KEUFFEL & ESSER CO., NEW YORK

INSTRUCTIONS FOR OPERATING

EVER-THERE SLIDE RULE No. 4097C

REG. U. S. PAT. OFF.

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.

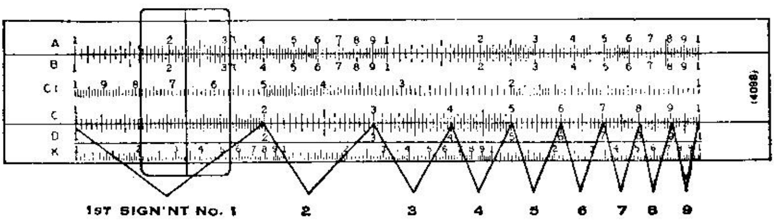


Fig. A.

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.

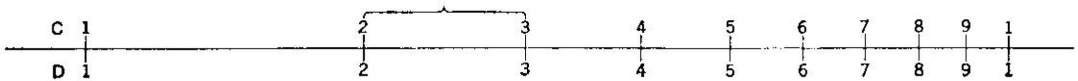


Fig. I. MAIN DIVISIONS.

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.

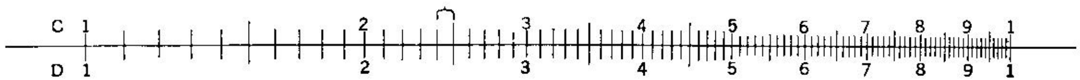


Fig. II. SECONDARY DIVISIONS

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:—**

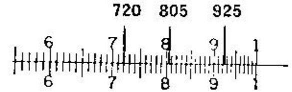
(*a*) The spaces between the secondary divisions lying between Main Divisions 1 and 2 are divided in fifths; so each of these subdivisions has a value of two.

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.

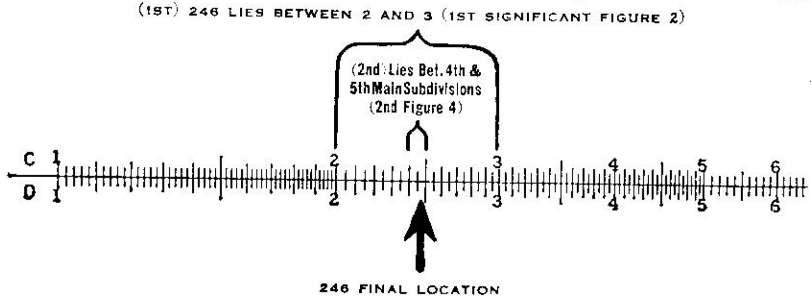


Fig. IV.

The CI Scale is like the C Scale inverted, i.e., the graduations and numbers run in the opposite direction; thus, to read 246 on this scale, find main division 2, then secondary 4 to the left, and subdivision 6 still further to the left.

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.).

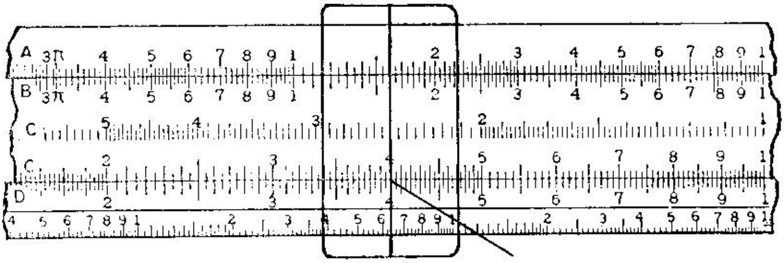


Fig. V.

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

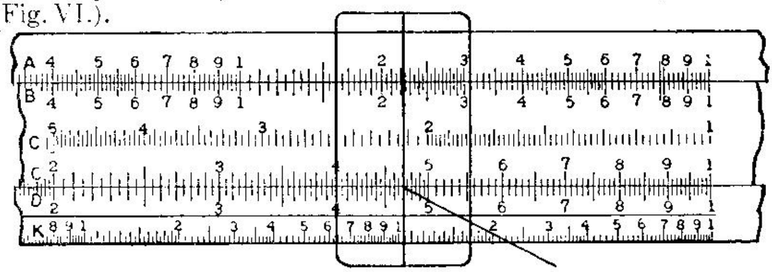


Fig VI.

