ANDREW MACKAY, LL.D. F.R.S. EDIN. &c.

Presented by Mr Mackay
[redacted] Mr Plimanloe 1822

DESCRIPTION AND USE

OF THE

SLIDING GUNTER

IN

NAVIGATION.

By ANDREW MACKAY, LL.D. F.R.S. Edin. &c.
MATHEMATICAL EXAMINER TO THE CORPORATION OF TRINITY-HOUSE,
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1812.

ADVERTISEMENT.

Dr Mackay has been long known to the mathematical world by his writings. He possessed remarkable assiduity and vigour of mind, which were principally directed to the advancement of the sciences connected with Navigation; and his *Theory and Practice of Finding the Longitude*, a work hitherto unrivalled, as well as his *Practical Navigator*, evince that his labours have not been unsuccessful. Nor is his ardour in the same line less displayed in the following Treatise on the Sliding Gunter. This is an instrument which has been used frequently at sea, but has been very little noticed of late by writers on navigation. Here, however, we have that useful instrument fully described, and its application to the various purposes of the seaman clearly explained, and illustrated by numerous examples.

It is a curious fact, that this is the first treatise on the Sliding Gunter, and even the first professedly on the Sliding Rule, which has been published since the days of Coggleshall; a circumstance the more remarkable, because it is an instrument very generally used in all kinds of measurement, and of late years has undergone many improvements. We have, indeed, in our treatises on guaging, directions for the use of the rule used in the customs and excise; for they would be essentially defective without such directions, considering the extensive use made of that instrument in guaging vessels. But these books are not in common use, and besides, are insufficient for guiding the practice in a variety of cases. In navigation they are of no value, for they do not describe the principal lines requisite in that science.

Above fifty years ago, the Sliding Rule, was employed very generally at sea; and if it be less so at present, we can account for it in no other way, but from the difficulty of finding a treatise that contains directions and examples sufficiently plain and extensive to guide the mariner in the use of it. This defect being so completely supplied by the present work, may we not reasonably expect, that the use of the Sliding Gunter will revive; and that the method of performing the practical operations of navigation by it will again become general.

In calculating a day's work at sea, the shortest method now in use is that by the table of difference of latitude and departure; but, in finding the course, distance, and difference of longitude, by that table, sailors too frequently satisfy themselves with taking the nearest numbers in the table, without being at the trouble of taking proportional parts for the difference. Now, when proportion is neglected, this method is not so correct as that by the sliding rule, and when parts are taken, it is not so expeditious. The method of working by Gunter's scale and compasses, depends on the same principles with that by the sliding scale; but it is not so convenient, because the compasses, in every operation, must be lifted and removed from one part of the scale to another; a motion which is liable to alter their extent, and produce other mistakes; whereas, when the slider is once properly set, the answer on the sliding rule is discovered at once. So that upon the whole, the operation by the sliding scale will be found most convenient in practice, and at the same time sufficiently concise and accurate for most nautical purposes.

After the First Edition of this work was published, the Author revised the whole, and made many improvements, alterations, and additions. Some of these he had fully prepared for the press; but before completing the whole, he was snatched from his family and the world by a premature death; leaving a disconsolate widow and a numerous family. This dispensation was, not only an irreparable loss to his family, but, considering his abilities and unwearied application, a great loss to the scientific world in general.

The Author's corrected copy having come into my hands, I perceived the proposed alterations so particularly pointed out and described in it as to remove every difficulty in completing them according to the Author's mind. I therefore advised the republication of the work for the benefit of his family, and offered my assistance for supplying materials and superintending the press. To this I was induced from esteem for the memory of Dr Mackay, with whom I had lived long in habits of intimacy, and with whose abilities, I have had many opportunities of being particularly acquainted.

Alexr. Ingram, *Mathematician.*

Leith, 1st *July*, 1812.

PREFACE.

Of all the different methods which have hitherto been proposed for performing the various practical operations in Navigation, particularly in *Working a Day's Work*, that by the Sliding Gunter is the easiest, and, at the same time, sufficiently accurate for common practice. It is, therefore, very surprising, that no tract written directly on this subject has, as yet, been published; more especially, as many intelligent seamen have expressed a desire to be possessed of such a work.

In order, therefore, to supply this desideratum, the following Treatise was written; in which the Author has adopted that plan which, to him, appeared to be the easiest method of instruction—so that, it is presumed, the whole will be sufficiently plain, even to those who may not be much acquainted with navigation, provided they understand the meaning of the common terms in that art.

Since the Sliding Gunter is of great use in almost all the departments of practical mathematics, it is, therefore, to be hoped, that our Mathematical Instrument Makers will use their exertions to render the divisions as accurate as possible, and to provide proper materials for its construction: and although a scale two feet long may be sufficient for performing any *day's work*, with all the accuracy that may be desired, yet its divisions are too small for obtaining with exactness, the apparent time from the altitude of a celestial object, the latitude from double altitudes and the elapsed time, or for reducing the apparent to the true distance; and, therefore, it is to be wished, that its length was increased to at least double its present size, or that it were constructed in a circular form, of which specimens have been given by Messrs Nicholson and Margetts.

The description and use of another rule, called the MARITIME SCALE, is added, for two reasons: the first, because the apparent time, &c. can be found with more accuracy than by the common Sliding Gunter; and secondly, because some persons, not able to understand the scale, nor the tract which accompanies it, condemned both, and represented the examples in the pamphlet as erroneous.

The few tables at the end will be found useful for ascertaining the latitude from the meridian altitude of the sun: and the Author flatters himself, that the whole will be found highly beneficial to that numerous class of men, who form the chief glory, the support, and the bulwark of the British empire.

CONTENTS.

BOOK I.

Containing the Description of the Sliding Gunter, and its Use in the Solution of Problems in Arithmetic and Trigonometry.

BOOK II.

Containing the Solution of Problems in Navigation, by the Sliding Gunter,

BOOK III.

Containing Methods of finding the Latitude, Longitude, and Variation of the Compass, by the Sliding Gunter.

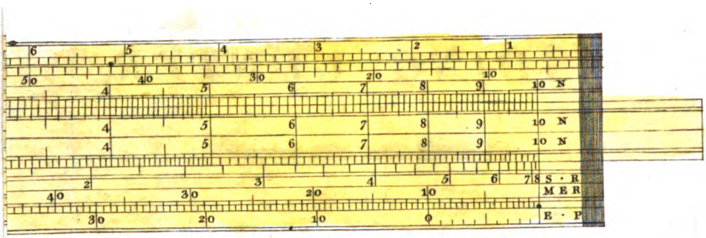
BOOK IV.

Containing the Method of keeping a Journal at Sea.

BOOK V.

Containing the Description and Use of the Maritime Scale.

BOOK VI.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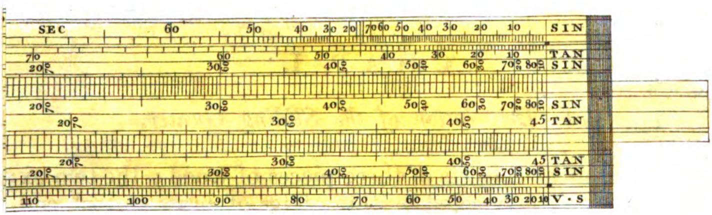
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THE

DESCRIPTION AND USE

OF THE

SLIDING GUNTER.

BOOK I.

CONTAINING THE SOLUTION OF PROBLEMS IN ARITHMETIC AND TRIGONOMETRY.

CHAP I.

The Description of the Sliding Gunter.

THIS instrument consists of three pieces of wood; the two extreme pieces are connected by thin plates of brass at each end, and the third is a slide moveable between the other two. The length of this rule is either one, or two feet; that which we shall more particularly describe is two feet long, as being more accurate, than those of a less size. The breadth of the whole is about two inches, and thickness a quarter of an inch. For the sake of distinction, we shall call one of the sides of this rule the *First Side*, and the other the *Second Side*.

Upon the first side of the Sliding Gunter are the following lines:

I.

A line of inches, each of which is subdivided into ten equal parts.

II.

A scale of equal parts, in which the foot is divided into ten equal parts, and each of these principal divisions is again subdivided into ten equal parts. These two are useful in constructing figures.

III.

A double line of numbers; being useful in arithmetic, mensuration, and navigation, when compared with other lines. These three lines are upon the farthest, or upper part of the rule.

IV.

A double line of numbers, similar to that above.

V.

Another line of numbers, similar to the former. These two are upon the slide.

VI.

A line marked S. R. at the right hand extremity, signifying *Sine Rhumbs;* which line contains the logarithmic sines of each point and quarter of the compass. It is used to find the difference of latitude and departure, when the course is given in points, and conversely.

VII.

A line marked M. P. or *Mer.* at the right hand end, signifying *Meridian Line.*

VIII.

A line marked E. P. at the right hand extremity, signifying *Equal Parts.* By these two lines the meridional parts, answering to any given degree of latitude, may be easily found. These three last lines are upon the nearest, or lowest part of the rule.

The second side of the rule contains the following lines:

I.

The first line contains the following Scales: Chords, marked *Cho.*; Sines, marked *Sin.*; Secants, marked *Sec.*; Tangents, marked *Tan.*; a scale of equal parts, usually called Leagues, marked *Lea.*

II.

The second line contains a scale of Rhumbs, marked *Rum.*; two lines of equal parts, marked E. and P.; a scale of semitangents, marked S. T.; and a line of longitudes, marked *Lon.*

These are called the *Natural Scales*, as being scales of natural sines, tangents, secants, &c. Lines of equal parts with those of chords and rhumbs, are used in constructing and measuring the problems in the different sailings: the line of sines is used in the orthographic projection of the sphere; and those of secants, tangents, and semitangents, in the stereographic and gnomonic projections.

III.

This is is a line of Logarithmic Sines, marked *Sin.* at the right hand extremity: Of which, each subdivision under 10 degrees is 10 minutes; from 10 to 30 degrees, each subdivision is 15 minutes; from 30 to 50 degrees, each is half a degree; from 50 to 70 each is one degree; from 70 to 80 each is two degrees; and the interval between 80 and 90 is divided into two parts; each is therefore 5 degrees. These three lines are upon the upper or farthest part of the rule.

IV.

A line of sines similar to the former.

V.

A line of Logarithmic Tangents, marked *Tan.* at the right hand extremity. Since the tangent of an arch above 45 degrees is the arithmetical complement of that of an arch as much under 45 degrees, the same division, therefore, represents 40 and 50 degrees; also, 30 and 60 degrees: and consequently, 45° are placed at the right hand termination of the line. Below 10° and above 80°, each subdivision is 10 minutes; and each of the other subdivisions is 15 minutes, or a quarter of a degree. These two lines are upon the slide.

VI.

A line of Log Tangents, marked *Tan.* similar to the above.

VII.

A line of Log sines, marked *Sin.* like the two former.

VIII.

A line of Versed Sines, marked V. S. This line, when compared with that of sines, &c. is useful in finding the sun's true azimuth, or the apparent time, the sun's altitude, declination, and the latitude of the place, being given.

Of all the lines upon the Sliding Gunter, that of *Numbers* is of the most general use, particularly in arithmetic, mensuration, navigation, &c.; and, therefore, it is thought proper to give a more particular description of this, than of any of the other lines.

The line of numbers is divided into two equal parts; each of these parts is divided into ten unequal parts; and each of these is subdivided into ten or more parts.

If the 1 at the beginning of the line represents 1, the next primary division represents 2, the third 3, and so on: the 1 at the middle of the line represents 10, the next primary division 20, and the 1 at the end of the line represents 100. But if the 1 at the beginning of the line denotes 10, then the 1 at the middle of the line represents 100, and the one at the end represents 1000; and the intermediate divisions are to be estimated accordingly. Hence it may be observed, that the numbers in the second half of the line are ten times the corresponding numbers in the first half: and hence, the following rule, to find the place of any proposed number on the line, will be obvious.

Among the primary divisions, take the same as in the highest figure in the given number; among the intermediate principal divisions, take that which is the same as the second highest figure; and for the other figures, a proportional part of the space between the last found and the next following, of the principal intermediate divisions, is to be taken by estimation.

Examples.

I.

Required the point representing 36?

The primary division 3 on either half is to be reckoned 30, and numbering forward towards the right hand until the 6th of the intermediate principal divisions, will be the point representing 36. This point may also represent 360, 3600, &c.

II.

Required the point representing 164?

The 1 at the beginning or middle of the line is to be esteemed 100.—In this case, therefore, the next primary division 2 denotes 200. Now, reckon forward from 100, among the principal intermediate divisions until the 6th, which point will, therefore, represent 160; and because the interval between 160 and 170 is divided into 5 parts, each of these parts is, therefore, to be estimated 2; and because the unit figure in the proposed number is 4, reckon forward two divisions; this last point will, therefore, be the place representing 164.

III.

The point on the line of numbers representing 543 is required?

The primary division 5 on the line will represent 500, and of the intermediate principal divisions 4 will be the point of 540. Now, the interval between 540 and 550 being supposed to be divided into ten parts, then the third division, taken by estimation, from 540, will be the point representing 543.

IV.

The place of 1846 on the line of numbers is required?

The 1 at the beginning or middle of the line is to be taken as 1000, and reckoning forward to the 8th of the principal intermediate divisions, will be the place of 1800; the second of the subdivisions will be the place of 1840; the interval between which and the next division 1860 is 20, of which the 6th division being taken by estimation, will be the place representing 1846.

CHAP. II.

The Use of the Sliding Gunter in Arithmetic.

Problem I.

MULTIPLICATION BY THE SLIDING GUNTER.

Multiplication is the method of finding the product of two given numbers. These numbers are usually called *Factors*, and sometimes the Multiplicand and Multiplier.

Rule.

Set 1 on the second line of numbers,* to either of the factors on the first; then, opposite to the other factor on the second line, is the product required on the first line of numbers.

Examples.

I.

Required the product of 6 by 4?

Draw out the slide until 1 on the second line of numbers coincide with 4 on the first line, then opposite to 6 on the second line is 24 on the first line.

II.

What is the product of 16 by 9?

Set 1 on the second line of numbers to 9 on the first line, and opposite to 16 on the second line is 144, the product on the first line.

* The three lines of numbers we have denominated the *first*, *second*, and *third*, lines of numbers; the first being that upon the immoveable part of the rule, and the two last those upon the slide.

III.

Required the product of 24 by 18?

Set 1 on the second line to 18 on the first line, and opposite to 24 on the second line is 432, the product on the first line of numbers.

REMARK.

When the product extends to three figures, it often happens, that the unit figure cannot be immediately distinguished on the rule; this, however, may be easily obtained by multiplying the unit figures in the factors. Thus, in the preceding example, 4 multiplied by 8 is 32; hence the unit figure in the product must be 2.

PROBLEM II.

DIVISION BY THE SLIDING GUNTER.

Division is the method of finding the number of times one quantity or number is contained in another. The greater of these two numbers is called the *Dividend*, the other the *Divisor*; and the resulting number the *Quotient*.

RULE.

Draw out the slide, until the divisor on the second line of numbers coincides with the dividend on the first line; then, opposite to 1 on the second line, is the quotient on the first line of numbers.

EXAMPLES.

I.

Divide 72 by 8?

Move the slide until 8 on the second line of numbers coincides with 72 on the first line, then opposite to 1 on the second line is 9, the quotient, on the first line.

II.

Divide 384 by 16?

Set 16 on the second line of numbers to 384 on the first line; and opposite to 1 on the second line is 24, the quotient, on the first line.

III.

Divide 1500 by 40?

Place the slide in such a manner, that 40 on the second line of numbers may coincide with 1500 on the first line, then opposite to 1 on the second line is $37\frac{1}{2}$, the quotient, on the first line.

Remark.

In the same manner is a vulgar fraction reduced to a decimal. Thus,

Let it be required to reduce $\frac{3}{4}$ to a decimal?

Place 4 on the second line to 3 on the first line, and opposite to 1 on the second line is 75, the corresponding decimal fraction, on the first line of numbers.

Problem III.

PROPORTION, OR THE RULE OF THREE, BY THE SLIDING GUNTER.

The rule of proportion is when three numbers are given to find a fourth, to which the third has the same proportion that the first has to the second.

Rule.

In stating the questions in this rule, the first and second terms are to be of one name, and the third term is to be of the same name as that required.

Let, therefore, that term which is of the same name as the required one, be placed as the third term of the proportion. Now consider, from the nature of the question, whether the required term ought to be greater or less than the third term. If it ought to be greater, the least of the other two terms is to be placed as the first term of the proportion, and the other as the middle term. But if it ought to be less, the greater of the two terms is to be placed as the first, and the least in the middle.

Then, draw out the slide until the first term on the second line of numbers, coincides with the second term on the first line of numbers; then, opposite to the third term on the second line of numbers, is the fourth term or answer on the first line of numbers.

EXAMPLES.

I.

If 7 yards of cloth cost 9 shillings, what is the value of 21 yards?

As 7 : 21 : : 9.

Now, set 7 on the second line of numbers to 21 on the first line, and opposite to 9 on the second line is the answer, 27 shillings, on the first line.

II.

What is the value of 4 yards of cloth, when 30 yards cost £.24.

As 30 : 4 : : 24.

Now, place 30 on the second line of numbers to 4 on the first line, and opposite to 24 on the second line is 3 2-10ths on the first line, that is £.3 4. Or, opposite to 480, the shillings contained in £.24, is the point representing 64 shillings = £.3 4, as before.

III.

In what time will a ship sail from Aberdeen to Flamborough-head, the distance being 196 miles, at the rate of 23 miles in 3 hours?

As 23m : 196m : : 3h.

Set 23 on the second line of numbers to 196 on the first line, and opposite to 3 on the second line is the time required, 25½ hours on the first line, or more correctly 25h. 35m.

IV.

The debts of a bankrupt amounted to £.750, and his effects to £.400: How much will be recovered for a debt due by him of £.150?

As 750 : 150 : : 400.

Place the slide so, that 750 on the second line of numbers may coincide with 150 on the first line; then, opposite to 400 on the second line is 80, the answer, on the first line of numbers.

V.

If I lend a friend £.450 for 10 months, how long ought he to lend me £.300?

As 300 : 450 : : 10m.

Set 300 on the second line of numbers to 450 on the first line; and opposite to 10 on the second line is the answer, 15 months, on the first line.

CHAP. III.

Plane Trigonometry by the Sliding Gunter.

Plane Trigonometry is the method of determining the measures of the unknown parts of plane triangles, from certain parts given. It is the foundation of the various sailings in navigation; it is also useful in surveying coasts and harbours, in ascertaining the heights and distances of inaccessible objects, &c.

As this subject is detailed at considerable length in the author's Treatise on Navigation, those readers, therefore, who desire more information, together with the reason of the several rules, &c. are referred to that work.

Plane Trigonometry is divided into the solution of *right* and *oblique* angled triangles; each of which are subdivided into four problems.

I.

Solution of Right Angled Triangles.

In a right angled triangle five parts are concerned, the three sides and two acute angles; of which, one side and any of the other parts being given, the remaining parts may be found.

The longest side of a right angled triangle is called the *Hypothenuse;* and of the other two sides, the one is called the *Base*, and the other the *Perpendicular*.

Since the sum of the three angles of every plane triangle is equal to 180°, and in a right angled triangle one of the angles is 90°, the sum, therefore, of the other two angles is also 90°;

hence, if one of the acute angles be given, the other is found by subtracting the given angle from 90°.

The difference between any angle and 90° is called its *Complement*, and the difference between any arch and 180° is called the *Supplement* of that arch.

Problem I.

Given the Angles, and the Hypothenuse of a Right Angled Triangle, to find the Base and Perpendicular.

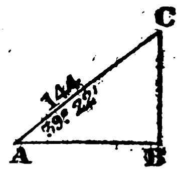
Rule.

Set 90° on the line of sines on the slide, to the angle at the base on the first line of sines, and opposite to the hypothenuse, on the line of numbers on the slide, is the perpendicular on the first line of numbers; again, 90° on sines being set to the other angle, then opposite to the hypothenuse on numbers is the base.

Or, reverse the slide, and place 90° on the line of sines on the slide, to the hypothenuse on numbers; then, opposite to the angle at the base is the perpendicular, and opposite to the angle at the perpendicular is the base.

Example.

Let the hypothenuse be 144, the angle contained between it and the base 39° 22′; and consequently, that contained between the hypothenuse and perpendicular is 50° 38′: Required the base and perpendicular?



Set 90° on the line of sines on the slide to 39° 22′ on the first line of sines, and opposite to 144 on the line of numbers on the slide is the perpendicular 91. Again, set 90° to 50° 38′ on the line of sines, and opposite to 144 is the base 111 on the line of numbers.

Or, reverse the slide, and set 90° on the line of sines on the slide, to 144 on the line of numbers; then, opposite to 39° 22′ on sines is the perpendicular 91 on numbers, and opposite to 50° 38′ on sines is the base 111 on numbers.

Problem II.

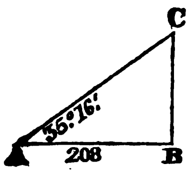
Given the Angles and one of the Sides, to find the Hypothenuse and the other Side.

Rule.

Set the angle opposite to the given side on the line of sines on the slide to 90°, then opposite to the given side on numbers on the slide, is the hypothenuse on the first line of numbers. Again, set the angle opposite to the given side on sines on the slide to the other acute angle, and opposite to the given side on numbers on the slide is the other required side.

Or, reverse the slide, and set the angle opposite to the given side on the line of sines on the slide to the given side on numbers; then, opposite to 90° on sines is the hypothenuse on numbers, and opposite the other angle on sines is the required side.

Example.



The base of a right angled triangle is 208, and the adjacent angle 35° 16′; hence, the opposite angle is 54° 44′: Required the hypothenuse and perpendicular?

Set 54° 44′ on the line of sines on the slide to 90°, and opposite to 208 on the line of numbers on the slide is the hypothenuse 255 nearly, on the first line of numbers. Again, set 54° 44′ on the line of sines on the slide, to 35° 16′ on the first line of sines; and opposite to 208 on numbers on the slide is the perpendicular 147, on the first line of numbers.

Or, reverse the slide, and set 54° 44′ on the line of sines on the slide to 208 on the first line of numbers; then, opposite to 90° on sines on the slide is the hypothenuse 255 on numbers, and opposite to 35° 16′ on sines is the perpendicular 147 on numbers.

Problem III.

The Hypothenuse and one Side being given, to find the Angles and the other Side.

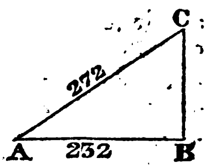
Rule.

Set the hypothenuse on the line of numbers on the slide, to the given side on the first line of numbers; then opposite to 90° on sines on the slide is the angle opposite to the above side. Now, set 90° on the slide to the complement of this angle on sines, and opposite to the hypothenuse on numbers on the slide, is the required side.

Or, reverse the slide, and bring 90° on the line of sines on the slide to coincide with the hypothenuse on the first line of numbers; then, opposite to the given side on the same line is the angle opposite to that side on the line of sines; and opposite to the complement of this angle on sines is the required side on the first line of numbers.

Example.

Let the hypothenuse be 272, and the base 232: Required the angles, and the perpendicular?



Set 272 on the line of numbers on the slide, to 232 on the adjacent line; then opposite to 90° on sines on the slide is about $58\frac{1}{2}$° on sines, the angle opposite to the base; hence, the angle opposite to the perpendicular is $31\frac{1}{2}$°. Now, set 90° on sines on the slide to $31\frac{1}{2}$° on sines, and opposite to 272 on numbers on the slide is the perpendicular 142 on numbers.

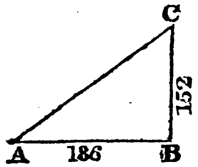
Or, reverse the slide, and set 90° on sines to 272 on the line of numbers; then, opposite to 232 on that line is the angle required $58\frac{1}{2}$°, on sines on the slide; and opposite to $31\frac{1}{2}$° the complement of the above angle, on the same line of sines, is the perpendicular 142 on the first line of numbers.

Problem IV.

Given the Base and Perpendicular, to find the Angles and Hypothenuse.

Rule.

Set the least of two given sides on the line of numbers on the slide, to the greater on the first line; then, opposite to 45° on the second line of tangents is the angle opposite to the least side on the first line of tangents, the other angle is the complement of this; or it may be found by numbering upon the slide towards the left hand. Then, set the greatest angle on the line of sines on the slide to 90°, and opposite to the greatest side on the line of numbers on the slide, is the hypothenuse on the first line of numbers. The hypothenuse may be found by using the least angle and the least side.



Example.

The base is 186 and perpendicular 152: Required the angles and the hypothenuse?

Set 152 on numbers on the slide to 186, and opposite to 45° on the second line of tangents is the angle at the base 39° 15′ on tangents on the slide; hence, the greater angle is 50° 45′. Now, set 50° 45′ on the second line of sines to 90 on the first, and opposite to the greater side 186 on the second line of numbers, is the hypothenuse 240 on the first line of numbers.

II.

Solution of Oblique Angled Triangles.

In an oblique angled plane triangle six parts are concerned; namely, the three sides, and the three angles: of these, one side, and any two other terms being given, the remaining parts may be found. In the solution of oblique triangles, it may be observed, that if any of the angles exceeds 90°, its supplement is to be used.

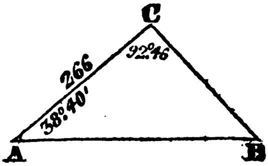
Problem I.

Given the Angles and one Side of an Oblique Angled Plane Triangle, to find the other two Sides.

Rule.

Reverse the slide, and place the angle opposite to the given side on sines on the slide, to the given side on numbers; then, opposite to each of the two other angles on sines, are the sides opposite to them respectively.

Example.



The angles of an oblique triangle are 38° 40′, 92° 46′, and 48° 34′, and the side opposite to the last angle is 266: Required the other two sides?

Set 48° 34′ on the line of sines on the slide to 266 on the first line of numbers; then, opposite to 38° 40′ the first angle on sines is 222, on the opposite side on numbers, and opposite to 87° 14′ the supplement of the second angle 92° 46′ on sines, is the opposite side 354 on numbers.

Problem II.

Given two Sides, and an Angle opposite to one of them, to find the other Angles, and the third Side.

Rule.

Set the side opposite to the given angle on the second line of numbers, to the other given side on the first line of numbers; then, opposite to the given angle on the second line of sines, is the angle opposite to the other given side on the first line of sines. Subtract the sum of these two angles from 180°, and the remainder will be the angle opposite to the required side.

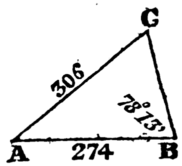
Now, set the angle opposite to the given side on the second line of sines, to the angle opposite to the required side upon the first line; and opposite to the above given side on the second line of numbers, is the required side on the first line of numbers.

Remark.

If the side opposite to the given angle be less than the product of the other given side by the sine of the given angle, the proposed triangle is impossible; since, from the given terms, a triangle cannot be constructed: if the side be equal to that quantity, the triangle will be right angled; if it exceeds that quantity, but is less than the other given side, the triangle is ambiguous, that is, admits of two solutions, the angle opposite to the greater side being either acute or obtuse. But when the side opposite to the given angle is greater than the other given side, the triangle admits only of one answer, as in the following example.

Example.

The two sides of a triangle are 306 and 274, and the angle opposite to the first 78° 13′: Required the other angles and the third side?



Set 306 on numbers on the slide to 274, and opposite to 78° 13′ on the line of sines on the slide is about 61° 14′, the angle opposite to the second given side. The sum of these two angles is 139° 27′; which, subtracted from 180°, the remainder 40° 33′ is the angle opposite to the required side.

Now, set 78° 13′ on the second line of sines to 40° 33′ on the first, and opposite to 306 on the second line of numbers, is the third side 203 on the first line of numbers.

Problem III.

Given two Sides and the included Angle, to find the other Angles and the third Side.

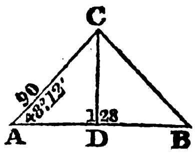
Rule.

Set 90° on the line of sines to the least of the two given sides on numbers, the slide being reversed; then, opposite to the given angle on sines is a No. which call *arch first*, on numbers; and opposite to the complement of the given angle is *arch second:* call the difference between arch second and the greater side *arch third.*

Of arches first and third, set the least on the line of numbers on the slide to the greater on the first line of numbers, and opposite to 45° on the second line of tangents is the angle opposite to the least of the two given sides, if arch third is greater than arch first, but its complement if less. The sum of these two angles being subtracted from 180° gives the third angle.

Set the angle opposite to the least side on the line of sines on the slide, to the given angle on the first line of sines, and opposite to the least side on the second line of numbers, is the third side on the first line of numbers.

Example.



The two sides of an oblique angled triangle are 90 and 128, and the angle contained between them is 48° 12′: Required the other angles and the third side?

Reverse the slide, and set 90° on the second line of sines to the least side 90 on numbers; then, opposite to the contained angle 48° 12′ on sines is arch first 67.1 on numbers; and opposite to 41° 48′, the complement of the contained angle on sines, is arch second 60 on numbers. Subtract arch second from the greater of the two given sides, and the remainder 68 is arch third.

Now, set 67.1 on the second line of numbers to 68 on the first, and opposite to 45° on the second line of tangents is the angle opposite to the least side, 44° 37′ on the first line of tangents.

Then, set 44° 37′ on the line of sines on the slide, to the given angle 48° 12′ on the first line of sines; and opposite to the least side 90 on the second line of numbers, is the third side 95.5 on the first line of numbers.

Problem IV.

Given the Three Sides to find the Angles.

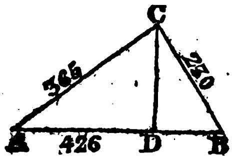
Rule.

Find the sum and difference of the two least sides; then, set twice the greatest side on the second line of numbers to the sum of the two least sides, and opposite to their difference on the second line of numbers is a certain number: Call the sum of this number and half the base the *greater segment*, and their difference the *less segment*.

Set the greatest segment on the second line of numbers to the greatest of the two least sides, and opposite to 90° on the second line of sines, is the complement of the angle contained between the base and greatest side, or of that opposite to the least side.

Again, set the less segment on the line of numbers on the slide to the least side, and opposite to 90° on the second line of sines, is the complement of the angle contained between the greatest and least sides.

The sum of these two angles subtracted from 180° gives the angle opposite to the base.



EXAMPLE.

The three sides of a triangle are 426, 365, and 230: Required the angles?

The sum of the two least sides 365 and 230 is 595, and difference 135. Now, set twice the greatest side 852, on the second line of numbers, to the sum 595, and opposite to 135 is about 94.3, the sum of which and 213, half the greatest side, is 307.3 the greatest segment, and their difference is 118.7 the less segment.

Now, set 307.3 on the second line of numbers to 365, and opposite to 90° on the second line of sines is about 57° 21′; hence, the angle between the two greatest sides is 32° 39′. Again, set 118.7 to 230 on numbers, and opposite to 90° on sines is about 31° 4′; the angle, therefore, contained between the greatest and least sides is 58° 56′. Then, the sum of 32° 39′ and 58° 56′ viz. 91° 35′, subtracted from 180°, gives 88° 25′ the angle opposite to the greatest side.

REMARK.

Various other methods might have been given for solving the two last problems; but, as the preceding are considered to be the easiest to be understood, by those not much acquainted with the use of the Sliding Gunter, the other methods were, therefore, intentionally omitted.

BOOK II.

CONTAINING THE SOLUTION OF PROBLEMS IN NAVIGATION BY THE SLIDING GUNTER.

INTRODUCTION.

NAVIGATION is the art of conducting a ship from one port to another. This art depends upon astronomical and mathematical principles, the places of the sun, planets, and fixed stars, are deduced from observation and calculation, and arranged in tables; the use of which is absolutely necessary in reducing observations taken at sea, for the purpose of ascertaining the latitude and longitude of the ship, and the variation of the compass. The problems in the various sailings are resolved, either by trigonometrical calculation, or by tables or rules formed by the assistance of trigonometry. By mathematics, also, the other necessary tables are constructed, and rules investigated for performing the more difficult parts of Navigation.

The Principles of the Sphere.

Day and Night arise from the circum-rotation of the earth. That imaginary line about which the rotation is performed is called the Axis; and its extremities are called Poles. The pole towards the most remote parts of Europe is called the North Pole: and its opposite, the South Pole. The axis of the earth being produced to the fixed stars will point out the Celestial Poles.

The Equator is a great circle circumscribing the earth, every point of which is equally distant from the pole. It divides the earth into two equal parts, called Hemispheres; that having the north pole in its centre is called the Northern Hemisphere; and the other, the Southern Hemisphere. The plane of this circle being produced to the fixed stars, will point out the Celestial Equator, or Equinoctial. The equator, as well as all other great circles of the sphere, is divided into 360 equal parts,*

D 2

* This method of division was introduced by the ancients, in consequence of their supposing the solar year to consist of the above number of days.

called *Degrees*; each degree is divided into 60 equal parts, called *Minutes*; and the sexagismal division is continued.

The Meridian of any place, is a semi-circle passing through that place, and terminating at the poles of the equator.

The Latitude of any place, is that portion of its meridian which is contained between the equator and the given place; and is either *North* or *South*, according as the given place is in the northern or southern hemisphere.

The Parallel of Latitude of any place, is a circle passing through that place parallel to the equator.

The Difference of Latitude between any two places, is an arch of a meridian intercepted between their corresponding parallels of latitude. Hence, if the places lie between the equator and the same pole, their difference of latitude is found by subtracting the less latitude from the greater: but if they are on opposite sides of the equator, the difference of latitude is equal to the sum of the latitudes of both places.

The First Meridian is an imaginary semi-circle passing through any remarkable place, and is, therefore, arbitrary. The meridian of the Royal Observatory at Greenwich is, by the British, esteemed the first meridian. In other countries, the first meridian is usually that which passes through the principal observatory, or chief city in that country.

The Longitude of any place, is that portion of the equator which is contained between the first meridian and the meridian of the given place. The longitude of a place is said to be *east* or *west* according as the place is on the east or west side of the first meridian; and it cannot exceed 180 degrees.

The Difference of Longitude between any two places, is the the intercepted portion of the equator between the meridians of these places.

Problem I.

Given the Latitudes and Longitudes of two Places, to find the Difference of Latitude and Difference of Longitude between them.

Rule.

Subtract the less latitude from the greater, if they are of the same name; but add them if they are of contrary names, and the difference or sum will be the difference of latitude.

If the longitudes be of the same name, subtract the less from the greater; but if of contrary names, add them. If the sum is greater than 180° subtract it from 360°, and the remainder will be the difference of longitude.

Examples.

I.

Required the difference of latitude and the difference of longitude between Edinburgh, in latitude 55° 58′ N. longitude 3° 12′ W. and Brest in latitude 48° 23′ N. longitude 4° 31′ W.?

Latitude of Edinburgh,	55°	58′	N.	Longitude,	3°	12′	W.
Latitude of Brest, -	48	23	N.	Longitude,	4	31	W.
Difference of latitude,	7	35		Diff. long.	1	19	

II.

What is the difference of latitude and difference of longitude between the Lizard, in latitude 49° 57′ N. longitude 5° 15′ W. and Bencoolen, in latitude 3° 49′ S. longitude 102° 0′ E.?

Latitude of Lizard -	49°	57′	N.	Longitude	5°	15′	W.
Latitude of Bencoolen	3	49	S.	Longitude	102	0	E.
Difference of latitude	53	46		Diff. long.	107	15	

III.

Required the difference of latitude and difference of longitude between Porto Bello, in latitude 9° 33′ N. longitude 79° 50′ W. and Canton, in latitude 23° 8′ N. longitude 113° 2′ E.?

Latitude of Porto Bello	9°	33′	N.	Longitude -	79°	50′	W.
Latitude of Canton	23	8	N.	Longitude -	113	2	E.
Difference of latitude	18	35		Sum -	192	52	
				Subtract from	360	0	
				Diff. longitude	167	8	

Problem II.

Given the latitude and longitude of a place, and the difference of latitude and difference of longitude between it and another place, to find its latitude and longitude.

Rule.

If the given latitude and difference of latitude be of the same name, their sum will be the latitude required: but, if they are of a contrary denomination, their difference will be the latitude, of the same name with the greater. In like manner proceed with the longitudes.

Examples.

I.

A ship from the Start, in latitude 50° 9′ N. longitude 3° 51′ W. sailed between the south and west, until the difference of latitude was 9° 43′, and difference of longitude 12° 18′. Required the latitude and longitude of the ship.

Latitude of Start -	50° 9′ N.		Longitude -	3° 51′ W.
Diff. of latitude -	9 43 S.		Diff. of long.	12 18 W.
Latitude come to	40 26 N.		Long. come to	16 9 W.

II.

From latitude 57° 9′ N. longitude 2° 8′ W. a ship sailed between the north and east, until the difference of latitude was 3° 14′, and difference of longitude was 6° 29′. Required the latitude and longitude come to?

Latitude left -	57° 9′ N.		Longitude -	2° 8′ W.
Diff. of latitude -	3 14 N.		Diff. of long.	6 29 E.
Latitude arrived at	60 23 N.		Long. arrived at	4 21 E.

CHAP. I.

Plane Sailing by the Sliding Gunter.

Plane Sailing is the art of navigating a ship, upon principles deduced from the notion of the earth's being an extended plane.

On this supposition, the meridians are esteemed to be parallel straight lines; the parallels of latitude to be at right angles to the meridians; the lengths of the degrees on the meridians, the equator, and parallels of latitude, also to be every where equal; and the degrees of longitude are reckoned on the parallels of latitude, as well as on the equator. In this sailing four things are principally concerned; namely, the *Course, Distance, Difference of Latitude*, and *Departure*.

The Course is the angle contained between the meridian and the line described by the ship, and is usually expressed in points of the compass.

The Distance is the number of miles a ship has sailed, on a direct course, in a given time.

The Difference of Latitude is the portion of a meridian contained between the parallels of latitude sailed from, and come to; and is reckoned either north or south, according as the course is towards the northern or southern hemisphere.

The Departure is the distance of the ship from the meridian of the place she left, reckoned on a parallel of latitude. In this sailing, the departure and difference of longitude are esteemed to be equal.

Problem I.

Given the Course and Distance, to find the Difference of Latitude and Departure.

Rule.

Draw out the slide, until the distance on the line of numbers coincides with 8 points on the line of sine rhumbs; then, opposite to the course on the line of sine rhumbs, is the departure on the line of numbers; and opposite to the complement of the course on sine rhumbs, is the difference of latitude on numbers.

If the course is given in degrees, the slide must be drawn out and reversed; then, the distance on the line of numbers being set to 90° on the line of sines, opposite to the course on the line of sines is the departure on numbers, and opposite to the complement of the course is the difference of latitude.

Examples.

I.

A ship from Aberdeen sailed S. E. by S. 81 miles: Required the difference of latitude and departure?

Draw out the slide, until 81 on the line of numbers coincide with 8 points on the line of sine rhumbs; then, opposite to the course, 3 points on sine rhumbs, is the departure 45.0 miles, on the line of numbers; and opposite to the complement of the course, 5 points on rhumbs, is the difference of latitude 67.3, on numbers.

Latitude Aberdeen,	- -	57°	9′	N.
Difference of latitude,	- -	1	7	S.
Latitude come to,	- -	56	2	N.

II.

A ship from the Lizard sailed S. 38° W. 255 miles: Required the difference of latitude and departure?

Since the course is given in degrees, the slide must, therefore, be drawn out and turned: Now, place 255 on numbers on the slide to 90° on the line of sines; then, opposite to 38° on sines, is the departure 157 on numbers, and opposite to the complement of the course, 52° on sines, is the difference of latitude 201 on numbers.

