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The POLYPHASE

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Slide Rule

No. N4053

A Self Teaching Manual
with
tables of settings, equivalents and gauge points

BY

WILLIAM E. BRECKENRIDGE, A. M.

Associate in Mathematics
Columbia University
New York City

PUBLISHED BY

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THE POLYPHASE SLIDE RULE.

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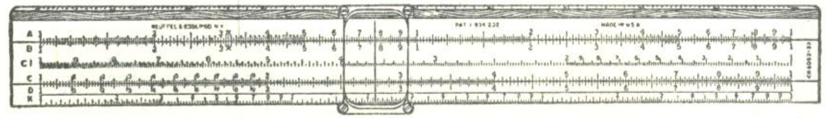


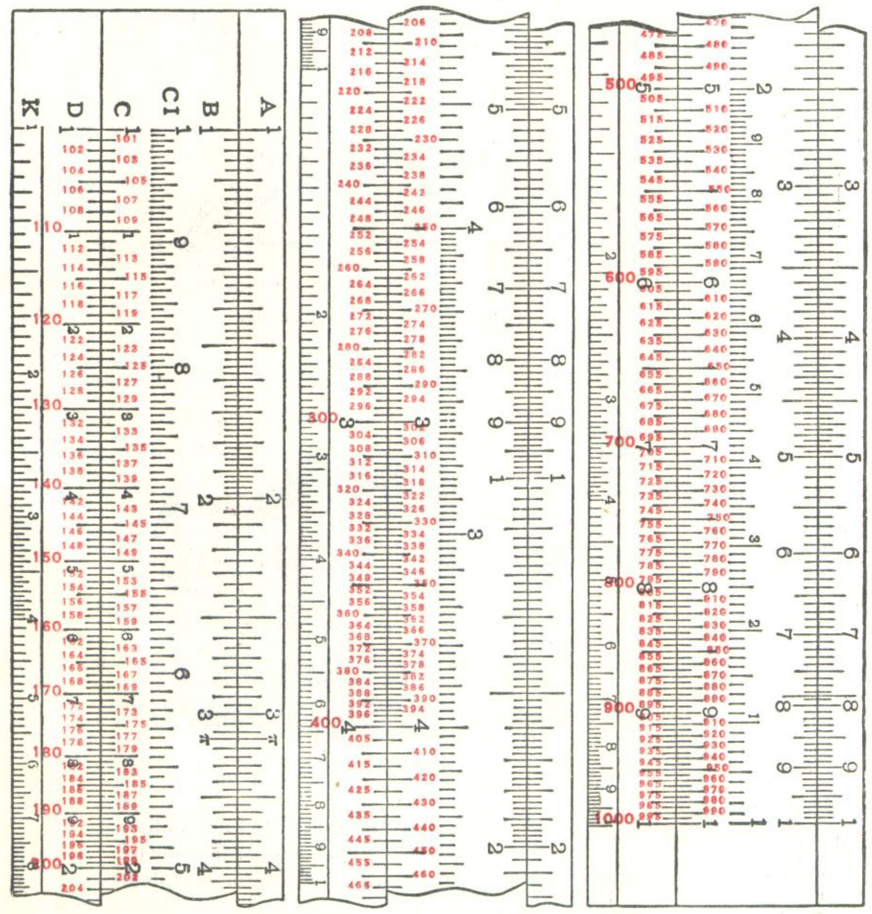
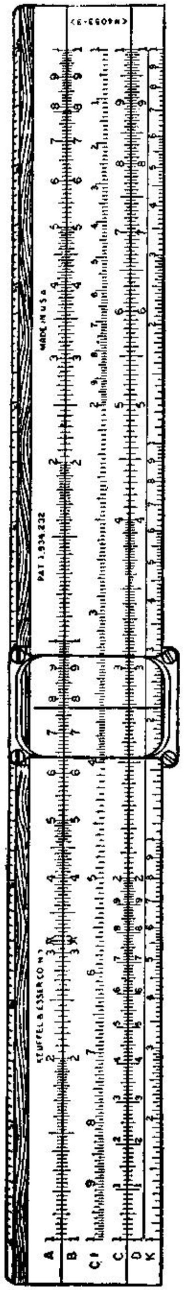


Diagram illustrating the reading of the graduations of the rule



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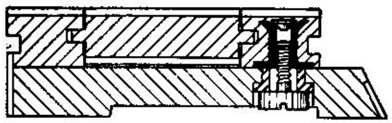
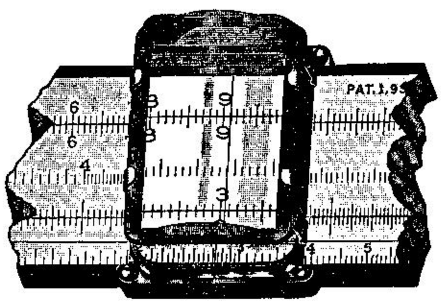


Cross section of **Polyphase*** Slide Rule showing slide adjustment.



Magnifier for Slide Rule.

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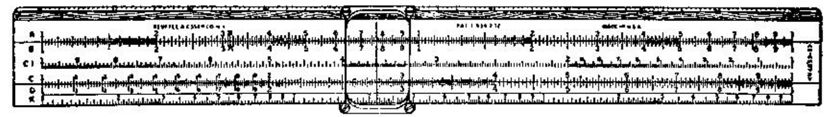

THE POLYPHASE SLIDE RULE

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PREFACE

This manual is designed to meet the needs of all who desire to learn the use of this slide rule.

Chapter I, through the use of numerous cuts and examples simply explained, is self-teaching. Some persons will learn all that they require from a few lessons in this chapter.

It is suggested that everyone learning to use the slide rule begin by working the problems in Chapter I.

In Chapters II, III, IV, and V, a simple explanation of the theory of the slide rule is followed by the advanced subjects of Cubes, Cube Root, Sines, Cosines, Tangents, Logarithms, and the Solution of Triangles.

Special work for technical men and typical problems from various occupations are presented in Chapters VI, VII, and VIII.

WHO SHOULD USE THE SLIDE RULE?

I. Teachers in the following types of schools:

1. Elementary Schools in the higher grades.
2. Junior High Schools for part of their practical mathematics.
3. High Schools in connection with logarithms, practical mathematics, or trigonometry.
4. Colleges in their courses in algebra or trigonometry. Most colleges have already made the slide rule a part of the trigonometry course.
5. Evening schools; since no subject holds the students so well as the teaching of the use of the slide rule.
6. Engineering and Trade Schools find the rule indispensable.

II. Engineers, Mechanics, Chemists, and Architects who have long understood its value.

III. Private Secretaries to check reports by the slide rule in a small fraction of the time required by ordinary calculation.

IV. Estimators, Accountants and Surveyors to make approximate calculations rapidly and with sufficient accuracy to check gross errors.

By means of the slide rule, all manner of problems involving multiplication, division and proportion can be correctly solved without mental strain and in a small fraction of the time required to work them out by the usual "figuring."

For instance, rapid calculation is made possible in the following everyday problems of office and shop: estimating; discounts; simple and compound interest; the conversion of feet into meters, pounds into kilograms and foreign money into U. S. money; the taking of a series of discounts from list prices; and adding profits to costs. Dozens of equivalents are instantly found, such as cubic inches or feet in gallons, and vice versa; centimeters in inches; inches in yards or feet; kilometers in miles; square centimeters in square inches; liters in cubic feet; kilograms in pounds; pounds in gallons; feet per second in miles per hour; circumferences and diameters of circles.

How much education is necessary?

Anyone who has a knowledge of decimal fractions can learn to use the slide rule.

How much time will it take?

The simplest operations may be learned in a few minutes, but it is recommended that at least the problems in Chapter I be worked thoroughly and checked by the answers, in order to gain accuracy and speed. This will take from one to ten hours, according to the previous training of the student.

How accurate is the Slide Rule?

The accuracy of the slide rule is about proportional to the unit length of the scales used.

The 10″ scale gives results correct to within about 1 part in 1000, or one tenth of one per cent.

The 20″ scale gives results correct to within one part in about 2000.

The Thacher Calculator (Cylindrical) gives an accuracy of about 1 part in 10000.

How to use this manual.

For the man who desires to perform the simplest operations of multiplication and division, the first few lessons in Chapter I will be sufficient. Work the illustrative examples and as many problems for practice as seem necessary to obtain accuracy and speed.

For educational use, Chapter II furnishes the necessary theory and history of the rule, while Chapter I provides additional examples for practice. Chapters III, IV, and V may be used for advanced work.

CHAPTER I
ESSENTIALS OF THE SLIDE RULE SIMPLY EXPLAINED

The slide rule is an instrument that may be used for saving time and labor in most of the calculations that occur in the practical problems of the business man, mechanic, draftsman, engineer, or estimator.

On scales C and D (front face), if 1 at extreme left is taken as unity, then 1 at the extreme right of these scales is 10.

On scales A and B (rear face), if 1 at the extreme left is taken as unity, then 1 in the middle of the scale is 10 and 1 at the extreme right is 100.

In order that you may see how the rule is used on simple problems where you know the answers, let us take the following:

Example: 2 × 3. (See Fig. 1)

Opposite 2 on scale D set 1 on scale C. Then move the indicator or glass runner so that the hair line is over 3 on scale C. Directly below this 3 you will find 6, the answer.

Indicator

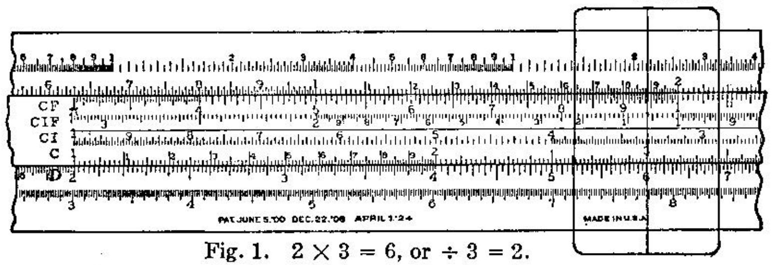


Fig. 1. 2 × 3 = 6, or ÷ 3 = 2.

Example: 2 × 4. (See Fig. 2)

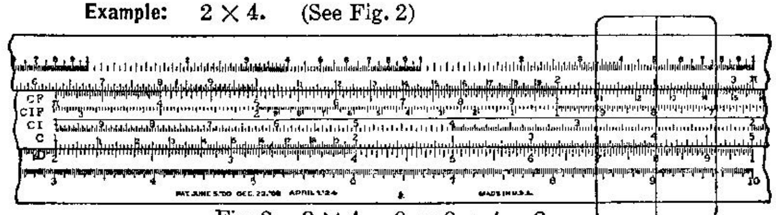


Fig. 2. 2 × 4 = 8, or 8 ÷ 4 = 2.

Example: 3 × 3. (See Fig. 3)

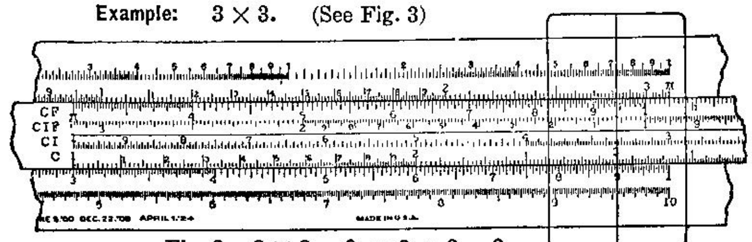


Fig. 3. 3 × 3 = 9, or 9 ÷ 3 = 3.

Example: 6 ÷ 3. (See Fig. 1)

Opposite 6 on scale *D*, set 3 on scale *C*. Look along *C* to the left, till you come to 1 at the end of the slide. Under this 1 you will find 2, the answer, on scale *D*.

Example: In the same way find 8 ÷ 4. (See Fig. 2)
Example: " " " 9 ÷ 3. (See Fig. 3)

SQUARES AND SQUARE ROOTS

Example: You will remember that to square a number means to multiply that number by itself; *e. g.*, 3^2 means $3 \times 3 = 9$. On the slide rule this is done as follows: set the hairline of the glass indicator to 3 on scale *D*. Above, on scale *A*, under the hairline, you will find 9, the answer. (Fig. 4).

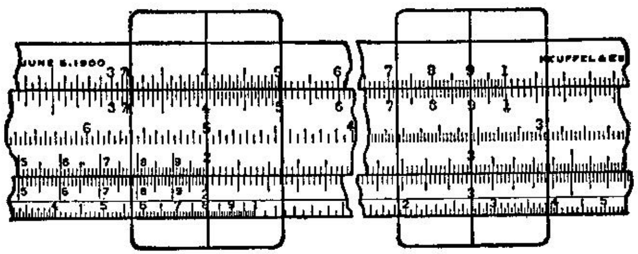


Fig. 4. $2^2 = 4$ and $3^2 = 9$.

Example: In the same way find 2^2. (See Fig. 4)

To find square roots simply do the work in the reverse order.

To find the square root of 9, find the number which multiplied by itself will give 9. The square root of 9 is indicated thus: $\sqrt{9.}$

Set the indicator to 9 on scale *A*, being careful to use the 9 on the left-hand half of the rule, because the other 9 is really 90. Below, on scale *D*, find 3, the answer. (Fig. 4).

Example: Find $\sqrt{4.}$

Set the indicator to 4 on *A*. Under the indicator on scale *D*, find 2, the answer. (Fig. 4).

We shall now proceed to apply the same methods to numbers of two or more figures.

MULTIPLICATION OF TWO OR MORE FIGURES.

Example: Find the value of 2×1.5.

Opposite 2 on *D* set 1 on *C*. Move the indicator to 1.5 on *C*. This will be between 1 and 2 at the division numbered 5; since the numbered divisions between 1 and 2 on *C* and *D* are the tenths. Under the indicator, find 3 on *D*. (Fig. 5)

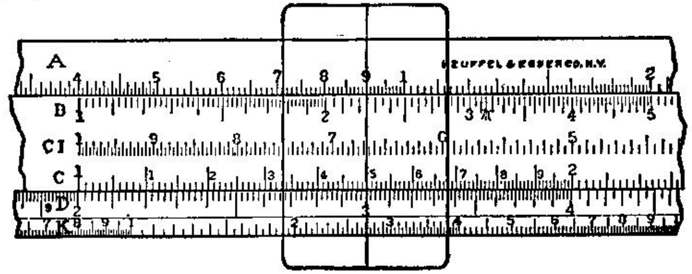


Fig. 5. $2 \times 1.5 = 3$.

Example: 2×1.8. Using Fig. 5, see if you can make it 3.6.

Example: 1.5×2.5. Opposite 1.5 on *D* set 1 on *C*. Move the indicator to 2.5 on *C*. Below 2.5, find 3.75, the answer, on *D*. Note that this answer is halfway between 3.7 and 3.8, which makes it 3.75. (Fig. 6).

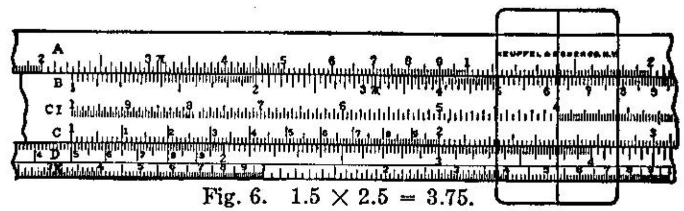


Fig. 6. $1.5 \times 2.5 = 3.75$.

HOW TO READ THE SCALES.

Graduations on the slide rule are not measures of length, but represent figures.

Scales *C* and *D* consist of nine prime spaces of unequal length; the first line of each space is numbered, respectively, 1 (called left index), 2, 3, 4, 5, 6, 7, 8, 9; the last line is numbered 1, and is called the right index. The spaces 1-2, 2-3, 3-4, etc., decrease in length, the space from 1 to 2 being the longest and every succeeding space being shorter than the one preceding it.

Each of these prime spaces is divided into ten (secondary) spaces, also decreasing in length, the nine lines between prime 1 and prime 2 being numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, in smaller figures than those of the prime graduations. On the 10-inch slide rule, space does not permit the numbering of the other secondary lines.

Each of the spaces between these secondary lines is again subdivided. Thus, each secondary space between prime 1 and prime 2 is divided into ten (unequal) parts. The secondary spaces between prime 2 and prime 4 are subdivided into five (unequal) spaces. The secondary spaces from 4 to the end are subdivided into two (unequal) parts by one line between the two secondary lines.

To find a number, always read the first figure to the left on the prime line, the second figure of the number on the secondary line to the right thereof, and the third figure on the subdivision; thus, to read 435 (say four, three, five, not four hundred and thirty-five) find prime 4, secondary 3 and sub. 5.

PLACING THE DECIMAL POINT.

Example: 2 × 15.

This is worked on the rule exactly like the above examples, but you can see by looking at the problem that the answer is 30 and not 3.

Problems:

1. 20 × 15.
2. 200 × 15.
3. 20 × 150.
4. 2 × .15.
5. 2 × .015.
6. .2 × 15.
7. .02 × .015.

All of these problems are worked like the above. As far as the slide rule is concerned, we multiply 2 by 1.5 and get 3. Then we place the decimal point by inspection. From arithmetic we remember that in multiplying decimals we first multiply as though there were no decimal points, then point off as many decimal places in the answer as there are total decimal places in the two numbers which were multiplied together. Thus, in Problem 7, there are two decimal places in .02 and three in .015. So in the answer, 30, we must have 2 + 3, or 5 places, making the result .00030. Of course the 0 at the right does not count and the final result is .0003.

From the above explanation it is evident that the decimal point is not considered in operating the slide rule. After the work of the rule has been done, the decimal point can usually be placed by inspection; i.e., through a mental survey of the influence of the involved factors upon the result. Where this is not feasible, a rough arithmetical calculation will serve to properly locate the decimal point.

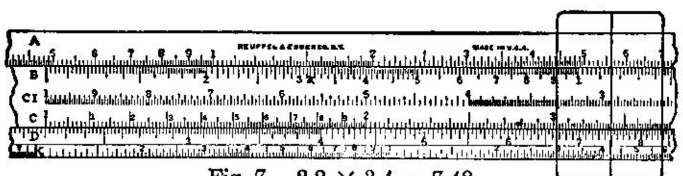


Fig. 7. 2.2 × 3.4 = 7.48

Example: 2.2 × 3.4.

Opposite 2.2 on *D* set 1 on *C*. Move the indicator to 3.4 on *C*. Under the hair line on *D* find 748.

That the sub. figure is 8 is further confirmed by observing that the product of the unit figures 2 and 4 in the example is 8.

Since 2.2 × 3.4 is roughly 2 × 3, or 6, place the decimal point in 748 so that the result will be as near 6 as possible. Evidently the answer is 7.48. (Fig. 7).

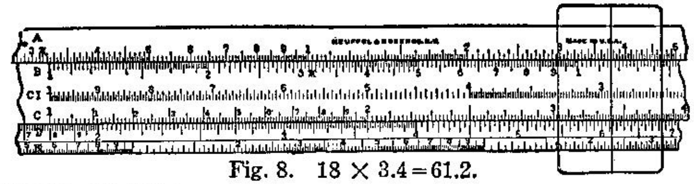


Fig. 8. 18 × 3.4 = 61.2.

Example: 18 × 3.4.

Using the same method as in the previous example, the slide rule gives 612.

By a rough calculation the problem is about equal to 20 × 3 = 60. Hence we make 612 look like 60 by placing the decimal point after the 1. The answer is 61.2.

Example: 16 × 2.4. Answer 33.4.
Example: 1.4 × 2.6. Answer 3.64.

Problem 8. Fill in the blanks in the following multiplication table, using the slide rule:

	21	22	23	24	25	26	27	28	29
31									
32									
33									
34									

Set left index of *C* to 31 on *D*. Note that the factors 21 to 29 can be taken without resetting the slide.

WHICH INDEX TO USE.

If we attempt to multiply 30 by 45, using the preceding methods of setting the 1 on the left hand end of *C* to 30 on *D*, we shall find it impossible to move the indicator to 45, since 45 on scale *C* lies beyond the right hand end of scale *D*. In such a case, begin the work on the rule by setting the 1 on the right hand end of *C* to 30 on scale *D*. It is then possible to set the indicator to 45 on *C*. Opposite the 45 on *C* find 135 on *D*. Placing the decimal point by inspection, the result is 1350.

We will now define the left hand 1 on scale *C* as the left index and the right hand 1 on scale *C* as the right index. In most examples, the following rule will be found useful in determining which index to use:

If the product of the first figures of the given numbers is less than 10, use the left index; if this product is greater than 10, use the right index.

Example 1. 2.13 × 3.33, 3 × 2 = 6. Use the left index.
Example 2. 7.23 × 4.71, 7 × 4 = 28. Use the right index.
Example 3. .131 × 4.6, 1 × 4 = 4. Use the left index.

An exception to this rule will be found in such a case as 3.12 × 3.31. According to the rule the left index should be used. It will be found, however, that it is necessary to use the right index. This is due to the fact that while the product of the first figures of the two numbers is less than 10, the product of the complete numbers is greater than 10.

In most cases, the use of the above rule will save time.

PER CENT.

Example: Suppose you are earning 56 cents per hour and you are given an increase of 8 cents. What per cent increase do you receive?

Of course you will divide 8 by 56.

To divide one number by another on the slide rule we simply reverse the order of the work we have been doing in multiplication.

Set the indicator to 8 on scale *D*.

Move the slide so as to set 56 on *C* to the hair line of the indicator.

Fig. 9. 8 ÷ 56 = .14.

