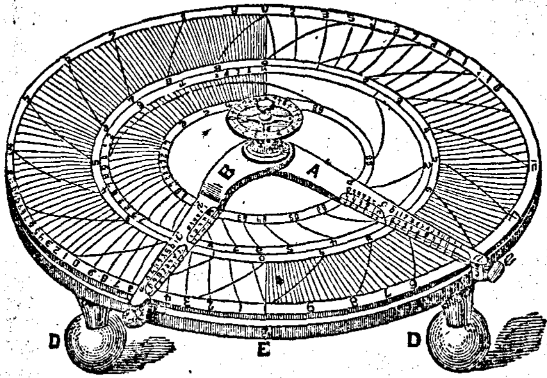
NYSTROM'S

CALCULATOR.



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1854.

DESCRIPTION AND KEY

TO

NYSTROM'S CALCULATOR,

WITH

Practical Rules and Examples

FOR

USING THE SAME.

BY

J. W. NYSTROM.

PHILADELPHIA:
BARNARD & JONES, PRINTERS,
No. 10 DECATUR STREET.
1854.

ADVERTISEMENT.

The inventor of the Machine designed to accompany this book being a practical engineer, and having multiplied calculations to make, felt the necessity of some simple instrument to aid in calculation. After much thought and labor, he has succeeded in producing such an instrument—simple in construction, and portable in size, yet so complete that every variety of calculation may be computed by it, from the school-boy's easy sum to the most intricate computation. Its operations are so simple, that it does not require great power of mind to comprehend them; they can be applied by any one to the common business purposes of life.

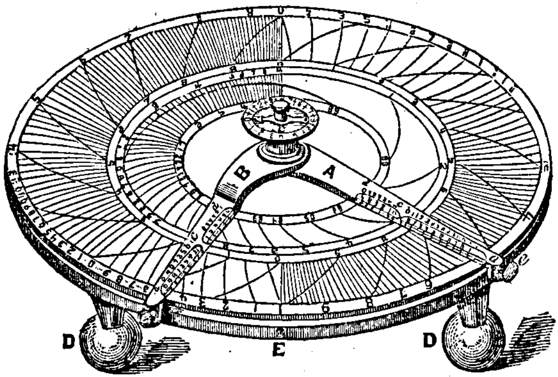
For Engineers, Constructors, Ship-builders, and for Navigation, this Calculator will be found the most valuable assistant in figuring. For trigonometrical calculations, it is so arranged that it is not necessary to notice the trigonometrical lines as sin. cos., &c., operating only by the angles themselves. This makes triognometrical calculations so simple, that any one that can read figures, will be able to solve trigonometrical questions. Its great recommendation is, the rapidity with which calculations can be made;—what, by the ordinary method, is the work of hours, filling pages with figures, can be done in a few seconds, without figures. Many important calculations are dispensed with, and often thrown aside before completion, owing to the length of time required to compute them.

For Teachers it will be found to be a valuable assistant, furnishing a test of the real acquirements of the pupil, without taxing the time of the teacher. Teachers are generally dependent upon text books for examples, and it is easy for the pupil, knowing where the example comes from, to be furnished with an answer; but an ingenious teacher, furnished with one of these *Calculators*, may vary the examples *ad infinitum*, and have the answer almost in an instant before him. The pupil is thrown on his own resources for the proper solution of the problem.

All the calculations in Nystrom's Pocket-Book of Mechanics and Engineering, have been computed by this instrument.

It was invented in 1848, received a *First Premium* at the Franklin Institute Exhibition in 1849, and *Patented* March 4, 1851.

NYSTROM'S



CALCULATOR.

DESCRIPTION AND KEY

TO THE

CALCULATOR.

THE *Calculator consists of a round disk* of brass, silvered white. It has two graduated arms A and B, extending from the centre C to the periphery. On the outer end of each arm is a screw *e*, for the purpose of fastening the arms in any particular place on the disk. In the centre is a screw C, to clamp the two arms together; when clamped they can be moved freely around the centre C.

The operation of calculation is performed by moving these arms together and independently; for each operation the arm B must be set in one particular place on the disk called *Zero*. In order to be correct, and facilitate the setting of the arm B on *Zero*, there is placed a spring E, which is to be operated when the arm approaches it; this is done by pinching the spring with the fore-finger, and the arm stops at *Zero*. A little practice, and this is done with great facility.

The Calculator has four different scales, marked on the arms thus: *a, log, sin, cos, and points.*

THE FIRST SCALE *a*.

The outer scale *a* is for *multiplication, division, involution and evolution.* It has two sizes of figures, of which the larger ones represents the first figure in a number, and the smaller ones the second; for instance, 28 is a number composed of two figures; 2 is the first figure, 8 the second.

Example. To set the arm A on number 28 (circle *a*). Set the arm A on the large 2, (circle *a*), move the arm further until it comes to the small 8, (the eighth curved line from the large 2;) fasten the arm A with the screw *e;* the arm is then set on 28. But this 28 can represent any multiple or divisor of 10; as

0·0028, 0·28, 2·8, 28, 280, 28000, &c.

If the number contains more than two figures, as 2835, the third and fourth figures are to be found on the arm where it intersects the curved line; the third figure is the small figure on the arms, (counted from *a*,) and the fourth figure the small divisions between the figures on the arms.

OPERATION.

Place the instrument in a position as represented by the accompanying figure, manœuvre the arm A and screw *e* by the left hand, and the arm B with the right.

MULTIPLICATION.

RULE I. Set the arm A on the first factor, fasten A^e;* set the arm B on *Zero*, clamp C † loose A^e, and move the arms until the arm B comes to the second factor; then the arm A shows the product.

Example 1. Multiply 3 by 2. Set the arm A on 3, (circle *a*,) and B on *Zero*, clamp C, move them until the arm B comes to 2; then the arm A shows the product = 6.

Example 2. Multiply 4 by 2. Set the arm A on 4, fasten A^e, set the arm B on *Zero*, clamp C, loose A^e, move the arms until B comes to 2; the arm A will show the product = 8.

Example 3. Multiply 6 by 4. Set A on 6, fasten A^e, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 4, then A shows the product = 24.

Example 4. Multiply 9 by 7. Set A on 9, fasten A^e, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 7; then A shows the product = 63.

Example 5. Multiply 12 by 3. Set A on 12, (the second curved line from the large 1,) fasten A^e, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 3; then the arm A shows the product = 36.

Example 6. Multiply 36 by 6. Set A on 36, fasten A^e, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 6; then the arm A shows the product = 216. The third figure, 6, will be found on the arm where the curved line 1 intersects the same at figure 6 on the arm A, counted from *a*.

Example 7. Multiply 216 by 16. $216 \times 16 = 3225$. The fourth figure, 5, is the fifth division between 2 and 3 on the arm, counted from *a*.

Example 8. What is the area of a rectangle in square feet, when one side is 3 feet 6 inches, and the other 1 foot 9 inches? Set A on 3·5, B on *Zero*, clamp B, move the arms until B comes to 1·75; then the arm A shows the answer, 61·25 square feet.

Example 9. A pine board is 16 feet 3 inches long, and 9 inches wide; how many square feet are there in it? Set A on 16·25, B on *Zero*, clamp C, move the arms until B comes to 0·75, (9 inches = 0·75 feet;) then A shows the answer = 12·19 square feet.

* The arm A with the screw *e*.

† The arms A and B with the screw C.

Example 10. How much will the same board cost at 4 cents per square foot? Set A on 12·19, B on *Zero*, clamp C, move the arms until B comes to 4; then A shows the answer = 48·75 cents.

Example 11. How long is the periphery of a circle 15 inches in diameter? Set A on 15, B on *Zero*, clamp C, move the arms until B comes to 3·14; then A shows the answer = 47·12 inches.

Example 12. The driving wheel on a locomotive is 5 feet 6 inches; in diameter how long is the periphery? Set A on 5·5, B on *Zero*, clamp C, move the arms until B comes to 3·14; then A shows the answer = 17·27 feet.

Example 13. How much for 39 yards of ribbon, at 5 cents per yard? 39 × 5 = $1·95. Set A on 39, B on *Zero*, clamp C, move the arms until B comes to 5; then A will show the answer = $1·95.

Example 14. How many square yards are there in a piece of cloth 37 yards and 29 inches long, and 2 yards and 18 inches wide? 29 inches = 0·75 yds., 18 in. = 0·5 yds. 37·75 × 2·5 = 94·37 square yards.

Example 15. When butter costs 23 cents per pound, how much for 23 pounds? 23 × 23 = $5·29.

Example 16. What will be the cost of a fly-wheel weighing 768 pounds, at 5 cents per pound? 768 × 5 = $38·40.

When there are more than two factors to be multiplied together, consider the product of the two factors as one factor, and continue the multiplication with the next factor as before described. It matters not how many factors there may be, the multiplication can be continued to any extent, but a correct account of the index of the factors must be kept, as described on page 14. The products which come between the operations need not be observed, only the last product.

A calculating machine of only nine inches in diameter, cannot give more than the four first figures correct; the rest must be filled up with ciphers (0). In common calculations, a result in four figures will generally suffice. For higher numbers, the remainder of the figures are commonly ciphers; these the machine tells to any extent. But if the calculation is an important one, requiring a dozen or more figures in the result, make the calculation by hand, but do not trust to the first result being correct. The second time proves the calculation by the machine; by it you are sure of obtaining the four first figures correct, which are always most important; for the last figures the operation by hand can be trusted.

We will see by the following, that this instrument easily manœuvres numbers with 10 or 20 figures, but in such examples there is more or less divisions or extraction of roots, which considerably reduces the number of figures before the result is obtained.

Example 17. $2\times3\times4=24$. Set the arm A on 2, B on *Zero*, clamp C, move the arms until B comes to 3, fasten A^e, loose C, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 4; the arm A will show the product$=24$.

