KEUFFEL & ESSER CO. NEW YORK

INSTRUCTIONS FOR OPERATING

K & E POCKET SLIDE RULE No. 4098A

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The Slide Rule has application in the fields of engineering, architecture, estimating, cost accounting, statistics, physics, chemistry, astronomy, merchandising,—wherever quick calculations are necessary.

It is used primarily for multiplication and division and the related operations of proportion, percentage, and combined multiplication and division.

Problems involving squares, square roots, and trigonometric functions are also solved by means of the Slide Rule; but the beginner is advised to confine his study to the simple operations of multiplication and division on the "C" and "D" scales.

Before attempting to perform the calculations, the student should practice the reading of the scale until he has acquired accuracy in locating numbers without hesitation.

The **C** and **D** scales are **identical** and are numbered from **1** to **10**, the spaces between the whole numbers **decreasing** steadily toward the right, as is brought out in the following diagram.

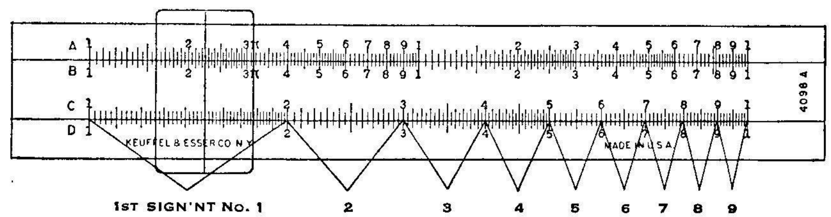

Fig. A.

10,035-1. kc, y, ao. sM.

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TO LOCATE THREE-FIGURE NUMBERS ON THE C AND D SCALES, there are *three* steps of procedure in the following sequence:

STEP I.—*Read the first significant figure.* (The first significant figure of a number is the first numeral that is *not* zero. Thus, 2 is the first significant figure of the numbers 0.0024, 24.0, 0.024, or 2.40.)

If the first significant figure is 1, the number will lie between the **main divisions** *1 and 2. If it is 2, the number will lie between 2 and 3. If 3, between 3 and 4, etc.* (*See Fig. A, page 1.*)

EXAMPLE: The number 246 lies between the main division 2 and 3 (as indicated by the bracket in figure I, a skeleton scale showing only the main divisions), since the first significant figure is 2.

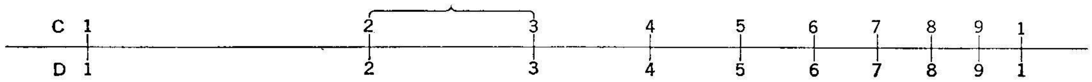


Fig. I. MAIN DIVISIONS.

STEP II.—*The second figure locates the number on the* **secondary divisions** *in a similar manner.*

EXAMPLE: In the number 246 the second figure 4 indicates that the location is between the 4th and 5th secondary divisions beyond the second main division, as indicated by the bracket in figure II, which is a skeleton scale with only the secondary divisions filled in. Note that there are ten of these secondary divisions to each main division.

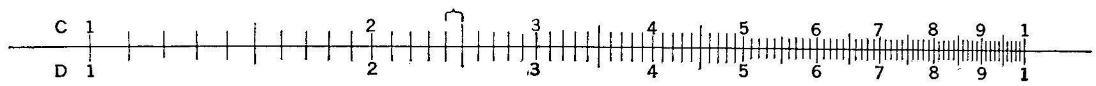


Fig. II. SECONDARY DIVISIONS

STEP III.—*In a like manner the third figure locates the number on the* **third set of divisions**, *which appear in Fig. III—the Slide Rule Scale in its final form.*

EXAMPLE: Since the the number 246 lies between the main divisions 2 and 3, where the subdivision is in halves, the third figure locates the number finally one fifth the distance beyond the half division between the 4th and 5th secondary divisions beyond the main division 2, as indicated by the arrow in Figure III.

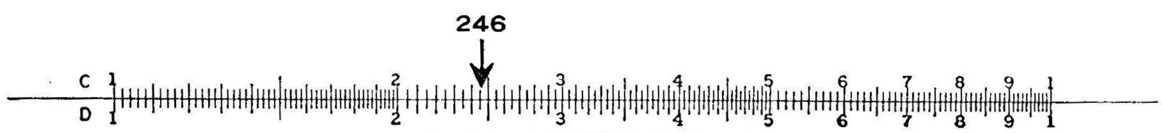
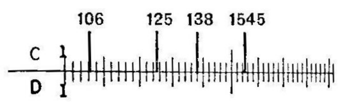


Fig. III. COMPLETE SCALE

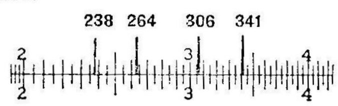
IMPORTANT NOTE.—Were it practical to manufacture a rule with ten subdivisions to every secondary division, it would certainly be done, so that each space would have a **single** value, as have the secondary divisions. However, since the spaces grow smaller toward the right end of the scale, **it is practically impossible to subdivide the secondary divisions even into fifths throughout the scale. Therefore:—**

(*a*) The spaces between the secondary divisions lying between Main Divisions 1 and 2 are divided in fifths; so each of these subdivisions has a value of two.