Under 1 on *C* we find 14 and a little over. But the result is nearer 14 than 15. Hence the correct result to two figures is 14. By inspection the decimal point must be placed before the number, making the answer .14 or 14 per cent.

Example: A man earned 35 cents per hour. He learned a new trade which increased his earning power to 67 cents per hour. What per cent increase did he receive?

His increase is 32 cents per hour. The per cent of increase is found by dividing 32 by 35.

Set the indicator to 32 on *D*.

Set 35 on *C* to the indicator. The result cannot be found under the left index i.e., the 1 at the extreme left of scale *C*, since this projects beyond scale *D*. So we use the right index of *C*. Under this index, find 91 on scale *D*. (Fig. 10).

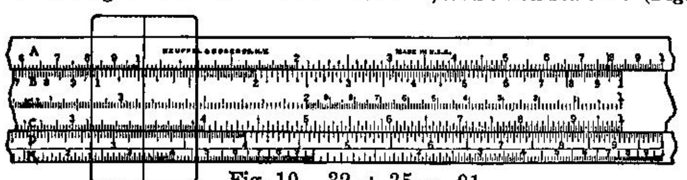


Fig. 10. 32 ÷ 35 = .91.

In the same way, for practice, try the following, obtaining the result correct to two figures:

Problem 9. What per cent of 91 is 45?
(Divide 45 by 91)

10. What per cent of 73 is 24?

11. What per cent of 67 is 61?

12. What per cent of 53 is 31?

13. What per cent of 82 is 13?

14. What per cent of 42 is 9?

If you have a long report to make out in which a large number of per cents are to be calculated, why not use the slide rule?

A secretary to the president of a big corporation recently said: "The slide rule does my work in one-third of the time that would be required otherwise."

READING TO THREE FIGURES.

Suppose you had to get per cents in a problem like the following:

Example: A baseball player made 57 hits out of 286 times at bat. What is his percentage?

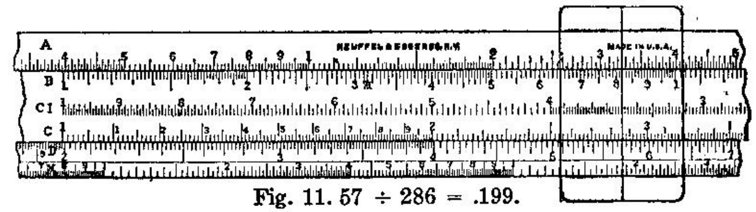


Fig. 11. 57 ÷ 286 = .199.

Opposite 57 on *D* set 286 on *C*. When we look for 286 we observe that between 2.8 and 2.9 there are five spaces on the rule. Hence every space counts one-fifth of .1, which is .02. Since we want six points for the third figure, we have to use three spaces, every one worth .02. 3 × .02 = .06.

Under the left index of *C* look for the result on *D*. When we read this result, we see that it comes on the rule between 1.9 and 2.0. There are ten small spaces between 1.9 and 2.0. Hence every space counts one point. The index is close to the ninth of these divisions. Hence the reading is 199. Now we must place the decimal point. A rough calculation shows that $\frac{57}{286}$ is nearly $\frac{60}{300}$, or $\frac{1}{5}$. Hence the decimal point must be placed so as to make the result somewhere near one-fifth or .2. Evidently the result is .199. This may be read 19.9 per cent or 19⁹⁄₁₀ hundredths, or 199 thousandths.

Example: If your income is $2,500 per year and you save $451, what per cent do you save?

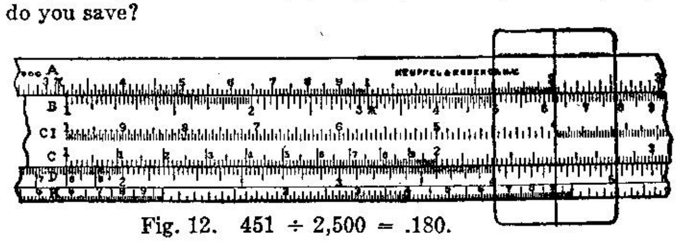


Fig. 12. 451 ÷ 2,500 = .180.

Opposite 451 on *D* set 25 on *C*. Under the index find 180 on *D*. Hence the answer is .180, or 18 per cent. We note that when we look for the 1 in 451 on the rule, we find only two spaces between 45 and 46. Hence each space counts one-half of a hundredth or one-half of .01, which is .005 or five points for the third figure. We estimate one-fifth of the small space to obtain .001. (Fig. 12)

Example: If your salary is $57.60 per week, and you are given an increase of $12.40, what per cent increase do you receive?

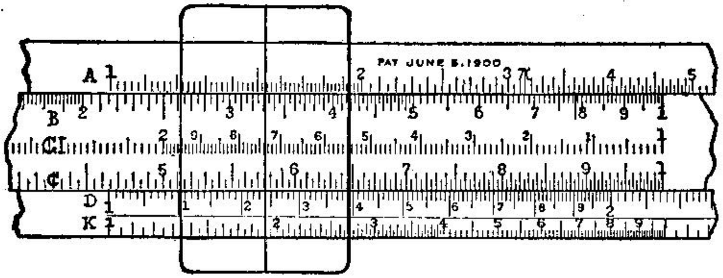


Fig. 13. 12.4 ÷ 57.6 = .215.

Opposite 124 on *D* set 576 on *C*. This means that between 5 and 6 on *C* we must take 7 of the large divisions and one of the small divisions. Under the right-hand index read 215 on *D*. Hence the answer is 21.5 per cent.

Problem 15. 5.42 ÷ 2.42.
16. 7.35 ÷ 3.14.
17. 6.13 ÷ 4.61.
18. 9.56 ÷ 7.26.
19. 10 ÷ 3.14. For 10, use either the right or left index.

In the following problems the location of the decimal point is determined by working the problems in round numbers.

Problem 20.	16.5 ÷ .245	is approximately	16 ÷ .2 = 80.
21.	.00655 ÷ .00034	" "	.0060 ÷ .0003 = 20.
22.	.00156 ÷ 32.8	" "	.0015 ÷ 30 = .00005.
23.	.375 ÷ .065	" "	.36 ÷ .06 = 6.
24.	.0385 ÷ .0014	" "	.038 ÷ .001 = 38.

There is another method of placing the decimal point in division. Work the problem as though both dividend and divisor were integers (*i. e.*, not decimals), pointing off as usual. Move the decimal point to the left as many places as there are decimal places in the dividend. Then move it to the right as many places as there are decimal places in the divisor. For example in problem 20, 165 ÷ 245 gives .673. Move the point one place to the left because there is one decimal place in the dividend, giving .0673. Then move it three places to the right because there are three places in the divisor, giving as a result 67.3. Try both methods and see which one you like the better. Let one check the other.

MORE THAN THREE FIGURES IN A FACTOR.

Suppose we have more than three figures, as in the following example:

Problem 25. Find the circumference of a wheel 28 inches in diameter.

Here we must multiply 28 by 3.1416. But the 10″ slide rule only reads to three figures. So cut off the fourth and fifth figures in 3.1416 and call it 3.14, since the number is nearer 3.14 than 3.15. It is, however, somewhat more convenient to work this problem on the *A* and *B* scales, where π (3.1416) is accurately marked. Use *A* in place of *D*, and *B* in place of *C*.

Problem 26. Multiply 26 by 8.149.
Call 8.149 equal to 8.15.

COMBINED MULTIPLICATION AND DIVISION.

Example: If bell metal is made 25 parts of copper to 11 parts of tin, find the weight of tin in a bell weighing 402 pounds.

The tin is evidently eleven thirty-sixths of 402, or $\frac{11 \times 402}{36}$.

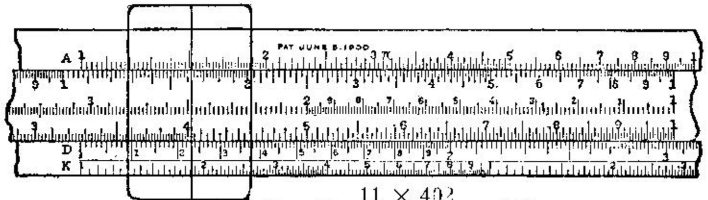


Fig. 14. $\frac{11 \times 402}{36} = 123.$

Opposite 11 on *D* set 36 on *C*. (Fig. 14)
Move the indicator to 402 on *C*.
Opposite 402 on *C* read 123 on *D*.
To place the decimal point, make a rough calculation as follows: The example is roughly equal to $\frac{10 \times 400}{40} = 100$. So make 123 look as nearly like 100 as possible by placing the point after 3. The answer is 123 pounds of tin.

Problem 27. $\frac{14 \times 525}{47}$

Problem 28. $\frac{24.5 \times 43.4}{3620}$

Example: $\frac{1.35 \times 3.16}{6.2}$ (See Fig. 15)

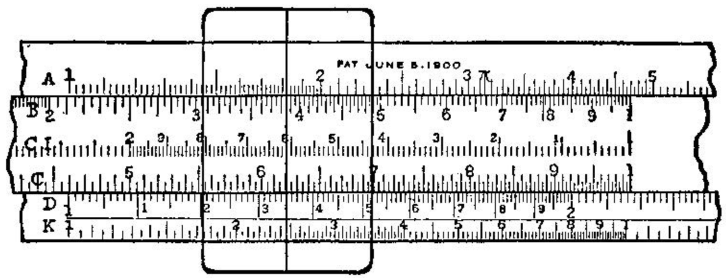


Fig. 15.

Opposite 1.35 on *D*, set 6.2 on *C*. If we try to move the indicator to 316 on *C*, it is impossible because 316 lies beyond the extremity of *D*. In such a case proceed as follows: Move the indicator to the right-hand index of *C*. (See Fig.16.)

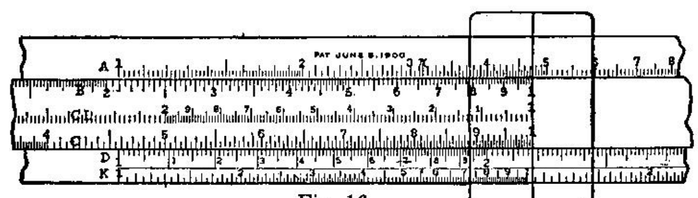


Fig. 16.

Then move the slide, setting the left-hand index of *C* to the indicator. (Fig. 17.)

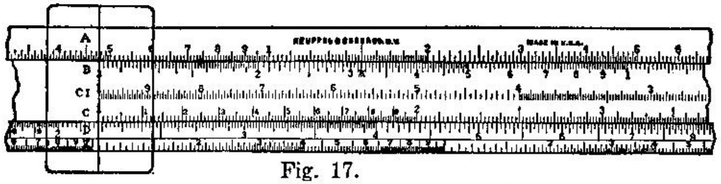


Fig. 17.

Now we can move the indicator to 316 on *C*. (Fig. 18.)

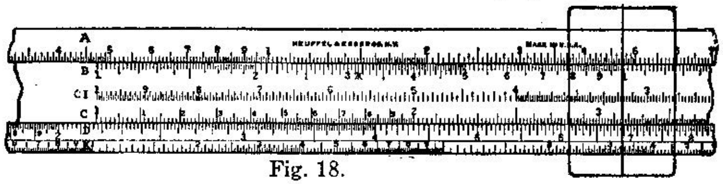


Fig. 18.

and under 316 on *C* read the answer 688 on *D*.

A rough calculation for the decimal point gives us $\frac{1 \times 8}{6} = \frac{8}{6}$, or .5. Making 688 look as much as possible like .5, we have .688.

Another method which will save the time of exchanging indexes is as follows: instead of dividing first, multiply first and then divide.

To 135 on *D* set index of *C*.
Indicator to 316 on *C*.
To indicator set 6.2 on *C*.
At index of *C* read 688 on *D*.

Example: $\frac{2.28 \times .0125}{4.36}$

The rough calculation for the decimal point might be $\frac{2 \times .012}{4} = .006$.

The answer is .00654.

Problem 29. $\frac{7.63 \times 2.34}{24.3}$ **Problem 31.** $\frac{82.5 \times 9.3}{56.5}$

Problem 30. $\frac{2.56 \times 1.78}{7.4}$ **Problem 32.** $\frac{32.6 \times 22.1}{9.25}$

PROPORTION.

Example: If an aeroplane flying 100 miles an hour travels 86 miles in a given time, how far will an automobile traveling 22 miles an hour go in the same time?

Writing this in the form of a proportion:

$$100 : 22 = 86 : x$$

which means that 100 is to 22 as 86 is to the answer.

The work on the rule is as follows:

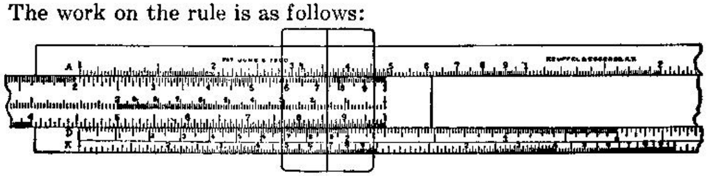


Fig. 19. 100 : 22 = 86 : 18.9.

Opposite 22 on *D*, set 100 on *C*. (Use right index for 100). Opposite 86 on *C* read the answer, 18.9 on *D*. An easy method of remembering this is:

$$\begin{matrix} C & & D & & C & & D \\ 100 & : & 22 & = & 86 & : & 18.9. \end{matrix}$$

In placing the decimal point, note that 100 has the same relation to 22 that 86 has to the answer. Since 22 is about one-fifth of 100, we must place the decimal point in 189 so that the answer shall be about one-fifth of 86. Hence the answer is 18.9.

In the same way solve the following proportions:

Problem 33. 24 : 31 = 15.2 : *x*.
34. 1.4 : 2.5 = 12 : *x*.
35. 3.71 : 2.4 = 51.2 : *x*.

Problem 36. If a post 13.2 feet high casts a shadow 27.2 feet long, how high is a tower which casts a shadow 116.8 feet long?

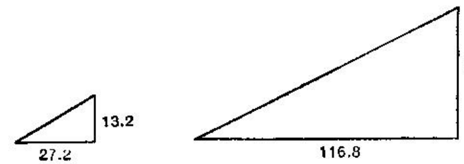


Fig. 20. 27.2 : 13.2 = 116.8 : *h*.

Problem 37. At 2,400 yards an increase of 1 mil in the elevation of a gun increases the range 25.0 yards. What change in elevation will increase the range 40 yards?

The mil is the unit of angle in the artillery. It is equal to $\frac{1}{6400}$ of 360°.

Example: The effects of wind on a shell are approximately proportional to the velocity of the wind. At 3,000 yards for a 3-inch gun, a rear wind of 10 miles per hour increases the range 30.1 yards. (a) What wind will increase the range 42.8 yards? (b) What wind will decrease the range 68.5 yards?

Answer (a) Rear wind of 14.2 miles per hour. (b) Head wind of 22.8 miles per hour.

SQUARES.

Example: Find the area of a square plot of ground measuring 128 yards on a side.

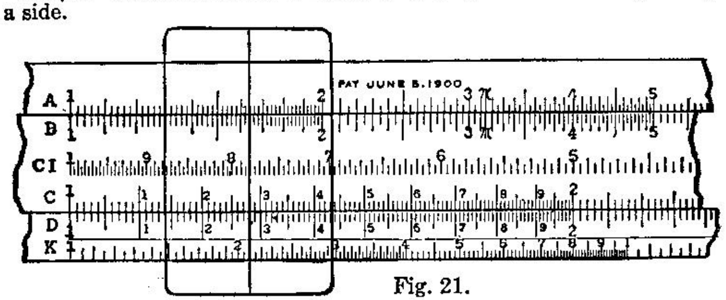


Fig. 21.

Set the indicator to 128 on *D*. Directly above on *A* find the square required, 164. To place the decimal point, make a rough calculation.

$(128)^2$ is roughly $(130)^2$ or 16900. Then make 164 look like 16900 by placing the point as follows: 16400. The result is only correct to three figures. The complete result is 16384.

If greater accuracy is desired, a number may be squared by the use of the longer scales C and D.

Example: Find the square of 128.

Regard this as an example in multiplication equivalent to:

Find 128 × 128.

To 128 on D set left index.

Opposite 128 on C read 1638 on D.

Placing the decimal point by a rough calculation, the result is 16380.

Example: Square 652.

Set the indicator to 652 on D reading the square 425 on A. Notice that here the arithmetic square would be 425104, but on the slide rule we can get only the first three figures, 425. This, however, is close enough for most practical purposes, such as estimating on contract work.

To place the decimal point,

$$652^2 > 600^2 = 360000.$$
$$< 700^2 = 490000.$$

since the value is between these limits the result is 425000.

Find the squares of the following numbers:

Problem 38.	3.2	**Problem 42.**	276.	**Problem 46.**	.0057
39.	4.65	**43.**	34.2	**47.**	.0244
40.	1.12	**44.**	.66	**48.**	2240.
41.	8.65	**45.**	.0625		

Example: Find the area of a circular plot of ground measuring 14.5 feet in diameter.

Use the formula $A = .7854\ d^2$, which means that the area of the circle is equal to .7854 multiplied by the square of the diameter. Set the indicator to 145 on D. The square is found directly above on A, but need not be read. Set the right-hand index of the slide to the indicator. Move the indicator to the constant, .7854 on B, and opposite find the result, 165 sq. ft. on A.

This constant, .7854, is so frequently used that it has been marked by a special line on the right-hand half of the A and B scales.

SQUARE ROOTS.

Example: How long must one side of a square garden bed be made in order that it shall contain 8 square yards?

Here we have to find the square root of 8.

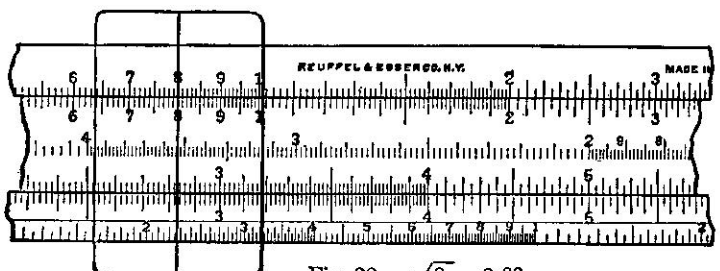


Fig. 22. $\sqrt{8} = 2.83$.

Set the indicator to 8 on scale A. Assume that scale A runs from 1 to 100, so that 8 is found on the left-hand half of the rule.

Now under the hair line on scale D, find 2.83, the square root.

Then the result is 2.83 yards.

Example: Find $\sqrt{3}$.

Set the indicator to 3 on A.

Under the hair line find 1.73 on D.

Example: Find $\sqrt{30}$.

Set the indicator to 30 on A, being careful to notice that 30 is indicated by 3 on the right-hand half of the rule. Opposite the indicator on D, find 5.48.

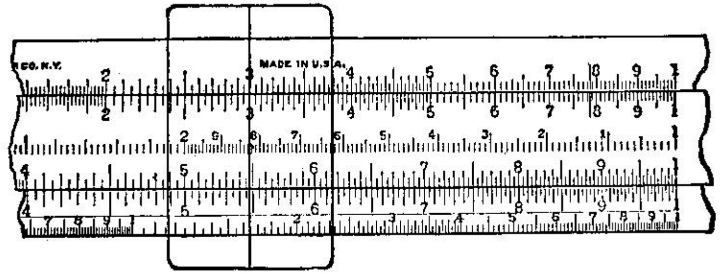


Fig. 23. $\sqrt{30} = 5.48$.

Example: Find $\sqrt{300}$.

Move the decimal point an even number of places in order to obtain a number that is between 1 and 100. This can be done by moving the point two places to the left, giving $\sqrt{3.00}$.

Find the $\sqrt{3}$, which is 1.73. Then move the decimal point half as many places as it was moved in the first place, but in the opposite direction. In this case, move the point in 1.73 one place to the right, giving 17.3.

Example: Find $\sqrt{.30}$.

Move the point two places to the right, obtaining 30.

Find $\sqrt{30} = 5.48$.

Move the point one place to the left, obtaining .548 for the result.

Example: Find $\sqrt{.03}$.

Move the decimal point two places to the right, obtaining $\sqrt{3}$.

Find $\sqrt{3} = 1.73$.

Move the point one place to the left, obtaining .173.

Example: Find $\sqrt{.003}$.

Move the point four places to the right, obtaining $\sqrt{30}$.

Find $\sqrt{30} = 5.48$.

Move the point two places to the left, obtaining .0548.

Find the square roots of the following numbers:

Problem 49.	1.42	**Problem 52.**	.142	**Problem 55.**	.365
50.	14.2	**53.**	2.43	**56.**	.31416
51.	142	**54.**	85.4	**57.**	1450

Problem 58. Make a list of square roots of whole numbers between 110 and 130.

Problem 59. On a baseball field find the distance from home plate to second base, measured in a straight line. (The distance between the bases is 90 feet.)

Problem 60. Water is conducted into a tank through two lead pipes having diameters of ⅝ and 1¾ inches, respectively. Find the size of the lead waste pipe that will allow the water to run out as fast as it runs in.

Use ⅝ and 1¾ in the decimal form.

$$\text{Find } \sqrt{(.625)^2 + (1.75)^2}.$$

NOTE:—Perform the addition by arithmetic. The slide rule cannot be used to advantage in addition.

Problem 61. Two branch iron sewer pipes, each 6 inches in diameter, empty into a third pipe. What should be the diameter of the third pipe in order to carry off the sewage?

TEST PROBLEMS.

