitude.

EXAMPLE.

On the coast of Portugal, March 23d, 1812, longitude 10 degrees west, the meridian altitude of moon's lower limb I observed to be 65 degrees 40 minutes, off the poop of a line of battle ship, 30 feet above the surface, to find the latitude.

	h.	m.	s.	
Longitude 10 degrees west, in time		40	00	
Corr. from Table XX.		1	00	
Sum	0	41	00	
Moon's south at Greenwich	9	9	00	
Moon's south at ship	9	50	00	
Moon's declination at noon	14°	40	00	
Correction for time at ship	1	5	0	
Moon's declination at ship	13	35	N.	

Moon's semi-diameter 14m 56½s. and horizontal parallax 54m. 45s.

Moon's altitude lower limb......	65	40	00	
Dip of horizon substract		5	14	
Moon's apparent altitude	65	34	46	
Correction from Table VIII.		22	28	
Moon's semidiameter............		14	56½	
Moon's true altitude............	66	12	10½	
	90	00	00	
Moon's zenith distance	23	47	50½	N.
Moon's declination	13	35	00	N.
Latitude	37	22	50½	N.

The apparent Time, Latitude and Longitude of the Ship being given, to find the apparent Altitude of the Moon's centre,

RULE.

TURN the longitude of the ship into time; if it be west add it to, but if it be east substract it from the apparent time at the ship, it will give the time at Greenwich.

To this time, take the sun's right ascension from page 11 of the Nautical Almanac, by the help of Table XII. add it to the apparent time at the ship, counted from the preceding noon, which will give the right ascension of the mid-heaven: take also the moon's horizontal parallax from page 7, and its declination and right ascension from page 6, by help of Table XXI. turn the right ascension into time, and take the difference between it and the right ascension of mid-heaven, which will be the distance of the moon from the meridian.

If the moon's declination and the co-latitude of the ship be one north and the other south, take their difference; but if they are both north or both south, take their sum for the moon's meridianal altitude; if the sum exceed 90 degrees, take if from 180 degrees.

Then with the distance of the moon from the meridian, take the log-rising out of Table XVI. to which add the co-sine of the ship's latitude, and the co-sine of the moon's declination; their sum, rejecting 20 from the index, will be the log of a natural number, which substract from natural sine of the moon's meridianal altitude, gives the natural sine of the moon's true altitude at the given time with the moon's horizontal parallax, and her true altitude diminished by the number that stands against them in Table VIII. take the correction of her altitude out of that Table, and substract it from her true altitude, which will give the apparent altitude of the moon's centre.

The foregoing question is worked from the book called the Requisite Tables, published under the authority of the Commissioners of Longitude; but the same may be worked from any other book of navigation now extant.

EXAMPLE.

What was the apparent altitude of the moon's centre on the 23d March, 1812, at 9h. 20m. 30s. P. M. apparent time at ship, in latitude 38 degrees 28 minutes north, and longitude 10 degrees west of Greenwich?

							h.	m.	s.
Sun's A. R. for noon on 23d							0	10	1
Corr. for 9h. 20m. 30s. P. M. Table XXII								1	23
Sun's right ascension for given time							0	11	24
Apparent time at ship							9	20	30
Right ascension of mid-heaven							9	31	54
	°	′							
Moon's A. R. for noon 23d	135	27							
Corr. for 9h. 20m. 30s.	4	33							
Moon's A. R. at time	140	00							
Turned into time	9	20					9	20	00
								11	54 dif. is.
Moon's distance from meridian	0	11	54		Log rising	2,1248			
Moon's declination	13	36	00		Log co-sine	9,9853			
Co-latitude	51	32	00		Log sine	9,8937			
Meridianal altitude	65	8	00	N. Sine 9,0729					
				101	Log 2,0054				
True altitude	65	16	30	N. Sine 9,0738					
Corr. from Table VIII.		22	00						
Apparent altitude	65	38	30						

Moon's horizontal parallax at time was 54′ 45″

The following is a proper method for working a Meridian Altitude to find the Latitude of the place of observation.

EXAMPLE.

July 20th, 1814, longitude 3 degrees west, the meridian altitude of the sun's lower limb I observed to be 57 deg. 12 min. 30 sec. the eye being 30 feet above the surface of the sea, required the latitude of the place of observation.

	°	′	″
Sun's declination for noon at Greenwich	20	46	3
Correction for 3 degrees west longitude .... sub.			6
Sun's declination at noon in longitude 3 degrees west ..	20	45	57
Sun's meridian altitude	57	12	30
Dip. for 30 feet 5m. 14s. refraction on altitude 36s. sum sub.		5	50
Apparent altitude, correction for dip and refraction......	57	6	40
Sun's parallax in altitude .... add			5
Semidiameter of the sun .... add		15	46
Sun's true altitude, take from 90 degrees	57	22	31
	90	00	00
Sun's true zenith distance	32	37	29
Sun's declination .... add	20	45	57
Latitude	53	23	16 N.*

In working an altitude, either to find the latitude or the time from noon at the ship, care should be taken to correct the sun's declination, and make allowance for refraction and parallax on the same altitude: a neglect of this sort in a long voyage has often proved fatal to the mariner.

EXAMPLE I.

Required the sun's declination at noon July 20th, 1812, in longitude 10 deg. west.

	°	′	″
Sun's declination in Nautical Almanac for the above day is	20	40	27 N
Correction for longitude sub.			20
Sun's true declination	20	40	7 N

EXAMPLE II.

What was the moon's declination March 23d, 1812, at 9h. 20m. 30s. P. M. in the longitude of 10 degrees west?

	h.	m.	s.
Time at the ship............	9	20	30
Longitude in time		40	00
Time at Greenwich	10	00	30
Moon's declination at noon ..	14	40	00
Correction for time at ship ..		54	00
Moon's declination at ship ..	13	46	00 N

In the like manner the declination of either sun, moon, or star, may be reduced to any intermediate time.

The Latitude & Longitude of the Ship being known, and the observed Altitude of the Sun, to find the apparent time at the Ship.

EXAMPLE I.

July 8th, 1813, latitude 53° 30′ 40″ north, longitude 2° 59′ 56″ west, the altitude of the sun's lower limb was observed 47° 20′ 30″,

* This latitude answers to the meridian of the North Battery, near the Mile End Rocks, Liverpool.

the eye being 10 feet above the surface of the sea, required the apparent time at the ship, or when the observation was made.

	°	′	″
Altitude of sun's lower limb	47	20	30
Dip for 10 feet 3′ 1″, refraction in altitude 53″, sub.		3	54
Sun's altitude, correction for dip and refraction	47	16	36
Sun's parallax in altitude .... add			6
Sun's semidiameter .... add		15	45
Sun's true altitude	47	32	27

Sun's declination at noon July 8th..	22°	31′	19″		
Correction for 3° west longitude, sub.			46		
Sun's declination at the time	22	30	33 N	Log sec.	10,03435
Co-latitude	36	30	00 N	Log co-sec. ..	10,22561
Sun's meridian altitude	59	00	33	Nat. sn. 85724	
Sun's true altitude	47	32	27	Nat. sn. 73768	
				11956 its log	4,07755
Apparent time P. M.	2h. 33m. 57s.			Log rising	4,33751

The apparent Time, the Ship's Latitude, Longitude, and Sun's declination being given, to find the true Altitude of the Sun's centre.

EXAMPLE II.

Required the true altitude of the sun's centre in latitude 53° 30′ 40″ north, and longitude 3 degrees west from Greenwich, July 8th, 1813, at 2h. 33m. 57s. P. M.

	h.	m.	s.				
Time from noon	2	33	57			Log rising ..	4,33751
Sun's declination	22	30	33			Log co-sine ..	9,96561
Co-latitude	36	30	00			Log sine	9,77438
Sun's meridian altitude	59	00	33	Nat. sine	85717		
					11956	Log..	4,07750
Sun's true altitude ..	47	32	30	Nat. sine	73761		

Of the Motion and Magnitude of the Fixed Stars.

All the fixed stars, except the polar star, appear to have a diurnal motion from east to west: such appearance arises from the diurnal motion of the earth's axis from west to east. The fixed stars have also a small apparent motion about their real places, arising from the velocity of the earth in its orbit, combined with the motion of light: this motion is called the aberration of the fixed stars, the very cause and laws of which are hid from man, by the same GREAT AUTHOR who governs the whole. It appears then that the fixed stars are prodigious spheres similar to our sun, and placed at inconceiveable distance from one another, as well as from us. It is reasonable to conclude that they are made for the same purposes as our sun is, each to bestow light, heat, and vegetation on inhabited planets, kept by gravitation within the sphere. What a sublime and amazing conception this gives to the mind of the works of the GREAT CREATOR! a thousand times ten thousand worlds, all in rapid motion, yet calm, regular, and harmonious, each keeping invariably the path prescribed to it. Several stars are mentioned by the ancient astronomers which are not now to be found, and others are now visible to the bare eye which are not recorded in the ancient catalogue. The star Arcturus has been observed to change his place above a minute of a degree in the heavens.

Those stars whose distance from the moon are laid down in the Nautical Almanac for determining the longitude at sea, are fixed stars of the first and second magnitude, namely, Arictes, Antares, Aldebaran, Pollux, Regulus, Spica, Aquilæ, Fomalhaut, and Pegasi. Besides those mentioned, I have also found the meridian altitude of other stars equally ready for the latitude, viz. Orion and Sirius, more especially the planet Jupiter, which from its magnitude is as convenient as the moon for obtaining the latitude at sea, both with ease and the operation short; therefore the mariner need not be at a loss to find the latitude of the ship, any hour of the night, by the meridian altitude of a star, should the horizon be anyways clear.

To find when a Star will be on the Meridian.

EXAMPLE I.

At what time will Aldebaran be on the meridian July 20th, 1814?

	h.	m.	s.
Aldebaran right ascension	4	25	35
add	24		
	28	25	35
Sun's right ascension	7	56	26
After midnight	20	29	9
Substract	12		
In the morning	8	29	9

EXAMPLE II.

At what time will Antares be on the meridian July 20th, 1814?

	h.	m.	s.
Antares' right ascension	16	17	50
Sun's right ascension	7	56	26
Time star's culminating aftern.	8	21	24

To find what Star will come upon the Meridian at any given time.

EXAMPLE I.

What star will be on the meridian July 20th, 1814, at 10h. P. M.

	h.	m.	s.
Sun's right ascension at 10h.	7	58	13
Given time 10h. P. M.	10		
Right ascension meridian ..	17	58	13

Answers to bright star Dragon.

EXAMPLE II.

What star will be on the meridian August 1st, 1814, at 7h. P. M.

	h.	m.	s.
Sun's right ascension at 7h.	8	45	45
Given time P. M.	7		
Right ascension meridian ..	15	45	45

Answers to bright star of Serpent.

To prove these questions, add the time after midnight to the sun's right ascension, the sum above 24h. is the star's right ascension, on more than 12 hours.

To find the Latitude by the Meridian Altitude of a Star or Planet.

EXAMPLE I.

On the 15th March, 1812, I observed the meridian altitude of Sirius 65° 26′ 30″, the eye elevated 30 feet above the surface of the sea, required the latitude of the ship.

	°	′	″
Observed altitude of Sirius ..	65	26	30
Dip 5′ 14″ refr. 26″ sum sub.		5	40
True altitude ..	65	20	50
	90	00	00
Zenith distance	24	39	10
Declination of Sirius, ... S.	16	28	7
Latitude of the ship ...... N.	8	11	3

EXAMPLE II.

At sea, 10th August, 1812, the meridian altitude of Aldebaran 52° 55′ 15″, the eye 20 feet above the sea, required the latitude of the ship.

	°	′	″
Star's observed altitude	52	55	15
Dip 4′ 16″ refr. 43″ sum sub.		4	59
Star's true altitude ..	52	50	16
	90	00	00
Star's zenith distance	37	9	44
Star's declination........ N.	16	8	38
Latitude of the ship ...... N.	53	18	22

EXAMPLE III.

July 8th, 1812, I observed the altitude of the Polar star below the pole 51° 48′ 15″, the eye 30 feet above the sea, required the latitude of the ship.

	°	′	″
Observed altitude Polar star	51	48	15
Dip 5′ 14″ refr. 45″ sum sub.		5	59
True altitude	51	42	16
Co-declination Polar star ..	1	42	12
Latitude..........	53	24	28

EXAMPLE IV.

At sea, 7th May, 1812, longitude 11° 30″ west, I observed the meridian altitude of Jupiter 65° 28′ 45″, eye 30 feet above the sea, required the latitude of the ship.

	°	′	″
Observed altitude of Jupiter	65	28	45
Dip 5′ 14″ refr. 26″ sum sub.		5	40
True altitude of Jupiter	65	23	5
	90	00	00
Zenith distance	24	36	55
Jupiter's dec. from Nau. Al. N.	23	28	00
Latitude............ N.	48	4	55

EXAMPLE V.

Given the right ascension of two fixed stars, and their declinations, required their distance.

Right ascension of Polar star 0h. 56m 21s. its declination 88° 18' 26" N. and the Right ascension of North star or Pointer, in square of Great Bear, is 10h. 51m. 55s. its declination 62° 45' 17" north.