Latitude Lizard,	- -	49°	57′	N.
Difference of latitude,	-	3	21	S.
Latitude come to,	- -	46	36	N.

Problem II.

Given the Course and Difference of Latitude, to find the Distance and Departure.

Rule.

Draw out the slide, until the difference of latitude on the line of numbers, coincides with the complement of the course on the line of sine rhumbs, if it is expressed in points, but on the line of sines, if it is expressed in degrees; then, opposite to

8 points on sine rhumbs, or 90° on sines, is the distance on numbers, and opposite to the course on sines is the departure on numbers.

Examples.

I.

From the Cape of Good Hope, in latitude 34° 29′ S. a ship sailed N. N. W. ½ W. until by observation she is found to be in latitude 28° 47′ S.: Required the distance run, and departure?

Latitude of Cape of Good Hope,	-	34°	29′	S.
Latitude in by observation,	-	28	47	S.
Difference of latitude,	-	5	42	= 342 miles.

Now, draw out the slide, until the difference of latitude 342 on the line of numbers, coincides with the complement of the course 5½ points on the line of sine rhumbs; then, opposite to 8 points is the distance 388 on the line of numbers, and opposite to the course 2½ points is the departure 183 on numbers.

II.

The true course from Cape Clear to Ushant is S. 54½° E. the latitude of Cape Clear is 51° 18′ N. and that of Ushant is 48° 28′ N.: Required the distance between these places, and also the departure?

Latitude Cape Clear,	-	51°	18′	N.
Latitude Ushant,	-	48	28	N.
Difference of latitude,	-	2	50	= 170 miles.

Now, reverse the slide, and place 170 the difference of latitude on the line of numbers, to 35½° the complement of the course on the line of sines; then, opposite to 90° on sines is the distance 293 miles on numbers, and opposite to 54½° the course on sines, is the departure 239 miles on numbers.

Problem III.

Given the Course and Departure, to find the Distance and Difference of Latitude.

Rule.

Draw out the slide, until the departure on the line of numbers coincides with the course on the line of sine rhumbs, if it is expressed in points, or on the line of sines if it is expressed in degrees: then, opposite to 8 points on the line of sine rhumbs, or 90° on the line of sines, is the distance; and opposite to the complement of the course is the difference of latitude.

Examples.

I.

Let the corrected course be N. E. by E. and the departure 220 miles: Required the distance and difference of latitude?

Place the departure 220 on the line of numbers, to the course 5 points on the line of sine rhumbs; then, opposite to 8 points on sine rhumbs is the distance 264 on numbers, and opposite the complement of the course 3 points, is the difference of latitude 147 miles.

II.

A ship from Cape Ortegal, in latitude 43° 46′ N. sailed upon a direct course, which, when corrected by variation, &c. was N. 24° W. and the departure was 196 miles: Required the distance, and latitude come to?

The slide being reversed, let it be so placed, that the departure, 196 on the line of numbers, may coincide with the course 24° on the line of sines; then, opposite to 90° on sines is the distance 482 on numbers, and opposite to the complement of the course 66°, is the difference of latitude 440.

Latitude Cape Ortegal,	-	43°	46′	N.
Difference of latitude,	-	7	20	N.
Latitude come to,	- -	51	6	N.

Problem IV.

Given the Distance and Difference of Latitude, to find the Course and Departure.

Rule.

Draw out the slide, until the difference of latitude on the second line of numbers, coincides with the distance on the corresponding, or first line of numbers; then, upon the other side of the rule, opposite to 90° on the line of sines, is the complement of the course on the corresponding line of sines: Now, set the course on the line of sines on the slide to 90° on the line of sines above, and opposite to the distance on the first line of numbers, is the departure on the second line of numbers.

Or, the slide being reversed, set the distance on the second line of numbers to 90° on sines; then, opposite to the difference of latitude on numbers, is the complement of the course on sines; and opposite to the course on sines, is the departure on numbers.

Examples.

I.

A ship from the island of Ascension, in latitude 7° 56′ S. sailed between the S. and W. 285 miles, and is then by observation found to be in latitude 11° 14′ S.: Required the course and departure?

Latitude of island of Ascension,	- -	7°	56′ S.
Latitude by observation,	- -	11	14 S.
Difference of latitude,	- -	3	18 = 198 miles.

Set 198 on the line of numbers on the slide to 285 on the line above, and opposite to 90° on the first line of sines, is the complement of the course 44° on the second line. Now, set the course 46° on the line of sines on the slide to 90°, and opposite to 285 on the first line of numbers, is the departure 205 on the second line of numbers.

II.

A ship from Ancona, in latitude 43° 38′ N. sailed 138 miles upon a direct course between the S. and E. and by observation was found to be in latitude 41° 54′ N.: Required the course and departure?

Latitude Ancona,	- -	43°	38′ N.
Latitude in by observation,	-	41	54 N.
Difference of latitude,	-	1	44 = 104 miles.

The slide being reversed, and the distance 138 miles on numbers set opposite 90° on sines, then, against the difference of latitude 104 on numbers is the complement of the course

49° nearly, on sines; and opposite to the course 41° on sines, is the departure $90\frac{1}{2}$ miles on numbers.

Problem V.

Given the Distance and Departure, to find the Course and Difference of Latitude.

Rule.

Set the departure on the line of numbers on the slide, to the distance on the first line of numbers; then, opposite to 90° on the first line of sines is the course on the second line of sines. Now, set the complement of the course on the second line of sines to 90° on the first, and opposite to the distance on the first line of numbers, is the difference of latitude on numbers on the slide.

Or, the slide being reversed, set the distance on the line of numbers to 90° on the line of sines; then, opposite to the departure on numbers is the course on sines, and opposite to the complement of the course on sines, is the difference of latitude on numbers.

Examples.

I.

A ship from Fort Royal in the island of Grenada, in latitude 12° 9′ N. sailed 260 miles between the S. and W. and made 190 miles of departure: Required the course and latitude come to?

Set 190 on numbers on the slide to 260 on the line above, and opposite to 90° on the first line of sines is the course 47° nearly, on the slide. Now, set the complement of the course 43° on sines on the slide to 90°, and opposite to 260 on the first line of numbers, is the difference of latitude 177 on the slide.

Latitude Fort Royal, -	12°	9′	N.
Difference of latitude, 177 =	2	57	S.
Latitude in, - - -	9	12	N.

II.

A ship from St Andrews, in latitude 56° 21′ N. sailed 256 miles upon a direct course between the N. and E. and has made 168 miles of easting: Required the course, and latitude come to?

Set the distance 256 on the line of numbers, to 90° on the line of sines; then, opposite to the departure 168 on numbers, is the course 41° on sines, and opposite to the complement of the course 49° on sines, is the difference of latitude 193 on numbers.

Latitude St Andrews,	- -	56° 21′ N.
Difference of latitude,	- -	3 13 N.
Latitude come to,	- -	59 34 N.

Problem VI.

Given the Difference of Latitude and Departure, to find the Course and Distance.

Rule.

Set the departure on the line of numbers on the slide, to the difference of latitude on the first line of numbers; then, on the other side of the rule, opposite to 45° on the line of tangents, is the course on the corresponding line of tangents, which is less than 45°, if the departure is less than the difference of latitude, otherwise greater.

Now, set the course on the line of sines, to 90° on the corresponding line of sines, and opposite to the departure on the line of numbers, on the slide, is the distance on the first line of numbers. Or, set the complement of the course on sines to 90° on the corresponding line, and opposite to the difference of latitude on the second line of numbers, is the distance on the first line of numbers.

Remark.

In finding the distance, the course, if greater than 45°, ought to be used; but if it is less, the complement of the course is to be employed.

Examples.

I.

From latitude 46° 10′ N. a ship sailed upon a direct course between the S. and W. and by observation is found to be in latitude 42° 56′ N. having made 144 miles of departure: Required the course, and distance?

Latitude sailed from,	- -	46° 10′ N.
Latitude come to,	- - -	42 56 N.
Difference of latitude,	- -	3 14 = 194 miles.

Place the slide so, that the departure 144 on the line of numbers on the slide, may coincide with the difference of latitude 194 on the adjacent line of numbers; then, opposite to 45° on tangents is the course $36\frac{2}{3}$° on the corresponding line of tangents.

Now, set $36\frac{2}{3}$° on the line of sines on the slide to 90°, and opposite to the departure 144 on numbers on the slide, is the distance 242 on the first line of numbers. Or, set the complement of the course $53\frac{1}{3}$° on sines to 90°, and opposite to the difference of latitude 194 on numbers on the slide, is the distance 242 on the corresponding line of numbers.

II.

From Port Louis in the Isle of France, in latitude 20° 8′ S. a ship sailed upon a direct course between the N. and W. until by observation she is found to be in latitude 17° 16′ S. having made 115 miles of westing: Required the course and distance?

Latitude Port Louis,	- -	20° 8′ S.
Latitude by observation,	- -	17 16 S.
Difference of latitude,	- -	2 52 = 172 miles.

Now, set 115 miles on numbers on the slide to 172 on the first line of numbers, and opposite to 45° on the second line of tangents, is the course 33° 45′ = 3 points on the first line of tangents; then, draw out the slide, until 115 on numbers coincides with 3 points on sine rhumbs, and opposite to 8 points is the distance 207 miles on numbers.

CHAP. II.

Traverse Sailing by the Sliding Gunter.

If a ship sails upon two or more courses in a given time, the irregular tract she describes is called a Traverse: and to resolve a traverse, is the method of reducing these several courses, and the distances run, into a single course and distance.

Rule.

Make a table of a convenient breadth, and of a depth sufficient to contain the several courses, &c. Divide this table into six columns, in the first of which the courses are to be put, and the corresponding distances in the second column; the third and fourth columns are to contain the differences of latitude, and the two last the departures.

Find the difference of latitude and departure, answering to each course and distance, by Prob. I. of Plane Sailing. The difference of latitude is to be put in a north or south column, according as the course is in the northern or southern hemisphere: and the departure is to be put into the east column, if the course is easterly, but in the west column, if the course is westerly; observing, that the departure is less than the difference of latitude, when the course is less than 4 points or 45°; otherwise, it is greater than the difference of latitude.

Place the sum of each difference of latitude and departure column at its bottom; then, the difference between the sums of the N. and S. columns will be the difference of latitude made good, of the same name with the greater; and the difference between the sums of the east and west columns is the departure made good, of the same name as the greater.

Now, with the difference of latitude and departure made good, find the course and distance by Prob. VI. of plane sailing.

The sum, or difference, of the latitude sailed from, and the difference of latitude, reduced to degrees, according as they are of the same, or of a contrary name, will be the latitude come to, of the same name as the greater.

Remark.

The usual method of performing Traverse Sailing is by Inspection: in any probable day's run, however, this method, by the Sliding Gunter, will be found to be more expeditious and equally exact; and, in most cases, the course and distance may be found with more accuracy, from the difference of latitude and departure made good, by this method than by inspection, when the common traverse tables are used.

Examples.

I.

From Cape St Vincent, in latitude 37° 2′ N. a ship sailed S. W. by S. 49 miles, S. by E. 56 miles, S. E. by E. 38 miles, S. W. 84 miles, N. N. W. 72 miles, and E. N. E. 24 miles: Required the course made good, and latitude come to?

Courses.	Dist.	Diff. of Lat. N.	Diff. of Lat. S.	Departure. E.	Departure. W.
S. W. by S.	49	- -	40.7	- -	27.2
S. by E.	56	- -	54.9	10.9	- -
S. E. by E.	38	- -	21.1	31.6	- -
S. W.	84	- -	59.4	- -	59.4
N. N. W.	72	66.5	- -	- -	27.6
E. N. E.	24	9.2	- -	22.2	- -
		75.7	176.1	64.7	114.2
			75.7		64.7
			100.4		49.5

Now, set 49.5 on the second line of numbers to 100.4 on the first line, and opposite to 45° on tangents is the course 26¼°. Again, set the complement of the course 63¾° on sines to 90°, and opposite to the difference of latitude 100.4 on the second line of numbers, is the distance 112 miles on the first line of numbers.

Latitude Cape St Vincent, -	37° 2′ N.
Difference of latitude, - -	1 40 S.
Latitude come to, - - - -	35 22 N.

II.

A ship from Easter Island, in latitude 27° 7′ S. sailed the following courses and distances, viz. N. W. by W. 98 miles, W. N. W. 64 miles, W. 46 miles, N. W. ½ W. 87 miles, W. by S. ½ S. 58 miles, and W. ¾ N. 32 miles: Required the course made good, and latitude come to?

Courses.	Dist.	Diff. of Lat.		Departure.	
		N.	S.	E.	W.
N. W. by W.	98	54.4	- -	- -	81.5
W. N. W.	64	24.5	- -	- -	59.1
W.	46	- -	- -	- -	46.0
N. W. ½ W.	87	55.2	- -	- -	67.2
W. by S. ½ S.	58	- -	16.8	- -	55.5
W. ¾ N.	32	4.7	- -	- -	31.7
		138.8	16.8		341.0
		16.8			

122.0 = 2° 2′ N.
Latitude Easter Island, 27 7 S.

Latitude come to, - 25 5 S.

Set the difference of latitude to the departure on the lines of numbers, and opposite to 45° on tangents, is the course 70⅓° on the corresponding line. Now, set 70⅓° on the line of sines to 90° and opposite to the departure 341 on numbers, is the distance 362 miles.

CHAP. III.

Parallel Sailing by the Sliding Gunter.

The principal use of this sailing is, to find the difference of longitude answering to a distance run upon a given parallel, and conversely: and hence, it is particularly useful in making low or small islands.

Problem I.

Given the Latitude of a Parallel, and the Number of Miles contained in a Portion of the Equator, to find the Number of Miles contained in a similar Portion of that Parallel.

Rule.

Draw out the slide until the complement of the latitude on the line of sines, coincides with 90° on the corresponding line of sines; then, opposite to the difference of longitude on the first line of numbers, is the distance required.

Examples.

I.

Required the number of miles contained in a degree of longitude in latitude 55° N.?

Set the complement of latitude 35° on the line of sines on the slide to 90°, on the corresponding line of sines; then opposite to 60, the number of miles in a degree of longitude at the equator, on the first line of numbers, is the number of miles 34.4 in a degree of longitude in that parallel, on the second line of numbers.

II.

Required the distance between Treguier in France, in longitude 3° 14′ W. and Gaspey Bay, in longitude 64° 27′ W. the common latitude being 48° 47′ N.?

Longitude Treguier, - -	3°	14′	W.
Longitude Gaspey Bay, - -	64	27	W.
Difference of longitude, -	61	13	= 3673′

Now, set the complement of the latitude 41° 13′ on the line of sines on the slide, to 90° on the corresponding line; then, opposite to the difference of longitude 3673 on the first line of numbers, is the distance 2420 on the second line of numbers.

Problem II.

Given the Number of Miles contained in a portion of a known Parallel, to find the Number of Miles in a similiar Portion of the Equator.

Rule.

Set the complement of the latitude of the given parellel on the second line of sines, to 90° on the first line; then opposite to the distance on the second line of numbers, is the difference of longitude required on the first line of numbers.

Example.

A ship from Cape Finisterre, in latitude 42° 52′ N. and longitude 9° 17′ W. sailed due W. 342 miles: Required the longitude come to?

Set the complement of latitude 47° 8′ on the second line of sines to 90° on the first line, and opposite to 342 on the second line of numbers, is the difference of longitude 467 nearly on the first line.

Longitude Cape Finisterre,	-	9° 17′ W.
Difference of longitude,	- -	7 47 W.
Longitude come to,		17 4 W.

Problem III.

Given the Number of Miles contained in any Portion of the Equator, and the Miles in a similar Portion of a Parallel, to find the Latitude of that Parallel.

Rule.

Place the distance, or given miles in the required parallel, on the second line of numbers, to the difference of longitude, or given miles in a similar portion of the equator, on the first line of numbers; then, opposite to 90° on the first line of sines, is the complement of the latitude of the required parallel on the second line of sines.

Example.

A ship sailed 224 miles upon a due west course, and by obser vation found she had differed her longitude 6° 18′: Required the latitude?

Place the slide so, that 224 on the second line of numbers may coincide with 378 the difference of longitude on the first line; then, opposite to 90° on the first line of sines, is the complement of latitude 36° 20′ on the second line of sines. Hence, the latitude of the parallel is 53° 40′.

Problem IV.

Given the number of Miles contained in the Portion of a known Parallel, to find the Length of a similar Portion of another given Parallel.

Rule.

Set the complement of the first latitude on the first line of sines, opposite to the complement of the second latitude on the second line of sines; then, opposite to the first distance on the first line of numbers, is the distance required on the second line of numbers.

Example.

From a port in latitude 57° 9′ N. a ship sailed due S. until she is in latitude 54° 29′, then due E. 81 miles, and lastly due N. until she is again in latitude 57° 9′ N.: Required her distance from the port she left?

Set the slide in such a manner, that 35° 31′ the complement of the first latitude on the first line of sines, may coincide with 32° 51′ the complement of the other latitude on the second line of sines; then, opposite to the distance on the first parallel 81 on the first line of numbers, is the distance on the second parallel 75.6 on the second line of numbers.

Problem V.

Given the length of a certain Portion of a known Parallel, together with that of a similar Portion of an unknown Parallel, to find the Latitude of that Parallel.

Rule.

Place the slide so, that the distance on the given parallel on the first line of numbers, may coincide with that on the unknown parallel on the second line of numbers; then, opposite to the complement of the given latitude on the first line of sines, is the complement of the required latitude on the second line of sines.

Example.

A ship from a port in latitude 54° 0′ N. sailed due E. 200 miles; then, having run due S. an unknown number of miles, she sailed W. 250 miles, and by observation found she had arrived at the meridian of the port she sailed from: The latitude come to, and distance run in the south direction, are required?

The slide being placed so, that 200 on the first line of numbers coincides with 250 on the second line of numbers; then, opposite to 36° the complement of the given latitude on the first line of sines, is 47° 17′ the complement of the required latitude on the second line of sines. Hence, the required latitude is 42° 43′ N. and the distance is 11° 17′ = 677 miles.

CHAP IV.

Middle Latitude Sailing by the Sliding Gunter.

Middle Latitude Sailing is a composition of plane and parallel sailing. In this sailing, the *departure* is reduced to miles of *longitude*, and conversely, by employing the middle parallel between the latitude sailed from and come to—and hence, its name.

Although this method of sailing is not strictly accurate, yet, it is an easy approximation for resolving the various problems relating to a ship's run. In common practice, when applied to the solution of those examples, where the distance does not exceed the probable run of a ship in 24 hours, it is sufficiently correct for most nautical purposes, and more expeditious than Mercator's sailing.

Problem I.

Given the Latitudes and Longitudes of Two Places, to find the Course and Distance between them.

Rule.

Reduce the difference of latitude and difference of longitude to miles, and take half the sum of the two latitudes for the middle latitude. Then, place 90° on the second line of sines, to the complement of the middle latitude on the first line of sines; and opposite to the difference of longitude on the second line of numbers, is the departure on the first line of numbers.

Now, set the difference of latitude on the second line of numbers to the departure on the first, and opposite to 45° on tangents, is the course on the correspondent line of tangents; which is greater than 45°, if the departure is greater than the difference of latitude, otherwise, less than 45°.

Again, set the complement of the course on the second line of sines to 90° on the first; and opposite to the difference of latitude on the second line of numbers, is the distance on the first line of numbers. But, if the course is greater than 45°, set it on the second line of sines to 90° on the first, and opposite to the departure on the second line of numbers, is the distance on the first line of numbers.

Remark.

The course may be found without using the departure, as follows:

Set the difference of latitude on the second line of numbers, to the difference of longitude on the first, and opposite to the complement of the middle latitude on the second line of sines, is the course, if less than 45°, on the second line of tangents; but, if the course is greater than 45°, the complement of the middle latitude on sines will be to the right hand of 45° on tangents; in this case, therefore, observe that division on the first line of tangents, which is opposite to 45° on the second line: Then move the slide, until the complement of the middle latitude on the second line of sines, coincides with 90° on the first line, and opposite to the above found number on the first line of tangents, is the course on the second line of tangents, to be reckoned to the left from 45°.

Example.

Required the course and distance from Flamborough-head, in latitude 54° 11′ N. and longitude 0° 19′ E. to the Naze of Norway, in latitude 57° 56′ N. and longitude 7° 15′ E.?

Latitude Flamborough-head,	54° 11′ N.		Lon. - -	0′ 19′ E.
Latitude Naze, - -	57 56 N.		Lon. - -	7 15 E.
Difference of latitude, - -	3 45	= 225′	Diff. of Long.	6 56 = 416′
Sum of latitudes, - - -	112 7			
Middle latitude, - - - -	56 4.			

Set the difference of latitude 225 on the second line of numbers, to the difference of longitude 416 on the first line; then, 33° 56′ the complement of the middle latitude on the second line of sines, is to the right hand of 45° on the second line of tangents: the division, therefore, on the first line of tangents opposite to 45° on the second line, is about 28° 24′. Now, make 33° 56′ the complement of the middle latitude on the second line of sines, coincide with 90° on the first line; then, opposite to 28° 24′ on the first line of tangents, is about 45° 54′ the course on the second line.

Again, set 44° 6′ the complement of the course on the second line of sines, to 90° on the first line; and opposite to 225 the difference of latitude on the second line of numbers, is the distance 323 miles on the first line of numbers.

Hence, if the variation at Flamborough-head be 2½ points west, the course, per compass, will be about E. N. E. ½ E.

Problem II.

Given one Latitude, Course, and Distance, to find the other Latitude, and Difference of Longitude.

Rule.

Draw out the slide, until the right hand termination of the lines on it, coincides with the complement of the course on the line of sines, or of sine rhumbs; then, opposite to the distance on the second line of numbers, is the difference of latitude on the first line: Hence, the latitude come to, and middle latitude, will be obtained.

Now, set the complement of the middle latitude on the second line of sines, to the course on the first line, and opposite to the distance on the second line of numbers, is the difference of longitude on the first line.

Example.

A ship from Cape Finisterre, in latitude 42° 52′ N. longitude 9° 17′ W. sailed S. W. by S. 250 miles: Required the latitude and longitude come to?

Set the right hand termination of the divisions on the slide, to the complement of the course 5 points on sine rhumbs; then, opposite to the distance 250 miles on the second line of numbers, is the difference of latitude 208 on the first line. Or, set 250 on numbers to 8 points on sine rhumbs, and opposite to 5 points on sine rhumbs, is the difference of latitude 208 on numbers.

Latitude Cape Finisterre,	42°	52′ N.	- -	42°	52′ N.
Difference of latitude, -	3	28 S.	Half, -	1	44 S.
Latitude come to, - -	39	24 N.	Mid. lat.	41	8.

Now, set 48° 52′ the complement of the middle latitude on the second line of sines, to the course 33° 45′ on the first line; then, opposite to the distance 250 miles on the second line of numbers, is the difference of longitude 184 on the first line.

Longitude Cape Finisterre, - -	9°	17′	W.
Difference of longitude, - -	3	4	W.
Longitude come to, - - -	12	21	W.

Problem III.

Given both Latitudes and Course, to find the Distance and Difference of Longitude.

Rule.

Set the complement of the course on the second line of sines, to 90° on the first line; and opposite to the difference of latitude on the second line of numbers, is the distance on the first line: Or, if the course is given in points, set the difference of latitude on the line of numbers on the slide, to the complement of the course on sine rhumbs, and opposite to 8 points on sine rhumbs, is the distance on numbers.

Now, set the complement of the middle latitude on the second line of sines, to the course on the first line; and opposite to the distance on the second line of numbers, is the difference of longitude on the first line of numbers.

EXAMPLE.

A ship from Tercera, in latitude 38° 45′ N. and longitude 27° 6′ W. sailed N. E. ½ N. and by observation is in latitude 42° 33′ N.: Required the distance run, and longitude come to?

Latitude of Tercera, - -	38°	45′ N.	
Latitude come to, - - -	42	33 N.	
Difference of latitude, - - -	3	48	= 228′
Sum of both latitudes, - - -	81	18	
Middle latitude, - - - -	40	39.	

Set the difference of latitude 228 on the line of numbers on the slide, to the complement of the course 4½ points on sine rhumbs; then, opposite to 8 points on sine rhumbs, is the distance 295 on numbers.

Now, set the complement of the middle latitude 49° 21′ on the second line of sines, to the course 3½ points, or 39° 22′, on the first line of sines; then, opposite to the distance 295 on the second line of numbers, is the difference of longitude 247 on the first line of numbers.

Longitude of Tercera, - - -	27°	6′ W.
Difference of longitude, - - -	4	7 E.
Longitude come to, - -	22	59 W.

PROBLEM IV.

Given one Latitude, Course, and Departure, to find the other Latitude, Distance, and Difference of Longitude.

RULE.

Set the departure on the line of numbers to the course on the line of sines, if given in degrees, or on the line of sine rhumbs, if expressed in points; then, opposite to 90°, or 8 points, is the distance, and opposite to the complement of the course is the difference of latitude. Hence, the latitude come to, and middle latitude, will be obtained.

Then, set the complement of the middle latitude on the second line of sines, to 90° on the first; and opposite to the departure on the second line of numbers, is the difference of longitude on the first line of numbers.

Example.

A ship from Cape Ortegal, in latitude 43° 46′ N. and longitude 7° 39′ W. sailed N. W. $\frac{3}{4}$ N. till her departure is 162 miles: Required the distance run, and the latitude and longitude come to?

Draw out the slide, until the departure 162 on the line of numbers, coincides with the course $3\frac{1}{4}$ points; then, opposite to 8 points is the distance 272 miles on numbers, and opposite to the complement of the course is the difference of latitude 218 miles.

Latitude Cape Ortegal, -	43° 46′ N.	- -	43° 46′ N.
Difference of latitude, -	3 38 N.	Half -	1 49 N.
Latitude come to, - -	47 24 N.	Mid. lat.	45 35.

Now, set the complement of the middle latitude 44° 25′ on the second line of sines, to 90° on the first line; and opposite to the departure 162 on the first line of numbers, is the difference of longitude 231 on the second line of numbers.

Longitude Cape Ortegal, - - -	7° 39′ W.
Difference of longitude, - - - -	3 51 W.
Longitude come to, - - - -	11 30 W.

Problem V.

Given both Latitudes and Distance, to find the Course and Difference of Longitude.

Rule.

Set the difference of latitude on the second line of numbers to the distance on the first line; then, opposite to 90° on the second line of sines, is the complement of the course on the first line of sines.

Now, set the complement of the middle latitude on the second line of sines, to the course on the first line of sines; and opposite to the distance on the second line of numbers, is the difference of longitude on the first line.

Example.

A ship from Cape Clear, in latitude 51° 18′ N. and longitude 11° 15′ W. sailed 284 miles upon a direct course between the S. and E. and by observation is found to be in latitude 47° 34′ N.: Required the course, and longitude in?

Latitude Cape Clear, - -	51°	18′	N.
Latitude in, - - -	47	34	N.
Difference of latitude, - -	3	44	= 224′
Sum of both latitudes, - -	98	52	
Middle latitude, - - -	49	26.	

Set the difference of latitude 224 on the second line of numbers, to the distance 284 on the first line; and opposite to 90° on the second line of sines, is the complement of the course 52° 4′ on the first line of sines: Hence, the course is 37° 56′.

Again, set the complement of the middle latitude 40° 34′ on the second line of sines, to the course 37° 56′ on the first line of sines; and opposite to the distance 284 on the second line of numbers, is the difference of longitude 268 on the first line of numbers.

Longitude Cape Clear, - -	11°	15′	W.
Difference of longitude, - -	4	28	E.
Longitude in, - - -	6	47	W.

Problem VI.

Given one Latitude, Distance, and Departure; to find the other Latitude, Course, and Difference of Longitude.

Rule.

Draw out the slide, until the departure on the second line of numbers, coincides with the distance on the first line; and opposite to 90° on the first line of sines, is the course on the second line of sines.

Set 90° on the second line of sines, to the complement of the course on the first line; then, opposite to the distance on the second line of numbers, is the difference of latitude on the first.

Place the complement of the middle latitude on the second line of sines, to the course on the first; and opposite to the distance on the second line of numbers, is the difference of longitude on the first line of numbers.

Example.

A ship from Cape St Vincent, in latitude 37° 2′ N. and longitude 9° 2′ W. sailed 296 miles upon a direct course between the S. and W. and made 220 miles of departure: Required the course, and the latitude and longitude come to?

Draw out the slide, until the departure 220 on the line of numbers on it, coincides with the distance on the line of numbers above; and opposite to 90° on the first line of sines, is the course 48° on the second line of sines.

Set 90° on the second line of sines, to the complement of the course 42° on the first line of sines; and opposite to the distance 296 on the second line of numbers, is the difference of latitude 198 on the first line.

Lat. of Cape St Vincent,	37°	2′	N.	-	-	37°	2′	N.
Difference of latitude, -	3	18	S.	Half,	-	1	39	S.
Latitude come to, -	33	44	N.	Mid. lat.		35	23.	

Now, set the complement of the middle latitude 54° 37′ on the second line of sines, to 90° on the first line; and opposite to the departure 220 on the second line of numbers, is the difference of longitude 270 on the first.

Longitude of Cape St Vincent, -	9°	2′	W.
Difference of longitude, - - -	4	30	W.
Longitude come to, - - - -	13	32	W.

Problem VII.

Given both Latitudes and Departure, to find the Course, Distance, and Difference of Longitude.

Rule.

Set the difference of latitude on the line of numbers on the slide, to the departure on the corresponding line of numbers; and opposite to 45° on the line of tangents, is the course on the corresponding line of tangents.

Then, set the course on the second line of sines, to 90° on the first line of sines; and opposite to the departure on the second line of numbers, is the distance on the first line of numbers.

Now, set the complement of the middle latitude on the second line of sines, to 90° on the first line; and opposite to the departure on the second line of numbers, is the difference of longitude on the first.

Example.

A ship from latitude 33° 45′ S. longitude 78° 37′ W. sailed upon a direct course between the S. and E. and is then found to be in latitude 36° 54′ S. and to have made 160 miles of easting: Required the course, distance, and difference of longitude?

Latitude sailed from, -	33°	45′ S.	
Latitude come to, - -	36	54 S.	
Difference of latitude, -	3	9	= 189 miles.
Sum of latitudes, - -	70	39	
Middle latitude, - -	35	20.	

Set the difference of latitude 189 on the second line of numbers, to the departure 160 on the first line of numbers; and opposite to 45° on the first line of tangents, is the course 40° 15′ on the second line of tangents.

Now, set the course 40° 15′ on the second line of sines, to 90° on the first line; and opposite to the departure 160 on the second line of numbers, is the distance 247½ on the first line of numbers.

Again, set the complement of the middle latitude 54° 40′ on the second line of sines, to 90° on the first line; and opposite to the departure 160 on the second line of numbers, is the difference of longitude 196 on the first line of numbers.

Longitude sailed from, - -	78° 37′	W.
Difference of longitude, - -	3 16	E.
Longitude come to, - - -	75 21	W.

Problem VIII.

Given one Latitude, Departure, and Difference of Longitude; to find the other Latitude, Course, and Distance.

Rule.

Set the departure on the second line of numbers, to the difference of longitude on the first: and opposite to 90° on the first line of sines, is the complement of the middle latitude on the second line of sines.

Now, from twice the middle latitude subtract the latitude sailed from, and the remainder will be the latitude come to; and hence, the difference of latitude will be obtained.

Then, set the departure to the difference of latitude on the lines of numbers, and opposite to 45° is the course on the lines of tangents.

Lastly, set the course to 90° on the lines of sines, and opposite to the departure is the distance on the lines of numbers.

Example.

From Ushant, in latitude 48° 28′ N. longitude 5° 5′ W. a ship sailed upon a direct course between the N. and W. and by observation is found to be in longitude 11° 10′ W. and has made 232 miles of departure: Required the latitude come to, and the course and distance run.

Longitude of Ushant, - -	5° 5′	W.
Longitude by observation, -	11 10	W.
Difference of longitude, - -	6 5 = 365′.	

Set the departure 232 on the second line of numbers, to the difference of longitude 365 on the first line; and opposite to 90° on the first line of sines, is the complement of the middle latitude 39° 28′ on the second line of sines: hence, the middle latitude is 50° 32′.

Now, from twice the middle lat.	101°	4′	
Subtract the latitude sailed from,	48	28	N.
Remains the latitude come to, -	52	36	N.
Difference of latitude, - -	4	8	= 248 miles.

Set the departure 232 on the second line of numbers, to the difference of latitude 248 on the first line; and opposite to 45° on the second line of tangents, is the course 43° 5′ on the first line.

Now, set the course 43° 5′ on the second line of sines, to 90° on the first line; and opposite to the departure 232 on the second line of numbers, is the distance 340 miles on the first line of numbers.

Problem IX.

Given the Course, Distance, and Difference of Longitude; to find the Latitudes sailed from and come to.

Rule.

Set the difference of longitude on the second line of numbers opposite to the distance on the first line of numbers; then, opposite to the course on the second line of sines, is the complement of the middle latitude on the first line of sines.

Set the complement of the course on the second line of sines, to 90° on the first line of sines; and opposite to the distance on the first line of numbers, is the difference of latitude on the second line of numbers.

Add half the difference of latitude to the middle latitude to get the latitude sailed from, and subtract them to get the latitude come to, because the ship is sailing towards the equator; if she had been sailing from the equator, the latter method would have given the latitude sailed from, and the former the latitude come to.

Example.

A ship from a port in north latitude sailed S. W. $\frac{1}{4}$ S. 560 miles, and thus differed her longitude 8° 24′: Required the latitudes sailed from and come to?

Set the difference of longitude 504 on the second line of numbers, to the distance 560 on the first line of numbers, and opposite to the course 42° 11′ on the second line of sines, is 48° 16′ the complement of the middle latitude on the first line of sines.

Set 47° 49′ the complement of the course on the second line of sines, to 90° on the first line of sines, and opposite to 560 the distance on the first line of numbers, is 415 on the second line of numbers, which is the difference of latitude.

Then, the sum of the middle latitude, -		41°	44′
And half the difference of latitude,	207 =	3	27
Gives the latitude sailed from, - -		45	11 N.
And their difference, the latitude come to,		38	17 N.

CHAP. V.

Mercator's Sailing by the Sliding Gunter.

This sailing has its name from Gerard Mercator, * who having observed the errors of the common charts, and the very great trouble and inconvenience attending the use of those constructed upon globular principles, he, therefore, in the year 1556, published a chart, in which the rhumbs were represented by straight lines, as in the plane chart; and the meridians, as well as the parallels of latitude, were also represented by straight lines parallel to each other: but, in order to compensate the error arising from the parallelism of the meridians, each degree was increased in length with its distance from the equator.

* Mercator was born at Ruremond, in Upper Guelderland, in the year 1512.

In 1579, Bernardus Puteanus, of Bruges, published a chart of the same kind, accompanied with a particular account of the method of construction, and its advantages over the charts then in common use. Similar charts were afterwards published by Jansonius and others.

In 1599, Mr Edward Wright, of Caius College, Cambridge, published his *Correction of certain Errors in Navigation;* which contains a table for the division of the meridian according to this principle, together with the demonstration and method of computation. By a comparison of the chart published by Mercator with this table, it appears, that the several portions of the meridian were not increased agreeable to the table; and it has from thence been inferred, that Mercator was not acquainted with the true principles of this method of projection.

Wright constructed his table of meridional parts, by the continual addition of the natural secants of each minute of latitude, in place of taking the sum of the secants of each point of latitude; and, therefore, the meridional parts towards the end of the quadrant exceeded the truth. A more accurate and expeditious method has since been employed, for the same purpose. *

The meridional difference of latitude, expressed in degrees, may be found by the Sliding Gunter, by taking the interval between the given latitudes from the line marked *Mer*. and applying this extent to the adjacent line marked E. P. It will, however, be more accurate to take the meridional parts of the given latitude, from a table of meridional parts; then will their difference, or sum, according as the latitudes are of the same, or of a contrary name, be the meridional difference of latitude.

Problem I.

Given the Latitudes and Longitudes of two Places, to find the Course and Distance between them.

Rule.

Set the meridional difference of latitude on the second line of numbers, to the difference of longitude on the first line of numbers; then, opposite to 45° on the line of tangents, is the

* See the Treatise on Navigation by the Author of this, in the Encyclopædia Britannica, vol. xii. page 705.

course on the corresponding line of tangents; which will be less than 45°, if the difference of longitude is less than the meridional difference of latitude; but, if the difference of longitude is greater than the meridional difference of latitude, then the course will be greater than 45°.

Now, set the complement of the course on the second line of sines, to 90° on the first line; and opposite to the difference of latitude on the second line of numbers, is the distance on the first line of numbers.

Examples.

I.

Required the course and distance from Bilboa, in latitude 43° 26′ N. longitude 3° 23′ W. to Cordovan Light-house, in latitude 45° 35′ N. and longitude 1° 11′ W.?

Lat. Cordovan light-h.	45° 35′ N.	Mer. parts,	3080	Long. -	1° 11′ W.
Latitude Bilboa, -	43 26 N.	Mer. parts,	2899	Long. -	3 23 W.
Difference of latitude,	2 9=129′	M. D. lat.	181	Diff. of lon.	2 12=132′

Set the meridional difference of latitude 181 on the second line of numbers, to the difference of longitude 132 on the first line; then, opposite to 45° on the line of tangents on the slide, is the course 36° 6′ on the adjacent line of tangents.

Then, place 53° 54′ the complement of the course on the second line of sines, to 90° on the first line of sines; and opposite to 129 the differencc of latitude on the second line of numbers, is the distance 159½ miles on the first line of numbers.

II.

Required the course and distance from the Cape of Good Hope to St Helena?

Lat. Cape of G. Hope,	34° 29′ S.	Mer. parts,	3080	Long. -	18° 23′ E.
Latitude St Helena, -	15 55 S.	Mer. parts,	968	Long. -	5 49 W.
Difference of latitude	18 34=1114′	M. D. lat.	1239	Diff. of lon.	24 12=1452′

Set 1239 on the second line of numbers, to 1452 on the first line; then, opposite to 45° on the line of tangents on the slide, is the course 49° 32′ on the adjacent line of tangents.

Place the complement of the course 40° 28′ on the second line of sines, to 90° on the first line of sines; and, opposite to

1114 the difference of latitude on the second line of numbers, is 1716 the distance on the first line of numbers.

PROBLEM II.

Given the Course and Distance sailed from a known Place, to find the Latitude and Longitude of the Place come to.

RULE.

With the given course and distance, find the difference of latitude by PROB. I. of plane sailing; which being added to, or subtracted from, the latitude left, according as they are of the same, or of different names, will give the latitude come to; then, find the meridional difference of latitude as before.

Now, set the course on the first line of tangents, to 45° on the second; and opposite to the meridional difference of latitude, is the difference of longitude on the lines of numbers, observing, that if the course is less than 45°, the meridional difference of latitude is to be found on the first line of numbers; but, if greater, it must be found on the second line of numbers.

EXAMPLE.

A ship from Cape Clear, in latitude 51° 18′ N. and longitude 11° 15′ W. sailed S. E. ¼ S. 120 miles: Required the latitude and longitude come to?

Set the distance 120 miles on the line of numbers, to 8 points on the line of sine rhumbs; and opposite to 4¼ points the complement of the course on sine rhumbs, is the difference of latitude 89 on numbers.

Latitude Cape Clear,	51° 18′ N.	Mer. parts, - -	3598
Difference of latitude,	1 29 S.		
Latitude come to, -	49 49 N.	Mer. parts, - -	3457
		Mer. diff. of latitude,	141

Now, set 45° on the second line of tangents, to the course 42° 11′ on the first line; and opposite to the meridional difference of latitude 141 on the first line of numbers, is the difference of longitude 128 on the second line of numbers.