Read carefully the following instructions:

a. Copy the test on your paper in the form given below.
b. Work the problems straight through, setting down the answers in the column at the extreme right.
c. Cover these answers.
d. Work the problems through again, setting down the answers in the other column.
e. Compare the two sets of answers.
f. If the answers to any problem do not agree (within one point in the third place), work the problem again.
g. The correct results are given on page 79.

TEST.

	Answers Second Time	Answers First Time	Credits
Problem 62. 1.28×2.46			20
63. $84 \div 59.5$			20
64. $\frac{58.5 \times 15.2}{78}$			20
65. $6.25 : 24.2 = 9.5 : x$			20
66. $\sqrt{182}$			20

CHAPTER II.

THEORY OF THE SLIDE RULE

HISTORICAL NOTE

In 1614 John Napier, of Merchiston, Scotland, first published his "Canon of Logarithms."

Napier concisely sets forth his purpose in presenting to the world his system of Logarithms as follows:

"Seeing there is nothing (right well beloved Students of Mathematics) that is so troublesome to mathematical practice, nor doth more molest and hinder calculators, than the multiplications, divisions, square and cubical extractions of great numbers, which besides the tedious expense of time are for the most part subject to many slippery errors, I began therefore to consider in my mind by what certain and ready art I might remove those hindrances."

Napier builded better than he knew. His invention of logarithms made possible the modern slide rule, the fruition of his early conception of the importance of abbreviating mathematical calculations.

In 1620 Gunter invented the straight logarithmic scale, and effected calculation with it by the aid of compasses.

In 1630 Wm. Oughtred arranged two Gunter logarithmic scales adapted to slide along each other and kept together by hand. He thus invented the first instrument that could be called a slide rule.

In 1675 Newton solved the cubic equation by means of three parallel logarithmic scales, and made the first suggestion toward the use of an indicator.

In 1722 Warner used square and cube scales.

In 1755 Everard inverted the logarithmic scale and adapted the slide rule to gauging.

In 1815 Roget invented the log-log scale.

In 1859 Lieutenant Amedee Mannheim, of the French Artillery, invented the present form of the rule that bears his name.

In 1881 Edwin Thacher invented the cylindrical form which bears his name.

In 1891 Wm. Cox patented the Duplex Slide Rule. The sole rights to this type of rule were then acquired by Keuffel & Esser Co.

For a complete history of the Logarithmic Slide Rule, the student is referred to "A History of the Logarithmic Slide Rule," by Florian Cajori, published by the Engineering News Publishing Company, New York City. This book traces the growth of the various forms of the rule from the time of its invention to 1909.

ACCURACY

The accuracy of a result depends upon (*a*), accuracy of the observed data; (*b*), accuracy of mathematical constants; (*c*), accuracy of physical constants; (*d*), precision of the computation.

ACCURACY OF THE OBSERVED DATA.

The precision of a measurement is evidently limited by the nature of the instrument, and the care taken by the observer.

Example 1. If a distance is measured by a scale whose smallest subdivision is a millimeter, and the result recorded 134.8 mm., evidently the result is correct to 134, but the .8 is estimated. Hence it is known that the actual measurement lies between 134 and 135 and is estimated to be 134.8.

The result 134.8 is said to be "correct to four significant figures."

If the result were desired correct to only three figures, it would be recorded 135, since 134.8 is nearer 135.0 than 134.0. This result is said to be "correct to three significant figures."

Example 2. If the distance is measured by a rule whose smallest subdivision is .1 inch, and found to be exactly 8. inches, the result would be recorded 8.00 inches. The zeros record the fact that there are no tenths and no hundredths, but the distance is exactly 8 inches. The result, 8.00 inches, is said to be "correct to three significant figures."

Example 3. If an object is weighed on a balance capable of weighing to .01 gram, then .001 gram can be estimated. Suppose several objects are weighed with the following results:

1. Seven grams	recorded	7.000	grams.
2. Seven and a half grams	"	7.500	"
3. Seven and 9/100 grams	"	7.090	"
4. Seven and 6/1000 grams	"	7.006	"
5. 4/100 and 2/1000 grams	"	.042	"

Note that readings with the same instrument should show the same number of places filled in to the right of the decimal point, even if zero occurs in one or all of these places.

In number 5, the result, .042 grams is said to be "correct to two significant figures." The first significant figure is 4 and the second is 2.

Example 4. When we say that light travels 186,000 miles per second, we mean that the velocity of light is nearer 186,000 miles than 185,000 miles, or 187,000 miles. The result is said to be "correct to three significant figures."

Summarizing the preceding examples:

Example 1. 134.8 is correct to four significant figures.

Example 2. 8.00 is correct to three significant figures.

Example 3. .042 is correct to two significant figures.

Example 4. 186,000. is correct to three significant figures.

Counting from the left, the first significant figure is the first figure that is not zero.

After the first significant figure, zero may count as a significant figure, as in Example 2, where it represents an observed value; or it may not so count, as in Example 4, where the zeros merely serve to place the decimal point correctly, the number 186,000. being correct only to the nearest thousand miles.

Similarly in results derived from calculation, zero counts as a significant figure if it represents a definite value, *e. g.* $25 \times 36 = 900$.

Both zeros in 900 are significant figures. On the other hand, zero is not a significant figure if it does not represent a definite value, but merely serves to place the decimal point.

Find the cube of 234.

The complete result is 12,812,904.

On the slide rule only the first three significant figures can be found, and the result is 12,800,000. Here 128 are significant figures and the five zeros following are not significant, since they do not represent definite values, but merely serve to place the decimal point.

As far as calculation on the slide rule can determine, each of these five zeros might be any one of the numbers from 0 to 9. Arithmetical calculation shows that they are really, 12,904.

ACCURACY OF MATHEMATICAL CONSTANTS.

A mathematical constant may be carried to any desired degree of accuracy, *e. g.*, the value of π usually given as 3.14159 has been calculated to 707 decimal places. For ordinary calculations 3.14 or $3\frac{1}{7}$ is sufficiently accurate.

ACCURACY OF PHYSICAL CONSTANTS.

Many physical constants are only correct to three significant figures and some only to two figures.

e. g., The weight of a cu. ft. of water is 62.5 lb.

The weight of a cu. in. of cast iron is .26 lb.

LIMITS OF ACCURACY.

Holman's rule states that if numbers are to be multiplied or divided, a given percentage error in one of them will produce the same percentage error in the result.

In other words, a chain is no stronger than its weakest link.

Since physical constants are not usually correct beyond three significant figures, and the observed data in an experiment are rarely reliable beyond this point, the slide rule reading to three figures gives results sufficiently accurate for most kinds of practical work.

PERCENTAGE OF ERROR.

If a result is correct to three significant figures, the ratio of the error to the result is less than 1:100.

Suppose, for example, the result is 3527.6, which is known to be correct to three significant figures. Then the figures 352 are known to be correct and the figures 7.6 are doubtful.

Since 7.6 is less than 10 and 3527.6 is greater than 1,000, the error must be less than 10:1000 or 1:100.

$$\frac{7.6}{3527.6} < \frac{10}{3527.6} < \frac{10}{1000}, \text{ or } \frac{1}{100}.$$

A result read on the 10-inch slide rule to four significant figures is 1324, which is correct to three figures, 132, while the fourth figure, 4, is a close estimate not more than one point away from the correct reading.

The error here is less than $\frac{1}{1324}$, which is less than $\frac{1}{1000}$. Hence the error in this reading is less than one-tenth of one per cent.

It is evident that the per cent of error holds throughout the length of the slide rule, since the first significant figure increases from 1 to 10 as spaces decrease.

e. g., On the right end of the rule, as a result read 998 might be really 999 making an error of 1 in 999 or approximately $\frac{1}{1000}$ or $\frac{1}{10}$ of 1%.

If greater accuracy is desired, a twenty-inch rule will give results correct to within one part in two thousand; while the Thacher Cylindrical Rule will give results correct to within one part in ten thousand.

LOGARITHMS.

$$10^2 = 100.$$

Another form of making this statement is:

The logarithm of 100 is 2.

In the same way, $10^3 = 1{,}000$

or the logarithm of 1,000 is 3.

From these examples it is evident that the logarithm is the exponent which is given to 10.

Fill out the blanks in the following table:

$10^4 = 10{,}000$	Log 10,000 =
$10^5 = 100{,}000$	Log 100,000 =
$10^1 = 10$	Log 10 =
$10^0 = 1$	Log 1 =

LAW OF MULTIPLICATION.

$$10^2 = 100.$$
$$10^3 = 1{,}000.$$
$$10^2 \times 10^3 = 100 \times 1{,}000.$$
$$10^5 = 100{,}000.$$

Log 100,000 is 5.

Since 5 is the sum of 2 and 3, log 100,000 = 2 + 3 = log 100 + log 1,000, or

The logarithm of a product is the sum of the logarithms of the multiplicand and the multiplier.

Hence to multiply one number by another, add their logarithms.

The construction of the rule allows this addition to be done easily.

The scales are divided proportionally to the logarithms of the numbers.

If the scale is considered as divided into 1,000 units, then any number—1, 2, 3, etc.,—is placed on the rule so that its distance from the left index is proportional to its logarithm.

Since log 1 = 0,	1 is found at the extreme left.	
" log 2 = .301,	2 " "	301 units from the left.
" log 3 = .477,	3 " "	477 " " " "
" log 9 = .954,	9 " "	954 " " " "
" log 10 = 1.000,	10 " "	1000 " " " "

On the scale the number 8 is placed three times as far from the left index as 2, because the logarithm of 8 is three times the logarithm of 2.

MULTIPLICATION.

When we multiply 2 by 4, we set the left index of the slide to 2 on scale *D* and under 4 on scale *C* find the product, 8 on scale *D*.

This is equivalent to adding log 2 to log 4 and finding log 8 (Fig. 24).

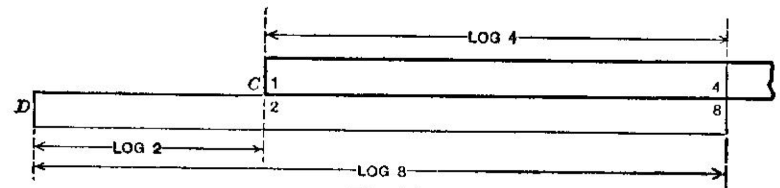


Fig. 24.

Example: Multiply 2.45 by 3.52.

Opposite 2.45 on *D*, set 1 on *C* and under 3.52 on *C* find 862 on *D*.

Roughly calculating, 2.45 × 3.52 = 2 × 4 = 8.

Hence, we place the decimal point to make the result as near 8 as possible; and the result is 8.62.

Example: Multiply 24.5 by 35.2.

Working this like the preceding example, without regard to the decimal point, we obtain 862.

Roughly calculating, 24.5 × 35.2 = 25 × 36 = 900.

Placing the decimal point to make 862 as near 900 as possible, we obtain 862.

Example: Multiply 6.234 by 143.

Taking 6.234 correct to three significant figures we multiply 6.23 by 143.

Opposite 623 on D set 1 on *C*.

Under 143 on *C* find 891 on *D*.

Roughly calculating, 6 × 140 = 840.

Therefore the result is 891.

Example: Multiply 2.46 by 7.82.

When the product of the given numbers is greater than 10, the sum of their logarithms will exceed the length of the rule. Hence if we set the left index of the slide to 246 on *D*, the other number 782 on *C* projects beyond the rule. In this case, think of the projection as wrapped around and inserted in the groove at the left. Now the right and left-hand indexes coincide.

Hence set the *right* index of the slide to 246 on *D*.

Under 782 on *C* find 192 on *D*.

Roughly calculating, 2 × 8 = 16.

Hence the result is 19.2.

Example: Multiply .146 by .0465.

Opposite 146 on *D* set 1 on *C*.

Under 465 on *C*, find 679 on *D*.

Roughly calculating, .1 × .05 = .005.

Hence the result is .00679.

Find the value of

Problem 67. 2.34 × 3.16.	**70.** 8.54 × 6.85.	**73.** .023 × 2.35.
68. 3.76 × 5.14.	**71.** 34.2 × 7.55.	**74.** .00515 × .324.
69. 1.82 × 4.15.	**72.** 4.371 × 62.47.	**75.** .00523 × .0174.

Problem 76. Find the circumferences of circles having diameters of 4 ft., 6.5 ft., 14 ft.

Opposite π on *A*, set 1 on *B*.

Above 4, 6.5, and 14 read the circumferences on *A*.

DIVISION.

In division, reversing the operation of multiplication,

8 ÷ 4 = 2. (See Fig. 24)

We subtract log 4 from log 8 and obtain log 2.

PROPORTION.

Problems in proportion are special cases of multiplication and division.

Example: Solve 16 : 27 = 17.5 : *x*.

$$x = \frac{27 \times 17.5}{16}.$$

Following the method on page 13, Fig. 14, we first divide 27 by 16 by setting 16 on *C* to 27 on *D*. We have subtracted the logarithm of 16 from the logarithm of 27. The result of this division, which is 169, is found on *D* under the left index. Now multiply by 17.5 by moving the indicator to 175 on *C*. On *D*, opposite the indicator, read 295. (See Fig. 25)

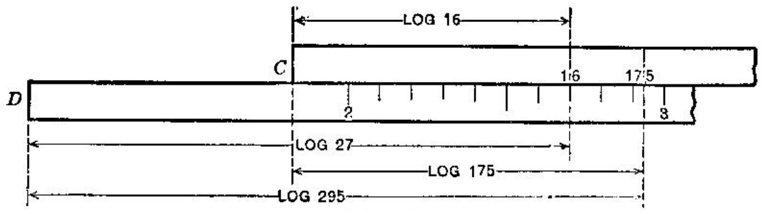


Fig. 25.

To place the decimal point, note that 16 has the same relation to 27 that 17.5 has to x. Since 27 is not quite twice 16, x will be not quite twice 17.5. Hence the decimal point must be placed so that the answer is 29.5.

The method of working a proportion is easily remembered as follows:

$$\begin{matrix} C & D & C & D \\ 16 : 27 & = & 17.5 : x. \end{matrix}$$

Example: Solve $x : 24 = 11 : 18$.

$$\begin{matrix} C & D & C & D \\ x : 24 & = & 11 : 18. \end{matrix}$$

To 18 on D, set 11 on C. Opposite 24 on D find x on C.

The significant figures of x are 147.

To place the decimal point, note that since 11 is a little more than half of 18, x will be a little more than half of 24, or 14.7.

SQUARES AND SQUARE ROOTS.

$$(10^3)^2 = 10^3 \times 10^3.$$
$$= 10^6.$$
$$\text{Since } 6 = 2 \times 3,$$
$$\text{Log } (10^3)^2 = 2 \times \log 10^3.$$

Hence, to square a number, multiply its logarithm by 2.

The space given to each number on scale D is twice that given to the same number on scale A.

As an example, suppose we wish to square 3.

This can be done by doubling the space given to 3 on scale A and finding 9, or looking for 3 on scale D and finding its square above it on scale A.

Reversing the operation gives the square root.

As an example, find the square root of 9.

Look for 9 on scale A, and directly below it on D find 3, its square root.

CUBES.

$$(10^2)^3 = 10^2 \times 10^2 \times 10^2.$$
$$= 10^6.$$
$$\text{Since } 6 = 3 \times 2,$$
$$\text{Log } (10^2)^3 = 3 \times \log 10^2.$$

Hence, to cube a number, multiply its logarithm by 3.

Scale K is graduated from 1 to 1,000, while scale D runs from 1 to 10. The space given to each number on scale D is three times that given to the same number on scale K.

Example: Find the cube of 2.

This could be done as follows:

Find 2 on scale K with the indicator. We have now measured log 2, from the left end of the rule.

Measure off three times this space on scale K and we have the indicator set at log 2^3 or 8.

But this measuring can be done by setting the indicator to 2 on scale D, since the space given to 2 on D is three times that given to 2 on K.

Hence, to cube a number, set the indicator to the given number on scale D.

On scale K, opposite the indicator, find the result which is 2^3, or 8.

In the same way show that

Example: $3^3 = 27$.
$4^3 = 64$.
(Note that the reading is on the second of the K scales running from 10 to 100. This scale we will call K_2).
$5^3 = 125$.
$6^3 = 216$.
$7^3 = 343$.
(Note that the reading is on the third of the K scales running from 100 to 1,000. This scale we will call K_3).
$8^3 = 512$.
$9^3 = 729$.
$11^3 = 1331$.

Roughly calculating, we know 11^3 is a little larger than 10^3, of 1,000. We also can see that the units figure will be the cube of 1, or 1. The mark on the rule gives 133. Hence the total result is 1,331.

In the same way, work the following:

Example: $12^3 = 1{,}728$.

Find the cubes of the following numbers correct to 4 significant figures:

Problem 77. Find the cube of 13.
78. " " " " 14.
79. " " " " 15.
80. " " " " 16.
81. " " " " 17.
Problem 82. Find the cube of 18.
83. " " " " 19.
84. " " " " 20.
85. " " " " 21.

Find the cubes of the following numbers correct to 3 significant figures:

Example: Find the cube of 22. (The complete answer is 10,648, but on the slide rule we get 10,600 correct to 3 significant figures. The error is less than one-half of one per cent.)

Problem 86. Find the cube of 31.
87. " " " " 46.
88. " " " " 47. (Set the right-hand index on the slide to 47 on D.)
89. " " " " 53.

Problem 90. Find the cube of 64.
91. " " " " 758.
92. " " " " 232.
93. " " " " 425.6.*
94. " " " " 87.9.
95. " " " " 139.
Problem 96. Find the cube of .342.
97. " " " " .057.
98. " " " " .0068.
99. " " " " 1.03.
100. " " " " 2.12.

*In Problem 93, 425.6 is approximately 426. Roughly approximating the result $400^3 = 64{,}000{,}000$. The rule gives us 771. The result is 77,100,000 correct to three significant figures. The complete result is 77,091,209.216.

Problem 101. How many gallons will a cubical tank hold that measures 26 inches in depth? (1 gal. = 231 cu. in.)

CUBE ROOTS.

Example: Find the cube root of 8.

Set the indicator to 8 on the left-hand K scale, called K_1. On scale D, opposite the indicator, find 2.

Explanation. $\text{Log } \sqrt[3]{8} = \frac{1}{3} \log 8.$

Hence, to find the cube root of a number, divide the logarithm of the number by 3.

Using log 8 on scale D as a unit, set the indicator to 8 on D.

Measuring from the left index one-third of this space, we find 2 on scale D.

But one-third of log 8 on D may be found by setting the indicator to 8 on the left-hand K scale, since each K scale is one-third as long as the D scale.

Example: Find $\sqrt[3]{27}$.

Set the indicator to 27 on the middle K scale, called K_2.

On scale D, opposite the indicator, find 3.

Example: Find $\sqrt[3]{125}$.

Set the indicator to 125 on the right-hand K scale, called K_3.

On scale D, opposite the indicator, find 5.

Example: Find $\sqrt[3]{9}$.

Set the indicator to 9 on K_1.

On D, opposite the indicator, find 208, the significant figures of the result.

Placing the decimal point by inspection, we have $\sqrt[3]{9} = 2.08$.

Example: Find $\sqrt{90}$.

Set the indicator to 90 on K_2.

On D, opposite the indicator, find 4.48, the cube root.

Example: Find $\sqrt[3]{900}$.

Set the indicator to 900 on K_3.

On D, opposite the indicator, find 9.65, the cube root.

Example: Find $\sqrt{.9}$.

Point off the number into periods of three figures each, counting from the decimal point, adding zeros to fill out the three figures. This gives .900. Now we have the problem of finding the cube root of 900 as in the previous example.

The significant figures are 966, the setting of the indicator being the same as in the previous example.

In placing the decimal point, there is a decimal place in the cube root for every decimal period of three figures in the given problem.

Given number .900,000,000.
Cube root 9 6 6
The result is .966.

Example: Find $\sqrt[3]{.09}$.

Following the plan of the previous example, the first decimal period is .090.

Finding $\sqrt[3]{90}$ as before we have 448 for the significant figures.

Hence, the result is .448.

Rule for placing the decimal point in Cube Root

From a consideration of the preceding eight examples, we derive a rule for placing the decimal point in finding the cube root of numbers that do not lie between 1 and 1,000.

a. Move the decimal point 3, 6, or 9 places, as may be necessary, in either direction to obtain a number between 1, and 1000.

b. Find the cube root of this new number using
K_1 for a number of one integer,
K_2 " " " " two integers,
K_3 " " " " three integers.

c. In the result, move the decimal point one third as many places as it was moved in *a*, and in the opposite direction.

Example: Find $\sqrt[3]{56,342}$

a. Move the decimal point three places to the left, obtaining 56.342
b. Find the cube root of 56.3 which is 3.83.
c. Move the decimal point one place to the right, obtaining 38.3.

Example: Find $\sqrt[3]{.00382}$.

a. Move the decimal point three places to the right, obtaining 3.82.
b. Find the cube root of 3.82. which is 1.563.
c. Move the decimal point one place to the left, obtaining 1563.

Problem		Problem	
102.	Find the cube root of 3.	112.	Find the cube root of 50.
103.	" " " 30.	113.	" " " 7.35.
104.	" " " 300.	114.	" " " .575.
105.	" " " .3.	115.	" " " 241.
106.	" " " .03.	116.	" " " 3840.
107.	" " " .003.	117.	" " " 52076.
108.	" " " 2613.	118.	" " " .0163.
109.	" " " 47.8.	119.	" " " .0094.
110.	" " " .784.	120.	" " " 1.036.
111.	" " " 45083.	121.	" " " 108723.