	°	'	"		
As radi	90	00	00		10,00000
is to the diff. rt. as ..	148	53	00	Co-sine	9,93253
So is the declin. Pointer	62	45	00	Co-tang.	9.71184
to the 1st arc........	23	47	40	Tang. ..	9,64437
Co. declin. Polar star ..	1	41	34		
Second arc	22	6	6		

As co-sine 1st arc	23	47	40	— 0,03854
is to the co-sine 2d arc	22	6	6	— 9,[illegible]6685
So is the co-sn. Point. dec.	62	45	0	— 9,66074
to sine distance	27	37	30	— 9,66613

In the like manner, the distance between any two stars may be obtained.

EXAMPLE VI.

What will be the true altitude of Aldebaran in latitude 47° 26' N. longitude 10° west from Greenwich, May 5th, 1812, at 6h. apparent time at the ship.

Apparent time at ship	6h	00'	00"
Longitude 10° in time		40	00
Time at Greenwich	6	40	00

Sun's right ascension at noon May 5th by Naut. Al.	2h	50'	15"	
Apparent time at the ship	6	0	0	
Right ascension of the meridian.................	8	50	15	
Star's right ascension at the time	9	25	15	
Star's distance from the meridian	4	25	00	Log rising 4,77616

Latitude in	47°	26'	00" N.			Log rising 9,83023
Star's declination ..	16	8	30 N.			Log rising 9,98255
Co-latitude of ship ..	42	34	00	Nat. num.	38801	Log 4,58894
Meridian altitude ..	58	42	30	Nat. sine	85446	
Star's true altitude	27	48	30		46647	

Of the Sextant, and Observations on the Lunar Tables.

THE Sextant, which is a valuable instrument, is constructed on the same principle as the Quadrant, the frame of which is made of brass in general, and the arc is divided into 130 degrees, and subdivided into minutes and seconds, and will be found far superior to an instrument called a Circle, for measuring the distance of the moon from the sun or star. The idea of finding the longitude at sea by lunar observations, is not modern; we are told of astronomers two hundred years ago who proposed this method; a science then so apparently simple, must have been long since adopted, but that two difficulties occurred, which were not removed until this present century: the first was the want of a proper instrument, which has since been supplied bv the subsequent improvement of the Sextant; and the second was the want of correct lunar tables. From the theory of the late Sir Isaac Newton, the late Professor Mayor formed his lunar tables, which are now found sufficiently correct, and from which those lunar distances in the Nautical Almanac were calculated, under the direction of the late Astronomer Royal. Besides, the Sextant is now furnished with appendages which render this instrument peculiarly well adapted for measuring the angular distance of the moon from the sun or star, and when placed in the hands of an expert observer, the longitude of the ship can be determined from 5 to 7 miles of the true spot.

Notwithstanding the correctness ascribed to Mayor's tables, I have found from a series of observations made by me on the moon's distance from the sun at different sides of her full, that some little errors remained among the distances in the Nautical Almanac, which when first discovered, and for a length of time afterwards, I attributed to the imperfection of the observation, to arise partly from the errors of the instrument, and partly to not making a true coincidence of the limbs of the object at the time of observation on board a ship; and being anxious to find out where this error originated, I was induced to make the following improvement on my Sextant, that instead of using the inverted telescope at the time of observation, I made use of an erect one previously prepared, with nearly as much power as the former, whereby the objects were more steady in the field of view; and I also corrected the screen glasses, which on some instruments show two shadows, and not homogeneous, and instead of having them fixed as usual, I had them made to swivel round occasionally; I had besides parallel wires placed to the horizon glass. Though this latter improvement was of little consequence when the telescope was fixed on, yet when an observation is made on the moon's distance from the sun with the plain tube, more especially when the altitude of one of the objects is high and the other low, it serves materially to guide the observation, and to place the objects in the centre of that glass. Having thus compleated my Sextant, and being at a well determined meridian in India, I repeated my observation on the moon's distance from the sun, and I shortly found that by placing the nearest limbs of the object to touch at different sides of her full, it did not give the longitude of the place of observation; and in consequence I afterwards observed close from her change to her first quarter, and for the other parts of her lunation, found about a needle's breadth open: the result of these observations gave the exact longitude.* These points have been further verified by observations which I afterwards made in a voyage in 1812, and the errors above described among the distances in the Nautical Almanac, were acknowledged by the late Astronomer Royal, Dr. Maskelyne, in 1806, and for the first time, the Nautical Almanac of 1813 came out distinguished with these considerable improvements.

The astronomer whose time is chiefly devoted to make astronomical observations, has the most ready and accurate means afforded him, as his instruments are supposed to be well fixed in the meridian; while the mariner on the other hand, who makes his celestial observations from on board a ship, is subject to many inconveniences; even the motion of the vessel, with all his care, render him liable to many disadvantages at sea.

Now the moon's true path in the heavens is delineated from a knowledge of the sun's path being well determinated in the ecliptic, in this manner for instance—at the meridian of St. Paul's, Liverpool, at the summer solstice on the 21st of June, 1813, I observed the sun's meridian altitude at noon 60° 5′ 15″, being his greatest summer elevation, and on the 21st December following, I observed his meridian altitude at noon 13° 9′ 35″, being his winter's greatest depression; take the latter from the former, it will give the breadth of the tropic 46° 55′ 40″, the half shews the obliquity of ecliptic, or the greatest north declination, to be 23° 27′ 50″ for that year. On the 21st June, I also measured the diameter with a Sextant to be 31′ 31″, and on

* The author's letter, wherein this subject is more fully treated, received the thanks of the Right Honorable Charles Philip York, then First Lord of the Admiralty, to whom the foregoing notes were sent in May, 1810.

the 21st December following, I measured the same to be 32′ 35″, thus showing that the sun's diameter measured 1 minute and 4 seconds more on the 21st December, being the shortest day of winter, than he actually did on the 21st June, the longest day of summer; this proves that the sun appears under a greater angle in winter than he does in summer. The above notes serve to verify those observations, and to make similar ones from the same mode of observing.

On the Lunar Observations, and of finding the Longitude at Sea by Time-keepers.

THE greatest modern improvement in navigation is certainly that of finding the longitude at sea, by measuring the distance between the moon and sun or star: it is one of the sciences which is obvious in theory, and more easily designed than executed. The most ancient method of finding the longitude was by the lunar eclipses; this method answers better for observations on land than can be reduced to practice at sea: but the eclipses of Jupiter's Satellites afford the most ready means of determining the longitude of places on the land, and by them the longitude of the sea coast may be better ascertained than they are at present. There are other methods for determining the longitude besides those already mentioned, namely, the sun's declination, and the variation chart, especially the moon's culminating, or passing over the meridian of a place, east or west of Greenwich; but even a small error in the time of such observations, will produce a considerable error in the difference of longitude.

It is therefore here observed, that the most practical method of finding the longitude at sea is by celestial observations, of which the moon is the chiefest guide, for the quickness of her motion renders her peculiarly well adapted for that purpose; for her daily mean motion being about 13 degrees, and her hourly mean motion about half a degree, or one minute of a degree in two minutes of time, consequently an error of one minute of a degree in measuring the distance, will produce an error of two minutes in time, equal to 28 miles of longitude.

Now the moon's distance from the sun may be observed from 36 to 120 degrees, comprehending eight days between her change and i a 120 to 36 degrees from her full towards her change, making 16 days in every lunation. Besides, the moon affords other opportunities of observing her distance from a fixed star, east and west of her, which are laid down in the Nautical Almanac, as they take place at the Observatory at Greenwich.

But if a perfect time-keeper could be constructed, it would obviate every difficulty, and render the longitude as simple a problem as the latitude: yet notwithstanding the great degree of perfection to which time-keepers have been brought, I have not found them such infallible guides to the longitude as the celestial observations; one advantage the former has, is its being at all times more readily consulted, and by making use of a Chronometer as an auxiliary to astronomical observations, the one tends to check the other, for such delicate pieces of mechanism will often be affected through the violence of motion and vicissitudes of seasons. I have known their rate to alter materially through firing of the great guns, and at other times to be affected by winding up faster than usual; and some Chronometers I have seen to vary by not winding them up at stated periods. Indeed time-keepers should be fixed in the cabin of a ship, stationary, and near the centre; the more couched the better defended; it should not be removed up on the deck to take sights by; those who make this a custom must expect alterations in their rate of going, which might be guarded against by making use of any common watch that beats seconds; for by comparing the time shewn by the watch with the time-keeper before the observer goes upon deck, and after his return, the necessary observations are made without the Chronometer being liable to any risk or accident. I have here enumerated what has passed under my own observation for determining the longitude at sea.

The navigator is further told that the like observations cannot be made with those instruments, which but too commonly are made use of; that for these last twenty years, reckonings have rolled on through the medium of convoys out and home: however the time is now at hand, that those to whom the charge of Navigating is given, must be aware that not only their own safety, but that the great trust placed in them, depends wholly upon the correctness of their observations at sea.*

* A few years ago, I was observing the sun's meridian altitude on the poop of a 80 gun ship, where I was passenger; the captain, who was then near, asked if the sun was up, (a sea term given when the sun is on the meridian of the place,) and was answered in the negative from the observing officer, who was on my right,

EXAMPLE I.

July 1st, 1813, a Chronometer was set to Greenwich mean time, and its daily rate of going was found to be five seconds gaining; that on the 8th day following, P. M. in the latitude 53° 30″ north, and longitude by accounts 3 degrees east, a set of altitudes of the sun's lower limb were taken, to ascertain the apparent time; required the longitude per time-keeper.

	Time per Chronometer.		Sun's altitude.		
	h. m. s.		° ′ ″		h. m. s.
	2 27 50		47 29 30		
	2 27 50		47 19 30		
	2 28 20		47 12 00		
Sum....	3 83 20	Sum	3 61 00		
Mean ..	2 27 47	Mean	47 20 20	Appar. time	2 33 59 at ship.
5s. rate for 8 days sub.	40			Equation add	4 40
Time per Chrono.	2 27 7				
Mean time at ship	2 38 39			Mean time ..	2 38 39 at ship.

Difference 11 32 equal to 2° 53′ east, because the time at the ship is greater than the time at Greenwich.

EXAMPLE II.

March 10th, 1812, the time-keeper was set to mean time at Greenwich, and its rate ascertained to lose four seconds per day; that on the 20th following, a set of observations were taken in the latitude 40° 30″ north, longitude 11° west per account, required the longitude per Chronometer.

	h. m. s.		h. m. s.
Apparent time at ship	8 17 12	Time per Chronometer..	9 11 45
Equation of time add	7 45	Error in rate........ add	40
Mean time	8 24 57	Corr. time per Cronom...	9 12 25
Time per Chronom	9 12 25		

Difference of time .. 47 28 equal to 11° 52′ west, for the time at the ship is less than the time at Greenwich.

which did not a little astonish me to find his observation differ 22 miles from mine; I in consequence requested to exchange instruments, and examine the adjustment, when I convinced him that the error in his was in the horizon glass, and that the sun had passed the meridian some time before the captain appeared. His observation placed the ship 22 miles more to the southward than she really was, and if it had been suffered to pass, the ship's intended course would have been in consequence altered more to the northward, and instead of making the Start as we did the next morning, the ship long before day-light would have been on shore near the Dodman.

Of the Use of the Terrestrial Globe.

LET a science be ever so clearly described, and projection made of the sphere, yet the idea will be more fully conceived by placing a pair of globes before the learner, and teaching him the use of them; for by setting the globe in a position to correspond with each projection, the whole secrecy of nature in a few examples will be brought to light, and will be found in all cases calculated to simplify the practice on spherical trigonometry; and as this work is designed for nautical purposes, I shall here lay down a description of the terrestrial globe, wherein those circles are drawn and named.

The brazen meridian is that ring or hoop in which the globe hangs on its axis; the graduated side of this brazen circle serves as a meridian for any point on the earth's surface: the quadrant of altitude is a thin slip of brass, which is also graduated to 90 degrees: the equator is that great circle which divides the north half of the earth from the southern; the ecliptic crosses the equator at right angles, and is that great path the sun moves in: the tropics are smaller circles parallel to the equator, each of them near 23½ degrees from it; the tropic of cancer lies on the north side, and the tropic of capricorn on the south of the equator. The artic circle has the north pole for its centre, and the antartic just as far from the south pole: the broad space lying between the tropic, like a girdle surrounding the globe, is called the torrid zone, of which the equator is in the middle; all round the space between the tropic of cancer and artic circle, is called the north temperate zone; that between the tropic of capricorn and antartic circle is the south temperate zone, and the circular space bounded by the polar circles are the two frigid zones, called north and south.

Astronomical problems are best elucidated by first consulting the subject upon a globe; this will direct and illustrate the projection, and the latter serve as a guide to check the calculation.

EXAMPLE I. IN FIGURE 4.

On the 20th May, 1814, the sun's longitude was 1 sign 58° 46′ 27″ and the obliquity of the ecliptic 23° 27′ 45″, required the sun's declination and right ascension.

1st by the Globe, placed on a table in a ship.

On the ecliptic, first find the sun's longitude as above 58° 46′ 27″, and bring it to the brazen meridian; then the arc of the equator between the first point of ♈ and the brazen meridian, shews the sun's right ascension; and the arc, or number of degrees on the brazen meridian, between the equator and the ecliptic, shews the sun's declination for the above day.