Longitude of Cape Clear,	- -	11° 15′ W.
Difference of longitude,	- -	2 8 E.
Longitude come to,	- - -	9 7 W.

Problem III.

Given the Latitudes of two Places, and the Course between them, to find their Distance and Difference of Longitude.

Rule.

With the difference of latitude and course, find the distance by Prob. II. of plane sailing; then, set the course to 45° on the lines of tangents, and opposite to the meridional difference of latitude, is the difference of longitude on the lines of numbers.

Example.

A ship from Bayonne, in latitude 43° 29′ N. longitude 1° 30′ W. sailed N. W. ½ N. and by observation is found to be in latitude 45° 54′ N.: Required the distance run, and longitude come to?

Latitude Bayonne,	43° 29′ N.	Mer. parts, -	2903
Latitude come to, -	45 54 N.	Mer. parts, -	3107
Diff. of latitude, -	2 25 = 145′	Mer. diff. of lat.	204

Set 50° 38′ the complement of the course on the second line of sines, to 90° on the first line of sines; and opposite to 145 the difference of latitude on the second line of numbers, is the distance 188 on the first line of numbers.

Again, set the course 39° 22′ on the first line of tangents, to 45° on the second line of tangents; and opposite to the meridional difference of latitude 204 on the first line of numbers, is the difference of longitude 167 on the second line of numbers.

Longitude of Bayonne,	- -	1° 30′ W.
Difference of longitude,	- -	2 47 W.
Longitude come to,	- - -	4 17 W.

Problem IV.

Given the Latitude and Longitude of the Place sailed from, the Course and Departure; to find the Distance, and the Latitude and Longitude of the Place come to.

Rule.

Find the distance and difference of latitude by Prob. III. of plane sailing; hence, the latitude come to, and meridional difference of latitude, may be obtained. Now, with the course and meridional difference of latitude, find the difference of longitude, by the rule given in last problem.

Example.

A ship from Gratiosa, in latitude 39° 2′ N. longitude 27° 58′ W. sailed N. N. E. $\frac{3}{4}$ E. and has made 66 miles of departure: Required the distance, and the latitude and longitude come to?

Set the departure 66 on the third line of numbers, to the course $2\frac{3}{4}$ points on the line of sine rhumbs; then, opposite to 8 points on sine rhumbs, is the distance 129 miles on numbers, and opposite to the complement of the course $5\frac{1}{4}$ points on sine rhumbs, is the difference of latitude 110 on numbers.

Latitude Gratiosa, -	39° 2′ N.	Mer. parts, - -	2548
Diff. of latitude, -	1 50 N.		
Latitude come to, -	40 52 N.	Mer. parts, - -	2691
		Mer. diff. of latitude,	143

Now, set 45° on the first line of tangents, to the course 30° 56′ on the second line of tangents; and opposite to the meridional difference of latitude 143 on the second line of numbers, is the difference of longitude 86 on the first line of numbers.

Longitude Gratiosa, - -	27° 58′ W.
Difference of longitude, - -	1 26 E.
Longitude come to, - -	26 32 W.

Problem V.

Given the Latitudes of two Places, and the Distance between them, to find the Course, and Difference of Longitude.

Rule.

With the distance and difference of latitude, find the course by Prob. IV. of plane sailing; and with the course and meridional difference of latitude, find the difference of longitude by Prob. I. of Mercator's sailing.

Example.

A ship from St Alban's Head, in latitude 50° 37′ N. and longitude 2° 13′ W. sailed 171 miles upon a direct course between the S. and W. and by observation is in latitude 48° 28′ N.: Required the course steered, and longitude come to?

Lat. St Alban's Head, -	50° 37′ N.		Mer. parts, - - -	3532
Lat. in by observation, -	48 28 N.		Mer. parts, - - -	3334
Difference of latitude, -	2 9	= 129′	Mer. diff. of latitude, -	198

Set the difference of latitude 129 on the second line of numbers, to the distance 171 on the first line; and opposite to 90° on the first line of sines, is the complement of the course 49° on the second line of sines.

Again, set the course 41° on the first line of tangents, to 45° on the second line of tangents; and opposite to the meridional difference of latitude 198 on the second line of numbers, is the difference of longitude 172 on the first line of numbers.

Longitude St Alban's Head, - -	2° 13′	W.
Difference of longitude, - - -	2 52	W.
Longitude in, - - - - - -	5 5	W.

Problem VI.

Given one Latitude, Distance, and Departure; to find the other Latitude, Course, and Difference of Longitude.

Rule.

With the distance and departure, find the course and difference of latitude, by Prob. V. of plane sailing: then, set the difference of latitude on the second line of numbers, to the meridional difference of latitude on the first line of numbers; and opposite to the departure on the second line of numbers, is the difference of longitude on the first line.

Example.

A ship from Venice, in latitude 45° 26′ N. and longitude 12° 4′ E. sailed 250 miles upon a direct course between the S. and E. and made 170 miles of departure: Required the course steered, and the latitude and longitude come to?

Set the distance 250 on the second line of numbers, to the departure 170 on the first line; and opposite to 90° on the second line of sines, is the course 43° on the first line of sines. Again, set the complement of the course 47° on the second line of sines, to 90° on the first line of sines; and opposite to the distance 250 on the first line of numbers, is the difference of latitude 183 on the second line.

Latitude of Venice,	45°	26′ N.	Mer. parts,	- -	3067
Diff. of latitude, -	3	3 S.			
Latitude come to,	42	23 N.	Mer. parts,	- -	2813
			Mer. diff. of latitude,		254

Now, set 45° on the second line of tangents, to the course 43° on the first line of tangents; and opposite to the meridional difference of latitude 254 on the first line of numbers, is the difference of longitude 236 on the second line of numbers.

Longitude of Venice, - -	12°	4′ E.
Difference of longitude, - -	3	56 E.
Longitude in, - - - -	16	0 E.

Problem VII.

Given the Latitudes of two Places, and the Departure; to find the Course, Distance, and Difference of Longitude.

Rule.

With the given difference of latitude and departure, find the course and distance, by Prob. VI. of plane sailing; then, with the difference of latitude, the merdional difference of latitude and departure, find the difference of longitude by last problem.

EXAMPLE.

A ship from Conception, in latitude 36° 43′ S. and longitude 72° 40′ W. sailed upon a direct course between the N. and W. and by observation is in latitude 29° 38′ S. and has made 324 miles of westing: Required the course and distance run, and the longitude come to?

Latitude of Conception, -	36° 43′ S.	Mer. parts, - - -	2371
Latitude come to, - -	29 38 S.	Mer. parts, - - -	1863
Difference of latitude, -	7 5 = 425′	Mer. diff. of latitude, -	508

Set the departure 324 on the second line of numbers, to the difference of latitude 425 on the first line of numbers; then, opposite to 45° on the second line of tangents, is the course 37° 19′ on the first line.

Now, set the course 37° 19′ on the second line of sines, to 90° on the first line; and opposite to the departure 324 on the second line of numbers, is the distance 534 on the first line.

Lastly, set the difference of latitude 425 on the second line of numbers, to the meridional difference of latitude 508 on the first line; and opposite to the departure 324 on the second line of numbers, is the difference of longitude 387 on the first line.

Longitude Conception, - -	72° 40′ W.
Difference of longitude, - -	6 27 W.
Longitude in, - - - - -	79 7 W.

PROBLEM VIII.

Given one Latitude, Course, and Difference of Longitude; to find the other Latitude, and Distance.

RULE.

Set the given course to 45° on the lines of tangents, and opposite to the difference of longitude, is the meridional difference of latitude on the lines of numbers. Now, the meridional difference of latitude being applied to the meridional parts of the latitude sailed from, by addition or subtraction, according as they are of the same, or of a contrary name, will give the meridional parts of the latitude come to; and hence, the difference of latitude may be obtained.

Then, set the complement of the course on the second line of sines, to 90° on the first line; and opposite to the difference of latitude on the second line of numbers, is the distance on the first line.

EXAMPLE.

A ship from Cape Verd, in latitude 14° 45′ N. and longitude 17° 39′ W. sailed S. S. W. ½ W. and by observation is found to be in longitude 21° 26′ W.: Required the latitude come to, and distance run?

Longitude Cape Verd, - -	17° 39′ W.
Longitude in by observation, -	21 26 W.
Difference of longitude, - -	3 47 = 227′

Set the course 28° 7′ on the first line of tangents, to 45° on the second line of tangents; and opposite to the difference of longitude 227 on the second line of numbers, is the meridional difference of latitude 425 on the first line of numbers.

Latitude Cape Verd,	14° 45′ N.	Mer. parts, -	895
		Mer. diff. lat.	425
Latitude come to, -	7 49 N.	Mer. parts, -	470
Difference of latitude,	6 56 = 416′		

Now, set the complement of the course 61° 53′ on the second line of sines, to 90° on the first line; and opposite to the difference of latitude 416 on the second line of numbers, is the distance 472 miles on the first line of numbers.

PROBLEM IX.

To find the Difference of Longitude made good upon compound Courses.

METHOD FIRST.

RULE.

Construct a table as in traverse sailing, in which insert the several courses and distances; and from thence, find the difference of latitude and departure, and the course and latitude come to, as in traverse sailing: find also, the meridional difference of latitude.

Now, set the difference of latitude on the second line of numbers, to the meridional difference of latitude on the first line; and opposite to the departure on the second line of numbers, is the difference of longitude on the first line.

EXAMPLE.

A ship from Buchanness sailed as follows: Required the latitude and longitude of the place come to?

Courses.	Dist.	Diff. of Lat.		Departure.	
		N.	S.	E.	W.
S. S. E.	48	- -	44.4	18.4	- -
S. W. by S.	54	- -	44.9	- -	30.0
E. by S.	71	- -	13.9	69.6	- -
N. E.	63	44.5	- -	44.5	- -
W. N. W.	50	19.1	- -	- -	46.2
		63.6	103.2	132.5	76.2
			63.6	76.2	
			39.6	56.3	

Lat. Buchanness, 57° 30′ N. Mer. parts, 4238
Diff. of latitude, 0 40 S.

Latitude come to, 56 50 N. Mer. parts, 4164

Meridional difference of latitude, - - 74

Now, set the difference of latitude 39.6 on the second line of numbers, to the meridional difference of latitude 74 on the first line; and opposite to the departure 56.3 on the second line, is the difference of longitude 105 on the first line.

Longitude Buchanness, - - 1° 47′ W.
Difference of longitude, - - 1 45 E.

Longitude come to, - - - 0 2 W.

This method is that which is commonly used, to find the difference of longitude made good during a day's run; and, in most cases, will be sufficiently accurate for the above period, especially in places near the equator: but when the run is extended to a longer period, and when the places are considerably distant from the equator, this method will be liable to an error, which will increase with the distance, and with the number of courses; in this case, therefore, the following rule becomes necessary.

Rule II.

Complete the traverse table as before; to which annex five columns. Place the latitude sailed from at the top of the first of these columns, which is to be titled *Succesive Latitudes*; then, to this latitude apply the first difference of latitude, by addition or subtraction, according as they are of the same, or of a contrary name, and the sum, or difference, will be the latitude in, at the end of the first course and distance. In like manner, find the several latitudes come to, and insert them under the former.

Find the meridional parts of each of these latitudes, and place them in the second column, entitled *Merid. Parts*; and in the third column, entitled *Mer. Diff. of Lat.* insert the difference between each adjacent pair of meridional parts; hence, are obtained, the meridional differences of latitude answering to each course and distance.

Now, set the first course to 45° on the lines of tangents, and opposite to the first meridional difference of latitude, is the difference of longitude on the lines of numbers; and place it in the fourth or fifth columns, according as the course is in the eastern or western hemisphere. In like manner, proceed with the other courses, and corresponding meridional differences of latitude; and place each difference of longitude in its respective column: then, the difference between the sums of these columns, will be the difference of longitude made good upon the whole traverse, of the same name with the greater.

Remarks.

I.

When the course is N. or S. there is no difference of longitude.

II.

When the course is E. or W. the difference of longitude cannot be found by Mercator's sailing; in this case, therefore, the following rule is to be used.

Set the complement of the latitude to 90° on the lines of sines, and opposite to the departure on the second line of numbers, is the difference of longitude on the first line.

Example.

A ship from Hangcliff, in Shetland, sailed as follows; S. E. by S. 82 miles, E. N. E. 68 miles, E. 106 miles, N. N. W. 54 miles, N. 118 miles, and S. W. by W. 97 miles: Required the latitude and longitude come to?

Traverse Table.

Courses.	Dist.	Diff. of Lat.		Departure.	
		N.	S.	E.	W.
S. E. by S.	82	- -	68.2	45.6	- -
E. N. E.	68	26.0	- -	62.8	- -
E.	106	- -	- -	106.0	- -
N. N. W.	54	49.9	- -	- -	20.7
N.	118	118.0	- -	- -	- -
S. W. by W.	97	- -	53.9	- -	80.6
		193.9	122.1	214.4	101.3
		122.1		101.3	
	D. Lat.	71.8		Dep. 113.1	

Longitude Table.

Succ. Lat.	Mer. parts	M.dif. of lat.	Diff. of Long. E.	Diff. of Long. W.
60° 9	4545			
59 1	4411	134	89.5	- -
59 27	4462	51	123.1	- -
59 27	4462	0	208.5	- -
60 17	4561	99	- -	41.0
62 15	4807	246	- -	- -
61 21	4693	114	- -	170.6
			421.1	211.6
			211.6	

Diff. of longitude, 209.5=3°29′.5e
Longitude Hangcliff, 0 56.5w

Longitude in, - - 2 33.0e.

Remark.

For a new method of resolving that celebrated problem, in which one latitude, the distance, and difference of longitude are given, together with a comparison thereof, with the various methods of solution hitherto proposed, the reader is referred to a paper, by the Author, in the fourth volume of Baron Maseres' Scriptores Logarithmici.

CHAP. VI.

Oblique Sailing by the Sliding Gunter.

Oblique Sailing is the application of oblique angled plane trigonometry to the solution of problems at sea. This sailing will be found particularly useful in going along shore, in surveying coasts and harbours, settling the latitudes of places from observations taken at sea, &c.

As the following examples are performed according to the rules laid down in Oblique Trigonometry, it is, therefore, unnecessary to give particular precepts for each example.

Examples.

I.

At 10h. A. M. Flamborough-head bore W. $\frac{1}{2}$ S. per compass, and at 1h. P. M. the head bore N. W. the ship going S. by W. at the rate of 3 knots an hour: Required the distance of the ship from the head, at the time of each observation? And supposing the latitude of the second place of observation, as deduced from double altitudes, to be 54° 7′ N. and the variation $2\frac{1}{4}$ points W. the latitude of the head is required?

The distance run between the observations is 9 miles; the angle contained between the ship's course and the first bearing of Flamborough-head is $6\frac{1}{2}$ points; and that between the opposite point to the course and the second bearing is 5 points: hence, the angle at the head is $4\frac{1}{2}$ points. Now, place 9 miles on the line of numbers on the slide, to $4\frac{1}{2}$ points on the line of sine rhumbs; then, opposite to 5 points on sine rhumbs, is the first distance 9′.7 on numbers, and opposite to $6\frac{1}{2}$ points is the second distance 11′.1 on numbers. Again, the second bearing being corrected by variation is W. N. W. $\frac{1}{4}$ W. or $6\frac{1}{4}$ points: Now, set the second distance on the line of numbers on the slide, to 8 points on the line of sine rhumbs, and opposite to $1\frac{3}{4}$ points, the complement of the corrected bearing on the same line, is the difference of latitude between the ship and the head 3.75, or 4 miles, on numbers; which, added to 54° 7′, the sum 54° 11′, is the latitude of Flamborough-head.

II.

The correct bearing of St Francois in the island of Guadaloupe, from Cape North in the island of Marigalante, is N. by W. ½ W. and the distance between them 17½ miles; the distance between St Francois and Port St Maria in the same island is 26 miles, and the bearing of Port St Maria, from Cape North, is W. by N. ½ N.: Required the distance between the two last places, and the bearing of Port St Maria from St Francois?

The angle at Cape North is 5 points = 56° 15′, the interval between W. by N. ½ N. and N. by W. ½ W. Now, set 17½ on numbers on the slide to 26 on the corresponding line; and opposite to 56° 15′ on the first line of sines, is the angle at Port St Maria 34° 2′ on the second line of sines. The sum of 56° 15′ and 34° 2′ is 90° 17′; which, subtracted from 180°, the remainder 89° 43′, is the angle at St Francois: from which 1½ points = 16° 52′ being subtracted, the remainder S. 72° 51′ W. is the bearing of Port St. Maria from St Francois, or nearly W. S. W. ½ W.

Now, set 56° 15′ on sines on the slide to 89° 43′, and opposite to 26 on numbers on the slide is about 31.3, the distance required, on the first line of numbers.

III.

Running S. by E. ½ E. at the rate of 5 knots an hour, in the Straits of Durion, at 10h. A. M. the S. E. point of the less Carimon bore W. S. W. distance 10 miles; and at 4h. 12′ P. M. we were close alongside of a rock, or small island: The bearing and distance of which, from the above mentioned point, are required?

The interval of time between the observations is 6h. 12′; and since the hourly rate of sailing is 5 knots, the distance run is, therefore, 31 miles. The angle between the ship's course and Carimon is 7½ points.

Now, set 10 miles on numbers to 8 points on the sine rhumbs; then, opposite to 7½ points is the perpendicular 9.95 on numbers, and opposite to ½ a point is the segment .98, or nearly 1 mile, which subtracted from 31, the remainder, 30 miles, is the other segment. Then, set the perpendicular 9.95 on numbers on the slide, to 30 on the first line; and opposite to 45°

on the second line of tangents, is the angle at the rock, or island, 18° 21′ on the corresponding line.

The sum of 18° 21′ and 1½ points, or 16° 52′, is 35° 13′; hence, the bearing of the rock from the S. E. point of the less Carimon is S. 35° 13′ E. or S. E. ¾ S. nearly.

Lastly, set 71° 39′, the complement of 18° 21′, on sines on the slide to 90°; and opposite to 30 on numbers on the slide, is 31.6 the distance required.

IV.

The distance of point Divata, in the island of Mindanao, from Hagna in the island of Bohol, is 68 miles, and bearing S. E. ½ E. The distance between Hagna, and the south end of the small island Limassava, is 56 miles; and the distance of point Divata from Limassava is 49 miles: The bearings of Hagna and point Divata, from Limassava, are required?

The three distances form an oblique triangle, the angles of which are found by Prob. IV. of oblique trigonometry, as follows:

The sum and difference of the two least distances are 105 and 7 respectively; and twice the greater side is 136.

Then, set 136 to 105 on numbers, and opposite to 7 is 5.4. half the difference of the segments. Now, the sum of half the greater side 34, and 5.4 is the greater segment 39.4; and their difference 28.6 is the less segment.

Set the greater segment 39.4 on numbers on the slide to 56, and opposite to 90° on the first line of sines, is 44° 43′ the complement of the angle at Hagna; hence, this angle is 45° 17′, to which 4½ points, or 50° 37′, being added, and the sum 95° 54′ subtracted from 180°, the remainder, S. 84° 6′ W. is the bearing of Hagna from Limassava.

Again, set the less segment 28.6 on the second line of numbers, to 49 on the first line; and opposite to 90° on the first line of sines, is the complement of the angle at point Divata on the second, viz. 35° 43′. Hence, that angle is 54° 17′ the difference between which and 50° 37′, is the bearing of point Divata from Limassava, namely, S. 3° 40′ W.

CHAP. VII.

Windward Sailing by the Sliding Gunter.

Windward Sailing is the method of gaining an intended port, by the shortest and most direct method possible, when the wind is in a direction unfavourable to the course the ship ought to steer for that port.

In order to attain this important point, it is evident the ship must sail in different tacks; the object, therefore, of this sailing is, to find the proper courses to be steered on each board, that the vessel may arrive at the intended port the soonest possible. The following examples will serve to illustrate this sailing.

Examples.

I

A ship is bound to a port 26 miles directly to windward, the wind being N. E. which it is intended to reach on two boards, the first being on the larboard tack; and the ship can ly within 6 points of the wind: Required the course and distance on each tack?

As the ship can ly within 6 points of the wind, which is N. E. the course on the larboard tack will, therefore, be E. S. E. and that on the starboard tack N. N. W.

Now, set half the distance of the port, viz. 13 miles, on numbers on the slide, to 2 points, the complement of 6, on sine rhumbs; and opposite to 8 points on sine rhumbs is 34 miles nearly, the distance the ship must sail on each board.

II.

The wind being S. S. W. a ship is bound to a port bearing S. by E. distance 54 miles, which she proposes to reach on three boards, each within $5\frac{1}{2}$ points of the wind; the first being in the S. E. quarter: Required the distance to be run on each board.

Since the ship can ly within $5\frac{1}{2}$ points of the wind, which is S. S. W. the first and last courses being in the S. E. quarter, will be S. E. ½ S. and the second course W. ½ S.; the interval between the bearing of the port S. by E. and the first course S. E. ½. S. is 2½ points; and that between S. by E. and the second course W. ½. S. is 8½ points: also the interval between W. ½ S. and N. W. ½ N. the opposite point to S. E. ½ S. is 5 points.

Now, set 27 miles, half the distance, on the slide, to 5 points on sine rhumbs; and opposite to 7½ points the supplement of 8½ points, is the distance 32.3 miles, to be run on the first and last boards; also opposite to 2½ points on sine rhumbs, is half the distance 15.3 on numbers; hence, the distance upon the second tack is 30.6 miles.

III.

The wind at N. ½ E. a ship is bound to a port bearing N. N. E. distance 68 miles, which it is proposed to make at four boards: the coast, which is to westward, trends N. N. E. also; so that the ship must go about as soon as she reaches the straight line joining the ports Required the course and distance on each board, the ship making her way good within six points of the wind?

The wind being N. ½ E. and the ship lying within six points of it, the course on the larboard tack will be E. N. E. ½ E. and that on the starboard N. W. by W. ½ W. The angles contained between N. N. E. the bearing of the port, and each of these courses are, therefore, 4½ and 7½ points; and the supplement of the angle between the courses is 4 points

Now, set half the distance 34 miles on numbers on the slide, to 4 points on sine rhumbs; and opposite to 7½ points on sine rhumbs, is the first distance on numbers 47.8 miles; which is also the third distance: and opposite to 4½ points on sine rhumbs is the second and fourth distances on numbers, 37.2 miles.

IV.

The wind being N. W. a ship lying within six points of the wind, and making half a point of leeway, sailed 64 miles on the larboard tack, and 48 miles on the starboard tack, and made her port: The bearing and distance of which, from the place sailed from, are required?

Since the course made good is 6½ points from the wind, therefore, the course on the larboard tack will be N. N. E. ½ E. and that on the starboard tack S. W. by W. ½ W.

Now, with the distance 64 miles, and the first course N. N. E. ½ E. = 2½ points, the difference of latitude will be found to be 56.4, and departure 30.2. And with the distance 48 miles, and the second course S. W. by W. ½ W. the difference of latitude is 22.6, and departure 42.3. The difference between the differences of latitude is 33.8, and that between the departures is 12.1.

Then, set 12.1 on numbers on the slide, to 33.8 on the line of numbers above; and opposite to 45° on tangents, is the course 19° 42′ on tangents on the slide: hence the bearing of the port from the place sailed from is N. 19° 42′ W. or N. by W. ¾ W. Again, set the difference of latitude 33.8 on numbers on the slide, to the complement of the course 6¼ points on sine rhumbs; and opposite to 8 points on sine rhumbs, is the distance between the places 36 miles on numbers.

CHAP. VIII.

Current Sailing by the Sliding Gunter.

The computations, in the two preceding chapters, have been performed upon the assumption that the water has no motion. This may, no doubt, answer tolerably well in those places where the tides are regular; as then, the effect of the flood will nearly counterbalance that of the ebb. But in places where there is a constant current, or setting of the sea, towards the same point, an allowance must be made for the change of the ship's place, arising therefrom. And the method of resolving those problems in sailing, in which the effect of a current, or heave of the sea, is taken into consideration, is called Current Sailing.

That point of the compass to which a current runs is called its *setting*, and its rate per hour is called its *drift*.

In a calm, it is evident, a ship will be carried in the direction, and with the velocity, of the current. Hence, if a ship sails in the direction of the current, her rate will be augmented by the rate of the current; but if sailing directly against it, the distance made good will be equal to the difference between the rate of the ship as given by the log, and that of the current: and the absolute motion of the ship will be a-head, if her rate exceeds that of the current; but if less, the ship will make sternway. If the ship's course be oblique to the direction of the current, her true course and distance will be compounded of the course and distance given by the log, and of the setting and drift of the current; and the distance made good in a given time will be represented by the third side of a triangle, of which the distance given by the log and the drift of the current, in the same time, are the other two sides.

In the open ocean, in calm weather, the setting and drift of a current are easily found, by taking a boat to some little distance from the ship; which being brought up, by sinking, from the stern, a heavy iron pot, or loaded kettle, to the depth of about 100 fathoms: then, the log being hove, its bearing will be the setting of the current; and the number of knots run out in half a minute will be its drift. When in sight of land, the setting and drift of a current may be found, by observing some remarkable place or places ashore, at certain intervals of time

Examples.

I.

A ship sailed S. W. by S. at the rate of 7 knots an hour, in a current setting S. E. 1½ miles an hour: Required the course, and distance made good in 24 hours?

Set 1 on numbers on the slide, to 24 on the first line of numbers; then, opposite to 7 on the slide is the distance per log, 168 miles, in 24 hours; and opposite to 1½ on the slide is the drift of the current, 36 miles, in the same time.

Now, set 168 miles on numbers on the slide to 8 points on sine rhumbs, and opposite to the course 3 points on sine rhumbs, is the departure 93.3; and opposite to the complement of the course 5 points, is the difference of latitude 139.7 miles.

Again, set 36 miles on numbers to 8 points on sine rhumbs, and opposite to the setting of the current 4 points, is the departure 25.5, which is also the difference of latitude.

Now, the sum of the two differences of latitude, because of one name, viz. 165.2, is the difference of latitude made good;

and the difference of the two departures, being of contrary names, viz. 67.8 is the departure made good.

Then, set 67.8 on numbers on the slide, to 165.2 on the first line of numbers, and opposite to 45° on the second line of tangents, is the course 22° 19′ on the first line of tangents; hence, the course made good is S. 22° 19′ W. Again, set 67° 41′ the complement of the course, on sines on the slide, to 90° on the first line of sines; and opposite to 165.2 on numbers on the slide, is the distance 179 on the first line of numbers.

II.

A ship bound from Dover to Calais, lying S. E. by E. ½ E. distant 21 miles, and the flood tide setting N. E. ½ E. 2½ miles an hour: Required the course she must steer, and the distance to be run by the log, at 6 knots an hour, to reach her port?

Set 6 miles on numbers on the slide, to 6 points on sine rhumbs, the angle contained between S. E. by E. ½ E. and N. E. ½ E.; then, opposite to 1½ miles on numbers is about 2 points on sine rhumbs, which being allowed to the right of the true course S. E. by E. ½ E. because the current sets to the left, gives S. E. ½ S. the course to be steered.

The sum of 6 points and 2 points is 8, which subtracted from 16, the remainder is 8 points: Now, bring 21 miles on numbers, the distance between the ports, to 8 points on sine rhumbs; then, opposite to 6 points on sine rhumbs is the distance to be run, 19.4 miles on numbers.

III.

A ship from latitude 38° 20′ N. sailed 24 hours in a current setting N. W. by N. and by account is in latitude 38° 42′ N. having made 44 miles of easting; but the latitude by observation is 38° 58′ N. Required the course and distance made good, and the drift of the current?

The difference between the latitudes by account and observation is 16 miles, which is, therefore, attributed to the current; and the setting of the current is N. W. by N. Now, set 16 miles on numbers on the slide, to 5 points on sine rhumbs, the complement of the setting of the current; and opposite to 8 points on sine rhumbs is 19.2 miles, the motion of the current in 24 hours. Then, set 24 hours on numbers on the slide, to

1 on the first line; and opposite to 19.2 on numbers on the slide, is 0.8 the drift of the current.

Again, set 3 points, or 33° 45′, on tangents on the slide to 45°, and opposite to 16 miles on the first line of numbers, is that part of the departure occasioned by the current, 10.7 miles; which subtracted from 44 miles, the departure by account, the remainder, 33.3 miles, is the true departure.

Now, set 33.3 on numbers on the slide, to the true difference of latitude 38 miles, and opposite to 45° on tangents is the course, $41\frac{1}{4}$° on tangents. Then, set the course $41\frac{1}{4}$, on sines on the slide, to 90°; and opposite to 33.3 on numbers on the slide is the distance, $50\frac{1}{2}$ miles on numbers. Or, set the complement of the course $48\frac{3}{4}$°, to 90° on sines, and opposite to the difference of latitude 38, is the distance $50\frac{1}{2}$ miles on numbers.

IV.

A ship from a port in latitude 42° 52′ N. sailed S. by W. $\frac{1}{2}$ W. 17 miles in 7 hours, in a current setting between the N. and W. and then, the same port bore E. N. E. and the ship's latitude by observation was 42° 42′ N.: Required the setting and drift of the current?

Set the distance 17 miles on numbers, to 8 points on sine rhumbs, and opposite to the course $1\frac{1}{2}$ points, is the departure 4.9 miles; and opposite to the complement of the course $6\frac{1}{2}$ points, is the difference of latitude 16.3 miles.

Again, set the bearing of the port 6 points, or 67° 30′, on tangents on the slide to 45°; and opposite to 10 miles, the difference of latitude, on the slide on numbers, is the departure 24.1. The difference between the differences of latitude 16.3 and 10, is 6.3 miles; and that between the departures 4.9 and 24.1, is 19.2.

Now, set 6.3 on numbers on the slide to 19.2, and opposite to 45° on tangents is the setting of the current, N. 71° 51′ W. Then, set 71° 51′ on sines on the slide to 90°, and opposite to 19.2 on numbers on the slide is the motion of the current, 20.2 miles. Lastly, set 7 to 1 on numbers, and opposite to 20.2 is 2.9 knots, the hourly rate, or drift, of the current.

Remark.

For various other examples, illustrating these sailings, with the methods of construction, calculation, &c. the reader is referred to the Author's Treatise on Navigation.

CHAP. IX.

Of Sea Charts.

A Chart is a representation of a part, or of the whole, of the water on the surface of the globe, and the adjacent coast, and is of two kinds, Plane and Mercator *.

A Plane Chart is constructed upon the assumption, that the surface of the earth is an extended plane.

A Mercator's Chart is constructed upon the supposition, that the figure of the earth is spherical.

Since the figure of the earth is nearly that of a sphere, it is evident from the nature of the construction of a plane chart, that it must be erroneous; and, therefore, can be of little or no real utility in the practice of navigation, except in that case, where the chart extends only to a few degrees on either side of the equator. With respect to a Mercator's chart, the figures of countries become more and more increased beyond their just proportion, according to their distance from the equator, upon account of the extension of the degrees of latitude, in order that the meridians, instead of being curves, may be straight lines, and parallel to each other. Yet, by this kind of a chart, the bearing and distance between any two places on it, may be easily and accurately found.

CONSTRUCTION OF CHARTS.

I.

OF A PLANE CHART.

The number of degrees of latitude, which the chart is in-

* There are various other kinds of charts, beside the above, but these are most generally known.

tended to contain, and the extent from east to west, being fixed upon; a line is to be drawn near the side or end of a sheet of paper, in length equal to the whole length of the chart from north to south, and this line is to be divided into degrees, and numbered accordingly. From each end of this line perpendiculars are to be drawn, and made equal to the intended extent of the chart from east to west; and their extremities are to be joined by a straight line. If the chart is to commence at or near the equator, and to extend only a few degrees in latitude, the divisions of the parallels may be equal to those of the meridian; but, if the chart begins at any considerable distance from the equator, it will conduce to accuracy, to make the length of each degree of the parallel equal to the co-sine of the mean latitude, the radius being 60′: Or, the extreme parallels may be divided according to the above proportion. Meridians and parallels are to be drawn at convenient distances.

A scale is now to be made, of stiff paper or pasteboard, equal in length to the extent of the chart from east to west, and divided and numbered accordingly. By this scale, the positions of those places contained within the limits of the chart are very easily laid down, by placing the divided edge of the scale over the latitude of the given place, and under the given longitude, a mark being made, will represent the position of the place on the chart.

A compass is to be inserted in any convenient place of the chart, and an arrow showing the direction of the flood tide or current. The times of high-water are to be marked in their proper places, expressed in Roman characters; the leading marks to avoid dangers, &c.

II.

OF A MERCATOR'S CHART.

A Mercator's Chart, for any given portion of the surface of the earth, is constructed as follows:

The limits of the proposed chart is first to be determined, that is, the number of degrees of latitude and longitude it is to contain, and the degree of latitude and longitude of its commencement.

A parallel, representing that of the least latitude, is to be drawn; upon which, the number of degrees in the proposed difference of longitude, from the scale of equal parts, is to be laid off, and divided into degrees, and smaller portions, if convenient, and numbered at each fifth or tenth degree. From each end of this parallel a perpendicular is to be drawn, and made equal to the difference between the extreme latitudes, from the meridian line; and the ends of these meridians are to be joined by a straight line, which is to be divided and numbered in the same manner as the first drawn parallel: the meridians are then to be divided into degrees, and numbered at every fifth or tenth degree.

If the chart is intended to be upon a larger scale, equimultiples of the intervals, from the line of equal parts and the meridian line, are to be taken, such as will answer to the proposed extent of the chart.

A slip of strong paper is to be divided and numbered, in the same manner as the first drawn parallel. Now, each place within the limits of the chart is to be laid down, by placing the slip of paper so, that its extreme points of division may be set to the latitude of the given place, on each meridian; then, under the longitude of the place a mark is to be made, which will represent the position of that place. In like manner, all the places on the coast are to be laid down, and connected by observations made on that coast, according to the directions given for surveying coasts and harbours, in the Author's Treatise on Navigation: Or, if no sketch had been previously made, the contour of the coast is to be drawn, agreeable to the best charts. Meridians and parallels are to be drawn, through every fifth or tenth degree of latitude and longitude, and extended to the coast.

A compass is to be inserted in some convenient part of the chart, and the points extended to the land; an anchor is to be drawn where there is good anchoring ground, and in places where it is safe only to stop a tide, an anchor without a stock is to be laid down. The soundings, and quality of the ground, the times of high-water, &c. are to be marked in their proper places.

A Mercator's Chart may be constructed by means of the line of logarithmic tangents, and a scale of equal parts, as follows:

Apply the tangent of half any co-latitude to a line of equal parts, and divide the corresponding number by the number of meridional degrees contained in the given latitude; hence, a line of longitude, adapted to the line of tangents, will be obtained. Thus, take any latitude, as 28° 43′, from the meridian line; which, applied to the adjoining line of equal parts, will measure exactly 30°. Now, the complement of 28° 43′ is 61° 17′, the half is 30° 38½′. Then, the extent from 30° 38½′ to 45° on the line of tangents, being applied to any line of equal parts, as the inch scale, will measure about 256; which divided by 30, the quotient 8.5, is the length of one degree of longitude on that scale, answering to the degrees of latitude, to be taken from the line of tangents. By means of this scale, the parallel is to be made of the proposed extent, and divided accordingly: from each end of this parallel perpendiculars are to be drawn, upon which are to be laid off, the interval between the co-tangents of half the co-latitudes of the extreme parallels, from the line of tangents, and the ends are to be joined by a straight line, which is to be divided similar to the first drawn parallel. The meridians are to be divided into degrees, and parts of a degree, by the line of tangents; and the chart is to be finished as before. It is scarcely necessary to observe, that if the chart is intended to be upon a larger scale, equimultiples of similar portions of the equator and meridian are to be taken.

Those who wish more information upon this subject, together with the method of constructing a Mercator's chart of any proposed dimensions, by means of a table of meridional parts, are referred to the Author's Treatise on Navigation.

MANNER OF USING CHARTS.

The principal use of a chart is, to find the course and distance between any two places within its limits; and to lay down the place of a ship on it, so that the position of the ship with respect to the intended port, the adjacent land, islands, &c. may be readily perceived. To those who understand the method of performing the several problems in sailing by projection, the manner of using a chart will be a very easy process; to others, however, the following rules will be of service.

I.

USE OF THE PLANE CHART.

Problem I.

To find the Latitude of a Place in the Chart.

Rule.

Take the least distance, between the given place and the

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nearest parallel of latitude, which being applied the same way on the divided meridian, from the point of intersection of the parallel and meridian, will give the latitude of the proposed place.

Example.

Required the latitude of Port Louis in the Isle of France?

The least distance between Port Louis and the nearest parallel, being laid the same way on the meridian, from the extremity of that parallel, will reach to 20° 8′ S. the latitude required.

Problem II.

To find the Course and Distance between two given Places on the Chart.

Rule.

Lay the edge of a scale over the given places, and take the nearest distance between the centre of any compass on the chart and the edge of the scale; move this extent along so as one point of the compasses may touch the edge of the scale, and the straight line joining the points may be perpendicular thereto: then will the other point show the course, and the interval between the places being applied to the scale, will give the required distance.

Example.

Required the course and distance from Cape St André to Cape St Sebastian, both in the island of Madagascar?

The edge of a scale being laid over the two places, then by moving the compasses as directed, the course will be found to be N. E. $\frac{1}{2}$ E. and the interval between them applied to the scale, will measure 105 leagues.

Problem III.

The Course and Distance sailed from a known Place being given, to find the Ship's Place on the Chart.

Rule.

Lay the edge of a scale over the place sailed from, parallel to the given course; then, take the given distance from the scale on the chart, and lay it off from the given place by the edge of the scale, and it will give the point on the chart representing the place of the ship.

Example.

The correct course of a ship from Cape St Maria, on the north side of the entrance of the river La Plata, was N. E. by E. and distance 238 leagues: Required the place of the ship on the chart?

The edge of the scale being laid over Cape St Maria in a N. E. by E. direction, and the distance 238 leagues laid off from Cape St Maria by the edge of the scale, will give the place of the ship, which will be found to be in latitude 28° 15′ S.

Problem IV.

Given the Latitude in, and Meridian Distance, to lay down the Place of the Ship on the Chart.

Rule.

Through that place from which the meridian distance is reckoned, let a meridian be drawn; then, lay a scale over the given latitude, and the meridian distance being taken from the scale on the chart, and laid off by the edge of the scale, from the point of its intersection with the meridian, will give the ship's place.

The manner of performing this problem is obvious; and the various other problems that may be resolved by the plane chart, require no further explanation, being only the construction of the remaining problems in plane sailing.

II.

USE OF MERCATOR'S CHART.

Problem I.

To find the Latitude of a Place.

Rule.

This is performed in the same manner as Prob. I. on the plane chart.

Problem II.

To find the Longitude of a Place.

Rule.

Take the least distance between the given place and the nearest meridian, which being laid off on the equator or divided parallel, from the point of intersection of the parallel and meridian, will give its longitude.

Example.

Required the longitude of Funchal in the island of Madeira?

The least distance being taken between Funchal and the nearest meridian, and laid off from the intersection of that meridian with the divided parallel, will give 17° 6′ W. the longitude required.

Problem III.

To find the Course between two given Places on Mercator's Chart.

Rule.

For the manner of performing this problem, the reader is referred to the use of the plane chart, Prob. III.

Problem IV.

To find the Distance between two given Places on the Chart.

I.