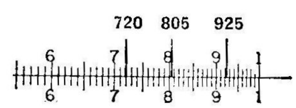
5 spaces, each = 2

(*b*) The spaces between the secondary divisions between Main Divisions 2 and 3, 3 and 4, and 4 and 5, are divided in halves; so each subdivision has a value of five.



2 spaces, each = 5

(*c*) The spaces between the secondary divisions for the remainder of the scale are not subdivided; so each subdivision has a value of ten.



1 space, each = 10

STEPS I, II and III are condensed in Fig. IV, below, showing the location of the number 246.

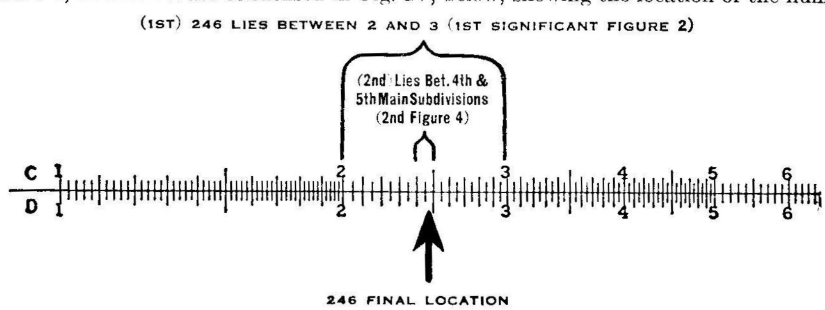


Fig. IV.

It is advisable for the student to follow the same procedure on his Slide Rule, locating those numbers with the aid of the **hairline** on the **indicator** (runner).

Now locate 478 in the same manner, using the **indicator** (runner) to follow each step.

I. First significant figure 4 (indicates that number lies between 4 and 5). **Set indicator at 4** (Fig. V).

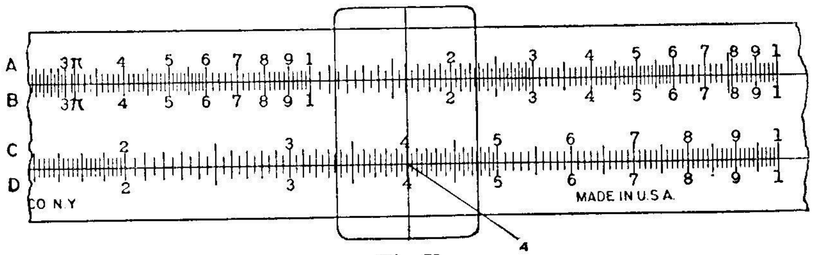


Fig. V.

II. Second figure 7 (indicates number lies between 7th and 8th secondary divisions). **Move indicator to 7th secondary division** (Fig. VI).

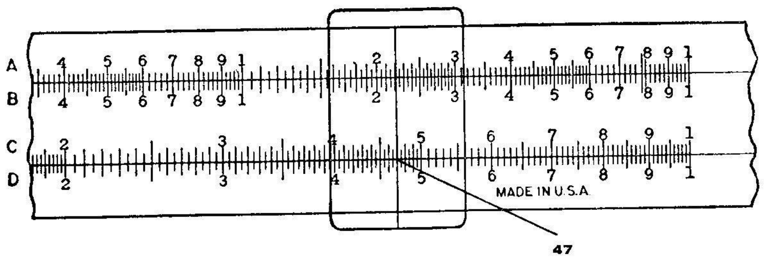


Fig. VI.

III. Third figure 8 (indicates the number lies 3/5ths of the distance between the **single subdivision** (**half**) and the next secondary division (Fig. VII).