It will be seen in this example, that the product of 2 and 3 was not noticed; the multiplication was continued by 4, and the product first noticed was 24.

Example 18. What will be the cost of a lot of ground 135 feet long and 73 feet wide, at 6 cents per square foot? $135\times73\times0{\cdot}06=\$591{\cdot}30$. Set A on 135, B on *Zero*, clamp C, move the arms until B comes to 73, fasten A^e, loose C, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 6; then the arm A will show the price$=\$591{\cdot}30$.

Example 19. What will be the cost of a piece of cloth, 63 yards long and 2½ yards wide, at \$1·56 per square yard? $63\times2{\cdot}5\times1{\cdot}56=\$236{\cdot}25$. Set A on 63, B on *Zero*, clamp C, move the arms until B comes to 2·5, fasten A^e, loose C, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 1·56; the arm A will show the cost$=\$236{\cdot}25$.

Example 20. What is the area of a circle 7 inches in diameter? $7\times7\times0{\cdot}785=38{\cdot}48$. Set A on 7, B on *Zero*, clamp C, move the arms until B comes to 7, fasten A^e, loose C, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 0·785; then B shows the area$=38.48$ square inches.

Example 21. What is the area of a circle with a radius of 11 feet? $11\times11\times3{\cdot}14=95$ square feet.

When a number is to be multiplied by itself, it will be marked with an exponent of the power, as $11\times11=11^2$, $12\times12\times12=12^3$.

Example 22. How many cubic inches are contained in an iron bar 3 inches square and 3 feet long? $3^2\times12\times3=324$.

Example 23. How many cubic inches are contained in an iron bar 27 inches long, 3 inches wide, and 2 inches thick?

$27\times3\times2=162$ cubic inches.

Example 24. How many cubic inches are contained in an iron bar 2 inches in diameter and 5 feet long? $2^2\times0{\cdot}785\times12\times5=188{\cdot}4$.

Example 25. What will be the weight of an iron bar 3 inches in diameter and 7 feet 6 inches long, if one cubic inch weighs 0·28 pounds? $3^2\times0{\cdot}785\times12\times7{\cdot}5\times0{\cdot}28=178$ pounds.

Example 26. What will be the price of an iron bar 9 feet 3 inches long, 3½ inches wide, and ¾ inches thick, at 7 cents per pound?

$9{\cdot}25\times3{\cdot}5\times0{\cdot}75\times0{\cdot}28\times7=\$0{\cdot}47{\cdot}5$.

Example 27. What will be the weight of a propeller shaft of wrought iron 61 feet long and 1 foot in diameter, when a cubic foot of wrought iron weighs 486·6 pounds.

$1^2\times0{\cdot}785\times61\times486{\cdot}6=23{,}300$ pounds.

DIVISION.

Division is the reverse of Multiplication, as the dividend is the product of the divisor and quotient.

RULE II. Set the arm A on the dividend, and B on the divisor, (circle *a*,) clamp C, move the arms until B comes to *Zero*; then the arm A shows the quotient.

Example 1. Divide 6 by 2. Set A on 6, B on 2, clamp C, move the arms until B comes to *Zero*; then A shows the product=3.

Example 2. Divide 8 by 4. Set A on 8, B on 4, clamp C, move the arms until B comes to *Zero*; then A shows the product=2.

Example 3. Divide 12 by 4. Set A on 12, B on 4, clamp C, move the arms until B comes to *Zero*; then A shows the product=3.

Example 4.	Divide 24	by 6.	24 :	6 =	4.
" 5.	" 36	" 4.	36 :	4 =	9.
" 6.	" 48	" 6.	48 :	6 =	8.
" 7.	" 63	" 9.	63 :	9 =	7.
" 8.	" 72	" 9.	72 :	9 =	8.
" 9.	" 125	" 5.	125 :	5 =	25.
" 10.	" 266	" 7.	266 :	7 =	38.
" 11.	" 378	" 9.	378 :	9 =	42.
" 12.	" 864	" 27.	864 :	27 =	32.
" 13.	" 5032	" 68.	5033 :	68 =	74.

Example 14. A piece of ribbon containing 12 yards, was sold for $3. What was the price per yard? Set A on 3, B on 12, clamp C, move the arms until B comes to *Zero*; then A shows the answer=·25 cents.

Example 15. If 23 yards of cloth cost $161, what will be the price per yard? Set A on 161, B on 23, clamp C, move the arms until B comes to *Zero*; A will show the answer=$7.

Example 16. A cog wheel weighing 4750 pounds cost $190. Required the price per pound? Set A on 190, B on 4750, clamp C, move the arms until B comes to *Zero*; A will show the answer, = 4 cents.

Example 17. A screw propeller of cast iron, weighing 6950 pounds cost $417. Required the price per pound?

417 : 6950=0·06 cents.

When the dividend contains more than one factor, multiply the factors by Rule I., and divide by the divisor according to Rule II.

Example 18. If 27 men can do a certain amount of work in 7 days, how many days will it take for 21 men to do the same work?

$$27 : 21 = x : 7. \quad x = \frac{27 \times 7}{21} = 9$$

Set A on 27, B on *Zero*, clamp C, move the arms until B comes to 7, fasten A^e, loose C, set B on 27, clamp C, loose A^e, move the arms until B comes to *Zero*; then the arm A shows the result=9 days.

Example 19. What is the area of a triangle 7 feet in height, the base being 12 feet?

$$\text{Area} = \frac{7 \times 12}{2} = 42 \text{ square feet.}$$

Set A on 7, B on *Zero*, clamp C, move the arms until B comes to 12, fasten A^e, loose C, set B on 2, clamp C, loose A^e, move the arms until B comes to *Zero*; then A shows the area=42 square feet.

Example 20. How many revolutions does the driving wheel of a locomotive make between Philadelphia and Baltimore, the distance being 99 miles, and the circumference of the wheel 27 feet?

$$\frac{99 \times 5280}{27} = 19{,}360 \text{ revolutions.}$$

This example can be computed in a single operation, as follows: Set A on 99, B on 27, clamp C, move the arms until B comes to 5280; then A shows the revolutions=19,360.

Example 21. What is the distance between Baltimore and Washington, a locomotive's driving wheel of 18 feet circumference making 11,733 revolutions on the road;

$$\frac{18 \times 11{,}733}{5280} = 40 \text{ miles.}$$

Set A on 18, B on 5280, clamp C, move the arms until B comes to 11,733; then A shows 40 miles.

Example 22. How many cubic inches are there in a sphere 4 inches in diameter?

$$\frac{\pi d^3}{6} = \frac{3{\cdot}14 \times 4^3}{6} = 33{\cdot}5 \text{ cubic inches.}$$

Set A on 3·14, B on 6, clamp C, move the arms until B comes to 4, fasten A^e, loose C, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 4; then A shows the cubic inches=33·5.

When the divisor contains more than one factor, divide by the first factor, as aforesaid, consider the quotient as a new dividend, and continue the division by the next factor.

Example 23. Divide 348 by 3 and 4.

$$\frac{348}{3\times 4}=29.$$

Set A on 348, B on 3, clamp C, move the arms until B comes to *Zero*, fasten A^e, loose C, set B on 4, clamp C, loose A^e, move the arms until B comes to *Zero*; then A shows the quotient=29.

Example 24. How many days will it take for a steamboat to run from New York to Liverpool, running 12 miles per hour, the distance being 3100 miles?

$$\frac{3100}{12\times 24}=10{\cdot}74.\text{ days},$$

Set A on 3100, B on 12, clamp C, move the arms until B comes to *Zero*, fasten A^e, loose C, set B on 24, clamp C, move the arms until B comes to *Zero*; then A shows=10·74. Set A on 74, B on *Zero*, clamp C, move the arms until B comes to 24, A shows 17·76; then the answer is 10 days 17¾ hours.

PROPORTION.

Rule III. The manœuvring of proportions, is the most valuable faculty of this instrument. Suppose we have the proportion as 3 : 2. Set A on 3, and B on 2, clamp B. Now, wherever the arms will be placed on the disk, the numbers at A and B will always be in the proportion as 3 : 2. Set A on 6, the arm B will show 4. Set B on 24, the arm A will show 36. Set A on 19·93, and B will show 13·29, &c., &c., &c.

In whatever proportion the arms are once clamped, it will remain so in any other position on the disk.

Constructors, Draughtsmen, Ship-builders, &c., &c., will find this a most valuable assistance; when changing a machine or drawing from one scale to another, any scales are instantly at hand on the calculator; by once placing the arms in the proportion of reduction, any measure in feet and inches on one arm will show the reduced or increased measure at the other arm.

To Ship-builders particularly, it will meet the highest approbation, when enlarging and reducing lines of vessels; and at the same time, the Calculator covers all the Ship-builder's calculations.

Example 1. 8 : 14 = 24 : x. Set the arm B on 8, and A on 14, clamp C, move the arms until B comes to 24, then A shows the fourth term x=42.

Example 2. 1·35 : 97·6 = x : 49·63. Set A on 1·35, B on 976, clamp C, move the arms until B comes to 49·53, the arm A will show the third term x=0·6864.

FRACTIONS.

To reduce a vulgar fraction to a decimal, or to another vulgar fraction.

RULE IV. Set the arm A on the numerator, and B on the denominator, clamp C, move the arms until B comes to *Zero;* then A shows the decimal.

Example 1. Reduce $\frac{1}{2}$ to a decimal. Set A on 1, B on 2, clamp C, move the arms until B comes to *Zero;* then A shows the decimal $= 0{\cdot}5$.

Example 2. Reduce $\frac{3}{4}$ to a decimal. Set A on 3, B on 4, clamp C, move the arms until B comes to *Zero;* then A shows the decimal $= 0{\cdot}75$.

