PROFESSOR FULLER'S
CALCULATORS
HAVING A
LOGARITHMIC SCALE OF NUMBERS
41 Feet 8 Inches in Length

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INSTRUCTIONS
FOR THE USE OF THE
CALCULATOR
THE FULLER CALCULATOR

is a logarithmic calculator. Its fundamental principle is precisely the same as the ordinary Slide Rule, but it differs radically in mechanical construction.

The principles of logarithmic calculators are too well-known to those likely to be interested in it, to be necessary to enlarge upon the subject here, especially as it is absolutely unnecessary to have any knowledge of the subject to use the calculator.

The FULLER CALCULATOR will perform all calculations involving:

- MULTIPLICATION
- PERCENTAGES and
- DIVISION
- COMBINED MULTIPLICATION
- PROPORTION and DIVISION,

giving an accuracy of 1 in 10,000.

It costs only a fraction of the cost of an Arithmometer, and it is far less complicated to use. Its construction is so simple that there is nothing to get out of order, consequently maintenance charges are practically nil.

Anyone can calculate with the Fuller after a brief study of the following instructions without any mathematical knowledge whatever.

For Percentage and Proportional Calculations, it is the most efficient calculator of its type in existence.

DESCRIPTION

The Calculator consists principally of a cylinder D about 6 inches high by 3 inches diameter, on which is mounted the spiral logarithmic calculating scale, which is 500 inches in length.

This revolves and slides on an inner cylinder H, which is held by a handle E. The settings are made and the calculations effected by use of the metal pointers or indexes A & B & F shown in the illustration.

As the accuracy of a Logarithmic Calculator, other things being equal, is directly proportional to its length, the vast superiority of this calculator over all others working on the same principle is obvious.

The instrument is contained in a mahogany box, which is also adapted for use as a stand to save the fatigue of holding the instrument in the hand. See Fig. 1.

Three different models are available. All are similar in construction but two of them bear additional scales on the inner cylinder H, a description of which will be found in the following pages.
MODEL No. 1

For calculations involving:

MULTIPLICATION
DIVISION
PERCENTAGES and
COMBINED MULTIPLICATION
and DIVISION.

This model has no scale on the inner cylinder \( B \) which is occupied by a table of useful data.

The Spiral Scale is divided as follows:

Each of the primary divisions as far as 650, is divided into ten parts, and from hence to 1000 into five parts; so that all numbers of four figures have either a mark upon the scale, or are midway between two marks. Thus 4786 is shown by a mark; also 8432; but 8431 is not shown by a mark, but is midway between 8430 and 8432. In a large part of the scale the space between these secondary divisions is large enough to be easily divided into parts by the eye. Thus many numbers of five figures are easily shown; for example, 26854. There are the first three figures at 268, then 5 is at the fifth secondary division, and the 4 must be estimated by the eye as \( \frac{1}{5} \) of the space between 2685 and 2686. As the decimal point is arbitrary the same figures do not always mean the same amount. Thus to represent 26854, 2685.4, 26855, 26854.5, 26854.7, 26854.9, etc., the same point on the scale is used.

To fix the decimal point in the result obtained (though this may most frequently be determined merely by inspection), rules will be given founded on the characteristics of the logarithms of numbers.

The index of the logarithms of numbers between 1000 and 9999 is 3.

\[
\begin{align*}
\text{between 1000 and} & \quad 9999 \quad \text{is} \quad 3, \\
100 & \quad 999 \quad 9 \quad 2, \\
10 & \quad 99 \quad 9 \quad 1, \\
1 & \quad 9 \quad 9 \quad 0, \\
.1 & \quad .999 \quad .9 \quad .1, \\
.01 & \quad .0999 \quad .09 \quad .01, \\
.001 & \quad .0099 \quad .00 \quad .001.
\end{align*}
\]

INDEXES OR READERS. (Common to all three Models.)

These are three in number. See figure 1.

(1). \( F \) the fixed index.
(2). \( A \) the top movable index.
(3). \( B \) the lower movable index.

The \( A \) and \( B \) movable indexes actually consist of two pairs of indexes, namely, one pair on the left, and one on the right. Those on the left should be used whenever possible, as it is easier to read the scale when the previous graduations are visible. It sometimes happens, however, that when using the left index a calculation terminates with the fixed index \( F \) disposed immediately over the bar of the \( A \) and \( B \) indexes, making it impossible to read the answer. In such cases, which will be rare, the calculation must be repeated, using the right index.

The bar carrying the movable indexes lies closely against the cylindrical scale, but the fixed index stands well away from the scale to allow the movable bar to pass freely under it and is pressed down by the thumb of the left hand when taking a reading.

Either \( A \) or \( B \) may be used and usually it is only possible to use one of them as the other will be off the scale. \textit{Whenever possible \( A \) should be used in preference to \( B \).}

TO ADJUST THE INDEXES

Before attempting to calculate it is as well to see that the Indexes \( A \) and \( B \) are in correct adjustment.

Referring to the illustration, it will be seen that they are fixed exactly the length of the spiral scale apart.