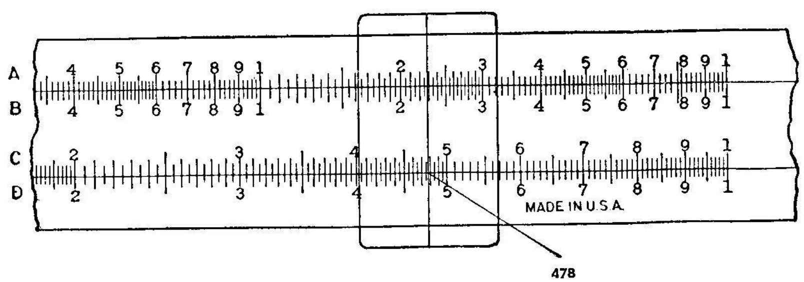


Fig. VII.

Numbers containing a single digit are located at the main divisions, as—

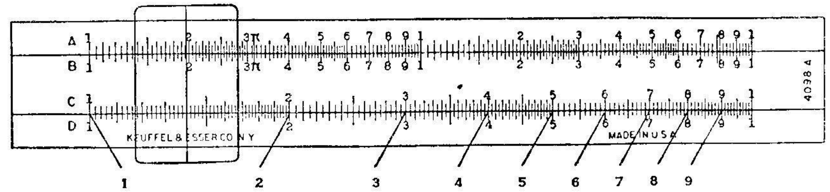


Fig. VIII.

Two digit numbers are located like the three digit numbers, but are finally located on the secondary divisions instead of the final subdivisions, as—

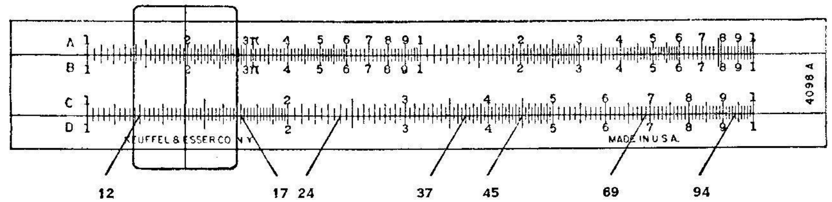


Fig. IX.

Number containing a large number of digits need only be set to the third place; since the percentage of error introduced in the result is so minute, as to be insignificant in the majority of problems,—especially ratio and percentage calculations, combined multiplication and division, and multiplications involved in estimating and appraising.

Thus, 187,475 would have to be called 187,000+ and set as follows:

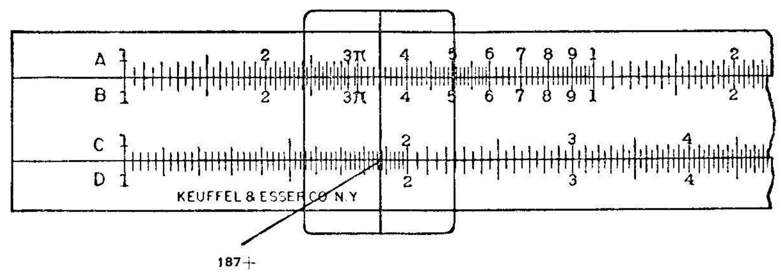


Fig. X.

The student should practice setting and reading until he feels confident that he can do so accurately and without hesitation. Then he is ready to give his attention to the solution of simple multiplication problems.

MULTIPLICATION

Rule: *To multiply two factors together, set the index of the C scale (either the right or left end figure one) adjacent to one of the factors on the D scale and opposite the other factor on C read the answer on D.*

2 × 3 = x.

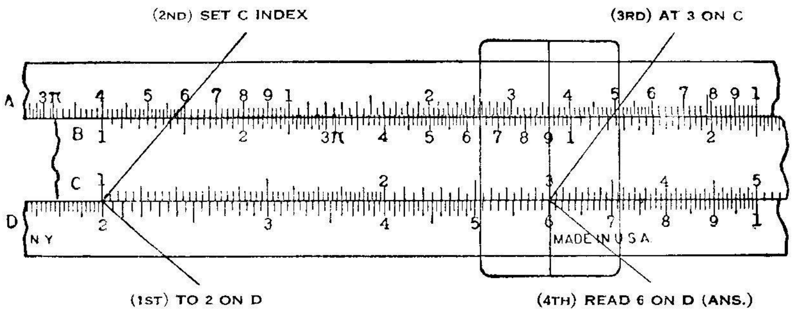


Fig. XI.

18 × 26 = x.