When the given places are under the same meridian.

Rule.

Find the latitude of each place; then, the difference or sum of their latitudes, according as they are on the same, or on opposite sides of the equator, will be the distance required.

Example.

Required the distance between the nearest extremities of the islands of Grenada and Guadaloupe?

Latitude of southernmost extremity of Guadaloupe,	-	15°	52′ N.	
Latitude of northernmost extremity of Grenada	- -	12	14 N.	
Distance,	- - - - -	3	38	= 218′

II.

When the given places are under the same parallel.

Rule.

If that parallel is the equator, the difference or sum of their longitudes, found by Prob. II. is the distance between them. Otherwise, take half the interval between the given places, lay it off on the meridian, on each side of the given parallel, and the intercepted degrees will be the distance between the places.

If the given parallel is near the north or south extremity of the chart, the following method may be used: Take an extent of a few degrees from that part of the meridian, where the given parallel is the middle of the extent; then, the number of extents, and parts of an extent, contained between the given places, being multiplied by the length of an extent, will give the required distance.

Example.

Required the distance between Cape Cantin and Funchal, both lying nearly in the same parallel?

By proceeding as directed above, the distance will be found to be 6° 44′, or 134⅔ leagues.

III.

When the given places differ both in latitude and longitude.

Rule.

Find the difference of latitude between the given places, and take it from the equator, or graduated parallel; then, lay the edge of a scale over the given places, and move or slide one point of the compasses along the edge of the scale, until the other point just touches a parallel. Now, the distance between the place where the point of the compasses rested, and the point of intersection of the edge of the scale and parallel, being applied to the equator, or divided parallel, will give the distance between the places in degrees, and parts of a degree; which, multiplied by 60, will give the distance in miles.

Example.

Required the distance between Cape Finisterre and Porto Sancto?

Take the difference of latitude between the given places 9° 54′, from the graduated parallel, and move one point of the compasses along the edge of a scale, laid previously over these places, until the other point just touches a parallel: Now, the interval between the place where the point of the compasses rested, and the point of intersection of the scale and parallel being applied to the divided parallel, will measure 11° 24′, or 228 leagues.

Remark.

To some charts, a set of scales is adapted to each degree of latitude, within the limits of the chart; by which the distance between any two places is easily measured, by applying that distance to the scale answering to the middle parallel of latitude of the two places.

Problem V.

Given the Latitude and Longitude in, to find the Ship's Place on the Chart.

Rule.

Lay the edge of a scale over the given latitude, and lay off the given longitude from the first meridian, or the difference of longitude from the nearest meridian, by the edge of the scale, and the ship's place will be obtained.

Example.

The latitude is 47° 30′ N. and longitude 12° 15′ W.: it is required to lay down the place of the ship on the chart?

Lay the edge of the scale over the latitude 47° 30′ N.; then, take from the divided parallel the interval between 10° and 12° 15′, which laid off by the edge of the scale from the meridian of 10° will give the ship's place.

Problem VI.

Given the Course sailed from a known Place, and the Latitude in, to find the Ship's place on the Chart.

Rule.

Lay the edge of a scale over the place sailed from, in the direction of the given course, and its intersection with the parallel of latitude arrived at, will be the place of the ship.

Example.

A ship from the Lizard sailed S. W. by S. and by observation is in latitude 45° 20′ N.: Required the place of the ship on the chart?

The edge of a scale being laid over the Lizard, parallel to the S. W. by S. rhumb, will intersect a parallel drawn through the given latitude 45° 20′ N. in the ship's place.

Problem VII.

Given the Course steered, and Distance run from a known Place, to lay down the Place of the Ship on the Chart.

Rule.

Lay the edge of a scale over the place sailed from, in the direction of the given course; then, take the distance from the equator, put one point of the compasses at the intersection of any parallel with the edge of the scale, and the other point of the compasses will reach to a certain place by the edge of the scale: Now, this point remaining in the same position, draw in the other point of the compasses, until it just touch the above parallel; apply this extent to the equator, or divided parallel, and it will give the difference of latitude. Hence, the latitude come to, will be known; and the point of intersection of the corresponding parallel with the edge of the scale, will be the place of the ship.

Example.

A ship from Cape St Vincent sailed S. S. W. 300 miles: Required the ship's place on the chart?

Lay the edge of a scale over Cape St Vincent, parallel to the

S. S. W. rhumb. Take the distance 5° from the divided parallel, place both points of the compasses close to the edge of the scale, so that one of these may be at the intersection of a parallel with the edge of the scale, and the other on that side of the parallel on which is the acute angle formed by scale and parallel. Now, this last point of the compasses remaining in this position, diminish the extent of the compasses, until the other point touches the parallel, and this extent applied to the divided parallel will measure 4° 37′ ; hence, the latitude in is 32° 25′ N. and a parallel drawn through 32° 25′, will intersect the edge of the scale in the place of the ship.

Problem VIII.

Given the Latitude and Longitude sailed from, the Course steered, and Longitude come to, to find the Ship's Place on the Chart.

Rule.

Draw a meridian through the longitude come to; then, lay the edge of a scale over the place sailed from, in the direction of the course; and its intersection with the meridian will be the place of the ship.

Example.

The true course of a ship from Cape St Bernard, in the island of Bourbon, was N. E. ½ N. and the longitude come to 59° 46′: Required the ship's place on the chart?

The edge of a scale laid over Cape St Bernard in a N. E. ½ N. direction, will intersect a meridian drawn through the given longitude 59° 46′, which will represent the ship's place, the latitude of which is 15° 18′ S.

Remark.

The various other problems in Mercator's sailing may be easily resolved by this chart; but, as they are of less use than the preceding, they are, therefore, omitted—and may serve as an exercise to the student.

BOOK III.

CONTAINING METHODS OF FINDING THE LATITUDE, LONGITUDE, AND VARIATION OF THE COMPASS, BY THE SLIDING GUNTER.

CHAP. I.

Of Finding the Latitude.

THE situation of a place on the surface of the earth is estimated by its distance from two imaginary lines, intersecting each other at right angles: the one of these is called the EQUATOR; and the other the FIRST MERIDIAN. The position of the equator is fixed, but that of the first meridian is assumed at pleasure; and, therefore, different nations have generally different first meridians. In Britain, the first meridian is that of the Royal Observatory at Greenwich; in France, it is that of the Royal Observatory at Paris, &c.

The equator divides the earth into two equal parts, called the NORTHERN and SOUTHERN *Hemispheres:* and the LATITUDE of a place is that portion of the meridian, passsing through the given place, which is contained between it and the equator; and is either North or South, according as the place is in the northern or southern hemisphere, and cannot exceed 90°.

The first meridian being continued round the globe, divides it into two equal parts, called the EASTERN and WESTERN *Hemispheres:* and the LONGITUDE of a place is that portion of the equator, which is contained between the first meridian and the meridian of the given place; and is either East or West, according as the given place is in the eastern or western hemisphere, and cannot exceed 180°.

The observation necessary for ascertaining the latitude is, that of the meridian altitude of a known celestial object; or two altitudes, when the object is out of the meridian. The latitude is deduced with more certainty, and with less trouble, from the first of these methods than from the second; and the sun, for various reasons, is the object most proper for this purpose at sea. It, however, frequently happens that, by the interposition of clouds, the sun is obscured at noon, and by this means the meridian altitude is lost; in this case, therefore, the method by double altitudes becomes necessary. The latitude may also be deduced from three altitudes of an unknown object; or from double altitudes, the apparent times of observation being given, &c.

The altitude of the limb of an object observed at sea requires four separate corrections, in order to obtain the true altitude of its centre; these are for *semidiameter*, *dip*, *refraction*, and *parallax*. The first and last of these corrections vanish, when the observed object is a fixed star.

When the altitude of the lower limb of any object is observed, its semidiameter is to be added thereto, in order to obtain the central altitude; but, if the upper limb be observed, the semidiameter is to be subtracted. If the altitude be taken by the back-observation, the contrary rule is to be applied. The dip is to be subtracted from, or added to, the observed altitude, according as the fore or back-observation is used. The refraction is always to be subtracted from, and the parallax added to the observed altitude.

Problem I.

To Reduce the Sun's Declination to any given Meridian.

Rule.

Find the difference between the declination for the given day, and that for the preceding or following days, according as the longitude is E. or W.; then, set 360 on the line of numbers on the slide, to the given longitude on the corresponding line of numbers, and opposite to the daily variation of declination on the line of numbers on the slide, is the correction of declination. Now, if the longitude is west, and the declination increasing, that is, from the 20th of March to the 22d of June, and from 23d September to the 22d December, the correction is to be added to the declination; during the other part of the year, or while the declination is decreasing, the correction is to be subtracted. In east longitude, the contrary rule is to be applied.

Example I.

Required the sun's declination at noon, April 15, 1802, in longitude 86° W.?

Sun's declination April 15,	-	9° 37′ N.
Sun's declination April 16,	-	9 58 N.
Daily variation,	- - -	0 21

Now, set 360 on numbers on the slide, to the longitude 86° on the corresponding line, and opposite to 21′ on numbers on the slide is 5′, the correction; which added to 9° 37′, because the declination is increasing, and the longitude west, gives 9° 42′, the reduced declination.

Example II.

Required the sun's declination at noon, October 17, 1802, in longitude 150° E.?

Sun's declination October 16,	-	8° 44′ S.
Sun's declination October 17,	-	9 6 S.
Daily variation	- - - - -	0 22

Now, set 360 on numbers on the slide, to the longitude 150° upon the line above, then, opposite to 22′ on the slide is 9′, the correction; which subtracted from 9° 6′, because the declination is increasing, and the longitude E. gives 8° 57′ S. the reduced declination.

Problem II.

Given the Meridian Altitude of the Sun, to find the Latitude of the Place of Observation.

Rule.

The sun's semidiameter 16′ is to be added to, or subtracted from, the observed altitude, according as the lower or upper limb is observed; the dip, from Table I. answering to the height of the eye above the water is to be subtracted, if the fore-observation is used—otherwise, it is to be added; and the refraction, from Table III. answering to the altitude is to be subtracted:* Hence, the true altitude of the sun's centre will be obtained. Subtract the true altitude from 90° the remain-

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* The dip, refraction, &c. may be ascertained by the Sliding Gunter; but being much easier found by inspection, tables containing these corrections are, therefore, annexed to this tract.

der will be the zenith distance, which call N. if the observer is north of the sun at the time of observation, otherwise S. Then the sum, or difference, of the zenith distance and declination,* according as they are of the same, or of a contrary denomination, will be the latitude, of the same name with the greater.

Example I.

April 15, 1802, in longitude 86° W. the meridian altitude of the sun's lower limb was 73° 54′, the observer being N. of the sun and height of the eye 16 feet: Required the latitude?

Observed altitude sun's lower limb,	73° 54′
Semidiameter, - - -	+ 16
Dip and refraction, - -	— 4
True altitude, - - -	74 6
Zenith distance, - - -	15 54 N.
Declination, - - -	9 42 N.
Latitude, - - - -	25 36 N.

Example II.

October 17, 1802, in longitude 150° E. the meridian altitude of the sun's lower limb was 32° 23′ the observer being N. of the sun, and height of the eye 14 feet: Required the latitude?

Observed altitude sun's lower limb,	32° 23′
Semidiameter, - - -	+ 16
Dip and refraction - -	— 5
True altitude of the sun's centre,	32 34
Zenith distance, - - -	57 26 N.
Declination, - - - -	8 57 S.
Latitude, - - - -	48 29 N.

Example III.

June 21, 1812, in longitude 130° E. the meridian altitude of the sun's upper limb was 25° 52′, the observer being S. of the sun, and height of the eye 18 feet: Required the latitude?

* The sun's longitude being given, the corresponding declination may be found by the Sliding Gunter, but not with that degree of accuracy necessary for determining the latitude. Some French scales contain the declination, adapted both to the longitude of the sun, and day of the month.

Observed altitude sun's upper limb,	25°	52′
Semidiameter, - - -	—	16
Dip and refraction, - -	—	6
True altitude sun's centre -	25	30
Zenith distance, - - -	64	30 S.
Declination - - - -	23	28 N.
Latitude, - - - -	41	2 S.

Problem III.

Given two Altitudes of the Sun, observed the same Day, the Interval of Time between the Observations, and the Sun's Declination, to find the Latitude.

Rule.

Correct the altitudes for semidiameter, dip, and refraction; subtract each from 90°, and the remainders will be the corresponding zenith distances. Reduce the interval of time between the observations to degrees, which may be done by dividing the minutes contained therein by 4, the half of which call the *half elapsed time.* Find the polar distance, which will be the sum or difference of 90°, and the declination according as the latitude of the place and the sun's declination are of the same, or of a contrary denomination.

Set 90° on the slide* to the polar distance on the corresponding line of sines, and opposite to the half elapsed time on sines is a certain number of degrees, which being doubled, call *arch first.*

Again, set 90° on sines to the declination on the adjacent line, and opposite to the half elapsed time on the line of tangents on the slide, is *arch second* on the corresponding line of tangents, to be reckoned to the left hand: in this case, the elapsed time is supposed to be less than six hours; but if greater, observe that division on the second line of tangents which is op-

* In order to avoid repetitions, it is to be observed, that in the following precepts, the first and third terms are to be found on the slide, and two lines of the same kind are to be compared with each other; that is, if the first term is 90° or a sine, the second term is a sine, and must be found on the first or upper line of sines; but if 45°, or a tangent, the other is a tangent, and will be found on the second or lower line of tangents.

posite to 45°, then move the slide until the half elapsed time coincides with this division, and opposite to 45° is *arch second.*

From half the sum, of the sum of the two zenith distances and arch first, subtract the least zenith distance. Then, set half the sum on the line of sines on the slide to the least zenith distance, and opposite to arch first on sines is an arch on the line above; find this arch on the slide, and set it to the remainder on sines, and opposite to 90° is another arch on sines, which being found on the third line of sines, will give *arch third* on versed sines. Let the difference between arches second and third, be called *arch fourth.*

Set 90° on sines to the complement of arch fourth, and opposite to the least zenith distance on tangents on the slide, is *arch fifth* on the adjacent line of tangents. If the least zenith distance exceeds 45°, it is to be found on the second line of tangents, opposite to which is arch fifth on the slide. The difference between arch fifth and the polar distance is *arch sixth.*

Then, set the complement of arch fifth on sines to the complement of arch sixth, and opposite to the greatest altitude on sines is the latitude.

Set arch fifth on sines to arch sixth, and opposite to arch fourth on the second line of tangents is *arch seventh,* which multiplied by 4 will be the time from noon, when the greatest altitude was observed.

Lastly, set the least zenith distance on sines to the polar distance, and opposite to arch seventh on sines is the azimuth, when the greatest altitude was observed.

Example I.

In latitude 56° N. by account, the times per watch were 11h. 23′ and 12h. 54′, the corresponding altitudes 12° 59½′ and 11° 37′, and the sun's declination 19° 47′ S.: Required the true latitude?

Times p. w.	11h.	23′	Altitudes,	12°	59½′	Zen. dist. =	77°	0½′
- - - -	12	54	- - -	11	37	- - - - -	78	23
Interval -	1	31						
Half - -	0	45½ = 11° 22½′				Polar dist. =	109	47

Set 90° on sines on the slide to 109° 47′, or 70° 13′ the polar distance, and opposite to the half elapsed time 11° 22½′ on sines is 10° 42′, which doubled gives 21° 24′, the first arch.

Again, set 90° on sines to 19° 47′ the declination, and opposite to the half elapsed time 11° 22½′ on tangents, is arch second, 86° 6′ on the line below.

Now, the sum of the two zenith distances and arch first is 146° 47½′; the half sum is 88° 23¾′; the difference betwixt which and the least zenith distance 77° 0½′, is 11° 23¼′ the remainder. Then, set 88° 23¾′ the half sum on sines, to 77° 0½′ the least zenith distance; then, opposite to arch first 21° 24′ on sines, is 20° 50′. Now, set 20° 50′ on sines on the slide to the remainder 11° 23¼′, and opposite to 90° on sines is 33° 44′; then, opposite to 33° 44′ on the third line of sines, is arch third 83° 40′ on versed sines. The difference between arches second and third, viz. 2° 26′ is arch fourth.

Set 90° on sines, to 87° 34′ the complement of arch fourth, then, because the least zenith distance exceeds 45°, it is to be taken on the second line of tangents, opposite to which is 77° arch fifth. The difference between which and the polar distance 109° 47′, is 32° 47′ arch sixth.

Then, set 13° the complement of arch fifth on sines, to 57° 13′ the complement of arch sixth; and, opposite to 12° 59½ the greatest altitude on sines, is 57° 9′ the latitude.

Now, set arch fifth 77° on sines, to arch sixth 32° 47′, and opposite to arch fourth 2° 26′ on the second line of tangents, is arch seventh 1° 21′, which, reduced to time, is 5′ 24″; hence, the greatest altitude was observed at 11h. 54′ 36″ A. M.

Lastly, set the least zenith distance 77° 0½′ on sines to the polar distance 109° 47′; and, opposite to arch seventh 1° 21′ on sines, is 1° 18′ the azimuth when the greatest altitude was observed.

Example II.

At 10h. 25′ A. M. per watch, the true altitude of the sun's centre was 39° 15′, and at 11h. 35′ the true altitude was 42° 23′, and the sun's declination 9° 47′ N.: Required the latitude?

Times p. w.	10h.	25′	Altitudes,	39°	15′	Zen. dist. =	50°	45′
- - - - -	11	35	- - -	42	23	- - - - -	47	37
Interval -	1	10						
Half - -	0	35 = 8° 45′				And polar dist.	80	13

Set 90° on sines on the slide to 80° 13′ the polar distance, and opposite to 8° 45′ the half elapsed time on sines is 8° 37′, which doubled is 17° 14′, arch first.

Again, set 90° on sines to 9° 47′ the declination, and opposite to 8° 45′ the half elapsed time on the line of tangents, is arch second, 88° 30′, on the line below.

Now, the sum of the two zenith distances and arch first is 115° 36′; the half sum is 57° 48′; the difference between which and the greatest zenith distance 50° 45′, is 7° 3′ the remainder. Then, set 57° 48′ the half sum on sines, to 47° 37′ the least zenith distance; then, opposite to arch first on sines is 15°. Now, set 15° on sines on the slide to the remainder 7° 3′, and opposite to 90° on sines is 28° 20′; then, opposite to 28° 20′ on the third line of sines, is arch third 92° 56′ on versed sines. The difference between arches second and third, viz. 4° 26′, is arch fourth.

Set 90° on sines to 85° 34′, the complement of arch fourth; then, because the least zenith distance exceeds 45°, it is to be found on the second line of tangents, opposite to which is 47° 32′, arch fifth; the difference between which and the polar distance 80° 13′ is 32° 41′, arch sixth.

Then, set 42° 28′ the complement of arch fifth on sines, to 57° 19′ the complement of arch sixth; and opposite to 42° 23′ the greatest altitude on sines, is about 57° 10′, the latitude.

Now, set arch fifth 47° 32′ on sines, to arch sixth 32° 41′, and opposite to arch fourth 4° 26′ on the second line of tangents, is arch seventh 6° 3, which reduced to time is 24′ 12″; hence, the greatest altitude was observed at 11h. 35′ 48″ A. M.

Lastly, set the least zenith 47° 37′ on sines, to the polar distance 80° 13′, and opposite to arch seventh 6° 3′, is 8° 5′ the azimuth, when the greatest altitude was observed.

Problem IV.

Given two observed Altitudes of the Sun, the elapsed Time, Sun's Declination, and Azimuth at the Time of Observation of the least Altitude, and the Course and Distance run between the Observations, to find the Ship's Latitude at the Time of Observation of the greater Altitude.

Rule.

Correct the observed altitudes, and reduce the half elapsed time to degrees. Then, find the angle contained between the ship's course, and the sun's bearing at the time of observation of the least altitude. Now, set the distance run between the observations on the line of numbers on the slide, to 8 points on sine rhumbs, and opposite to the complement of the above angle on sine rhumbs, is the *correction* of the least altitude.

Now, if the least altitude be observed in the forenoon, the correction of altitude is to be added thereto, if the angle between the ship's course and sun's bearing is less than 8 points; but if that angle is greater than 8 points, the correction is to be subtracted from the least altitude. If the least altitude be observed in the afternoon, the correction is to be subtracted therefrom, if the angle between the ship's course and sun's bearing is less than 8 points; but if greater, the correction is to be added to the least altitude.

With the corrected altitudes, the half elapsed time, and the sun's declination at the time of observation of the greatest altitude, the operation is to be performed by last problem.

Example.

June 22, 1818, at 2h. 44′ per watch, the altitude of the sun's lower limb was 52° 7′, and at 5h. 20′, the altitude was 17° 34′, and azimuth per compass W. N. W.; the ship's course during the elapsed time W. by S. at the rate of 7 knots an hour, height of the eye 20 feet: Required the latitude?

First observed altitude, -	52° 7′	Second, -	17° 34′
Semidiameter, - - - - -	+ 16	- - - - -	+ 16
Dip and refraction - -	— 5	- - - - -	— 7
Corrected altitude, - -	52 18	Cor. alt. -	17 43
Time of first observation, -	2h 44	Sun's declin.	23 28
Time of second observation,	5 20		
		Polar distance,	66 32
Elapsed time, - - - -	2 36		
Half, - - - - - - -	1 18 = 19° 30′		

Set 1 on the line of numbers on the slide to 7 on the line above, and opposite to the elapsed time 2h. 36′, or 2.6 on numbers, is the distance 18.2 miles. Now, set 18.2 on the third line of numbers to 8 points on sine rhumbs, and opposite to 5 points on sine rhumbs, the complement of the angle between the ship's course and sun's bearing, is the correction 15.2 miles, which subtracted from 17° 43′ the least altitude, gives 17° 28′ the reduced altitude.

Now, set 90° on sines to 66° 32′ the polar distance, and opposite to 19° 30′ the half elapsed time on sines is 17° 50′, which doubled is 35° 40′, arch first.

Again, set 90° on sines to 23° 28′ the declination, and opposite to the half elapsed time 19° 30′ on the line of tangents is arch second, 81° 58′ reckoning towards the left.

The sum of the two zenith distances and arch first is 145° 54′; the half 72° 57′; and the difference between the half sum and the greatest zenith distance is 0° 25′ the remainder. Now, set 72° 57′ the half sum on sines, to 37° 42′ the least zenith distance, and opposite to 35° 40′ arch first on sines, is about 21° 54′. Then, set 21° 54′ on sines on the slide to the remainder 0° 25′: but this point is not to be found on the scale; therefore, since in small angles the sines and their corresponding arches are nearly proportional, set 21° 54′ to 0° 50′ the double of 0° 25′, and opposite to 90° on the slide is 2° 14′; then, opposite to 1° 7′ the half of 2° 14′, on the third line of sines, is arch third 163° 56′ on the line of versed sines. The difference between arches second and third, 81° 58′, is arch fourth.

Set 90° on sines to 8° 2′ the complement of arch fourth, and opposite the least zenith distance 37° 42′ on the line of tangents on the slide is 6° 10′, arch fifth. The difference between arch fifth and the polar distance 66° 32′ is 60° 22′, arch sixth.

Now, set 83° 50′ the complement of arch fifth on sines, to 29° 38′ the complement of arch sixth, and opposite to 52° 18′ the greatest altitude on sines is 23° 10′, the latitude.

This method of finding the latitude by double altitudes is given, only with a view to show, that it can be performed by the Sliding Gunter; although great accuracy cannot be expected from a scale of the common construction. In the present example, however, it is preferable to the common method by two altitudes, the elapsed time, and a supposed latitude. Upon this account, therefore, the following *new method* is subjoined; which will answer in all cases, and is not liable to the restrictions and limitations of the common method, and in which, the change of declination between the observations may be taken into account.

Problem V.

Given two Altitudes of the Sun, the Interval of Time between them, and the Sun's Declination, to find the Latitude.

Rule.*

To the rising answering to the elapsed time, add the log. co-sines of the sun's declination at each observation; then, the natural number answering to the sum of these three logs, being added to the natural versed sine of the difference of declination, the sum will be the natural co-versed sine of *arch first*.

To the log. co-sine of arch first, add the secant of the declination at the greatest altitude, the log. of the elapsed time; and the time answering to the sum of these three logs, in table of half elapsed time, will be *arch second*.

From the natural versed sine of the difference between arch first and the least latitude, subtract the natural co-versed sine of the greatest altitude; to the log. of the remainder, add the log. secants of arch first and the least altitude, and the corresponding time to this sum in table of rising will be *arch third*; the difference between arches second and third is *arch fourth*.

To the log. rising of arch fourth, add the log. co-sine of the declination at the time of observation of the least altitude, and the log. co-sine of the least altitude; add the natural number answering to the sum of these three logarithms, to the natural versed sine of the difference of the declination and least altitude, if the latitude and declination be of the same name, but to that of their sum, if of contrary names, and the sum will be the natural co-versed sine of the latitude.

Remark.

In order to attain accuracy, it will be necessary first to take one set of altitudes, consisting of any odd number, as three, five, &c. as accurately as possible, and nearly at equal intervals of time, as one or two minutes, the mean of which, that is, their sum divided by the number of observations, will be the first

* This rule is extracted from the First Volume of the Author's Treatise on the Theory and Practice of finding the Longitude at Sea or Land, page 305; where it is applied to find the latitude from the altitudes of two stars observed at the same, or at different times; and from double altitudes of the moon. The tables for performing the calculations are contained in the second volume of that work.

mean altitude; and in like manner, the mean of the times of observations per watch is to be found: another set of altitudes is to be again taken, with the corresponding times per watch, at a suitable interval, and the mean altitude and time per watch found as before; and the latitude is to be computed from the mean altitudes corrected, the observed interval of time, and sun's declination, as directed in the precepts.

The reason for taking an odd number of observations, in preference to an even number is, that, if the mean time and mean altitude agree nearly with the middle observation, it may be presumed these observations have been accurately taken. In this case, however, the altitudes are supposed to have been taken at nearly equal intervals of time.

For the sake of comparison, we shall apply this method to the former example.

Example.

In north latitude, June 22, 1818, at 2h. 44′ P. M. per watch, the true altitude of the sun was 52° 18′; and at 5h. 20′ the true altitude was 17° 28′: Required the latitude?

Time per watch of 1st ob.	2h. 44′				
Time per watch of 2d ob.	5 20				
Elapsed time - -	2 36	- -		rising - -	4.34802
Declination at 1st observ.	23 28	- -		co-sine - -	9.96251
Declination at 2d observ.	23 28	- -		co-sine - -	9.96251
Difference, - -	0 0	- nat. ver. sine -	000000		
			187515	- - -	4.27304
Arch I. - - -	54° 20′ 22″	nat. co-ver. sine	187515	- co-sine -	9.76566
Declin. at greatest alt.	23 28	- -		secant - -	0.03749
Elapsed time - -	2 36	- -		H. E. T. - -	0.20113
Arch II. - - -	5h. 27′ 53″	- -		H. E. T. - -	0.00428
Arch I. - - -	54° 20′ 22″	- -		secant - -	0.23434
Least altitude, - -	17 28	- -		secant - -	0.02050
Difference, - -	36 52 22	nat. ver. sine	200030		
Greatest altitude, -	52 18	nat. co-ver. sine	208776		
		Difference, -	8746		3.94181
Arch III. - - -	0h. 40′ 42″	- -		rising - -	4.19665
Arch II. - - -	5 27 53				
Arch IV. - - -	4 47 11	- -		rising - -	4.83793

Arch IV. - - -	4h. 47′ 11″ - -	rising - -	4.83733
Declin. at least altitude,	23 28 - -	co-sine - -	9.96251
Least altitude, - -	17 28 - -	co-sine - -	9.97950
Difference, - - -	6 0 - -	nat. ver. sine - 005478	
		601644 - -	4.77934
Latitude, - - -	23 8 - -	nat. co-ver. sine 607122	

If 6 places of decimals in the logarithms be used, the latitude will be found to be 23° 7′ 53½″.

The latitude may be deduced from two altitudes and the elapsed time, by the common log. sines, tangents, and secants, independent of those of half elapsed time, middle time, and rising; and without having the latitude by account. And as a method for this purpose will be useful, when such tables only as those of Dr Hutton, Messrs J. de Mendoza Rios, Taylor, Gardner, Sherwin, &c. are at hand, the following, deduced from the simplest spherical principles, is therefore subjoined.*

Rule.

Reduce half the interval of time between the observations to degrees. Then, to the co-sine of the sun's declination, add the sine of the half elapsed time, the sum, rejecting radius, will be the sine of an arch, which doubled call *arch first.* Again, to the sine of the declination, add the tangent of the half elapsed time, the sum, rejecting radius, will be the co-tangent of *arch second,* the latitude and declination being of the same name; but if of a contrary denomination, the supplement will be arch second.

From half the sum of the least and greatest altitudes and arch first, subtract the greatest altitude, and arch first; then, to the secant of the greatest altitude, add the co-secant of arch first, the sine of the first remainder, and the co-sine of the second; half the sum of these four logarithms will be the co-sine of an arch, which doubled will be *arch third:* the difference between arches second and third will be *arch fourth.*

To the co-sine of arch fourth, add the co-tangent of the greatest altitude, the sum will be the tangent of *arch fifth;* the difference between which and the polar distance is *arch sixth;*

* In the Author's Treatise on the Longitude, a method is given of finding the latitude by two altitudes of the sun, the elapsed time, and latitude by account, by tables of log. sines and secants only.

Now, to the sine of the greatest altitude, add the secant of arch fifth, and the co-sine of arch sixth; the sum will be the sine of the latitude.

APPLICATION TO THE PRECEDING EXAMPLE.

The elapsed time is 2h. 36′, the half is 1h. 18′, which reduced to degrees is 19° 30′.

Sun's declin.	23°	28′		co-sine	9.9625076	sine	9.6001181
Half elap. time,	19	30		sine	9.5234953	tangent	9.5491487
	17	49	49	sine	9.4860029	Arch II. 81° 58′ 24″ co-tan.	9.1492668
Arch I.	35	39	38				
Least altitude,	17°	28′					
Greatest altitude,	52	18				secant	0.2135843
Arch I.	35	39	38			co-secant	0.2348448
Sum,	105	25	38				
Half,	52	42	49				
— Greatest alt.	0	24	49			sine	7.8584658
— Arch I.	17	3	11			co-sine	9.9804732
							18.2868681
	82	0	8			co-sine	9.1434340
Arch III.	164	0	16				
Arch II.	81	58	24				
Arch IV.	82	1	52	co-sine	9.1418741		
Greatest altitude,	52	18	0	co-tangent	9.8881165	sine	9.8982992
Arch V.	6	6	57	tangent	9.0299906	secant	0.0024788
Polar distance,	66	32	0				
Arch VI.	60	25	3			co-sine	9.6934423
Latitude,	23	7	54			sine	9.5942203

REMARKS.

I.

The preceding methods may be extended to observations taken in the afternoon of one day, and the morning of the next; or to a longer period.

II.

The latitude is very easily deduced, from observations of the times of the rising and setting of the sun the same day; or, from the time of setting, and that of rising next morning: For, the sum of the co-sine of half the interval of time between the observations, and the co-tangent of the declination, will be the tangent of the latitude.

In order to avoid the correction of the time of rising or setting, arising from the horizontal refraction, dip, &c. the time when the altitude of the sun's lower limb is equal to the sum of 15′ and the dip of the horizon, is to be taken as that of the rising or setting of that object: but, if the observation is made when the sun's centre is in the horizon, the correction of the time of rising or setting may be found by table B. in the second volume of the Longitude. When great accuracy is required, other corrections, depending on the change of declination, the difference of latitude, and longitude between the observations, are to be made.

Example.

Let the time per watch of sun-setting, May 30, 1805, be 8h. 8′ P. M. and that of sun-rising, May 31, 3h. 58′ A. M.: Required the latitude of the place of observation?

Time per watch of ☉ setting,	8h. 8′ P. M.					
Time per watch of ☉ rising,	3 58 A. M.					
Interval,	7 50					
Half,	3 55	=	58°	45′	co-sine	9.71498
Declination at midnight,			21	49	co-tangent	10.39760
Latitude,			52	21 N.	tangent,	10.11258

CHAP. II.

Of Finding the Longitude at Sea, by Lunar Observations.

It has already been observed, that the longitude of a place is, that arch of the equator which is contained between the first meridian, and the meridian of the given place; and is reckoned E. and W. until the opposite meridian—and, therefore, cannot exceed 180°. The first meridian, from which the subjects of the British dominions reckon the longitude, is that of the Royal Observatory at Greenwich, to which meridian the Nautical Almanac is adapted.

The observations necessary to determine the Longitude by Lunar Observations are, the distance between the sun and moon, or the moon and a fixed star near the ecliptic, together with the altitude of each. The stars used in the Nautical Almanac for this purpose are the following, namely, *α Arietis*, *Aldebaran*, *Pollux*, *Regulus*, *Spica Virginis*, *Antares*, *α Aquilæ*, *Fomalhaut*, and *α Pegasi*. The distances of the moon's centre from the sun, and from one or more of these stars, are contained in the VIII. IX. X. and XI. pages of the month, at the beginning of every third hour apparent time by the meridian of Greenwich. The distance between the moon and the sun, or one of these stars, is to be observed with a Sextant, or Circular Instrument; and the altitudes of the objects are to be taken as usual, with a Hadley's Quadrant. Since the methods of adjusting, and taking the observations with these instruments, are fully detailed in the Author's Treatise on the Longitude in two volumes, we shall, therefore, in this place, only point out the method of finding the apparent time from the altitude of the sun, and that of reducing the apparent to the true distance; referring those who wish farther information, to the above-mentioned work.

Problem I.

Given the observed Altitude and Declination of the Sun, and the Latitude of the Place, to find the Apparent Time, and Error of the Watch.

Rule.

Correct the observed altitude of the sun for the index error, if any, for semidiameter, dip, and refraction; reduce the declination to the meridian of the place of observation, and to the estimated time under that meridian.

From half the sum of the corrected altitude, the polar distance and latitude, subtract the altitude, and let this difference be called the remainder.

Set 90° on the line of sines on the slide, to the complement of the sun's declination; and opposite to the complement of the latitude on sines, is *arch first*.

Now, set arch first on the line of sines to the complement of half the sum, and opposite to the remainder on sines is *arch second;* then opposite to arch second on the third line of sines, is the supplement of the hour angle on versed sines; and the hour angle reduced to time, will give the sun's distance from the meridian in time; and hence, the apparent time and error of the watch will be known.

Remarks.

I.

If the interval between arch second and 90° on the line of sines, be bisected by a pair of compasses, it will give half the horary angle.

II.

The altitudes for ascertaining the apparent time are generally taken when the object is about two or three hours distant from the meridian; and, therefore, the hour angle is, for the most part, less than a quadrant. Now, the divisions on the line of versed sines below 90° are very small, but above 90° they increase rapidly; for these reasons, therefore, the rules are adapted to find the supplement of the hour angle, in preference to the hour angle itself.

Example.

October 9, 1804, in latitude 43° 30′ N. and longitude by account 158° 1′ W. in the afternoon, several altitudes of the sun's lower limb, and the corresponding times per watch, were observed: the mean of the altitudes was 22° 51′, and that of the times of observation 3h. 16′ 47″, and height of the eye 18 feet. Required the error of the watch?

Alt. sun's low. limb,	22° 51′	Sun's declin. at noon,	6° 18′ S.	
Semidiameter, -	+ 16	Equat. to - 3h. 17′	+ 3	
Dip and refraction,	— 6	Equat. to 158° 1′	+ 10	
Corrected altitude, -	23 1	Reduced declination, -	6 31 S.	

Now, the sum of the altitude, polar distance, and latitude, is 163° 2′; the half is 81° 31′; and the difference between the half sum and the altitude is 58° 30′, the remainder.

Set 90° on sines to 83° 29′ the complement of the sun's declination, and opposite to 46° 30′ the co-latitude on sines, is, about 46° 7′, arch first.

Again, set 46° 7′ arch first on sines, to 8° 30′ the complement of the half sum, and opposite to 58° 30′ the remainder on sines, is about 10° 3′, arch second. Then, opposite to 10° 3′ on the third line of sines, is about 130° 36′ on versed sines, the supplement of the hour angle; hence, the hour angle is 49° 24′, which reduced to time is 3h. 17′ 46″, the apparent time of observation; the difference between which and 3h. 16′ 47″ is 49″, the error of the watch, slow.

Or, the middle point between 10° 3′ and 90° is 24° 42′, which doubled is 49° 24′, the hour angle, as before.

Problem II.

Given the Apparent Distance between the Moon and the Sun, or a fixed Star, together with the Altitudes of each, and the Moon's Horizontal Parallax, to find the true Distance.

Rule.

Set 90° on the line of sines on the slide, to the complement of the moon's altitude, and opposite to the moon's horizontal parallax on the line of numbers on the slide, is the moon's parallax in altitude; the refraction in altitude being subtracted from the parallax, gives the correction of the moon's altitude.

Find half the sum and half the difference of the apparent altitudes of the moon and star. Now, draw out the slide, until the half sum on the line of tangents coincides with the half difference on the second line of tangents; then, opposite to the complement of half the distance on tangents on the slide, is *arch first*. If the complement of half the distance on the slide should be beyond 45°, then observe that division on the line of tangents on the slide, which is opposite to 45°; now, move in the slide, until the complement of half the distance be opposite to 45°, and opposite to the above-mentioned division on the line of tangents on the slide, is arch first, on the second line of tangents.

If the moon's altitude is less than that of the sun or star, the sum of arch first and half the apparent distance is *arch second*, and their difference *arch third;* but if the moon's altitude is greater than that of the sun or star, the difference is arch second, and sum arch third.

Then, set arch second on the line of tangents on the slide, to the moon's altitude on the adjacent line of tangents, and opposite to the correction of the moon's altitude on the line of numbers on the slide, is the *first correction.* In this case, one of the two first terms is supposed to be above 45°; but if both be below 45°, then bring 45° on tangents on the slide, to coincide with the least of the two terms on the adjacent line of tangents, and opposite to the greater on tangents on the slide, is an arch on the second line of tangents. Now, move the slide, until 45° coincides with this arch, and opposite to the correction of the moon's altitude on numbers on the slide, is the *first correction.*

Again, set 45° on the line of tangents on the slide, to arch third on the corresponding line of tangents, and opposite to 57″ on the line of numbers on the slide, is the *second correction.*

If arch first is less than half the apparent distance, the first correction must be subtracted from, and the second added to, the apparent distance. But if arch first is greater than half the apparent distance, both corrections are to be added, if the altitude of the moon is greater than that of the sun or star; but subtracted, if the moon's altitude is less than the altitude of the sun or star.

Find the sum and difference of the correction of the moon's altitude, and the first correction of distance: Now, set 687 to the sum in minutes, and opposite to the distance on the line of tangents on the slide, is an arch on the adjacent line of tangents; then, bring 45° on the line of tangents on the slide to this arch, and opposite to the difference in seconds, on the line of numbers on the slide, is the *third correction;* to be added, if the apparent distance is less than 90°, but to be subtracted, if greater than 90°.

If the object from which the moon's distance is observed be the sun, another correction, depending on the parallax of that object, is to be found; thus, set 90° on the line of sines on the slide to the sun's altitude, then opposite to the sun's horizontal parallax, which may be taken at 8″.7, is a certain number. Now, set 45° on the line of tangents on the slide to arch second, if less than 45°; but if greater, find it on the slide, and bring it to 45°; and opposite to the above number is the final correction of distance: which is to be added, if the second correction is subtractive—but subtracted, if the second correction is additive.

Example.