When the index \( A \) is set to the beginning of the scale, the index \( B \) should coincide with the last division on the scale. Should it not so coincide owing to the bar being out of adjustment, viz., not parallel to the axis of the cylinder, it can be adjusted by means of the screws fixing the bar to the inner cylinder at the top. \textit{See figure 2.}

\( P \) is a pivoting screw. \( T \) is the tightening screw and \( C \) is not really a screw at all, but a Cam. If \( T \) is released and \( C \) turned, the bar will be seen to move from side to side, with respect to the Axis of the instrument. When it is in correct alignment, tighten \( T \) and the rule is ready for use.
INSTRUCTIONS FOR USING THE FULLER CALCULATOR

MODEL No. 1

The foregoing details of construction show that in operating the Calculator there can only be two different movements, viz., the moving of the Scale or the moving of the Indexes A and B. The former is a multiplying movement and the latter a dividing movement.

Therefore taking any factor of any calculation, if it is a Numerator it must be brought to the Index by moving the Scale, but if it is a Denominator it must be set by moving the Index A or B to the Scale.

Obviously, the same form of movement cannot be made twice in succession, that is, if the last movement was multiplying (moving the Scale), the next must be a dividing movement (moving the Index) to complete the sequence and give a result.

When no factor exists, the sequence of movement is completed by taking 1 as the factor. For instance, in simple or continuous multiplication the dividing movement is carried out using 1 as the factor, and moving the Index accordingly.

The Sequence of Movement is therefore the same whether for Multiplication, Division, or both combined.

The only other points to remember in this connection are that the first and last movements must always be multiplying (moving the Scale), and the Fixed Index F is used on these occasions only. That is, a multiplying factor is first of all set to the Fixed Index and no further attention is paid to this Index until the answer is read under it.

Note Carefully.

When the Indexes A and B are to be moved, the term set is used. When the Cylinder is to be moved, the term bring is used.

EXAMPLE OF MULTIPLICATION

\[
\frac{173 \times 24}{1} = 4152.
\]

Factor 173 is multiplying, therefore bring 173 to the Fixed Index F. The next movement must be dividing and the denominator factor is 1 understood, therefore set the movable Index A or B to 1 on the Scale.

The next movement must be multiplying, therefore bring 24 (240) to the movable Index A or B. The answer, 4152, is now under the Fixed Index F.

\[
\frac{173 \times 24 \times 12}{1 \times 1} = 49824.
\]

Having obtained the above answer, suppose we find it necessary to multiply further, say by 12 to bring feet to inches.

Simply continue the sequence of movements. The last movement was multiplying, therefore divide by 1 by setting the Index A or B to 1 on the Scale, and then multiply by bringing 12 to the movable Index A or B. The answer, 49824, is now under the Fixed Index F. It should be noticed that the accuracy of the last figure 4, can be checked at once mentally.

EXAMPLE OF DIVISION

\[
\frac{286 \times 1}{24} = 11.916.
\]

\[
\frac{286 \times 1 \times 1}{24 \times 11} = 1.0833.
\]

Being the multiplying factor 286 to the Fixed Index F.

Set the Index A or B to the dividing factor 24. To complete the sequence of movements, multiply by 1 understood by bringing 1 on the Scale to the Index A or B. The answer, 11.916, is under F Index.

To divide further by, say, 11 set the Index A or B to 11 on the Scale, complete the operation by multiplying by 1 understood, bringing 1 on the Scale to the Index. The answer, 1.0833, is under F Index.

COMBINED MULTIPLICATION AND DIVISION

\[
\frac{25 \times 22 \times 16}{11 \times 29 \times 14} = 1.9704.
\]

Bring 25 to F. Divide by setting A to 11. Multiply by bringing 22 to A or B. Divide by setting A or B to 29. Multiply by bringing 16 to A or B. Divide by setting A or B to 14. Complete sequence by bringing 1 to A or B. The answer 1.9704 (correct to four places) is under F.

It will be observed that these are operations of merely adding and subtracting lengths on the Scale, adding for multiplication and subtracting for division.
The following Tables cover all types of multiplication and division and set out the sequence of operations very clearly.

When the indexes are to be moved the term Set is used. When the cylinder is to be moved the term Bring is used.

**MULTIPLICATION**

\[
\begin{align*}
(a \times b) & \rightarrow F \\
\text{Bring } (a) & \text{ to } F \\
\text{Set } A & \text{ to } 100 \\
\text{Bring } (b) & \text{ to } A \text{ or } B \\
\text{Product read at } F \\
(a \times b \times c) & \rightarrow F \\
\text{Bring } (a) & \text{ to } F \\
\text{Set } A & \text{ to } 100 \\
\text{Bring } (b) & \text{ to } A \text{ or } B \\
\text{Set } A & \text{ to } 100 \\
\text{Bring } (c) & \text{ to } A \text{ or } B \\
\text{Product read at } F \\
(a \times b \times c \times d) & \rightarrow F \\
\text{Bring } (a) & \text{ to } F \\
\text{Set } A & \text{ to } 100 \\
\text{Bring } (b) & \text{ to } A \text{ or } B \\
\text{Set } A & \text{ to } 100 \\
\text{Bring } (c) & \text{ to } A \text{ or } B \\
\text{Set } A & \text{ to } 100 \\
\text{Bring } (d) & \text{ to } A \text{ or } B \\
\text{Product read at } F
\end{align*}
\]