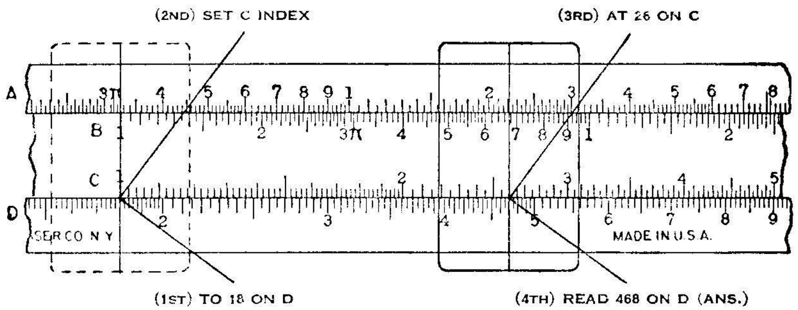


Fig. XII.

72 × 51 = x.

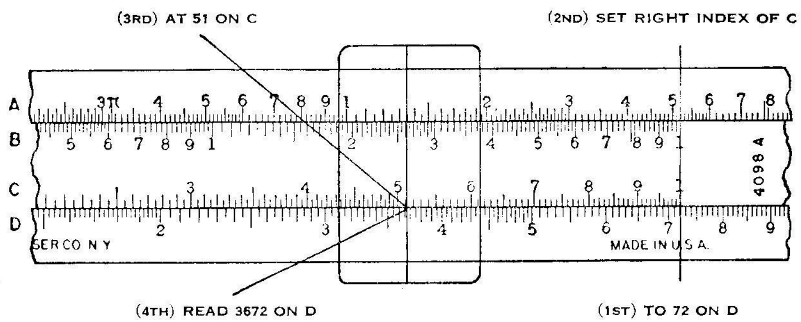


Fig. XIII.

The slide rule gives 3670, but the 4th digit is obviously 2, since the last digits of 72 and 51 are 2 and 1 respectively.

Note that in making settings to solve the last problem that the right index must be used, instead of the left, as was used in the first two problems. *If the factor on the slide falls beyond the limit of the D scale when the left index is used, use the right index.*

THE DECIMAL POINT

Important: No mention has been made as to the method of determining the position of the decimal point in the last problems, since it has been apparent at a glance. In most cases, however, the operator should substitute round numbers for those appearing in the problem and determine the correct position of the decimal point by approximation.

Thus—2.47 × 34.2

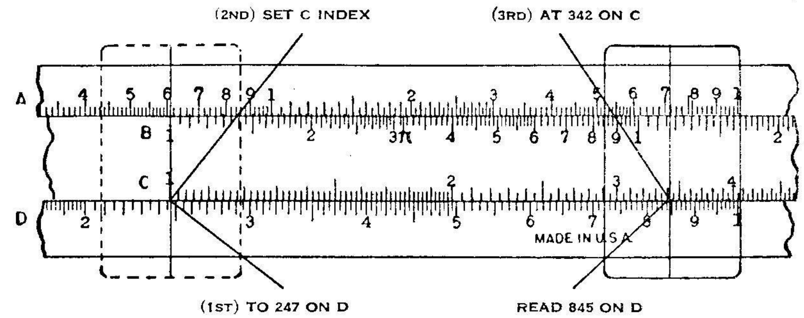


Fig. XIV.

Make the setting in the regular way, and read the answer 845. Substitute 2 for 2.47 and 30 for 34.2 and note that the answer would be approximately 60. Therefore the answer must be 84.5 which is nearer to the approximation than 845 or 8.45.

When the student has operated the slide rule for some time, he will learn to make these approximations mentally and almost instantaneously.

MULTIPLICATION OF THREE OR MORE FACTORS

Example: 642 × 3.5 × .0164

The first two factors are multiplied together, as previously indicated.

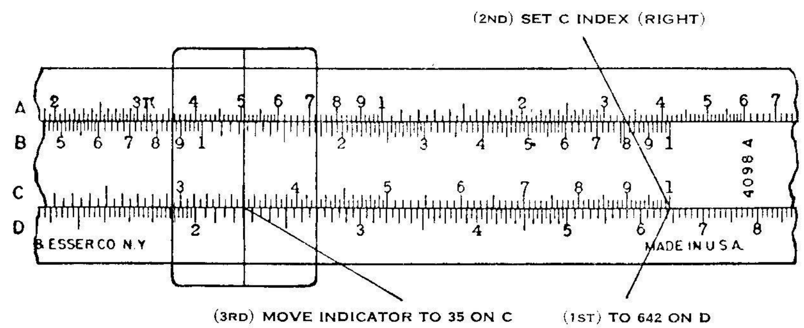


Fig. XV.

No note need be taken of the product of these two numbers since only the final product is sought.