The apparent central distance between the sun and moon is

107° 44′ 12″, the apparent altitude of the sun 15° 50′, that of the moon 6° 30′, and horizontal parallax 54′ 30″. Required the true distance?

Set 90° on the line of sines on the slide, to 83° 30′ the moon's zenith distance; and opposite to 54′ 30″ the moon's horizontal parallax on the line of numbers on the slide, is 54′ 9″ the moon's parallax in altitude; from which the refraction 7′ 51″ being subtracted, the remainder 46′ 18″ is the correction of the moon's altitude.

Altitude of the sun, -	15°	50′			
Altitude of the moon, -	6	30			
Sum, - - - -	20	20	Half, -	11°	10′
Difference, - - -	9	20	Half. -	4	40
Apparent distance, -	107	44	Half, -	53	52
And complement, - - - - - - - -				36	8

Now, set the half sum 11° 10′ on the line of tangents on the slide, to the half difference 4° 40′ on the adjacent line of tangents, and opposite to the complement of half the distance 36° 8′ on the line of tangents on the slide, is 16° 48′, arch first. Then, since the moon's altitude is less than that of the sun, the sum of arch first and half the apparent distance viz. 70° 40′, is arch second; and their difference 37° 4′, is arch third.

Set arch second 70° 40′ on the line of tangents on the slide, to the moon's altitude 6° 30′ on the adjacent line, and opposite to the correction of the moon's altitude 46′ 18″ on the line of numbers on the slide, is the first correction 15′ 2″ on the line above.

Again, set 45° on the line of tangents on the slide, to arch third 37° 4′ on the adjacent line; and opposite to 57″ on the line of numbers on the slide, is the second correction 43″ on the second line of numbers.

Arch first being less than half the apparent distance, the first correction is to be subtracted from, and the second added to, the apparent distance.

The sum of the correction of the moon's altitude and the first correction of distance is 61′ 20″, and the difference 31′ 16″ = 1876″. Now, set 687 on the line of numbers on the slide to 61′ 20″, and opposite to 72° 16′ the supplement of the distance on the line of tangents on the slide, is about 16° on the adjacent line; then, set 45° on tangents on the slide to 16°, and opposite to the difference 1876″ on numbers on the slide, is the third correction 5″ on the corresponding line, which is subtractive, the distance being greater than 90°.

Again, set 90° on the line of sines on the slide, to the sun's altitude 15° 50′, and opposite to the sun's horizontal parallax 8″.7, is about 2″.37. Now, set 45° on the line of tangents on the slide, to arch third 37° 4′ on the second line of tangents, and opposite to 2″.37 on the line of numbers on the slide is 1″.8, which may be called 2″, the fourth correction—subtractive, because the second correction is additive.

Apparent distance, - - -		107°	44′	12″
First correction, - - -	−		15	2
Second correction, - - -	+		0	43
Third correction, - - -	−		0	5
Fourth correction, - - -	−		0	2
True distance, - - - - -		107	29	46

Problem III.

Given the Latitude of a Place, and its Longitude by Account, together with the Distance between, and the Altitudes of the Moon and the Sun, or one of the Stars in the Nautical Almanac; to find the correct Longitude of the Place of Observation.

Rule.

Reduce the estimate time to the meridian of Greenwich, by adding thereto the longitude by account in time, if west—but subtracting, if east: to this time take, from the Nautical Almanac, page vii. of the month, the moon's horizontal parallax and semidiameter: increase the semidiameter, by the augmentation answering to the moon's altitude.*

Find the apparent and true altitudes of each object's centre, and the apparent central distance, with which, let the true distance be found by the preceding problem; and find the apparent time at Greenwich answering to this distance.

* The augmentation is contained in Table XXXI. Vol. II. of the Longitude. It may be found nearly by the Sliding Gunter, as follows:—Set 90° on sines on the slide to the moon's altitude, and opposite to 16″ on the line of numbers on the slide, is the augmentation.

If the sun or star be at a proper distance from the meridian when the distance was observed, compute the apparent time at the ship from the altitude of that object. If not, the error of the watch may be found from observations of the altitudes of the sun or stars, taken either before or after that of the distance.

The difference between the apparent times of observation at the ship and Greenwich, will be the longitude of the ship in time, which is east or west, according as the time at the ship is later or earlier than that at Greenwich.

Examples.

I.

♃ November 8, 1804, in latitude 34° 53′ N. and longitude 24° W. by account, about 3h. 50′ P. M. the observed distance between the nearest limbs of the sun and moon was 67° 48′ 29″; the observed altitude of the moon's lower limb was 31° 11′, and that of the sun's 14° 46′; height of the eye 12 feet. Required the true longitude?

Time at ship, 3h. 50′ P. M.	Obser. dist. ☉ & ☽'s n. l.		67° 48′ 29″	
Lon. in time, 1 36 W.	Sun's semidiameter, -	+	16 13	
	Moon's semidiameter,	+	15 1	
Reduc. time, 5 26 P. M.	Augmentation, - -	+	0 7	
	Appar. central dist. -		68 19 50	

Ob. alt. ☽'s l. limb,		31° 11′	Ob. alt. ☉'s l. limb, -		14° 46′	
Semidiameter, -	+	15	Semidiameter, -	+	16	
Dip, - - - - -	—	3	Dip, - - - - -	—	3	
App. alt. ☽'s centre,		31 23	App. alt. ☉'s centre,		14 59	
App. alt. ☉'s centre,		14 59	Moon's horiz. parallax,		0 55 6″	

Sum, - - - - -	46 22	Half, -	23° 11′
Difference, - - -	16 24	Half, -	8 12
Apparent distance,	68 20	Half, -	34 10

Set 90° on the line of sines on the slide, to 58° 37′ the complement of the moon's altitude, and opposite to 55′ 6″ the moon's horizontal parallax on numbers on the slide is 47′ 2″ the parallax in altitude; from which subtract the refraction 1′ 33″ and the remainder 45′ 29″, is the correction of the moon's altitude.

Set 23° 11′, half the sum of the apparent altitudes on tangents on the slide, to 8° 12′ the half difference; and since half the distance is less than 45°, observe, therefore, the point opposite to 45°, which is 18° 36′; then, bring half the distance 34° 10′ to 18° 36′, and opposite to 45° on tangents on the slide is 26° 22′, arch first.

Now, since the moon's altitude is greater than that of the sun, the difference of half the distance and arch first, viz. 7° 48′, is arch second, and their sum 60° 32′, is arch third.

Now, since both arch second and the moon's altitude are less than 45°, therefore, bring 45° on the slide to arch second on the second line of tangents, and opposite to 31° 23′ the moon's altitude, is about 4° 46′; now, bring 45° on the slide to 4° 46′, and opposite to 45′ 29″, the correction of the moon's altitude, on the line of numbers on the slide, is 3′.8 = 3′ 48″, the first correction.

Again, because arch third is greater than 45°, move the slide, until that arch on the line of tangents coincides with 45°, and opposite to 57″ on the line of numbers on the slide is 101″, the second correction.

Now, arch first being less than half the apparent distance, the first correction is to be subtracted from, and the second added to, the apparent distance.

The sum of the correction of the moon's altitude and the first correction is 49′ 17″, and the difference is 41′ 41″ = 2501″; now, set 687 on numbers on the slide to 49′ 17″, and opposite to the distance 68° 20′ on the line of tangents on the slide, is about 15¾°: then, bring 45° on tangents on the slide to coincide with 15¾°, and opposite to the difference 2501″ on numbers on the slide, is the third correction 7″ on the first line of numbers—additive, because the distance is less than 90°.

Set 90° on the line of sines on the slide, to 75° 1′ the complement of the sun's altitude, and opposite to 8″.7 on numbers on the slide, is a number 2″.25. Now, because arch third is greater than 45°, find it on the line of tangents on the slide, and bring it to 45°: then, opposite to 2″.25 on numbers on the slide is 4″, the fourth correction—which is subtractive, because the second correction is additive.

Apparent distance,	-	68°	19′	50″				
First correction,	-	—	3	48				
Second correction,	-	+	1	41				
Third correction,	-	+	0	7				
Fourth correction,	-	—	0	4				
True distance,	- -	68	17	46				
Distance at III. hours,		67	9	17	Difference, -	1°	8′	29″
Distance at VI. hours,		68	32	30	Difference, -	1	23	13

Hence, the proportional part is 2h. 28′ 8″; and consequently, the apparent time at Greenwich is 5h. 28′ 8″.

App. alt. of the ☉,	14°	59′	☉'s decl. Nov. 8, at noon,		16° 37′ S.
Correction, -	—	3	Equat. to, 5h. 28′ -	+	4
True altitude, -	14	56	Reduced declination, -		16 41 S.
Polar distance, -	106	41			
Latitude, - -	34	53			
Sum, - - -	156	30			
Half, - - -	78	15			
Remainder, - -	63	19			

Set 90° on sines on the slide, to 73° 19′ the complement of the sun's declination, and opposite to 55° 7′ the co-latitude on sines, is about 51° 48′, arch first. Again, set arch first 51° 48′ on sines on the slide, to 11° 45′ the complement of the half sum, and opposite to the remainder 63° 19′ on sines on the slide, is 13° 23′; opposite to which, on the third line of sines, is 122° 28′ on versed sines, the supplement of the hour angle: which in degrees is, therefore, 57° 32′, or in time 3h. 50′ 48″, the apparent time at the ship.

Apparent time at Greenwich,	5h.	28′	8″	
Apparent time at ship, - -	3	50	48	
Longitude in time, - - - -	1	37	20	= 24° 20′ W.

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The following examples are inserted, as exercises to this method, from the First Volume of the Theory and Practice of finding the Longitude at Sea or Land.

II.

♀ December 21, 1804, in latitude 42° 24′ S. and longitude 149° 18′ W. by account, about 8h. 20′ A. M. a set of observations of the distance between, and altitudes of the sun and moon was observed; the mean of the distances of the nearest limbs of the sun and moon was 114° 52′ 56″, that of the moon's upper limb 16° 37′, and of the sun's lower limb 40° 33′; height of the eye 17 feet. Required the true longitude?

Answer.—149° 45′ W.

III.

☿ October 10, 1804, in latitude 15° 15′ N. and longitude by account 68° E. the mean of a set of observations of the moon's remote limb from Fomalhaut was 60° 37′ 35″, the mean of the altitudes of the moon's upper limb 46° 30′, and that of Fomalhaut 21° 24′; the mean of the times per watch 6h. 4′ 54″, P. M.; height of the eye 14 feet. Required the ship's true longitude?

Answer.—68° 2′ E.

IV.

♀ September 14, 1804, in latitude 17° 40′ S. and longitude 85° E. by account, intending to find the ship's true longitude by an observation of the distance between the moon and a fixed star: In order, therefore, to ascertain the apparent time, and consequently the error of the watch, several altitudes of the sun's lower limb was observed, together with the corresponding times per watch; the mean of the altitudes was 26° 13′, and that of the times per watch 4h. 2′ 15″, P. M.; and height of the eye 18 feet.

Again, having observed several distances between the moon's enlightened limb and Antares, with the corresponding altitudes of each, the mean of the times per watch was 10h. 1′ 24″, P. M. that of the distances 42° 5′ 50″; the mean of the altitudes of the moon's lower limb was 61° 41′, and that of Antares 19° 54′. Required the true longitude of the ship?

Answer.—84° 17′ E. the longitude of the ship, at the time the observations were taken to find the error of the watch.

Those who wish more information on this subject, are referred to the Author's Treatise on the Longitude, in two volumes.

CHAP. III.

Variation of the Compass.

The Variation of the Compass is, the deviation of the points of the mariner's compass, from the corresponding points of the horizon; and is denominated *East* or *West* Variation, according as the north point of the compass is to the east or west of the true north point of the horizon.

The variation of the compass may be found by various methods, as *Amplitudes*, *Azimuths*, *Equal Altitudes*, &c.

The True Amplitude of any celestial object is, an arch of the horizon contained between the north or south points thereof, and the centre of the object at the time of its rising or setting.

The Magnetic Amplitude is, the arch contained between the centre of the object, when in the horizon, and the magnetic meridian: or, in other words, it is the bearing of the object per compass when in the horizon.

The True Azimuth of any object is, the angle contained between the true meridian, and the vertical passing through the centre of the object.

The Magnetic Azimuth is, the angle contained between the magnetic meridian, and the azimuth circle passing through the centre of the object.

The true amplitude or azimuth may be found by the Sliding Gunter; and the magnetic amplitude or azimuth is found by observation.

Problem I.

Given the Latitude of a Place, the Declination and observed Amplitude of the Sun, to find the Variation of the Compass.

Rule.

Set the complement of the latitude on the line of sines on the slide, to 90° on the corresponding line of sines; and opposite to the declination on the line of sines on the slide, is the complement of the true amplitude on the first line of sines—which is to be reckoned from the north when the declination is north, but from the south when the declination is south; towards the east when the observation is made at the time of sun rising, but towards the west if at sun setting.

The difference between the true and observed amplitudes is the variation.

Now, let the observer be supposed to look directly towards the point representing the true amplitude; then, if the observed amplitude is to the left of the true amplitude, the variation is easterly; but if to right, it is westerly.

Examples.

I.

Let the latitude be 48° 50′ N. the sun's declination 16° 20′ N. and the observed amplitude N. 88° 50′ W. Required the variation?

Set the complement of the latitude 41° 10′ on the second line of sines, to 90° on the first line of sines; then, opposite to the declination 16° 20′ on the second line of sines, is the complement of the amplitude 25° 18′ on the first line of sines. Hence, the

True amplitude is,	-	N. 64° 42′ W.
Observed amplitude,	-	N. 88 50 W.
Variation,	- -	24 8

Which is east, because the observed amplitude is to the left of the true amplitude.

II.

May 15, 1800, in latitude 33° 10′ N. and longitude 18° W. about 5 hours A. M. the sun was observed to rise E. by N. Required the variation?

Sun's declination, May 15, at noon,	-	18° 53′ N.
Equation to 7 hours from noon,*	-	— 4
Equation to 18° W.	- - -	+ 1
Reduced declination,	- - -	18 50

* For the method of finding these equations, see page 82.

Now, set the complement of the latitude 56° 50′ on the second line of sines, to 90° on the first line; and opposite to the declination 18° 50′ on the second line of sines, is the complement of the true amplitude 22° 41′ on the first line of sines: Hence, the true amplitude is N. 67° 19′ E.

True amplitude, - - -	N.	67°	19′ E.
Observed amplitude, E. by N. or	N.	78	45 E.
Variation, - - - - -		11	26

Which is west, because the observed amplitude is to the right of the true amplitude.

Problem II.

Given the Latitude of a Place, the Declination, Altitude, and observed Azimuth of the Sun, to find the Variation.

Rule.

Find the sum of the sun's polar distance, the altitude and latitude of the ship; and take the difference between half this sum and the polar distance.

Now, set 90° on the second line of sines, to the co-latitude on the corresponding line of sines; and opposite to the co-altitude on the second line of sines, is a certain number of degrees on the first line of sines, which call *arch first.*

Then, set arch first on the second line of sines, to the difference between the half sum and the polar distance on the first line of sines; and opposite to the complement of the half sum on the second line of sines, is *arch second* on the first line of sines.

Now, find arch second on the third line of sines, or that which is adjacent to the line of versed sines, and opposite thereto on the versed sines, is the true azimuth; to be reckoned from the north, if the latitude is north—but from the south, if the latitude is south.

The difference between the true and observed azimuths, reckoned from the same point, is the variation as before.

Example.

Let the latitude be 38° 34′ S. the sun's declination 7° 16′ N, altitude 14° 10′, and magnetic azimuth N. 77° 50′ W. Required the variation?

The half sum of the sun's polar distance, altitude, and latitude of the place is 75°, and the difference between the half sum and polar distance is 22° 16′.

Now, set 90° on the second line of sines, to the co-latitude 51° 26′ on the first line of sines; and opposite to the co-altitude 75° 50′ on the second line of sines, is arch first 49° 18′.

Then, set arch first 49° 18′ on the second line of sines, to 67° 44′, the complement of the difference between the half sum and polar distance, on the first line of sines; and opposite to 15° the complement of the half sum on the second line of sines, is arch second 18° 25′ on the first line of sines.

Now, opposite to arch second 18° 25′ on the line of sines adjacent to the versed sines, is the true azimuth 111° 36′ on the versed sines, which is to be reckoned from the south, because the latitude is south: hence, the true azimuth from the north is 68° 24′; the difference between which, and the magnetic azimuth 77° 50′, is 9° 26′, the variation—which is east, because the observed azimuth is to the left of the true azimuth.

Problem III.

To find the Variation of the Compass by Equal Altitudes of the Sun.

Rule.

Let the sun's altitude be observed in the eastern hemisphere, when its meridian distance exceeds two hours, and at the same instant let another observer take the azimuth. Then, when the sun comes to the same altitude in the afternoon, let the bearing of its centre be again observed. Now, half the difference between the eastern and western azimuths will be the variation—which, when the observations are made in the southern hemisphere, will be east, or west, according as the eastern or western azimuth is greatest.—The contrary rule is to be applied, when the azimuths are observed in the northern semicircle.

Remark.

The western azimuth will be affected by the change of declination in the interval between the observations. This correction may be found thus;

To the log. co-sine of the latitude, add the log. sine of the horary angle, and the log. of the change of declination in the elapsed time; the sum will be the log. of the correction of azimuth, which is additive to the western azimuth, when the object is approaching towards the elevated pole, but subtractive, if receding therefrom.

Examples.

I.

In the forenoon, the bearing of the sun's centre per compass was S. S. E. $\frac{3}{4}$ E. the altitude of its lower limb, being 40° 18′, and in the afternoon, when the sun had attained the same altitude, the azimuth was S. W. by W. $\frac{1}{4}$ W. Required the variation?

Eastern azimuth,	= S. S. E. $\frac{3}{4}$ E.	=	S. 2 $\frac{3}{4}$ E.
Western azimuth,	= S. W. by W. $\frac{1}{4}$ W.	=	S. 5 $\frac{1}{4}$ W.
Difference,	- - - - -		2 $\frac{1}{2}$
Variation,	- - - - -		1 $\frac{1}{4}$ points,

which is *West*, both observations being reckoned from the south, and the western azimuth the greater.

II.

In the forenoon, the sun's azimuth was N. 51° 28′ E. and in the afternoon, when the sun had come to the same altitude, the azimuth was N. 67° 18′ W. Required the variation?

Eastern azimuth, - -	N. 51° 28′ E.	
Western azimuth, - -	N. 67 18 W.	
Difference, - - -	15 50	
Variation, - - -	7 55,	*East*, the ob-

servations being reckoned from the north, and the western azimuth the greater.

Problem IV.

Given the true Course between any two Places, and the Variation of the Compass, to find the Course per Compass.

Rule.

If the variation is westerly, allow it to the right hand of the true course, but if easterly, to the left; and hence, the course per compass will be obtained.

Example.

Required the course per compass from the Lizard to St Mary's the true course being S. W. ¼ W. and the variation at the Lizard 2½ points west?

Two and a half points being allowed to the right hand of S. W. ¼ W. gives W. S. W. ¾ W. the course per compass, which the ship must steer from the Lizard for St Mary's; and this course must be altered according as the variation alters.

Problem V.

Given the Course per Compass, and the Variation, to find the true Course.

Rule.

The variation, if westerly, being allowed to the left of the course steered, or to the right if easterly, will give the true course.

Example.

Let the course steered be S. E. ½ E. and the variation a point and a half west. Required the true course?

One point and a half being allowed to the left of S. E. ½ E. gives E. S. E. the true course.

BOOK IV.

CONTAINING THE METHOD OF KEEPING A JOURNAL AT SEA, &c.

CHAP. I.

Of a Ship's Journal.

A JOURNAL is a regular and exact register of all the various transactions which happen on board of a ship, whether at sea or in a harbour; and more particularly, those which concern a ship's way, from whence her place at noon, or at any other time, may be truly ascertained.

The accouut of a ship's way, &c. kept at sea, is called *Sea Work;* and the remarks taken down while the ship is in port, are called *Harbour Work.*

The computations made to determine the place of a ship, from the courses and distances run in 24 hours, or from any noon to the following noon, are called a *Day's Work;* and the latitude and longitude of a ship deduced from them, are called the Latitude and Longitude in by *Account*, or by *Dead Reckoning*, in order to distinguish them from the latitude and longitude as inferred from observation.

At sea, the day begins at noon, and ends at the noon of the following day. The first 12 hours, or those contained between noon and midnight, are denoted by P. M. signifying *after mid-day;* and the other 12 hours, or those from midnight to noon, are denoted by A. M. signifying *before mid-day.* A day's work, marked Monday, December 25, began on Sunday at noon, and ended on Monday at noon.

The days of the week are usually represented by the astronomical planetary characters: thus, ☉ represents Sunday; ☾, Monday; ♂, Tuesday; ☿, Wednesday; ♃, Thursday; ♀, Friday; and ♄ Saturday.

When a ship is bound to a port which is so situated, that in her run to it she will be out of sight of land, the bearing and distance of the port must be previously found: this may be done by Problem I. of Middle Latitude or Mercator's sailing; the most expeditious method, however, is by a chart. But, because these methods give the true bearing, and not that by the compass the variation of the compass must, therefore, be applied thereto, by allowing it to the right hand if westerly, or to the left hand if easterly. If islands, capes, or headlands intervene, it will be necessary to find the several courses and distances between each successively.

At the time of leaving the land, the bearing of some known place is to be observed, and its distance is usually found by estimation. As perhaps the distance found in this manner will be liable to some error, particularly in hazy or foggy weather, or when that distance is considerable, it will, therefore, be proper to use the following method for this purpose: Let the bearing be observed, of the place from which the departure is to be taken; then, the ship having run a certain distance on a direct course, the bearing of the same place is again to be observed: now, subtract the sum of the angles contained between the ship's course and the two bearings, from 16 points; then, set the distance run between the time of taking the two bearings on the line of numbers, to the above difference on sine rhumbs, and opposite to the number of points between the first bearing and the ship's course on sine rhumbs, will be the distance of the ship from the place, at the time of taking the second bearing. In like manner, may the departure be taken from a Light-house at night.

The several courses and distances sailed during the interval of 24 hours, or from noon to noon, and whatever remarks are thought worthy of notice, are set down with chalk on a board painted black, called the *Log-board*. This board is usually divided into six columns: the first column, on the left hand, contains the hours from noon to noon; the second and third the knots, and parts of a knot, sailed every hour, or every two hours, according as the log is marked *; the fourth column contains the courses steered; the fifth the winds; and in the sixth, the various remarks are written, such as the state of the weather, the sail set or taken in, the observations for ascertaining the ship's place, and variation of the compass, and whatever else may be thought necessary. Another column is sometimes

* In the Royal Navy, and in ships in the service of the East India Company, the log is hove every hour; but in most other trading vessels, only once every two hours.

added, containing the leeway. It is, however, most common, and certainly the most accurate method, for the officer of the watch to correct the courses for leeway, before he puts them down in the log-board. The log-board is transcribed every day at noon into the Log-Book, which is ruled and divided after the same manner.

The courses steered must be corrected by the variation of the compass and leeway. If the variation is west, it is to be allowed to the left hand of the course steered; but if east, to the right hand, in order to obtain the true course. The leeway is to be allowed to the right or left of the course steered, according as the ship is on the larboard or starboard tack. The method of finding the variation, which should be determined daily, if possible, is given in the preceding chapter; or, it may be found from a variation chart. The leeway may be understood from what follows:

When a ship is close-hauled, and the wind blowing fresh, that part of the wind which acts upon the hull and rigging, together with a considerable part of the force which is exerted on the sails, tend to drive her to the leeward. But since the bow of a ship exposes less surface to the water than the side, the resistance will be less in the first case than in the second; the velocity, therefore, in the direction of her head will, in most cases, be greater than the velocity in the direction of her side, and the ship's real course will be between the two directions. The angle contained between the line of the ship's apparent course, and the line she really describes through the water, is called the *Angle of Leeway*, or simply the *Leeway*.

A very easy and accurate method of determining the quantity of the leeway is, to have a semicircle described on the taffrail, with its diameter at right angles to the ship's keel, and its circumference divided into points and quarters, and having a low crutch or swivel in its centre. Then, after heaving the log, the line is to be slipped into the crutch just before it is drawn in, and the points, and parts of a point, contained between the direction of the log-line and the fore and aft line of the semicircle, will be the leeway. The leeway may also be found, by observing the direction of the ship's wake on the semicircle.

Many writers on navigation have given rules for ascertaining the quantity of leeway, independent of observation. These are as follow:

1. When a ship is close-hauled, has all her sails set, the water smooth, with a light breeze of wind, she is then supposed to make little or no leeway.

2. Allow one point when the top-gallant sails are handed.
3. ——— two points when under close-reefed topsails.
4. ——— two points and a half when one topsail is handed.
5. ——— three points and a half when both topsails are handed.
6. ——— four points when the fore-course is handed.
7. ——— five points when under the mainsail only.
8. ——— six points when under the balanced mizen.
9. ——— seven points when under bare poles.

As these rules depend entirely on the quantity of sail set, without having any regard to the form of the ship, or nature of the cargo she may have on board, it is hence evident, they are nothing more than probable conjectures; they may, however, be of some service when, through negligence or otherwise, the quantity of the leeway has not been inferred from observation.

In hard blowing weather, with a contrary wind and a high sea, it is impossible to gain any advantage by sailing: in such cases, therefore, the object is to avoid, as much as possible, being driven back. With this intention it is usual to ly-to, under no more sail than is sufficient to prevent the violent rolling which the vessel would otherwise acquire, to the endangering of her masts and rigging.* When a ship is brought-to, the

* The following observations are extracted from Mr Gower's Treatise on Seamanship, page 42.

If a ship is to be brought-to, in a part where other vessels may be expected to be sailing in a contrary direction, the best sails to ly-to under are, a reefed fore-topsail, mizen staysail, and storm-mizen, with the helm so much a lee, as is found best to answer the purpose. The reason for not putting the helm hard a-lee, which is the usual custom, is this, that when the helm is hard a-lee she will come up in the wind, and shake the sails, causing her to get stern-way, and fall round off. On the contrary were the helm never put so far over as to oblige the ship to come up in the wind, she would come-to, and fall off, much less; a ship thus brought-to will be in readiness for veering in case of necessity. Where there is good sea-room, a reefed mainsail, storm-mizen, and mizen staysail, are excellent sails to ly-to under, as a ship will keep to the wind under these sails without much of the lee-helm, and for that reason, be very little subject to fall off, or come-to, in any considerable quantity.

If the sea be extremely high, and the ship very stiff and labouring, she will ly-to better under a main, and even a mizen topsail, which will prevent her rolling so rapidly by their lofty situation; and as these sails are much above the sea, they are not likely to be becalmed by the waves.

tiller is put over to the leeward, which brings her head round to the wind. The wind then having very little power on the sails, the ship loses her way through the water, which ceasing to act upon the rudder, her head falls off from the wind, the sail which she has set fills, and gives her fresh way through the water, which, acting on the rudder, brings her head again to the wind. Thus, the ship has a kind of vibratory motion, coming up to the wind and falling off from it again alternately.

Ships ly-to under different sails, according to circumstances; and one vessel will ly-to better under some particular sail than another. In general, a main topsail close-reefed is, perhaps, the best sail to ly-to under; because, being near the point *velique*, and also in consequence of its height, it is not so easily becalmed by a high sea as any lower sail would be. It may, however, be observed, that a ship that lies-to with a head sail is for the most part a good sailer, and easily under command. For, in case of accident, by clapping the helm a-weather when she sails off, she is easily got before the wind. The last resource in lying-to, under any canvas, is perhaps a balanced mizen; under this sail she will come up, and fall off, the greatest possible.

In lying-to under a main topsail and mizen staysail, a ship generally comes up within 5 points of the wind, and falls off to 7 points. But under storm staysails, a vessel will come up to $3\frac{1}{2}$ points, and fall off to $8\frac{1}{2}$ points, from the wind.

The middle point, between those upon which a ship comes up and falls off, is to be taken for her apparent course, and the leeway and variation are to be allowed from that point, to find the true course.

The setting and drift of currents, and the heave of the sea,

If a ship is to be brought-to in those latitudes, where a sudden shift of the wind is expected, the course staysails are the best sails to ly-to under, as then a vessel is in readiness for either tack, let the wind come as it may; and should one of these staysails be blown away, it will very little affect the ship.

REMARK.

The topsails are certainly superior to the courses for lying-to under, as they can be readily braced about, and are much easier to take in. If topsails be used for this purpose, it will be found convenient to have a fourth reef, of such a depth as to admit the sail to be a taught leach, with the yard a foot or two off the cap; and as this part of the sail is intended for more boisterous weather than the rest, it must be made of stouter canvas.

are to be marked down. These are to be corrected by varia tion only.

The computation made from the several courses, corrected as above, and their corresponding distances, is called a *day's work;* and the ship's place as deduced therefrom, is called her place by *account*, or *dead reckoning*.

It is almost constantly found, that the latitude by account does not agree with that inferred from observation. From an attentive consideration of the nature and form of the common log, that its place is alterable by the weight of the line, by currents, by the motion of the surface of the water, occasioned by the wind, and other causes; to the difficulty attending the heaving it in a gale of wind and a high sea; to the little attention which is sometimes paid in heaving it, particularly during the night; to sudden squalls during the interval between the times of heaving the log, &c.: Also, from the errors to which the course is liable by a bad compass, which in an irregular hollow sea will not stand; * from the very often wrong position of the compass in the binnacle; bad steerage, especially in the night; the variation not being well ascertained,† &c.—an exact agreement of the latitude by dead reckoning with that by observation, cannot be expected.

If, therefore, the latitudes by account and observation disagree, several writers on navigation have proposed to apply a conjectural correction to the departure, or difference of longitude, as deduced from the dead reckoning. Thus, if the course be near the meridian, the error is wholly attributed to the distance; and the departure is to be increased or diminished accordingly: if it is near the parallel, the course only is supposed to be erroneous; and if the course is towards the middle of the quadrant, both course and distance are assumed to be wrong. This last correction, being computed and applied according to the methods given by different authors, will place the ship upon opposite sides of her meridian by account. As these corrections

* In this case, Mr M'Culloch's Steering Compass will be found of the utmost service. See his Report, p. 14.

† One very principal cause of error, and which, it is presumed, has not hitherto been sufficiently attended to is, that of allowing the same variation upon the day's work as had been found at noon, by observation or otherwise; whereas, it ought to be the mean between the variations at the noons of the given and preceding days, that ought to be allowed; or the mean of the variations observed in the afternoon and following morning, ought to be employed in correcting the courses in that day's work

are, therefore, nothing else than a kind of guess work, they should be absolutely rejected.

If these latitudes are not found to agree, the navigator ought to examine his log-line and half-minute glass, and correct the distance accordingly: and if this is not found to produce an agreement of the latitude by account with that by observation, he is then to consider if the variation and leeway have been properly ascertained; if not, the courses are to be again corrected, and no other alteration whatever is to be made on them. He is next to observe, if the ship's place has been affected by a current or heave of the sea, and then to allow for them, according to the best of his judgment. By applying these corrections, the latitudes will generally be found to agree tolerably well; and the longitude is not to receive any farther alteration.

It will, however, be proper for the navigator to determine the longitude of the ship from observation, as often as possible; and the reckoning is to be carried forward, in the same manner as that of the latitude, from the last good observation: yet it will, perhaps, be very satisfactory to keep a separate account of the longitude by dead reckoning.

CHAP. II.

General Rules for Working a Day's Work, by the Sliding Gunter.

Correct the several courses for variation, and leeway, if any, and place them and the corresponding distances in a table prepared for that purpose.

To find the Difference of Latitude and Departure made good.

Find the first distance on the line of numbers on the slide, and place it opposite to 8 points on the line of sine rhumbs; then, opposite to the course on sine rhumbs, is the departure on the line of numbers on the slide, and opposite to the complement of the course on sine rhumbs, is the difference of latitude on the line of numbers. In like manner, proceed with each of the other courses and distances separately. Now, the difference between the sums of the N. and S. columns will be the difference of latitude made good; and the difference between the sums of the E. and W. columns will be the departure made good.

To find the Course and Distance made good.

Of the difference of latitude and departure made good, find the least on the line of numbers on the slide, and set it opposite to the greater on the first line of numbers; then, on the other side of the rule, opposite 45° on the second line of tangents, is the course on the first line of tangents, which is less than 45°, if the departure is less than the difference of latitude—otherwise, it is greater. Now, find the course on the second line of sines, and put it to 90° on the first line; and opposite to the departure on the second line of numbers, is the distance on the first line of numbers: or, set the complement of the course on the second line of sines, to 90° on the first line; and opposite to the difference of latitude on the second line of numbers, is the distance on the first line of numbers.

To find the Latitude in by Dead-Reckoning.

The difference of latitude being added to, or subtracted from, the latitude from which the departure was taken, or from the yesterday's latitude, according as they are of the same, or of a contrary name, will give the ship's latitude at noon by account, or dead reckoning.

To find the Difference of Longitude.

I.

BY MIDDLE LATITUDE SAILING.

Set the complement of the middle latitude on the second line of sines, to 90° on the first line of sines; then, opposite to the departure on the second line of numbers, is the difference of longitude on the first line of numbers.

II.

BY MERCATOR'S SAILING.

Set the difference of latitude on the second line of numbers, to the meridional difference of latitude on the first line, and opposite to the departure on the second line of numbers, is the difference of longitude on the first line of numbers.

To find the Longitude in by Account.

The longitude in, is found by adding the difference of longitude to the yesterday's longitude, if they are of the same name, but subtracting the less from the greater, if they are of contrary names. It will be of the same name as the greater.

To find the Bearing and Distance of any Place from the Ship.

I.

BY MIDDLE LATITUDE SAILING.

Put the complement of the middle latitude on the second line of sines, to 90° on the first line; and opposite to the difference of longitude on the first line of numbers, is the departure on the second line of numbers.

Now, of the difference of latitude and departure, set the least on the second line of numbers, to the greatest on the first line of numbers; and opposite to 45° is the course or bearing, on the lines of tangents.

Then, draw out the slide, until the course on the second line of sines is opposite to 90° on the first line, and opposite to the departure on the second line of numbers, is the distance on the first line of numbers.

Or, place the complement of the course on the second line of sines to 90° on the first, and opposite to the difference of latitude on the second line of numbers, is the distance on the first line of numbers.

It will be proper to use the first of these methods when the course is greater than 45°, and the second when it is less.

II.

BY MERCATOR'S SAILING.

Place the meridional difference of latitude opposite to the difference of longitude on the lines of numbers, and opposite to 45°, is the course or bearing on the lines of tangents.

Place the complement of the course to 90° on the lines of sines, and opposite to the difference of latitude, is the distance on the lines of numbers.

The true course or bearing of the intended port, or any other place being given, the course per compass is found by allowing the variation to the right, if westerly—but to the left hand, if easterly.

BY INSPECTION.

To find the Difference of Latitude and Departure made good.

In a table, similar to those used in traverse sailing, place the several corrected courses, and their corresponding distances: find the difference of latitude and departure answering to each course and distance, and place them in their respective columns; then, the difference between the sums of the N. and S. columns will be the difference of latitude made good; and that between the sums of the E. and W. columns, will be the departure made good.

To find the Course and Distance made good.

Of the difference of latitude and departure find, in the traverse table, the greater in the column next the distance, and the least in the adjacent right hand column; where these are found to agree nearest, the corresponding distance will be found in its proper column, and the course at the top or bottom of the page, according as the departure is less or greater than the difference of latitude.

To find the Latitude in by Account.

This is found as directed in page 119.

To find the Difference of Longitude.

BY MIDDLE LATITUDE SAILING.

Find the middle latitude at the top or bottom of the traverse table, according as it is less or more than 45°, and the distance answering to the departure found in a latitude column, will be the difference of longitude.

BY MERCATOR'S SAILING.

The departure answering to the course made good, and the meridional difference of latitude in a latitude column, is the difference of longitude.

To find the Longitude in by Account.

This is performed as directed in page 120.

To find the Bearing and Distance of any Place from the Ship.

BY MIDDLE LATITUDE SAILING.

Find the middle latitude, between the ship and the proposed place, at the top or bottom of the traverse table, according as it is less or greater than 45°; then, the difference of latitude, answering to the difference of longitude in a distance column, will be the departure—with which, and the difference of latitude, the course and distance are to be found as before.

BY MERCATOR'S SAILING.

The course answering to the meridional difference of latitude found in a latitude column, and the difference of longitude in a departure column, will be the bearing of the proposed place; and the distance answering to the difference of latitude, will be the distance of the ship from the proposed place. If these numbers exceed the limits of the table, aliquot parts of each are to be taken; and the distance is to be multiplied by the number by which the difference of latitude is divided.

In the following Journal, the log is supposed to be hove at the end of every two hours, as is the practice in most trading vessels, except those in the service of the East India Company; and although it is not customary to introduce a column for leeway in real Journals, as the officer of the watch puts down the course corrected by leeway, it is, however, inserted here, for the benefit of the young practitioner.

In those books on navigation, which have Journals from England to Funchal, the bearing and distance of Funchal from the ship is found. But because Funchal lies upon the opposite side of the island of Madeira, with respect to a ship from England bound to that place, it is, therefore, more proper to find the bearing and distance either of the east or west end of that island; for obvious reasons, however, the east end is to be preferred. But, as the island of Porto Sancto lies a little to the N. E. of Madeira, it, therefore, seems to be the most proper place to find the bearing and distance of. In some of the late books on navigation, the ship is made to sail through the body of the island of Madeira, in order to arrive at Funchal!

A

JOURNAL OF A VOYAGE

FROM

ENGLAND TO FUNCHAL IN MADEIRA,

IN THE

SHIP URANIA OF LONDON,

A—— M——, COMMANDER.

ANNO 1804.

A JOURNAL FROM ENGLAND TO MADEIRA.

Days of Month.	Winds.	REMARKS on board the Ship URANIA, Anno 1804.
♄ Sept. 15.	S. W.	Strong gales and heavy rain; at 3 P. M. sent down top-gallant yards. At 11 A. M. the pilot came on board.
☉ Sept. 16.	S. W.	Moderate and cloudy with rain; at 10 A. M. cast loose from the sheer hulk at Deptford, got up top-gallant yards, and made sail down the river; at noon running through Blackwall Reach.
☽ Sept. 17.	S. W. Var.	The first part moderate, the latter squally with rain. At half past one anchored at the Galleons, and moored ship with near a whole cable each way, in 5 fathoms, a quarter of a mile off shore. At 3 A. M. strong gales; sent down top-gallant yards. A. M. the people employed in working up junk. Bent the sheet cable.
♂ Sept. 18.	S. S. W. S. W.	Fresh gales and squally. P. M. received the remainder of the boatswain's and carpenter's stores on board. The clerk of the cheque mustered the ship's company.
☿ Sept. 19.	Var. N. by E.	Variable weather with rain; at noon weighed and made sail. At 5 P. M. anchored in Long Reach in 8 fathoms; received the powder on board. At 6 A. M. weighed and got down the river. At 10 A. M. passed the Nore; brought-to and hoisted in the boats; double reefed the top-sails, and made sail for the Downs. At noon running for the flats of Margate.
♃ Sept. 20.	N. by E. N.	First part stormy weather, latter moderate and clear. At 4 P. M. got through Margate roads. At 5 run through the Downs, and at 6 anchored in Dover roads, in 10 fathoms, muddy ground. Dover castle bore N. and the South Foreland N. E. by E. $\frac{1}{2}$ E. off shore $1\frac{1}{4}$ miles. Discharged the pilot. Employed making points, &c. for the sails. Sealed the guns. Up top-gallant yards.
♀ Sept. 21.	N.	Moderate and fair. Employed working up junk. Received from Deal, a cutter of 17 feet, with materials. A. M. strong gales and squally. Sent down top-gallant yards.