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.).

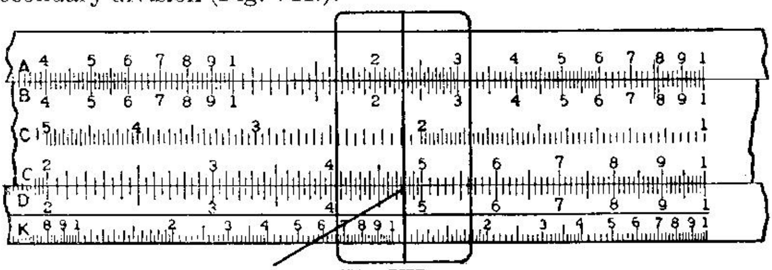


Fig. VII.

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

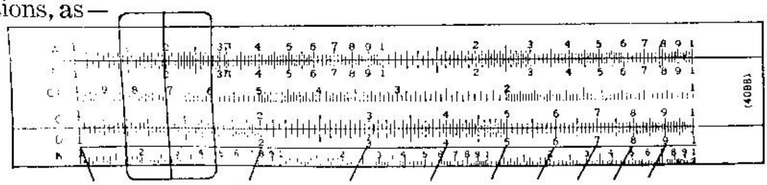


Fig. VIII.

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

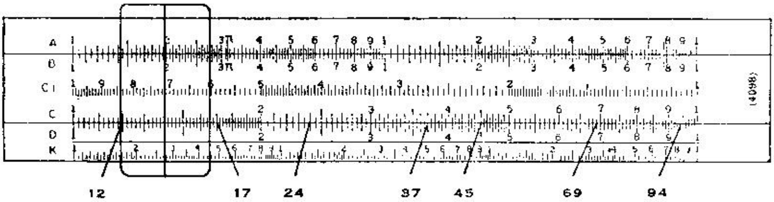


Fig. IX.

Numbers 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:

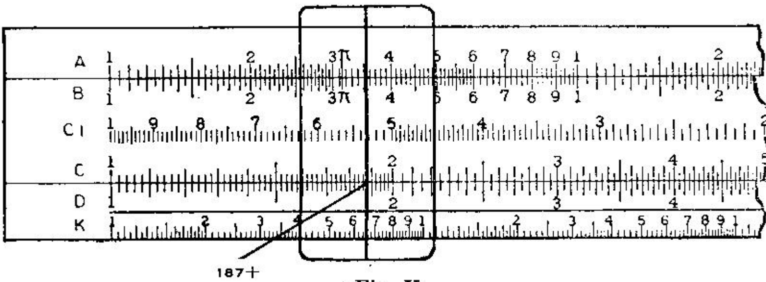


Fig. X.

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.*

$2 \times 3 = x$

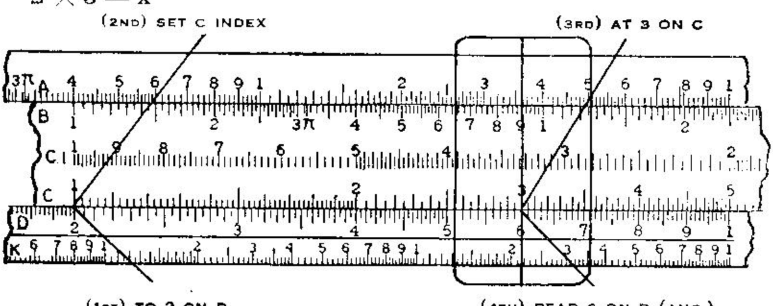


Fig. XI.

$18 \times 26 = x$

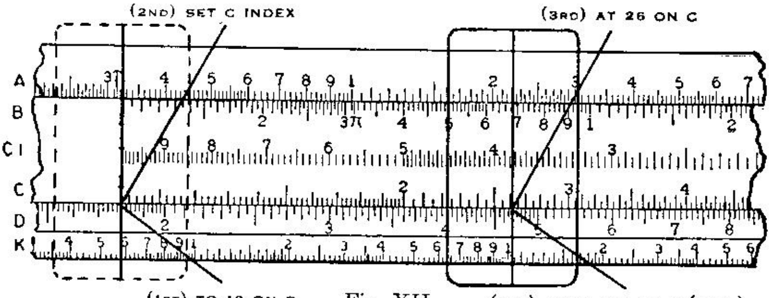


Fig. XII.