2d by Projection.

This triangle is constructed on the plane of the solstitial colure, which is the most simple and easy to be understood for the given angle; the obliquity of the ecliptic, or the sun's greatest declination, will be then in the centre of the primitive, which is the first point of ♈. With the sweep of 60 from the line of chords, describe the primitive circle P. E. S. Q. draw the diameter E. Q. for the equator, and P. S. for the equinoctial colure; lay off E. ♋ 23° 27′ 45″ for the obliquity of the ecliptic, and draw the diameter ♋ ♑ for the ecliptic; then from the scale of semi-tangents lay off the sun's longitude 58° 46′ 27″ from ♈ to ☉ in the ecliptic, which is the sun's place through the points P. ☉ S. draw a circle of right ascension, then A. ☉ ♈ will be the triangle.

3d by Calculation.

In the right angled triangle ♈ ☉ A.
Given the sun's longitude ...... ♈ ☉ 58° 46′ 27″
Greatest declination angle ...... ☉ ♈ A. 23 27 45
Require the right ascension ♈ A. and the present decl. A. ☉

	°	′	″			°	′	″	
As rad...........	90	0	0—	10,0000	As rad...........	90	0	0—	10,0000
to sn. sun's long.	58	46	27—	9,93199	is to tan. sun'slong.	58	46	27—	10,21724
so is the sn. sun's	23	27	45—	9,60002	so is co-sn. obl. ecli.	23	27	45—	9,96268
to sn. prest. decli.	19	54	18—	9,53201	to tangt. rt. ascen.	56	32	30—	10,17992

The questions here given in a right angled spheric triangle, are intended for exercise of the learner, both by the globe and projection: others of the same kind are formed by the ecliptic and eqaator, namely, 7th February, 1st May, and 2d November, in the same year.

EXAMPLE II. FIGURE 4.

Given the obliquity of the ecliptic, and the sun's present declination, required the sun's longitude and right ascension.

Obliquity of the ecliptic .... 23° 27′ 45″
Sun's present declination......... 19 54 18

1st by a Globe, placed on the table in a ship.

Mark the sun's present declination on the brazen meridian, and turn the globe till the ecliptic comes under the meridian, then will the distance from the meridian to the first point of ♈ shew the sun's longitude on the ecliptic, and his right ascension on the equator.

2d by Projection.

With the sweep of 60 in your compasses, from the line of chords on the scale, describe the solstitial colure, with the equator and ecliptic, and equinoctial colure as in the first example; put E. *n* and Q. *m.* equal to the given declination, then round P. as a pole describe the parallel of declination *n. m.* where this intersects the ecliptic in ☉ is the sun's place, then through P ☉ S. describe the circle of right ascension P. ☉ S. then is ♈ ☉ A. the triangle required.

3d by Calculation.

In the right angled spheric triangle ♈ ☉ A.

Given	the obliquity of the ecliptic ...	A. ♈ ☉	23° 27′ 45″
	the declination	A. ☉	19 54 18

Required the sun's longitude and right ascension.

	°	′	″			°	′	″	
As the sn. obli. eclip.	23	27	45—	0,39988	As rad.	90	0	0—	10,00000
is to sn. sun's decli.	19	54	18—	9,53201	is to co-tn ob ecl.	23	27	45—	10,36239
so is rad.	90	0	0—	10,00000	so is tan. sun's dec.	19	54	18—	9,55910
to sn. sun's longitude	58	46	20—	9,93189	to sn. right ascen.	56	33	0—	9,92149

And with sun's longitude and present declination, require the obliquity of the ecliptic.

RULE.

	°	′	″	
As rad.	90	0	0—	10,00000
is to sn. sun's longitude	58	46	27—	0,06800
so is sn. sun's present dec	19	54	18—	9,53201
to the sn. greatest dec. or	23	27	45¼—	9,60001 the obliquity of the ecliptic.

In the Nautical Almanac, on the 6th June, 1812, the moon's latitude was 4° 33′ 45″ south, her longitude 37° 20′, and the longitude of the sun 75° 32′ 11″, required their distance at noon the above day.

EXAMPLE IN FIGURE 6.

In the oblique angled spheric triangle z. ☽ ☉

are given	the angle at the zenith	27°	45′	25″	These are found from the sides.
	the angle at ☉	131	40	00	
	and the side z. ☾	94	33	45	

To find the true distance from ☉ to ☾

1st by Projection.

With the sweep of 60 in your compasses, from the scale of chords describe the primitive circle z. E. N. Q. draw the diameter z. N. and E. Q. set off the moon's latitude from Q. to M. or the complement from N. to M. which is the same, and from E. to M. and from N. to ☉ on the primitive, draw the diameter M. M. and with one foot of the compasses at ☉ on the primitive, describe the great circle M. M. with the sun's longitude 75° 33′ from the line of chords; set one foot of your compasses in z. let the other mark the equator, from which draw the great circle z. ☉ N. and describe the small circle *n. m,* 22° 40′ 26″ from the equator as the parallel of declination for that day, through the sun's place ☉ at noon; then the true distance will measure from the scale 38° 26′ from ☉ to ☾ in the figure.

2d by Computation.

	°	′	″		
As the sn. of the angle at ☉	131	40	0	—	0,126660
is to the sn. of the side z. ☾	94	33	45	—	9,998689
so is the sn. of the angle at z	27	45	25	—	9,668167
to the sn. of the distance ☉ ☾	38	26	0	—	9,79351,6

Which is the true distance in the spheric hypothesis at noon of that day, between the sun and moon's nearest limb.

Of finding the Latitude of a Ship at Sea by a single Altitude of the Sun.

It frequently happens at sea that the meridian altitude can not be obtained, therefore the mariner should be acquainted with other means to come at the knowledge of this important problem so useful in navigation.

EXAMPLE IN FIGURE 1.

Given the sun's altitude and hour from noon, and the sun's declination, required the latitude of ship.

1st by Projection.

Describe the primitive circle Z. H N. Q. draw the diameter Z. N. and H. O., and the axis P. S. and equator E. Q. at right angles 21° 37′ from H. O then from ⊙ on the primitive describe the great circle P. ⊙ S. and about Z. as pole, describe the small circle *s. t.* the sun's altitude; then with complement of the polar distance 76 degrees in your compasses, set one foot in Z. and mark the horizon line with the other; from the latter describe the great circle Z. ⊙ N. the sun's place at 5 P. M. Given day 28th October, 1805.

2d by Computation.

In the oblique angled spheric triangle Z. O. P.

Given	the sun's co-altitude Z. O.	81°	44′	required the co-latitude Z. P.
	the polar distance... P. O.	104	00	
	the hour angle. . Z. P. O.	75	00	

	°	′	″			°	′	″	
As rad.	90	0	0	—10,0000	As co-sn.	104	0	0	—10,6613
is to co-sn. angle ..	75	0	0	— 9,4129	is to co-sn.......	18	44	0	— 9,1577
so is tangt. side	104	0	0	—10,6030	so is co-sn. arc A..	46	3	0	— 9,8414
to the tangt. arc A..	46	3	0	—10,0159	to co-sn. arc B ..	65	37	0	— 9,1654
					Sum both arcs	111	40	0	taken from 180°
					Co-latitude north..	68	20	0	Saugar

Roads, Bengal, where the ship was anchored at the time.

EXAMPLE IN FIGURE 3.

Given the sun's altitude, the hour from noon, and sun's declination, required the latitude of the place of observation.

1st by Projection.

With the sweep of 60 in your compasses, from the line of chords on the scale, describe the primitive circle Z. H. N. R. to represent the meridian of St. Paul's Church, Liverpool, H. R. the horizon, Z. N. the prime vertical; make R. P. 53° 22′ 41″ the height of the pole at Liverpool, draw the axis P. S. and E. Q. for the equator, lay off the declination E. *n* and Q. *m.* 22° 30′ north, the sun's altitude H. *s.* 47° 32′, about P. as a pole describe the parallel of declination *n. m.* nd *s. t.* from about Z. cutting in ⊙ the place of the sun at the time of observation; from Q. describe the hour circle P. ⊙ S. and from out R. describe the azimuth circle Z. ⊙ N. then the angle ⊙ P. S.

will give the hour from noon and co-latitude z. P. on the 8th of July 1813; then rectify a globe for the meridian and latitude of St Paul's Church, Liverpool, and let it be compared with the corresponding projection in Figure 3.

2d by Computation.

In the oblique angled spheric triangle z. o. P.

Given	the zenith distance.........	z. o.	42°	28′	Required co-latitude z. P.
	the polar distance	⊙ P.	67	30	
	the hour angle from noon	z. P. o.	38	29	

As rad.............	90	0	0—10,0000	As the sn.	22	30	0—0,4070	
is to the co-sn. hour	32	29	0— 9,8936	is to sn. sun's alt.	47	32	17—9,8670	
so is the co-tan. decl.	22	30	0—10,3827	so is co-sn.......	62	5	30—9,6704	
to tang. 1st arc	65	5	30—10,2763	to co-sn. 2d arc	25	33	25—9,9554	
				Co-latitude......	36	32	5	N. of Formby Point, near Liverpool.

Of the Essential Properties of the Sextant, and its Adjustment.

To enumerate all the advantages navigation has derived from the use of this instrument is not my intention, but to point out some of its distinguished qualities, which rank it the greatest improvement in the practice of navigation that has hitherto been invented. This instrument has derived its properties from the laws of reflection. The half and quarter degrees on the arc answer to whole ones in the angle measured; this renders it peculiarly advantageous to the mariner at sea, and the errors to which it is liable are readily discovered and soon adjusted, while the application and use of it is both easy and simple. The arc on it, is extended to 130 degrees for measuring the angular distance between moon, sun or fixed star, thereby to determine the longitude at sea; and the adjustments of the sextant are, first to set the index and horizon glasses perpendicular to the plane of the instrument, and this plane parallel to each other when the index division is at 0 on the arc, so that when measuring the angular distance the line of sight or axis of the telescope should be set parallel to the plane of the instrument, as a deviation in that respect will occasion a considerable error in the distance, and this is most sensible in large angles; each of these particulars must be carefully examined, before and after the observation, and allowances made for the index error if any.

To set the Axis of the Telescope parallel to the Plane of the Sextant.

Screw on the telescope, in the field of which there are placed two wires parallel to each other, equidistant from the centre, to which are added two others at right angles; turn the tube containing the eye glass till the wires are parallel to the plane of the instrument, then take two objects as the sun and moon or the moon and a fixed star, whose distance must not be less than 90 degrees, because the error is more easily discovered when the distance is great; bring the object into contact at the wire which is nearest the sextant, and fix the index, then by altering a little of the position of the instrument, so as to make the image appear on the other wire; if the contact still remains perfect, the axis of the telescope is in its right situation, but if the limbs of the two objects appear to seperate at the wire that is furthest from the plane of the instrument, it shows that the object end of the telescope inclines towards the plane of the instrument, which must be rectified by tightening the screw nearest the sextant, which is attached to the ring that holds the telescope, and *vice versa* if the images over-lap; the quicker this adjustment is made the better, for it is here observed, that at the time the observer is making this adjustment the distance between the objects are increasing or decreasing rapidly.

An Improved Method of Observing the Meridian Altitude of a Star or Planet, and of taking the Angular distance.

THE observer having compleated the adjustment of his instrument, he may safely proceed to take the altitude of either moon, or star; for the latter place, the index at 0, and having previously found the star, hold the instrument up, and direct the telescope for the star, or bring the star's image on the silvered part of the horizon glass, then move the index until the star is brought down to horizon in the manner as that of the sun, or moon, but to bring down a star with a quadrant I have made the observation more perfect by looking at the star over the sight vane, when turned horizontally for that purpose, than by directing the sight through the hole of the vane.

—

But in taking the distance between the moon and a fixed star, which is in general a bright one, and lies in a line nearly perpendicular to the horns of the moon, the most convenient method I ever found from practice is by carrying the moon to the star, instead of taking the star to the moon; and this is most readily done, by first finding the moon in the silvered part of the horizon glass, while the index stands at 0, then to move the index until the enlightened limb of the moon comes in contact with the star.

For the distance between the sun and moon, the index and horizon adjustments being already made, screw on the telescope, and place the wires parallel to the plane of the instrument, and when the sun is to the westward of the moon, the observer must place himself in the most convenient situation on deck, from whence the objects are best seen, and fix himself so that his whole body may be borne up, and rather inclining backwards, the sextant being held with the right hand, and the index moved with the left; and when the sun is to the eastward of the moon, I have made the observation more perfect by holding the sextant again in my right hand, the face of the instrument from me, and the movement of the index regulated by the left hand. Now to make the observations three assistants are necessary; two are to observe the altitudes of the moon and sun, or star, at the same time that the distance is taken by the principal observer. If the sun is at a proper distance from the meridian, the apparent time at the ship may be inferred from the sun's altitude, observed at the same time with the distance; this I have found sufficiently exact when the object was two hours distant from the meridian; but if the distance of the moon from a star is observed, a watch is necessary, previously regulated from a set of altitudes taken for that purpose, when the sun is 15 to 20 degrees high, for the horizon in the night is seldom clear enough to depend upon the altitude of a star, for regulating the apparent time of observation at the ship. (See page 22.)