Problem 122. How deep should a cubical box be made in order to contain 8,500 cubic inches?

THE INVERTED SCALE CI

An important improvement found on the Polyphase Slide Rule is the inverted scale, *CI*.

This scale enables reciprocals of all numbers to be read at once, without setting the slide. It also enables three factors to be taken at a single setting, thus saving one or more settings in many formulas, and increasing both speed and accuracy.

An examination of the *CI* scale will show that it is similar to the *C* scale but with the numbers increasing from right to left rather than from left to right. If you remove the slide and replace it *upside down*, you will see that the *CI* scale graduations and numbers are now in the same position as the *C* scale is normally.

RECIPROCALS

Two numbers are reciprocals if their product is equal to 1, or we may say that the reciprocal of a number is 1 divided by that number.

e. g. 5 and 1/5 are reciprocals since $5 \times 1/5 = 1$.

To find the reciprocal of a number:

Set the indicator to the given number on scale *C*.

Opposite the indicator on scale *CI* will be found the significant figures of the reciprocal.

The decimal point is placed by inspection.

Example: Find the reciprocal of 2.

Set the indicator to 2 on *C*. Opposite the indicator on *CI*, find 5.
Placing the decimal point by inspection, the result is .5.

Example: Find the reciprocal of .236.

Set the indicator to 236 on *C*.
On *CI*, opposite the indicator, find 424.
Roughly calculating $1/.236 = 1/.2 = 5$.
Hence the result is approximately 5 or 4.24.

Find the reciprocals of the following numbers:

Problem	123.	7.2	**Problem**	128.	.182
	124.	.41		129.	56.5
	125.	37.8		130.	.85
	126.	68.2		131.	7.35
	127.	.073		132.	.0063

MULTIPLICATION

Example: Multiply 3 by 2, using scale *CI*.

Set the indicator to 3 on *D*.
To the indicator set 2 on *CI*.
Opposite the right index, find 6 on *D*.

Note that 3 on scale *CI* is also in alignment with 2 on scale *D*. Hence we may set the indicator to 2 on *D*.

To the indicator set 3 on *CI*.
Opposite the right index, find 6 on *D*.

Explanation

log 3	+ log 2	= log 6
measured on *D*	measured on *CI*	measured on *D*

Example: Multiply 3 by 5, using scale *CI*.

Set the indicator to 3 on *D*.
To the indicator set 5 on *CI*.
Opposite the left index, find 15 on *D*.
An advantage of scale *CI* in multiplication is that no uncertainty can exist as to which index to use.

Exercise

Work problems 67 to 75 on page 23, using scale *CI*. Note the saving in time.

DIVISION

Example: Divide 28 by 7, using scale *CI*.
To 28 on scale *D* set left index.
Set indicator to 7 on *CI*.
Opposite indicator on scale *D* read 4.

Successive Division

The *CI* scale is useful in problems of the type $x = \frac{a}{y}$, where a is constant and y assumes successive values.

Example: A field rheostat on an electric generator is used to vary the resistance so as to give it the following values in ohms: 250, 298, 347, 401 453, 496.

If the voltage is 125, what are the values of the field current?

$$I = \frac{E \text{ (Constant)}}{R \text{ (Varying)}}$$

where I is the current in amperes, E the electromotive force in volts, and R the resistance in ohms.

$$I = \frac{125}{250}, \quad \frac{125}{298}, \quad \frac{125}{347}, \quad \frac{125}{401}, \quad \frac{125}{453}, \quad \frac{125}{496}.$$

To 125 on *D* set 10 on *CI* (left index).

Opposite	250 on *CI*,	read	.500	on *D*.
"	298 " *CI*,	"	.419	" "
"	347 " *CI*,	"	.360	" "
"	401 " *CI*,	"	.312	" "
"	453 " *CI*,	"	.276	" "
"	496 " *CI*,	"	.252	" "

From one setting of the slide all six values are read.

By the use of scales *C* and *D* only, six settings of the slide would have been required.

THREE OR MORE FACTORS

Explanation

Example: $2 \times 3 \times 4 = x$.

Set the ndicator to 2 on *D*.

Set 3 on *CI* to the indicator.

Opposite 4 on *C*, read 24 on *D*.

log 2	+ log 3	+ log 4	= log 24.
measured on *D*	measured on *CI*	measured on *C*	measured on *D*

Example: $5.2 \times 3.4 \times a\ (=2.8) = x$.

Method 1. Using scales *CI*, *C* and *D*.

1. Set indicator to 52 on *D*.
2. Set 34 on *CI* to the indicator.
3. Opposite any value of *a*, say 28, on *C*, read 495 on *D*.

To place the decimal point, roughly estimating,

$$5 \times 3 \times 3 = 45.$$

Hense the result is 49.5

Note that this result is obtained with only one setting of the slide, and with no uncertainty as to whether the right or left index should be used.

Method II. Using only scales *C* and *D*.

1. Set right index to 52 on *D*.
2. Move indicator to 34 on *C*.
3. Set left index to indicator.
4. Opposite 28 on *C* read 495 on *D*.

This method requires two settings of the slide, and involves some uncertainty as to which index to use in steps 1 and 3.

Hense Method I should be used in problems of this type.

Example: $\dfrac{72}{.75 \times a\ (=6.4)} = x$.

To 72 on *D* set 75 on *D*; opposite any value of *a*, say 64, on *CI* read 15 on *D*.

The decimal point of the result can be placed by inspection.

Note that when the *C* and *D* scales alone are used in solving problemt of this type, two settings will be required, including a seperate setting for each value of the variable (*a*) of the denominator; whereas, by employing the *CI* scale also, a single setting of the slide permits a solution for all the values of the variable (*a*).

Four Factors

Example: $1.43 \times 5.12 \times 1.76 \times 0.725 = x$.

Method I.

1. Set indicator to 143 on *D*.
2. To indicator set 512 on *CI*. — Ans. 7.32 on *D* opp. rt. index.
3. Indicator to 176 on *C*. — Ans. 12.89 on *D* opp. indicator
4. Set 725 on *CI* to indicator.
5. Opposite right index, read 934 on *D*.

This method requires only two settings of the slide.

Method II: Using only scales *C* and *D*.

1. Set left index of C to 143 on *C*.
2. Move indicator to 512 on *C*. — Ans. 7.32 on *D* opp. indicator
3. Set right index to indicator
4. Indicator to 176 on *C*. — Ans. 12.89 on *D* opp. indicator
5. Left index to indicator
6. Opposite 725 on *C* read 9.34 on *D*.

This method involves three settings of the slide, and some uncertainty as to which index to use in steps 1 and 3. Hense Method I will save considerable time in the solution of problems of this type.

Five Factors

Example: $2 \times 3 \times 4 \times 5 \times 6 = x$.

To 2 on *D* set 3 on *CI*.
Indicator to 4 on *C*.
Set 5 on *CI* to indicator.
Opposite 6 on *C*, read 72 on *D*.
Placing the decimal point, the result is 720.

Note that the five factors are handled with only two settings of the slide, Without the *CI* scale, four settings of the slide would be required.

Occasionally in finding the product of three or more numbers, using scale *CI*, it is necessary to re-set the index.

Example: $2 \times 3 \times 1.3 = x$.

To 2 on *D*, set 3 on *CI*.
Since 1.3 on *C* is beyond the left end of the rule,
Move indicator to 10 on *C*.
Set 1 on *C* to the indicator.
Opposite 1.3 on *C*, read, 7.8 on *D*.

Using scale *CI*, find the value of:

133. $6.1 \times 2.4 \times 5.2$
134. $6.1 \times 24 \times .32$
135. $.53 \times 42 \times 1.6$
136. $.53 \times 42 \times 6.5$
137. $54.3 \times 1.26 \times 2.3$
138. $54.3 \times 1.26 \times 1.17$
139. $0.75 \times 1.1 \times 6.5 \times 8.65$
140. $8.2 \times 0.45 \times 6.4 \times 16$
141. $5.5 \times 2.1 \times 3.5$
142. $7.1 \times 31 \times .42$
143. $.64 \times 32 \times 5.6$
144. $16.3 \times 3.65 \times 243 \times 1210$
145. $8.25 \times .036 \times 1.07 \times 4.12$
146. $37.8 \times .0052 \times 46 \times 6.2$
147. $6.3 \times 2.5 \times .17 \times 5.4 \times 3.4$

Example: Solve $x = \dfrac{\sqrt{78}}{y}$ where *y* has the series of values, 1.2, 2.4, 3.6 and 4.8.

Set right index to 78 on scale A, right; opposite any value of *y* on scale *CI*, read *x* on *D*.

when $y = 1.2$	$x = 7.36.$	Answer.
2.4	3.68	
3.6	2.45	
4.8	1.84	

Example: Solve $x = \dfrac{y}{\sqrt{2.7}}$

Set 2.7 on scale B left to index.
Opposite any value of y on scale C read x on D.

Example: Find the value of $4.3\sqrt[3]{25}$.
Using indicator: to 25 on scale K_2, set 4.3 on scale CI.
At index read 12.57, the result, on D.

Example: Find the value of $\dfrac{\sqrt[3]{760}}{84}$

To 760 on K_3 set 84 on C.
At index find .1086 on D.
The decimal point may be placed by inspection. The cube root of 760 has one integer, roughly 9; which divided by 80, shows the magnitude of the answer.

Example: Solve $x = \dfrac{.27}{\sqrt[3]{.069}}$

Set indicator to 69 on K_2,
Set 27 on scale C to indicator,
At index on D read 658 on scale C.
Roughly calculating:

$$\frac{.27}{\sqrt[3]{.069}} = \frac{.28}{\sqrt[3]{.064}} = \frac{.28}{.4} = .7$$

Hence the result is .658.

Example: Solve $x = 3\sqrt{23} \times \sqrt[3]{127}$.
To 127 on K_3 set 3 on scale CI.
Indicator to 23 on scale B_2,
Opposite indicator on scale D, read 723.

Roughly calculating,

$$3\sqrt{23} \times \sqrt[3]{127} = 3 \times \sqrt{25} \times \sqrt[3]{125} = 3 \times 5 \times 5 = 75.$$

Hence, the result is 72.3

CHAPTER III

ADVANCED PROBLEMS

COMBINED MULTIPLICATION AND DIVISION

Example: Find the value of

$$\frac{23.5 \times 45.3}{2670}.$$

To 235 on D, set 267 on C. Opposite 453 on C find 399 on D. To obtain the decimal point make a rough calculation as follows:

$$\frac{23.5 \times 45.3}{2670} \text{ is roughly equal to } \frac{20 \times 50}{3000} = \frac{1}{3}.$$

Hence, we must place the decimal point so as to make 399 approximately equal to ⅓. The result is evidently .399.

Another method of placing the decimal point:

$$\frac{23.5 \times 45.3}{2670} = \frac{(2.35 \times 10) \quad (4.53 \times 10)}{2.67 \times 1000} = \frac{2.35 \times 4.53}{2.67} \times \frac{1}{10} = 3.99 \times \frac{1}{10} = .399$$

The first method will be found preferable, but may be checked by the second.

Example: Find the value of $\dfrac{1.34 \times 2.15}{4.2}$.

To 1.34 on D, set 4.2 on C. When we attempt to move the indicator to 2.15 on C, it is impossible, because 2.15 projects beyond the left end of the rule. Bring the indicator to 10 on C and move the slide so as to set the left index to the indicator. This divides by 10, but is permissible, since dividing by 10 does not change the order of significant figures. Now move the indicator to 2.15 on C; and on D, opposite the indicator, read 686. A rough calculation shows that:

$$\frac{1.34 \times 2.15}{4.2} \text{ is approximately equal to } \frac{1 \times 2}{4} = \frac{1}{2}, \text{ or } .5.$$

Hence, the result is .686.

Example: Find the value of

$$\frac{30.5 \times 50.6 \times 835}{3.64 \times 380 \times 42.5} = x.$$

$$\frac{\overset{D}{30.5} \times \overset{C}{50.6} \times \overset{C}{835}}{\underset{C}{3.64} \times \underset{C}{380} \times \underset{C}{42.5}} = \overset{D}{x}.$$

The five operations are as follows:	Intermediate Results on D.
1. At 305 on D set 364 on C.	838, opposite right index.
2. Move indicator to 506 on C.	424, opposite indicator.
3. Set 380 on C to the indicator.	111, opposite left index.
4. Indicator to 835 on C.	932, opposite indicator.
5. Set 425 on C to the indicator, and opposite the index on C, find 219 on D.	

Calculating roughly,

$$\frac{30 \times 50 \times 800}{3 \times 400 \times 40} = 25.$$

Hence 219 must be made to look as near as possible like 25, giving the result 21.9. It is not necessary to obtain the intermediate results, but with beginners it is an advantage to check the work at every step.

Example: Find the value of

$$\frac{25.4 \times 570 \times 26.8 \times 8.63 \times 1.3}{1.55 \times 8350 \times 4.15 \times 2.24}.$$

$$\frac{\overset{D}{25.4} \times \overset{C}{570} \times \overset{C}{26.8} \times \overset{C}{8.63} \times \overset{C}{1.3}}{\underset{C}{1.55} \times \underset{C}{8350} \times \underset{C}{4.15} \times \underset{C}{2.24}} = \overset{D}{x}.$$

	Intermediates on D
1. At 254 on D, set 155 on C.	164
2. Move indicator to 570 on C.	934
3. Move the slide, setting 835 to indicator.	112
4. Indicator to 268 on C.	300
5. Move slide, setting 415 on C to indicator.	722
6. Indicator to 863 on C.	623
7. Move slide, setting 224 to indicator.	278
8. Indicator to 13 on C.	362

Find the answer 362 on D opposite the indicator.

Calculating roughly:

$$\frac{25 \times 600 \times 80 \times 8 \times 1}{1 \times 8000 \times 4 \times 2} = 60.$$

Making 362 look as much as possible like 60, we have 36.2.

Example: Find the value of

$$\frac{7.45}{3.65 \times .0267}$$

The preceding examples have had as many factors in the numerator as in the denominator or one more. This example can be changed to conform to these types by introducing unity as a factor in the numerator.

Method I. Using scales CI, C, and D.

1. To 745 on D set 365 on C.
2. Opposite 267 on CI read 764 on D.

Roughly calculating:

$$\frac{8 \times 1}{4 \times .02} = \frac{2.00}{.02} = 100.$$

Making 764 look as much as possible like 100, the result is 76.4.

This method is preferable, since it requires only one setting of the slide.

Method II. Using only scales C and D.

$$\frac{7.45}{3.65 \times .0267} = \frac{\overset{D}{7.45} \times \overset{C}{1}}{\underset{C}{3.65} \times \underset{C}{.0267}} = x.$$

	Check by Intermediates on D.
1. Divide 7.45 by 3.65.	204, opposite left index.
2. Move indicator to 1 on C.	204, opposite indicator.
3. Move slide, setting 267 to indicator.	764, opposite right index.

Example: Find the value of $\frac{1}{2.34 \times .33 \times 5.25}$.

	Check by Intermediates on D
1. To 1 on D, set 234 on C.	427, opposite right index.
2. Indicator to 33 on CI.	1295, opposite indicator.
3. 525 on C to indicator.	2467, opposite right index.

Rough calculation: $\frac{1}{2 \times \frac{1}{3} \times 6} = \frac{1}{4} = .25.$

Making 2467 look as much as possible like .25 the result is .2467.

Example: Find the value of: $\sqrt{\frac{21.4 \times 3.45 \times 640}{4.15 \times .75 \times .08}}$.

Method I.—Work the example without regard to the square root, then find the square root of the result.

Method II.—Using scales A and B:

$$\frac{\overset{A}{21.4} \times \overset{B}{3.45} \times \overset{B}{640}}{\underset{B}{4.15} \times \underset{B}{.75} \times \underset{B}{.08}} = \overset{D}{x}.$$

	Intermediate on A.
1. To 21.4 on A set 4.15 on B.	516, opposite index.

Be careful to use 21.4 on the right half of A and not 2.14 on the left half, since the square root of 21.4 has different significant figures from the square root of 2.14. For the same reason use 4.15 on the left half of B.

2. Indicator to 3.45 on B (left half of rule)	178, opposite indicator.
3. Move slide setting .75 (right half) to indicator.	237, opposite index.
4. Indicator to 6.4 (left half) on B.	152, opposite indicator.

Change 640 to 6.4, by moving the decimal point an even number of places, in order not to change the square root.

5. Move slide setting 8 (left half) on B to indicator.	190, opposite index.
6. Opposite right index of B find 436 on D.	

Rough calculation

$$\sqrt{\frac{20 \times 3 \times 600}{4 \times 1 \times .1}} = \sqrt{90000} = 300.$$

Placing the decimal point so as to make 436 as near as possible to 300, the result is 436.

Find the value of

Problem 148. $\frac{3.26 \times .0235}{4.22}$.

149. $\frac{6.75 \times 1.35}{14.4}$

150. $26.4 \times 4.8 \times 7.12$.

151. $6.2 \times 28 \times .35 \times 5.4$.

Problem 152. $.65 \times 24 \times 7.5 \times 9.5$

153. $\frac{6.45}{4.55 \times .0276}$

154. $\frac{1}{2.66 \times .75 \times 1.42}$

155. $\frac{3}{2.54 \times 7.45}$

Problem 156. $\frac{2.14 \times 4.6 \times .39}{24.3 \times .06 \times .575}$

157. $\frac{5.8 \times 4.5 \times 8.7 \times 132}{7.3 \times 6.2 \times 28 \times 14}$

158. $\sqrt{\frac{2.63 \times 82.5}{2450}}$

159. $\sqrt{\frac{48.6 \times 22.4}{56.5 \times 245}}$

160. $\sqrt{\frac{22.5 \times 12.2 \times 126 \times 405}{2760 \times 715 \times 6.16}}$

MISCELLANEOUS CALCULATIONS

Example: Find the value of $\frac{2.45 \times (76.5)^2 \times 625}{.55 \times .087}$

Method I. Use scales A and B, but use C for 76.5.
At 245 on A set 55 on B.
Indicator to 765 on C.
Set 87 on B to the indicator.
Indicator to 625 on B.
Opposite the indicator on A, find 187.
A rough calculation shows:

$$\frac{2 \times 70 \times 80 \times 600}{.5 \times .1} = \frac{200 \times 70 \times 80 \times 600}{5 \times 1} = 134000000.$$

The result is 187,000,000.

Method II. Write the example:

$$\frac{2.45 \times 76.5 \times 76.5 \times 625}{.55 \times .087 \times 1}$$

Method III. Find $(76.5)^2$ as a separate problem, then work the example on C and D.

Example: Find the value of $\frac{135 \times \sqrt{475} \times 430}{26 \times 250 \times 628}$.

Use C and D, but use B for 475.
At 135 on D, set 26 on C.
Indicator to 4.75 on B (left half of slide, because the decimal point must be moved an even number of places).

Set 250 to the indicator.
Indicator to 430 on C.
Set 638 on C to the indicator.
On D, opposite the right-hand index, find 305.
Roughly calculating:

$$\frac{100 \times 20 \times 400}{25 \times 250 \times 600} = \frac{16}{75} = \text{about } \frac{1}{5}, \text{ or } .2$$

The result, then, is .305.

Example: Find the value of

$$\frac{\sqrt{260} \times \sqrt{3.80}}{\sqrt{1310}}.$$

Use A and B, but read the result on D.
At 2.6 on A set 13.1 on B (moving the decimal point an even number of places).

If we try to move the indicator to 3.8 on B, 3.8 projects beyond the end of the rule. Hence, move the indicator to the right index of the slide, then set the left index to the indicator. This operation divides by 100, but does not change the significant figures of the result.

Now move the indicator to 3.8 on B.
On D, opposite the indicator, read 869.
Roughly calculating:

$$\sqrt{\frac{300 \times 3}{1600}} = \frac{3}{4} = .75$$

Hence the result is .869.

Settings:
The result is denoted by x

Problem 161.	$\frac{13.5 \times (14)^2}{82}$	A	To 135	Find x
		B	Set 82	
		C		Over 14
		D		
162.	$1.35 \times \sqrt{2}$	A		
		B		Under 2
		C	Set 1	
		D	To 135	Find x
163.	$\frac{42.3}{\sqrt{6720}}$	A		
		B	Set 67.2	
		C		Under 10
		D	To 42.3	Find x
164.	$\frac{5.2}{(3.4)^2}$	A	To 5.2	Find x
		B		Over 1
		C	Set 3.4	
		D		
165.	$\frac{(16.2)^2 \times 45.2}{(2.7)^2}$	A		Find x
		B		Over 452
		C	Set 27	
		D	To 162	

166. $\left(\frac{.0347}{.0058}\right)^2$

A	:		:	Find x
B	:		:	Over 100
C	:	Set 58	:	
D	:	At 347	:	

167. $\frac{2.31 \times (48.5)^2 \times 413}{.45 \times .087}$

168. $\frac{175 \times \sqrt{285} \times \sqrt{17 \times 410}}{28 \times 228 \times 634}$

169. $\frac{\sqrt{8.32} \times \sqrt{56.5}}{\sqrt{2830}}$

170. $\frac{2.6}{(7.4)^3}$

171. $\left(\frac{.0325}{.0075}\right)^3$

172. $\sqrt[3]{\frac{420 \times 1.65}{2.64}}$

CHAPTER IV

PLANE TRIGONOMETRY

SINES

Method I. Remove the slide from the groove, turn it over so that the face that was underneath is now uppermost and insert it in the groove with the indexes coinciding as in Fig. 26.