Example 3. Reduce $\frac{5}{9}$ to a decimal. Set A on 5, B on 9, clamp C, move the arms until B comes to *Zero;* then A shows the decimal $= 0{\cdot}5555$.

Example	4.	Reduce	$\frac{7}{13}$	$= 0{\cdot}5384.$
"	5.	"	$\frac{9}{15}$	$= 0{\cdot}6000.$
"	6.	"	$\frac{12}{19}$	$= 0{\cdot}6368.$
"	7.	"	$\frac{16}{27}$	$= 0{\cdot}5925.$
"	8.	"	$\frac{38}{79}$	$= 0{\cdot}4810.$
"	9.	"	$\frac{136}{372}$	$= 0{\cdot}3387.$
"	10.	"	$\frac{793}{5934}$	$= 0{\cdot}1338.$

To reduce a vulgar fraction to another vulgar fraction.

Example 11. Reduce $\frac{3}{4}$ to 12ths. Set the arm A on 3, B on 4, clamp C, move the arms until B comes to 12; then A shows 9 or 9-12$=\frac{3}{4}$. In whatever position the arms are placed on the disk, the numbers will always remain in the same proportion as 3 : 4. In this consists the great convenience of the machine for working vulgar fractions.

Example 12. Reduce $\frac{135}{216}$ to 8ths. Set A on 135, B on 216, clamp C, move the arms until B comes to 8; then A shows$=5$ or $\frac{5}{8}$.

Example 13. Reduce $\frac{18}{37}$ to 3ds. $= \frac{1{\cdot}46}{3}$.

To multiply a whole number by a vulgar fraction.

Example 14. Multiply 24 by $\frac{3}{4}$. $\frac{3}{4}\times 24 = 18$. Set A on 3, B on 4, clamp C, move the arms until B comes to 24, then A shows the product $= 18$.

Example 15. $\frac{19}{39}\times 365 = 177{\cdot}8$.

Example 16. $\frac{23}{422}\times\frac{37}{39} = 0{\cdot}05235$.

INVOLUTION.

The power of a number is only a multiplication by the number itself, and is marked by a small figure called *exponent*, on the right of the number.

Example 1. What is the square of 3? $3^2=9$. Set A on 3, B on *Zero*, clamp C, move the arms until B comes to 3; then A shows the power$=9$. To obtain the third power of 3, continue the multiplication by 3; but the fourth power of 3, or

$3^4=9^2=81$.
$3^6=9^3=729$.
$3^8=9^4=81^2=6561$.
$3^9=9^4\times3=81^2\times36561\times3=19683$.

Example 2. Compute the 9th power of 3. Set A on 3, B on *Zero*, clamp C, move the arms until B comes to 3; then A shows $9=3^2$; fasten A^e, loose C, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 9; then A shows $81=9^2=3^4$; fasten A^e, loose C, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 81; then A shows $6561=81^2=9^4=3^8$; fasten A^e, loose C, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 3; then A shows the 9th power of 3, or $19683=3^9$.

INTEREST.

Example 1. What is the interest on 765 dollars at 6 per cent. per annum?

Set A on 6, (circle *a*,) B on *Zero*, clamp C, move the arms until B comes to \$765, then A shows the interest$=\$45{\cdot}90$.

On whatever number of dollars the arm B is set, the arm A will show the interest for one year; or if the arm A be set on any interest per annum, B will show the capital. If the interest is to be found for any number of years, months, or days, let the arm A remain on the interest for one year,

Set B on	*Zero* if number of years,	clamp C.
	12 " " " months,	
	52 " " " weeks,	
	365 " " " days,	

Now for any number of years, months, weeks, or days on the arm B, the interest will be found on the arm A.

Example 2. Require the interest of 34,770 dollars for 13 months at 6 per cent. per annum?

Set A on $34,770, B on *Zero;* clamp C, move the arms until B comes to 6 per cent., fasten Ae, set B on 12, clamp C, move the arms until B comes to 13 months, then A shows the interest, $2250.

Example 3. A capital $65,680 gave an interest $10,840 in 3 years and 5 months. Required the per centage per annum?

Three years and 5 months is 41 months.

Set A on the interest $10,840, and B on the capital $65,680; clamp C, move the arms until B comes to 12 months, fasten Ae, set B on 41 months, clamp C, move the arms until B comes to *Zero;* A shows the annual per centage $4\frac{82}{100}$ per cent.

Example 4. What capital is required to give an interest 1500 dollars per year, at 6 per cent. per annum?

Set A on the interest $1500, and B on 6 per cent., clamp C, move the arm until B comes to *Zero,* then A shows the capital required = $25,000.

LOGARITHMS.

The second scale *log.* is for addition and subtraction; and also, the logarithm for the number in the circle *a.*

Example 1. Find the logarithm of 4721?

Set the arm A on 4721, (circle *a,*) and the logarithm will be found where the curved line 6 intersects the arm, which is 3·6740.

The index of the logarithm is always one less than the number of figures in the number; it is not to be found on the calculator, only the decimal part 6740, of which the first figure 6 is the 6th curve line in circle *log.* The second figure 7 is on the arm, counted from *log.*; and the third figure 4 is the fourth division between 7 and 8, where the curved line intersects the arm. The decimal part of a logarithm is called *mantissa.* It is well known that in the system of logarithms, the index is *always* one less than the number of figures in the number for which the logarithm is to be found; as, log. 7000 = 3·845. Here the number is four figures, and the index 4−1 = 3; but the mantissa is the same as for 7.

In calculations, where the number of figures in the result is uncertain, a correct account must be kept of the indices. For that purpose, there is a small hand on the screw C, which is to be moved by the hand for each operation with the arms; as, for multiplication add the factors' indices, the sum is the index for the product; and for division, subtract the index for the divisor from the index for the dividend, the remainder is the index for the quotient. When the operations are finished, the small hand shows the index; add one to it, gives the number of figures in the result. If the index becomes negative, the result is a corresponding decimal fraction, and the hand shows how many 0 it is before the figures included the unity 0. If the arm shows 28, (circle *a*,) and the hand shows the

Index	—3	the decimal fraction is	0·0028
Index	—2	" "	0·028
Index	—1	" "	0·28
Index	0	the number is	2·8
Index	+1	"	28
Index	+3	"	2800
Index	+6	"	2800000

If it is made a rule to move the arms *with* the arrow for multiplication, and *opposite* the arrow for division, it follows that when, for multiplication, the arm A moves over *Zero*, add 1 to the index, and for division subtract 1 from the index; but as it is more convenient to move the arm to the nearest factor, these rules will not be followed, and the arms will be moved in every direction for any operation.

Then it must be observed that, for multiplication or division, when the arm A moves over *Zero* with the arrow, add 1 to the index; and subtract 1 if it moves over *Zero* opposite the arrow.

Example 1. Multiply 36800 by 2250.

Set A on 36800, and the small band on the index 4. Set B on *Zero*, clamp C, move the arms until B comes to 2250, add the index 3 to 4, which will be 7, and indicates that there are eight figures in the product, which will be found on A 82800000.

Example 2. Multiply 582500 by 88000.

Set A on 88000, and the small hand on the index 4. Set B on *Zero*, clamp C, move the arms until B comes to 582500, add the index 5 to 4, which will be 9; if the arms were moved with the arrows, the arm A moved over *Zero*, and one more is to be added to the index, 9 or 10 is the index for the product, which indicates that there are 11 figures in the product on A 51260000000.

The account of the index is but trifling after a little practice. If there is a supposition as to what the number of figures in the result will be, the account of the index need not be kept.

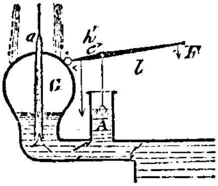
Example 3. A ship's crew of 300 men were so supplied with provisions for 12 months, that each man was allowed 30 ounces per day, but after being out 6 months, they found it would require 9 months more to finish it, and 50 of their number were lost. It is required to find the daily allowance of each man during the last nine months.

$$\frac{300 \times 30\ (12-6)}{9\ (300-50)} = \frac{300}{9} \times \frac{30}{250} \times \frac{6}{} = 24 \text{ ounces.}$$

Set A on 300, B on 9, clamp C, move the arms until B comes to 30, fasten A^e, loose C, set B on 250, clamp C, loose A^e, move the arms until B comes to 6; then A shows the answer, 24 ounces. Here is five factors computed in two operations.

When complicated questions are to be solved, it is best to set it up in the form of equation, and it will be managed by the calculator almost instantly.

For complicated examples we refer to Nystrom's Pocket-Book of Mechanics and Engineering, which are all calculated by this instrument. Operators will find that Pocket-Book excellent for practising intricate examples. From pages 206 and 207 we extract the following example:



A hand pump is to throw up 25 cubic feet of water 17 feet high, in a time of 9 minutes and 16 seconds. The lever on which the force F is applied is $l=36$ inches, and the lever $e=9$ inches. The stroke of the piston A is 0·65 feet, and the force F=23 pounds.

Required how many double strokes the hand pump must make per minute? $9 \times 60 + 16 = 556$ seconds.

$$\text{Number of strokes} = \frac{3630}{556} \times \frac{25}{0{\cdot}65} \times \frac{17}{23} \times \frac{9}{36} = 46\tfrac{1}{3} \text{ per minute.}$$

Set A on 3630, B on 556, clamp C, move the arms until B comes to 25; fasten A^e, loose C, set B on 65, clamp C, move the arms until B comes to 17, fasten A^e, loose C, set B on 23, clamp C, move the arms until B comes to 9, fasten A^e, loose C, set B on 36, clamp C, move the arms until B comes to *Zero,* then A shows 46·35 which are the number of strokes per minute required. The product and quotients in the operation need not be noticed, only notice the result you want to know. You will here also discover the rules by which the operation is performed.

EVOLUTION.