$72 \times 51 = x$

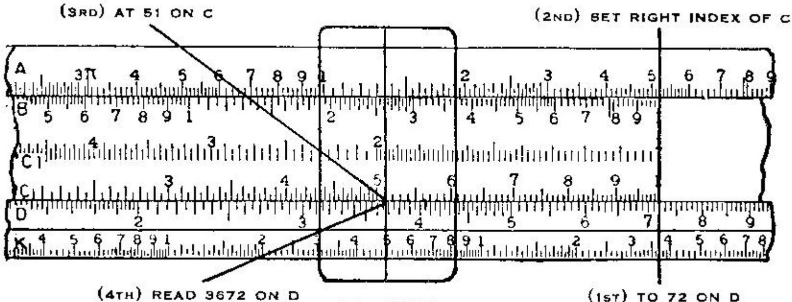


Fig. XIII.

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

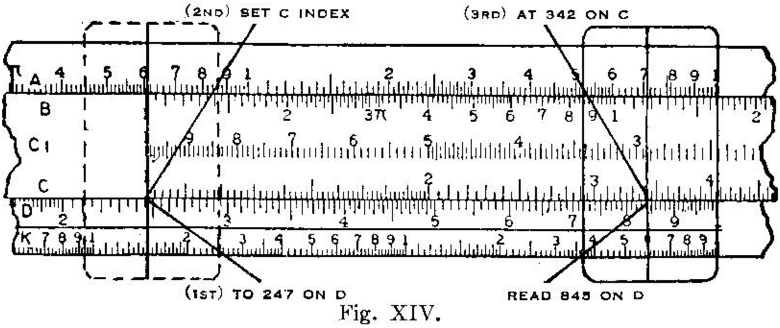


Fig. XIV.

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.

DIVISION

Division is the reverse of multiplication; refer to Fig. XI, showing $2 \times 3 = 6$. 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 $875 \div 35$

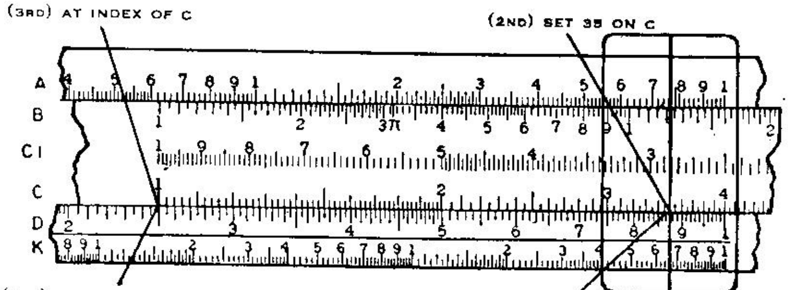


Fig. XV.

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

THE INVERTED SCALE

By using the "CI" scale the operations of multiplication and division are reversed.

Rule: *To multiply two factors together, set the hairline of the indicator to one factor on D, bring the other factor on CI to the hairline of the indicator, and read the answer on D opposite whichever index of C is on the scale.*

$24 \times 35 = x$.

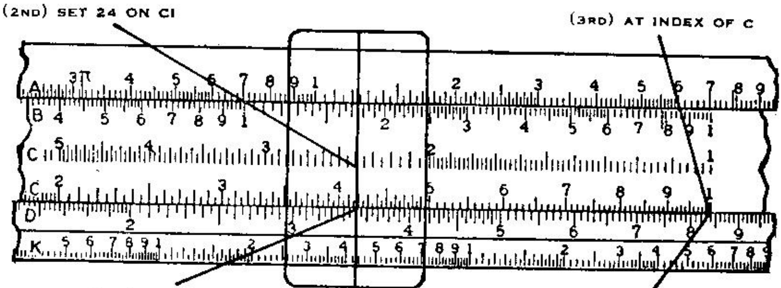


Fig. XVI.