**DIVISION**

\[
\begin{align*}
\frac{a}{m} & \rightarrow F \\
\text{Bring } (a) & \text{ to } F \\
\text{Set } A & \text{ or } B \text{ to } (m) \\
\text{Quotient read at } F \\
\frac{a \times b}{m} & \rightarrow F \\
\text{Bring } (a) & \text{ to } F \\
\text{Set } A & \text{ or } B \text{ to } (m) \\
\text{Bring } (b) & \text{ to } A \text{ or } B \\
\text{Quotient read at } F \\
\frac{a \times b \times c}{m} & \rightarrow F \\
\text{Bring } (a) & \text{ to } F \\
\text{Set } A & \text{ or } B \text{ to } (m) \\
\text{Bring } (b) & \text{ to } A \text{ or } B \\
\text{Set } A & \text{ or } B \text{ to } (m) \\
\text{Bring } (c) & \text{ to } A \text{ or } B \\
\text{Quotient read at } F \\
\frac{a \times b \times c \times d}{m \times n} & \rightarrow F \\
\text{Bring } (a) & \text{ to } F \\
\text{Set } A & \text{ or } B \text{ to } (m) \\
\text{Bring } (b) & \text{ to } A \text{ or } B \\
\text{Set } A & \text{ or } B \text{ to } (m) \\
\text{Bring } (c) & \text{ to } A \text{ or } B \\
\text{Set } A & \text{ or } B \text{ to } (m) \\
\text{Bring } (d) & \text{ to } A \text{ or } B \\
\text{Quotient read at } F
\end{align*}
\]

It will be seen that a similar sequence of operations applies to the division of the product of any number of factors by the product of any number of other factors.

**EXAMPLES**

The Characteristic of 4360 is 3

\[
\begin{align*}
\text{"} & \text{ "} & \text{"} & \text{"} & \text{"} \\
\text{"} & \text{ "} & \text{"} & \text{"} & \text{"} \\
\text{"} & \text{ "} & \text{"} & \text{"} & \text{"} \\
\text{"} & \text{ "} & \text{"} & \text{"} & \text{"}
\end{align*}
\]

Similarly, if there is a nought immediately following the decimal point, the Characteristic will be \(-2\); if two noughts, \(-3\); and so on, thus:

The Characteristic of \(0.0436\) is \(-2\)

\[
\begin{align*}
\text{"} & \text{ "} & \text{"} & \text{"} & \text{"} \\
\text{"} & \text{ "} & \text{"} & \text{"} & \text{"} \\
\text{"} & \text{ "} & \text{"} & \text{"} & \text{"} \\
\text{"} & \text{ "} & \text{"} & \text{"} & \text{"}
\end{align*}
\]

**In Multiplication**, the Characteristic of the Product is the sum of the Characteristics of the factors, plus 1 for every time a factor is brought to the lower movable index \(B\), instead of the upper movable index \(A\).

\[
48.42 \times \cdot06434 = 3.115. \text{ In this case, 6434 is brought to } B, \text{ so that the Characteristic of the product } = 1 + 2 + 1 = 0 \text{ } \\
\cdot \text{there is one figure before the decimal point in the product which is therefore } 3.115.
\]

\[
13.28 \times 142.7 = 1895. \text{ In this case, neither factor is brought to } B, \text{ therefore the Characteristic of the product is } 1 + 2 \text{ } = 3, \text{ so that there are four figures before the decimal point.}
\]

\[
14 \times 12 \times 3 \times 2 \times \cdot277 = 279.2. \text{ In this case, 2 is brought to } B, \text{ so that the Characteristic of the product is } 1 + 1 + 0 + 0 = 0 \text{ } \\
\cdot -1 + 1 = + 2. \text{ There are therefore three figures before the decimal point.}
\]

**In Division**, the Characteristic of the Quotient is the algebraical difference between the sum of the Characteristics of the
factors of the numerator and the sum of the Characteristics of the factors of the denominator. To this difference 1 is added every time a factor of the numerator is brought to B, and 1 is subtracted every time B is set to a factor of the denominator.

\[
4.75 \times 3.5 \times 2.75 \times \frac{1}{1.604} = 285.0
\]

In this case, 2.75 is brought to B, so that the Characteristic of the quotient is \(0 + 0 + 0 \) \(-1\) \(+ 1 = + 2.\) There are, therefore, three figures before the decimal point.

\[
21.75 \times 15.25 \times 8.333 \times 238 \times 2240 \times \frac{1}{268.75 \times 1728} = 3773.
\]

In this case 15.25, 8.333 and 238 of the numerator are brought to B, and B is set to 268.75 and 1728 of the denominator.

The Characteristic of the quotient is, therefore \((1 + 1 + 0 + 2 + 3) - (2 + 3) + 3 - 2 = + 3\) and there are four figures before the decimal point.

LOGARITHMS, POWERS AND ROOTS

To obtain powers not higher than the seventh, the quickest way is by direct multiplication.