Extraction of Roots is the reverse of Powers; as, the root of a number taken to the same power as the index for the root is coequal to the number. This is to be computed by the circle *log*. which contains the logarithms for the number in circle *a*.

Example 1. What is the square root of 9, or $\sqrt{9}$? Set A on 9, the mantissa on circle *b* is 9542; say 2 in 9 four times, set B on 4, (circle *log*) 2 in 15 7, move the arm until the curved line 4 crosses the division 7, (circle *log*,) 2 in 14 seven times, move the arm B a little further, until the curved line crosses the seventh division between 7 and 8, counted from *log*; then fasten B^e, and you will find on circle *a* the answer $3=\sqrt{9}$.

Example 2. What is the square root of 16, or $\sqrt{16}$? Set the arm A on 16, the mantissa on circle *log*, is 2041, but 16 has an index 1, which is to be added to mantissan, 1·2041 : 2=0·602; set the arm B on 602, (circle *log*,) on circle *a* we have the answer

$$4=\sqrt{16}.$$

Example 3. What is the cube root of 216, or $\sqrt[3]{216}$? Set A on 216, the mantissan on circle *log* is 3344, index=2; 2·3344 : 3= 0·7781; set the arm B on 7781, (circle *log*,) on circle *a* is the answer $6=\sqrt[3]{216}$.

Example 4. What is the fourth root of $\sqrt[4]{69350}$? Set A on 69350, the mantissan on circle *log* is 841, index=4; 4·841 : 4= 1·2102; set B on 2102, (circle *log*,) the index for the answer is 1, and on circle *a* is the answer, 16·23.

Example 5. $\sqrt[7]{8926000}$. Set A on 8926000, the mantissan on *log* is 9506, index=6; 6·9506 : 7=0·9929, which corresponds with 9·838, the answer on circle *a*.

Example 6. What time will it take a ball to fall vertical 231 feet?

$$\text{time } \sqrt{\frac{231\times 2}{32{\cdot}17}}=3{\cdot}79 \text{ seconds.}$$

Set A on 231, B on 32·17, clamp C, move the arms until B comes to 2, fasten A^e, loose C, the index for the number on *a* is 1, and mantissan on the circle *log*. is 157; 1·157 : 2=578, set B on 578 circle *log*, and the answer will be on circle *a* 3·79 seconds.

To extract Roots of Decimals.

Example 1. $\sqrt[3]{0 \cdot 349}$. The given index is —1, which is to be subtracted from the root index=3 —1=2, which will be the index for the mantissan. Set A on 349, fasten A°; on circle *log.* is the mantissa 5428, and 2·5428 : 3=0·8476. Set A on 8476, circle *log*, then on the circle *a* will be found the root=0·7041.

When the given index exceeds the root index, it will be as many ciphers before the figures in the root as the root index contains in the given index, (excepting the unity cipher.)

Example 2. $\sqrt[4]{0 \cdot 0000000008945}$. The given index= —10, and 10 : 4=2; the remainder, 2, will be the index for the mantissa. Set A on 8945, the mamtissan on circle *log.* is 9515, and 2·9515 : 4= 0·7379. Set A on 7379, circle *log.;* on circle *a* we have the root =0·005469.

Example 3. $\sqrt[5]{0 \cdot 0000000000007528}$. The given index = —13, and 13 : 5=2, which shows there must be two ciphers before the figures, (excepting the unity 0,) and the remaining 3 is the index for the mantissa. Set A on 7528, the mantissan on circle *b* is 8766, and 3·8766 : 5=0·7773. Set A on 77733, circle *b;* on circle *a* we have the root=0·005989.

TRIGONOMETRY.

The scale between *sin.* and *cos.*, marked on the arms, is for trigonometrical calculations. The numbers in the circles *sin.* and *cos.*, are angles in degrees, and the divisions between *sin.* and *cos.*, shows the exceeding minutes where the line intersects the arm.

When the arm is set on an angle circle, *sin.*, the circle *a* shows the length of its *sinus;* when set on an angle circle, *cos.*, the circle *a* shows the length of its *cosine.*

Example 1. Required the length of *sin.* 30° ?

Set the arm A on 30° circle *sin.*, and the circle *a* shows the answer *sin.*30° = 0·5.

Example 2. Required the length of *cos.* 63° 30′ ?

Set A on 63° circle *cos.*, move the arm a little further towards 64° until the 63d line intersects 30′ on the arm, then the circle A shows the length of *cos.*63° 30′ = 0·4462.

To find the Tangent.

Example 3. Find the length of the *tan.*54° 25′?

Set the arm A on *sin.*54° 25′, B on *cos.* 54° 25′, clamp C, move the arms until B comes to *Zero;* then A shows the

*tan.*54° 25′ = 1·397.

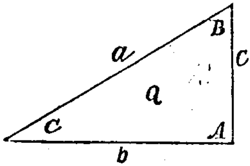
To find the Cotangent.

Example 4. Find the *cotangent* of 25° 35′?

Set A on 25° 35′, B on *sin.* 25° 35′, clamp C, move the arms until B comes to *Zero;* then A shows the length of the

cotan. 25° 35′ = 2.088.

Right Angled Triangles.



Given the side A *and the angle* C, *to find the sides* b *and* c.

Example 5. The side *a* = 34 feet 8 ins., and the angle *C* = 38° 46′. Required the sides *b* and *c*?

Set the arm A on 34·66 feet, B on *Zero,* clamp C, move the arms until B comes to *sin.*38° 46′; then A shows the length of the side, *c* = 21·7 feet. Move the arms until B comes to *cos.*38° 46′, then the arm A shows the length of the side, *b* = 27·02 feet.

Given the sides a *and* b *to find the angle* C *and the side* c.

Example 6. The side *a* = 113·6 feet, and *b* = 74·31. Required the angle *C*?

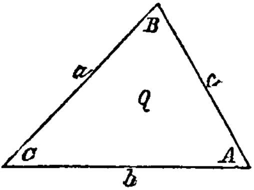
Set the arm B on 74·31 feet, A on 113.6, clamp C, move the arms until A comes to *Zero;* then B shows the angle *cos.*49°8′ Set A on 113·6, B on *Zero,* clamp C, move the arms until B comes to *sin.*49° 8′; then A shows the length of the side, *c* = 85·91 feet.

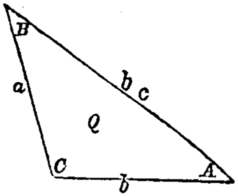
Example 7. An inclined plane is to be built for a railroad, the highest point of which is to be 264·5 feet above the base, and to form an angle with the horizon of not more than 10° 25′. What will be the length of the inclined plane ?

$$\text{Length} = \frac{264{\cdot}5}{sin.10^\circ\ 25'} = 1463 \text{ feet.}$$

Set A on 264·5, B on *sin.*10° 2′, clamp C, move the arms until B comes to *Zero;* then A shows the length = 1463 feet.

Oblique Angled Triangles.





Given the angle B, *and the two sides* a *and* b, *to fine the angle* A *and side c.*

Example 8. The side a = 86 feet 3 inches, b = 58 feet 6 inches, and the angle $B = 35^\circ\ 51'$. Required the angle A, and side c?

$$Sin.\ A = \frac{86{\cdot}25 \times sin.35^\circ\ 51'}{58{\cdot}5} = 59^\circ\ 43'.$$

Set the arm A on 86·25, B on 58·5, clamp C, move the arms until B comes to *sin.*35° 51′; then A shows the angle *sin. A* = 59° 43′.
The angle $C = 180 - (35^\circ\ 51' + 59^\circ\ 43') = 84^\circ\ 26'$.

$$\text{The side } c = \frac{86{\cdot}25 \times sin.84^\circ\ 26'}{sin.59^\circ\ 43'} = 99{\cdot}41 \text{ feet.}$$

Set A on 84° 26′, B on 59° 43′, clamp C, move the arms until B comes to 86·25 feet; then A shows the side c = 99·41 feet on the circle *a*.

Given the side c, *and the angles* A *and* C *to find the side* a.

Example 7. The side c = 27·6 feet, the angle $A = 47^\circ\ 40'$, and $C = 34^\circ\ 10'$. Required the side a = ?

$$a = \frac{27{\cdot}6 \times sin.47^\circ\ 40'}{sin.34^\circ\ 10'} = 36{\cdot}33 \text{ feet.}$$

Set the arm A on 27·6, B on *sin.*34° 10′, clamp C, move the arms until B comes to *sin.*47° 40′; then A shows the side a = 36·33 ft.

Given the sides b *and* c, *and the including angle* A, *to find the side* a.

Example 8. $b = 360$ feet, $c = 866$, and the including angle $A = 53° 45'$. Required the side $a = ?$

$$a = \sqrt{360^2 + 866^2 - 2 \times 360 \times 866 \times \cos. 53° 45'} = 714{\cdot}7 \text{ feet.}$$

Set A on 360, B on *Zero*, clamp C, move the arms until B comes to 360; then A shows the square 129600; in the same manner square 866; set up these squares and add them together.

$$360^2 = 129600$$
$$866^2 = 749956$$
$$+879556$$
$$-368600$$
$$\sqrt{510956} = 714{\cdot}7\text{ft.}$$

Set A on 2, B on *Zero*, clamp C, move the arms until B comes to 360, fasten A^e, loose C, set B on *Zero*, clamp C, loose A^e, move the arms until B comes to 866, fasten A^e, loose C, set B on *Zero*, clamp C, loose A^c, move the arms until B comes to *cos.* 53° 45′; then A shows the product, 368600. Subtract this from the sums of the two squares, and set A on the difference, 510956. The index for this number is 5, added to the mantissa in the circle *log.*, will be 5·708, divided by 2 = 2·854. Set the arm A on the mantissa, 854, and the length of the side a = 714·7 feet will be found on the circle a.