The third assistant must be provided with pencil and paper, to write down the observations as they are taken; then all are to begin to observe at the same time, and when the principal observer has brought the nearest limbs of the sun and moon, or the enlightened limb of the moon and star into contact, he is to ask the other observers if they are ready, and being answered in the affirmative, he is to call out any particular word, the person having the pencil and paper marks down the distances as they are read off to him by the principal observer: the other assistants are in the like manner to report the observed altitudes of the limbs of the objects separately, and in the same way repeat the observations till five sets are observed, which may be easily accomplished in the space of six to nine minutes, and these sets ought to be taken at nearly equal intervals of time.

It is to be further remarked here, that the longitude wholly depends upon the accuracy of the instrument, and the distance being measured correct. It will greatly assist the principal observer before he enters on the observation, to refer to the Nautical Almanac for the distances between the objects on that day, which are laid down for every three hours, and turn it into time; the observer will then find how many seconds the objects increase or decrease from one another in three hours, and having a watch that beats seconds, he will be able to mark time by it from his first distance taken, how he may keep pace with the movement of the object in the heavens. I have invariably made this a maxim, and found it in practice an excellent guide, so that I seldom failed to determine the longitude at sea five miles over or under the true spot.

But to illustrate what has been advanced, the following observations were taken between the moon and sun's distance on the morning of the 7th May, 1812, off the coast of Portugal, from the poop of a line of battle ship. The altitudes of the objects shew that they were nearly equal height above the horizon, and the sun two hours from the meridian, therefore the mean of the sun's altitude is taken to find the apparent time at the ship, a watch being introduced merely to guide the observation—viz.

	h. m. s.		Nearest limbs. ° ′ ″	☉ low. l. ° ′ ″	☽ l. l. ° ′ ″
Time per watch	9 16 20	Appar. dist. S. M.	49 32 10		
	17 50	.. .. ..	33 10		
	19 27	.. .. ..	34 20		
	21 2	.. : ..	35 10		
	22 31	.. .. ..	36 10		
Sum	97 10	Sum........	171 00	☉ap. 47 17 59	☽ ap. 45 10 9
Mean	9 19 26	Mean	48 34 10		
		Index err. add	22		
			49 34 32		
		Semi-diam.	32 15	☽ horizon paral.	59 51
		Appar. dist.	50 6 47		

Thus in taking the mean of the several distances, those which appear doubtful ought absolutely to be rejected, for a doubtful distance or altitude may be easily discovered, by observing if the difference of the observed distances or altitude be proportional to the movements of the objects in the heavens. But some writers on the longitude give new precepts for taking a set of lunar observations by one person only: this mode of observing was first proposed by the Abbe de la Caille; but those who have had experience of the practice of taking the angular distance at sea, will admit that the bishop was more an astronomer than a seaman, and that ideas are often framed in the closet, which cannot at all times be well reduced to practice at sea. Indeed I have seen those who pretend to follow such a rule at sea, make the by-standers gaze, by beholding a person first measure the distance between sun and moon, then lay down his instrument upon deck, the ship rolling at the time—take up a quadrant, bring down the sun, then the moon's altitude - return to his first instrument all in bustle, and after all, when called upon for the observation, he could not make anything of it. Such writers and operators deceive both themselves and others, who adopt their precepts and presume to follow their examples; and it is abundantly obvious that they are infinitely better qualified to write on theory in their studies, than to know anything correctly of the practice at sea.

On the contrary, it requires the greatest nicety in measuring the distance between the moon and sun, or fixed star, for the least motion in the ship, with all the care of the observer, will often put him out of the field of view; and it is further to be noted, that at the time of observing the angular distance, the objects are flying from each other as rapid as the movement of the seconds on a watch; and that instead of using an inverted telescope to the sextant, it is recommended to use an erect one, whose power for that purpose has been already prepared. The observer will find that he will be able with the latter to guide the objects to a better and steadier coincidence, for with the former screwed on to the instrument, the least motion of the ship puts the object out of the field of view, which renders the observation doubtful.*

* Erect telescopes, with nearly as much power, may be obtained from that ingenious mathematician, Mr. Dolland.

Having the Observed Distance of the Moon from the Sun or fixed Star, with the apparent Altitudes of each, and the Moon's Horizontal Parallax, to find the True Distance by the following short and easy method in Spherical Trigonometry.

RULES.

1st. Add together the apparent distance, the moon's co-altitude, and the sun or star's co-altitude, their sum is the sides of the triangle formed by the object; from the half sum take the apparent distance, and call it the first remainder; do likewise with the moon and sun's co-altitude, and call them the second and third remainder; the sum of these four logarithms as shewn by the formula, gives the angle at each object.

2d. Then to the log. secant of the angle at the moon, add the proportionable logarithm of the moon's correction in altitude, the sum of these two logarithms is the effect of the moon's parallax on the distance, which must be always substracted from the apparent distance, when the angle at the moon is less than 90 degrees, and added when above; and

3d. To the log. secant of the angle at the sun or star, add the proportionable logarithm of the sun or star's correction in altitude, the sum of these two logarithms is the effect of refraction on the distance, which must always be added to the apparent distance, if the angle at the sun or star is less than 90 degrees, but subtract if above.

4th. Again, for the third correction, look in the Parallactic Tables for the distance twice corrected at the top, and in the left hand column for the moon's correction in altitude; take out the number of seconds which stands under the former, and opposite the latter, enter it again with the effect of the moon's parallax in the left hand column, and do the like; the difference of these two numbers is to be added to the distance twice corrected, if less than 90 degrees, but substract when above.

5th. For the fourth correction, enter the tables again with half the moon's correction in altitude in the left hand column, and under the distance three times corrected, add the whole number of seconds that stands there to the distance, if less than 45 degrees, but when the distance is greater, the half only must be added; now these four corrections being applied to the apparent distance of the moon from a star or the sun's centre, the true distance will be found to the nearest second, clear of the effect of refraction and parallax.

EXAMPLE I.

Given the apparent distance of the moon from a star 43° 35′ 42″, and the apparent altitude of the star 11° 17′, that of the moon 9° 38′ and horizontal parallax 54′ 42″, to find the true distance.

* Refraction .. 4′ 39″	☽ horizon. par.....	54′ 42″	P. L...	5173
	☽ altitude	9 38	sec. ..	0061
	☽ parallax in alt...	53 56	P. L...	5234
	☽ refraction in alt	5 28		
	☽ correction in alt.	48 28		

Apparent dist. * ☾	43 36	co-sec. ..	1613		co-sec. ..	1613
☽ co-alt.	80 22	co-sec. ..	0061			
* co-alt..........	78 43				co-sec. ..	0084
Sum 3 sides	202 41					
½ sum......	101 20½					
1st remainder	57 44	sn. ..	9,9271		sn. ..	9,9271
2d ditto..........	20 58	sn. ..	9,5536			
3d ditto..........	22 37				sn. ..	9,5849
			19,6481			19.6817
	41 50	sn. ..	9,8240	43 53	sn. ..	9,8408
	2			2		

Angle at the ☽ 83° 40′	sec...	9573	Angle at * 87° 46′	sec.	11,4093
☽ corr. in alt. .. 48 28	P. L.	5698	* corr. in alt. 4 39	P. L.	1,5878
Eff. ☽ par. in dis. 5 20½	P.L.	1,5271	Eff. * refr. in dist. 11	P.L.	2,9971

Apparent dist.	43 35 42
	43 30 21½
Eff. * ref. in dist.	11
	43 30 32½
Third cor. in dist.	22½
Fourth cor. in dis.	5½
True distance..	43 31 00½

This method of clearing the effect of parallax and refraction on the distance is deduced from fluxionals of spheric triangles. This and the two following are the three first lunar questions in the Requisite Tables as calculated by different authors.

EXAMPLE II.

Let the apparent distance of the moon from the sun be 103° 29′ 27″ the apparent altitude of the sun 19° 3′ 36″, that of the moon 41° 6′ 2″ and her horizontal parallax 58′ 35″, what will be their true distance.

☉ refrac. in alt...	2′ 43″	☽ horizon. parallax	58′ 35″	P. L...	4865
☉ parallax......	8	☽ altitude......	41 6 2	sec. ..	1229
Correction ☉ alt.	2 35	☽ parallax in alt.	44 8½	P. L...	6104
		☽ refrac. in alt..	1 4½		
		☽ correction in alt.	43 4		

Apparent dist. ☽ ☉	103 29½....	co-sec...	0121	....	co-sec..	0121
☽ co-altitude	48 54	co-sec...	1229			
☉ co-altitude	70 56			....	co-sec..	0245
Sum 3 sides	223 19					
½ sum	111 39½					
1st remainder	8 10	sn..	9,1524	....	sn. ..	9,1524
2d ditto	62 45	sn..	9,9489			
3d ditto	40 43			....	sn. ..	9.8146
			19,2363			19,0036
	24 31½	sn..	9,6181	18 30½	sn. ..	9,5018
	2			2		

Angle at the ☽ 49° 3′		sec...	1835	Angle at ☉ 37° 1′		sec..	0978
☽ corr. in alt..	43 4	P. L.	6211	☉ refr. in alt.	2 35	P. L.	1,8431
Eff. ☽ par. in dis.	28 13½	P. L.	8046	☉ refr. in dis.	2 3½	P. L.	1,9409

Appar. dist. ☽ ☉	103	29	27
	103	1	13½
☉ refr. in distance		2	3
	103	3	16½
Third correction			2
True distance ..	103	3	18½

It is here noted, that when the angle at the moon, sun, or star, is acute, or less than 90 degrees, the effect of the moon's parallax on the distance is always substractive, and the sun or star's refraction in distance additive; and the contrary when the angle at each object is greater than 90 degrees.

EXAMPLE III.

Having the apparent altitude of a star 24° 48′, and that of the moon's centre was 12° 30′, their apparent distance 51° 28′ 35″, the horizontal parallax 56′ 15″, what was the true distance?

* Correction in alt. 4′ 39″	☽ horizon. parallax	56′ 15″	P. L... 5051
	☽ altitude	12 30 0	sec. .. 0104
	☽ parallax in alt...	54 55	P. L... 5135
	☽ refraction in alt	4 14	
	☽ correction in alt.	50 41	

Apparent dist. ☽ *	51 29	co-sec. ..	1066	co-sec. ..	1066
☽ co-alt.	77 30	co-sec. ..	0104		
* co-alt.	65 12			co-sec. ..	0420
Sum 3 sides	194 11				
½ sum......	97 5½				
1st remainder	45 36	sn. ..	9,8540	sn. ..	9,8540
2d ditto..........	19 35	sn. ..	9,5253		
3d ditto..........	31 53			sn. ..	9,7229
			19,4963		19.7255
	34 3	sn. ..	9,7481	46 48 sn. ..	9,8627
	2			2	

Angle at the ☽ 68° 6½′		sec... 4283	Angle at * 93° 36½′		sec. 11,2021
☽ corr. in alt.	50 41	P. L. 5504	* corr in alt.	2 5	P.L. 1,9365
Eff. ☽ par. in dis.	18 54½	P.L. 9787	* refr. in dist.	7	P.L. 3,1386

Appar. dist. ☽ *	51 28 35
	51 9 40½
* ref.. in dist...	7
	51 9 33½
Third cor. in dist.	14½
Fourth cor. in dis.	2
True distance..	51 9 50

In this operation, the angle at the star is greater than 90 degrees, therefore its refraction in distance is substractive. A mistake of this sort in working a lunar by Lyon's method, of adding the effect of the moon's parallax instead of substracting it from the distance, nearly proved the loss of two of his Majesty's ships on the Island of Barbadoes, to which I was witness.

EXAMPLE IV.

The apparent distance of the moon and sun's nearest limbs 72° 21′ 40″, and the apparent altitude of the moon 19° 19′, that of the sun 21° 16′, and the moon's horizontal parallax 56′ 32″, what was the true distance?

☉ refraction....	2′ 0½″	☽ horizon. parallax	56′ 32″	P. L...	5030
☉ parallax in alt.	8	☽ altitude......	19 19	sec. ..	0252
Correction ☉ alt.	1 52½	☽ parallax in alt.	53 21½	P. L...	5282
		☽ refrac. in alt..	2 38		
		☽ correction in alt.	50 43½		

Apparent dist. ☽ ☉	72 22	.... co-sec...	0209	....	co-sec..	0209
☽ co-altitude	70 41	.... co-sec...	0252			
☉ co-altitude	64 44	....		....	co-sec..	0437
Sum 3 sides	207 47					
½ sum	103 53½					
1st remainder	31 31	...... sn..	9,7183	....	sn. ..	9,7183
2d ditto	33 12	...... sn..	9,7384			
3d ditto	39 9	....		....	sn. ..	9.8003
			19,5028			19.5832
	34 20½	sn..	9,7514	38 14	sn. ..	9,7916
	2			2		

Angle at the ☽	68°41′	sec...	4395	Angle at ☉	76° 28′	sec..	6308
☽ corr. in alt..	50 43½	P. L.	5501	☉ refr. in alt.	1 52½	P. L.	1,9822
Eff. ☽ par. in dis.	18 26	P. L.	9896	☉ refr. in dis.	26½	P. L.	2,6130

Appar. dis. ☽☉	72 21 40
	72 3 14
Eff. ☉ ref. in dis.	26½
Third correction	7
Fourth correction	¾
True distance	72 3 48¼ in the spheric hypothesis.