Rule: *To divide one number by another set the index of C adjacent to the dividend on D. Move the indicator to the divisor on CI, and read the answer under the hairline of the indicator on D.*

$74 \div 4 = x.$

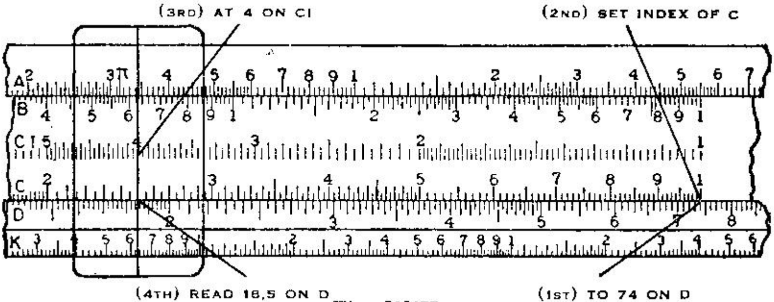


Fig. XVII.

SOLUTION OF PROBLEMS INVOLVING BOTH MULTIPLICATION AND DIVISION.

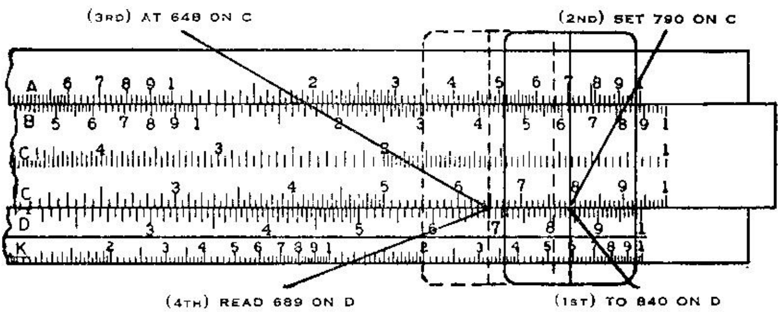
Problems involving both multiplication and division can be worked out on the slide rule with great rapidity, whereas considerable time would be required for solution by the arithmetic method. Note, in solving a problem of this type, that it is not necessary to read the answer for each step, since only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

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

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).



XVIII.

MULTIPLICATION OF THREE OR MORE FACTORS

Three factors can be multiplied at one setting of the slide. This is accomplished by setting two of the factors on the regular scales and one on the "CI" scale.

Example. 942 × 3.5 × .0164.

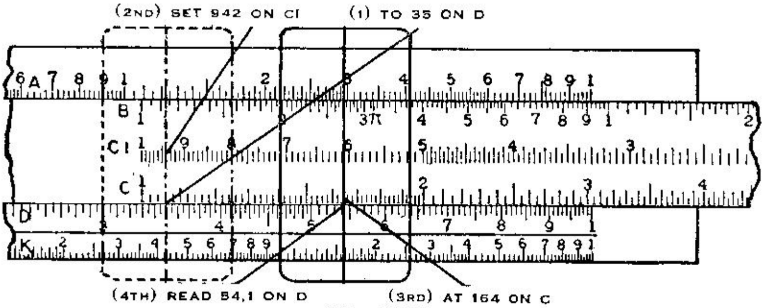


Fig. XIX.

If four factors are to be multiplied, proceed as above for the first three, bringing the hairline of the indicator to the third factor, shifting the index of C to the hairline, and reading the answer on D under the fourth factor on C. Any number of factors can be handled through this procedure.

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 under 1.4 read the answer 2.07.

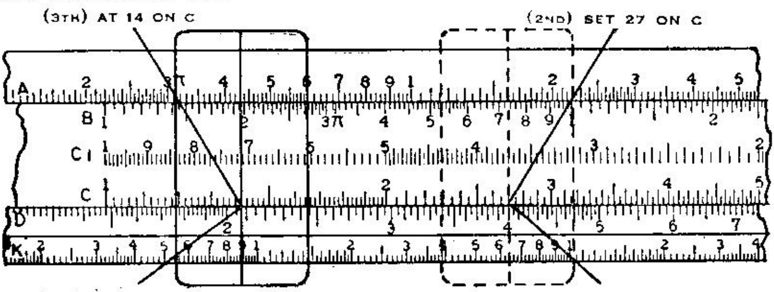


Fig. XX.