Example 9. In a triangle, the side $b = 356$ feet 3 inches, and $c = 257$ feet 9 inches; the angle $A = 25° 13'$. Required the area of the triangle?

$$Q = \frac{b\ c\ \sin. A}{2} = \frac{356{\cdot}25 \times 257{\cdot}75 \times \sin. 25° 13'}{2} = \text{square feet.}$$

Example 10. What will be the length of the side c in the triangle, when the area is Q = 12677000 square feet, and the angles
$A = 48° 55'$, $C = 56° 30'$?

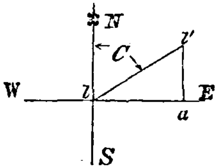
$$A + C = 105° 25'.$$

$$c = \sqrt{\frac{2\ Q\ \sin.\ C}{\sin. A\ \sin. (A \times C)}} = \sqrt{\frac{2 \times 12677000 \times \sin. 56° 30'}{\sin. 48° 55' \times \sin. 105° 55'}} = 5533.$$

Set A on 2, B on *sin.* 48° 55′, clamp C, move the arms until B comes to 12677000, fasten A_e, loose C, set B on *sin.* 105° 55′, clamp C, loose Ae, move the arms until B comes to *sin.* 56° 30′, fasten A^e, the index is 7, the mantissan = 46374; 7·46374 : 2 = 3·73187; set B on 73187, circle *log.*; the circle a shows the length of the side $c = 5533$ feet.

NAVIGATION. PLANE SAILING.

Plane Sailing is when navigating a ship with the supposition that the earth is a level plane, on which the meridians are drawn north and south, parallel with each other ; and the parallels east and west, at right angles to the former.



The line N S, represents a meridian north and south. The line E W, represents a parallel, east and west.

A ship in *l*, sailing in the direction *l l'*, and having reached *l'*, it is required to know her position to the point *l*, which is measured by the line *l l'*, and the angle N, *l l'*, and imagined by the lines *l a*, and *a l'*.

These four quantities bear the following names :

l l', distance from *l* to *l'*.

N *l l'*, *course* or *points* from the meridian.

l a, departure or difference in longitude.

a l', difference in latitude.

The calculations for plane sailing are to be operated by the inner scale *points*, in connexion with the outer scales. The points represent the courses on the mariner's compass, and are laid out from the trigonometrical scale, so that when the arm is set on a point numbered in the circle *dep.sin.* shows the corresponding angle in degrees and minutes. Set the arm A on *dep.*3½ points, and *sin.* will show the corresponding angle, 39° 22'. Set A on *sin.*53° 20', and *dep.* shows the corresponding course, 4¾ points nearly.

To Find the Departure and Difference in Latitude.

Given the course and distance.

Example 1. A vessel sails east north-east, (6 points), 34·5 miles. Required her departure and difference in latitude?

Set the arm A on the distance, 34·5 miles (circle *a*), B on *Zero*, clamp C, move the arms until B comes to the course *dep.* 6 points, then A shows the departure = 31·87 miles circle *a.* Move the arms until B comes to the course, *lat.* 6 points, and A shows the difference in latitude = 13·2 miles.

Example 2. A ship sails N.N.E.¼E, (2¼ points,) 266 miles. Required her departure and difference in latitude?

Set the arm A on the distance, 266 miles, (circle *a*), B on *Zero*, clamp C, move the arms until B comes to the course *dep.*, 2¼ points, then A shows the departure = 113·7 miles, circle *a.* Move the arms until B comes to the course, *lat.* 2¼ points, and A shows the difference in latitude = 244 miles.

Given the course and difference in latitude.

Example 3. A ship sailing S. E. by S., (3 points,) and makes a difference in latitude of 87 miles. Required her departure?

Set the arm A on the diff. lat. 87, B on *lat.* 3 points; clamp C, move the arms until A comes to the course dep. 3 points, then B shows the departure, 58·1 miles.

Given the course, latitude, and difference in longitude.

Example 4. A ship sails E. N. E.½E., (6½ points,) from latitude 48° 45′, made a difference in longitude of 2° 20′ = 140 miles at the equator. Required her departure and difference in latitude?

Set the arm A on the difference in longitude, 140 miles, (circle *a*), B on *Zero*; clamp C, move the arms until B comes to the latitude, cos. 48° 45′, then A shows the departure = 92·31 miles.

Let the arm A remain on the departure, 92·31; loose C, set B on the course, *dep.* 6½ points; clamp C, move the arms until B comes to the course, *lat.* 6½ points, then A shows the difference in latitude = 28·02 miles.

Note. If the arm A covers 6¼ points, move it to 92·31 miles on the opposite side.

To Find the Distance.

Given the departure and difference in latitude.

Example 5. A vessel sailed between N. and W., and made 13 miles departure, and 32 in difference of latitude. Required her course and distance sailed?

Set the arm A on the difference in latitude, 32 miles, and B on the departure, 13; clamp C, move the arms until the arm B shows the same number of points on *dep.* as the arm A shows on *lat.*; it will be found to be nearly 2 points, or the course sailed was N.N.W. Let the arm B remain on this course; loose C, and set A on *Zero;* clamp C, move the arms until B comes to the departure, 13 miles, then A shows the distance= 34·25 miles.

Given the course and difference in latitude.

Example 6. A ship sails S. W. by S. (3 points), and made a difference in latitude of 69 miles. Required the distance sailed?

Set the arm A on the diff. lat. 69 miles, and B on the course *lat.*3 points, clamp C, move the arms until B comes to *Zero,* then A shows the distance=83 miles. Move the arm until B comes to dep. 3 points, and A shows the departure=46.1 miles.

Given the course, latitude, and difference in longitude.

Example 7. A vessel sails S. E. ½ E. (4½ points) from latitude 41° 36′, and made a difference in longitude of 2° 15=135 miles at the equator. Required her distance sailed?

Set the arm A on 135 miles (circle *a*), and B on the course *dep.* 4½ points, clamp C, move the arms until B comes to the latitude *cos.* 41° 36′, then A shows the distance=130·5 miles.

Given the Course and Departure.

Example 8. A vessel sailing S. W. by W. ¾ W., (5¾ points), and makes a departure of 52·6 miles. Required the distance sailed?

Set A on the departure 52·6 (circle *a*), and B on the course *dep.*5¾ points, clamp C, move the arms until B comes to *Zero,* then A shows the distance=58·2 miles.

To Find the Latitude.

Given the Departure and difference in Longitude.

Example 8. A ship sails due West 214 miles departure, and found the difference in longitude to be 5° 25′. Required the latitude in? Multiply 5° by 60, and add 25′=325′.

Set the arm A on 214, B on 325, clamp C, move the arms until A comes to *Zero*, then B shows the latitude *cos*.48° 49′.

Given the Course, Distance, and Difference in Longitude.

Example 9. A vessel sails N. E. ¾ E. (4¾ points), a distance of 158 miles in north latitude, and made a difference in longitude of 2° 57′. Required the middle latitude, and latitude in? 2° 57′=177′.

Set A on 177, B on the distance 168, clamp C, move the arms until A comes to the course *dep*.4¾ points, then B shows the middle latitude *cos*.40° 20′. Set A on the distance 168 miles, B on *Zero*, clamp C, move the arms until B comes to the course *lat*.4¾ points, then A shows the difference in latitude=100·4 miles, of which one-half added to the middle latitude gives 41° 10′ the latitude in.

Given the Course, difference in Latitude, and difference in *Longitude.*

Example 10. A ship sailing S. W. by W. ½ W. (5½ points) in north latitude, makes a difference in latitude of 98 miles, and difference in longitude 3° 42′=222′. Required the middle latitude and latitude in?

Set the arm A on 222, B on difference in latitude 98, clamp C, move the arms until A comes to the course *dep*.5½ points, fasten B^c, loose C, set A on the course lat.5½ points, fasten C, move the arms until A comes to *Zero*, then B shows

the middle latitude	*cos*.34°	21′.
Sub. half diff. lat. 98′,		49
Latitude in	33	32

To Find the Course.

Given the distance and difference in Latitude.

Example 11. The distance between two places is 378 miles, and difference in latitude 231. Required the course from one to the other?

Set A on 378, B on 231, clamp C, move the arms until A comes to *Zero*, then B shows the course, lat.4¾ points nearly.

Given the distance and departure.

Example 12. The distance between two places is 725 miles, and the departure 248·5 miles. Required the course from one to the other?

Set A on the distance 725, B on the departure 248.5, clamp C, move the arms until A comes to *Zero*, then B shows the course *lat.* dep.1¾ points nearly.

Given the difference in Latitude and Departure.

Example 13. Departure=63 miles, and difference in latitude=29.5. Required the course?

Set A on 63, B on 29·5, clamp C, move the arms until *dep.* on the arm A shows the same course as *lat.* on B; it will be found to be 5¾ points nearly.

Given the Middle Latitude, difference in Longitude and Distance.

Example 14. The distance between two places is 722 miles, difference in longitude 10° 35′=635′, and middle latitude 54°. Required the course from the one place to the other?

Set A on the difference in longitude 635′, B on the distance 722 miles, clamp C, move the arms until A comes to the middle latitude *cos.* 54°, then B shows the course *dep.*3¾ points nearly.

Given the Middle Latitude, difference in Latitude, and difference in Longitude.

Example 15. Required the course and distance from Havana to New Orleans?

Latitude	29° 57′	of New Orleans.
"	23 9	of Havana.
Diff. in latitude,	6° 48′=408 miles.	
Middle latitude,	26 33	
Longitude,	90° 00′	of New Orleans.
"	82 22	of Havana.
Diff. in longitude.	7° 38′=458′	

Set the arm A on the diff. in longitude 458′, B on different latitude 408 miles, clamp C, move the arms until B comes to the middle latitude *cos.* 26° 33′, then A shows the tangent for the course=1, or the course is 4 points N. W. from New Orleans. Set A on difference in latitude 408, B on *lat.* 4 points, clamp C, move the arms until B comes to *Zero*, then A shows the distance, 577 miles from Havana to New Orleans.