For higher powers and roots. Place the upper movable index \((A)\) to the number, and read the scales \((N\) and \(M\). These added together give the \textit{mantissa} of the logarithm of the number. To this the \textit{characteristic} has to be added. The characteristic of the logarithm of a number greater than unity is \textit{one less} than the number of figures in the integral part of that number. Thus the characteristic of 5432 is 3, of 543.2 is 2, of 54.32 is 1, and of 5.432 is 0.

Multiply or divide the resulting number by the power or root, as shown above. Then place the cylinder so that it reads on the scales \((N\) and \(M\)\) the decimal part of the quotient. The power or root is then at the index \((A)\). In the result the number of figures before the decimal point is \textit{one more} than the number in the integral part of the above quotient.

The scale \((N)\) is read from the top divided spiral line and \((M)\) from the vertical edge of the scale \((N)\).

\textbf{Examples.} 5\(^1\), on placing \((A)\) to 500, scale \((N)\) reads .68 and scale \((M)\) .01897, which gives the logarithm of 5 = .69897, the characteristic being 0. Then .69897 \times 13 = .908661. Now placing the cylinder so that it reads .08861 on scales \((N\) and \(M)\) the index \((A)\) reads 12207, and the required power is 1220700000, having to figures, as the integral part of the above quotient is 9.

\[\sqrt[5]{741},\text{ on placing } (A) \text{ to } 741, \text{ scale } (N) \text{ reads } .86 \text{ and scale } (M) \cdot 00982, \text{ which gives the logarithm of } 741=2.86982, \text{ the characteristic being 2. Then } 2.86982 + 5 = 7.86982. \text{ Now placing the cylinder so that it reads } .57396 \text{ on scales } (N \text{ and } M) \text{ the index } (A) \text{ reads 37495, and the required root is } 3.7495, \text{ having one figure before the decimal point, as the integral part of the above quotient is } 0.\]
ROOTS OF DECIMAL FRACTIONS

Write them as vulgar fractions, and multiply numerator and
denominator by ten or a power of ten, so that the denominator
may have a complete root. Then take the required root of the
numerator by the method given above, and of the denominator
by inspection.

Thus
\[ \sqrt{0.4} = \sqrt{\frac{4}{10}} = \sqrt{\frac{40}{10^2}} = \frac{\sqrt{40}}{10} \]

\[ 3\sqrt{0.04} = 3 \sqrt{\frac{4}{10^3}} = \frac{3\sqrt{40}}{10} \]

\[ 5\sqrt{0.586} = 5 \sqrt{\frac{586}{10^3}} = \frac{5\sqrt{58600}}{10} \]

\[ 3\sqrt{0.0065} = 3 \sqrt{\frac{65}{10^3}} = \frac{3\sqrt{650}}{10^2} \]

\[ (0.434)^\frac{1}{8} = (\frac{434}{10^4})^{\frac{1}{8}} = (434000)^{\frac{1}{8}} \]

The facility of obtaining and working with logarithms of
numbers gives the rule a great additional value.

NOTE.—The Scales \( N \) and \( M \) have been replaced in
Model 2 by a very long open scale on the inner cylinder.
This model is specially recommended for calculations
involving the extended use of logs.

TABLES

The tables printed on pages 27-32 have been made and selected
as those considered most useful. Owing to our want of a decimal
system, it has been deemed most important to have a series of
tables which give for our measures of weight, length, time, etc.,
the equivalent decimal fraction of the larger for successive numbers
of the smaller unit. This enables results to be obtained without
the necessity of reduction. Thus to find the area of a rectangle
whose sides are 24.61" and 43.54". The table gives by inspection
-5208 and -4583 opposite 61" and 54" respectively, so that the
area is obtained by multiplying 24.524 by 43.458. The result,
as shown by the calculator, is 1065.6. If the parts of a square foot
are required in twelfths, the table shows that \( \frac{1}{2} \) of a foot is
equivalent to \( \frac{74}{12} \) twelfths, and the result reads 1065.174.

DIRECTIONS FOR
PERFORMING CALCULATIONS
INvolving PERCENTAGES AND RATIO

For rapidity combined with accuracy, the Fuller Calculator
is probably the most efficient instrument in existence for calculating
Percentage Costs and all Proportional Values.

When either of the movable indexes is at one number and the
fixed index at another, and the cylinder is turned into any
other position, though the numbers at the indexes will be different
their ratio will remain constant.

Example.—To convert francs and centimes into sterling money,
supposing exchange 25f. 25c. for £1. The ratio between centimes
and pence is 2525 to 240. Place the cylinder so that the fixed
index is at 2525, and make one of the movable indexes point to
240. Then on moving the cylinder to read off different numbers of
centimes at the fixed index, the corresponding value in pence will
be read at the movable index.

Wages Table.—To find the wages for different times at 35s.
per week of 57 hours. Place the cylinder so that the fixed index
is at 57, and make one of the movable indexes point to 420, the
number of pence in 35s. Then on moving the cylinder to read off
different numbers of hours at the fixed index, the corresponding
wages in pence will be read at the movable index.

To determine Percentages.—Set the fixed index \( F \) to the
total number or quantity and the movable indexes to the 100
and 1000 marks which are at the top and bottom of the scale. Then
bring each of the component numbers in turn to the fixed index \( F \),
when the percentage will be shown by whichever of the movable
indexes is upon the scale.
Example.—What percentage of 840 are the following numbers?