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.

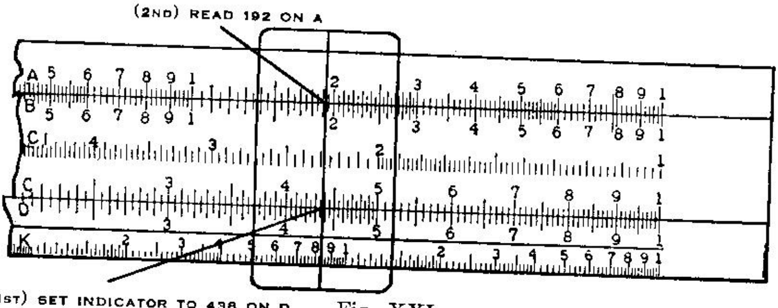


Fig. XXI

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.)

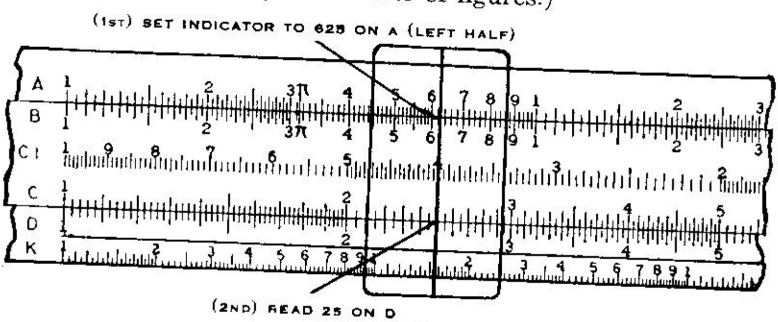


Fig. XXII.

Find square root of 6250. Since this number contains an even number of figures to the left of the decimal point, use the right half of the A Scale.

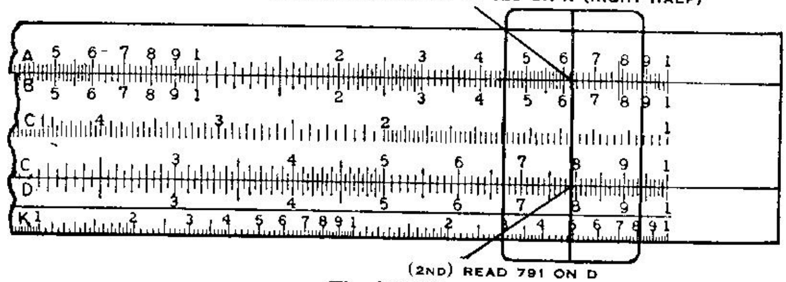


Fig. XXIII.

By approximation, the answer is 79.1.

CUBES AND CUBE ROOTS

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

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

Example. Find the cube of 4.38.

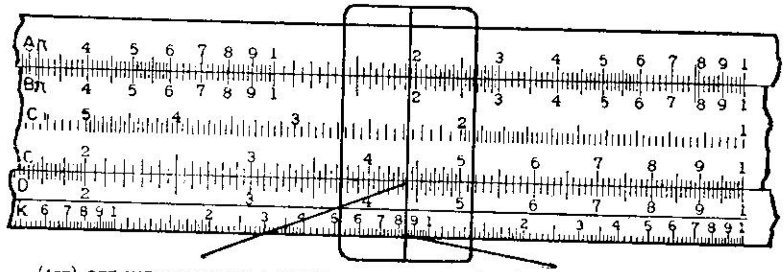


Fig. XXIV.

The decimal point is set as previously explained on page 6. Cubing 4, the nearest round number to 4.38, $4 \times 4 \times 4 = 64$. Therefore the answer must be 84, and not 8.4 or 840.