Example 16. A ship in north latitude 48° 46′, and longitude 39° 18′, is bound for New York. Required her course and distance to the latter place?

Latitude in	48° 46′	of the ship.
"	40 42	of New York.
Diff. in latitude,	8° 4′=484 miles.	
Middle latitude,	44 44	
Longitude,	74 0	of New York.
" in	39 18	of the ship.
Diff. in longitude,	34° 42′=2082′	

Set A on 2082, B on difference in latitude 484, clamp C, move the arms until B comes to the middle latitude *cos*.44° 44′, fasten Ae, loose C, set B on *Zero*, clamp C, move the arms until *dep.* on the arm A shows the same course as *lat.* on B, it will be found to be 6½ points nearly, or W. S. W. ½ W. the course required.

Set A on difference in latitude 484, B on the course *lat*.6½ points, clamp C, move the arms until B comes to *Zero*, then A shows the distance=1535 miles.

To Find the Difference in Longitude.

Given the Departure and Latitude.

Example 17. Departure=204 miles, and latitude 61° 35′. Required the difference in longitude?

Set A on the departure 204, B on the latitude *cos*.61° 35′, clamp C, move the arms until B comes to *Zero*, then A shows the difference in longitude=428.8 minutes, divided by 60 gives the difference in longitude=7° 8.8′.

Given the Course, Distance, and Middle Latitude.

Example 18. A ship sailing S. W. by S. (5 points), 115 miles in a middle latitude 47° 39′. Required her difference in longitude?

Set A on the distance 115 miles, B on the middle latitude *cos*.47° 39′, clamp C, move the arms until B comes to the course *dep*.5 points, then A shows the difference in longitude=142·5′, divided by 60 is 2° 22·5′ the difference in longitude required.

In working traverse sailing, it is more convenient to find the difference in latitude and departure by this calculator, than by the ordinary method with tables. Instead of setting down the departure in the transverse table, the difference in longitude can be set down at once, by dividing the departure by *cos.* for the middle latitude, which is only to place the arm B on *cos.* for the middle latitude, while A remains on the departure; clamp C, and move the arms until B comes to *Zero,* then A shows the difference in longitude in minutes. This method is more correct than the ordinary one.

To Find how many Miles per Degrees of Longitude in different Latitudes.

Set the arm A on 60, B on *Zero,* clamp C, move the arms until B comes to the given latitude in the circle *cos.*, then A shows the length of one degree in longitude.

Examples. Latitude	6°	27′?	59·62	miles.
"	13	41 ?	58·31	"
"	27	33 ?	53·20	"
"	45	0 ?	42·42	"
"	67	52 ?	22·6	"
"	71	13 ?	18·32	"

Spherical Distances.

In high latitudes and very long distances, the preceding rules will not give such correct results as may be desired, owing to the spheroidal form of the earth; but by the aid of spherical trigonometry, we are enabled to ascertain courses and distances *correctly* from and between any known points on the earth.

To Find the true Course and Distance between two Places in the same Latitude.

Example. Boston (North America), and Cape Creaux (South Spain), are in the same latitude, about 42° 20′, and difference in longitude 74° 20′. Reqnired the course and distance from Boston to Cape Creaux?

Set the arm A on *Zero,* B on half the difference in longitude *sin.*37° 10′, clamp C, move the arms until A comes to the latitude *cos.*42° 20′, then B shows half the distance *sin.*26° 32′, multiplied by 2=53° 4′, the true distance.

Set A on the difference in longitude *sin.* 74° 20′, B on the distance *sin.*53° 4′, clamp C, move the arms until B comes to the latitude *cos.* 42° 20′, then A shows the course 5½ points, or more correctly on the trigonometrical scale *sin.*62° 56′, the true course.

To Find the True Course and Distance between two Places in different Latitudes.

Example. Required the course and distance from latitude 52° 28′ longitude 27° 18′, to New York in latitude 40° 42′, longitude 74° ? Difference in longitude 46° 42′.

Find the angle $\tan. m = \frac{\cos. 52° 28' \times \cos. 46° 42'}{\sin. 52° 28'} = 27° 47'$.

Set the arm A on the latitude *sin*.52° 28′, B on *cos*.58° 28′, clamp C, move the arms until A comes to the difference in longitude *cos*. 46° 42′, fasten Be, loose C, set A on *Zero,* clamp C, move the arms until *cos.* on A shows the same angle as *sin.* on B, it will be

found to be		27° 47′
Latitude of New York	add	40 42
Subtract this		68° 29′
from		90° 0
		n=21° 31′

The true distance $\cos. = \frac{\sin. 52° 28' \times \cos. 21° 31'}{\cos. 27° 47'} = 33° 30'$.

Set A on *cos.* 27° 47′, B on *sin.* 52° 28′, clamp. C, move the arms until A comes to *cos.* 33° 30′=2010 miles.

The true course $dep. = \frac{\sin. 46° 42' \times \cos. 40° 42'}{\sin. 33° 30'} = 8$ points.

Set the arm A on *sin*.46° 42′, B on *sin*.33° 30′, clamp C, move the arms until B comes to *cos.* 40° 42′, then A shows the course, *dep*.3 points, or W. This course will vary continually southwards, until the approach of New York, it will be

$dep. = \frac{\sin. 46° 42' \times \cos. 52° 28'}{\sin. 33° 30'} = 4\frac{3}{4}$ points, or S. W. $\frac{3}{4}$ W.,

or, more correctly, on the trigonometrical scale, *sin*.53° 27′ from meridian.

In connexion with the preceding example, it is required to find the latitude, longitude, and courses, at four points, in the track, say at distances 10°, 16°, and 25° from New York ?

Calculation for the point 25°.

$$\tan. m = \frac{\sin. 25° \times \cos. 53° 27'}{\cos. 25°} = 15° 31'.$$

Set the arm A on *cos.*25°, B on *sin.*25°, clamp C, move the arms until A comes to the course from New York, *cos.*53° 27′, fasten Be, loose C, set A on *Zero,* clamp C, move the arms until *cos.* on A shows the same angle as *sin.* on B, it will be found to be 15° 31′.

Latitude of New York, . .	add,	40 42
		56 13
Subtract this angle from . . .		90 00
		n = 33° 47′

$$tan., diff., long., = \frac{sin.15^\circ\ 31' \times sin.53^\circ\ 27'}{sin.33^\circ\ 47' \times cos.53^\circ\ 27'} = 33^\circ\ 2'.$$

Set the arm A on *sin.*33° 47′, B on *sin.*15° 31′, clamp C, move the arms until A comes to *sin.*53° 27′. fasten Be, loose C, set A on *cos.*53° 27′, clamp C, move the arms until *cos.*on A shows the same angle as *sin.* on B, is the difference in longitude from New York, =33° 2′, and

$$\text{latitude } cos. = \frac{sin.25^\circ \times sin.53^\circ 27'}{sin.33^\circ\ 2'} = 51^\circ\ 29'.$$

Set the arm B on the distance, *sin.*25°, A on *diff., long., sin.,* 33° 2′, clamp C, move the arms until A comes to the course from New York, *sin.*53° 27′, then B shows the latitude *cos.*51° 29′.

The course in this point will be,

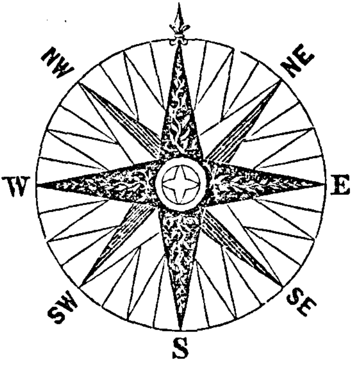
$$sin. = \frac{sin.53^\circ\ 27' \times cos.40^\circ\ 42'}{cos.51^\circ\ 29'} = 6\tfrac{7}{8} \text{ points.}$$

W. by S. nearly, or 78° from the meridian.

In a similar manner, calculate the latitude, longitude, and courses in the points 16° and 10° from New York, the answer will be found in the accompanying track-table:

Sailing Track to New York.

Distance from New York.	Latitude in	Longitude in	Course.	Points.
33° 30′	52° 38′	27° 18′	West.	8
25	51 29	40 58	W. by S.	$6\frac{7}{8}$
16	48 44	54 23	W.S.W.	6
10	46 9	62 23	S. W. by W. ½ W.	$5\frac{1}{2}$



North.	South.	Points.	Degrees.	*sineC.*	*Cos.C.*	*tan.C.*
N.	S.	¼ ½ ¾	2° 49′ 5 37 8 26	·0491 ·0979 ·1544	·9988 ·9952 ·9880	·0492 ·0983 ·1982
N. by E. and N. by W.	S. by E. and S. by W.	1 1¼ 1½ 1¾	11 15 14 4 16 52 19 41	·1936 ·2430 ·2901 ·3368	·9811 ·9700 ·9570 ·9416	·1989 ·2505 ·3032 ·3577
N. N. E. and N. N. W.	S. S. E. and S. S. W.	2 2¼ 2½ 2¾	22 30 25 19 28 7 30 56	·3827 ·4276 ·4713 ·5140	·9239 ·9039 ·8820 ·8577	·4142 ·4730 ·5343 ·5993
N. E. by N. and N. W. by N.	S. E. by S. and S. W. by S.	3 3¼ 3½ 3¾	33 45 36 44 39 22 42 11	·5555 ·5981 ·6343 ·6715	·8314 ·8014 ·7731 ·7410	·6883 ·7463 ·8204 ·9062
N. E. and N. W.	S. E. and S. W	4 4¼ 4½ 4¾	45 0 47 49 50 37 53 26	·7071 ·7410 ·7731 ·8014	·7071 ·6715 ·6345 ·5981	1·000 1·103 1·218 1·348
N. E. by E. and N. W. by W.	S. E. by E. and S. W. by W.	5 5¼ 5½ 5¾	56 15 59 4 61 52 64 41	·8314 ·8577 ·8820 ·9039	·5555 ·5140 ·4713 4276	1·496 1·668 1·870 2·114
E. N. E. and W. N. W.	E. S. E. and W. S. W.	6 6¼ 6½ 6¾	67 30 70 19 73 7 75 56	·9239 ·9416 ·9570 ·9700	·3827 ·3368 ·2901 ·2430	2·414 2·795 3·295 3·991
E. by N. and W. by N.	E. by S. and W. by S.	7 7¼ 7½ 7¾	78 45 81 34 84 22 87 11	·9811 ·9880 ·9952 ·9988	·1936 ·1544 ·0979 ·0491	5·027 6·744 11·14 20·32
East or	West . .	8	90°	1·000	0.000	∞

To Find the Apparent Time by an Altitude of the Sun.