On examination of Lunar 1st and 2d, it will be found that the whole operation, which contains the work of every lunar observation, is fully given, and consists only of one statement and a few figures, for finding the angles at each object. The corrections are afterwards found, and applied simply as above.

This method of working a lunar observation, which is short, is never liable to err, tho' the distances and altitudes of the objects may be great or small, and it is still capable of undergoing a further improvement, so that the angle of either moon, sun, or star, might be obtained by Tables, which, if my efforts in this Work meet encouragement, I intend to bring forward.

EXAMPLE IN LUNAR 1st, FIGURE 2.

On the 28th October, 1805, the sun's apparent altitude was 8° 16′ 22″, that of the moon 45° 10′ 35″, their apparent distance 99° 10′ 50″, the moon's horizontal parallax 54′ 59″; what was the true distance, the apparent time, and longitude of the ship at the time of observation.

☉ refraction......	6′ 18″
☉ parallax	9
Correction ☉ alt...	6 9

☽ horizon. parallax	54 59	P. L	5150
☽ altitude........	45 10 35	sec.	1518
☽ parallax in alt..	38 46	P. L.	6668
☽ refraction in alt..	56		
Correction in ☽ alt.	37 50		

Apparent dist. ☽ ☉	99° 11′....	co-sec.	0056	co-sec.	0056
☽ co-altitude	44 49	co-sec.	1518		
☉ co-altitude	81 44		....	co-sec.	0045
Sum 3 sides	225 44				
½ sum......	112 52				
1st remainder	13 31	sn...	9,3739	sn...	9,3739
2d ditto	68 3	sn...	9,9673		
3d ditto	31 8		....	sn...	9.7135
			19.4986		19.0975
	34 9 / 2	sn...	9,7493	20 43 / 2 sn...	9,5487

Angle at the ☽	68° 18′	sec.	4321
☽ cor. in alt..	37 50	P. L	6774
Effect ☽ par..	14 1½	P. L.	1,1095

Angle at ☉	41° 26′	sec...	1251
☉ refr. in alt.	6 9	P. L.	1,4664
Effect ☉ refr.	4 36½	P. L.	1,5915

Apparent dist.	99 10 50	
	98 56 48½	
Effect ☉ refr.	4 36½	
True distance	99 1 25	
Dist. by N. A. {	98 3 2	
	99 25 51	
	58 22	P. L. 4891
	1 22 51	P. L. 3270
	h. 2 6 49	P. L. 1521
	21	
Time at Green.	23 6 49	
Time at ship..	29 0 15	

Longitude .. 5 53 26—88 21 30 E. Saugar Roads, Calcutta.*

To find the Apparent Time at Ship.

Co-decli....	104 00	co-sec.	0131
co-latitude..	68 23	co-sec.	0317
co-altitude..	81 44		
sum	254 7		
½ sum....	127 3½		
1st remainder	23 3½	sn.	9,5927
2d ditto	58 40½	sn.	9.9315
			19,5690
	37 00 ½ / 2	sn.	9,7845
hour angle ..	75 00 1	or h. 5 00 15	P. M.

* It is evident that the longitude thus found was the longitude of the ship at the time of observation, and it is the difference between the time at Greenwich and the time at the ship, which is taken for the longitude of the ship under that meridian.

EXAMPLE IN LUNAR 2d, FIGURE 5.

Being at sea on the 7th May, 1812, the apparent distance of the moon from the sun was 50° 6′ 47″, the apparent altitude of the sun 47° 17′ 59″, that of the moon 45° 10′ 9″, and her horizontal parallax 60′ 14″, what was the time, distance, and longitude of the ship at the time of observation?

☉ refraction	52″	☽ horizontal parallax..	60 14	P. L.	4754
☉ parallax in alt...	6½	☽ altitude............	45 10 9	sec..	1518
		☽ parallax in alt......	42 28	P. L.	6272
Correction ☉ alt...	45½	☽ refraction in alt.....	46½		
		☽ correction	41 41½		

Apparent dist. ☉ ☾	56° 7′	co-sec.	0808		co-sec.	0808
☽ co-altitude......	44 50	co-sec.	1518			
☉ co-altitude......	42 42				co-sec.	1618
Sum 3 sides........	143 39					
½ sum	71 49½					
1st remainder......	15 42	sn.	9,4323		sn.	9,4323
2d ditto	26 59	sn.	9,6568			
3d ditto	39 7				sn.	9,7999
			19,3217			19,4817
	27 15	sn.	9,6608	33 24	sn.	9,7408
	2			2		

Angle at ☽........	54 30	sec.	2361	Angle at ☉..	66 48	sec.	4046
☽ correction	41 41	P. L.	6353	☉ cor. in alt.	45½	P. L.	2,3800
Effect ☽ par. in dist.	24 13	P. L.	8714	effect ☉ refr.	17½	P. L.	2,7846

Apparent distance..	50 6 47		
	49 42 34		
Effect ☉ refraction	17½		
	49 42 51½		
Third correction ..	9		
Fourth ditto	1½		
True distance......	49 43 2		
Dist. at 9h. N. A...	50 16 21		
Dist. at 12h. N. A...	48 34 11		
	33 19	P.L.	7326
	1 42 10	P.L.	2460
	58 42	P.L.	4866
	9 0 0		
Time at Greenwich	9 58 42		
Time at ship	9 17 48		
Difference of time..	40 54—10° 13′ 30″ W.		

Cape Finisterre bore then S. 24° E. distance 34 leagues.

To find the Apparent Time at Ship.

Co-declination	73 15	co-sec.	0188
co-latitude ..	48 40	co-sec.	1224
co-altitude ..	42 42		
sum	164 37		
½ sum	82 18½		
1st remainder	9 3½	sn.	9,1967
2d ditto......	33 30	sn.	9,7418
			19,0797
	20 16½	sn.	9,5398
	2		
hour angle	40 33 or 9h 17 48 A.M.		

To project the figure stereographically from the apparent altitude and distance given as above, with the sweep of 60 from the line of chords on the scale, describe the primitive circle H. Z. R. N., draw Z. N. and H. R. at right angles, then Z. represents the zenith, and H. R. the horizon; lay off 47° 18′ the sun's altitude from H. to *s.* and from about Z. describe the small circle *s. t.*, then lay off 45° 10′ the moon's altitude from R. to M. and from H. to M. and draw the diameter M. M.; then is R. M. the moon's height above the horizon; from *m.* describe the great circle M. S. M. cutting *s. t.* in S., then will S. be the apparent place of the sun, and M. the apparent place of the moon; then from about R. describe the great circle N. S. Z. and the measure of S, M. will be the apparent distance. See figure 2, and page for a further explanation on parallax and refraction.

The Elements of Spheric Trigonometry explained, and projected Orthographically, in Figure 2.

In the oblique angled spheric triangle Z. S. M. in Figure 2, the side S. M. the apparent distance is given 99° 10′ 50″, the side S. Z. 81° 43′ 38″ the sun's apparent zenith distance, and the side Z. M. 44° 49′ 25″ the moon's apparent zenith distance, to find the angles at each object and the true distance, and project the figure.

With the sweep of sixty from the scale of chords, describe the primitive circle H. Z. R. N. and draw Z. N. and H. R. at right angles, then Z represents the zenith, and H. R. the horizon, make H. *c.* and R. *m.* the height of the moon's altitude above and below the horizon; do likewise R. S. and H. S. for the sun's altitude, or Z. S. his co-altitude, and R. O., which is the same; from *o.* draw the great circle S. S, cutting *m. c.* in M and about R. draw the great circle N. Z.; then will M S. represent the apparent distance, M. Z the moon's co-altitude, and S. Z. the sun's co-altitude. Refer to page for further explanation of the sun and moon's true place as seen from the earth's surface and centre.

Apparent dist.	99 11	co-sec. 0056		co-sec. 0056		
☽ co-altitude	44 49	co-sec. 0513				co-sec. 1519
☉ co-altitude	81 44			co-sec. 0045		co-sec. 0046
Sum 3 sides..	225 44					
½ sum	112 52					
1st remainder	13 31	sn. 9,3739		sn. 9,3739		
2d ditto	68 3	sn. 9,9673				sn. 9,9673
3d ditto	31 8			sn. 9,7136		sn. 9,7136
		19,4976		19,0976		19,8374
	34 9	sn. 9,7488	20 43	sn. 9,5488	56 1 15	sn. 9,9187
	2		2		2	

Angle at ☽.. 68° 18′ Angle at ☉ 41° 26′ Ang. at zen. 112° 2′ 30″ See Fig. 2.

These are the apparent angles at each object and zenith, therefore to find the true distance between the sun and moon in Figure 2 and 5, their true angles must be found in the same way, and the work is as follows.

As sn. true angle at the ☽..	68° 7½′	0,032440
is to the sn. ☉ co-alt....	81 49½	9,995554
So is the supl. ang. at zenith	67 49	9,966602
to the sn. supl. distance..	80 58 37	9,994596
True distance	99 1 23	

True distance .... 99 1 23 differs two seconds only from the work in lunar the first, which shortens the operation materially from this long method of finding the true distance by trigonometry, which is here work'd to shew the difference, and serves to check the operation in all other methods, when the distance is doubtful.

General Remarks upon the Longitude, and a comparative view of the various methods of determining this important problem in Nautical Astronomy.

A lunar observation comprehends three sides of a spherical triangle in the heavens, viz. the co-altitudes of the observed bodies, and their distance assunder; and the operation in spheric trigonometry depends upon the solution of the angles at each object and zenith, to find the true distance according to the spheric hypothesis. But as various methods are produced by authors to find the true distance, the first of note in the Requisite Tables is that by the late Dr. Maskelyne, Astronomer Royal, and the second in the same book is Mr. Lyon's method for clearing the effect of parallax and refraction on the moon's distance from the sun or fixed star; and the other two methods contained in the same volume are derived from the same principle, which are equally long. It is admitted that arithmetical questions worked by the rule of three, may be shortened by other rules equally correct; but the like does not follow in all methods of working a lunar observation; therefore preference must be given to trigonometry, as the safest method of clearing the effect of parallax and refraction on the distance, especially when short and the altitudes low. Thus it may seem a matter of astonishment that this important question, one of the most interesting that ever engaged the human attention, is little more than to be enabled to tell what o'clock it is elsewhere; for as the sun in his daily course passes over 360 degrees of longitude in 24 hours, he passes over 15 degrees in one hour. This subject is more fully explained in the succeeding notes, which were sent by the author to the Board of Admiralty.

Liverpool, December 14th, 1811.

SIR,

As the great end of navigation, and the safety of ships at sea, wholly depend on the latitude and longitude being well determined; and as it frequently happens, for the want of an horizon, great inconvenience has arisen, for several days together, no meridian, nor even a single altitude, being obtainable, many methods have been proposed, and trials made, on the use of the false horizon, the utility of which is better founded on theory than practice. To obviate and remove such difficulties, I beg leave to present, for their lordship's inspection, an instrument of my own construction, that will answer all the purposes required, being a circle on one part, and a sextant on the other; the circle measures the sun's height above, and his depression below the horizon, which is one and the same altitude; for the circle shows that the midnight depression is equal to the noon-day elevation; then the telescope gives the angle from the sun to the *zenith*, and the circle from the sun to the horizon, and the snm of both makes 90°, independant of an horizon.

At the same time, I have the honor to lay before their lordships a lunar observation, taken by me on board H. M. S. Medusa. In the accompanying figure 2 will be seen the whole nature and properties fully explained, being the first projection of a lunar that ever appeared. And I further beg to observe, that various methods have been very ingeniously devised, for working lunar observations; and to answer the end, new tables and logarithms have been made, to suit the calculations, which affords room for exterminating errors through algebraical combinations and substitutions, which shortens the operation. That the four methods inserted in the Requisite Tables for working a lunar, as likewise Mendoza's logarithms, are severally founded on the above principles; and although it may shorten the work from that of finding angles and sides by spherical trigonometry, yet it will be found that neither of these methods possess any excellencies in themselves, so as to make up for any error in the observed distance, which often arises, in taking the distance too great or too little.

Volumes have been industriously propagated for working lunar observations, filled with terms which not one mariner out of fifty understands; and, after all, the whole amounts in the end to nothing more than working of a lunar, the great object of which, as I have before stated, wholly depends in taking the distance, and the lunar tables being correct; and although the calculations in all lunars are more tedious than might be wished for, yet I am persuaded, by placing less dependance on watches, and more practice in taking the distance between the sun and moon, and a thorough knowledge of the sextant, that seeming difficulty which at first appears, would, through practice, ultimately vanish, and the longitude be determined very exact, that is, from 5 to 7 miles, over or under.

Permit me to remind their lordships, that great assistance and information would be derived in the practice of the lunar observations, as well as other branches of navigation at sea, by placing a pair of globes to each ship; as also a manual, containing some plain intelligent rules, and practical inferences, on finding the latitude and longitude at sea; the former by one single altitude, as may be seen by the work in figure 1st, and the latter by the lunar observation herewith presented in figure the 2d; which work I have now in some state of forwardness.