Rule: *To find the cube root of a number, set the indicator to the number on the K scale and read the cube root on D, under the indicator line.*

Important. The K scale consists of three sections. The cube roots of whole numbers with 1 or 4 digits, and the cube roots of decimal quantities with two or five zeros following the decimal point, are found by using the left hand section. The cube roots of whole numbers with 2 or 5 digits, and the cube roots of decimal quantities with 1 or 4 zeros following the decimal point are found by using the middle section. The cube roots of whole numbers with 3 or 6 digits, and the cube roots of decimal quantities with no zero or 3 zeros following the decimal point are found by using the right hand section. Thus: the cube roots of .008, .000008, and 8000 are found on D opposite the left hand 8; the cube roots of .00008, .08, 80 and 80000 are found on D opposite the middle 8; and the cube roots of .0008, 0.8, 800 and 800,000 are found on D opposite the right hand 8.

Example. Find the cube roots of 6.25, 62.5 and 625.0.

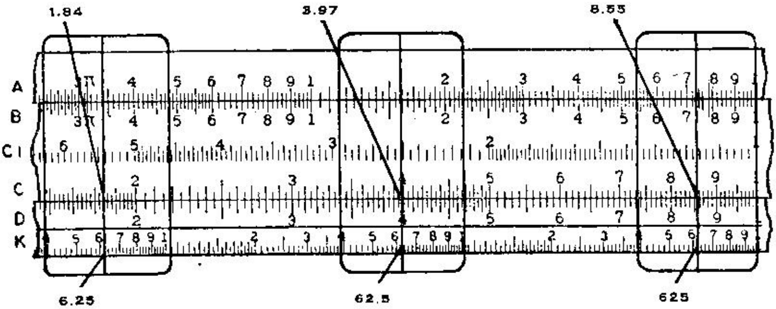


Fig. XXV.

The Decimal Point. In cube root the decimal point is placed as follows.

Where a decimal fraction has 3, 4 or 5 zeros after the decimal point, its cube root will have one zero between the decimal point and the answer as given on the D scale.

Where a decimal fraction has no zeros, 1 or 2 zeros after the decimal point, its cube root will be the answer as given on the D scale, preceded by the decimal point.

Where a whole number consists of 1, 2 or 3 digits, its cube root will have one digit before the decimal point.

Where a whole number consists of 4, 5 or 6 digits, its cube root will have two digits before the decimal point.

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 value of the sine of any angle 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; or by removing the slide and re-inserting it with the S and T scales outward, in which case, when the indices of the slide and stock are in alignment, the sine may be read directly on the A scale opposite the angle on the S scale.*

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

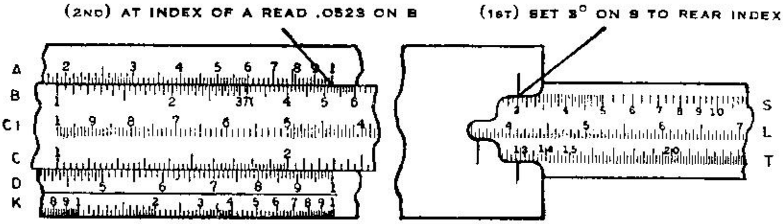


Fig. XXVI.

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; or if the slide is reversed, the gauge point on S is set to the number of minutes or seconds on A, and the sine read on A at the index of S. 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; or, with the slide reversed, set the "seconds" gauge point to 10 on A, and at the index of S read 485 on A. Since the sine of 1″ is about .000005, the sine of 10″ 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; or with the slide reversed, set the "minutes" gauge point on S to 12 on A, and at the index of S read 349 on A. Since the sine of 1′ is about .0003, the sine of 12′ 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; or, by reversing the slide as noted under sines, in which case, when the indices of the slide and body are in alignment, the tangent may be read directly on scale D opposite the angle on scale T. 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°

Slide reversed:

To 4 on A set left index of S. At 11° on S read 7.64 on A.

Slide in regular position:

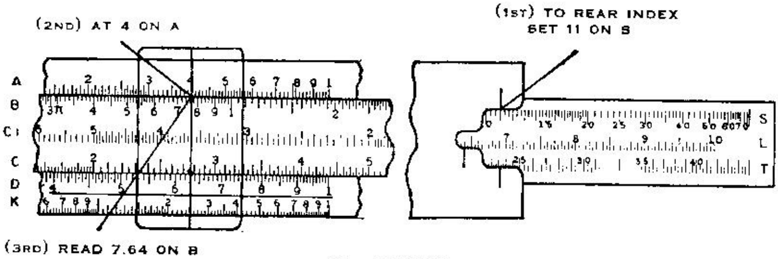


Fig. XXVII.