<table>
<thead>
<tr>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>336</td>
<td>40%</td>
</tr>
<tr>
<td>231</td>
<td>27.5%</td>
</tr>
<tr>
<td>73.5</td>
<td>8.75%</td>
</tr>
<tr>
<td>47.25</td>
<td>5.625%</td>
</tr>
</tbody>
</table>

Bring 840 to the fixed index and set the movable indexes to the ends of the scale, that is, the 100 and 1,000 marks respectively; now shift the scale to bring 336 to the fixed index. The movable index then shows the percentage to be 40. Then bring the following numbers in turn to the fixed index, when the percentage will be simultaneously found at the movable index.

To Add or Subtract a Percentage.—Bring 100 to the fixed pointer and set the movable index to 100 plus or minus the required percentage. The percentage ratio is now set and any amount brought to the fixed index will reveal the corresponding amount under the movable index A or B.

Example.—Add 24% to £40; £120; £60. Bring 100 to the fixed index F and set movable index A to 1024 or 102.5. Bring £40; £120; and £60 in succession to the fixed index F and the respective answers will be found under the movable index A, namely £41; £123; and £61.5.

To subtract 24% the procedure is exactly the same, but the movable index B would be set to 100 − 24 or 97.5.

INSURANCE BROKERAGE CALCULATIONS BY THE FULLER CALCULATOR

How much are 10%, 15%, 25%, 1/2%, 41/2% and 45% of £586 18s. 3d.

Bring 100 to the fixed index to represent 100% and set the movable indexes to £586·9125, the decimal equivalent of £586 18s. 3d.; then bring each of the percentages to the fixed index, when whichever of the movable indexes is upon the scale will show the answer as follows:

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>£586·69125 or £58 13 10</td>
</tr>
<tr>
<td>15%</td>
<td>£586·88·035 or 88 0 9</td>
</tr>
<tr>
<td>25%</td>
<td>£586·146·73 or 146 14 7</td>
</tr>
<tr>
<td>1/2%</td>
<td>£586·2·9345 or 2 18 8</td>
</tr>
<tr>
<td>41/2%</td>
<td>£586·26·411 or 26 8 3</td>
</tr>
<tr>
<td>45%</td>
<td>£586·264·11 or 264 2 2</td>
</tr>
</tbody>
</table>

£586·9090  £586 18 3

Example 1.—£60,000 @ 5/6% = £165. Bring 600 (for 60,000) to the fixed index and set the upper movable index A to 20; then bring 5·5 (for 5/6) to the lower movable index B when the index F shows the answer to be 165.

Example 2.—£5,000 @ 7/5% = £18 10s. 10d. Bring 500 (for 5,000) to index F and set the index A to 20; then bring 7·417 shillings to the lower index, when the index F reads £18·541.

Example 3.—£12,000 @ 10/6% = £63. Bring 120 (for 12,000) to index F and set the index B to 20; then bring 10·5 (10/6) to index A, when index F shows the answer as £63.

Example 4.—£400 @ 10/6% = £22 2s. 6d. When dealing with small amounts it is sometimes more convenient to read the answer in shillings instead of in pounds and decimals, so bring 400 to index F, as usual, but place the index A at 100 (1) instead of at the division 20. Then bring 10·5 (shillings) to the index A, when the index F gives the answer as 42·5.
FULLER CALCULATOR
MODEL No. 2

Two-thirds full size LOG. 2 = 0.3010. Fig. 3

MODEL No. 2

This is a Fuller Calculator with two extra Scales on the Inner Cylinder in place of the Table of Data.

1. A Scale of Logarithms to four decimal places.
2. A Scale of Sines from 5° 45' up to 88°.

INSTRUCTIONS FOR USING THE LOGARITHM SCALE

A logarithm consists of two portions; a whole number portion, or characteristic, and a decimal fraction or mantissa.

For numbers less than unity the characteristic is minus, for example:

The log. of 0.4821 = 1.6831, or \(-1 + 0.6831\).

This may also be expressed as a quantity which is all negative thus: \(-3.69\).

Quantities in this form are much more easily handled when calculating with a slide rule, than quantities which are partly positive and partly negative. This fact has been made use of in graduating the logarithm scale of the Fuller Calculator.

The scale has been figured to read both ways, from right to left and from left to right. One set of readings (right to left) is marked + and deals with numbers of unity or more. The other reading is marked — and deals with numbers of less than unity.

To find the logarithm of a number:

If any number on the main scale be brought to the fixed index \(F\), the logarithm of that number automatically appears on the inner cylinder under the index \(L\), at the top of the movable cylinder. If the number dealt with is greater than unity, the plus reading is taken, but if it is less than unity, the minus reading is the correct one.
EXAMPLES

Find the log. of 4·480. Bring 4448 to F and under L read: +·6481, or —·3519. As the number dealt with is greater than unity, obviously the plus reading is correct.

To find the log. of ·2590. Being less than unity, the log. will be minus. Bring 2590 to F, and under L read: —·3868.