The C index is moved to the product of the first two and the final reading is made on D, under the third factor on C. Thus—

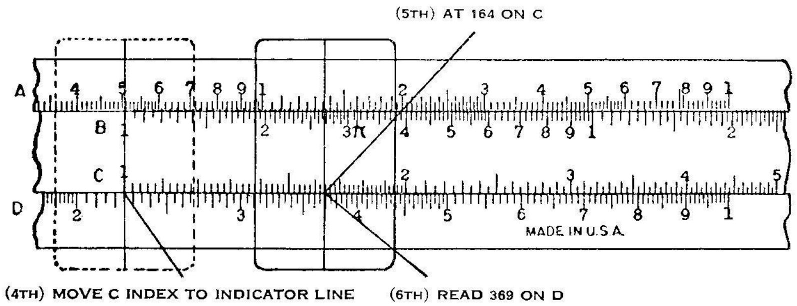


Fig. XVI.

Approximating, 600 × 3 × .01 = 18, it is certain that the final answer must be 36.9 and not 369 or 3.69.

Any number of factors can be multiplied together in a similar manner. The decimal point in multiplications such as these can be quickly determined by the approximation method, which has already been explained.

DIVISION

Division is the reverse of multiplication; refer to Fig. XI, showing 2 × 3 = 6. The same setting shows 6/3 = 2.

Rule: *To divide one number by another, set the divisor on the C scale to the dividend on the D scale and opposite the index of C read the quotient on the D scale.*

Example:—875 ÷ 35

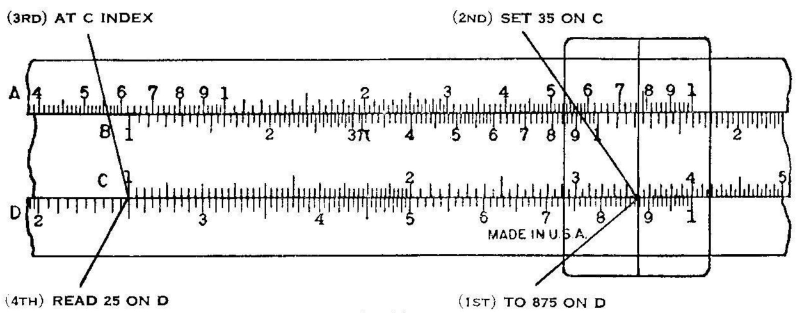


Fig. XVII.

As in multiplication, the decimal point should be set by approximation. Substituting round numbers, in the last problem, it is found that 900 divided by 30 equals 30. Therefore the answer must be 25, as this is closer to 30 than 250 or 2.5.

SOLUTION OF PROBLEMS INVOLVING BOTH MULTIPLICATION AND DIVISION

Problems involving both multiplication and division can be worked out on the slide rule with great rapidity, whereas considerable time would be required for solution by the arithmetic method. Note, in solving a problem of this type, that it is not necessary to read the answer for each step, since only the final answer is of interest.

Example. $\frac{840 \times 648}{790} = x.$

The best method for solving problems of this type is to perform division first; then multiplication; and to continue in this order as far as possible.

To 840 on D set 790 on C (division).

Move indicator to 648 on C (multiplication).

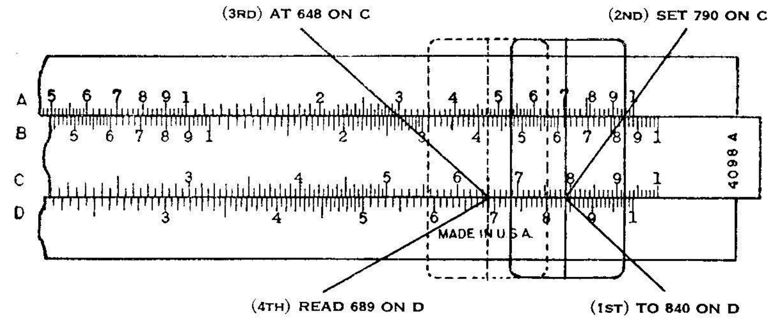


Fig. XVIII.

PROPORTION

Problems in proportion are encountered daily, and offer one of the most common uses for the slide rule. Among problems of this type are those which call for—

(1) The conversion of—

Yards to meters,
Dollars to pounds,
Knots to miles,
Inches to centimeters, etc.

(2) The determination of weight of one quantity when the weight of another quantity is known.

It will be found that when the slide is set so that 2 on C coincides with 4 on D, that all readings on C bear to the coinciding reading on D a ratio of 2 : 4 or 1 : 2.

Stating this in a general rule—*with any setting of the slide, all coinciding readings are in the same ratio to each other.*

Example:

2.7 quarts of a liquid weigh 4 lbs. To determine the weight of 1.4 quarts, set 2.7 on C scale adjacent to 4 on D scale and at 1.4 read the answer 2.07.