H.	K.	Fath.	Courses.	Winds.	Lew.	REMARKS ♄ Sept. 22, 1804.
2				N. N. E.		Fresh gales with rain. Hove short.
4	4					Weighed and made sail.
6	7		W. S. W.			
8	7					Shorten.sail. Dung.light N.E.by E.
10	6		W. by N.	N. E.		
12	6					Fresh breezes and cloudy.
2	6					
4	6					Do. weather.
6	6					Up top-gallantyards. Setstud.sails.
8	7					Do. weather.
10	7					
12	8					St Alban's Head N. $\frac{1}{4}$ E.

A JOURNAL FROM ENGLAND TO MADEIRA.

H.	K.	Fath.	Courses.	Winds.	Lew.	REMARKS ☉ Sept. 23, 1804.
2	6		W. by N.	N. E.		A fresh steady breeze.
4	6					Spoke H. M. ship Repulse.
6	6					
8	6					Do. weather.
10	6					
12	6					Do. weather.
2	6					A light on the larboard bow.
4	6					Do. weather.
6	6					
8	7					Fresh breezes and clear.
10	8					Lizard N. E. ½ E. distance 5 leagues.
12	8					Do. weather.

Course.	Dist.	D. Lat.	Dep.	N. Latitude by Accou.	N. Latitude by Observ.	D. L.	W. Long. by Accou.	W. Long. by Observ.	W va by ac.
S. 49° W.	28	18	21	49° 39′		33 W	5°. 48′		2½ pt.

The departure is taken from the Lizard, the bearing of which at 10 A. M. is N. E. half E. distance 15 miles; now, the opposite point is S. W. half W. and the variation 2½ points being allowed to the left hand, because it is westerly, gives S. S. W. the true bearing of the ship from the Lizard. The course the ship has been going is W. by N. which corrected for variation is W. S. W. half W. and the distance run from 10 A. M. to noon, at 8 knots an hour, is 16 miles. Now, these being inserted in the traverse table, as under, the difference of latitude and departure to each course and distance will be found, by prob. I. of traverse sailing. Hence, the difference of latitude and departure made good, will be obtained; with which, the course and distance made good from the Lizard are to be found, by prob. VI. of plane sailing; and the difference of longitude is to be found, with the dep. and middle latitude, by prob. VII. of middle lat. sailing.

Courses.	Dist.	Differ. of Lat. N.	Differ. of Lat. S.	Departure. E.	Departure. W.
S. S. W.	15	- -	13.9	- -	5.7
W. S. W. ½ W.	16	- -	4.6	- -	15.3
S. 48° 40′ W.	28		18.5		21.0

Latitude Lizard, - - 49° 57′ N.

Latitude in, - - - 49 39 N.

Sum, - - - - - - 99 36

Middle latitude, - - 49 48 Comp. 40° 12′

Now, set 40° 12′ on the second line of sines to 90° on the first line, and opposite to the departure 21′ on the second line of numbers, is nearly 33′ on the first line, the difference of longitude.

Longitude Lizard, - 5° 15′ W.
Difference of longitude, 0 33 W.

Longitude in, - - 5 48 W.

A JOURNAL FROM ENGLAND TO MADEIRA.

H.	K.	Fath.	Courses.	Winds.	Lew.	REMARKS ☽ Sept. 24, 1804.
2	8		W. by S.	N. E.		Fresh gale.
4	8	4				A sail upon the lee-beam.
6	8	6				
8	9		W. S. W.			Do. weather.
10	9					
12	9					Do. weather.
2	9					
4	9					
6	9					
8	9		S. W. by W.			Do. weather and clear.
10	9	6				
12	9	4				Mer. alt. ☉'s lo. l. 42° 24′ height eye 18 feet.

Course.	Dist.	D.Lat.	Dep.	N. Latitude by		D.L.	W. Long. by		W va	Porto Sancto's	
				Accou.	Observ.		Accou.	Observ.	by ac	Bearing.	Dist.
S. 39° W.	212	165	133	46° 54′	46° 56′	201	9° 9′		2½ pt.	S. 21° 37′ W.	901 m.

The several courses being corrected for variation, and the difference of latitude, and departure, answering to each course and distance, being found by the Sliding Gunter, by the preceding rules, will be as under.

Courses.	Dist.	Differ. of Latitude		Departure.	
		N.	S.	E.	W.
S. W. ½ W.	50	- -	31.7	- -	38.6
S. W. ½ S.	108	- -	83.5	- -	68.5
S. S. W ½ W.	56	- -	49.4	- -	26.4
S. 39° W.	212		164.6		133.5

Yesterday's lat. -	49° 39′ N.		Ob. alt. ☉'s l. l.	42° 24′		
Difference of lat.	2 45		Semidiameter,	+	16	
			Dip and refrac.	—	5	
Lat. in by acct. -	46 54 N.					
			True altitude,	42	35	
Sum, - -	16 33		Zenith distance,	47	25	N.
Middle Latitude,	48 17		Declination, -	0	29	S.
Complement, -	41 43					N.
			Latitude -	46	56	

With the co-middle latitude 41° 43′, and the departure 133.5, the difference of longitude is found by the Sliding Gunter to be 201′ = 3° 21′ W.

Yesterday's longitude, - 5 48 W.

Longitude in by account, 9 9 W.

It is now necessary to find the bearing and distance of the intended port, namely Funchal, but as that place is on the opposite side of the island with respect to the ship, it is, therefore, more proper to find the bearing of the east or west end of Madeira; the east end is, however, preferable. But as the small island of Porto Sancto lies a little to the N. E. of the east end of Madeira, it, therefore, seems more eligible to find the bearing and distance of that island. This may be done either by Mercator's or middle latitude sailing, which shall be used occasionally, but in the present instance the first of these methods shall be employed.

Latitude in by observa.	46° 56′ N.	Mer. parts, -	3197	Longitude,	9° 9′ W.
Latitude Porto Sancto,	32 58	Mer. parts, -	2097	Longitude,	16 25 W.
Difference of latitude,	13 58 = 838′	M. D. Lat. -	1100	Diff. of Lon.	7 16 = 436.

For the Method of finding the Course and Distance, see page 134.

A JOURNAL FROM ENGLAND TO MADEIRA.

H.	K.	Fath.	Courses.	Winds.	Lew.	REMARKS ♂ Sept. 25, 1804.
2	9		S. W. ½ W.	N. E.		Fresh gale, some cloudy.
4	9					
6	8	5				
8	8			E. N. E.		Do. weather.
10	8					
12	8					
2	8					
4	7	5		E.		Do. with rain.
6	8					
8	7	5				
10	7					
12	7			E. by S.		Cloudy, no observation.

Course.	Dist.	D. Lat.	Dep.	N. Latitude by		D. L.	W. Long. by		W va byac.	Porto Sancto's	
				Accou.	Observ.		Accou.	Observ.		Bearing.	Dist.
S.S.w¼w	191	175	77	44° 1′		110	10° 59′		2¼	S. 21° W.	710 m

Since the variation at noon yesterday was two and a half points, and at the noon of this day two and a fourth points; the mean of these ought, therefore, to be applied to the course steered since yesterday at noon. It will, however, be more convenient to find the difference of latitude and departure answering to the distance run, and the course corrected by yesterday's variation, and then, to the same distance, and the course corrected by the variation to-day; and the mean of these may be taken as the true difference of latitude and departure. Thus, the distance run is 191 miles; with which, and the course corrected by two and a half points variation, the difference of latitude is 176.5, and the departure 73.1. Again, to the same distance, and the course corrected by two and a fourth points of variation, the difference of latitude is 172.6, and the departure 81.7; the mean of these 174.6 and 77.4, will be the difference of latitude and departure respectively.

Yesterday's latitude by observation,	46°	56′	N.
Difference of latitude, - -	2	55	S.
Latitude in by account, - -	44	1	N.
Sum of latitudes, - - -	90	57	
Middle latitude, - - -	45	29	Complement, 44° 31′

Now, set 44° 31′ on the second line of sines to 90° on the first line, and opposite to 77.4 on the second line of numbers, is the difference of longitude 110, on the first line of numbers.

Yesterday's longitude, -	9°	9′	W.
Difference of longitude, -	1	50	W.
Longitude in by account,	10	59	W.

To find the Bearing and Distance of Porto Sancto.

Latitude Ship, - -	44°	1′ N.		Meridional parts,	2947	Long.	10°	59′ W.	
Latitude Porto Sancto,	32	58 N.		Meridional parts,	2097	Long.	16	25 W.	
Difference of latitude, -	11	3	=663′	Meridion. D. lat.	850	D. Long.	5	26	= 326′

Set 326 on the second line of numbers to 850 on the first line, and opposite to 45° on the second line of tangents, is the bearing 21° on the first line of tangents. Then set 69°, the complement of the bearing on the second line of sines, to 90° on the first, and opposite to 663 on the second line of numbers, is the distance 710 miles on the first line of numbers. Hence, the bearing of Porto Sancto, per compass, is S. W. ¼ W. nearly; which is, therefore, the course to be steered, if the wind is favourable.

A JOURNAL FROM ENGLAND TO MADEIRA.

H.	K.	Fath.	Courses.	Winds.	Lew.	REMARKS ☿ Sept. 26, 1804.
2	7		S. W.	E. by S.		Dark gloomy weather.
4	7					
6	7			S. E.		Handed top-gallant sails.
8	7					Do. weather.
10	6			S. S. E.	1	A great swell from the S. W.
12	6					
2	5	5	W. S. W.	S.	1½	In first reef topsails.
4	5	5			2	In second reef, down top-gallant yards.
6	5				3	Close reefed topsails.
8			upws woffwnw	S. S. W.	5	Handed fore and mizen topsails, fore-sail,
10			Drift 1 k. p. hour			&c. and lay-to under a close-reefed main
12						top-sail.

Course.	Dist.	D. Lat.	Dep.	N. Latitude by		D.L.	W. Long. by		W va by ac.	Porto Sancto's	
				Accou.	Observ.		Accou.	Observ.		Bearing.	Dist.
S.38°W.	106	83	65	42° 38′		90	12° 29′		2¼pt.		

The several courses being corrected for variation and leeway. Then, the difference of latitude and departure answering to each course and its corresponding distance, being found by the Sliding Gunter, will be as under.

Courses.	Dist.	Differ. of Lat.		Departure.	
		N.	S.	E.	W.
S. by W. ¾ W.	56	- -	52.7	- -	18.9
S. S. W. ¾ W.	24	- -	20.6	- -	12.3
S.W. by W ¼ W	11	- -	5.7	- -	9.4
S.W. by W ¾ W	11	- -	4.7	- -	9.9
W. by S. ¼ S.	10	- -	2.4	- -	9.7
N.W by W ¼ W	6	3.1	- -	- -	5.1
		3.1	86.1	- -	65.3
			3.1		
S. 38° W.	106		83.0	= 1° 23′ S.	

Yesterday's latitude, - - 44 1 N.

Latitude in by account, - - 42 38 N.
Sum, - - - - - - 86 39
Middle latitude, - - - 43 20
Complement, - - - - - 46 40

Now, set 46° 40′ on the second line of sines, to 90° on the first line; and opposite to 65.3 the dep. on the second line of numbers, is 90′ the difference of longitude on the first line of numbers.

Yesterday's longitude, - - 10° 59′ W.
Difference of longitude 90′ = 1 30 W.

Longitude in by account, - 12 29 W.

A JOURNAL FROM ENGLAND TO MADEIRA.

H.	K.	Fath.	Courses.	Winds.	Lew.	Remarks ♃ Sept. 27, 1804.
2			Up S. E. off E.	S. S. W.	5	Do. weather, tacked ship.
4						Set close reefed fore and mizen topsails.
6	5		S. S. W.	W.	2	
8	5					The swell abates fast.
10	5					
12	6			W. N. W.	0	More moderate.
2	6					
4	6					Moderate and clear weather.
6	5					Variation per azimuth, 23° W.
8	5					Out all reefs
10	4					
12	3					Mer. alt. ☉'s l. l. 46° 52' S. height eye 18 feet

Course.	Dist.	D.Lat.	Dep.	N. Latitude by Accou.	N. Latitude by Observ.	D.L.	W. Long. by Accou.	W. Long. by Observ.	W va by ob	Porto Sancto's Bearing.	Porto Sancto's Dist.
S. 9° E.	95	94	15	41° 4'	41° 17'	27	12° 2'		23°	S. S. W.	540 m.

As the variation was found in the morning, it may, therefore, be used for correcting all the courses of the day's run; and because it is given in degrees, it will be found much more convenient, and, at the same time, more accurate, to reduce the several courses into one, leeway only being allowed upon them: The course thus found, is then to be corrected for variation; with which, and the distance made good, the difference of latitude and departure are to be found as before.

Courses.	Dist.	Differ. of Latitude N.	Differ. of Latitude S.	Departure E.	Departure W.
N. E. by E.	4	2.2	- -	3.3	- -
S.	30	- -	30.0	- -	- -
S. S. W.	70	- -	64.7	- -	26.8
		2.2	94.7	3.3	26.8
			2.2		3.3
S. 14° W.	95		92.5		23.5
Varia. 23					

Tr. Co. S. 9 E. to which, and the distance 95 m. the difference of latitude is 93.8 and departure 14.9.

Yesterday's lat.	42°	38'	N.	Ob. alt. ☉'s l. l.	46°	52'	S.
Differ. of lat. -	1	34	S.	Semid. dip, refr.	+	11	
Lat. by account,	41	4	N.	True altitude,	40	3	S.
Lat. by observ.	41	17	N.	Zenith dist. -	42	57	N.
				Declin. red. -	1	40	S.
Difference, - -	0	13		Latitude, - -	41	17	N.

The difference between the latitudes, by account and observation, may arise from the swell of yesterday and to-day; and since the swell was from the S. W. the ship would, therefore, be set in the opposite direction, or N. E. or N. N. E. nearly, the variation being allowed; with that course, therefore, and 13 miles, the difference between the latitudes by account and observation, the departure is found to be 5.4, which added to 14.9, this day's departure, because both are of the same name, gives 20.3. Now, to the dep. and the middle lat. 42°, the difference of long. is 27'.

Yesterday's longitude, - -	12°	29'	W.
Difference of longitude, - -	0	27	E.
Longitude in by account, - -	12	2	W.

By proceeding as before, the bearing of Porto Sancto will be found to be S. S^t. W. or, S. W. nearly, per compass, and distance 540 miles.

A JOURNAL FROM ENGLAND TO MADEIRA.

H.	K.	Fath.	Courses.	Winds.	Lew.	Remarks ♀ Sept. 28, 1804.
2	3		S. S. W.	W. N. W.		Moderate and clear.
4	3					
6	3					
8	2					Do. weather.
10	2					
12	1					Calm, a long swell from W. S. W. sprung
2	0		Ship's head			fore top-gallant mast, got up another.
4	0		round the com-			
6	0		pass.			
8	0					Moderate.
10	0					
12	2		S. W.	N.		Pleasant weather.

Course.	Dist.	D. Lat.	Dep.	N. Latitude by		D.L.	W. Long. by		W va byac.	Porto Sancto's	
				Accou.	Observ.		Accou.	Observ.		Bearing.	Dist.
S. ¼ W.	32	32	1	40° 45′		2	12° 4′		2pts.	S. S. W.	510

The courses being corrected by variation will, with their corresponding distances, be as under.

Courses.	Dist.	Differ. of Lat.		Departure.	
		N.	S.	E.	W.
S.	28	- -	28.0	- -	- -
S. S. W.	4	- -	3.7	- -	1.5
S. ¼ W.	32		31.7	=32′S.	1.5

Yesterday's latitude by observa. - 41° 17 N.

Latitude in, - - - - - - - - 40 45 N.
With the middle lat. and dep. the D. Lon. is 0 2′ W.
Yesterday's longitude, - - - - - - 12 2 W.

Longitude in, - - - - - - - - - - 12 4 W.

To find the Bearing and Distance of Porto Sancto.

Latitude Ship, -	40° 45′	Meridion. parts,	2682	Longitude,	12° 4′ W.
Latitude Porto Sancto,	32 58	Meridion. parts,	2097	Longitude,	16 25 W.
Difference of latitude, -	7 47 = 467′	Mer. diff. of lat.	585	Diff. of long.	4 21 = 261′

Set 261 the difference of longitude on the second line of numbers, to 585 the meridional difference of latitude on the first; then, opposite to 45° on the second line of tangents, is 24°, the true bearing, on the first line of tangents. Again, set 66° the complement of the bearing on the second line of sines, to 90° on the first line; and opposite to 467, the difference of latitude on the second line of numbers, is 510 miles the distance, on the first line of numbers. The variation being allowed to the right hand of the true bearing, will give S. W. the bearing per compass of Porto Sancto.

A JOURNAL FROM ENGLAND TO MADEIRA.

H.	K.	Fath.	Courses.	Winds.	Lew.	REMARKS ♄ Sept. 29, 1804.
2	3	5	S. W.	N.		Fine breeze, set top-gallant sails.
4	4					
6	4	5				Variation per amplitude $21\frac{1}{2}°$ W.
8	5					
10	5					
12	5					
2	5					
4	5					
6	5	5				Set studding sails. Variation per amplitude,
8	6					$20\frac{1}{2}°$ W.
10	6	5				
12	6	5				Lat. per doub. alt. red. to noon, 38° 54′

Course.	Dist.	D. Lat.	Dep.	N. Latitude by Accou.	N. Latitude by Observ.	D. L.	W. Long. by Accou.	W. Long. by Observ.	W va byac.	Porto Sancto's Bearing.	Porto Sancto's Dist.
S. 24° W.	123	112	50	38° 53′	38° 54′	65	13° 9′		21°	S. 24° W.	390 m.

The mean of the variations is 21°, which being allowed to the left of S. W. or 45°, the course per compass, gives S. 24° W. the true course; with which, and the distance 123 miles, the difference of latitude is 112.4 and the departure 50.0.

Yesterday's latitude, - -	40° 45′ N.	- - -		40°	45′
Difference of latitude, - -	1 52 S.	Half difference of lat.		0	56
Latitude in by account, -	38 53 N.	Middle latitude, - -		39	49

Now, set 50° 11′, the complement of the middle latitude on sines, to 90°; and opposite to 50, the departure on the second line of numbers, is the difference of longitude 65′, on the first line of numbers.

Yesterday's longitude, - - -	12°	4′ W.
Difference of longitude, - - -	1	5 W.
Longitude in by account, - - -	13	9 W.

To find the Bearing and Distance of Porto Sancto by Middle Latitude Sailing.

Latitude of Ship -	38°	54′ N.	Longitude Ship,	13°	9′ W.
Latitude Porto Sancto, -	32	58 N.	Longitude P. S.	16	25 W.
Difference of latitude, -	5	56 = 356′	Difference of lon.	3	16 = 196′
Sum of latitudes, -	71	52			
Middle latitude, -	35	56	Complement 54° 4′		

Set the complement of the middle latitude 54° 4′ on the second line of sines to 90°, and opposite to the difference of longitude 196 on the first line of numbers, is the departure 159, on the second line of numbers.

Then, set the departure 159, on the second line of numbers, to the difference of latitude 356, on the first line of numbers; and opposite to 45° on the second line of tangents, is the course 24°, on the first line of tangents.

Again, set the complement of the course 66°, on the second line of sines, to 90°; and opposite to the difference of latitude 356, on the second line of numbers, is the distance 390, on the first line of numbers. The distance may also be found by the course and departure.

A JOURNAL FROM ENGLAND TO MADEIRA.

H.	K.	Fath.	Courses.	Winds.	Lew.	REMARKS ☉ Sept. 30, 1804.
2	7	5	S. W.	N.		A fine steady breeze.
4	7	5				
6	8					
8	8					Fine clear weather.
10	8					From an observation of the distance between
12	8			N. N. E.		the Moon and Pollux with the altitude
2	8					of each, the ship's longitude at 10h. P. M.
4	8			N. E.		was 13° 58′ W.
6	9					Variation per amplitude, $1\frac{3}{4}$ points W.
8	9					
10	9	5		E. N. E.		
12	9	5				Cloudy weather.

Course.	Dist.	D. Lat.	Dep.	N. Latitude by		D.L.	W. Long. by		W va	Porto Sancto's	
				Accou.	Observ.		Accou.	Observ.	by ob	Bearing.	Dist.
s s.w$\frac{1}{4}$w.	200	181	85	35° 53′		108	14° 57′	15° 13′	$1\frac{3}{4}$ pt.	S. 21° 8′ W.	188 m.

The course corrected by variation is S. S. W. $\frac{1}{4}$ W. with which, and the distance 200 miles, the difference of latitude, found as usual by the Sliding Gunter, is 180.8, or 181 miles, and the departure 85.5.

Yesterday's latitude by observation,	38°	54′ N.			38°	54′ N.
Difference of latitude, - - - -	3	1 S.	Half, - - -		1	30 S.
Latitude in by account, - -	35	53 N.	Middle latitude, -		37	24

Set the complement of the middle latitude 52° 36′, on the second line of sines, to 90°; and opposite to the departure 85.5 on the second line of numbers, is the difference of longitude 108, on the first line of numbers.

Yesterday's longitude, - - - -	13°	9′ W.
Difference of longitude, - - -	1	48 W.
Longitude in by account, - - -	14	57 W.

To reduce the Longitude observed at 10h. P. M. to Noon.

With 122 miles, the distance run from 10h. P. M. to noon, and the corrected course $2\frac{1}{4}$ points, the difference of latitude is 110.3, and the departure 52.2. Now, half the difference of latitude 55 miles, added to 35° 53′, the latitude at noon, gives 36° 48′ the middle latitude: Then, set the complement of the middle latitude 53° 12′ on the second line of sines, to 90°, and opposite to the departure 52.2 on the second line of numbers, is the difference of longitude 65 on the first line of numbers.

Longitude by observation, at 10h. P. M. - - - - -	13	58 W.
Difference of longitude, - - - - - - - - -	1	5 W.
Longitude in at noon, deduced from observation, - - -	15	3 W.

To find the Bearing and Distance of Porto Sancto by Middle Latitude Sailing.

Latitude of Ship, - -	35	53	Longitude Ship, -	15	3 W.
Latitude Porto Sancto, -	32	58	Longitude P. Sancto,	16	25 W.
Difference of latitude, -	2	55 = 175′	Diff. of longitude, -	1	22 = 82′
Sum of latitudes, - -	68	51			
Middle latitude, - -	34	25	Complement 55° 35′		

Set 55° 35′ on the second line of sines to 90°, and opposite to the difference of longitude 82, on the first line of numbers, is the departure 68, on the second line of numbers. Now, draw out the slide, until 68 on the line of numbers is opposite to the difference of latitude 175 on the corresponding line, and opposite to 45° on the second line of tangents, is the bearing S. 21° 8′ W. on the first line of tangents. Again, set 68° 52′, the complement of the bearing, on the second line of sines to 90°, and opposite to the difference of latitude 175 on the second line of numbers, is the distance 188 miles, on the first line of numbers.

From the direction of the wind, and the probability of it getting more to the eastward, it will, therefore, be proper to alter the course, in order to keep to the windward of Porto Sancto,

A JOURNAL FROM ENGLAND TO MADEIRA.

H.	K.	Fath.	Courses.	Winds.	Lew.	REMARKS ☽ Oct. 1, 1804.
2	9	5	S. W. by S.	E. N. E.		A fresh gale.
4	9	5				
6	9					
8	9					Ditto weather.
10	9					
12	9					
2	8			E.		
4	8					
6	8					Porto Sancto W. by S.
8	8		S. W.			
10	8					
12	8					Porto Sancto N. per compass.

Course.	Dist.	D. Lat.	Dep.	N. Latitude by		D. L.	W. Long. by		W va byob
				Accou.	Observ.		Accou.	Observ.	
s16°40w	205	197	59	32° 36′		71	16° 8′	16° 14′	$1\frac{3}{4}$pt.

The courses being corrected by variation will be as under.

Courses.	Dist.	Differ. of Lat.		Departure.	
		N.	S.	E.	W.
S. by W. $\frac{1}{4}$ W.	158	- -	153.3	- -	38.4
S. S. W. $\frac{1}{4}$ W.	48	- -	43.4	- -	20.5
S. 16° 40′ W.	205		196.7=3°17′s		58.9

Yesterday's latitude, - - 35 53 N.

Latitude in by account, - - 32 36 N.

Sum of latitudes, - - - 68 29

Middle latitude, - - - 34 15co.55°45′

Set 55° 45′ on the second line of sines, to 90°, and opposite to the dep. 58.9 on the second line of numbers, is the difference of longitude 71, on the first line.

Yesterday's longitude, - - 15° 3′ W.

Difference of longitude, - 1 11 W.

Longitude in, - - - 16 14 W.

The long. carried forward from the dead reckoning will be 16° 8′ W.

As the ship is now to the southward of Porto Sancto, the bearing and distance of Funchal may be found. The difference of latitude between the ship and Funchal is 2 miles, and the difference of longitude 52; hence, the course being near a parallel, both it and the distance ought to be found by middle latitude sailing. Therefore, set the complement of the middle latitude 57° 23′, on the line of sines on the slide, to 90°; and opposite to the difference of longitude 52, on the first line of numbers, is the dep. 44, on the second line of numbers. Now, set the diff. of lat. 2 to the dep. 44 on the lines of numbers, and opposite to 45° is the course 87° 24′ on the lines of tangents. Hence, the course per compass is W. N. W.; but, because the Deserters ly in the way, it will be proper to haul to the southward. The distance is nearly the same as the departure, viz. 44 miles.

A JOURNAL FROM ENGLAND TO MADEIRA.

H.	K.	Fath.	Courses.	Winds.	Lew.	REMARKS ♂ Oct. 2, 1804.
2	8		W. by S.	E.		A steady breeze.
4	8					
6	8					The Deserters N. by E. hove to.
8						
10						
12						Squally weather.
2						
4						
6			Various.			Made sail.
8						
10						Running into Funchal roads.
12						Anchored in Funchal road, with the best bower in 30 fathoms, black sand and mud. Brazen-head E. by S. ½ S. Loo rock N. W. the great church N. N. E. and the southernmost Deserter S. E. ½ S. off shore 2-3ds of a mile.

Oberservation referred to page 126.

Now, set 436 on the second line of numbers, to 1100 on the first, and opposite to 45° on the second line of tangents, is the bearing 21° 37′ on the first line of tangents. Again, set 68° 23′ the complement of the bearing on the second line of sines, to 90° on the first line, and opposite to the difference of latitude 838 on the second line of numbers, is the distance 901 on the first line. Hence, the true bearing being S. 21° 37′ W. and the variation 2½ points W. the bearing per compass will be nearly S. W. ½ W. which is, therefore, the course to be steered per compass, provided the wind holds favourable.

Again, since the latitude and longitude of Cape Finisterre are 42° 52′ N. and 9° 17′ W. respectively, it is hence evident, that the true bearing of the Cape is nearly due S. or S. S. W. ½ W. per compass, and the distance, being equal to the difference of latitude, is 244 miles.

Hence, by PROB. I. of Mercator's sailing, the bearing will be found to be S. 21° 37′ W. or nearly S. S. W. and as the variation is 2½ points W. the bearing per compass is S. W. ½ W. and distance 901 miles.

This journal is performed by the Sliding Gunter, agreeable to the precepts given. Other instrumental methods might have been used for the same purpose, particularly that by the Author's Rectangular Instrument, described in the article *Navigation*, in the twelfth volume of the Encyclopædia Britannica. And it may be performed as usual by Inspection, for which precepts have been given.

As it is of the utmost importance to the practical navigator, to be able to direct his ship to any known port, we cannot omit the following observations—although they have, in part, been already anticipated.

When a ship is bound to a port so situated that, in her passage thereto, she will be out of sight of land. If, then, no land intervenes, the course and distance is to be found by the chart, or by PROB. I. of middle latitude, or Mercator's sailing; and as it is the true course, that is thus found, the variation, if west, is to be allowed to the right hand of the true course, but to the left if east; and hence, the course per compass will be obtained. Thus, suppose a ship is bound from the Forth to North Bergen, and that she takes her departure from the island of May;

then, the true course from thence to Bergen will be N. E. $\frac{1}{4}$ E. nearly; hence, the variation $2\frac{1}{2}$ points being allowed to the right hand, gives E. N. E. $\frac{3}{4}$ E. the course per compass, and the distance is 120 leagues.

But if any land intervenes, the course and distance to that point, which lies most directly in the way, is to be found, and the true course is to be reduced to that per compass, as before; and in this manner proceed until the voyage is completed. Thus, in a voyage from England to Gibraltar, let the ship be supposed to take her departure from the Lizard; then, the course and distance from thence to Cape Finisterre may be found: the true course is nearly S. S. W. Now, the variation at the Lizard, which is about $2\frac{1}{2}$ points, being allowed to the right of S. S. W. because it is westerly, gives S. W. $\frac{1}{2}$ W. the course per compass. It is, however, to be observed, that the variation decreases from the Lizard to the Straits; and, therefore, less variation is to be allowed, as the ship proceeds southerly. The distance between the Lizard and Cape Finisterre will be found to be 152 leagues. The ship having made Cape Finisterre, the course and distance to Cape Roxent may now be found. The course by the chart, or otherwise, will be found to be about S. $\frac{1}{4}$ W.; hence, the variation, which may be taken at $2\frac{1}{4}$ points, being allowed to the right, gives S. S. W. $\frac{1}{2}$ W. the course per compass; and the distance is 82 leagues. As the Burlings ly almost in the fair way, being distant about 15 leagues from Cape Roxent, a look-out must be kept for them, when, by the reckoning, they may be seen or rather sooner. Again, from Cape Roxent to Cape St Vincent the true course is S. by E. $\frac{1}{4}$ E. distance 35 leagues; hence the course per compass is S. by W. The true course from Cape St Vincent to the small island Tariffa is E. S. E. $\frac{1}{4}$ E.; hence, the course per compass is nearly S. E. and the distance 59 leagues. From this island the distance to Gibraltar is about 5 leagues.

If the wind proves contrary, the object is to ly as near the proper course as possible, and by the rules laid down in windward sailing, the vessel must be kept near the right track. And, if at any particular instant of time, as six in the evening, the wind should veer about and become favourable, then, with the latitude and longitude of the ship reduced to this time, and the latitude and longitude of the place bound to, or of the intervening headland or island, the bearing and distance is to be found, and a course steered accordingly.

In those cases where a ship is bound to a port within the limits of the general trade winds, as in going to the West Indies, &c. it is found to be eligible to make some place to the windward of the intended port, otherwise the ship in consequence of currents, might fall to the leeward of the proposed place.

It will be found to be of essential service to mark down the place of the ship, every day at noon, on the chart, and the corresponding day of the month; hence, the position of the ship with respect to the intended port, the adjacent land, &c. will be readily perceived. In making the land, particular attention is to be paid to the soundings, the quality of the ground, and colour of the water.

CHAP. III.

Of the Tides.

THE daily rising and falling of the waters of the ocean are in general denominated *Tides*. The rising is called the *Flood* or *Flux*; and when it ceases to rise it is called *High Water*. The falling is called the *Ebb*, or *Reflux*; and when it ceases to fall it is said to be *Low Water*. The interval between the times of high and low water is called a *Tide*. The tides are produced by the attractions of the sun and moon, principally that of the latter object.

A mean lunation, or synodic period of the moon, is completed in 29 days, 12h. 44′ 2″.8.* Hence, the mean retardation of the tides, or of the moon's coming to the meridian in 24 hours, is 48′ 45″.7; and the mean interval between two successive tides is 12h. 25′ 14″.2; hence, the retardation of high water from any one day to the following is 50′ 28″.4. If, therefore, the tides were wholly governed by the moon, and that object always in the equinoctial, and at the same distance from the earth, the tides would constantly return at equal intervals of time. But the tides are produced by the joint actions of the sun and moon; and, although the action of the sun upon the earth is much greater than that of the moon, yet the sun being near 400 times more distant from the earth than the moon, the dif-

* Theory and Practice of finding the Longitude, vol. i. page 33.

ference of its attraction, upon different parts of the earth, is not near so considerable as that of the moon; and, therefore, this last object is the principal cause of the tides. In a lunar day, or the interval of time between successive transits of the moon, two tides are raised by that object; and in a solar day, or 24 hours, there are two tides produced by the sun. That tide which happens while the moon is above the horizon is called the *Superior Tide;* and the other the *Inferior Tide.* When the moon is in the equinoctial, other things remaining the same, the superior and inferior tides are of the same height; but when the moon declines towards the elevated pole, the superior tide is higher than the inferior: if the latitude and declination are of contrary names, the inferior tide will be the highest, the difference between them being equal to the height of that under the parallel of the moon, multiplied by the difference of the squares of the co-sines of two arches, of which one is the sum, and the other the difference of the latitude of the place and de clination of the moon.

The highest tide at any particular place within the limits of the lunar tropics is, when the moon's declination is equal to the latitude of the place, and of the same name; and the height of the tide diminishes, as the difference between the latitude and declination increases. When the latitude is equal to the complement of the moon's declination, there will be only one tide in a lunar day, which will be a superior or inferior tide, according as the latitude of the place and declination of the moon are of the same, or of a contrary name.

Since the tides are raised by the attractions of the sun and moon, when these objects, therefore, are in conjunction or opposition, the tides will be highest, being raised by the sum of the attractions of these objects, and are hence called *Spring Tides;* but when the moon is in quadrature, the tides are lowest, being produced by the difference of their forces, and are called *Neap Tides.* Hence, since the moon is in conjunction with the sun, and in opposition once in every lunation, there will be two spring and two neap tides in that period.

The attraction of any object is in the inverse ratio of the square of its distance; the nearer, therefore, an object is to the earth the greater is its attraction, and the more remote the less.

The orbit of the earth is an ellipse, in one of whose foci is the sun; and, therefore, in a year, or one revolution of the earth, it will be at its least and greatest distance from the sun*. By observation, the earth is found to be nearest the sun about the first of January; hence, the attraction of that object being then greatest, those spring tides which happen about the beginning of the year will be greater than at any other time.

The moon's orbit being also elliptical, once, therefore, in every revolution about the earth, it will be at its least and greatest distances. When nearest the earth, it is said to be in *perigée*; and when most distant therefrom, in *apogee:* hence, if the moon is in perigee at the time of conjunction or opposition, the spring tides will be highest, and lowest when the moon is in apogee.†

Since the highest tide is in that parallel whose latitude is equal to the declination of the moon, and of the same name, the nearer, therefore, that parallel is to any given place, the higher is the tide. Hence, if at the beginning of the year the sun and moon be in conjunction or opposition, the moon in perigee, and the parallel described by the moon near that of any given place, there will be a high spring tide at that place. ‡

The variation in the height of the tides is least at the time of a syzygy, § or quadrature; however, in this last, the variation is about double that in the first. The greatest change in decreasing happens about the 6th day after new or full moon; and that while the tides are increasing, about the 4th day after the quadratures.

In flowing or ebbing, the height of the tide increases or de-

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* When in the first of these positions, it is said to be in *Perihelion*, and in its *Aphelion*, in the other.

† When the moon is in perigee, its horizontal parallax is greatest, and least when in apogee. The times when the moon is in these situations may, therefore, be known by the nautical almanac, page VII. of the month.

‡ The tides are, however, subject to very great irregularities from local circumstances. In the Euripus, a celebrated Strait in the Grecian sea, between the island of Negropont and Greece, the irregularity of the tides has always been very remarkable: during the three last and eight first days of the moon, and from the fourteenth until the twentieth, the tides are regular; but on the other days they are irregular, flowing twelve, thirteen, or fourteen times in the space of twenty-four hours, and ebbing as often. At the port of Batsha, in latitude 20° 50′ N. the water stagnates when the moon is in the equator, at every other time there is one tide daily; when the moon is in the southern hemisphere it is high water at the rising, and low water at the setting of the moon: and while the moon's declination is north, it is high water at the setting, and low water at the rising of the moon, the height of the tide increasing with the declination.

§ New or full moon.

creases in the ratio of the square of the radius to the square of the sine of the horary angle, reckoning from the instant of high water.

From what has been said, it will appear that, to find the time of high water with accuracy, the latitude of the place, the moon's declination, transit, and horizontal parallax, the time of the year, and of high water at full and change at the given place, must be taken into account. In this place, however, the following easy method only will be given, reserving a more accurate mode of computation to the Treatise on Navigation.

Problem I.

To find the Time of High Water at a known Place upon a given Day.

Rule.

Find the given month and day in part first, table VII.: then, on the same horizontal line, and under the given year, is the moon's age;* observing, that N. stands for new moon, and F. for full moon.

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* The common method of finding the moon's age is by the Epacts, as follows:

Problem I.

To find the Epact of any given Year.

Rule.

Divide the given year by 19, multiply the remainder by 11, and if it exceeds 30, divide it thereby, and the remainder will be the epact.

Example.

Required the epact of the year 1830?

1830 being divided by 19, the remainder is 6; which multiplied by 11, and the product divided by 30, the remainder 6 is the epact; or more accurately, 5d. 6h. 7′ 33″.

Problem II.

To find the Epact of any given Month.

Rule.

From the number of days contained in the preceding months, reckoning from the beginning of the year, subtract the number of days contained in the mean lunations in that period, and the remainder will be the epact of the month required.

Example.

Required the epact of October?

In the months preceding October there are 273 days, and in 9 lunations there are 266 days, the difference 7 is the epact of October.

Then, set 1 on numbers on the slide to 49 on the first line of numbers, and opposite to the moon's age on the second line of numbers, is the moon's southing in minutes on the first, which is reduced to hours by dividing by 60*.

Now, to the moon's southing add the time of high water at full and change, and the sum will be the time of high water required. If this sum exceeds 12 hours, subtract 12h. 24′ therefrom, and the remainder will be the time of high water in the afternoon of the given day.

Examples.

I.

Required the time of high water at Gravesend, Oct. 17, 1882?

In Table VII. opposite October 17, and under 1882, the moon's age is 6 days. Hence, the moon's southing is 4h 54′
Time of high water at full and change at Gravesend, 1 30

Time of high water at Gravesend, Oct. 17, 1882, 6 24

The epacts of the months to the nearest second are as follow:

January,	0d	0h	0′	0″	May,	1d	21h	3′	49″	September,	6d	18h	7′	38″
February,	1	11	15	57	June,	3	8	19	46	October,	7	5	23	35
March,	29	11	15	57	July,	3	19	35	43	November,	8	16	39	32
April,	1	9	47	52	August,	5	6	51	41	December,	9	3	55	29

Problem III.

Given the Year, Month, and Day, to find the Moon's Age.

Rule.

To the epact of the year add the epact of the month and the day of the month, the sum rejecting 30 will be the moon's age.

Example.

Required the Moon's Age, May 1, 1803?

Epact of 1803, - - -	7
Epact of May, - - -	2
Day of the month, - -	1
Moon's Age, - - -	10

* Or, the moon's age being multiplied by 8, and the right hand figure pointed off, then the left hand figure or figures will be the hours, and the product of the right hand figure by 6 the minutes of the moon's southing nearly.

II.

Required the time of high water at Rio Janeiro, Sept. 28, 1850?

By the table the ☽'s age is 23 days; hence, by the Sliding Gunter, or by multiplying 49 by 23, the ☽'s southing will be 18h 47′

Time of high water at Rio Janeiro at new and full ☽,	4	30
Sum, - - - - - - - -	23	17
Subtract the time of a tide, - - - -	12	24
Time of high water at Rio Janeiro, Sept. 28, 1850,	10	53

As the knowledge of the time of high water at new and full moon, at different places, is of the utmost importance to the navigator—at those places, therefore, where this necessary element is unknown, it may be found by observing the time when it is high water upon the day of new or full moon, or upon any other day of the moon, although with less accuracy, by the following problem.