Suppose the log. of a still smaller number is required, say ·02590, obviously the reading will be the same, prefixed by the characteristic "1," i.e., —1·3867.

To find the antilog. of any number, the procedure is, of course, the reverse of the foregoing.

To find the value of (24·2)2. Bring 24·2 to F, and under the index L, read: 3837, the mantissa of the log.

The characteristic is 1, and the complete log. is 1·3837. Multiply this by 2·2 by usual method, and the result will be 3·1827; set the mantissa 1827 to the Index L, and under the index F, read: 15333, the antilog.

The answer is therefore + 1523·3.

To find the value of (-3642)4. Set -3642 to F and the log. = —·4387. (Being less than unity, the negative value is taken.)

Multiply this by 4·2 by usual method, and the result will be —1·8425.

Bring —·8425 to L, and read 1437 at F, which makes the answer —·01437.

THE SINE SCALE

This scale occupies the lower half of the inner cylinder. Like the other scales it is a spiral, having a total length of approximately 32 ft. resulting in a very open reading.

Each division on the scale from 5° 45' to 48° represents one minute, but from 48° onwards each division represents 5 minutes. This scale is recommended to Engineers and Surveyors for solving any expressions involving the use of Sines or Cosines. Calculations in latitude and departure can be solved in a fraction of the time spent in working with tables, and triangles can be solved with great rapidity and accuracy.

INSTRUCTIONS FOR USE

If any angle on the Sine Scale is brought to the Index S Fig. 3, the Sine of the angle will be found on the movable cylinder against the fixed index F.

:. Bringing any angle on the Sine Scale to the Index S is equivalent to setting F to the actual value of the Sine of the angle concerned.

Solution of Triangles.

From the general formula:

\[
\begin{align*}
\frac{a}{\sin A} &= \frac{b}{\sin B} = \frac{c}{\sin C} \\
\frac{a}{\sin A} &= \frac{b}{\sin B} = \frac{c}{\sin C} \\
\frac{a}{\sin A} &= \frac{b}{\sin B} = \frac{c}{\sin C} \\
\frac{a}{\sin A} &= \frac{b}{\sin B} = \frac{c}{\sin B}
\end{align*}
\]

hence: Given two angles and one side or two sides and the angle opposite one of them we can solve the triangle by using one of the above formulae.
Example I.

Let \[ A = 75^\circ \]
\[ C = 44^\circ \]
\[ b = 126 \text{ yards.} \]

Then \[ B = 180^\circ - (75^\circ + 44^\circ) = 81^\circ \]

To find \( a \).

\[ a = \frac{b \sin A}{\sin B} = \frac{126 \times \sin 75^\circ}{\sin 81^\circ} \]

Thus the calculation is performed as in ordinary combined multiplication and division, except that the index \( S \) is used for setting the sines values.

Move the cylinder until its index \( S \) marks \( 81^\circ \) on the scale of sines: set the movable index to \( 126 \): move the cylinder until its index \( S \) marks \( 75^\circ \) on the scale of sines: read \( a \) \((12323)\) on the movable index.

\[ i.e., \quad a = 123.23 \]

To find \( c \).

\[ c = \frac{b \sin C}{\sin B} = \frac{126 \times \sin 24^\circ}{\sin 81^\circ} \]

Move the cylinder until its index \( S \) marks \( 81^\circ \) on the scale of sines: set the movable index to \( 126 \): move the cylinder until its index \( S \) marks \( 24^\circ \) on the scale of sines: read \( c \) \((51888)\) on the movable index.

\[ i.e., \quad c = 518.88 \text{ yards.} \]

Where the sine of an angle greater than \( 90^\circ \) is involved, we can make use of the following:

\[ \sin A = + \sin (180^\circ - A). \]

Example II.

Let \[ A = 49^\circ \]
\[ C = 41^\circ \]
\[ b = 120 \text{ yards} \]

\[ \therefore B = 97^\circ \]

To find \( c \).

\[ c = \frac{b \sin C}{\sin B} = \frac{120 \times \sin 41^\circ}{\sin 97^\circ} \]

\[ \sin 97^\circ = \sin (180^\circ - 97^\circ) = \sin 83^\circ. \]

Move the cylinder until its index \( S \) marks \( 83^\circ \) on the scale of sines: set the movable index to \( 120 \): move the cylinder until its index \( S \) marks \( 41^\circ \) on the scale of sines: read \( c \) \((79318)\) on the movable index.

\[ i.e., \quad c = 79.318 \text{ yards.} \]

To find \( a \).

\[ a = \frac{b \sin A}{\sin B} = \frac{120 \times \sin 42^\circ}{\sin 97^\circ} = \frac{120 \times \sin 42^\circ}{\sin 83^\circ} \]

Move the cylinder until its index \( S \) marks \( 83^\circ \) on the scale of sines: set the movable index to \( 120 \): move the cylinder until its index \( S \) marks \( 42^\circ \) on the scale of sines: read \( a \) \((8091)\) on the movable index.

\[ i.e., \quad a = 80.91 \text{ yards.} \]

Example III. Two sides and one angle given.

Let \[ a = 71.3 \text{ yards}, \]
\[ b = 109.0 \text{ yards} \]
\[ B = 54^\circ 15' \]

To find \( A \).