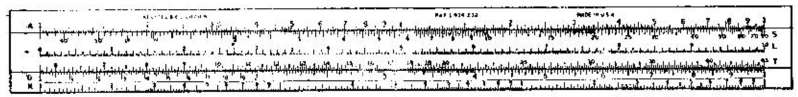


Fig. 26.

The scale marked S is a scale of sines. Angles are given on scale S, opposite their sines on scale A.

Example: Find sine 20°.

Opposite 20 on scale S is found its sine on scale A. This reads 342. To place the decimal point, a number read on the right half of scale A has the first significant figure in the first decimal place, except sine 90, which is 1; a number read on the left half of scale A has the first significant figure in the second decimal place.

Hence since 20° = .3420.

Example: Find sine 2°.

The significant figures are 349.

The reading is on the left of scale A, hence the result is .0349.

Method II. With the slide in the usual position showing scales B and C, set the given angle on scale S to the mark opposite the index on the under side of the rule; then opposite the right index of scale A read the sine on scale B.

Example: Find sin 5° 40′ × 35.

Method I. With the slide having scales S and T uppermost,

A	:	to 35	:	Find 3.46
S	:	Set Right Index	:	Over 5° 40′

Log 35 is added to log sin 5° 40′, the sum being counted on scale A.

Method II. With the slide having scales B and C uppermost, set sin 5° 40′ on S to the mark in the groove at the right end of the rule.

Under 35 on A, read the product 3.46 on B.

Evidently we have added log sin 5° 40′ to log 35, the sum being counted on scale B.

Or sin 5° 40′ × 35 = x may be written as a proportion using scales A and B.

$$\overset{A}{1} : \overset{B}{\sin 5^\circ 40'} = \overset{A}{35} : \overset{B}{x}.$$

Opposite 1 on A, set sin 5° 40′ on B.

Under 35 on A, find 3.46 on B.

Example: Find $\frac{35}{\sin 5° 40'}$.

Method I. With scale S uppermost

A	: To 35	: Find 354
S	: Set 5° 40′	: Over left index

To place the decimal point, note that sin 5° 40′ is a trifle less than **.1.** Hence dividing 35 by .1 we have 350 for the rough calculation.

Method II. With the slide having scales B and C uppermost, set sin 5° 40′ to the mark in the groove at the right end of the rule.

Over 35 on B, read the quotient 354 on A.

Explanation

Method I. We have taken the proportion by alternation, securing

$$\underset{S}{\sin 5° 40'} : \underset{A}{35} = \underset{S}{1} : \underset{A}{x}$$

Method II. We have solved the proportion:

$$\underset{B}{\sin 5° 40'} : \underset{A}{1} = \underset{B}{35} : \underset{A.}{x.}$$

EXERCISES

Problem 173. Find the sine of 90°.
174. " " " 45°.
175. " " " 30°.
176. " " " 3°.
177. " " " 40′.
Problem 178. Find the sine of 15° 20′.
179. " " " 1° 30′.
180. " " " 8° 30′.
181. " " " 2° 15′.
182. " " " 21° 30′.

COSINES

Since the cosine of an angle is equal to the sine of the complement of the angle, the cosine may be found on the slide rule.

Example: Find cos 30°.

Cos 30° = sin (90°—30°).
= sin 60°.
= .866.

Problem 183. Find the cosine of 80°.
184. " " " 65°.
185. " " " 42°.
186. " " " 14°.
187. " " " 12°.
Problem 188. Find the cosine of 75° 30′.
189. " " " 54° 10′.
190. " " " 20° 30′.
191. " " " 81° 45′.
192. " " " 88° 25′.
193. Sin 25° × 45.
194. Cos 56° × 27.
195. $\frac{18}{\sin 12° 30'}$.
196. $\frac{21.5}{\sin 42° 10'}$

Problem 197. A = 32°. (Fig. 27).
c = 65
Find a.

Problem 198. A = 70° 30′.
a = 15.4.
Find c.

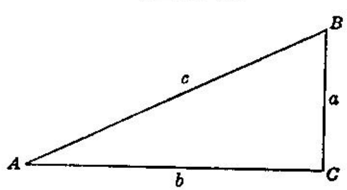


Fig. 29.

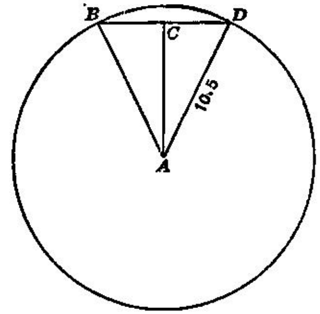


Fig. 30

Problem 199. A disk is 21 inches in diameter. Find the distance necessary to set a pair of dividers in order to space off a,) 7 sides; b,) 8 sides c,) 10 sides; d,) 13 sides.

The angle $DAB = \frac{1}{7}$ of 360° = 51° 26′.

(to the nearest minute).

The angle $DAC = \frac{1}{2}$ of 51° 26′ = 25° 43′.

$\frac{CD}{AD}$ = sine angle DAC.

$CD = AD \times$ sine angle DAC.
$BD = 2 \times CD = 2 \times AD \times$ sine angle DAC
$= d$ sine angle DAC where d = diameter of circle.

200. Holes A and C are to be drilled on the milling machine. After drilling C, in order to drill A, how much movement of the table will there be in each direction?

The table moves from C to B, then from B to A.
$BC = 5 \times \cos 20°$.
$BA = 5 \times \sin 20°$.

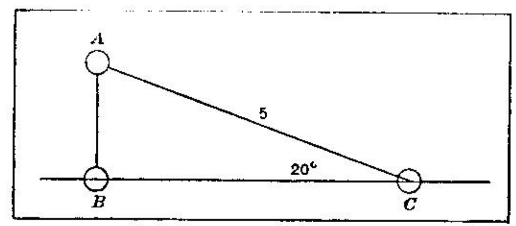


Fig. 31.

TANGENTS

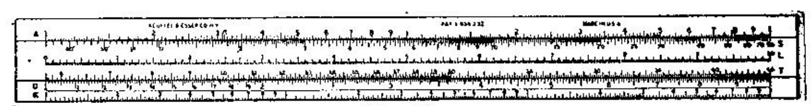


Fig. 30.

With the slide in position for reading sines, scale T gives readings for angles whose tangents are found opposite on scale D.

The first significant figure comes in the first decimal place for all values found on the rule.

Example: Find tan 30°.

Method I. Opposite 30 on scale T, find 577 on D.

Pointing off, we have tan 30° = .5770, which is correct to three significant figures; the result correct to four figures being .5774.

Method II. With the slide in the usual position showing scales B and C, set 30 on the T scale to the mark on the under side of the rule and opposite 1 on D read 577 on C.

Example: Find the value of tan 18° 30′ × 175.

Find tan 18° 30′ by Method II.

Shift "C" scale so that right index takes position of left index.

Above 175 on D, find 586 on C.

Since tan 18° 30′ is. 334, the product must be roughly $\frac{1}{3}$ of 175, making the result 58.6.

The scale gives tangents only as far as 45°.

For larger angles, use the formula:

$$\tan A = \frac{1}{\tan(90° - A)}$$

Example: Find the tan of 75°.

$$\tan 75° = \frac{1}{\tan(90° - 75°)}.$$
$$= \frac{1}{\tan 15°}.$$

Opposite the mark in the notch on the under side of the rule, set 15° on the T scale. Opposite the left index of C, read 373 on D. Placing the decimal point by a rough calculation, remembering that tan 45° is 1,

$$\frac{1}{\tan 15°} = \frac{1}{\frac{1}{3}} = 3.$$

Hence the result is 3.73.

Owing to the presence of the CI scale we may also obtain the answer by setting 90°—A on T to 10 on D. Under the mark in the notch on the under side of the scale read 3.73 on CI. This simplifies the operation, but is applicable only to angles less than 84°. For angles from 84° to 90° the formula

$$\tan A = \frac{1}{\tan(90° - A)}$$

must be used. Tan (90°—A) can be obtained by finding sine (90°—A) as explained on page 44.

Example: Find the value of 565 ÷ tan 65°.

$$565 \div \tan 65° = 565 \div \frac{1}{\tan 25°}$$
$$= 565 \times \tan 25°.$$
$$= 263.$$

Find tan 25° by Method II.

Opposite 565 on D find 263 on C.

Example: Find the value of

$$256 \div \tan 10° 30'.$$

Method I. Opposite 256 on D set 10° 30′ on T. Under the left index of T, find 138 on D. Roughly calculating for the decimal point, remembering that tan 45° = 1,

$256 \div \tan 10° 30' = \frac{256}{.2} = 1280.$ Making 138 look as much as possible like 1280 we have 1380.

Method II. With the slide in the usual position with scale C uppermost, set 10° 30′ on T to the mark on the under side of the rule. Opposite 256 on C, find 138 on D. Placing the decimal point, we have 1380.

Example: Find the value of

$$256 \div \tan 40° 10'.$$

By Method II, setting 40° 10′ on T to the mark on the under side of the rule, under 256 on C, find 303 on D.

Roughly calculating: $\frac{256}{\tan 40° 10'} = \frac{256}{.8} = 320.$

Hence, the result is 303.

The tangent of an angle less than 5° 43′ cannot be obtained directly from the 10 in. rule, but the sine may be used in place of the tangent, since the sine and the tangent of any of these angles are in close agreement.

$$\tan 1° 30' = \sin 1° 30' = .0262.$$

COTANGENTS

The cotangents of angles from 5° 43′ to 45° may be read upon the CI scale. In every case the first significant figure is a whole number.

Cotangents for angles greater than 45° may be found as follows:

$$\text{Cot } A = \tan(90° - A) = \frac{1}{\tan A}.$$

Example: Find cot 65°.

$$\text{Cot } 65° = \tan(90° - 65°).$$
$$= \tan 25°.$$
$$= .466.$$

Example: Find cot 18°.

$$\text{Cot } 18° = \frac{1}{\tan 18°} = 3.08.$$

SECANT AND COSECANT

The secant and cosecant may be found by the formulas:

$$\sec A = \frac{1}{\cos A}$$
$$\csc A = \frac{1}{\sin A}$$

Problem 201. Find tangent of 25°.
202. " " " 14° 30′.
203. " " " 35° 30′.
204. " " " 26° 20′.
205. " " " 18° 30′.
206. " " " 55° 20′.

Problem 207. Find tangent of 75° 10′.
208. " " " 20° 10′.
209. " " " 15° 5′.
210. " " " 6° 25′.
211. " " " 1° 45′.
212. " " " 42° 20′.

Problem 213. Tan 15° × 18.

Problem 214. $\tan 65° 30' \times 13.2 = \frac{13.2}{\tan 24° 30'}$.

Problem 215. $\frac{5.62}{\tan 10°}$.

Problem 216. $\frac{8.5}{\tan 70° 20'} = 8.5 \times \tan 19° 40'$.

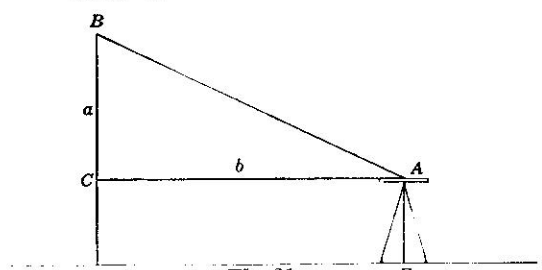


Fig. 31.

Example: To find BE, the height of a building, a transit is set up at A; a level line AC is sighted on a rod held at E.

CE is found to be 5.2 ft.

EF, which is equal to CA, is measured and found to be 138 ft.

The angle CAB is taken by the transit and found to be 28° 30′.

Find BE, the height of the building.

BE = BC + CE.
BE = CA × tan *A*.
BE = CA × tan A + CE.
= 138 × tan 28° 30′ + 5.2.
= 74.9 + 5.2.
= 80.1 ft.

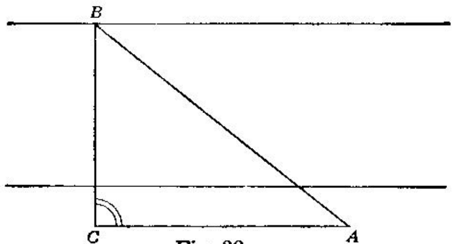


Fig. 32.

Example: To find CB, the width of a river.

A transit is set up at *C* and a right angle, BCA is laid off.

CA is measured and found to be 235 ft.

Then the transit is set up at *A* and the angle *A* found to be 75° 30′.

Find CB, the width of the river.

$$CB = CA \times \tan A.$$
$$= 235 \times \tan 75^\circ 30'.$$
$$= \frac{235}{\tan 14^\circ 30'}.$$
$$= 909 \text{ ft.}$$

SINES AND TANGENTS OF SMALL ANGLES

Gauge points are placed on the sine scale for reading sines of angles smaller than those given on the regular scale. Near the 1° 10′ division on the *S* scale is the "second" gauge point and near the 2° division is the "minute" gauge point. By placing one of these gauge points opposite any number on the *A* scale, the corresponding sine of that number of minutes or seconds is read over the index of the sine scale on *A*. Or place the gauge point opposite the left index. Then for any value on scale *B* the corresponding sine may be read on scale *A* for angles from 4′ to 100′ or from 3″ to 100″, depending upon which gauge point is used. By placing the gauge point opposite the right index sines for angles as small as 1″ may be read. In order to point off, it should be remembered that sine 1″ is about .000005 (5 zeros, 5), and sine 1′ is about .0003 (3 zeros, 3).

The sines and tangents of small angles being practically identical, these gauge points, as well as the portion of the sine scale below 5° 43′, may also be used for the tangents.

The tangents of angles greater than 89° 26′ are found as follows:

Determine 90° — *A*.

Set gauge point to index of scale. Set indicator to value on scale *B* corresponding to the angle whose tangent is sought. Shift index to indicator. Opposite the other index read tangent of angle on scale *B*.

Example: Find sine 10″.

Opposite 10 on scale *A* (center index) set the gauge point for seconds.

Opposite the left index of scale *S* find 485 on *A*.

Since sine 1″ = .000005,

sine 10″ is roughly 10 × .000005 or .00005.

Hence sine 10″ = .0000485.

Example: Find sine 12′.

Opposite 12 on scale *A* set the gauge point for minutes.

Opposite the left index find 349 on *A*.

Since sine 1′ = .0003,

sine 12′ is roughly 12 × .0003 = .0036.

Making 349 look as near as possible like .0036,

sine 12′ = .00349.

Example: Find tan 89° 45′.

90°—89° 45′ = 15′.

Set minute gauge point to left index of scale.

Set indicator to 15 on *B*.

Shift right index of *B* to indicator.

Opposite left index of *A* read 229 on *B*.

The complete tangent of 89° 45′ is really 229.18.

Example: Find tan 89° 45′ 45″.

90°—89° 45′ 45″ = 14′ 15″ = 855″.

Set second gauge point to left index of *A*.

Set indicator to 855 (left half) of *B*.

Shift right index of *B* to indicator.

Opposite left index of *A* read 241 on *B*.

The tangent of 89° 45′ 45″ is actually 241.16 +

Another method of finding sines and tangents of very small angles depends upon the fact that, for small angles the sine or the tangent varies directly as the angle.

Example: Find tan 15′.

$$\text{Tan } 15' = \sin 15'.$$
$$= \frac{1}{10} \sin 150'.$$
$$= \frac{1}{10} \sin 2^\circ 30'.$$
$$= \frac{1}{10} .0436 \text{ by the slide rule.}$$
$$= .00436.$$

LOGARITHMS

Between the scale of sines and the scale of tangents is a scale of equal parts, by means of which the logarithm of a number may be found.

Example: Find log 50.

Placing the slide in its usual position, with the scale of equal parts (which is numbered from left to right) underneath, set 5 on *C* opposite the right index of *D*. On the scale of equal parts opposite the hair line on the underside of the rule, read 699. Placing the decimal point and prefixing the characteristic, as usual in working with logarithms, log 50 = 1.699.

(The characteristic is found by taking one less than the number of figures at the left of the decimal point).

NOTE.—Some slide rules have the scale of equal parts numbered from right to left, in which case proceed in the above example as follows: Set the left index of scale *C* to 5 on *D*. On the scale of equal parts opposite the right index on the underside of the rule read 699. Prefix the characteristic as above, making log 50 = 1.699.

Example: Find $(2.36)^5 = x$.

$$\begin{aligned}\text{Log } x &= 5 \times \log 2.36.\\ &= 5 \times .373.\\ &= 1.865.\end{aligned}$$

Note that 1 is the characteristic. Find what number has .865 for a mantissa by reversing the method of the preceding example.

$$x = 73.2.$$

Example: Find $\sqrt[5]{187} = x$.

$$\begin{aligned}\text{Log } 187 &= 2.272.\\ \text{Log } \sqrt[5]{187} &= \frac{1}{5} \text{ of } 2.272 = .454.\\ x &= 2.84.\end{aligned}$$

Problem 217. Find the logarithm of 1.34.
218. " " " " 54.5.
219. " " " " .312.
220. " " " " .067.
221. " " " " 735.
222. Find the value of $(3.2)^5$ to three significant figures.
223. " " " " $(425)^4$.
224. " " " " $\sqrt[3]{3.46}$.
225. " " " " $\sqrt[5]{286}$.
226. " " " " $\sqrt[7]{1430}$.

Example: $x = (2.7)^{1.41}$

$\log x = 1.41 \times \log 2.7$
$= 1.41 \times 0.431$ (Log 2.7 found on slide rule as in first example).
$= 0.608$ (Multiply, using scales *C* and *D*).
$x = 4.05$

Example: $x = (41.5)^{0.23}$

$\log x = 0.23 \times \log 41.5$
$= 0.23 \times 1.618$ (Find mantissa of log 41.5 = .618. Then prefix characteristic of 1, making 1.618).
$= 0.372$ (Multiply, using scales *C* and *D*).
$x = 2.36$

Example: $x = \sqrt[4.2]{51.3}$.

$\log x = \dfrac{\log 51.3}{4.2}$
$= \dfrac{1.710}{4.2}$ (Finding log 51.3 = 1.710).
$= .0407$ (Divide; using scales *C* and *D*).
$x = 2.56$

To Change Radians to Degrees or Degrees to Radians

$$\frac{\pi}{180} = \frac{\text{Radians}}{\text{Degrees}}.$$

A	Opposite π	Opposite Radians	or	Read Radians
B	Set 180	Read Degrees		Opposite Degrees

CHAPTER V

SOLUTION OF TRIANGLES

By the Slide Rule a right triangle or an oblique triangle may be solved in a few seconds. On the 10″ Slide Rule a side of a triangle may be read to three significant figures, and most angles to within a few minutes. For many kinds of applied work this degree of accuracy is sufficient.

Where greater accuracy is required, as in surveying calculations, the work should be done by logarithms, and then checked by the slide rule. This check will show any gross error and will locate the error. For classes in Trigonometry it is recommended that the student proceed as follows:

a. Solve the triangle by logarithms.
b. Check by solving on the Slide Rule.
c. If the Slide Rule shows that there is an error, find the error and correct it.
d. If no error appears and it is desired to check to a greater degree of accuracy, apply the usual trigonometric check.

The use of the Slide Rule saves time and locates the error in a particular part of the work.

RIGHT TRIANGLES

Example: Given an Acute Angle and the Hypotenuse.
Let $A = 32° 30'$ and $c = 14.7$.
Find, *B*, *a*, and *b*.
Solution: $B = 90° — A = 57° 30'$.

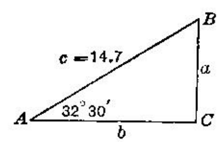


Fig. 33.

$$\frac{c}{\sin C} = \frac{a}{\sin A} = \frac{b}{\sin B}$$

Substituting the given values,

$$\frac{14.7}{\sin 90°} = \frac{a}{\sin 32° 30'} = \frac{b}{\sin 57° 30'}.$$

Setting the rule as in proportion, using right half of scale *A*,

A	Opposite 14.7	Read a = 788	Read b = 124
S	Set 1 (sin 90°)	Opposite 32° 30′	Opposite 57° 30′

To place the decimal point, note that the sides will be in the same order of magnitude as their opposite angles.

C = 90°	c = 14.7.
C = 50° 30′	c = 12.4.
A = 32° 30′	a = 7.88.

Where the S scale is involved, care should be taken to set the number on the proper half of scale A. The following diagram will make this clear. The numbers on the scale are continuous.

	Left End	Middle	Right End
Scale A	.01	.1	1.
	1.	10.	100.
	100.	1000.	10000.

Example: Given an Acute Angle and the Opposite Side.
Let A = 55° 15′ and a = 465.
Find B, b, and C.
Solution: B = 90°—A = 90°—55° 15′ = 34° 45′.

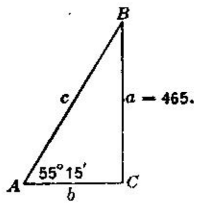


Fig. 34.

$$\frac{a}{\sin A} = \frac{c}{\sin C} = \frac{b}{\sin B}$$

Using left half of scale A,

A	Opposite 465	Find c = 566	Find b = 323
S	Set 55° 15′	Opposite 1 (sin 90°)	Opposite 34° 45′

Placing the decimal point,

C = 90°	c = 566.
A = 55° 15′	a = 465.
B = 34° 45′	b = 323.

Example: Given an Acute Angle and the Adjacent Side.
Let A = 15°, b = 12.5.
Find B, a, and c.
Solution: B = 90°—A = 75°.