Problem II.

Given the Time of High Water upon any given day of the Moon, to find the Time of High Water at new and full Moon.

Rule.

From the observed time of high water, increased by 12h. 24′ if necessary, subtract the time of the moon's southing, and the remainder will be the time of high water nearly upon the days of new and full moon.

Examples.

I.

Let the observed time of high water be 9h. 40′, and the moon's southing 5h. 24′: Required the time of high water upon the days of new and full moon?

Observed time of high water, - -	9h	40′
Moon's southing, - - - - -	5	24
Time of high water at new and full moon,	4	16

II.

December 12, 1805, the time of high water was observed to be 7h. 45′: Required the syzygial time of high water?

Observed time of high water, - -	7h	45′
Add, - - - - - - -	12	24
Sum, - - - - - - -	20	9
Moon's southing, per Nautical Almanac,	18	1
Time of high water at new and full moon,	2	8

When great accuracy is required, several corrections become necessary.

BOOK V.

CONTAINING THE DESCRIPTION AND USE OF THE MARITIME SCALE.

INTRODUCTION.

This Scale was invented by Mr Matthew Richmond. The pamphlet which accompanies this rule consists of four leaves, including that which contains the title page, and its date is 1786. It contains a very brief description of the first line of hours only, that of the other lines being omitted. Three problems follow:

The first—'*To find the latitude of a ship from the observed meridional altitude of the sun's upper or lower limb.*' This is performed according to the common method, without the assistance of any rule.

The second problem is—'*To find the true latitude of a ship, having the latitude by account, and an observed altitude of the sun, with the true time from noon, not exceeding one hour.*' In performing this problem, he has recourse to a table of natural sines.

And the third problem, although not titled so is as follows: '*Given the true latitude, with the true altitude of the sun's centre, at any time within an hour from noon, to find the true time from noon.*' In performing this, he also uses a table of natural sines.

CHAP. I.

Description of the Maritime Scale.

This rule is two feet long, and one inch broad: one of the sides contains a scale of inches divided into tenths; and the other the lines for finding the apparent time from the sun's altitude, &c.

The lines upon this side may be reduced to three. The first called a *Line of Hours*, and marked Hours at the end, begins at the right hand extremity at 6 hours; and at the left hand end of the rule it terminates at 0h. 32′; this line is continued below, and disposed in such a manner, that the former termination, *viz.* 0h. 32′, may be at or near the middle of the rule:

between III. and VI. each division is two minutes; and in the remaining part of this line and its continuation, each division is one minute.

The next is a line of numbers, similar to that upon a common two feet Gunter.

The first part of the last line, as far as the second 5 on numbers, is divided into hours and minutes, and intituled *Corrected Time*. At the right hand extremity of this part of the line, which is exactly under 5 on the second half of the line of numbers, is the division representing two hours, and that at the left, two minutes. That part of the line between 11 hours, which also represents 60 degrees, and 0 is divided into degrees, and reckoned contrary to the order in which the former part of the line is numbered; and to the right of 0, the divisions are continued, in a retrograde order, as far as 30, and marked D for declination.

Both the first and last lines are adapted to the line of numbers, the first being the natural versed sines of the corresponding times, and the last the natural sines; the first 80° being expressed in time, and the remaining part in degrees, and numbered in a contrary order to the first part. The line of numbers, therefore, being constructed, which is easily done by means of a table of logarithms and an accurate diagonal scale, the upper or lower lines may either be laid down or examined. Thus, let it be required to find the division, answering to two hours, on the line of hours?

The number of degrees contained in two hours is 30; the three first figures of the natural versed sine of 30 are 134 nearly.† Now, opposite to 134 on numbers, is the division answering to two hours.

Again, let it be examined, if the point representing five hours be correct? In five hours are 75°, the three first figures of the natural versed sine of which are 741: now, upon the rule, which the author has, the point representing five hours is not exactly opposite to 741, being a little beyond it; and, therefore, this division is not correctly marked.

In the lower line, the point opposite to the natural sine of any given degree upon the line of numbers, will be the division

† The Author's Treatise on the Longitude, vol. ii. table XLI.

answering to that degree. Thus, to find the division corresponding to 1h. 20′? The number of degrees in 1h. 20′ is 20°; the three first figures of the natural sine of 20° are 342, opposite to which, on the line of numbers, is the point on the line marked *corrected time*, answering to 1h. 20′. Again, to find the division on the line of *latitude by reckoning*, which represents 50°? Because in this part of the line the divisions are numbered in a retrograde order, find, therefore, the natural sine of 40°, the complement of the given arch, which is 643 nearly; now, opposite to this division, on the line of numbers, is the point on the line of *latitude by reckoning* which denotes 50°.

CHAP. II.

Use of the Maritime Scale.

Problem I.

To find the Natural Sine of any given Arch by the Maritime Scale.

Rule.

If the given arch is less than 30°, reduce it to time; and opposite thereto, on the line marked *corrected time*, is the corresponding natural sine on the line of numbers.

If the given arch is greater than 30°, find its complement on that part of the line marked latitude by reckoning, and opposite thereto is the required natural sine on the line of numbers.

Examples.

I.

Required the natural sine of 20°?

20° = 1h. 20′; opposite to which, on the line of corrected time, is the natural sine 342 on the line of numbers.

II.

What is the natural sine of 50°?

The complement of 50° is 40°; opposite to which, on the line of latitude by reckoning, is the natural sine 766 on the line of numbers.

Problem II.

Given the Latitude of a Place, the Altitude and Declination of the Sun, to find the Apparent Time of Observation, and the Error of the Watch.

Rule.

If the latitude and declination be of contrary names, add them; but if of the same name, subtract the less from the greater: find this sum or difference on the line of latitude by reckoning, or if less than 30°, find it on the line of corrected time, and the corresponding division on the line of numbers will be the natural sine of the meridian altitude; from which, subtract the natural sine of the true altitude. Then, extend the compass from the latitude, to the declination on the lines of latitude by reckoning and declination; that extent being laid the same way from the difference of the natural sines on numbers, will reach to the distance of the object from the meridian on the line of hours; hence, the apparent time is known.

Examples.

I.

Let the latitude be 50°, the sun's declination 10° N. and altitude 20°: Required the apparent time?

The latitude and declination being of the same name, their difference must be taken, which is 40°; opposite to which, on the line of latitude by reckoning, is 766 on numbers. The altitude being less than 30° must be reduced to time, which is 1h. 20′; opposite to which, on the line of corrected time, is the corresponding natural sine 342 on the line of numbers: the difference of the two natural sines is 424. Now, the extent of the compass from the latitude 50°, to the declination 10°, being laid the same way from 424 on numbers, will reach to a point opposite to which, on the line of hours, is the time from noon 4h. 43′. Hence, if the observation was made in the afternoon, the apparent time is 4h. 43′; but if in the morning, the apparent time was 7h. 17′.

II.

June 21, 1812, in latitude 37° 40′ S. at 3h. 14′ P. M. per watch, the altitude of the sun's lower limb was 14° 12′, and height of the eye 20 feet: Required the error of the watch?

Observed alt. ☉'s l. limb,	14° 12′	Latitude, -	37° 40′	S.
Semidiameter, - -	+ 16	Declination,	23 28	N.
Dip and refraction, -	— 8			
		Sum, - -	61 8	
True altitude, - - - -	14 20 = 0h. 57′ 20″.			

Since the sum of the latitude and declination exceeds 60°, its complement must be taken and reduced to time, which gives 1h. 55′ 28″; opposite to which, on the line of corrected time, is 483 on numbers, and opposite to 0h. 57′ 20″ is the division 248 on numbers; their difference is 235.

Now, the extent from the latitude 37° 40′ to the declination 23° 28′, being laid the same way from 235 on numbers, will reach to 3h. 10′ the apparent time; the difference between which and 3h. 14′, the time per watch, is 4′, the error of the watch for apparent time, fast.

Problem III.

Given the Latitude of a Place, the Apparent Time, and Declination of the Sun, to find the true Altitude of that Object.

Rule.

The extent of the compass from the declination to the latitude, being laid the same way from the distance of the object from the meridian, on the line of hours, will reach to a certain number on the line of numbers; which, being subtracted from the natural sine of the meridian altitude, will give the natural sine of the true altitude; opposite to which, on the line of numbers, is the altitude in time on the line *corrected time*, if below 30°, but its complement on the line of latitude by reckoning, if above that number.

Examples.

I.

Required the true altitude of the sun's centre, October 17, 1809, at 8h. A. M. in latitude 57° 9′ N. and longitude 9° W.?

Sun's declination at noon, -	9°	38′	S.
Equation to 4 hours, - - -	—	$3\frac{1}{2}$	
Equation to 9° W. - - - -	+	$\frac{1}{2}$	
Reduced declination, - - -	9	35	S.
Complement of latitude, -	32	51	N.
Meridian altitude, - - - -	23	16,	

which reduced to time = 1h. 33′ 4″, of which the corresponding natural sine is 395. Now, the extent from 9° 35′ to 57° 9′, on the lines of latitude and declination, being laid the same way from 4 hours, the time from noon on the line of hours, will reach to 267 on the line of numbers, which subtracted from 395, the remainder is 128; opposite to which on the line of numbers is about 29′ 20″, which reduced to degrees, gives the true altitude 7° 20′.

II.

Required the true altitude of the sun's centre, April 18, 1803, at 4h. 26′ 20″, in latitude 46° 20′ N. and longitude 60° W.?

Sun's declination at noon, -	10°	35′	N.
Equation to 4h. 26′ 20″	+	4	
Equation to 60°, - -	+	4	
Reduced declination, - -	10	45	N.
Latitude, - - - - - -	46	20	N.
Difference, - - - - - -	35	37,	

opposite to which, on the line of latitude by reckoning, is the natural sine of the sun's meridian altitude 813. Now, the extent of the compass from the declination 10° 43′ to the latitude 46° 20′, being laid the same way from 4h. 26′ 20″ on the line of hours, will reach to 409 on the line of numbers, which subtracted from 813, the remainder is 404: opposite to which, on the line of numbers, is about 2h. 35′ 20″, which reduced to degrees gives the true altitude 23° 50′.

Problem IV.

Given the Latitude by Account, the Declination and Altitude of the Sun, and the Distance of that Object from the Meridian, to find the true Latitude.

Rule.

The extent from the declination to the latitude by account, being laid the same way from the time from noon on the line of hours, will reach to a certain number on the line of numbers, which being added to the natural sine of the given altitude, will give the natural sine of the meridian altitude; with which, and the declination, the latitude is obtained as usual.

Remark.

The time from noon may be found by equal altitudes.

Examples.

I.

The latitude by account is 57° N. sun's declination 7° 22′ S. altitude 23° 52′, and apparent time 10h. 32′ A. M.: Required the true latitude?

The extent from 7° 22′ to 57°, being laid the same way from the time from noon 1h. 28′, on the line of hours, will reach to about 39 on numbers, which being added to 405, the number answering to 23° 52′ = 1h. 35′ 28″, gives 444; opposite to which, on the line of numbers, is 1h. 45′ 24″ = 26° 21′, the meridian altitude: hence, the zenith distance is 63° 39′, from which the declination 7° 22′ being subtracted, the remainder 56° 17′ N. is the latitude.

II.

December 21, 1806, in latitude 50° 30′ N. by account, at 10h. 43′ A. M. per watch, the apparent altitude of the sun's lower limb was 13° 51′, and at 1h. 19′ P. M. the sun's altitude was the same, height of the eye 12 feet: Required the true latitude?

Time per watch,	10h	43′	A. M.	Obs. alt. ☉'s l. limb,	13°	51′
- - -	1	19	P. M.	Sun's semidiameter,	+	16
				Dip and refraction,	—	7
Interval of time, -	2	36				
Half, - -	1	18		True alt. ☉'s centre,	14	0

The extent from 23° 28′ to 50° 30′, being laid the same way from 1h. 18′ on the line of hours, will reach to about 33 on the line of numbers. The altitude being less than 30° must be reduced to time, which is 56′; opposite to which, on the line of corrected time, is about 242 on numbers, to which 33 being added, the sum is 275; opposite thereto on numbers, is about 1h. 4′ on the line of corrected time. Now, 1h. 4′ = 16° 0′ = meridian altitude; hence the zenith distance is 74° 0′, from which the declination 23° 28′ being subtracted, the remainder 50° 32′ is the latitude.

Problem V.

Given the Latitude by Account, the Declination, and two observed Altitudes of the Sun, and the Time elapsed between them, to find the true Latitude.

Rule.

With the nearest degree to the latitude by account, the declination and each altitude, find the corresponding apparent times of observation, by Prob. II. If the interval between these times be equal to that by observation, the latitude used in the computation is the true latitude. But if the interval of time by computation exceeds that by observation, a less latitude must be assumed—but if that interval is less, a greater latitude must be taken; with which, the declination and altitudes, the apparent times of observation are to be re-computed. Now, take the difference between the two intervals by computation, and also the difference between the interval by observation, and that resulting from the computations from the least assumed latitude; then, the extent of the compass from the first of these differences to the second on the line of numbers, will reach from the difference of the assumed latitudes to the correction of latitude, which being applied to the least assumed latitude, will give the true latitude.

Examples.

I.

October 18, 1804, in latitude 51° N. by account, at 0h. 32′ P. M. per watch, the altitude of the sun's lower limb was 28° 32′, and at 2h. 41′, it was 19° 25′, height of the eye 12 feet; Required the true latitude?

Time p. watch,	0h	32′	First ob. alt.	28°	32′	Sec. ob. alt.	19°	25′
- - -	2	41	Semidia. +		16	- - - - - +		16
			Dip & ref. —		5	- - - - - —		6
Observ. interv.	2	9						
			True alt. -	28	43	True alt. -	19	35

With the latitude 51° N. the declination 9° 39′ S. and first altitude 28° 43′, the corresponding time will be found, by Prob. II. to be 0h. 40′ 30″, and that answering to the second altitude will be 2h. 45′ 30″, the difference is 2h. 5′; which being less than the interval by observation, the assumed latitude is, therefore, less than the truth. Let the second assumed latitude be 51° 30′; hence, by Prob. II. the times of observation will be 0h. 19′ and 2h. 42′, the interval of time is, therefore, 2h. 23′, which is 18′ greater than that by the first computation; and the difference between the interval answering to the first assumed latitude and that by observation, is 4′.

Now, the extent from 18′ to 4′ being laid the same way from 30, will reach to near 7′; hence, the true latitude is 51° 7′ N.

II.

September 14, 1814, in latitude 38° 12′ N. by account, at 9h. 28′ A. M. per watch, the true altitude of the sun's centre was 40° 43′, and at 11h. 16′ A. M. the true altitude was 53° 23′: Required the true latitude?

Let the first assumed latitude be 38° 0′ N. with which, the sun's declination 3° 34′ N. and the true altitudes 40° 43′ and 53° 23′, the corresponding times from noon are 2h. 34½′ and 0h. 54½′ respectively; hence, the interval is 1h. 40′, being 8′ less than the observed interval: a greater latitude must, therefore, be assumed, which let be 39°, with which, the declination and altitudes, the times from noon will be found to be 2h. 31′ and 0h. 41′; the difference is 1h. 50′, being 10′ greater than that resulting from the first operation.

Now, the extent from 10′ to 8′ on the line of numbers, will reach from 60′ the difference between the assumed latitudes, to 48′; which, therefore, being added to the least of the two assumed latitudes, gives 38° 48′ N. the true latitude.

Problem VI.

Given the Latitude of a Place, the Declination and Altitude of the Sun, to find the true Azimuth; and hence, the Variation of the Compass.

Rule.

If the sum of the latitude and altitude be less than 90°, add the natural sine of its complement to the natural sine of the declination; but if greater find the difference of these numbers.

Now, extend the compass from the latitude to the altitude, on the lines of latitude and declination: and that extent being laid the same way from the sum or difference of the natural sines, on the line of numbers, will reach to a certain time on the line of hours, which reduced to degrees will be the true azimuth of the sun, from the south in north latitude, but from the north in south latitude.

The difference between the true and observed azimuths will be the variation; which will be west, if the observed azimuth is to the right of the true, but east if to the left.

Remark.

If both the latitude and altitude exceed 30°, the limits of the declination scale, the altitude may be taken from the latitude scale; and being placed from the latitude towards the left, then the interval between the left point of the compass and 0, will be the interval between the latitude and declination.

Examples.

I.

Let the latitude be 50° N. the true altitude 28° 0′, and declination of the sun 14° 30′ N.: Required the sun's true azimuth?

Latitude,	50°	0′ N.		
Altitude,	28	0		
Sum, -	78	0		
Complem.	12	0, in time 0h. 48′,	correspond. nat. sine,	208
Declina. -	14	30, in time 0 58	natural sine, - -	250
Sum,	- - - - - - - - -		-	458

Now, the extent from the latitude 50° 0′ to the altitude 28° 0′, being laid the same way from 458 on the line of numbers, will reach to about 5h. 15′.6 on the line of hours; which time being reduced to degrees, gives 78° 54′ the true azimuth, from the south towards the east or west, according as the observation was made in the morning or afternoon.

II.

The latitude is 57° 7′ N. true altitude of the sun 41° 32′, and declination 10° 30′ N.: Required the true azimuth? And suppose the observation to have been made in the forenoon, and the magnetic azimuth S. ½ W. the variation is required?

Latitude,	57° 7′ N.	
Altitude,	41 32	
Sum, -	98 39	
Complem.	8 39, in time 34′ 36″, and the corres. nat. sine,	150
Declina -	10 30, in time 42 0 - - natural sine, -	182
Difference, - - - - - - - -		32

The extent from 57° 7′ to 41° 32′, being laid the same way from 32, will reach to about 1h. 32′, which in degrees is 23°, the true azimuth.

Observed azimuth S. ½ W. or	S. 5° 37′ W.	
True azimuth, - - -	S. 23 0 E.	
Variation, - - - -	28 37 W.	the

observed azimuth being to the right of the true.

BOOK VI.

CONTAINING TABLES FOR CALCULATING THE LATITUDE OF A PLACE, FROM THE MERIDIAN ALTITUDE OF THE SUN.

WITH AN EXPLANATION PREFIXED.

TABLE I.

Depression, or Dip of the Horizon.

The dip of the horizon is the vertical angle contained between a horizontal plane passing through the eye of an observer, and a line joining the eye and the visible horizon.

This table contains the dip answering to a free or unobstructed horizon; it is calculated by the rule given in Page 79, Vol. I. of the Longitude: each number is diminished by one-tenth, for the effect of terrestrial refraction, and wrote out to the nearest tenth of a minute.

TABLE II.

Dip of the Sea at different Distances from the Observer.

When the sun is over the land at the time of observation, and the ship nearer to it than to the visible horizon when uninterrupted, and if the sun's limb is brought into contact with the line of separation of the sea and land, the dip will be considerably greater than in the preceding table; and will increase as the distance of the ship from the land diminishes, and as the height of the observer increases. In this case, therefore, the distance of the ship from the land is to be found; and the dip answering thereto, and to the height of the eye above the water, is to be taken from this table, and subtracted from the observed altitude.

TABLE III.

Refraction in Altitude.

The refraction is necessary for correcting altitudes and distances observed at sea; it is always to be subtracted from the observed altitude. This table is adapted to a mean state of the atmosphere in Britain, namely, to 29.6 inches of the Barometer, and 50° of Thermometer. If the height of the mercury in these instruments be different from the mean, a correction, when great accuracy is required, becomes necessary, to reduce the tabular to the true refraction. This may be found in Table VIII. Vol. II. of the Longitude.

TABLE IV.

Declination of the Sun.

This table contains the declination of the sun for four successive years, namely, 1811, 1812, 1813, and 1814; and may be continued for several years, without any very great error; but when accuracy is required, the declination, when wanted for any other year, is to be reduced to that year by the following table.

TABLE V.

Change of the Sun's Declination for Periods of Four Years.

By this table, the declination as given in the preceding one, may be reduced to any future period, by applying the number answering to the interval between the given year and one found in the table, such that the difference shall be a multiple of 4, to the tabular declination according to its sign.

Examples.

I.

Required the sun's declination 1st May 1820?

The proposed year is 8 years after 1812. Now, the declination 1st May, 1812, is - - - - 15° 7′ N.
Change of declination for 8 years, Table V. + 1

Sun's declination, 1st May, 1820, - - 15 8 N.

II.

What is the sun's declination 20th August 1825?

The year 1825 is 12 years after 1813. Hence the sun's declination 20th August 1813, is - - 12° 33′ N.
Change of declination in 12 years, - — 2

Sun's declination 20th August 1825, - 12 31 N.

TABLE VI.

To reduce the Sun's Declination to any given Meridian, and to any proposed Time under that Meridian.

The declination in Table IV. is adapted to the meridian of Greenwich, and by this table it may be reduced to any other meridian, and to any given time of the day under that meridian: the titles at the top and bottom of this table, direct when the reduction is to be added or subtracted. In order to prevent any ambiguity, which might happen in applying the equation at the times of the equinoxes, it may be observed, that when the declination is increasing, the equation is additive in west longitude, or when the time is after mid-day—and subtractive in east longitude, or the time before mid-day. When the declination is decreasing, the contrary rule is to be applied.

TABLE VII.

The Right Ascensions and Declinations of Fixed Stars.

This table contains the right ascensions and declinations of 60 principal stars, adapted to the beginning of the year 1812. Columns fourth and sixth contain the annual variations arising from the precession of the equinoxes, and the proper motion of the stars, which will serve to reduce the place of a star to a period of a few years after the epoch of the table with sufficient accuracy. When the place of a star is wanted after the beginning of 1812, the variation in right ascension is to be added, and that in declination is to be applied according to its sign; the contrary rule is to be used when the given time is before 1812. The stars marked with an asterisk are those employed in the Nautical Almanac for finding the Longitude by Lunar observations.

TABLE VIII.

For Finding the Moon's Age.

This table contains the moon's age for a period of 95 years. It is divided into two parts; the first of which contains the months and days, and the other the years, with the corresponding age of the moon. In this last part, N. stands for new moon, and F. for full moon.—The manner of using this table is obvious. It is also explained in page 139.

TABLE I.

DIP OF THE HORIZON.

Height in Feet.	Dip.	Height in Feet.	Dip.	Height in Feet.	Dip.
	′		′		′
0 4	0.6	18	4.1	110	10.0
0 8	0.8	19	4.2	120	10.5
1 0	1.0	20	4.3	130	10.9
1 6	1.2	22	4.5	140	11.3
2 0	1.4	24	4.7	150	11.7
3 0	1.7	26	4.9	160	12.0
4 0	1.9	28	5.0	170	12.4
5 0	2.1	30	5.2	180	12.8
6 0	2.3	35	5.6	190	13.1
7 0	2.5	40	6.0	200	13.5
8 0	2.7	45	6.4	210	13.8
9 0	2.9	50	6.7	220	14.1
10 0	3.0	55	7.1	230	14.4
11 0	3.2	60	7.4	240	14.7
12 0	3.3	65	7.7	250	15.1
13 0	3.4	70	8.0	260	15.4
14 0	3.6	75	8.2	270	15.7
15 0	3.7	80	8.5	280	16.0
16 0	3.8	90	9.0	290	16.2
17 0	4.0	100	9.5	300	16.5

TABLE II.

DIP OF THE SEA AT DIFFERENT DISTANCES FROM THE OBSERVER.

Distance of land in sea miles.	Ht. of the eye above the sea, in feet.							
	5	10	15	20	25	30	35	40
	Dip	Dip	Dip	Dip	Dip	Dip	Dip	Dip
miles. ten.	′	′	′	′	′	′	′	′
0 1	28	56	85	113	141	170	198	226
0 2	14	28	42	56	71	85	99	113
0 3	9	19	28	38	47	56	66	75
0 4	7	14	21	28	35	42	49	57
0 5	6	11	17	22	28	34	39	45
0 6	5	9	14	19	23	28	33	38
0 7	4	8	12	16	20	24	28	32
0 8	4	7	11	14	18	21	25	28
0 9	3	6	9	13	16	19	22	25
1 0	3	6	9	11	14	17	20	23
1 ¼	3	5	7	9	12	14	16	19
1 ½	3	4	6	8	10	11	14	15
1 ¾	2	3	5	7	8	10	12	13
2 0	2	3	5	6	8	10	11	12
2 ½	2	3	5	6	7	8	9	10
3 0	2	3	4	5	6	7	8	8
3 ½	2	3	4	5	6	6	7	7
4 0	2	3	4	4	5	6	7	7
5 0	2	3	4	4	5	5	6	6
6 0	2	3	4	4	5	5	6	6

TABLE III.

REFRACTION IN ALTITUDE.

Alt.	Refra.	Alt.	Refra.	Alt.	Refra.
0° 0′	33′ 0″	5° 40′	8′ 54″	23°	2′ 14″
0 5	32 10	5 50	8 41	24	2 7
0 10	31 22	6 0	8 28	25	2 2
0 15	30 35	6 10	8 15	26	1 56
0 20	29 50	6 20	8 3	27	1 51
0 25	29 6	6 30	7 51	28	1 47
0 30	28 22	6 40	7 40	29	1 42
0 35	27 41	6 50	7 30	30	1 38
0 40	27 0	7 0	7 20	31	1 35
0 45	26 20	7 10	7 11	32	1 31
0 50	25 42	7 20	7 2	33	1 28
0 55	25 5	7 30	6 53	34	1 24
1 0	24 49	7 40	6 45	35	1 21
1 5	23 54	7 50	6 37	36	1 18
1 10	23 20	8 0	6 29	37	1 16
1 15	22 47	8 10	6 22	38	1 13
1 20	22 15	8 20	6 15	39	1 10
1 25	21 44	8 30	6 8	40	1 8
1 30	21 15	8 40	6 1	41	1 5
1 35	20 46	8 50	5 55	42	1 3
1 40	20 18	9 0	5 48	43	1 1
1 45	19 51	9 10	5 42	44	0 59
1 50	19 25	9 20	5 36	45	0 57
1 55	19 0	9 30	5 31	46	0 55
2 0	18 35	9 40	5 25	47	0 53
2 5	18 11	9 50	5 20	48	0 51
2 10	17 48	10 0	5 15	49	0 49
2 15	17 26	10 15	5 7	50	0 48
2 20	17 4	10 30	5 0	51	0 46
2 25	16 44	10 45	4 53	52	0 44
2 30	16 24	11 0	4 47	53	0 43
2 35	16 4	11 15	4 40	54	0 41
2 40	15 45	11 30	4 34	55	0 40
2 45	15 27	11 45	4 29	56	0 38
2 50	15 9	12 0	4 23	57	0 37
2 55	14 52	12 20	4 16	58	0 35
3 0	14 36	12 40	4 9	59	0 34
3 5	14 20	13 0	4 3	60	0 33
3 10	14 4	13 20	3 57	61	0 32
3 15	13 49	13 40	3 51	62	0 30
3 20	13 34	14 0	3 45	63	0 29
3 25	13 20	14 20	3 40	64	0 28
3 30	13 6	14 40	3 35	65	0 26
3 40	12 40	15 0	3 30	66	0 25
3 50	12 15	15 30	3 24	67	0 24
4 0	11 51	16 0	3 17	68	0 23
4 10	11 29	16 30	3 10	69	0 22
4 20	11 8	17 0	3 4	70	0 21
4 30	10 48	17 30	2 59	72	0 18
4 40	10 29	18 0	2 54	74	0 16
4 50	10 11	18 30	2 49	76	0 14
5 0	9 54	19 0	2 44	78	0 12
5 10	9 38	20 0	2 35	80	0 10
5 20	9 23	21 0	2 27	85	0 5
5 30	9 8	22 0	2 20	90	0 0

TABLE IV.

Declination of the Sun for the Year 1811, (or 1815, 1819, 1823, 1827,) Being the First before Leap Year.

	MONTHS.											
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Octr.	Nov.	Dec.
Days.	South.	South.	N.&S.	North	North	North	North	North	N.&S.	South.	South.	South.
1	23° 4′	17°16′	7°48′	4°18′	14°53′	21°58′	23°11′	18°13′	8°32′	2°56′	14°15′	21°44′
2	22 59	16 59	7 25	4 42	15 11	22 7	23 7	17 58	8 11	3 19	14 34	21 53
3	22 54	16 41	7 3	5 5	15 29	22 15	23 2	17 42	7 49	3 43	14 53	22 2
4	22 48	16 24	6 40	5 28	15 47	22 22	22 58	17 27	7 27	4 6	15 12	22 11
5	22 41	16 6	6 17	5 50	16 4	22 29	22 52	17 11	7 4	4 29	15 31	22 19
6	22 35	15 47	5 53	6 13	16 21	22 36	22 47	16 55	6 42	4 52	15 49	22 27
7	22 27	15 29	5 30	6 36	16 38	22 42	22 41	16 38	6 20	5 15	16 7	22 34
8	22 20	15 10	5 7	6 58	16 55	22 48	22 35	16 21	5 57	5 38	16 25	22 41
9	22 12	14 51	4 43	7 21	17 11	22 53	22 28	16 4	5 35	6 1	16 42	22 47
10	22 3	14 32	4 20	7 43	17 27	22 59	22 21	15 47	5 12	6 24	16 59	22 53
11	21 54	14 13	3 57	8 5	17 43	23 3	22 13	15 30	4 49	6 47	17 16	22 58
12	21 45	13 53	3 33	8 27	17 58	23 7	22 5	15 12	4 26	7 10	17 33	23 3
13	21 35	13 33	3 9	8 49	18 14	23 11	21 57	14 54	4 4	7 32	17 49	23 8
14	21 25	13 13	2 46	9 11	18 28	23 15	21 49	14 36	3 41	7 55	18 5	23 12
15	21 14	12 52	2 22	9 33	18 43	23 18	21 40	14 17	3 17	8 17	18 21	23 16
16	21 3	12 32	1 59	9 54	18 57	23 20	21 30	13 58	2 54	8 40	18 36	23 19
17	20 52	12 11	1 35	10 15	19 11	23 23	21 20	13 40	2 31	9 2	18 51	23 21
18	20 40	11 50	1 11	10 36	19 25	23 25	21 10	13 20	2 8	9 24	19 6	23 24
19	20 28	11 29	0 47	10 57	19 38	23 26	21 0	13 1	1 45	9 46	19 21	23 25
20	20 15	11 7	0 24	11 18	19 51	23 27	20 49	12 41	1 21	10 7	19 35	23 27
21	20 2	10 46	0 0	11 39	20 3	23 28	20 38	12 22	0 58	10 29	19 48	23 27
			North									
22	19 49	10 24	0 24	11 59	20 16	23 28	20 26	12 2	0 35	10 50	20 2	23 28
23	19 35	10 2	0 47	12 19	20 28	23 27	20 14	11 41	0 11	11 12	20 14	23 28
									South.			
24	19 21	9 40	1 11	12 39	20 39	23 27	20 2	11 21	0 12	11 33	20 27	23 27
25	19 6	9 18	1 35	12 59	20 50	23 26	19 50	11 1	0 36	11 54	20 39	23 26
26	18 52	8 56	1 58	13 19	21 1	23 24	19 37	10 40	0 59	12 15	20 51	23 24
27	18 36	8 33	2 22	13 38	21 12	23 22	19 24	10 19	1 23	12 35	21 2	23 22
28	18 21	8 11	2 45	13 57	21 22	23 20	19 10	9 58	1 46	12 55	21 13	23 20
29	18 5		3 9	14 16	21 32	23 17	18 56	9 37	2 9	13 16	21 24	23 17
30	17 49		3 32	14 35	21 41	23 14	18 42	9 15	2 33	13 36	21 34	23 13
31	17 32		3 55		21 50		18 28	8 54		13 55		23 9

TABLE V.

Change of the Sun's Declination for Periods of Four Years.

Periods of complete Years.	MONTHS.															Periods of complete Years.
	JANUARY.					*FEBRUARY.*					*MARCH.*					
	DAYS.					DAYS.					DAYS.					
	1	7	13	19	25	1	7	13	19	25	1	7	13	19	25	
	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	
4	0′.1	0′.2	0′.3	0′.4	0′.4	0′.5	0′.5	0′.6	0′.6	0′.7	0′.7	0′.7	0′.7	0′.7	0′.7	4
8	0.3	0 .4	0 .6	0 .7	0 .8	1 .0	1 .1	1 .2	1 .2	1 .3	1 .3	1 .4	1 .4	1 .4	1 .4	8
12	0 .4	0 .7	0 .9	1 .1	1 .3	1 .5	1 .6	1 .7	1 .9	2 .0	2 .0	2 .1	2 .1	2 .1	2 .1	12
16	0 .6	0 .9	1 .2	1 .4	1 .7	2 .0	2 .2	2 .3	2 .5	2 .6	2 .7	2 .7	2 .8	2 .8	2 .8	16
20	0 .7	1 .1	1 .5	1 .8	2 .1	2 .5	2 .7	2 .9	3 .1	3 .3	3 .4	3 .5	3 .5	3 .6	3 .6	20

TABLE IV.

Declination of the Sun for the Year 1812, (or 1816, 1820, 1824, 1828,) being Leap Year.

	MONTHS.											
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Octr.	Nov.	Dec.
Days.	South.	South.	S.&N.	North	North	North	North	North	N.&S.	South.	South.	South.
1	23° 5′	17°20′	7°31′	4°36′	15° 7′	22° 5′	23° 8′	18° 1′	8°16′	3°14′	14°29′	21°51′
2	23 0	17 3	7 8	4 59	15 25	22 13	23 3	17 46	7 54	3 37	14 48	22 0
3	22 55	16 46	6 45	5 22	15 42	22 20	22 59	17 31	7 32	4 0	15 7	22 9
4	22 49	16 28	6 22	5 45	16 0	22 27	22 54	17 15	7 10	4 24	15 26	22 17
5	22 43	16 10	5 59	6 7	16 17	22 34	22 48	16 59	6 48	4 47	15 44	22 25
6	22 36	15 52	5 36	6 30	16 34	22 40	22 42	16 42	6 25	5 10	16 2	22 32
7	22 29	15 34	5 13	6 53	16 51	22 46	22 36	16 26	6 3	5 33	16 20	22 39
8	22 22	15 15	4 49	7 15	17 7	22 52	22 29	16 9	5 40	5 56	16 38	22 45
9	22 14	14 56	4 26	7 36	17 23	22 57	22 22	15 51	5 18	6 19	16 55	22 51
10	22 5	14 37	4 2	8 0	17 39	23 2	22 15	15 34	4 55	6 42	17 12	22 57
11	21 56	14 17	3 39	8 22	17 55	23 6	22 7	15 16	4 32	7 4	17 29	23 2
12	21 47	13 58	3 15	8 44	18 10	23 10	21 59	14 58	4 9	7 27	17 45	23 7
13	21 37	13 38	2 52	9 6	18 25	23 14	21 51	14 40	3 46	7 49	18 1	23 11
14	21 27	13 18	2 28	9 27	18 39	23 17	21 42	14 22	3 23	8 12	18 17	23 15
15	21 17	12 57	2 4	9 49	18 54	23 20	21 32	14 3	3 0	8 34	18 33	23 18
16	21 6	12 37	1 41	10 10	19 8	23 22	21 23	13 44	2 37	8 56	18 48	23 21
17	20 54	12 16	1 17	10 31	19 21	23 24	21 13	13 25	2 14	9 18	19 3	23 23
18	20 43	11 55	0 53	10 52	19 35	23 26	21 2	13 6	1 50	9 40	19 17	23 25
19	20 30	11 34	0 29	11 13	19 48	23 27	20 52	12 46	1 27	10 2	19 31	23 26
20	20 18	11 13	0 6	11 34	20 0	23 27	20 40	12 26	1 4	10 24	19 45	23 27
			North									
21	20 5	10 51	0 18	11 54	20 13	23 28	20 29	12 7	0 40	10 45	19 58	23 28
22	19 52	10 29	0 42	12 14	20 25	23 27	20 17	11 46	0 17	11 6	20 11	23 27
									South.			
23	19 38	10 8	1 5	12 34	20 36	23 27	20 5	11 26	0 6	11 28	20 24	23 27
24	19 24	9 46	1 29	12 54	20 48	23 26	20 53	11 6	0 30	11 49	20 36	23 26
25	19 10	9 24	1 52	13 14	20 58	23 24	20 40	10 45	0 53	12 9	20 48	23 25
26	18 55	9 1	2 16	13 33	21 9	23 23	20 27	10 24	1 17	12 30	21 0	23 23
27	18 40	8 39	2 39	13 52	21 19	23 20	20 13	10 3	1 40	12 50	21 11	23 20
28	18 25	8 16	3 3	14 11	21 29	23 18	20 0	9 42	2 4	13 11	21 21	23 17
29	18 9	7 54	3 26	14 30	21 38	23 15	18 46	9 21	2 27	13 31	21 32	23 14
30	17 53		3 49	14 48	21 48	23 11	18 31	8 59	2 50	13 50	21 42	23 10
31	17 36		4 13		21 56		18 16	8 38		14 10		23 6

TABLE V.

Change of the Sun's Declination for Periods of Four Years.

Periods of complete Years.	MONTHS.															Periods of complete Years.
	APRIL.					MAY.					JUNE.					
	DAYS.					DAYS.					DAYS.					
	1	7	13	19	25	1	7	13	19	25	1	7	13	19	25	
	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	
4	0′.7	0′.7	0′.7	0′.6	0′.6	0′.6	0′.5	0′.5	0′.4	0′.3	0′.3	0′.2	0′.1	0′.0	0′.1	4
8	1 .4	1 .4	1 .3	1 .3	1 .2	1 .1	1 .0	0 .9	0 .8	0 .7	0 .5	0 .4	0 .2	0 .0	0 .1	8
12	2 .1	2 .1	2 .0	1 .9	1 .8	1 .7	1 .6	1 .4	1 .2	1 .0	0 .8	0 .5	0 .3	0 .1	0 .2	12
16	2 .8	2 .7	2 .6	2 .5	2 .4	2 .3	2 .1	1 .9	1 .6	1 .3	1 .0	0 .7	0 .4	0 .1	0 .3	16
20	3 .5	3 .4	3 .3	3 .2	3 .0	2 .8	2 .6	2 .3	2 .0	1 .6	1 .3	0 .9	0 .5	0 .1	0 .3	20

TABLE IV.

Declination of the Sun for the Year 1813, (or 1817, 1821, 1825, 1829,) Being the First after Leap Year.