In May, 1806, I was directed, by letter from Mr. Secretary Marsden, to present the instrument named on the other side (for taking the sun's altitude, independant of an horizon,) to the Astronomer Royal, which I did on the 20th August, 1806, accompanied by Mr. Dolland, who made it;* but he, without trial, said that he believed nothing could be invented to do away what he had already done, but that he would thank me for any information on the lunar observations. I then told him, that from a series of lunar observations made by me at well determined meridians, I found that in the Nautical Almanacs of 1803-4-5 and 6, the moon was placed too far to the eastward; and that those niceties appeared to me to be more the effect on the delineation of the moon's path than the sun's longitude, because the obliquity of the ecliptic at each of the solstices affords an excellent opportunity for determining its quantity, and measure the breadth of the tropic; to which he replied, he believed the moon is placed a little too far to the eastward.

In April, 1806, I sent my surveys of Prince of Wales' Island, and the Straits of Sincapore, to the Admiralty, together with a series of lunar observations, made by me at Madras, and other places in India, accompanied with a letter on the subject of observations on the moon at different sides of her full. In consequence of the above-mentioned inequalities in the Nautical Almanac, I took the distance of the observation in the figure about a needle's breadth open; had I made the limbs to have touched, the distance would have been about 30 seconds more, the result would have come out 15 miles less for the longitude; and by the Ephemeris of the above day's work, the distance between the sun and moon for three hours are laid down 82′ 51″, which answers to the observed distance being taken a little open; but had I brought their limbs to touch, this would have given 30″ more on the sextant, and to answer this last distance, 82′ 51″ is too short by 50″.

* The instrument which accompanied this letter is now made of tin, and at present in the hydrographer's office, is an improvement on the first I made; the principal on which the latter was founded. for measuring the angle from the sun to the zenith, is now on this instrument annexed to the quadrant, and may be used occasionally.

But far be it from me for a moment to hold my feeble efforts in competition with so able an astronomer; nor do I pretend to assume a level; but I may be permitted to say, that feeling myself thoroughly acquainted with spherical trigonometry, in which all lunar observations lay, and able to correct those small errors which unavoidably arise in the use of the sextant, and being persuaded, that if the lunar tables were correct, so as an observation could be made with exactness at sea, to determine the longitude, I could not be far off the mark, as may be seen by referring to the figure of the lunar explained.

I am, Sirs, &c. &c. &c.

THOMAS EVANS, Lieut.

To J. W. Croker, &c. Admiralty.

Investigation of a Lunar Observation in Figure 2, shewing the principle Rational of the Projection both of the Moon's Parallax and Sun's Refraction, and how the latter operates on the distance from the surface and earth's centre.

Liverpool, December 14*th*, 1811.

SIR,

I beg leave to submit to their lordships a lunar observation, taken by me on board H. M. S. Medusa, Sir John Gore, then at anchor in Saugar Roads, near the mouth of the Ganges. In the accompanying figure 2 will be seen the position of the sun and moon at the time of observation, by which the side, the observed distance, is found by spherical trigonometry; as well as the method I work a lunar, which is of my own invention, and very short, requires no new tables or substitutions, the logarithms only to four places of figures, besides the index, which may be always taken at one sight, without making proportions, and will be found best adapted to suit the capacity of seamen in general, and less liable to error than any other method at present extant; the angle at each object is first found by spherical trigonometry, being the most universally correct, and the examples sufficiently show that the whole may be worked by Gunter's scale with readiness, and I find, by analyzing the work, that even five miles error in the angle at either object, will not cause more than one or two seconds effect on the corrections of either sun or moon.

By referring to figure 2, S. the sun, and M. the moon's apparent altitudes, Z. the zenith, and M. S. the apparent distance between the objects at the time of observation, which forms three sides of the triangle, by which the angles are first formed, then the side M. S. the apparent distance, as may be seen by referring to the figure. But as the apparent places of the sun and moon, as seen in the heavens at the time of observation on the surface, is not their true places, and both stand in need of being corrected for parallax and refraction, especially the moon, from her approximity to the earth; this arises from circumstances of the observed distances of the heavenly bodies not being the true distance, for the altitudes of their bodies are more or less affected, both by parallax and refraction, which effect cannot operate in any other way, but in a vertical direction; for it is clear, by the observation formed by the triangle in figure 2, that cause which changes the altitudes of their bodies, must inevitably change their distance asunder.

To explain this more fully, by a figure representing the earth, drawn on the plane of the meridian, let *e. q.* be the equator, *s.* the south pole, *n.* the north pole of the earth, floating as it may in an open space, s. Saugar Roads on the surface, latitude 21° 37″ N.; place of the Medusa at anchor near the mouth of the Ganges, at 5 P. M. 28th October, 1805, the time of observation; the moon M. in the figure, appeared from the ship s. in the line *s.* M. *s.*, but to a person at the same instant at c. on the earth's centre, the moon M. would appear in the line *c.* M. *c.* by which it is plain that the angle *c.* M. *s.* is the moon's parallax in altitude, and no other, and is equal to the opposite angle M. *s. c.* whose measure is the arc *s. c.* by which it appears this angle must affect the moon's altitude, viewed at the same instant from the surface and the centre, being 90 degrees apart, that is, from Saugar Roads, the place of the ship on the surface, to c. on the earth's centre, therefore a correction is necessary, which is, as radius is to the co-sine of the moon's altitude, M. 45° 10′, so is her horizontal angle *c.* M. *s.* 54′ 59″, to the moon's parallax in altitude, which is 38′ 46″, from which substract her refraction on the altitude, leaves 37′ 50″ for the moon's correction, which being added to the apparent altitude, place her at ☽ her true place, as seen from the earth's centre, near 38 miles above M. her apparent place, as seen from the ship on the surface, then a right line drawn from s. the ship on the surface, to the outer part of the line *c.* M. *c.* will pass through the ☽ on the azimuth circle, then the dotted line drawn from the centre

c. to the moon ☽ will cut the side M. S. the apparent distance, a little below P. as seen from C. on the earth's centre, then from P. to M. is the moon's parallax on the side M. S. the apparent distance in the figure, which forms the small triangle M. ☽ P., then the solution is simple to find the side P. M. for as the secant of the angle at the moon M. 68° 18″, so is the proportional logarithms for the moon's correction 37′ 50″, being the side M. ☽ to the principal effect of the moon's parallax 14′ 1½″ on the apparent distance, that is from P. to M. which must be substracted from the side M. S. the observed distance, because the angle at the moon is less than 90 degrees.

The sun also stands in need of a similar correction, both for refraction on his altitude, and parallax on the distance; for by the figure it will be seen that the correction on his altitude operates in a different way to that of the moon, for through refraction his apparent place is raised above his true place, the line *c. s. c.* drawn from the earth's centre, passing through the sun at S. and carried out to *c.* in the open space, is below the line *s.* S. *s.* drawn from the ship on the surface, then the arc *s. c.* is the sun's refraction on his altitude, and measures 6′ 9″, then a dotted line drawn from the ship on the surface, and carried out to the outer part of the line *c.* S. *c.* will cross the sun at ☉ his true place on the primitive circle 6′ 9″ below S. his apparent place, then to find the sun's parallax on the distance, that is from ☉ to P. which forms the small triangle P. ☉ S. the solution is, as the secant of the angle at the sun S. 41° 26′, so is the correction on his altitude 6′ 9″, to the sun's parallax on the distance 4′ 36½″, which must be added to the apparent distance, because the angle at the sun is less than 90°, then the arc ☽ ☉ in the figure is the distance twice corrected, as seen from the earth's centre and the surface, which may be taken for the true distance, because the third and fourth correction in this observation are nothing; yet when the moon is in her first and last quarter, the effect is greatest, and in some cases the third correction amounts to half a mile and upwards, especially when the altitudes are low, and the distance short; this arises from a consideration, that the extreme smallness of right lines drawn from positions, more or less affect the distance in their small triangles, formed at each object, through refraction and parallax, a supposition which fully amounts to a geometrical question, and in my treatise which is now preparing, will be given new parallactic tables, whereby the third and fourth corrections, not here given, may be taken out at one view.

I am, Sir, &c. &c. THOMAS EVANS, 1st Lieut.

To J. W. Croker, Esq. &c. Admiralty.

Of the Mariner's Compass.

Before the invention of the compass, the navigation of ships was a very precarious undertaking, and seldom performed out of sight of land. In this manner, we are told that three Phenecian ships, which sailed out of the Straits of Gibraltar for the East Indies. coasted it along the land: this voyage, it appears, took up three years, from the time they left Cape Spartel until their return thither. However, a more thorough discovery since of the properties of the needle, enables the mariner to hold good his course over the seas in a true and direct track; but it is only within a few years that sea compasses have been freed from many inconveniencies which formerly attended the best of them. We find that those designed for the use of the King's ships and India vessels, are constructed with more care, and on a better principle, than those commonly used in merchant-vessels, especially those in the coasting line, whose course depends more on the compass than on observation.

The attractive power of the magnet was known in Europe about 600 years before the christian aera, and according to the Chinese records, its directive property was known in that country 1000 years earlier. The magnetic needle is subject to an annual and a diurnal vibratory motion: in the first of these, the motion of the north end of the needle is in general towards the east, from the time of the vern l equinox to the summer solstice, and during the other nine months, its motion is in general towards the west point of the horizon. Besides, the magnetic needle has another property called the inclination, or dip, which is the angle contained between the direction of the needle and an horizontal line.

Of the Variation of the Needle.

Notwithstanding the discovery of the most essential properties of the loadstone, the compass was used for many years without knowing that its direction anyways deviated from the poles of the world; and as late as the beginning of the seventeenth century, we are told that vessels then bound up the English Channel, were carried into St. George's; however, careful observations soon discovered its deviation in England. Since 1657 the needle has been found to point to the westward of the true north, and this is various in different parts of the globe. At the Island of Barbadoes, I have found the needle to point 2 degrees westward of the true north, and at the Island of St. Helena 18 degrees W. and on the bank of Lagallas, off the Cape of Good Hope, in soundings 74 fathoms grey sand, the latitude being 35° 47′ S. longitude 21° 13′ E. thermometer stood 75, the variation was 26° 55′ W.; and about 110 leagues E. S. E. from the same spot, I found a still greater increase in the variation, 29° 20′ W. in the very part of those seas where it is particularly wanted to be powerfully acting on the course steered. So wonderful then is this sublime and mysterious agent, which has so much occupied the pens of poets, divines and philosophers, that the effect only is perceived, whilst the real cause remains hid. In the navigation from India to Europe, so great an help is found in the variation, that without its influence, a ship would not be able to round the Cape of Good Hope at certain seasons, especially in the months of September and January, when I have known the S. E. trade wind to veer to S. by E. and south, and blow strong from the latter point.

January 1806, in the English Channel, I have found the variation 27° 50′ W. and in St. George's Channel in June 1812, 26° 10′. To enumerate all the observations I have made at different parts on this important problem, would fill a volume, and altho' its change is but slow, yet I have observed at different parts of the globe, the *morning* aplitudes to differ from the *evening* ones, and that too when clear of all ferruginous matter, especially in the Pacific Ocean, and in that track between Java and the south end of Madagascar, I have known the morning variation per compass to be two degrees less than the evening variation: this then, and the like observations, render the longitude ever doubtful when taken from a variation chart.

At Liverpool, I settled the deviation of the needle with great exactness, by observations on the polar star in the months of January and July, 1813, and for those who are acquainted with plane and spheric trigonometry, the angles which I here insert will serve to verify those observations, and to make similar ones from the same points. The angles taken at High Park Mill, St. Paul's Church Liverpool, and Bidston Lighthouse, shew that there is as much matter contained in the hypothenuse of a right angle plane triangle, as in both the other sides. Now standing on St. Paul's, the angle of Bidston Lighthouse and High Park Mill measures on the arc 105° 8′ 37½″, and from High Park Mill, the angle of St. Paul's and Bidston Lighthouse measures 48° 51′ 22½′. To project these angles orthographically by a figure, St. Paul's Church and Bidston Lighthouse will be the perpendicular, the latter and High Park Mill the hypothenuse, and High Park Mill and St. Paul's the base; then St. Paul's and Bidston Lighthouse are the co-sine, and St. Paul's and High Park Mill the sine of this triangle.

These observations demonstrate that the centre of Bidston Lighthouse bears from St. Paul's Church N. 74° 55′ 10″ W. and the centre of High Park Mill bears from St. Paul's S. 3′ 47½″ W.; by comparing the latter bearings with a good azimuth compass, it will be found that the magnetic poles of the world pass through these two latter points on the earth's surface, (a circumstance very rare to be found elsewhere,) as shewn in figure the 7th on the plate. Having thus settled two situations answering to the magnetic meridian, it became a question to find what angle the polar star made from these points, or in other words, how far east the polar star bore from the meridian line of High Park Mill and St. Paul's Church, Liverpool; for which purpose two lanthorns were placed on the vanes of the mill, whilst I stood on St. Paul's, and with a good sextant, well adjusted, measured the angle from the mill to the polar star 122° 6′ 45″,* and the solution is in the following example.