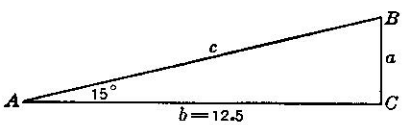


Fig. 35.

$$\frac{b}{\sin B} = \frac{a}{\sin A} = \frac{c}{\sin C}.$$

$$\frac{12.5}{\sin 75°} = \frac{a}{\sin 15°} = \frac{c}{1\ (\sin 90°)}.$$

Using the right half of scale A,

A	Opposite 12.5	Find a = 3.35	Find c = 12.9
S	Set 75°	Opposite 15°	Opposite 90°

Placing the decimal point by arranging the angles and sides in order,

C = 90°	c = 12.9.
B = 75°	b = 12.5.
A = 15°	a = 3.35.

Example: Given the Hypotenuse and a Side.
Let a = 1.64, c = 2.55
Find A, B and b.

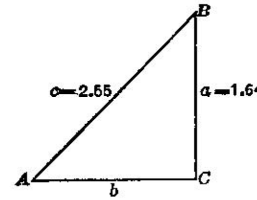


Fig. 36.

$$\text{Solution: } \frac{c}{\sin C} = \frac{a}{\sin A} = \frac{b}{\sin B}.$$

$$\frac{2.55}{1\ (\sin 90°)} = \frac{1.64}{\sin A} = \frac{b}{\sin B}.$$

A	Opposite 2.55	Opposite 1.64	Find b = 195
B	Set 1 (sin 90°)	Find A = 40°	Opposite B (90°-A)

B may be found after A is known.
B = 90°—40° = 50°.
To place the decimal point in b:
Since B is a little larger than A, b will be a little larger than a.
Hence b = 1.95.

Example: Given the Two Sides.

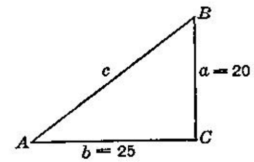


Fig. 37.

Case 1. Where tan A or $\frac{a}{b}$ is less than 1.
Let a = 20 and b = 25.
Find A, B and c.

$$\text{Solution: } \frac{a}{b} = \frac{\tan A}{1\ (\tan 45°)} \text{ or } \frac{b}{1} = \frac{a}{\tan A}.$$

T	Set 1 (tan 45°)	Find A = 38° 40′
D	Opposite 25	Opposite 20

Or tan A = $\frac{20}{25}$

C	Set 20	
D	Opposite 25	
T		Read 38° 4′
		Opposite line on underside of scale

To find c, use the formula, $\frac{a}{\sin A} = \frac{c}{\sin C}$.

Case II. When tan A or $\frac{a}{b}$ is greater than 1.
Let a = 30, b = 25.
Find A, B and c.

Solution: Find B first in order to avoid finding the tangent of an angle greater than 45° since the T scale reads only to 45°.

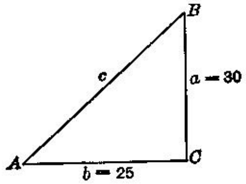


Fig. 38.

$$\frac{a}{1} = \frac{b}{\tan B} \qquad \frac{1}{a} = \frac{\tan B}{b}$$

T	Set 1 (tan 45°)	Find B = 39° 50′
D	Opposite 30	Opposite 25

Or $\tan B = \frac{25}{30}$

C	Set 25	
D	Opposite 30	
T		Read 39° 50′
		Opposite line on under-side of scale

A = 90°—39° 50′ = 50° 10′.

Find c by the formula $\frac{b}{\sin B} = \frac{c}{\sin C}$.

See optional solution on page 61.

OBLIQUE TRIANGLES

Example: Given Two Angles and a Side.
Let a = 22.5 A = 44° 33′ B = 24° 15′
Find C, b and c.

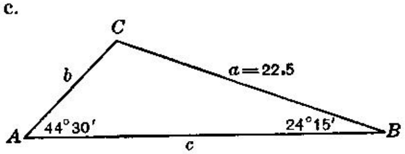


Fig. 39.

Solution: C = 180°—(44° 30′ + 24° 15′)
= 180°—68° 45′
= 111° 15′

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C \text{ or } \sin (A+B)}$$

$$\frac{22.5}{\sin 44° 30'} = \frac{b}{\sin 24° 15'} = \frac{c}{\sin 111° 15' (\sin 68° 45')}.$$

Using the right half of rule:

A	Opposite 22.5	Find b = 132	Find c = 299
S	Set 44° 30′	Opposite 24° 15′	Opposite 68° 45′

To place the decimal point, the sides will follow the same order of magnitude as their opposite angles.

C = 111° 15′	c = 29.9.
A = 44° 30′	a = 22.5.
B = 24° 15′	b = 13.2.

Example: Given Two Sides and the Angle Opposite One of these Sides. This example has two possible solutions, both of which are given below.
Let a = 175., b = 215., A = 35° 30′
Find B, C, and C, B′ and c′

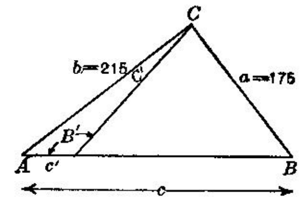


Fig. 40.

Solution: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$. Note: Sine C = Sine (A + B).

Using left half of rule.

A	Opposite 175	Opposite 215	Find c = 298
S	Set 35° 30′	Find B = 45° 30′	Opposite (A + B) or 81°

B′ = 180°—45° 30′ (B).
= 134° 30′.
A+B′ = 35° 30′+134° 30′.
= 170°.
C′ = 180°—170°.
= 10°.

Indicator to right index	Find c′ = 52.2
Left index to indicator	Opposite C′ = 10°

To place the decimal point, arrange angles and sides in order of magnitude.

In triangle ABC,

C = 99°	c = 298.
B = 45° 30′	b = 215.
A = 35° 30′	a = 175.

In triangle AB′C,

B′ = 134° 30′	b = 215.
A = 35° 30′	a = 175.
C′ = 10° 0′	c′ = 52.2.

Example: Given Two Sides and the Included Angle. The fact that the tangent scale runs only to 45° makes two cases.

Case I. When $\frac{C}{2}$ is greater than 45° whence ½ $(A + B)$ is less than 45°.

Example: $a = 5.14$, $b = 2.12$, $C = 112° 30'$.
Find A, B and c.

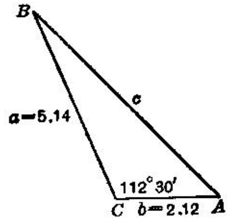


Fig. 41.

Solution:

$a = 5.14.$
$b = 2.12.$
$a+b = 7.26.$
$a-b = 3.02.$

$A+B = 67^\circ 30'.$
$\tfrac{1}{2}(A+B) = 33^\circ.45'.$
$\tfrac{1}{2}(A-B) = 15^\circ 32'.$
$A = 49^\circ 17'.$
$B = 18^\circ 13'.$

Use the formula,

$$\frac{\tan \frac{1}{2}(A+B)}{a+b} = \frac{\tan \frac{1}{2}(A-B)}{a-b}.$$

T	Set $\frac{1}{2}(A+B)$	Find $\frac{1}{2}(A-B)$
D	Opposite $(a+b)$	Opposite $(a-b)$

T	Set 33° 45′	Find $\frac{1}{2}(A-B)$ = 15° 32.
D	Opposite 7.26	Opposite 3.02

c is found by the usual sine formula:

$$\frac{a}{\sin A} = \frac{c}{\sin C}$$

$$\frac{5.14}{\sin 49^\circ 17'} = \frac{c}{\sin 112^\circ 30' \text{ or } \sin 67^\circ 30'}.$$

A	Opposite 5.14 (Left half of scale A)	Find c = 6.27
S	Set 49° 17′	Opposite 67° 30′

Check: $\dfrac{c}{\sin C} = \dfrac{b}{\sin B}.$

A	Opposite 6.27 (Left half of scale A)	Find 2.12
S	Set 67° 30′	Opposite 18° 13′

NOTE.—In the mathematics classroom this check formula may be used after the student has solved the triangle by logarithms.

Example: $a = 154$, $b = 73.5$, $C = 120^\circ 30'$.

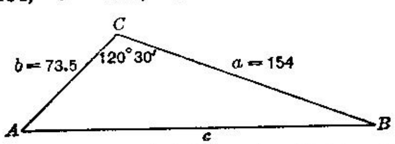


Fig. 42.

Solution:

$$\frac{\tan \frac{1}{2}(A+B)}{a+b} = \frac{\tan \frac{1}{2}(A-B)}{a-b}.$$

$$\frac{\tan 29^\circ 45'}{227.5} = \frac{\tan \frac{1}{2}(A-B)}{80.5}.$$

T	Set 29° 45′	Indicator to right index	Find $\frac{1}{2}(A-B)$ = 11° 26′
D	Opposite 227.5	Left index to indicator	Opposite 80.5

$\tfrac{1}{2}(A+B) = 29^\circ 45'.$
$\tfrac{1}{2}(A-B) = 11^\circ 26'.$
$A = 41^\circ 11'.$
$B = 18^\circ 19'.$

By the method of the preceding example, c is found to be 202.

Case II. When $\dfrac{C}{2}$ is less than 45°, whence $\frac{1}{2}(A+B)$ is greater than 45°.

Example: $a = 75.5$, $b = 42.5$, $C = 65^\circ 30'$.
$a+b = 118.$ $a-b = 33.$
$\tfrac{1}{2}(A+B) = 57^\circ 15'.$

$$\frac{\tan \frac{1}{2}(A+B)}{a+b} = \frac{\tan \frac{1}{2}(A-B)}{a-b}$$

$$\frac{\tan 57^\circ 15'}{118} = \frac{\tan \frac{1}{2}(A-B)}{33}$$

Since tan 57° 15′ is not on the rule, we substitute for it

$$\frac{1}{\tan(90^\circ - 57^\circ 15')} = \frac{1}{\tan 32^\circ 45'}$$

The formula now reads:

$$\frac{1}{118 \times \tan 32^\circ 45'} = \frac{\tan \frac{1}{2}(A-B)}{33}.$$

T	Set 1 (Left index)	Indicator to 32° 45′	Find $\frac{1}{2}(A-B)$ = 23° 30′
D	Opposite 118	Right index to indicator	Opposite 33

$\tfrac{1}{2}(A+B) = 57^\circ 15'.$
$\tfrac{1}{2}(A-B) = 23^\circ 30'.$
$A = 80^\circ 45'.$
$B = 33^\circ 45'.$

Find c by the usual method.
Check by the sine formula.

Example: $b = 83.4$, $a = 78$, $C = 72^\circ 15'$.
$b+a = 161.4$ $b-a = 5.4$
$\tfrac{1}{2}(B+A) = 53^\circ 53'.$

T	Set 1 (Right index)	Indicator to 36° 7′	Find 24° 38′
D	Opposite 161	Left index to indicator	Opposite 5.4

$\tfrac{1}{2}(B-A) = 24^\circ 38'.$
$B = 78^\circ 31'.$
$A = 29^\circ 15'.$

Testing these results by the formula:

$$\frac{a}{\sin A} = \frac{b}{\sin B},$$

it will be found that the angles are incorrect. This results from the fact that the slide rule gives the significant figures of the tangent, but does not fix the decimal point. In this example, there are three values for $\frac{1}{2}(B-A)$ between 2° and 88°, corresponding to the natural tangent whose significant figures are 459.

1. $\tan^{-1} .0459 = 2^\circ 38'.$
2. $\tan^{-1} .459 = 24^\circ 38'.$
3. $\tan^{-1} 4.59 = 77^\circ 43'.$

Other values may be found less than 2° or between 88° and 90°, but these will seldom be required.

Hence, in the solution of any problem in this case, it is necessary to test the results by the check formula.

An inspection of the example shows that b is slightly larger than a. Hence B will be only slightly larger than A. This would be possible if $\frac{1}{2}(B-A)$ were smaller than 24° 38′, which we obtained on the rule.

Find tan 24° 38′, which is .459.

Find $\tan^{-1} .0459$.

In order to secure this small angle, we use the sine scale, since the sine of an angle less than 5° 43′ is practically equal to the tangent.

Opposite .0459 on the left half of scale A, find 2° 37′ on S.

$\frac{1}{2}(B+A) = 53° 53'$.

$\frac{1}{2}(B-A) = 2° 37'$ Using the check formula, $\frac{a}{\sin A} = \frac{b}{\sin B}$

$B = 56° 30'$.

$A = 51° 15'$. these results will be found to be correct.

Suppose it is desired to obtain the next larger angle than 24° 38′.

$\tan 24° 38' = .459$.

The next larger angle with the same significant figures for the tangent would be: $\tan x = 4.59$.

Since this angle is evidently greater than 45°, we may write:

$$\tan(90° - x) = \frac{1}{\tan x} = \frac{1}{4.59}.$$

Solving by the slide rule

T	Set 1 (tan 45°)	Find 12° 17′
D	Opposite 4.59	Opposite 1

$90° - x = 12° 17'$.

$x = 77° 43'$.

Example: $a = 10$, $b = 90$, $C = 65°$.

$b + a = 100$. $b - a = 80$.

$\frac{1}{2}(B+A) = 57° 30'$.

$\frac{1}{2}(B-A) = 7° 10'$. by the first trial on the rule

$B = 64° 40'$.

$A = 50° 20'$.

These results do not check.

Since b is nine times a, B must be considerably larger than A.

Using the method above,

$\tan 7° 10' = .126$.

$\tan x = 1.26$.

$$\tan(90° - x) = \frac{1}{1.26}.$$

T	Set 1 (Tan 45°)	Find 38° 32′.
D	Opposite 1.25	Opposite 1

$90° - x = 38° 32'$.

$x = 51° 28'$.

$\frac{1}{2}(B+A) = 57° 30'$.

$\frac{1}{2}(B-A) = 51° 28'$.

$B = 108° 58'$.

$A = 6° 2'$.

These results check by the formula $\frac{a}{\sin A} = \frac{b}{\sin B}$

ANOTHER METHOD—

Example: $b = 83.4$, $a = 78$. $C = 72° 15'$.

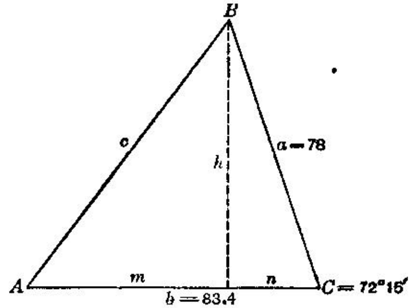


Fig. 43.

$h = a \sin C = 74.3$.
$n = a \cos C = a \sin(90° - C) = 23.8$.
$m = b - n = 59.6$.

$90° - A = \tan^{-1}\frac{m}{h} = 90° - 38° 44'$.

$A = 51° 16'$.

$B = 180° - (A + C) = 56° 31'$.

$C = \frac{h}{\text{Sin A}} = 95.3$.

Check, $\frac{a}{\text{Sin A}} = \frac{b}{\text{Sin B}} = \frac{c}{\text{Sin C}}$.

Example: Given three sides: –

Method I. Let $a = 32.0$. $b = 26.5$. $c = 14.7$.

Find A, B, and C. $s = \frac{1}{2}(a + b + c)$.

$a = 32.0$.
$b = 26.5$.
$c = 14.7$.
$2s = 73.2$.
$s = 36.6$.
$s - a = 4.6$.
$s - b = 10.1$.
$s - c = 21.9$.

$$\sin \tfrac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{bc}}.$$

$$= \sqrt{\frac{10.1 \times 21.9}{26.5 \times 14.7}}$$

$= 0.754$. By the slide rule.

Hence $\frac{1}{2} A = 49°$ (Using scales A and S.)

$A = 98°$

Find B and C by the formula:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}.$$

$$\frac{32}{\sin 98^\circ\ (=\sin 82^\circ)} = \frac{26.5}{\sin B} = \frac{14.7}{\sin C}$$

A / S	Opposite 32 / Set 82°	Opposite 26.5 / Find B = 55°	Opposite 14.7 / Find C = 27°

Method II. $\cos C = \frac{a^2 + b^2 - c^2}{2\,ab}$.

or $\sin (90^\circ - C) = \frac{1024. + 702. - 216.}{1696.} = \frac{1510}{1696}$

$\sin (90^\circ - C) = .890.$

$90^\circ - C = 63^\circ$ (to the nearest degree).

$C = 27^\circ.$

Find B from the formula $\frac{c}{\sin C} = \frac{b}{\sin B}$.

and A from the formula $\frac{c}{\sin C} = \frac{a}{\sin A}$.

Check: $A + B + C = 180^\circ$.

Example: Given the three sides:—

$a = 20, \quad b = 18, \quad c = 15.$

Find the angles A, B and C.

An easy indirect solution suited to the slide rule is as follows:

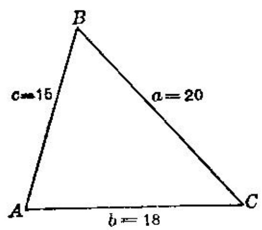


Fig. 44.

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}.$$

$A + B + C = 180^\circ$.

By inspection a is the longest side, hence angle A is the greatest angle and is greater than 60°.

Try A = 65°	Try A = 75°	Try A = 74°
B = 55° Roughly	B = 61°	B = 60°
C = 43°	C = 46°	C = 46°
163°	182°	180°
Too small	Slightly too large	

To 20 on scale A set trial value of A on scale S; opposite sides b and c on A read corresponding angles on S. Only a few trials are necessary.

CHAPTER VI.

TYPICAL EXAMPLES RELATING TO VARIOUS OCCUPATIONS.

SECRETARIAL WORK

A secretary in checking a traveling man's expense account for one week found the following items:

Railroad fares	\$27.50
Hotel bills	56.00
Total	83.50

Find what per cent of the total expense was used in hotel bills.

Solution: $56 \div 83.50 = 67.1$ per cent.

Opposite 56 on D set 835 on C.

Opposite the right index of C, find 67.1 on D.

EXCAVATING

What will be the cost of excavating rock for a cellar measuring 43 ft. × 28 ft. to an average depth of 6.5 ft. at \$2.50 per cubic yard?

$$x = \frac{43 \times 28 \times 6.5 \times 2.5}{27}.$$

1. To 43 on D set 27 on C.
2. Indicator to 28 on C.
3. 65 on CI to indicator.
4. Opposite 25 on C read 725 on D.

Roughly calculating for the decimal point:

$x = 800.$

Hence, the result is \$725; which is correct to the nearest dollar.

PER CENT OF PROFIT

A merchant purchased a bill of goods for \$318 and sold the same for \$360. Find the per cent of profit reckoned.

a. On the cost.

b. On the selling price.

Solution: Profit = \$360 — \$318 = \$42.

Per cent of profit reckoned on the cost $= \frac{42}{318} = 13.2$ per cent.

Per cent of profit reckoned on the selling price $= \frac{42}{360} = 11.7$ per cent.

DISCOUNT

Goods marked \$7.25 are sold at a discount of 35½ per cent. Find the net price.

Solution: The net price is 100 per cent — 35½ per cent or 64½ per cent.

$.645 \times 7.25 = 4.68.$

COMPOUND INTEREST

How many years will it take a sum of money to double itself if deposited in a savings bank paying 4 per cent interest, compounded semi-annually.

Using the formula $A = P(1 + r)^n$, where A is the amount, P the principal, r the interest on \$1. for 6 months, and n the number of half years, if we take \$1. as P, we have:

$$2 = (1 + .02)^n.$$

$$\text{and } n = \frac{\log 2}{\log 1.02}.$$

$$= \frac{.301}{.0086}.$$ See page 45.

$$= 35 \text{ half years.}$$ See page 11.

or $17\frac{1}{2}$ years.

PHYSICS

In a photometer a 16 c. p. lamp is used as a standard. The following distance readings are obtained in testing a nitrogen filled lamp.

D_s	D_x	
317 mm.	683 mm.	By experiment 1
304 mm.	696 mm.	" " 2
322 mm.	678 mm.	" " 3
248 mm.	570 mm.	" " 4

Using the following equation calculate the observed candle power of the unknown lamp.

$$\frac{D_s^2}{D_x^2} = \frac{\text{c. p. of standard}}{\text{c. p. of unknown}}$$

$$\frac{(317)^2}{(683)^2} = \frac{16}{x}.$$

To 683 on scale D set 317 on C.
Above 16 on B find x on A.

$$x = 74.4.$$

The operation of transferring from scales C and D to A and B squares the fraction $\frac{317}{683}$.

The first experiment	gives	$x = 74.4$
The second	" "	$x = 83.9$
The third	" "	$x = 70.9$
The fourth	" "	$x = 84.5$
		4)313.7
The result............		= 78.4

CHEMISTRY

By weight 80 parts of sodium hydroxide combine with 98 parts of sulphuric acid. How many grams of sodium hydroxide will neutralize 50 grams of

sulphuric acid?

Solution: $98 : 50 = 80 : x$.
To 50 on D set 98 on C.
Under 80 on C find 40.8 on D.

SPEEDS OF PULLEYS

The diameter of the driving pulley is 9 inches and its speed is 1,300 R. P. M If the diameter of the driven pulley is 7 inches, what is its speed?

Solution: The diameter of the driving pulley, multiplied by its speed, is equal to the diameter of the driven pulley, multiplied by its speed.

$$7 \times S = 9 \times 1300.$$

$$S = \frac{9 \times 1300}{7}.$$ See page 13.

$S = 1670$ correct to three significant figures.

CUTTING SPEED

A certain grindstone will stand a surface or rim speed of 800 ft. per min. At how many R. P. M. can it run if its diameter is 57 in.?