	MONTHS.											
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Octr.	Nov.	Dec.
Days.	South.	South.	S.&N.	North	North	North	North	North	N.&S.	South.	South.	South
1	23° 1′	17° 7′	7° 37′	4° 30′	15° 2′	22° 3′	23° 9′	18° 5′	8° 21′	3° 8′	14° 25′	21° 49′
2	22 56	16 50	7 14	4 53	15 21	22 11	23 5	17 50	7 59	3 31	14 44	21 58
3	22 51	16 32	6 51	5 16	15 38	22 18	23 0	17 35	7 37	3 55	15 3	22 7
4	22 45	16 14	6 28	5 39	15 56	22 26	22 55	17 19	7 15	4 18	15 22	22 15
5	22 38	15 56	6 5	6 2	16 13	22 33	22 50	17 3	6 53	4 41	15 40	22 23
6	22 31	15 38	5 41	6 25	16 30	22 39	22 44	16 46	6 31	5 4	15 58	22 30
7	22 24	15 19	5 18	6 47	16 47	22 45	22 38	16 30	6 8	5 27	16 16	22 37
8	22 16	15 0	4 55	7 10	17 3	22 51	22 31	16 13	5 46	5 50	16 34	22 44
9	22 7	14 41	4 31	7 32	17 20	22 56	22 24	15 56	5 23	6 13	16 51	22 50
10	21 59	14 22	4 8	7 55	17 35	23 1	22 17	15 38	5 1	6 36	17 8	22 56
11	21 49	14 2	3 44	8 17	17 51	23 5	22 9	15 21	4 38	6 59	17 25	23 1
12	21 40	13 43	3 21	8 39	18 6	23 10	22 1	15 3	4 15	7 21	17 41	23 6
13	21 30	13 22	2 57	9 0	18 21	23 13	21 53	14 45	3 52	7 44	17 58	23 10
14	21 19	13 2	2 34	9 22	18 36	23 16	21 44	14 26	3 29	8 6	18 13	23 14
15	21 9	12 42	2 10	9 43	18 50	23 19	21 35	14 8	3 6	8 29	18 29	23 17
16	20 57	12 21	1 46	10 5	19 4	23 22	21 25	13 49	2 43	8 51	18 45	23 20
17	20 46	12 0	1 23	10 26	19 18	23 24	21 15	13 30	2 19	9 13	18 59	23 23
18	20 34	11 39	0 59	10 47	19 32	23 25	21 5	13 11	1 56	9 35	19 14	23 25
19	20 21	11 18	0 35	11 8	19 45	23 27	20 54	12 51	1 33	9 57	19 28	23 26
20	20 8	10 56	0 12	11 29	19 57	23 27	20 43	12 32	1 10	10 18	19 42	23 27
			North									
21	19 55	10 35	0 12	11 49	20 10	23 28	20 32	12 12	0 46	10 40	19 55	23 28
22	19 42	10 13	0 36	12 9	20 22	23 28	20 20	11 52	0 23	11 1	20 8	23 28
									South.			
23	19 28	9 51	0 59	12 30	20 34	23 27	20 8	11 31	0 1	11 22	20 21	23 27
24	19 13	9 29	1 23	12 49	20 45	23 26	19 56	11 11	0 24	11 44	20 33	23 26
25	18 59	9 7	1 47	13 9	20 56	23 25	19 43	10 50	0 48	12 4	20 45	23 25
26	18 44	8 44	2 10	13 29	21 7	23 23	19 30	10 29	1 11	12 25	20 57	23 23
27	18 29	8 22	2 34	13 48	21 17	23 21	19 17	10 8	1 34	12 46	21 8	23 21
28	18 13	7 59	2 57	14 7	21 27	23 19	19 3	9 47	1 58	13 6	21 19	23 18
29	17 57		3 20	14 26	21 36	23 16	18 49	9 26	2 21	13 26	21 29	23 15
30	17 41		3 44	14 44	21 46	23 12	18 35	9 5	2 45	13 46	21 39	23 11
31	17 24		4 7		21 54		18 20	8 43		14 5		23 7

TABLE V.

Change of the Sun's Declination for Periods of Four Years.

Periods of complete Years.	MONTHS.															Periods of complete Years.
	JULY.					AUGUST.					SEPTEMBER.					
	DAYS.					DAYS.					DAYS.					
	1	7	13	19	25	1	7	13	19	25	1	7	13	19	25	
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	
4	0′.1	0′.2	0′.3	0′.4	0′.4	0′.5	0′.5	0′.6	0′.6	0′.7	0′.7	0′.7	0′.7	0′.7	0′.7	4
8	0 .3	0 .4	0 .6	0 .7	0 .9	1 .0	1 .1	1 .2	1 .3	1 .3	1 .4	1 .4	1 .4	1 .4	1 .4	8
12	0 .4	0 .7	0 .9	1 .1	1 .3	1 .5	1 .6	1 .8	1 .9	2 .0	2 .0	2 .1	2 .1	2 .1	2 .1	12
16	0 .6	0 .9	1 .2	1 .4	1 .7	2 .0	2 .2	2 .4	2 .5	2 .6	2 .7	2 .8	2 .8	2 .9	2 .9	16
20	0 .7	1 .1	1 .5	1 .8	2 .2	2 .5	2 .7	3 .0	3 .2	3 .3	3 .4	3 .5	3 .5	3 .6	3 .6	20

TABLE IV.

Declination of the Sun for the Year 1814, (or 1818, 1822, 1826, 1830,) Being the Second after Leap Year.

	MONTHS.											
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Octr.	Nov.	Dec.
Days.	South.	South.	S.&N.	North	North	North	North	North	N.&S.	South.	South.	South.
1	23° 3′	17°11	7°42′	4°25′	14°58′	22° 1′	23°10′	18° 9′	8°27′	3° 2′	14°20′	21°47′
2	22 58	16 54	7 19	4 48	15 16	22 9	23 6	17 54	8 5	3 26	14 39	21 56
3	22 52	16 37	6 56	5 11	15 34	22 17	23 1	17 38	7 43	3 49	14 58	22 5
4	22 46	16 19	6 33	5 34	15 52	22 24	22 56	17 23	7 21	4 12	15 17	22 13
5	22 40	16 1	6 10	5 56	16 9	22 31	22 51	17 7	6 59	4 35	15 36	22 21
6	22 33	15 43	5 47	6 19	16 26	22 38	22 45	16 50	6 36	4 59	15 54	22 29
7	22 25	15 24	5 24	6 42	16 43	22 44	22 39	16 34	6 14	5 22	16 12	22 36
8	22 18	15 5	5 1	7 4	16 59	22 49	22 33	16 17	5 51	5 45	16 30	22 43
9	22 9	14 46	4 37	7 27	17 16	22 55	22 26	16 0	5 29	6 8	16 47	22 49
10	22 1	14 27	4 14	7 49	17 32	23 0	22 19	15 43	5 6	6 30	17 4	22 55
11	21 52	14 7	3 50	8 11	17 47	23 4	22 11	15 25	4 43	6 53	17 21	23 0
12	21 42	13 48	3 27	8 33	18 3	23 9	22 3	15 7	4 20	7 16	17 38	23 5
13	21 32	13 28	3 3	8 55	18 18	23 12	21 55	14 49	3 57	7 39	17 54	23 9
14	21 22	13 7	2 40	9 17	18 32	23 16	21 46	14 31	3 34	8 1	18 9	23 13
15	21 11	12 47	2 16	9 38	18 47	23 19	21 37	14 12	3 11	8 23	18 25	23 17
16	21 0	12 26	1 52	10 0	19 1	23 21	21 28	13 53	2 48	8 46	18 41	23 20
17	20 49	12 5	1 28	10 21	19 15	23 23	21 18	13 34	2 25	9 8	18 56	23 22
18	20 37	11 44	1 5	10 42	19 28	23 25	21 8	13 15	2 2	9 30	19 10	23 24
19	20 24	11 23	0 41	11 3	19 41	23 26	20 57	12 56	1 38	9 52	19 24	23 26
20	20 12	11 2	0 17	11 24	19 54	23 27	20 46	12 36	1 15	10 13	19 38	23 27
			North									
21	19 58	10 40	0 6	11 44	20 7	23 28	20 35	12 16	0 52	10 35	19 52	23 28
22	19 45	10 18	0 30	12 5	20 19	23 28	20 23	11 56	0 28	10 56	20 5	23 28
23	19 31	9 56	0 54	12 25	20 31	23 27	20 11	11 36	0 5	11 18	20 18	23 27
									South.			
24	19 17	9 34	1 17	12 45	20 42	23 26	19 59	11 16	0 19	11 39	20 30	23 27
25	19 2	9 12	1 41	13 4	20 53	23 25	19 46	10 55	0 42	11 59	20 43	23 26
26	18 47	8 50	2 4	13 24	21 4	23 24	19 33	10 34	1 5	12 20	20 54	23 24
27	18 32	8 27	2 28	13 43	21 14	23 22	19 20	10 13	1 29	12 41	21 5	23 22
28	18 17	8 5	2 51	14 2	21 24	23 19	19 6	9 52	1 52	13 1	21 16	23 19
29	18 1		3 15	14 21	21 34	23 17	18 53	9 31	2 16	13 21	21 27	23 16
30	17 45		3 38	14 40	21 43	23 13	18 38	9 10	2 39	13 41	21 37	23 12
31	17 28		4 1		21 52		18 24	8 48		14 1		23 8

TABLE V.

Change of the Sun's Declination for Periods of Four Years.

Periods of complete Years.	MONTHS.															Periods of complete Years.
	OCTOBER.					*NOVEMBER.*					*DECEMBER.*					
	Days.					Days.					Days.					
	1	7	13	19	25	1	7	13	19	25	1	7	13	19	25	
	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	
4	0′.7	0′.7	0′.7	0′.6	0′.6	0′.5	0′.5	0′.4	0′.4	0′.3	0′.2	0′.2	0′.1	0′.0	0′.0	4
8	1 .4	1 .4	1 .3	1 .3	1 .2	1 .1	0 .0	0 .9	0 .8	0 .7	0 .5	0 .4	0 .2	0 .0	0 .1	8
12	2 .1	2 .0	2 .0	1 .9	1 .8	1 .6	1 .5	1 .3	1 .2	1 .0	0 .7	0 .5	0 .3	0 .1	0 .1	12
16	2 .8	2 .7	2 .6	2 .5	2 .4	2 .2	1 .0	1 .8	1 .5	1 .3	1 .0	0 .7	0 .4	0 .1	0 .2	16
20	3 .5	3 .4	3 .3	3 .2	3 .0	2 .8	2 .5	2 .2	2 .0	1 .7	1 .3	0 .9	0 .5	0 .2	0 .3	20

 TABLE VI. To reduce the Sun's Declination to any given Meridian, and to any given Time under that Meridian.

	Add. in W. Sub. in E.		Sub. in W. Add. in E.	LONGITUDE. 10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°	160°	170°	180°		Add. in W. Sub. in E.		Sub. in W. Add. in E.
December.	20	December.	22	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	June.	20	June.	22
	19		23	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4		19		23
	18		24	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6		18		24
	17		25	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9		17		25
	16		26	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1		16		26
	15		27	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.8	0.9	0.9	1.0	1.1	1.2	1.2	1.3		15		27
	14		28	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.9	1.0	1.1	1.2	1.3	1.4	1.4	1.5		14		28
	13		29	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8		13		29
	11		31	0.1	0.2	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8	1.9	2.1	2.2		11		1
	10		1	0.1	0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.0	2.1	2.3	2.4		10		2
	9		2	0.1	0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5	1.6	1.8	1.9	2.0	2.2	2.3	2.5	2.6		9		3
	8		3	0.1	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.4	1.6	1.7	1.9	2.1	2.2	2.4	2.5	2.7	2.8		8		4
	7		4	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.7	2.9	3.1		7		5
	6		5	0.2	0.4	0.5	0.7	0.9	1.1	1.3	1.4	1.6	1.8	2.0	2.2	2.4	2.5	2.7	2.9	3.1	3.3		6		6
	5		6	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5		5		7
	4		7	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7		4		8
	3	January.	8	0.2	0.4	0.6	0.9	1.1	1.3	1.5	1.7	1.9	2.2	2.4	2.6	2.8	3.0	3.2	3.5	3.7	3.9		3	July.	9
	1		10	0.2	0.5	0.7	0.9	1.2	1.4	1.7	1.9	2.1	2.4	2.6	2.9	3.1	3.3	3.6	3.8	4.1	4.3		1		11
	29		12	0.3	0.5	0.8	1.0	1.3	1.6	1.8	2.1	2.3	2.6	2.9	3.1	3.4	3.6	3.9	4.2	4.4	4.7		30		13
	27		14	0.3	0.6	0.8	1.1	1.4	1.7	2.0	2.3	2.5	2.8	3.1	3.4	3.7	4.0	4.2	4.5	4.8	5.1		28		15
	25		16	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.3	4.6	4.9	5.2	5.5		26		17
	23		18	0.3	0.6	1.0	1.3	1.6	1.9	2.3	2.6	2.9	3.2	3.6	3.9	4.2	4.5	4.9	5.2	5.5	5.8		24		19
	21		20	0.3	0.7	1.0	1.4	1.7	2.1	2.4	2.8	3.1	3.4	3.8	4.1	4.5	4.8	5.2	5.5	5.9	6.2		22		21
	19		22	0.4	0.7	1.1	1.5	1.8	2.2	2.5	2.9	3.3	3.6	4.0	4.4	4.7	5.1	5.5	5.8	6.2	6.6		20		23
November.	17		24	0.4	0.8	1.1	1.5	1.9	2.3	2.7	3.1	3.4	3.8	4.2	4.6	5.0	5.4	5.7	6.1	6.5	6.9	May.	18		25
	15		26	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0	6.4	6.8	7.2		16		27
	13		28	0.4	0.8	1.3	1.7	2.1	2.5	2.9	3.4	3.8	4.2	4.6	5.0	5.5	5.9	6.3	6.7	7.1	7.6		14		29
	11		30	0.4	0.9	1.3	1.7	2.2	2.6	3.1	3.5	3.9	4.4	4.8	5.2	5.7	6.1	6.6	7.0	7.4	7.9		12		31
	9		1	0.4	0.9	1.4	1.8	2.3	2.7	3.2	3.6	4.1	4.5	5.0	5.4	5.9	6.4	6.8	7.3	7.7	8.2		10		2
	7		3	0.5	0.9	1.4	1.9	2.3	2.8	3.3	3.8	4.2	4.7	5.2	5.6	6.1	6.6	7.0	7.5	8.0	8.5		8		4
	5		5	0.5	1.0	1.4	1.9	2.4	2.9	3.4	3.9	4.3	4.8	5.3	5.8	6.3	6.8	7.3	7.7	8.2	8.7		6		6
	3		7	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0		4		8
	1	February.	9	0.5	1.0	1.5	2.0	2.5	3.1	3.6	4.1	4.6	5.1	5.6	6.1	6.7	7.2	7.7	8.2	8.7	9.2		2		10
	30		11	0.5	1.0	1.6	2.1	2.6	3.1	3.7	4.2	4.7	5.3	5.8	6.3	6.8	7.3	7.9	8.4	8.9	9.5		30	August.	12
	28		13	0.5	1.1	1.6	2.1	2.7	3.2	3.8	4.3	4.8	5.4	5.9	6.5	7.0	7.5	8.1	8.6	9.1	9.7		28		14
October.	26		15	0.5	1.1	1.6	2.2	2.7	3.3	3.8	4.4	4.9	5.5	6.0	6.6	7.2	7.7	8.2	8.8	9.3	9.9	April.	26		16
	24		17	0.6	1.1	1.7	2.2	2.8	3.4	3.9	4.5	5.0	5.6	6.2	6.7	7.3	7.9	8.4	9.0	9.6	10.1		24		18
	21		20	0.6	1.1	1.7	2.3	2.9	3.5	4.0	4.6	5.2	5.8	6.3	6.9	7.5	8.1	8.7	9.2	9.8	10.4		21		21
	18		23	0.6	1.2	1.8	2.4	3.0	3.5	4.1	4.7	5.3	5.9	6.5	7.1	7.7	8.3	8.9	9.5	10.0	10.6		18		24
	15		26	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0	6.6	7.2	7.9	8.5	9.1	9.7	10.3	10.9		15		27
	12	March.	1	0.6	1.2	1.8	2.5	3.1	3.7	4.3	4.9	5.5	6.2	6.8	7.4	8.0	8.6	9.2	9.8	10.5	11.1		12		30
	9		4	0.6	1.2	1.9	2.5	3.1	3.7	4.4	5.0	5.6	6.3	6.9	7.5	8.1	8.8	9.4	10.0	10.6	11.3		9	September.	2
	6		7	0.6	1.3	1.9	2.5	3.2	3.8	4.4	5.1	5.7	6.3	7.0	7.6	8.2	8.9	9.5	10.1	10.8	11.4		6		5
	3		10	0.6	1.3	1.9	2.6	3.2	3.8	4.5	5.1	5.8	6.4	7.0	7.7	8.3	9.0	9.6	10.3	10.9	11.5		3		8
Sept.	30		13	0.6	1.3	1.9	2.6	3.2	3.9	4.5	5.2	5.8	6.5	7.1	7.7	8.4	9.0	9.7	10.3	11.0	11.6	March.	31		11
	27		16	0.7	1.3	1.9	2.6	3.2	3.9	4.5	5.2	5.8	6.5	7.1	7.8	8.4	9.1	9.7	10.4	11.0	11.7		28		14
	24		19	0.7	1.3	1.0	2.6	3.2	3.9	4.5	5.2	5.9	6.5	7.2	7.8	8.5	9.1	9.8	10.4	11.1	11.7		28		17
	Add. aft. N. Sub. bef. N.		Sub. aft. N. Add. bef. N.	h $0\frac{2}{3}$	h $1\frac{1}{3}$	h 2.0	h $2\frac{2}{3}$	h $3\frac{1}{3}$	h 4.0	h $4\frac{2}{3}$	h $5\frac{1}{3}$	h 6.0	h $6\frac{2}{3}$	h $7\frac{1}{3}$	h 8.0	h $8\frac{2}{3}$	h $9\frac{1}{3}$	h 10.0	h $10\frac{2}{3}$	h $11\frac{1}{3}$	h 12.0		Add. aft. N. Sub. bef. N.		Sub. aft. N. Add. bef. N.

TIME FROM NOON.

TABLE VII.

Right Ascensions and Declinations of the Principal Fixed Stars, adapted to the Beginning of the Year 1812.

Names of Stars.	Mag.	Right Ascension in Time	An. Var	Declination.	Ann. Var.
γ Pegasi - - *Algenib*	2	0h 3′ 34″	3″.06	14° 8′ 26″ N	+ 20″.0
α Cassiopeiæ - *Schedar*	3	0 29 54	3.31	55 29 56 N	+ 19.9
α Ursæ Minoris *Alruccabah*, p. Star	2.3	0 54 56	12.89	88 18 20 N	+ 19.6
β Andromedæ - *Mirach*	2	0 59 14	3.30	34 31 22 N	+ 19.4
α Eridane - - *Achernar*	1	1 30 42	2.25	58 19 5 S	— 18.5
γ Andromedæ - *Almach*	2	1 52 24	3.61	41 22 21 N	+ 17.7
α Arietis *	2.3	1 56 35	3.33	22 33 11 N	+ 17.5
α Ceti - - - *Menkar*	2	2 52 27	3.12	3 19 27 N	+ 14.6
β Persei - - *Algol*	Vari.	2 55 58	3.85	40 13 25 N	+ 14.4
η Pleiadum - *Alcyone*	3	3 35 55	3.54	23 30 58 N	+ 11.7
α Tauri * - - *Aldebaran*	1	4 25 8	3.42	16 7 19 N	+ 8.1
α Aurigæ - - *Capella*	1	5 2 49	4.41	45 47 33 N	+ 5.0
β Orionis - - *Rigel*	1	5 5 31	2.87	8 26 46 S	— 4.8
β Tauri	2	5 14 25	3.78	28 26 16 N	+ 4.0
η Orionis - - *Bellatrix*	2	5 15 2	3.21	6 10 11 N	+ 4.0
δ Orionis	2	5 22 24	3.06	0 27 45 S	— 3.3
ε Orionis	2	5 26 40	3.04	1 19 46 S	— 3.0
ζ Orionis	2	5 31 7	3.02	2 2 1 S	— 2.6
α Columbæ	2	5 32 50	2.17	34 10 46 S	— 2.4
α Orionis - - *Betelguese*	1	5 44 59	3.24	7 21 34 N	+ 1.4
α Navis - - - *Canopus*	1	6 19 47	1.33	52 35 48 S	+ 1.7
α Canis Majoris *Sirius*	1	6 36 51	2.65	16 27 51 S	+ 4.3
α Geminorum - *Castor*	1.2	7 22 35	3.85	32 17 22 N	— 6.9
α Canis Minoris *Procyon*	1.2	7 29 27	3.14	5 42 0 N	— 7.5
β Geminorum * *Pollux*	2.3	7 33 47	3.69	28 23 15 N	— 7.9
ι Navis	2	8 18 39	1.25	58 54 35 S	+ 11.4
α 2 Canori - - *Acubens*	4.3	8 48 12	3.29	12 34 54 N	— 13.2
α Hydræ - - *Alphard*	2	9 18 20	2.93	7 50 56 S	+ 15.2
α Leonis * - - *Regulus*	1	9 58 20	3.20	12 52 55 N	— 17.2
β Ursæ Majoris	2	10 50 24	3.71	57 24 27 N	— 19.1
α Ursæ Majoris *Dubhe*	2.1	10 52 2	3.85	62 46 57 N	— 19.2
β Leonis - - *Deneb*	2.1	11 39 26	3.06	15 37 26 N	— 19.9
γ Corvi - - - *Algorab*	3	12 6 9	3.08	16 29 50 S	+ 20.0
α Crucis	1	12 16 15	3.24	62 3 26 S	+ 20.0
γ Crucis	2	12 20 48	3.24	56 3 22 S	+ 20.0
ε Ursæ Majoris *Aliath*	2	12 45 41	2.40	57 58 59 N	— 19.7
ε Virginis - - *Vendemiatrix*	3	12 52 49	3.00	12 58 24 N	— 19.5
α Virginis * - *Spica Virginis*	1	13 15 17	3.13	10 10 28 S	+ 18.9
η Ursæ Majoris *Benetnach*	2	13 40 8	2.39	50 15 25 N	— 18.1
α Bootis - - *Arcturus*	1	14 7 4	2.72	20 9 56 S	— 19.1
γ Bootis - - *Seginus*	3	14 24 30	2.43	39 8 8 N	— 16.2
α Centauri	1	14 27 25	4.45	60 3 50 S	+ 16.1
α 2 Libræ - - *Zubenesch*	2.3	14 40 30	3.29	15 15 3 S	+ 15.3
α Coronæ Borealis *Alphacca*	2	15 26 43	2.53	27 21 26 N	— 12.4
β Scorpii	2	15 54 32	3.47	19 16 48 S	+ 10.5
α Scorpii * - *Antares*	1	16 17 53	3.64	26 0 6 S	+ 8.7
α Herculis - *Ras Algethi*	2.3	17 6 4	2.73	14 36 49 N	— 4.7
λ Scorpii - - *Lesath*	3.2	17 20 52	4.06	36 57 10 S	+ 3.5
α Ophiuchi - *Ras Alhague*	2	17 26 13	2.77	12 42 31 N	— 3.0
γ Draconis - *Rasteben*	3	17 52 15	1.39	51 30 57 N	— 0.7
α Lyræ - - - *Vega*	1	18 30 34	2.03	38 36 46 N	+ 2.6
β Cygni - - - *Albirio*	3	19 23 8	2.42	27 34 20 N	+ 7.1
α Aquilæ * - - *Altair*	1.2	19 41 36	2.92	8 22 40 N	+ 8.5
α Pavonis	1.2	20 10 42	4.84	57 19 27 S	— 10.7
α Cygni - - *Deneb*	1.2	20 35 1	2.03	44 36 50 N	+ 12.5
α Cephei - - *Alderaimen*	3	21 14 4	1.43	61 47 31 N	+ 15.0
α Canis	2	21 56 19	3.85	44 52 52 S	— 17.1
α Pisc. Australis* *Fomalhaut*	1	22 47 14	3.33	30 36 48 S	— 19.0
β Pegasi - - *Scheat*	2	22 54 40	2.87	27 3 47 N	+ 19.2
α Pegasi * - - *Markab*	2	22 55 24	2.96	14 11 48 N	+ 19.2
α Andromedæ *Alpheratz*	2	23 58 41	3.06	28 3 10 N	+ 20.0

TABLE VIII. TO FIND THE MOON's AGE.

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

TABLE IX.

To Reduce Points of the Compass to Degrees, and Conversely.

North-east Quadrant.	South-east Quadrant.	Points.	D.	M.	S.	South-west Quadrant.	North-west Quadrant.
North.	South.	0 0	0	0	0	South.	North.
N¼E	S¼E	0 ¼	2	48	45	S¼W	N¼W
N½E	S½E	0 ½	5	37	30	S½W	N½W
N¾E	S¾E	0 ¾	8	26	15	S¾W	N¾W
N*b*E	S*b*E	1 0	11	15	0	S*b*W	N*b*W
N*b*E¼E	S*b*E¼E	1 ¼	14	3	45	S*b*W¼W	N*b*W¼W
N*b*E½E	S*b*E½E	1 ½	16	52	30	S*b*W½W	N*b*W½W
N*b*E¾E	S*b*E¾E	1 ¾	19	41	15	S*b*W¾W	N*b*W¾W
NNE	SSE	2 0	22	30	0	SSW	NNW
NNE¼E	SSE¼E	2 ¼	25	18	45	SSW¼W	NNW¼W
NNE½E	SSE½E	2 ½	28	7	30	SSW½W	NNW½W
NNE¾E	SSE¾E	2 ¾	30	56	15	SSW¾W	NNW¾W
NE*b*N	SE*b*S	3 0	33	45	0	SW*b*S	NW*b*N
NE¾N	SE¾S	3 ¼	36	33	45	SW¾S	NW¾N
NE½N	SE½S	3 ½	39	22	30	SW½S	NW½N
NE¼N	SE¼S	3 ¾	42	11	15	SW¼S	NW¼N
NE	SE	4 0	45	0	0	SW	NW
NE¼E	SE¼E	4 ¼	47	48	45	SW¼W	NW¼W
NE½E	SE½E	4 ½	50	37	30	SW½W	NW½W
NE¾E	SE¾E	4 ¾	53	26	15	SW¾W	NW¾W
NE*b*E	SE*b*E	5 0	56	15	0	SW*b*W	NW*b*W
NE*b*E¼E	SE*b*E¼E	5 ¼	59	3	45	SW*b*W¼W	NW*b*W¼W
NE*b*E½E	SE*b*E½E	5 ½	61	52	30	SW*b*W½W	NW*b*W½W
NE*b*E¾E	SE*b*E¾E	5 ¾	64	41	15	SW*b*W¾W	NW*b*W¾W
ENE	ESE	6 0	67	30	0	WSW	WNW
E*b*N¾N	E*b*S¾S	6 ¼	70	18	45	W*b*S¾S	W*b*N¾N
E*b*N½N	E*b*S½S	6 ½	73	7	30	W*b*S½S	W*b*N½N
E*b*N¼N	E*b*S¼S	6 ¾	75	56	15	W*b*S¼S	W*b*N¼N
E*b*N	E*b*S	7 0	78	45	0	W*b*S	W*b*N
E¾N	E¾S	7 ¼	81	33	45	W¾S	W¾N
E½N	E½S	7 ½	84	22	30	W½S	W½N
E¼N	E¼S	7 ¾	87	11	15	W¼S	W¼N
East.	East.	8 0	90	0	0	West.	West.

TABLE X.

The Miles and Parts of a Mile in a Degree of Longitude at every Degree of Latitude.

D. L.	Miles.	D. L.	Miles.	D. L.	Miles.	D. L.	Miles.	D. L.	Miles.	D. L.	Miles.
1	59.99	16	57.67	31	51.43	46	41.68	61	29.09	76	14.52
2	59.96	17	57.38	32	50.88	47	40.92	62	28.17	77	13.50
3	59.92	18	57.06	33	50.32	48	40.15	63	27.24	78	12.47
4	59.85	19	56.73	34	49.74	49	39.36	64	26.30	79	11.45
5	59.77	20	56.38	35	49.15	50	38.57	65	25.36	80	10.42
6	59.67	21	56.01	36	48.54	51	37.76	66	24.40	81	9.39
7	59.55	22	55.63	37	47.92	52	36.94	67	23.44	82	8.35
8	59.42	23	55.23	38	47.28	53	36.11	68	22.48	83	7.31
9	59.26	24	54.81	39	46.63	54	35.27	69	21.50	84	6.27
10	59.08	25	54.38	40	45.96	55	34.41	70	20.52	85	5.23
11	58.89	26	53.93	41	45.28	56	33.55	71	19.53	86	4.19
12	58.68	27	53.46	42	44.59	57	32.68	72	18.54	87	3.14
13	58.46	28	52.97	43	43.88	58	31.80	73	17.54	88	2.09
14	58.22	29	52.47	44	43.16	59	30.90	74	16.54	89	1.05
15	57.95	30	51.96	45	42.43	60	30.00	75	15.53	90	0.00

TABLE XI.

To Convert Degrees, &c. into Time, and Conversely.

D.	H. M.	D.	H. M.	D.	H. M.	D.	H. M.	D.	H. M.	D.	H. M.
M.	M. S.	M.	M. S.	M.	M. S.	M.	M. S.	M.	M. S.	M.	M. S.
1	0 4	61	4 4	121	8 4	181	12 4	241	16 4	301	20 4
2	0 8	62	4 8	122	8 8	182	12 8	242	16 8	302	20 8
3	0 12	63	4 12	123	8 12	183	12 12	243	16 12	303	20 12
4	0 16	64	4 16	124	8 16	184	12 16	244	16 16	304	20 16
5	0 20	65	4 20	125	8 20	185	12 20	245	16 20	305	20 20
6	0 24	66	4 24	126	8 24	186	12 24	246	16 24	306	20 24
7	0 28	67	4 28	127	8 28	187	12 28	247	16 28	307	20 28
8	0 32	68	4 32	128	8 32	188	12 32	248	16 32	308	20 32
9	0 36	69	4 36	129	8 36	189	12 36	249	16 36	309	20 36
10	0 40	70	4 40	130	8 40	190	12 40	250	16 40	310	20 40
11	0 44	71	4 44	131	8 44	191	12 44	251	16 44	311	20 44
12	0 48	72	4 48	132	8 48	192	12 48	252	16 48	312	20 48
13	0 52	73	4 52	133	8 52	193	12 52	253	16 52	313	20 52
14	0 56	74	4 56	134	8 56	194	12 56	254	16 56	314	20 56
15	1 0	75	5 0	135	9 0	195	13 0	255	17 0	315	21 0
16	1 4	76	5 4	136	9 4	196	13 4	256	17 4	316	21 4
17	1 8	77	5 8	137	9 8	197	13 8	257	17 8	317	21 8
18	1 12	78	5 12	138	9 12	198	13 12	258	17 12	318	21 12
19	1 16	79	5 16	139	9 16	199	13 16	259	17 16	319	21 16
20	1 20	80	5 20	140	9 20	200	13 20	260	17 20	320	21 20
21	1 24	81	5 24	141	9 24	201	13 24	261	17 24	321	21 24
22	1 28	82	5 28	142	9 28	202	13 28	262	17 28	322	21 28
23	1 32	83	5 32	143	9 32	203	13 32	263	17 32	323	21 32
24	1 36	84	5 36	144	9 36	204	13 36	264	17 36	324	21 36
25	1 40	85	5 40	145	9 40	205	13 40	265	17 40	325	21 40
26	1 44	86	5 44	146	9 44	206	13 44	266	17 44	326	21 44
27	1 48	87	5 48	147	9 48	207	13 48	267	17 48	327	21 48
28	1 52	88	5 52	148	9 52	208	13 52	268	17 52	328	21 52
29	1 56	89	5 56	149	9 56	209	13 56	269	17 56	329	21 56
30	2 0	90	6 0	150	10 0	210	14 0	270	18 0	330	22 0
31	2 4	91	6 4	151	10 4	211	14 4	271	18 4	331	22 4
32	2 8	92	6 8	152	10 8	212	14 8	272	18 8	332	22 8
33	2 12	93	6 12	153	10 12	213	14 12	273	18 12	333	22 12
34	2 16	94	6 16	154	10 16	214	14 16	274	18 16	334	22 16
35	2 20	95	6 20	155	10 20	215	14 20	275	18 20	335	22 20
36	2 24	96	6 24	156	10 24	216	14 24	276	18 24	336	22 24
37	2 28	97	6 28	157	10 28	217	14 28	277	18 28	337	22 28
38	2 32	98	6 32	158	10 32	218	14 32	278	18 32	338	22 32
39	2 36	99	6 36	159	10 36	219	14 36	279	18 36	339	22 36
40	2 40	100	6 40	160	10 40	220	14 40	280	18 40	340	22 40
41	2 44	101	6 44	161	10 44	221	14 44	281	18 44	341	22 44
42	2 48	102	6 48	162	10 48	222	14 48	282	18 48	342	22 48
43	2 52	103	6 52	163	10 52	223	14 52	283	18 52	343	22 52
44	2 56	104	6 56	164	10 56	224	14 56	284	18 56	344	22 56
45	3 0	105	7 0	165	11 0	225	15 0	285	19 0	345	23 0
46	3 4	106	7 4	166	11 4	226	15 4	286	19 4	346	23 4
47	3 8	107	7 8	167	11 8	227	15 8	287	19 8	347	23 8
48	3 12	108	7 12	168	11 12	228	15 12	288	19 12	348	23 12
49	3 16	109	7 16	169	11 16	229	15 16	289	19 16	349	23 16
50	3 20	110	7 20	170	11 20	230	15 20	290	19 20	350	23 20
51	3 24	111	7 24	171	11 24	231	15 24	291	19 24	351	23 24
52	3 28	112	7 28	172	11 28	232	15 28	292	19 28	352	23 28
53	3 32	113	7 32	173	11 32	233	15 32	293	19 32	353	23 32
54	3 36	114	7 36	174	11 36	234	15 36	294	19 36	354	23 36
55	3 40	115	7 40	175	11 40	235	15 40	295	19 40	355	23 40
56	3 44	116	7 44	176	11 44	236	15 44	296	19 44	356	23 44
57	3 48	117	7 48	177	11 48	237	15 48	297	19 48	357	23 48
58	3 52	118	7 52	178	11 52	238	15 52	298	19 52	358	23 52
59	3 56	119	7 56	179	11 56	239	15 56	299	19 56	359	23 56
60	4 0	120	8 0	180	12 0	240	16 0	300	20 0	360	24 0

TABLE XII.

To Find the Distance of Objects at Sea.

Height in Feet.	Distance in SeaMiles	Height in Feet.	Distance in SeaMiles	Height in Feet.	Distance in SeaMiles	Height in Feet.	Distance in SeaMiles	Height in Feet.	Distance in SeaMiles
1	1.06	61	8.31	142	12.67	720	28.53	2550	53.70
2	1.50	62	8.37	144	12.76	740	28.93	2600	54.22
3	1.84	63	8.44	146	12.85	760	29.32	2650	54.74
4	2.13	64	8.51	148	12.94	780	29.70	2700	55.25
5	2.38	65	8.58	150	13.03	800	30.08	2750	55.76
6	2.60	66	8.64	155	13.24	820	30.45	2800	56.27
7	2.81	67	8.70	160	13.45	840	30.82	2850	56.77
8	3.01	68	8.77	165	13.66	860	31.19	2900	57.27
9	3.19	69	8.83	170	13.87	880	31.55	2950	57.76
10	3.36	70	8.89	175	14.07	900	31.90	3000	58.25
11	3.53	71	8.96	180	14.27	920	32.25	3050	58.73
12	3.68	72	9.02	185	14.46	940	32.60	3100	59.21
13	3.83	73	9.09	190	14.66	960	32.95	3150	59.68
14	3.98	74	9.15	195	14.85	980	33.29	3200	60.15
15	4.12	75	9.21	200	15.04	1000	33.63	3250	60.62
16	4.25	76	9.27	210	15.41	1020	33.96	3300	61.09
17	4.38	77	9.33	220	15.77	1040	34.29	3350	61.55
18	4.51	78	9.39	230	16.13	1060	34.62	3400	62.01
19	4.53	79	9.45	240	16.47	1080	34.95	3450	62.46
20	4.76	80	9.51	250	16.81	1100	35.27	3500	62.91
21	4.87	81	9.57	260	17.15	1120	35.59	3550	63.36
22	4.99	82	9.63	270	17.47	1140	35.90	3600	63.80
23	5.10	83	9.69	280	17.79	1160	36.22	3650	64.24
24	5.21	84	9.75	290	18.11	1180	36.54	3700	64.68
25	5.32	85	9.80	300	18.42	1200	36.84	3750	65.12
26	5.42	86	9.86	310	18.72	1220	37.14	3800	65.55
27	5.52	87	9.92	320	19.02	1240	37.45	3850	65.98
28	5.62	88	9.98	330	19.32	1260	37.75	3900	66.41
29	5.72	89	10.03	340	19.61	1280	38.05	3950	66.83
30	5.82	90	10.09	350	19.80	1300	38.34	4000	67.26
31	5.92	91	10.14	360	20.18	1320	38.64	4100	68.09
32	6.01	92	10.20	370	20.46	1340	38.93	4200	68.92
33	6.11	93	10.25	380	20.73	1360	39.22	4300	69.73
34	6.20	94	10.31	390	21.00	1380	39.50	4400	70.54
35	6.29	95	10.36	400	21.27	1400	39.79	4500	71.34
36	6.38	96	10.42	410	21.53	1420	40.07	4600	72.12
37	6.47	97	10.47	420	21.79	1440	40.35	4700	72.91
38	6.56	98	10.53	430	22.05	1460	40.63	4800	73.68
39	6.64	99	10.58	440	22.31	1480	40.91	4900	74.44
40	6.73	100	10.63	450	22.66	1500	41.19	5000	75.20
41	6.81	102	10.74	460	22.81	1550	41.87	5100	75.95
42	6.89	104	10.84	470	23.05	1600	42.54	5200	76.69
43	6.97	106	10.95	480	23.30	1650	43.20	5300	77.42
44	7.05	108	11.05	490	23.54	1700	43.85	5400	78.15
45	7.13	110	11.15	500	23.78	1750	44.49	5500	78.87
46	7.21	112	11.25	510	24.01	1800	45.12	5600	79.58
47	7.29	114	11.35	520	24.25	1850	45.74	5700	80.29
48	7.37	116	11.45	530	24.48	1900	46.35	5800	80.99
49	7.44	118	11.55	540	24.71	1950	46.96	5900	81.69
50	7.52	120	11.65	550	24.94	2000	47.56	6000	82.38
51	7.59	122	11.75	560	25.16	2050	48.15	Height	Distance
52	7.67	124	11.84	570	25.39	2100	48.73		in Nautical or Sea Miles.
53	7.74	126	11.94	580	25.61	2150	49.31		
54	7.81	128	12.03	590	25.83	2200	49.88		
55	7.89	130	12.12	600	26.05	2250	50.44		
56	7.96	132	12.22	620	26.48	2300	51.00		
57	8.03	134	12.31	640	26.90	2350	51.55	1	82.92
58	8.10	136	12.40	660	27.32	2400	52.10	2	117.28
59	8.17	138	12.49	680	27.73	2450	52.64	3	143.64
60	8.24	140	12.58	700	28.14	2500	53.17	4	165.89

USE OF TABLE XII.

To find the distance between two Objects, of which the Heights above the Level of the Sea are given.

Rule.

Take distances answering to the two heights from the table, and add them, and the sum is the distance between the objects.

Examples.

I.

At a place 104 feet above the level of the sea, with a telescope, a small portion of the main-top-gallant sail of a ship, which had sailed the day before, was observed apparently above the horizon. Now, the height of that part of the sail, which appeared in the horizon, above the sea, is 165 feet, the distance of the ship is required?

To height 104 feet, the distance is	-	-	10.84
165 feet, the distance is	-	-	13.66
Distance of the ship	- -	- -	24.50 miles.

II.

The upper part of a light-house, whose height above the sea is 68 feet, was observed in the horizon, the height of the eye being 14 feet. Required the distance of the light-house?

To height 68 feet, the distance is	-	-	8.77
14 feet, the distance is	-	-	3.98
Distance of the light-house	- -	-	12.75 miles.

F I N I S.