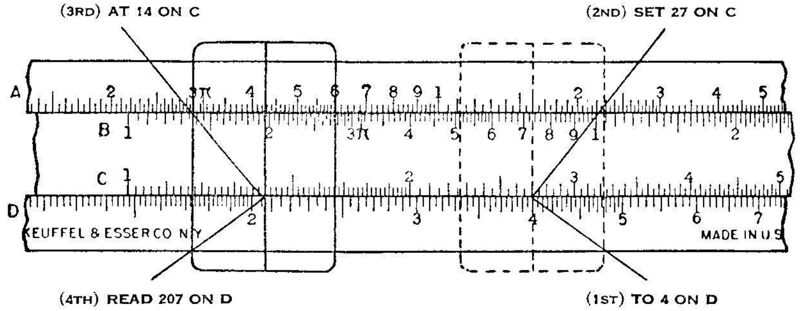


Fig. XIX.

Example:

To convert a number of different readings in square meters to square yards, set 1 on C to 1.196 on D (1 square meter = 1.196 square yards) and opposite any reading in square meters on C, find the corresponding reading in square yards on D.

SQUARES AND SQUARE ROOTS

The A and D scales are so arranged that if the indicator is set over a number on D, its square will be found on the A scale under the indicator line.

Rule: *To find the square of a number, set the indicator to the number on the D scale and read its square under the indicator line on the A scale.*

Example. Find the square of 43.8.

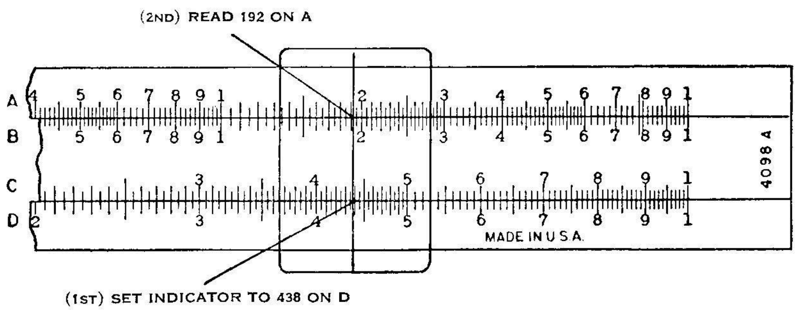


Fig. XX.

The decimal point is set in the same manner as in multiplication and division. Squaring 40, the nearest round number to 43.8, gives 1600. Therefore the answer must be 1920 and not 192.0 or 19200.

Rule: *To find the square root of a number, the reverse process is used. Set the indicator at the number on the A scale and read the square root on D, under the indicator line.*

Important. Always use the left half of the A scale for numbers with an odd number of figures before the decimal point, and the right half for those with an even number of figures to the left of the decimal point. For numbers less than 1 (decimal fractions) use the left half of the A scale when an odd number of zeros occur between the decimal point and the first digit. Use the right half of the scale when no zeros or an even number of zeros occur between the decimal point and the first digit.

Example. Find the square root of 625.

Use left half of A (odd number of figures).

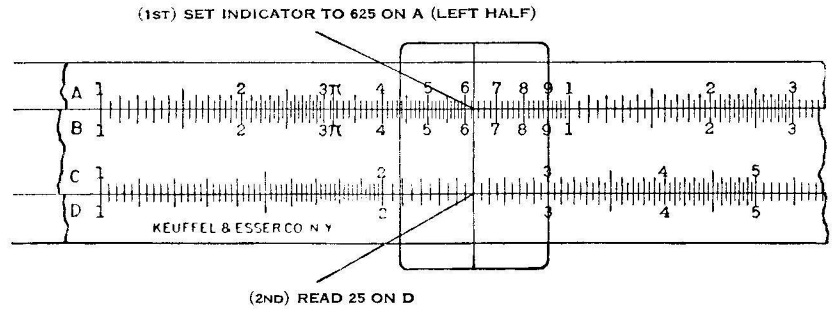


Fig. XXI.

Find square root of 6250. As this number contains an even number of figures to the left of the decimal point, the right half of the A scale is used.