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

Slide reversed:

To 3 on D set 25° on T. At right index of T read 6.44 on D.

Slide in regular position:

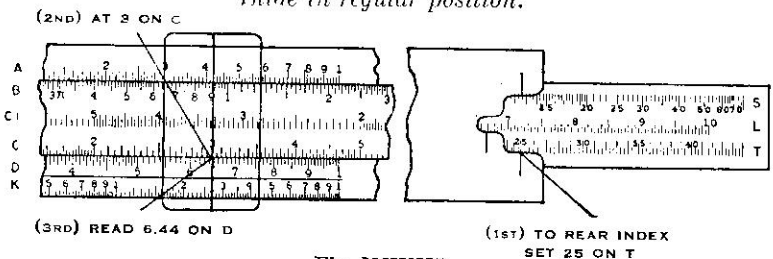


Fig. XXVIII.

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

Slide reversed:

To 3 on A set 9° on S. At 30° on S read 9.59 on A.

Slide in regular position:

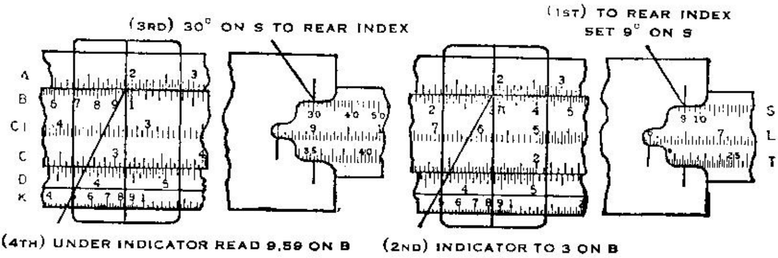


Fig. XXIX.

CHECKING AND SOLVING OF TRIANGLES

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

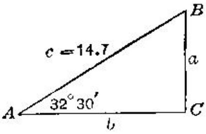


Fig. XXX.

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—

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

Slide in regular position:

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

Slide reversed:

To 14.7 on A set 90° on S. At 32° 30′ on S read 7.9 on A. At 57° 30′ on S read 12.4 on A.

If it had 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.

$\cos x = \sin\ (90° - x)$

$$\cot x = \frac{1}{\tan x}$$

$$\sec x = \frac{1}{\sin\ (90° - x)}$$

$$\csc x = \frac{1}{\sin x}$$

Thus, if make the problem read $3.4 \times \csc 14^\circ = y$

$$y = \frac{3.4}{\sin 14^\circ}$$

and solve as follows:

With slide reversed:

To 3.4 on A set 14° on S. At right index of S read 14.05 on A.

Slide in regular position:

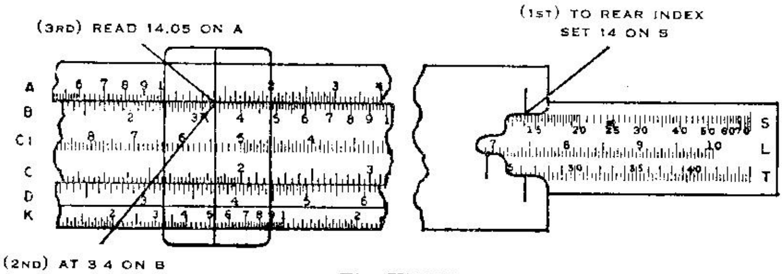


Fig. XXXI.

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 opposite the index on the underside of the rule; or, with the slide reversed, set the indices of L and D in alignment, and read the logarithim directly on L opposite the number on D.*

Example.—To find the logarithm of 40, set 4 on C over the right index of D; underneath read 602 on L; or, with the slide reversed and indices of L and D in alignment, bring hairline of indicator to 40 on D, and read 602 on L under hairline of indicator.

12.364. kk. y. yx. chM.

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