Solution: The cutting speed is equal to the circumference of the stone in feet multiplied by the number of revolutions per minute

$$\text{or } C = \frac{\pi d \times \text{R. P. M.}}{12} \text{ where d is expressed in inches.}$$

$$\text{Hence R. P. M.} = \frac{12\,C}{\pi d}.$$

$$= \frac{12 \times 800}{3.1416 \times 57}.$$

$$= 53.$$ See page 34.

GEARING

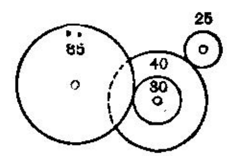


Fig. 45.

The gear with 85 teeth (Fig. 45) revolves 50 times per minute. Find the speed of the gear with 25 teeth.

Solution: The continued product of the R. P. M. of the first driver and the number of teeth in every driving gear is equal to the continued product of the R. P. M. of last driven gear and the number of teeth in every driven gear.

$$\text{Hence, } 50 \times 85 \times 40 = 30 \times 25 \times S.$$

$$S = \frac{50 \times 85 \times 40}{30 \times 25}.$$ See page 33.

$$S = 227.$$

LENGTH OF PATTERN

If window weights are $1\frac{1}{2}$ inches in diameter, how long must we make the pattern for 8 lb. weights (1 cu. in. of cast iron weighs .26 lb.)?

Solution: The number of pounds in the window weight is equal to the volume of the cylindrical weight $\times$ .26 lb.

$$8 = \frac{\pi \times (1.5)^2 \times L \times .26}{4}.$$

and $L = \frac{4 \times 8}{\pi \times (1.5)^2 \times .26}$. See page 34.

= 17.4 inches, or 17 and 7/16 inches to the nearest 16th.

COMPOSITION METAL MIXING

If bell metal is made of 25 parts of copper to 11 parts of tin in weight, find the weight of each metal in a bell weighing 1054 lbs.

Solution: The copper weighs $\frac{25}{36}$ of 1054 = 732 lbs. See page 13.

The tin weighs $\frac{11}{36}$ of 1054 = 322 lbs.

SURVEYING

The slide rule is used in surveying to check gross errors in computation, to reduce stadia readings, and to solve triangles.

See Chapter V for the solution of triangles by the slide rule.

Example: Find the latitude and departure of a course whose length is 525 ft. and bearing N 65° 30′ E.

Latitude = length of course × cosine of bearing.
= 525 × cos 65° 30′.
= 525 × sin 24° 30′.
= 218.

To the mark in the groove at the right of the rule set 24° 30′ on scale *S*.

Opposite 525 on *A*, find 218 on *B*.

The decimal point may be placed by inspection, since the sine and cosine are always less than one.

Departure = length of course × sine of bearing.
= 525 × sin 65° 30′.
= 478.

NOTE.—Keuffel and Esser Co. make a special rule for surveyors, known as the SURVEYORS' DUPLEX Slide Rule, which, has not only *A*, *B*, *CI*, *C* and *D* scales on one face, but two full length stadia scales for computing horizontal distances and vertical heights.The other face is arranged for the determination of the meridian by direct solar observations, and carries the sine and cosine scales used in calculating latitudes and departures of the course. Hence, this rule reduces many complicated surveying calculations to mere mechanical operations.

For those who desire to calculate stadia reductions, and latitudes and departures, with a considerable degree of accuracy, the above mentioned company makes a complete STADIA Slide Rule.

Rectangular Co-Ordinates

$$c = \sqrt{a^2 + b^2} = a\sqrt{1 + \frac{b^2}{a^2}}$$

B	Set 1	Read $\left(\frac{b}{a}\right)^2$	At $1 + \left(\frac{b}{a}\right)^2$
D	To a	At b	Read c

or

A	To 1	Read $\left(\frac{b}{a}\right)^2$	At $1 + \left(\frac{b}{a}\right)^2$
C	Set a	At b	Read c

Example:

Find the diagonal of a rectangle with sides 6½ and 11½ feet in length.

Diagonal $= \sqrt{(6\frac{1}{2})^2 + (11\frac{1}{2})^2} = 6\frac{1}{2}\sqrt{1 + \left(\frac{11\frac{1}{2}}{6\frac{1}{2}}\right)^2}$

To 6½ on *D* set 1 on *B*.
At 11½ on *D* read 3.13 on *B*.
Adding 1 = 4.13.
Indicator to 4.13 on *B*.
At indicator read 13.21 on *D*. Answer.

This solution required only one setting of the slide. Compare this with the solution required if the equation has remained in its original form. This would have required 3 settings and an addition on paper.

CHAPTER VII

METHODS OF WORKING OUT MECHANICAL AND OTHER FORMULAS

Diameters and Areas of Circles $A = .7854\ D^2$.

The *B* scale has .7854 $\left(\frac{\pi}{4}\right)$ marked by a long line on the right half.

A	R. Index	
B	Set .7854	Find Areas.
C		
D		Above Diameters

or

A	To 11	
B	Set 6	Find Areas in square feet
C		
D		Above Diameter in inches

To Calculate Selling Prices of Goods, with percentage of profit on Cost Price

C	Set 100	Below cost price
D	To 100 plus percentage of profit	Find selling price

To Calculate Selling Prices, of Goods, with percentage of profit on Selling Price

C	Set 100 less percentage of profit	Below cost price
D	To 100	Find selling price

Example: If goods cost 45 cents a yard, at what price must they be sold to realize 15 per cent profit on the selling price?

C	Set 85 (= 100—15)	Below 45
D	To 100	Find 53. Ans.

To find the Area of a Ring. $A = \frac{(D + d) + (D - d)}{1.2732}$

D	To sum of the two diameters	Find area
C	Set 1.273	Under difference of the two diameters

Compound Interest [Log A = Log P + n Log (1 + r)]

Set one plus the rate of interest, on C to the right index of D, then take the corresponding number on the scale of Equal Parts, and multiply it by the number of years. Set this product on L scale to the index on the under side of the Rule, then on C will be found the amount of any coinciding sum on D for the given years at the given rate.

Example: Find the amount of $150. at 5 per cent compounded annually at the end of 10 years.

C	Set 105	E. P. = .021 × 10 = .21	.21 to 1	*C*	Find $244.35—Ans.
D	To R. I.	Under side of Rule and	Slide	*D*	Over 150

Note that it is necessary to shift C from the left to the right index before the C scale can be read opposite 150 on D.

We thus obtain on C, above 1 on D, a gauge-point for 10 years at 5 per cent and can obtain in like manner similar ones for any other number of years and rate of interest.

Levers

C	Set distance from fulcrum to power or weight transmitted	Below power or weight applied
D	To distance from fulcrum to power or weight applied	Find power or weight transmitted

Diameter of Pulleys or Number of Teeth of Gears

(See page 54)

C	Set diameter or teeth of **driving**	Revolutions of **driven**
D	To diameter or teeth of **driven**	Revolutions of **driving**

Diameter of two Gears to work at given Velocities

C	Set distance between their centers	Find diameter
D	To half sum of their revolutions	Above revolutions of each

Strength of Teeth of Gears $P = \frac{\sqrt{H}}{0.6V}$

A	To H. P. to be transmitted	
CI		At velocity in ft. per sec.
C	Set gauge point 0.6	
D		Read pitch in inches

Diameter and Pitch of Gears $N = \frac{D \times \pi}{P}$

DF	To D	Find number of teeth
CF	Set P	Opposite π

Strength of Wrought Iron Shafting

$D = \sqrt[3]{\frac{83\ H}{N}}$ for crank shafts and prime movers

$D = \sqrt[3]{\frac{65\ H}{N}}$ for ordinary shafting

C	Set R. P. M.	Indicator to H. P.	
D	To 83 or 65	Read D^3	Read D
K			Opposite D^3

NOTE.—In this, as in other cases, the coefficients (83 and 65) may be altered to suit individual opinions, without in any way altering the methods of solution.

To find the Change Wheel in a Screw-Cutting Lathe

$$N = T\frac{S \times W}{M \times P} \qquad W = N\frac{M \times P}{T \times S}$$

where

- N = Number of threads per inch to be cut.
- T = " " " " " on traverse screw.
- M = " " teeth in wheel on mandril.
- W = " " " " stud wheel (gearing in M).
- P = " " " " stud pinion (gearing in S).
- S = " " " " wheel on traverse screw.

C	Set T	Ind. to P	S to Ind	Under M
D	To N			Find No. of teeth in W or stud wheel

Rules for Good Leather Belting

$$W = \frac{600 \text{ or } 375 \text{ H. P.}}{\text{V ft. per min.}}$$

D	To 600	Find width in inches	for **Single Belts**
C	Set velocity in feet per min.	Opposite actual H. P.	
D	To 375	Find width in inches	for **Double Belts**
C	Set velocity in feet per min.	Opposite actual H. P.	

Best Manila Rope Driving

A	To velocity in feet per min.	Find **Actual Horse Power**
B	Set 307	
C		Above diameter in inches
D		

A	To 4	Find **Strength in Tons**
B		
C	Set 1	Above diameter in inches
D		

A	To 107	Find **Working Tension in Pounds**
B		
C	Set 1	Above diameter in inches
D		

A	To 0.28	Find **Weight per Foot in Pounds**
B		
C	Set 1	Above diameter in inches
D		

Weight of Iron Bars in Pounds per Foot Length

A	To 1	Weight of **Square Bars**
B	Set 3	
C		Above width of side in inches

A	To 55	Weight of **Round Bars**
B	Set 21	
C		Above diameter in inches

C	Set 0.3	Below thickness in inches
D	Breadth in inches	Weight of **Flat Bars**

Weight of Iron Plates in Pounds per Square Foot

C	Set 32	Below thickness in thirty-seconds of an inch
D	To 40	Find weight in pounds per square foot

Weights of other Metals

C	Set 1	Below G. P. for other metals
D	To weight in iron	Find weight in other metals

Gauge-points of other metals, and weight per cubic foot.

	W. I.	C. I.	Cast Steel.	Steel Plates.	Copper.	Brass.	Lead.	Cast Zinc.
G. P.......	1	.93	1.02	1.04	1.15	1.09	1.47	.92
Weight....	480	450	490	500	550	525	710	440 lbs.

Example: What is the weight of a bar of copper, 1 foot long, 4 inches broad and 2 inches thick?

C	Set 0.3	Indicator to 2 inches thick	1 to indicator	Below G. P. 1.15
D	To 4 inches broad			Find 30.7 pounds–Ans.

Weight of Cast Iron Pipes

C	Set .4075	Below **Difference** of inside and outside diameters in inches
D	To **Sum** of inside and outside diameters in inches	Find weight in pounds per lineal foot

	Brass.	Copper.	Lead.	W. Iron
G. P. for other metals........	.355	.333	.259	.38

Safe Load on Chains

A		Safe load in tons
B	Set 36 for open link or 28 for stud-link	Above 1
C		
D	To diameter in sixteenths of an inch	

Gravity

C	Set 1	Below 32.2
D	To seconds	Velocity in feet per second

A	Space fallen through in feet	
B		
C	Set 1	Under 8
D		Velocity in feet per second

A		Space fallen through in ft.
B		Above 16.1
C	Set 1	
D	To seconds	

Oscillations of Pendulums

A		
B	Set length pendulum in in.	
C		Below 1
D	To 375	Number oscillations per minute

Comparison of Thermometers

C	Set 5	Degrees Centigrade
D	To 9	Degrees Fahrenheit — 32
C	Set 4	Degrees Reaumur
D	To 9	Degrees Fahrenheit — 32

C	Set 4	Degrees Reaumur
D	To 5	Degrees Centigrade

Force of Wind

P = .0021 V² (ft. per sec.)

A	To 21	Find pressure in pounds per square foot
B	R. Index	
C		Velocity in Feet *per second*

P = .0045 V² (m. per hr.)

A	To 45	Find pressure in pounds per square foot
B	R, Index	
C		Velocity in **Miles** *per hour*

Discharge from Pumps

A		Gallons delivered per stroke
B	Set 294	Stroke in inches
D	To diameter in inches	

Diameter of Single-acting Pumps

A	Set 294			
B	Set length of stroke in inches	Indic. to gallons to be delivered per min.	No. strokes per min. to indic.	
C				Below 1
D				Diam. pump in inches

Horse Power required for Pumps

C	Set G. P.	Height in feet to which the water is to be raised
D	To cubic feet or gallons to be raised per minute	Horse power required

Gauge Points with different percentages of allowance.

Per Cent	None	10	20	30	40	50	60	70	80
For Gallons Imp.	3300	3000	2750	2540	2360	2200	2060	1940	1835
" C. Feet	528	430	440	406	377	352	330	311	294
" U.S. Gallons	3960	3600	3300	3050	2830	2640	2470	2330	2200

Theoretical Velocity of Water for any Head

A	Head in feet	
C	Set 1	Under 8
D		Velocity in feet per second

Theoretical Discharge from an Orifice 1 inch Square

B	Set 1	Under head in feet	If the hole is round and one inch dia. the G. P. is 2.62
C			
D	To G. P. 3.34	Discharge in cubic feet per minute	

Real Discharge from Orifice in a Tank 1 inch Square

B	Set 1	Under head in feet	If the hole is round and 1 inch diam., the G. P. is 1.65
D	To 2.1 G. P.	Discharge in cubic feet per minute with coefficient .63	

Gauge Points for other coefficients.

Coefficient......	.60	.66	.69	.72	.75	.78	.81	.84	.87	.90	.93	.96
G. P. Square....	2.	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.	3.1	3.2
" Round....	1.57	1.73	1.80	1.88	1.96	2.04	2.12	2.20	2.28	2.36	2.44	2.52

Discharge from Pipes when real velocity is known

A	Velocity in ft./sec.	Discharge in cu. ft./min.
CI	Diameter in inches	Above 1.75

Delivery of Water from Pipes

$$W = 4.71 \sqrt{\frac{D^5 H}{L}}$$

Eytelwein's Rule

A			To D^5		
B			Set L in ft.	Indicator to head in feet	
L	Read log D	Opp. 5×log D			
C				Index to indic.	Opposite 4.71
D	Opp. D in in.	Read D^5			Read cu. ft. per min.

When setting 5×log D on L do not include characteristic

Gauging Water with a Weir

A	To depth in inches	At 4.3
CI	Set depth in inches	Read discharge in cubic feet per minute from each foot width of sill

Discharge of a Turbine

$$\frac{\sqrt{H} \times V}{0.3} = D$$

A	To head in feet	
C	Set 0.3	Under square inches of water vented
D		Cubic feet discharged per minute

Revolutions of a Turbine

A	To head in feet			
C	Set diameter in inches	Indicator to 1840	1 to Indicator	Under rate of peripheral velocity
D				Find revolutions per min.

Horse Power of a Turbine

C	Set 530	Indicator to discharge per c. ft. per min.	1 to Indicator	Percentage useful effect
D	Head in ft.			Horse power

or

A	Under head in ft.					
C	Set 1	Indicator to head in ft.	158 to Indicator	Indicator to vent in sq. in.	1 to Indicator	Under useful effect
D						Horse power

Horse Power of a Steam Engine

CI	Set dia. in inches				Mean pressure p. sq. in. to indic.	
C		Indicator to stroke in feet	21,000 to indic.	Indic. to R.P.M.		At index
D	To dia. in inches					Read H.P.

or

A						H. P.
B	Set 21,000	Indicator to Stroke in ft.	1 to Indicator	Indicator to revolutions	1 to Indicator	Mean pressure
D	To diam. in inches					

Dynamometer; to Estimate the indicated H. P.

$$H = \frac{P\,L\,N}{5262}$$

H = actual horse power.
P = pressure or weight applied at end of lever in pounds, including weight of scale.
L = length of lever in feet from center of shaft.
N = revolutions of shaft per minute.

C	Set 5252	Indic. to L	1 to indic.	At N
D	To P			Read H

Geometric Mean

To find the Geometric Mean, or Mean Proportional between two numbers, or $m : x :: x : n$

Set index of B to m on A.
Under n on B read x on D.

NOTE.—In operations involving square root, care should be taken to move the decimal point an even number of places and to use the proper right or left half of A or B.

Fractions and Decimals

To reduce fractions to decimals:

C	Set numerator	Find equivalent decimal
D	To denominator	Above 1

To duce decimals to fractions:

C	Set decimal	Find equivalent numerators
D	To 1	Find equivalent denominators

Quadratic Equation

$$x^2 + ax + b = o$$
$$x_1 \times x_2 = \pm b$$
$$x_1 + x_2 = -a$$

CI	Set index	Opposite x_1
D	To b	Find x_2

Example: $x^2 + 7x - 17 = o$

Find two numbers opposite each other on D and CI whose sum is -7, as follows:

CI	Set index	Opposite − 8.91
D	To 17	Find 1.91

The sum of − 8.91 and 1.91 is − 7.

CHAPTER VIII

TABLE OF EQUIVALENTS OR GAUGE POINTS FOR SCALES C AND D

The following equivalents are in the form of proportions, which should be solved as such, thus

$$\text{Diameters of circles} = \frac{113}{355}\text{ Circumferences of circles}$$

$$\text{Circumferences of circles} = \frac{355}{113}\text{ Diameters of circles}$$

GEOMETRICAL

113 = Diameters of circles	355 = Circumferences of circles
79 = Diameter of circle	70 = Side of equal square
99 = Diameter of circle	70 = Side of inscribed square
39 = Circumference of circle	11 = Side of equal square
40 = Circumference of circle	9 = Side of inscribed square
70 = Side of square	99 = Diagonal of square
205 = Area of square whose side = 1	161 = Area of circle whose diameter = 1
322 = Area of circle	205 = Area of inscribed square

ARITHMETICAL

100 = Links	66 = Feet
12 = Links	95 = Inches
101 = Square links	44 = Square feet
6 = U. S. Gallons	5 = Imperial gallons
1 = U. S. gallons	231 = Cubic inches
800 = U. S. gallons	107 = Cubic feet
22 = Imperial gallons	6100 = Cubic inches
430 = Imperial gallons	69 = Cubic feet

METRIC SYSTEM

26 = Inches	66 = Centimeters
82 = Yards	75 = Meters
4300 = Links	865 = Meters
82 = Feet	25 = Meters
87 = Miles	140 = Kilometers
43 = Chain	865 = Meters

31 = Square inches	200 = Square Centimeters
140 = Square feet	13 = Square meters
61 = Square yards	51 = Square meters
42 = Acres	17 = Hectares
22 = Square miles	57 = Square kilometers
5 = Cubic inches	82 = Cubic centimeters
600 = Cubic feet	17 = Cubic meters
85 = Cubic yards	65 = Cubic meters
6 = Cubic feet	170 = Liters
14 = U. S. gallons	53 = Liters
46 = Imperial gallons	209 = Liters
108 = Grains	7 = Grams
75 = Pounds	34 = Kilograms
6 = Ounces	170 = Grams
63 = Hundredweights	3200 = Kilograms
63 = English ton	64 = Metric tons

PRESSURES

640 = Pounds per square inch	45 = Kilogs per square centimeter
51 = Pounds per square foot	249 = Kilogs per square meter
59 = Pounds per square yard	32 = Kilogs per square meter
57 = Inches of mercury	28 = Pounds per square inch
82 = Inches of mercury	5800 = Pounds per square foot
720 = Inches of water	26 = Pounds per square inch
74 = Inches of water	385 = Pounds per square foot
60 = Feet of water	26 = Pounds per square inch

5 = Feet of water	312 = Pounds per square foot
15 = Inches of mercury	17 = Feet of water
99 = Atmospheres	2960 = Inches of mercury
34 = Atmospheres	500 = Pounds per square inch
34 = Atmospheres	7200 = Pounds per square foot
30 = Atmospheres	31 = Kilogs per square centimeter
23 = Atmospheres	780 = Feet of water
3 = Atmospheres	31 = Meters of water
29 = Pounds per square inch	67 = Feet of water
1 = Kilogs per square centimeter	10 = Meters of water

COMBINATIONS

43 = Pounds per foot	64 = Kilogs per meter
127 = Pounds per yard	63 = Kilogs per meter
46 = Pounds per square yard	25 = Kilogs per square meter
49 = Pounds per cubic foot	785 = Kilogs per cubic meter
27 = Pounds per cubic yard	16 = Kilogs per cubic meter
89 = Cubic feet per minute	42 = Liters per second
700 = Imperial gallons per minute	53 = Liters per second
840 = U. S. gallons per minute	53 = Liters per second
38 = Weight of fresh water	39 = Weight of sea water
5 = Cubic feet of water	312 = Weight in pounds
1 = Imperial gallons of water	10 = Weight in pounds
3 = U. S. gallons of water	25 = Weight in pounds

50 = Pounds per U. S. gallon
6 = Kilogs per liter

10 = Pounds per Imperial gallon
1 = Kilogs per liter

30 = Pounds per U. S. gallon
25 = Pounds per Imperial gallon

3 = Cubic feet of water
85 = Weight in kilogs

46 = Imperial gallons of water
209 = Weight in kilogs

14 = U. S. gallons of water
53 = Weight in kilogs

44 = Feet per second
30 = Miles per hour

88 = Yards per minute
3 = Miles per hour

41 = Feet per second
750 = Meters per minute

82 = Feet per minute
25 = Meters per minute

340 = Footpounds
47 = Kilogrammeters

72 = British horse power
73 = French horse power

3700 = One cubic foot of water per minute under one foot of head
7 = British horse power

75 = One liter of water per second under one meter of head
1 = French horse power

In no case does the departure, in these equivalents, from the exact ratio attain one per thousand.