	°	′	″			°	′	″	‴	
As radius	90	0	0	.. 10,00000	As the co-sn. B.	107	41	23		.. 0,02018
is to co-sn. angle ..	122	6	45	.. 9,72551	is to co-sn. A.	139	47	23		.. 9,88292
So is the tangent side	57	50	30	.. 10,20154	So is the sn. side	32	6	00		.. 9,72542
to the tangent A. ..	40	12	37	.. 9,92705	to sn. of the angle	25	9	16	40	.. 9,62846
	139	47	23							
Side	32	6	00							
Side B.	107	41	23							

Hence Polar Star bears N. 25° 9′ 16″ 40‴ E of the meridian of St. Paul's Church and High Park Mill, Liverpool.

Further Definitions of the Variation of the Compass.

Magnetic Poles are those points of the world towards which the north and south ends of the needle in a sea compass are directed.

Magnetic Meridians are imaginary lines passing through the magnetic poles.

* The altitude of the mill is 7 degrees, therefore this angle may also be considered the celestial arc at the time of observation: if any object in the heavens had been the height of the mill above the horizon. and in the like position, their distances would have been the same; so that the same points serve to follow up the variation of the needle, with great precision, by the polar star, as in the work above.

VARIATION of the needle is the difference between the bearings of the *true* and *magnetic* north poles. The variation is named east, when the magnetic north point is to the eastward of the true north, and when to the westward it is called the west variation.

The MAGNETIC AMPLITUDE of a celestial object, is its bearing by the compass when in the horizon ; and the magnetic AZIMUTH of a celestial object is its bearing by the compass when above the horizon, but the true azimuth of a celestial object is its bearing from the north and south points of the horizon. In the forenoon the azimuth is reckoned eastward, and in the afternoon westward.

EXAMPLE.

The following work is an azimuth taken to find the variation of the needle on the 8th of July, 1812, when the sun's height was 8° 46' above the horizon of the place of observation, required the variation, and which way.

Sun's co-altitude......	81	14		.... co-sec.	0051
Co-latitude	36	36		.... co-sec.	2246
Co-declination........	37	30			
Sum	185	20			
½ sum	92	40			
1st remainder	11	26		...... sn.	9,2672
2d remainder	56	4		...... sn.	9,4189
					19,4458
	31	54	2	.... sn.	9,7229
			2		
	°	'	"		
Sun's true azimuth....	63	48	4		
Magnetic azimuth	38	50	29		
Variation of the Needle	24	57	35	Westwardly, because the true azimuth is to right hand of the magnetic azimuth.	

Of the Division of Time.

TIME is determined by the revolution of some celestial body in its orbit, namely, the sun or moon The sidereal year is the quantity of time measured by the sun's revolution from any fixed star, to the same star again, making 365 days, 6 hours, 9 minutes, 14½ seconds, and is 20 minutes 17½ seconds longer than the true solar year. See page 24. A lunar year is measured by twelve revolutions of the moon from the sun to the sun again, making 354 days, 8 hours, 48 minutes, 36 seconds, and is therefore 10 days, 21 hours, 21 seconds shorter than the solar year, which contains 365 days, 5 hours, 48 minutes, 57 seconds, and is the only natural year, because it always keeps the same seasons to the same months.

According to the method of astronomers, the day in the Nautical Almanac is reckoned from noon to noon: therefore the distance between the sun and moon the 3d of October, XXI. hours, belongs to the 4th of October, at nine in the morning, by the civil account. Seamen in general are more acquainted with the latter mode of reckoning, [the civil day,] than with the former.

Of the Ebbing and Flowing of the Tides.

THE cause of the tides was first discovered by Kepler, but their theory was considerably improved by Sir Isaac Newton, who discovered the cause of their rising on the side of the earth opposite to the moon; for Kepler believed that the presence of the moon occasioned an impulse, whilst her absence caused another, but by the laws of gravitation, hereafter shewn, observation teacheth, that the moon's influence in raising the tides is otherwise than suggested by Kepler, for daily experience shews that all bodies thrown upwards from the earth, fall down to its surface in perpendicular lines, and tend to its centre: this weight or gravity by which they fall is called the law of gravitation; and by the law of attraction, we find that a loadstone being held near pieces of iron will draw them to it; so likewise will a piece of hammered iron that has been rubbed with a magnet, have the like property of drawing iron or steel.

The earth's diameter bears a considerable proportion to its distance from the moon, but it is next to nothing when compared to its distance from the sun; therefore the sun's attraction on the sides of the earth under and opposite to him, is much less than the moon's attraction on the sides of the earth under and opposite to her; consequently the moon must raise the tides much higher than they can be raised by the sun, and from observation we find, that the highest tides do not happen when the moon is directly on and opposite to the meridian, but that she has in general passed the north and south points before it is high water at the meridian of the place; and this reasoning is obvious, for if the moon's attraction was to cease altogether when she had passed the meridian, yet the motion of ascent being communicated by her to the waters before that time, would make them continue to swell for some time after, as she phased round the earth in her orbit; just as a little impulse given to the pendulum of a clock will cause it to move faster than it otherwise would have done; and experience shews that the day is hotter about three in the afternoon, than when the sun is on the meridian, because of the increase made to the heat already imparted.

By this and the like theory, the action of the tides will appear to be influenced and governed chiefly by the moon, for as she phases round the earth in her orbit, the tides must also turn on the moon's axis, inclining 23½ degrees from the earth's axis, and by the same laws, the poles of the tides must differ from the poles of the world, and that the tides must be affected through the different positions of the moon, by the unequal time of their return; for when the earth's axis inclines to the moon, the north tides are the greatest when the moon is above the horizon, and the least when she is below it, and quite the reverse when the earth's axis decline from her; for in every lunation the earth's axis inclines once to the moon, once from her, and twice sideways to her, as it does to the sun every year, because the moon goes round the ecliptic from her change to her full, and the sun but once in a year. The earth is nearer to the sun in February and October than it is in March and September, (see page 24) therefore the greatest tides do not happen till some time before the vernal, and after the autumnal equinox. This will more fully appear when we consider that the longer diameter of the spheroid, or the two opposite floods, will be at that time in the earth's equator, and that the joint attraction of the sun and moon is more uniform on the waters, which are thereby thrown more forcibly against the shores, must of course rise higher; but the reverse happens in neap tides, because in the quarters of the moon, the sun raises the tide where the moon depresses it, and depresses it where the moon raises it. Thus we find in winter the morning tides are highest, and in a period of six months, the order of the tides are inverted, the morning and evening tides will have changed places, the winter morning high tides becoming the summer evening high tides; for in summer, observation shews that the full moons are low in the ecliptic, but in winter the full moon is as high in the ecliptic as the summer sun. The moon never sets at the poles in winter, considering her to move in the ecliptic, thus making her stay long above the horizon in winter nights, when she is most wanted.

But some writers on the theory of the tides, maintain that the course of the flood tide follows the moon in general from east to west, but common experience shews that the flood tide sets southwardly along the west coast of Norway, from the North Cape to the entrance of the Baltic Sea, and proceeds to the southward along the coast of England, the coast of Scotland having the tide first, and so on it continues its course from the northward to the southward; and this will appear obvious when it is considered, that the diurnal rotation of the earth gives to all its parts a centrifugal force, combined with the concurring action of the sun and moon in the equator, consequently the waters receed from the poles, and ascend about the equatorial parts, which are higher, return from thence and fill the shores alternately, as we find along the west coast of Florida a regular rise and fall of the tides, altho' in the middle of the Gulf the current keeps up a constant stream to the northward; and also a strong current at the entrance of the Gut of Gibraltar, rushing to the eastward from the Atlantic Ocean through that Strait with rapidity, and its effects are felt as far eastward as Cape de Gatt, yet in shore and off Europia point, there is a regular return of the current into the bay of Gibraltar, through which I have turned in a line of battle ship. To confirm this hypothesis of the flood tide setting to the southward, we find it high water full and change at Cape Clear a little after 4h., and about 6h. at Ushant; a branch of this tide falls into St George's Channel, the flood running up N. E. making high water at Saltees Rock three hours before it is high water at Dublin, and three quarters of an hour ebb at the latter, before it is high water at Douglas, Isle of Man, &c. But in open seas, the tides rise very little in proportion to what they do in wide mouth rivers, opening in the direction of the stream of the tide; like a gentle wind, little felt on an open plain, but strong and brisk in a narrow street;* as we find in England strong tides, and in several parts a great rise, especially in the rivers Thames, Severn, and Mersey; the River Rouen in France, the Ganges and Indus in India, and in North America the Mississippi, and St. Lawrence off Green Island: in the latter, I have known the ebb to run 7 knots.

* The best method I ever found for trying a current at sea, was by letting down a white flag, already made fast to the moorings of the boat, about three fathoms below the surface; if any current, the flag will blow out in the direction it sets, and the point of its course better ascertained on board the ship, than it can by a compass in a boat, especially if there be any swell on at the time.

To find the Moon's Southing on a given day.

RULE.—The moon's age in days multiplied by 8, gives the time of her southing, nearly, in hours and tenths: that time if less than 12 hours, is the time after mid-day; but if greater, then 12 hours taken from it leaves the southing after midnight.

EXAMPLES.

At what time does the moon come to the meridian of Liverpool September 20th, 1814

Moon's age........	7 days.
which multiply by	8
Moon souths past noon	5h. 6m.

Required the time of the moon's southing on the 12th of September, 1814.

Moon's age	29 days.
which multiply by	8
	23 2
	12 0
Moon's southing A. M...	11h. 2m.

To find the Time of High Water on any day of the Moon's age, at any particular place.

RULE.—To the time of the moon's southing on the given day, add the time of high water on the full and change days at the given place, and the sum is the hour past noon on the given day when it is high water at the place; but if this time exceeds 12 hours, substract 12 from it, the remainder shews the time of high water in the morning, and if it exceeds 24, substract 24 from it, the remainder is the time of high water in the afternoon.

EXAMPLES.

On the 20th September, 1814, at what time will it be high water at Liverpool?

	h.	m.
Moon souths at	5	6
H.W. at Liver. change & full	10	56
Sum	16	2
	12	24
H.W. at Liverpool given day	3	38*

At what hour will it be high water at Dublin, September 20th, 1814?

	h.	m.
Moon souths at Dublin	5	5
H.W. at Dublin full & change	9	45
Sum	14	50
	12	24
H. W. on given day	2	26

* This method of computing the moon's southing and time of high water, is generally made use of in navigation, but it often gives those times many hours wide of the truth, and may thereby occasion fatal accidents; for altho' the time of high water on the full and change days is nearly the same at most places, yet the time of high water from day to day between the syzigies alters from 48 minutes, which is generally reckoned in pilotage, the difference being sometimes more and sometimes less, for a change in the moon's declination, aided by a strong current of wind, will quicken or delay the tides; therefore the most accurate method for computing the time of high water between the change and full, is by the phases of the moon.

PARALLECTIC TABLES

For computing the effect of the Third & Fourth Corrections on the Distance.

Par. in dis.	30°	31°	32°	33°	34°	35°	36°	37°	38°	39°	40°	41°	42°	43°	44°	45°	46°
M.	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
12	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1
13	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1
14	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1
15	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2
16	4	4	4	3	3	3	3	2	2	2	2	2	2	2	2	2	2
17	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	2	2
18	5	5	5	4	4	4	4	3	3	3	3	3	3	3	3	3	3
19	5	5	5	5	5	4	4	4	4	4	3	3	3	3	3	3	3
20	6	6	6	5	5	5	5	4	4	4	4	4	4	3	3	3	3
21	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	4
22	7	7	7	6	6	6	6	5	6	5	5	5	4	4	4	4	4
23	8	7	7	7	7	6	6	6	6	5	5	5	5	5	5	4	4
24	9	8	8	7	7	7	7	6	6	6	6	6	6	5	5	5	5
25	9	9	9	8	8	8	7	7	7	7	6	6	6	6	6	5	5
26	10	9	9	9	9	8	8	7	7	7	7	7	7	6	6	6	6
27	11	10	10	10	9	9	9	8	8	8	7	7	7	7	6	6	6
28	12	11	11	10	10	9	9	8	8	8	8	8	8	7	7	7	7
29	13	12	12	11	11	10	10	9	9	9	9	9	8	8	7	7	7
30	14	13	13	12	12	11	11	10	10	9	9	9	9	8	8	8	8
31	15	14	14	13	13	12	11	11	11	10	10	10	9	9	8	8	8
32	16	15	15	14	14	13	12	11	11	10	10	10	10	9	9	9	9
33	17	16	16	15	14	14	13	12	12	11	10	10	10	10	10	9	9
34	18	17	17	16	15	14	14	13	13	12	11	11	11	10	10	10	10
35	19	18	17	17	16	15	14	14	13	13	12	12	11	11	11	10	10
36	20	19	18	17	17	16	15	14	14	13	13	13	12	11	11	11	11
37	21	20	19	18	18	17	16	15	15	14	13	13	12	12	11	11	11
38	22	21	20	19	19	18	17	16	16	15	14	14	13	13	12	12	12
39	23	22	21	20	20	19	18	17	17	16	15	15	14	14	13	13	13
40	24	23	22	21	21	20	19	18	18	17	16	16	15	15	14	14	14
41	25	24	23	23	22	21	20	19	19	18	17	17	16	16	15	14	14
42	27	26	25	24	23	22	21	20	20	19	18	18	17	16	15	15	15
43	28	27	26	25	24	23	22	21	21	20	18	18	17	16	16	15	15
44	29	28	27	26	25	24	23	22	22	20	19	19	18	17	16	16	16
45	30	29	28	27	26	25	24	23	23	21	20	20	19	18	17	17	16
46	32	30	29	28	27	26	25	24	24	22	21	20	19	19	18	18	17
47	33	32	30	29	28	27	26	26	25	23	22	22	21	20	20	19	18
48	35	33	32	31	30	29	28	27	26	24	23	23	22	22	21	20	19
49	36	35	33	32	31	30	29	28	27	26	24	24	23	22	21	20	19
50	38	36	35	33	32	31	30	29	28	27	26	26	25	24	23	22	21
51	39	38	36	35	33	32	31	30	29	28	27	26	25	24	23	22	22
52	41	39	38	36	35	33	32	31	30	29	28	27	26	25	24	23	22
53	42	41	39	38	36	35	33	32	31	30	29	28	27	26	25	24	23
54	44	42	41	39	38	36	35	33	32	31	30	29	28	27	26	25	24
55	45	44	42	41	39	38	36	35	33	32	31	30	29	28	27	26	25

PARALLECTIC TABLES

For computing the effect of the Third & Fourth Corrections on the Distance.