Given the sun's centre, altitude and declination, and latitude of the place of observation.

Example. Latitude and declination of equal names.

On the 21st day of July, 1854, at 4h. 30m. P. M. per watch, was taken an altitude of the sun's lower limb by a force observation 28° 18′, the correction for semidiameter, parallax, and *dep.*, add 12′; for refraction subtract 4′; correct centre altitude 28° 26′. Latitude of the place 48° 31′ N. Longitude by account 36° 42′ W. from Greenwich. The sun's declination 20° 27′ (corrected). Required the apparent time of observation ?

To	90°
Add declination, N.	20 27′
From this	110° 27′
Subtract latitude N.	48 31
Meridian altitude,	61° 56′

Set the arm A on the decl. *cos*.20° 27′, B on *sin*.20° 27′, clamp C, move the arms until A comes to the lat. *sin*.48° 31′, fasten Be, loose C, set A on *cos*.48° 31′, clamp C, loose Be, move the arms until A comes to *Zero*, then B shows 4217, circle *a*, note this. Set A on 1·4217, B on the meridian altitude *sin*.61° 56′, clamp C, move the arms until B comes to the altitude *sin*.28° 26′, then A

shows	7671
Subtract the noted number	4217*
Set the arm B on	3454

which then shows the hour, angle *cos*.69° 47′ divided by 15 is the apparent time 4h. 39m. 8s.

```
15) 69° (=4h.
    60
    ──
     9×60=540
           47′
          ───
     15) 587=39m.
         45
         ───
         137
         135
         ───
           2×60=120=8 s.
```

Perform this division by the calculator.

* Add if latitude and declination are of equal names.

Example. Latitude and declination of different names.

On the 16th day of May, 1854, at 8h. 10m. A. M. per watch, was taken an altitude 12° 18′ of the sun's lower limb. For corrections add 8′, centre altitude 12° 26′, latitude of the place 31° 42′ S. Longitude by account 150° W. from Greenwich. Suns declination, 19° 9′ N. (corrected). Required the apparent time of observation?

Declination N.,	19° 9′
Latitude S. add	31 42
Subtract this	50° 51′
from	90 00
Meridian altitude,	39° 9′

Set the arm A on the decl. *cos.*, B on *sin.* 19° 9′, clamp C, move the arms until A comes to the latitude *sin.* 31° 42′, fasten Be, loose C, set A on *cos.* 31° 42′, clamp C, loose Bc, move the arms until A comes to *Zero*, then B shows 2146, note this.

from	10000
Snbtract	2146*

Set the arm A on 7854, B on the merd. alt. *sin.* 39° 9′, clamp C, move the arms until B comes to the alt. *sin.* 12° 26′,

then A shows	2678 circle *a*.
add the noted number	2146†

Set the arm B on 4824, which then shows the hour angle *cos.* 61° 9′, divided by 15 and the quotient subtracted from 12 hours is the apparent time 7h. 55m. 24s.

15) 61 (=4h.
50
1 × 60 = 60 = 4m.
4 × 9 = 36 s.

from	11h. 59m. 60′
subtract	4h. 4m. 36s.
	7h. 55m. 24s. the apparent time of observation.

By the same rules, the apparent time can be calculated by an altitude of any heavenly body, whose declination and right ascension are known.

If the moon is used, it is best to find the time when the moon passes the meridian at Greenwich, from the Nautical Almanac, and proceed as the following example:

* Add if latitude and declination are of equal names.

† Subtract if latitude and declination are of different names.

Example. On the 25th day of September, 1852, in north latitude 22° 35′, and west longitude about 53° 9′, at 7h. 15m. o'clock by watch, was taken an altitude

Of the moon's lower limb,		33° 42′
Correction semd. parlx. refn. add		45
Moon's correct centre altitude,		34 27
Moon's declination corrected,		13 53 S.
Passes the meridian at Greenwich,		10h. 21 m.
Correction add	53×0.14 =	0 7
Passes the meridian, at		10h. 29m.

Required the *mean time* and *longitude* from Greenwich?

Declination S.	13° 53′
Latitude N. add	22 35
Subtract this	36 28
From	90 00
Meridian altitude,	53 32

$$\text{Note} = \frac{sin.13° \ 53'}{cos.13° \ 53'} \times \frac{sin.22° \ 35'}{cos.22° \ 35'} = 0.10275.$$

$$\frac{sin.34° \ 27' \ (1-0{\cdot}10275)}{sin.53° \ 82'} + 0{\cdot}10275 = 0{\cdot}73385 = 42° \ 47',$$

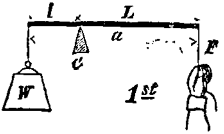
$$\frac{42° \ 47'}{15} = \text{2h. 51 m. 8 sec. apparent moon time.}$$

Divided by 0·965 will be 2h. 57′ 20″.

Moon passes the meridian at	10h. 29′
Subtract,	2 57 20″
Mean time of observation,	7h. 31′ 40″
Watch too slow,	16 40
Time of observation by *chronometer,*	11 13 15
Subtract *mean time* of obs.	7 31 40
	3h. 41′ 35″
Multiply by	15
West longitude,	55° 23′ 45″

MECHANICS.

Lever of the first kind.



Example 1. The lever L = 158 inches; $l = 8\frac{1}{2}$ inches, and W = 48,230 pounds. Required the force F = ?

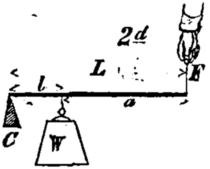
$$\text{Force } F = \frac{48230 \times 8{\cdot}5}{158} = 2592 \text{ pounds.}$$

Set A on 48,230, B on 158; clamp C, move the arms until B comes to 8·5, then A shows the force F = 2592 pounds.

Example 2. The weight W = 868 pounds; $l = 5{\cdot}5$ inches, and the force F = 50 pounds. Required the length of the lever L = ?

$$\text{Lever } L = \frac{868 \times 5{\cdot}5}{50} = 95{\cdot}48 \text{ inches.}$$

Lever of the second kind.



Example 3. The force F = 880 pounds; L = 10 feet, and W = 16260 pounds. Required the lever l = ?

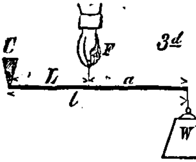
$$\text{Lever } l = \frac{880 \times 10 \times 12}{16260} = 6{\cdot}494 \text{ inches.}$$

Set A on 88, B on 16260; clamp C, move the arms until B comes to 12, then A shows the lever $l = 6{\cdot}494$ inches.

Example 4. The lever L = 12 feet 3 inches; $l = 6$ inches, and the force F = 362 pounds. How much can it lift W = ?

$$\text{The weight } W = \frac{362 \times 12{\cdot}25}{0{\cdot}5} = 8870 \text{ pounds.}$$

Set the arm A on 362, B on 5; clamp C, move the arms until B comes to 12·25, then A shows the weight, W = 8870 pounds nearly



Lever of third kind.

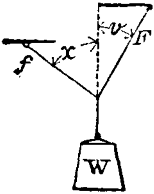
Example 5. The lever $l=8$ feet. How far from the fulcrum c shall a force $F=47$ pounds be applied to lift a weight $W=165$ pounds?

$$L=\frac{165\times 8}{47}=2{\cdot}81 \text{ feet.}$$

Set the arm A on 165, B on 47; clamp C, move the arms until B comes to 8, then A shows the lever L = 2·81 feet.

Example 6. The lever $l=6{\cdot}8$ feet, and $L=1{\cdot}42$ feet. What force F is required to lift the weight $W=27{\cdot}5$ pounds?

$$\text{Force } F=\frac{27{\cdot}5\times 6{\cdot}8}{1{\cdot}42}=131{\cdot}5 \text{ pounds.}$$



An oblique fixed pulley.

Example 7. The weight $W=3840$ pounds; angle $v=34°\ 25'$, and $x=43°\ 35'$. Required the forces that acts in F and f?