Since \[ \frac{a}{\sin A} = \frac{b}{\sin B} \]

\[ \therefore b \sin A = a \sin B \]
\[ \sin A = \frac{a \sin B}{b} = \frac{71.3 \times \sin 54^\circ 15'}{109} \]

Move the cylinder until its index \( S \) marks \( 54^\circ 15' \) on the scale of sines: set the movable index to \( 109 \): move the cylinder to bring \( 71.3 \) to the movable index: read \( A \) \((32^\circ 3' 40')\) against the index \( S \) on the scale of sines.

\[ A = 32^\circ 3' 40' \]

To find \( C \).

\[ C = 180^\circ - (A + B) = 180^\circ - (32^\circ 3' 40' + 54^\circ 15' 0') = 93^\circ 41' 20'. \]

To find \( c \).

\[ c = \frac{b \sin C}{\sin B} = \frac{109 \times \sin 93^\circ 41' 20'}{\sin 54^\circ 15' 0'} \]

\( \text{(Note: } \sin 93^\circ 41' 20' = \sin 86^\circ 18' 40' \text{)} \)

Move the cylinder until its index \( S \) marks \( 54^\circ 15' 0' \) on the scale of sines: set the movable index to \( 109 \): move the cylinder until its index \( S \) marks \( 86^\circ 18' 40' \) on the scale of sines: read \( c \) \((134.02)\) on the movable index.

\[ i.e., \quad C = 134.02 \text{ yards.} \]
THE
FULLER-BAKEWELL
CALCULATOR
FOR ENGINEERS AND SURVEYORS

The replacing of the table of constants on the fixed cylinder $H$ (fig. 1, page 2) of the Fuller Calculator by two logarithmic scales, one of cosines squared and the other of sines multiplied by cosines, is due to the suggestion of Mr. W. N. Bakewell, M.I.C.E., and it will be seen from the following that this alteration gives very great power to the instrument for the calculations required when **surveying and levelling with the Tacheometer**.

The formula for the **horizontal distance** between the Tacheometer station and the reading staff, when the latter is held vertical, is: $d = 100 S^2 \cos^2 a + K \cos a$.

where $d$ = the horizontal distance,
$S = $ stadia intercept
$a$ = angle of the telescope,
$K$ = the constant of the instrument
(when the telescope is anallastic)

For the **difference of level** between the centre of the telescope of the tacheometer and the point where its axis cuts the vertical staff: $v = AB \sin a \cos a + K \sin a$.

where $v$ = vertical height,
$AB$ = Inclined distance to staff,
$a$ = angle of the telescope.

To explain the use of the Calculator a model of a Field Book for a Tacheometrical survey is given on page 24.

**DESCRIPTION OF THE SCALES**

The two Scales on the inner cylinder $H$, Fig. 1, are separated by a Zero mark, which is just over an inch up from the handle.

(1) The Scales of **Cosines Squared** occupies about an inch of the cylinder below the Zero, and is subdivided to ten minutes up to 10 deg., and from thence up to 35 deg. (which is the full extent of the Scale) it is subdivided to five minutes.

(2) The Scale of Sines multiplied by Cosines occupies most of the cylinder above the Zero. It starts at $0^\circ 35'$, and extends to $45^\circ$, subdivided as follows:

- From $0^\circ 35'$ up to $26^\circ$, to single minutes,
- From $26^\circ$ up to $39^\circ$, to 5 minutes,
- and the remainder of the scale to 10 minutes.

**TO READ THE SCALES**

The readings on Scales 1 and 2 are taken by means of the two indexes $L$ and $S$ (fig. 3, page 16). $L$ is used for taking readings on the Scale of Sines multiplied by Cosines, from $5^\circ 46'$ to $45^\circ$, and $S$ is used for readings on the remainder of the Scale and also for all readings on the Cosines Squared Scale.
**DIRECTIONS FOR USE**

The operation of the Calculator for Tacheometrical Calculations is simplicity itself and is as follows:—

To find \(d\) and \(v\).

1. Bring the lower index \(S\) (Fig. 3) to Zero. Incidentally, this also brings the fixed index \(L'\) to Zero. 
2. Set \(A\) or \(B\) to the standia intercept \(S\). 
3. Bring the index \(S\) to the vertical angle of the telescope on the Scale of **Cosines Squared** (below the Zero) and read the horizontal distance at \(A\) or \(B\), whichever is on the cylinder. 
4. Bring the index \(L\) to the vertical angle of the telescope on the scale of **Sines multiplied by Cosines**, above the Zero and read the vertical height at \(A\) or \(B\), which ever is on the Scale.

Note.—The decimal point is arbitrary as with a slide rule.

As the instrument fails to give \(v\) for angles of less than 35', the following table gives the sin. cos. for angles from 1' to 34'.