Par. in dis	47°	48°	49°	50°	51°	52°	53°	54°	55°	56°	57°	58°	59°	60° 120	65° 115	70 110	75 105	80 100	8[illegible] 9[illegible]
M.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
16	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
17	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	0	0	0	0
18	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	0	0	0
19	3	3	3	3	3	3	2	2	2	2	2	2	2	2	1	1	0	0	0
20	3	3	3	3	3	3	2	2	2	2	2	2	2	2	1	1	1	0	0
21	4	3	3	3	3	3	3	3	2	2	2	2	2	2	1	1	1	0	0
22	4	3	3	3	3	3	3	3	3	3	3	2	2	2	2	1	1	0	0
23	4	3	3	3	3	3	3	3	3	3	3	3	3	2	2	1	1	0	0
24	5	4	4	4	4	4	3	3	3	3	3	3	3	3	2	1	1	1	0
25	5	5	5	4	4	4	4	4	3	3	3	3	3	3	2	1	1	1	0
26	6	5	5	5	5	5	4	4	4	4	4	3	3	3	3	2	1	1	0
27	6	5	5	5	5	5	5	5	4	4	4	4	4	3	3	2	1	1	0
28	7	6	6	6	6	6	5	5	5	5	5	4	4	4	3	3	2	1	0
29	7	6	6	6	6	6	5	5	5	5	5	4	4	4	3	3	2	1	0
30	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	3	2	1	0
31	8	7	7	7	6	6	5	5	5	5	5	5	5	4	4	3	2	1	0
32	8	8	7	7	6	6	5	5	5	5	5	5	5	5	4	3	2	1	0
33	8	8	7	7	7	6	6	6	5	5	5	5	5	5	4	3	2	1	0
34	9	9	8	8	8	7	6	6	6	6	6	5	5	5	4	4	2	1	0
35	9	9	8	8	8	8	7	7	6	6	6	6	6	5	4	4	2	1	0
36	10	10	9	9	9	8	8	7	7	7	7	6	6	6	5	4	3	2	1
37	10	10	10	10	10	9	9	8	8	8	7	7	7	6	5	4	3	2	1
38	12	11	11	11	11	10	10	9	9	9	8	8	7	7	5	4	3	2	1
39	13	12	12	11	11	11	10	10	9	9	9	8	8	7	5	4	3	2	1
40	13	13	12	12	12	11	11	10	10	9	9	8	8	8	6	5	3	2	1
41	14	13	13	12	12	12	12	11	10	10	10	9	9	8	6	5	3	2	1
42	14	14	13	13	13	12	12	11	11	10	10	9	9	9	7	5	4	2	1
43	14	14	13	13	13	12	12	11	11	10	10	9	9	9	7	5	4	2	1
44	15	14	13	13	13	12	12	11	11	11	10	10	9	9	7	6	4	2	1
45	15	14	14	13	13	13	12	12	11	11	11	10	10	9	7	6	4	2	1
46	16	15	14	14	14	13	13	12	12	12	11	11	10	10	8	7	5	3	1
47	17	16	15	15	15	14	14	13	12	12	12	11	11	10	8	7	5	3	1
48	18	17	16	16	16	15	14	13	12	12	12	12	11	11	9	7	5	3	2
49	18	17	17	17	17	16	15	14	14	14	13	13	12	11	9	7	5	3	2
50	20	19	18	18	18	17	16	15	15	14	13	13	12	12	10	8	6	4	2
51	21	20	19	18	18	17	16	16	15	15	14	14	13	12	10	8	6	4	2
52	21	20	19	19	18	17	17	16	16	15	15	14	14	13	10	8	6	4	2
53	22	21	20	19	19	18	18	17	16	16	15	14	14	13	10	8	6	4	2
54	23	22	21	20	19	19	18	17	17	16	16	15	15	14	11	9	7	4	2
55	24	23	21	21	20	19	18	18	17	17	16	16	15	14	11	9	7	4	2

Having the Latitude and Longitude of the Ship by Account, to correct the observed distance and altitudes of the objects, thereby to find the true Longitude.

RULE.

Turn the longitude by account into time; if it be west add, but if east substract it from the time at the ship when the observation was made, and it will give the time at Greenwich nearly. To this time, take the moon's semi-diameter and horizontal parallax from page VII. Nautical Almanac, also the sun's semi-diameter for the day, page III.; augment the moon's semi-diameter by adding to it the number of seconds found standing against her observed altitude.

Correct the observed distance by adding to it the sum of both semi-diameters; correct likewise the observed altitudes, by substracting the dip of the horizon for the height of the observer's eye above the surface of the sea, adding or substracting the semi-diameters of the objects according as the altitudes of the lower and upper limb were observed; then the apparent distance and altitudes of the centre of the sun and moon will be obtained, and with the apparent distance, and two apparent altitudes, find the true distance. See page 38.

The Adjustment of the Index.

The index error is the number of degrees and minutes pointed out by the nonius, when the direct object and its reflecting image coincide with each other, and the sun is incomparably the best object for this purpose; and in the practice of this method, the telescope must be used, and the dark glasses set on the hither side of the speculum to darken both suns at once: at the same time, I have applied on the telescope a square pasteboard, with a hole in the middle; this serves to defend the eye from the direct light of the sun, also from the ambient brightness of the sky, while making the observation. To do this, measure the sun's diameter twice or more with the index placed alternately before and behind 0 the beginning of the divisions, half the difference of these two measurements will be the correction of the index, which must be added to or substracted from all observations; for instance, I have measured the sun's diameter by moving the index on the arc to the left hand of 0 to be 32′ 45″, and to the right hand of 0 33′ 30″, the difference is 45″, the half 22½″ to be added to the observations. It is therefore requisite when observing the angular distance of the moon from the sun or star, to examine the instrument and adjust the index error, if any, before and after the observation. Large errors in the index are not to be depended upon, and may be compared to an over-going rate in a watch.

A TABLE

SHEWING THE LATITUDES OF PLACES IN INDIA, &c.

WITH THEIR LONGITUDES FROM THE MERIDIAN OF GREENWICH, TAKEN BY THE AUTHOR.

NAMES OF PLACES.	LATITUDES.				LONGITUDES.			
	o	'	"		o	'	"	
Acheen Roads, Isle Sumatra,	5	36	30	N.	95	30	15	E.
Andamans, (little) S. point	10	37	20		92	30	25	
Aor Pulo, Chinese seas,	2	29	30		104	41	45	
Algnado Flag Staff	15	37	40		74	00	00	
Anjando	8	40	20		77	1	20	
Allippo	9	30	40		76	36	15	
Arro Round, Straits Malacca,	2	45	15		100	40	10	
Arro Long, ditto,	2	51	25		100	34	15	
Anambas, northernmost,	3	26			106	2		
Anambas, southernmost,	3	18	15		105	47	20	
Amboyna Flag Staff	3	40	20	S.	128	15	30	
Amblaor, south point,	3	52	15		127	10	40	
Arentes Island	5	7	45		114	29	0	
Alguardaref	15	41	0	N.	94	11		
Apo Shoal, N. W. point	12	48	30		120	7	45	
Apo Shoal, S. E. point	12	24	15		120	22	30	
Alphonso Island	7	4	0	S.	52	21	0	
Reef, due south of ditto	7	19	10					
Asses' Ears	13	6	0	N.	75	12	30	
Adam's Peak	6	51	49		80	41	15	
Barn Hill, Malabar coast,	12	40	50		75	9	30	
Bank of 17 & 19 fathoms	7	40	20	S.	70	52	0	
Brypone Mill	11	11	0	N.	76	0	0	
Beujore Island	10	40	0	S.	121	43	20	
Brasse Pulo	5	39	15	N.	95	18	0	
Basses, great, } off Island Ceylon, le-	6	6	40		81	45	0	
Basses, little, } vel with the water	6	20	0		81	59	0	
Berberyn Island	6	30	15		80	8	15	
Bombay Lighthouse	18	54	40		72	59	30	
Bombay Flag Staff	18	56	20		73	0	0	
Barbucet Mount, Straits Sincapore	1	25	15		104	20	0	
Bintang Hill, ditto	1	11	45		104	24	0	
Black Pagoda, coast Coromandel	19	52	30		86	8	30	
Balasore Roads	21	19	20		87	1	15	
Batacolo Roads, Island Ceylon	7	44	0		81	56	0	
Bald Point, ditto	9	49	15		80	18	0	
Banton Island, south point, Celebeis	5	41	30	S.	122	51	30	
Ditto, east point, ditto	5	16	45		123	20	0	
Boara Bay ditto	8	24	0		127	5	0	
Branca Pedro, Straits Sincapore	1	20	15	N.	104	21	0	
Bolus Tanjong, ditto	1	19	0		103	31	0	
Brothers, northernmost, do.	1	12	30		103	23	30	
Bangueg Peak, Malacca	7	20	15		117	15	0	
Bencoolen, Island Sumatra	3	50	0	S.	102	3	0	
Bridge Town, Barbadoes, W. Indies	13	5	15	N.	59	41	15	
Bale of Cotton Rock, (doubtful)	5	35	0		92	0	0	
Cross'd its supposed meridian, clear day, no land in sight from mast head, but several water snakes round the ship, of various sizes and colours.								

NAMES OF PLACES.	LATITUDES.			LONGITUDES.		
	°	'	"	°	'	"
Carimon, little, Straits Sincapore	1	12	15 N.	103	25	0 E.
Ceylon Island, N. E. part	9	48	15	80	28	0
Cavoy River	12	2	0	75	24	0
Cape Tonthe, Malabar coast	17	33	0	78	18	0
Chimney Hill, Island Ceylon	6	31	15	81	49	20
Comerin Cape	8	3	30	77	45	0
Calymene Pagodas	10	24	15	80	4	0
Cuddalore Head	11	38	0	79	57	0
Chelteaa Church	10	33	0	76	20	9
Chedduba Northernmost Rocks	18	58	0	93	16	0
Cocas Island, off Sumatra	3	7	45	96	7	0
Cocas Island, off Great Andaman	11	5	0	93	32	0
Columba Flag Staff, Ceylon	6	56	30	80	4	0
Cochin ditto	11	16	0	75	58	0
Cornwallis Fort, Pulo Pinang........	5	26	30	100	23	39
Carr Nicobar	9	24	0	93	0	20
Dunde Rajapore, entrance	18	15	0	73	9	0
Diamond Point, Sumatra, coast Pedere	5	18	30	97	51	0
Dillyon Timor	8	36	0 S.	125	40	15
Dondre Head, Ceylon	5	53	30 N.	80	57	30
Formosa Mount, Malabar coast	12	15	0	75	26	0
Fort St. David's, Coromondel coast ..	11	30	5	79	50	30
Friar's Hood, Ceylon	7	26	0	81	50	0
Ganjan Roads	19	22	45	85	10	15
Gunners' Quoins, Ceylon	7	50	0	81	20	0
Haycock, Ceylon	6	22	30	80	22	30
King's Point, Sumatra.............	5	25	45	93	38	15
Madrass Lighthouse	13	4	45	80	29	15
Malacca Flag Staff	2	9	50	102	9	45
Mangalone.......................	12	49	30	75	2	15
Manilla Flag Staff	14	34	45	120	52	45
Negapatam Roads..................	10	47	0	79	55	0
Parcelar Hill, Straits Malacca........	2	49	30	101	25	30
Point de Galle, South end Island Ceylon	6	2	15	80	20	30
Pidgeon Island, Trincomalay........	8	41	30	81	27	15
Pondicherry Roads	11	54	15	80	2	45
Romania Point, Straits Sincapore	1	24	0	104	17	15
Red Island, New Holland	15	8	30 S.	124	26	0
South Red Buoy, Sands Heads, Bengal	21	18	45 N.	88	20	30
Tellicherry, Malabar coast	11	46	30	75	30	15
Tranqubar, Coromandel coast	10	57	15	79	41	30
Trincomale, Island Ceylon	8	31	50	81	27	15
Trinstran de Acunha, Pacific Ocean ..	37	30	15 S.	12	3	45 W.
Variation at ditto 9° 27' west.						
Telessimoy Good Harbour, yet little known, on the coast of Pedere, Island Sumatra	5	30	15 N.	96	50	45 E.

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