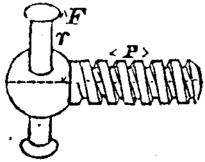
43° 35′
34 25
77° 50′

$$F=\frac{3840\times sin.43°\ 35'}{sin.77°\ 50'}=2709 \text{ pounds.}$$

Set the arm A on 3840, B on *sin*.77° 55′; clamp C, move the arms until B comes to *sin*. 43° 35′, then A shows the force F=2709 pounds. Move the arms until B comes to *sin* 34° 25′, then A shows the force

$$f=\frac{3840\times sin.34°\ 25'}{sin.77°\ 50'}=2220 \text{ pounds.}$$

Example 8. A force $F=138$ pounds is applied on a radius $r=36$ inches. The pitch of the screw is $P=1{\cdot}25$ inch. Required the actuated power of the screw ?



$$\text{Power}=\frac{138\times6{\cdot}28\times36}{1{\cdot}25\text{ inch}}=24960\text{ pounds.}$$

Set the arm A on 138, B on 1·25, clamp C, move the arms until B comes to 6·28, fasten A^e, loose C, set B on *Zero*, clamp C, move the arms until B comes to 36, then A shows the power of the screw=24960 pounds. This is the theoretical power of the screw, when taking the friction and diameter of the screw into consideration, it will be, if the diameter of the screw is 5 inches, and lubricated with oil.

$$\text{Power}=\frac{138\times6{\cdot}28\times36}{1{\cdot}25+0{\cdot}25\times5}=12480\text{ pounds.}$$

Multiply 5 by 0·25=	1·25
Add	1·25
Denominator	2·5

Set A on 138, B on 2·5, clamp C, move the arms until B comes to 6·28, fasten A^e, loose C, set B on *Zero*, clamp C, move the arms until B comes to 36, then A shows the power=12480 pounds.

Power of Steam Engines.

Example 9. The piston in a steam engine moves a space of 90 feet in 25 seconds, with a steam pressure 25000 pounds. Required the horse power of the engine ?

$$\frac{25000\times90}{550\times25}=163{\cdot}6\text{ horses,}$$

deducting ¼ for friction will be actual power $163{\cdot}6\times0{\cdot}75=122{\cdot}8$ horses.

Set the arm A on 25000, B on 550, clamp C, move the arms until B comes to 90, fasten A^e, loose C, set B on 25, clamp C, loose A^e, move the arms until B comes to *Zero*, then A shows the horse power 163·6, move the arms until B comes to 0·75, then A shows the actual horse power 122·8.

Example 10. Area of steam piston 1018 square feet,
Stroke of piston, 4 feet,
Pressure in the boiler, 35 pounds per sq. inch.
Vacuum in the condenser, 11 " " "
Effectual pressure, 46 " " "

To make 45 revolutions per minute. Required the horse power of the engine ?

$$\frac{1018\times4\times46\times45}{24250}=347{\cdot}5 \text{ actual horses.}$$

Example 11. Required the power of a high pressure engine of the following dimensions: area of piston 572·5 square inches, stroke 3 feet, pressure of steam 42 pounds per square inch ? to make 38 revolutions per minute.

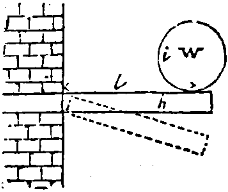
$$\frac{572{\cdot}5\times3\times42\times38}{19000}=220 \text{ actual horses.}$$

Nominal Horse Power.

Example 12. Diameter of cylinder 24 inches, stroke of piston 9 feet. Required the nominal horse power ?

$$\frac{24^2\times\sqrt[3]{9}}{47}=25{\cdot}5 \text{ horses.}$$

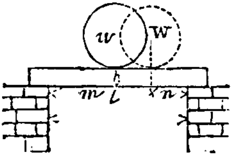
Lateral Strength.



Example 1. A rectangular beam of oak 5 inches thick by 3 inches deep, projects out from its support 10 feet 6 inches. Required how much weight W, it can bear on the end with safety ?

$$W=\frac{40\times5\times8^2}{11{\cdot}5}=1113 \text{ pounds.}$$

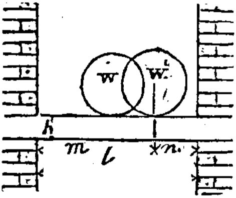
Example 2. A rectangular beam of pine 8 inches thick by 12 inches deep, is supported at both ends $l=16{\cdot}5$ feet. Required how much weight it can bear on the middle, and how much at 5 feet from one end?



$$W=\frac{4\times32\times8\times12^2}{16{\cdot}5}=4462 \text{ pounds on the middle.}$$

$$W'=\frac{4462\times16{\cdot}5^2}{4\times5\times11{\cdot}5}=5270 \text{ lbs. at 5 feet from one end.}$$

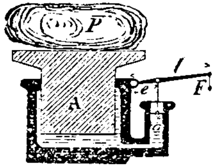
Example 3. A cast-iron beam 2·75 inches thick by $10\frac{1}{2}$ inches, is fast supported at both ends; the distance between supports is $l=20$ feet. Required how much weight it can bear on the middle?



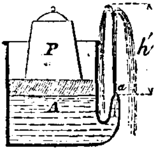
$$W=\frac{8\times150\times2{\cdot}75\times10{\cdot}5^2}{20}=18150 \text{ pounds.}$$

Hydraulics.

Example 4. The area of a piston in a hydraulic press is $A=238$ square inches, area of the pump $a=2{\cdot}3$ square inches, the lever $l=42$ inches, $e=5$ inches. Required the pressure $P=?$ when the force $F=36$ pounds.



$$\text{pressure}=\frac{36\times42\times238}{5\times2{\cdot}3}=31250 \text{ pounds.}$$



Example 5. The weight P=158 lbs. and the area A=0·96 square feet. Required the height of the jet h'=? and how many gallons of water will be discharged per minute through the orifice a=0·0003 square feet?

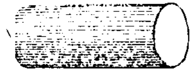
$$h'=\frac{158}{60{\cdot}5\times0{\cdot}96}=2{\cdot}72 \text{ feet.}$$

$$60\times0{\cdot}0003\sqrt{\frac{158}{0{\cdot}96}}=0{\cdot}231 \text{ gallons per minute.}$$

Set the arm A on 158, B on 0·96, clamp C, move the arms until B comes to *Zero*, then A shows the mantissa 216 (circle *log.*) the index is 2, and 2·16 divided by the index of the root 2 is 1·108. Set A on the mantissa 108, (circle *log.*), B on *Zero*, clamp C, move the arms until B comes to 3, fasten A°, loose C, set B on *Zero*, clamp C, loose A°, move the arms until B comes to 60, then A shows 0·231 gallons.

In this example the indexes must be carefully operated by the small band.

Capacity and Weight.

Names of substracts.								
	FFF	Fii	iii	FF^2	Fi^2	ii^2	F^3	i^3
Cubic inches, .	···5787	0·0833	1.	···7374	0·1061	1·273	···1106	1·912
Cubic feet,	1	144	1728	1·273	182·1	2272	1·912	4125
Gallons, .	0·1337	19·23	230·9	0·1704	2·451	294·5	0·2557	442·4
Water, fresh,	0·016	2·31	27·7	0·0204	2·94	35·33	0·0305	52·63
Water, salt, .	0·0155	2·247	26·5	0·0198	2·85	34·48	0·0297	50·
Oil, .	0·0174	2·5	30·3	0·0222	3·2	38·3	0·033	58·8
Cast iron, .	0·0022	0·32	3·83	0·00283	0·488	4·9	0·00425	7·35
Wrought iron,	0·00205	0·296	3·557	0·0026	0·3773	4·52	0·00392	6·8
Brass, .	0·00188	0·2717	3·257	0·0024	0·3448	4·15	0·0036	6·21
Copper, .	0·0018	0·259	3·115	0·00229	0·330	3·968	0·003436	5·95
Zinc, .	0·00227	0·327	3·937	0·0029	0·4166	5·	0·00434	7·51
Lead, .	0·00141	0·2032	2·439	0·00179	0·2584	3·105	0 00269	4·65
Tin,	0·00219	0·3164	3·802	0·00279	0·4032	4·83	0·00418	7·246
Stones common,	0·00641	0·926	11·11	0·0082	1·176	14·08	0·0122	21·27
Coal, stone, .	0·0185	2·66	32·25	0·0238	3·401	41·16	0·0354	62·5
Oak, dry, .	0·0172	2·5	30·	0·0227	3·16	38·4	0·0333	58·8

Example 1. A rectangular basin is 16 feet long, 27 inches wide, and 13 inches deep. Required how many cubic feet, and how many gallons it contains?

$$\text{cubic feet}=\frac{16\times27\times13}{144}=39$$

Set the arm A on the length 16 feet, B on the coefficient 144 (see column *F i i* and cubic feet), clamp C, move the arms until B comes to 27, fasten A^e, loose *e* set B on *Zero*, clamp C, loose A^e, move the arms until B comes to the *dept* 13 inches, then A shows 39 cubic feet.

$$\text{Gallons}=\frac{16\times27\times13}{19{\cdot}23}=291{\cdot}5$$

Example 2. A cylindrical vessel is 33 inches in diameter and 45 inches high. Required how many gallons of water it can contain?

$$\frac{45\times33\times33}{294{\cdot}5}=166 \text{ gallons.}$$

Proceed as in the preceding example, but find the coefficient 294·5 in the column $i\,i^2$ and gallons.

Example 3. A cast iron ball is 8½ inches in diameter. Required the weight of it?

$$\text{weight}=\frac{8{\cdot}5\times8{\cdot}5\times8{\cdot}5}{7{\cdot}35}=83\tfrac{1}{2} \text{ pounds.}$$

Find the coefficient 7·35 in the column i^3 and cast-iron, and opperate as before.

Example 4. A flat rolled bar of iron is ½ inch by 2¾, and 13 feet 6 inches long. Required the weight of the bar?

$$\text{weight}=\frac{0{\cdot}5\times2{\cdot}75\times13{\cdot}5}{0{\cdot}296}=62{\cdot}7 \text{ pounds.}$$

Example 5. A round bar of wrought iron is 5 inches diameter, and 11 feet long. Required the weight of it?

$$\text{weight}=\frac{5\times5\times11}{0{\cdot}3773}=728 \text{ pounds.}$$

Example 6. A lead ball is 5¾ inches diameter. Required the weight of it?

$$\text{weight}=\frac{5{\cdot}75^3}{4{\cdot}65}=40{\cdot}8 \text{ pounds.}$$