<table>
<thead>
<tr>
<th>(d)</th>
<th>(v)</th>
<th>(S)</th>
<th>(d)</th>
<th>(v)</th>
<th>(S)</th>
<th>(d)</th>
<th>(v)</th>
<th>(S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.68</td>
<td>1.00</td>
<td>0.5</td>
<td>6.58</td>
<td>1.00</td>
<td>10.15</td>
<td>6.67</td>
<td>1.00</td>
<td>18.75</td>
</tr>
<tr>
<td>9.65</td>
<td>2.00</td>
<td>13.45</td>
<td>1.00</td>
<td>10.15</td>
<td>6.67</td>
<td>1.00</td>
<td>18.75</td>
<td></td>
</tr>
<tr>
<td>7.22</td>
<td>1.15</td>
<td>12.45</td>
<td>1.15</td>
<td>6.11</td>
<td>1.17</td>
<td>1.15</td>
<td>10.15</td>
<td></td>
</tr>
<tr>
<td>184</td>
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<td>30</td>
<td>28</td>
<td>15</td>
<td>23</td>
<td>184</td>
<td>17</td>
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</tr>
<tr>
<td>195</td>
<td>24</td>
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<td>184</td>
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<td>195</td>
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</tr>
<tr>
<td>220</td>
<td>16</td>
<td>35</td>
<td>16</td>
<td>220</td>
<td>16</td>
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<td>220</td>
<td>16</td>
</tr>
<tr>
<td>300</td>
<td>30</td>
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<td>300</td>
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<td>15</td>
<td>23</td>
<td>184</td>
<td>17</td>
<td>30</td>
<td>220</td>
<td>16</td>
</tr>
</tbody>
</table>

When, therefore, \(a\) is below 35', \(S\) has to be multiplied by the number opposite to the observed angle. Thus in the model field book given, the last vertical angle observed is 15', and the height \(v\) is found by multiplying 1015 by 0.00436 in the ordinary manner by the Calculator.

When the Tacheometer used has not an anallatic telescope it will be seen that to the calculated distance, as found above, \(K\) \(\cos. a\) has to be added; when, however, \(a\) is below 21°, which is most usual, \(K\) may be taken for \(K\) \(\cos. a\); and suppose \(K = t' 6", 1\cdot5\) ft. would have to be added to each value of \(d\).

For the height \(v\), when the angle \(a\) is not above 21°, \(K\) is to be added to \(S\) and then multiplied by \(\sin. a \cos. a\); the error from multiplying \(K\) by \(\sin. a \cos. a\) instead of only by \(\sin. a\) when \(K = 1\cdot5\) ft., and \(a = 21°\) is only 0.37 ft.
### TABLES AND FORMULAE

**FOR USE WITH FULLER'S CALCULATING RULES**

<table>
<thead>
<tr>
<th>Material</th>
<th>Cubic Ins.</th>
<th>Round Rod ft. long. x&quot; dim.</th>
<th>Square Bar in. x in.</th>
<th>Plate in. x ft. x ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass, cast</td>
<td>298</td>
<td>2.81 3.58 43.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wire</td>
<td>308</td>
<td>2.91 3.70 44.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bronze</td>
<td>303</td>
<td>2.86 3.64 43.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper, sheet</td>
<td>318</td>
<td>2.98 3.81 45.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hammered iron</td>
<td>322</td>
<td>3.03 3.86 46.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron, cast</td>
<td>327</td>
<td>2.42 3.08 33.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrought iron</td>
<td>278</td>
<td>2.52 3.33 40.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>412</td>
<td>3.88 4.94 59.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel</td>
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<td>2.67 3.40 40.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>253</td>
<td>2.38 3.93 36.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
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<td>8,500</td>
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<tr>
<td>Wrought iron</td>
<td>400</td>
<td>65,000 29,000,000</td>
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<tr>
<td>Steel bars</td>
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<td>7,900</td>
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<tr>
<td>Plates</td>
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<td>7,500</td>
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</tr>
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<tr>
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<td>Yellow Pine</td>
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<td>Oak, English</td>
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<td>48</td>
<td>15,000 2,400,000</td>
<td>15,000</td>
<td></td>
</tr>
</tbody>
</table>
Decimals of a Pound.

| a   | b   | c   | d   | e   | f   | g   | h   | i   | j   | k   | l   | m   | n   | o   | p   | q   | r   | s   | t   | u   | v   | w   | x   | y   | z   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |

Decimals of a Shilling.

| a   | b   | c   | d   | e   | f   | g   | h   | i   | j   | k   | l   | m   | n   | o   | p   | q   | r   | s   | t   | u   | v   | w   | x   | y   | z   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |

π = 3.1416. Surface of Sphere = πd². Volume of Sphere = πd³ ÷ 6.

Arc equal to radius 57° 29'.

Cos A = sin (90° - A).
Tan A = sin A ÷ cos A.
Cosec A = 1 + sin A.
Cot A = cos A ÷ sin A.
Versin A = 1 - cos A.
<table>
<thead>
<tr>
<th>Deg.</th>
<th>o'</th>
<th>10'</th>
<th>20'</th>
<th>30'</th>
<th>40'</th>
<th>50'</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<td>0087</td>
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<td>0145</td>
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<td>0243</td>
<td>0361</td>
<td>0480</td>
<td>0598</td>
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<td>0994</td>
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</tr>
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<td>1408</td>
<td>1537</td>
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</tr>
<tr>
<td>6</td>
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<td>1503</td>
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