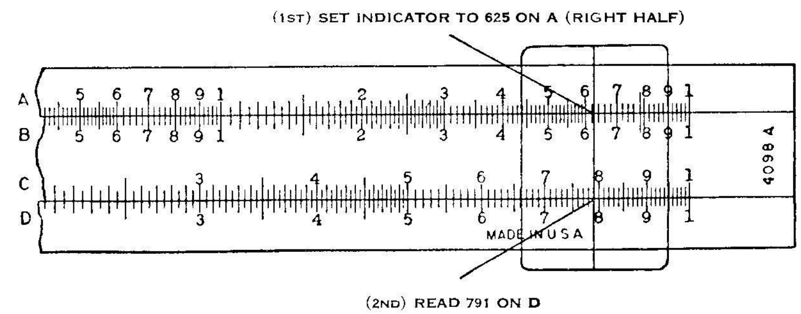


Fig. XXII.

By approximation, the answer is 79.1.

TRIGONOMETRY

The slide rule has been adopted by many High Schools for use in connection with their Trigonometry work. It can be used for the actual solution of triangles, but is more often used to check answers obtained by other methods.

Problems of multiplication, division and proportion, in which one factor is the sine or tangent of an angle, can be quickly solved. The method is the same as used when both factors are numbers.

Rule: *The numerical values of the sines of the angles appearing on the S scale can be found by setting the angle on the S scale opposite the index mark on the back of the rule and reading the sine on B at the index of A.*

Important. *All natural sines read on the left half of the B scale have one zero between the first significant figure and the decimal point. The natural sines read on the right half of the B scale have the decimal point just before the first significant figure.*

This must be borne in mind in determining the final location of the decimal point in problems making use of the sine and tangent scale.

To find sin 3°.

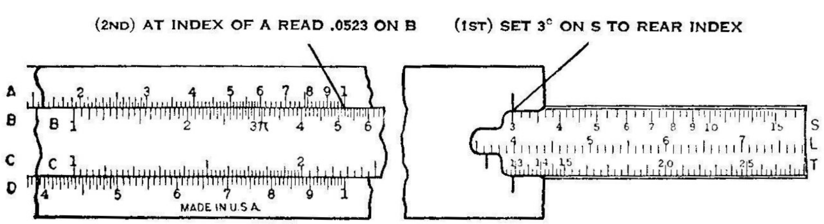


Fig. XXIII.

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 "seconds" gauge point, and near the 2° division is the "minutes" gauge point. By placing one of these gauge points opposite the index on the back of the rule, the sine corresponding to any number of minutes or seconds on B can be read on A. Thus to find the sine of 10″, set the "seconds" gauge point to the index on the back of the rule, and above 10 on B read 485 on A. Since the sine of 1″ is about .000005, the answer is .0000485. To find the sine of 12′, set the "minutes" gauge point on S to the rear index, and above 12 on B read 349 on A. Since the sine of 1′, is about .0003 the answer is .00349.

Rule: *The natural tangents of various angles are read by placing the angle on the T scale opposite the index mark on the back of the rule and reading the tangent on C at the index of D. The natural tangents of all angles read in this way on the C scale have the decimal point just before the first significant figure.*

Angles below 5° 43′, as will be noted, cannot be read on the T scale. However, as the natural tangents of angles below 5° 43′, for all practical purposes, are the same as the natural sines of like angles, the natural tangents can be read from the S and B scales.

The natural tangents of angles greater than 45° should be found by using the formula $\tan x = \frac{1}{\tan(90° - x)}$

SIMPLE PROBLEMS MAKING USE OF THE S & T SCALES

Example.—Multiplication—4 × sin 11°.

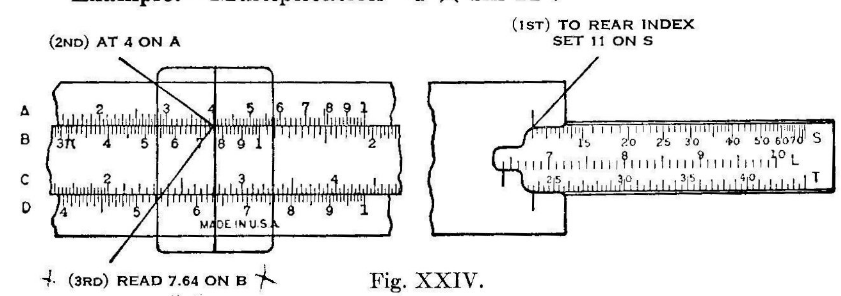


Fig. XXIV.