EXAMPLES

What is the pressure in pounds per square inch equivalent to a head of 34 feet of water?

C	Set 60	Under 34
D	To 26	Find 14.75 pounds—Answer

What head of water, in feet, is equivalent to a pressure of 18 pounds per square inch?

C	Set 26	Under 18
D	To 60	Find 41.5 feet—Answer

How many horse power will 50 cubic feet of water per minute give under a head of 400 feet?

C	Set 3700	Runner to 400	1 to R	Under 50
D	To 7			Find 37.8 H. P.—Answer

HIGHER POWERS AND ROOTS.

The fourth root of a number is obtained by finding the square root of the square root. The sixth root is obtained by finding the square root of the cube root. The eighth root is the square root of the fourth root.

Expressions Which May Be Read Directly By Means Of The Indicator, Without Setting The Slide.

1. x = a^2, set Indicator to a on D, read x on A.
2. x = a^3 set Indicator to a on D, read x on K.
3. x = $\sqrt{a}$ set Indicator to a on A, read x on D.
4. x = $\sqrt[3]{a}$ set Indicator to a on K, read x on D.
5. x = $\sqrt{a^3}$ set Indicator to a on A, read x on K.
6. x = $\sqrt{a^2}$, set Indicator to a on K, read x on A.
7. x = $\frac{1}{a}$, set Indicator to a on CI, read x on C.
8. x = $\frac{1}{a^2}$, set Indicator to a on CI, read x on B.
9. x = $\frac{1}{\sqrt{a}}$, set Indicator to a on B, read x on CI.

With Indices in Alignment.

10. x = $\frac{1}{a^3}$, set Indicator to a on CI, read x on K.
11. x = $\frac{1}{\sqrt[3]{a}}$, set Indicator to a on K, read x on CI.

EXPRESSIONS SOLVED WITH ONE SETTING OF SLIDE.

ONE FACTOR

12. x = a^4, set 1 to a on D, over a on C, read x on A.
13. x = $\frac{1}{a^4}$, set a on CI to a on D, under 1 on A, read x on B.
14. x = a^5, set a on CI to a on D, over a on B, read x on A.
15. x = $\frac{1}{a^5}$, set a on C to a on K, under a on CI, read x on K.
16. x = a^6, set 1 on C to a on D, under a on C, read x on K.
17. x = a^7, set a on CI to a on K, under a on C, read x on K.
18. x = a^9, set a on CI to a on D, under a on C, read x on K.
19. x = $\sqrt{a^5}$, set 1 to a on K, under a on B, read x on K.
20. x = $\sqrt{a^9}$, set 1 to a on A, under a on C, read x on K.
21. x = $\sqrt{a^{11}}$, set a on CI to a on K, under a on B, read x on K.
22. x = $\sqrt{a^{15}}$, set a on CI to a on D, under a on B, read x on K.
23. x = $\frac{1}{\sqrt[3]{a^2}}$, set 1 to a on K, under 1 on A, read x on B.
24. x = $\sqrt[3]{a^4}$, set 1 to a on K, under a on C, read x on D.
25. x = $\frac{1}{\sqrt[3]{a^4}}$, set a on CI to a on K, over 1 on D, read x on C.
26. x = $\sqrt[3]{a^5}$, set 1 to a on K, over a on B, read x on A.

27. $x = \frac{1}{\sqrt[3]{a^5}}$, set a on C to a on K, under a on CI, read x on D.

28. $x = \sqrt[3]{a^7}$, set a on CI to a on K, under a on C, read x on D.

29. $x = \sqrt[3]{a^8}$, set 1 to a on K, over a on C, read x on A.

30. $x = \frac{1}{\sqrt[3]{a^8}}$, set a on CI to a on K, under 1 on A, read x on B.

31. $x = \frac{1}{\sqrt[3]{a^{10}}}$, set a on C to a on K, over a on CI, read x on A.

32. $x = \sqrt[3]{a^{11}}$, set a on CI to a on K, over a on B, read x on A.

33. $x = \sqrt[3]{a^{11}}$, set a on CI to a on K, over a on C, read x on A.

34. $x = \sqrt[6]{a}$, set a on B to a on K, over 1 on D, read x on C.

35. $x = \frac{1}{\sqrt[6]{a}}$, set on a on B to a on K, under 1 on C, read x on D.

36. $x = \sqrt[6]{a}$, set 1 to a on K, under a on B, read x on D.

37. $x = \sqrt[6]{a}$, set a on B to a on K, over a on D, read x on C.

38. $x = \frac{1}{\sqrt[6]{a^7}}$, set a on B to a on K, over a on D, read x on CI.

39. $x = \sqrt[6]{a^{11}}$, set a on CI to a on K, under a on B, read x on D.

SETTINGS FOR TWO FACTORS.

40. $x = ab$, set 1 to a on D, under b on C, read x on D.

41. $x = \frac{1}{ab}$, set a on CI to b on D, over 1 on D, read x on C.

42. $x = \frac{a}{b}$, set b on C to a on D, under 1 on C, read x on D.

43. $x = \frac{1}{\frac{a}{b}}$, set b on C to a on D, over 1 on D, read x on C.

44. $x = ab^2$, set 1 to a on A, over b on C, read x on A.

45. $x = \frac{1}{ab^2}$, set b on CI to a on A, under 1 on A, read x on B.

46. $x = \frac{a}{b^2}$, set b on C to a on A, over 1 on B, read x on A.

47. $x = \frac{a^2}{b}$, set a on C to b on A, under 1 on A, read x on B.

49. $x = a^2b^2$, set 1 on C to a on D, over b on C, read x on A.

49. $x = \frac{1}{a^2b^2}$, set a on CI to b on D, under 1 on A, read x on B.

50. $x = \frac{1}{a^3b^3}$, set a on C to 1 on D, under b on CI, read x on K.

51. $x = \frac{a^2}{b^2}$, set b on C to a on D, at 1 on C, read x on A.

52. $x = a\sqrt{b}$, set 1 to a on D, under b on B, read x on D.

53. $x = \frac{1}{a\sqrt{b}}$, set a on CI to b on A, over 1 on D, read x on C.

54. $x = \frac{\sqrt{a}}{b}$, set b on C to a on A, under 1 on C, read x on D.

55. $x = \frac{a}{\sqrt{b}}$, set b on B to a on D, under 1 on C, read x on D.

56. $x = a^2\sqrt{b}$, set a on CI to a on D, under b on B, read x on D.

57. $x = a^4b$, set a on CI to b on A, over a on C, read x on A.

58. $x = a^6\sqrt{b^3}$, set a on CI to b on A, under a on C, read x on K.

59. $x = \frac{a^2}{\sqrt{b}}$, set b on B to a on D, under a on C, read x on D.

60. $x = \frac{\sqrt{a}}{b^3}$, set b on C to a on A, under b on CI, read x on D.

61. $x = ab^3$, set 1 on C to a on K, under b on C, read x on K.

62. $x = \frac{a}{b^3}$, set b on C to a on K, under 1 on C, read x on K.

63. $x = \frac{a^3}{b^2}$, set a on CI to a on A, over b on CI, read x on A.

64. $x = \frac{a^2}{b^3}$, set b on B to a on D, over b on CI, read x on A.

65. $x = a^2b^3$, set b on CI to a on D, over b on B, read x on A.

66. $x = a\sqrt[3]{b}$, set 1 on C to b on K, under a on C, read x on D.

67. $x = 1 \div a\sqrt[3]{b}$, set a on CI to b on K, over 1 on D, read x on C.

68. $x = a \div \sqrt[3]{b}$, set a on C to b on K, over 1 on D, read x on C.

69. $x = \sqrt[3]{a} \div b$, set b on C to a on K, under 1 on C, read x on D.

70. $x = a^3b^3$, set 1 on C to b on D, under a on C, read x on K.

71. $x = \frac{a^3}{b^3}$, set b on C to a on D, under 1 on C read x on K.

72. $x = ab^4$, set b on CI to a on A, over b on C, read x on A.

73. $x = b^6\sqrt{a^3}$, set b on CI to a on A, under b on C, read x on K.

74. $x = a^2\sqrt[3]{b^2}$, set 1 on C to b on K, over a on C, read x on A.

75. $x = \frac{\sqrt[3]{a^4}}{b}$, set b on C to a on K, under a on C, read x on D.

76. $x = \frac{\sqrt[3]{a^8}}{b^2}$, set b on C to a on K, over a on C, read x on A.

77. $x = \frac{a^4}{b^3}$, set b on C to a on K, over a on C, read x on K.

SETTINGS FOR THREE FACTORS.

78. $x = a.\,b.\,c$, set a on CI to b on D, under c on C, read x on D.

79. $x = a^2 \times b^2 \times c^2$, set a on CI to b on D, over c on C, read x on A.

80. $x = a^3 \times b^3 \times c^3$, set a on CI to b on D, over c on C, read x on K.

81. $x = \frac{a \times b}{c}$, set c on C to a on D, under b on C, read x on D.

82. $x = \frac{a^2b^2}{c^2}$, set c on C to a on D, over b on C, read x on A.

83. $x = \frac{a^3b^3}{c^3}$, set c on C to a on D, over b on C, read x on K.

84. $x = \frac{a}{b.c}$, set b on C to a on D, under c on CI, read x on D.

85. $x = \frac{a^2}{b^2 \times c^2}$, set b on C to a on D, over c on CI, read x on A.

86. $x = \frac{a^3}{b^3 \times c^3}$, set b on C to a on D, over c on CI, read x on K.

87. $x = ab\sqrt{c}$, set a on CI to c on A, under b on C, read x on D.

88. $x = a^2b^2c$, set a on CI to c on A, over b on C, read x on A.

89. $x = a^3b^3\sqrt{c^3}$, set a on CI to c on A, over b on C, read x on K.

90. $x = ab\sqrt[3]{c}$, set a on CI to c on K, under b on C, read x on D.

91. $x = a^2b^2\sqrt[3]{c^2}$, set a on CI to c on K, over b on C, read x on A.

92. $x = a^3.b^3.c$, set a on CI to c on K, over b on C, read x on K.

93. $x = \frac{\sqrt{a}}{b\sqrt[3]{c}}$, set b on CI to c on K, under a on A, read x on C.

94. $x = \frac{a\sqrt{b}}{\sqrt[3]{c}}$, set a on C, to c on K, under b on A, read x on C.

And scores of other combinations.

ANSWERS

(Answers given with the problems are not given below.)

1. 300.
2. 3000.
3. 3000.
4. .3
5. .03
6. 3.
7. .0003

8.

	21	22	23	24	25	26	27	28	29
31	651	682	713	744	775	806	837	868	899
32	672	704	736	768	800	832	864	896	928
33	693	726	759	792	825	858	891	924	957
34	714	748	782	816	850	884	918	952	986

9. 49%
10. 33%
11. 91%
12. 59%
13. 16%
14. 21%
15. 2.24
16. 2.34
17. 1.33
18. 1.32
19. 3.18
20. 67.3
21. 19.3
22. .0000476
23. 5.77
24. 27.5
25. 87.9 In.
26. 212
27. 156.
28. .294
29. .735
30. .615
31. 13.6
32. 77.9
33. 19.6
34. 21.4
35. 33.1
36. 56.7
37. 1.6 mils.
38. 10.2
39. 21.6
40. 1.25
41. 74.8
42. 76200.
43. 1170.
44. .436
45. .0039
46. .0000325
47. .000595
48. 5020000.
49. 1.19
50. 3.77
51. 11.9
52. .377
53. 1.56
54. 9.24
55. .604
56. .560
57. 38.1
58. Square roots of numbers from 110 to 130.

Number	Square Roots
110.	10.5
111.	10.5
112.	10.6
113.	10.6
114.	10.7
115.	10.7
116.	10.8
117.	10.8
118.	10.9
119.	10.9
120.	11.0

121.	11.0
122.	11.0
123.	11.1
124.	11.1
125.	11.2
126.	11.2
127.	11.3
128.	11.3
129.	11.4
130.	11.4

59. 127 feet, 3 inches.
60. 1.86 inches. Use a 2-in. pipe, the nearest standard size.
61. 8.5 inches. (Use a 9-in. pipe, the nearest standard size.)

Answers to test problems on Page 18.

62. 3.15
63. 1.41
64. 11.4
65. 36.8
66. 13.5

ANSWERS

Multiplication

67. 7.39
68. 19.3
69. 7.55
70. 58.5
71. 258.
72. 273.
73. .0541
74. .00167
75. .0000910
76. 12.6 20.4 44.0.

Cubes

77. 2197.
78. 2744.
79. 3375.
80. 4096.
81. 4913.
82. 5832.
83. 6859.
84. 8000.
85. 9261.

(Three significant figures.)

86. 29800.
87. 97300.
88. 104000.
89. 149000.
90. 262000.
91. 436,000,000.
92. 12,500,000.
93. 77,100,000
94. 679,000.
95. 2,690,000.
96. .04
97. .000185
98. .000,000,314
99. 1.09
100. 9.53
101. 76.1 gal.

Cube Roots

102. 1.44
103. 3.107
104. 6.69
105. .669
106. .3107
107. .144
108. 13.77
109. 3.628
110. .922
111. 35.59
112. 3.68
113. 1.94
114. .832
115. 6.22
116. 15.66
117. 37.33
118. .2535
119. .211
120. 1.012
121. 47.7
122. 20.4

Reciprocals

123. .139
124. 2.44
125. .0265
126. .0147
127. 13.7
128. 5.49
129. .0177
130. 1.176
131. .136
132. 159.

Three or More Factors

133. 76.1
134. 46.8
135. 35.6
136. 144.7
137. 157.4
138. 80.
139. 46.4
140. 378.
141. 40.4
142. 92.4
143. 114.7
144. 17,490,000.
145. 1.309
146. 56.1
147. 49.2

Combined Multiplication and Division

148. .01815
149. .633
150. 902.
151. 328.
152. 1111.
153. 51.4
154. .353
155. .1585
156. 4.58
157. 1.69
158. .298
159. .280
160. 1.073

Miscellaneous Calculations

161. 32.3
162. 1.91
163. .516
164. .45
165. 1627.
166. 35.8
167. 57,300,000.
168. 1.234
169. .408
170. .00642
171. 81.4
172. 6.4

Sines and Cosines

173. 1.
174. .707
175. .5
176. .0523
177. .0116
178. .264
179. .0262
180. .1478
181. .0393
182. .3665
183. .1736
184. .423
185. .743
186. .970
187. .978
188. .250
189. .585
190. .937
191. .1435
192. .0276
193. 19.
194. 15.1
195. 83.2
196. 32.0
197. 34.5
198. 16.3
199. $a = 9.11, b = 8.04, c = 6.49, d = 5.03.$
200. $BC = 4.70,\ BA = 1.71$

Tangents.

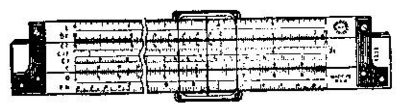
201. .466
202. .259
203. .713
204. .495
205. .335
206. 1.446
207. 3.78
208. .367
209. .270
210. .1125
211. .0306
212. .911
213. 4.82
214. 29.0
215. 31.9
216. 3.04

Logarithms.

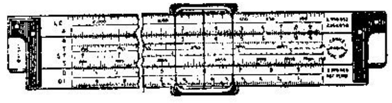
217. .127
218. 1.736
219. $\bar{1}.494$, or 9.494–10.
220. $\bar{2}.826$, or 8.826–10.
221. 2.866
222. 335.
223. 32,600,000,000.
224. 1.512
225. 3.10
226. 2.825

INDEX

COOKE RADIO SLIDE RULE



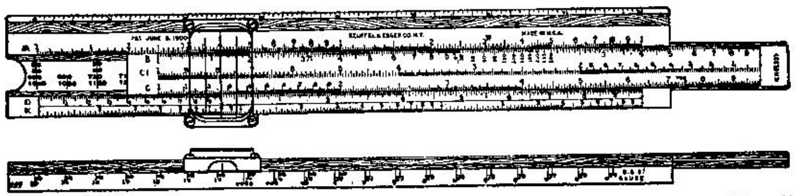
Front



Back

The COOKE Radio Slide Rule No. 4139 not only facilitates the rapid solution of radio engineering problems, but is also suitable for general use.

THE ROYLANCE ELECTRICIANS' SLIDE RULE



This rule is a modification of our regular Polyphase* Slide Rule and can be used for all the calculations made with the ordinary Slide Rule. In addition to the usual scales, it carries a series of scales or gauge marks by means of which the different properties of copper wire, such as size, conductivity weight, etc., may be determined without the use of tables.

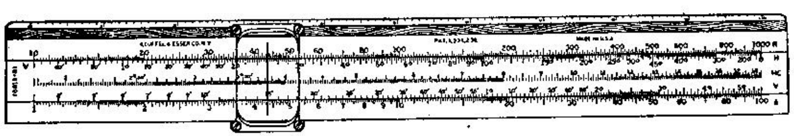
SURVEYOR'S DUPLEX SLIDE RULE

REG. U. S. PAT. OFF.

The fact that all astronomical data essential to surveying, such as azimuth, time, latitude, etc., can be ascertained by means of the usual type of Transit with vertical circle but without solar attachment, while generally known, is rather seldom utilized in this country. The main reason for this condition is the difficulty of computing, in the field, by spherical trigonometry, the results of observations.

The K & E Surveyor's Duplex* Slide Rule entirely eliminates this difficulty by reducing the hitherto complicated calculations to mere mechanical operations, thereby rendering the method of field astronomy with the regular Engineer's Transit extremely simple and practical.

K & E STADIA SLIDE RULE



This form of Stadia Slide Rule is remarkable for its simplicity. By one setting of the slide the horizontal distance and vertical height can be obtained at once when the stadia rod reading and the angle of elevation or depression of the telescope are known.

*REG. U. S. PAT. OFF.

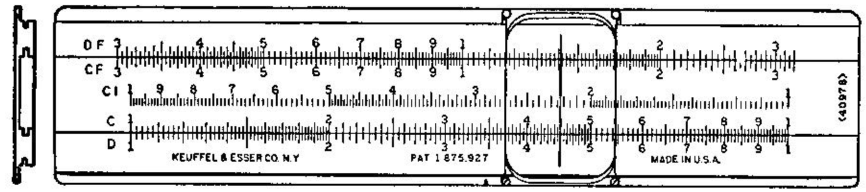
EVER-THERE SLIDE RULES.

REG. U. S. PAT. OFF.

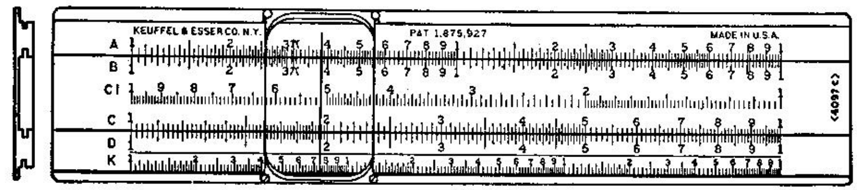
The EVER-THERE Slide Rule is made entirely of white Xylonite, a strong, tough material. On this base the graduations are engine-divided. The handiness of the **EVER-THERE** slide rule is evident from the fact that it weighs no more than a fountain pen, and is much less bulky in the pocket.

The Ever-There Slide Rule No. 4097C is pre-eminently a pocket instrument, as the following dimensions will indicate:

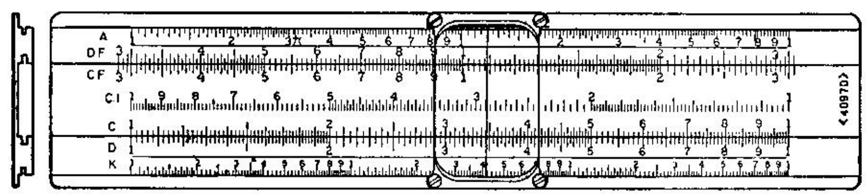
Length over all.........6 inches. Width over all.........................$1\frac{9}{32}$ inches.
Thickness ....$\frac{1}{4}$ inch. Thickness of Indicator......... $\frac{3}{16}$ inch.
Weight.......................about $\frac{3}{4}$ ounce.



EVER-THERE Slide Rule No. 4097B has the scales shown in the illustration above, and is convenient for all multiplication, division, proportion and percentage problems. It also has inch and centimeter scales on the back.



EVER-THERE Slide Rule No. 4097C has all the scales of the Polyphase* Slide Rule including the Logarithmic and Trigonometrical Scales, as well as inch and centimeter scales is on the back. The slide is reversible.

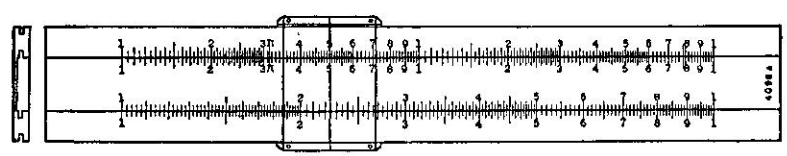


EVER-THERE Slide Rule No. 4097D has all the scales of the Polyphase Duplex* Slide Rule except the CIF scale, together with inch and centimeter scales on the back. The slide reversible.

*REG. U. S. PAT. OFF.

K & E POCKET SLIDE RULE.

REG. U. S. PAT. OFF.



The K & E POCKET Slide Rule No. 4098A is 6 inches long, less than 1⅛ inches wide, and ⅛ inch thick. In addition to the A, B, C & D scales on the front, the trig scales S and T and L scale are on the back of the slide. It also carries inch and millimeter scales.