Example.—Division— $\frac{3}{\tan 25°} = x.$

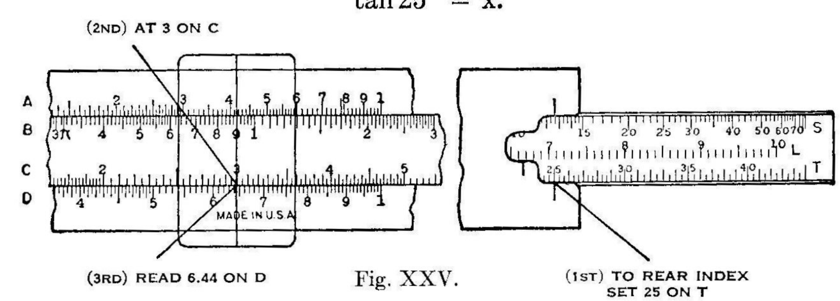


Fig. XXV.

Example.—Proportion— $\frac{3}{\sin 9°} = \frac{x}{\sin 30°}$

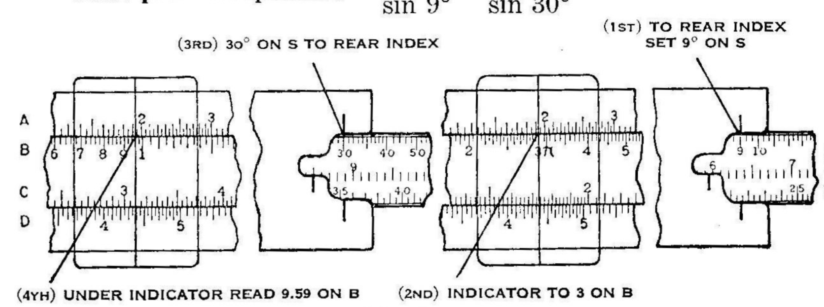


Fig. XXVI.

CHECKING AND SOLVING OF TRIANGLES

The following is a typical right angle triangle problem, with one side and adjacent angle known.

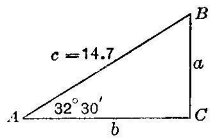


Fig. XXVII.

Given A = 32° 30′
c = 14.7

To find: Sides a and b.

Solution by logarithms gives the following results:

a = 7.9
b = 12.4

These answers are generally checked in the following manner:

$$a^2 = c^2 - b^2 = (c + b)\ (c - b)$$
$$2 \log a = \log (c + b) + \log (c - b)$$
$$1.79526 = \log 27.1 + \log 2.3$$
$$= 1.43297 + .36173$$
$$= 1.79470 -$$

This checks, as can be seen, to only three figures, but this is as much as can be expected since c, a and b are given to only 3 figures.

In comparison with the above check, which takes about 10 minutes, that on the slide rule requires only a few seconds.

According to formula—

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

Set 90° on S to Rear Index
Runner to 14.7 on B
32° 30′ on S to Rear Index
Under hairline of runner read 7.9 on B
57° 30′ on S to Rear Index
Under hairline of runner read 12.4 on B
(a) opposite angle (A) is 7.9.
(b) opposite angle (B) is 12.4

Had it been desired to do so, the problem could have been solved in the first place in exactly the same manner, but it is the general practice in High School work to have the student use the logarithmic method first.

When functions other than the sine or tangent are encountered, make use of the following formulae to express them in terms of sine or tangent.

$$\cos x = \sin (90° - x) \qquad \sec x = \frac{1}{\sin (90° - x)}$$
$$\cot x = \frac{1}{\tan x} \qquad \csc x = \frac{1}{\sin x}$$

Thus, if $3.4 \times \csc 14° = y.$

$$y = \frac{3.4}{\sin 14°}$$

and solve as follows:

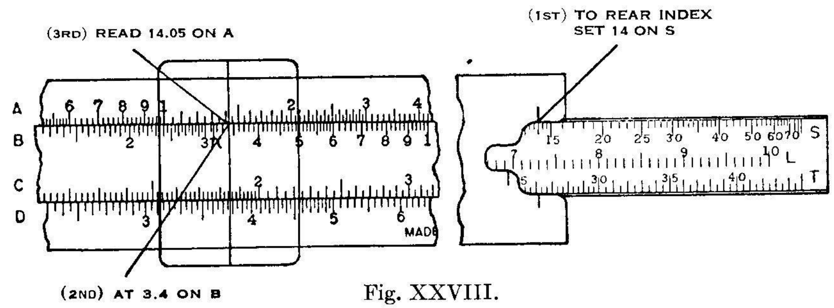


Fig. XXVIII.

LOGARITHMS

Logarithms are read by *setting the number on C above the right index of D and reading the value of the mantissa on the L scale at the index on the underside of the rule.*

Example.—To find the logarithm of 40, set 4 on C over the right index of D; underneath read 602 on L. Placing the decimal point, and prefixing the characteristic as usual, log 40 = 1.602.