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Self-teaching

INSTRUCTION MANUAL

MANIPHASE Slide Rule

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HOW TO USE A SLIDE RULE

The slide rule is an instrument for performing mathematical operations quickly and easily and yet with sufficient accuracy for most engineering computations. The slide rule is based on logarithms and those familiar with the use of logarithms know that to multiply, the logarithms of the numbers are added together; to divide, the logarithms are subtracted. A slide rule makes the necessary addition or subtractions of logarithms **mechanically.** It should be remembered though, it is **not** necessary to understand logarithms to be able to use a slide rule.

The slide rule has application to problems involving multiplication and division of numbers, squares, square roots, proportions, percentages, trigonometric functions, logarithmic functions and combinations involving all of these phases of mathematics.

To the uninstructed student or layman, the slide rule may appear difficult to understand because of the confusion caused by the numerous scales. However, in reality, it is very simple to operate. By far, its greatest use is confined to Multiplication and Division, and the beginner is advised to devote his first study to simple operations in these two phases.

The beginner should have no difficulty in mastering the use of the slide rule if he will study the instructions carefully and follow the directions, step by step. Go slowly and surely, and much time will be saved.

GENERAL DESCRIPTION OF A SLIDE RULE

The Slide Rule consists of three parts:—The **BODY**, or "stock", as it is sometimes called; the **SLIDE**, which moves in the grooves of the rule; and the **INDICATOR**.

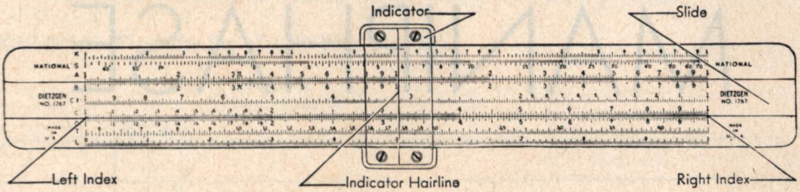

Fig. 1

The face of the rule contains the following ten scales. Each scale has a specific use and each will be explained in detail in subsequent sections of this manual.

"D" Scale—Used with the "C" Scale for Multiplication and Division.

"C" Scale—Identical to the "D" Scale, and used with the "D" Scale for Multiplication and Division.

"A" Scale—Used with the "C" and "D" for finding Squares and Square Roots.

"B" Scale—Identical to the "A" Scale, and also used with the "C" and "D" Scales for finding Squares and Square Roots.

"K" Scale—Used with "C" and "D" Scales for finding Cubes & Cube Roots.

"CI" Scale—A reciprocal scale used with the "C", "D" and "T" Scales.

"S" Scale—A Trigonometric Scale used with the "A" and "B" Scales for problems involving the Sine of angles.

"T" Scale—A Trigonometric Scale used with the "C", "D" and "CI" Scales for problems involving the Tangent of angles.

"L" Scale—Used with the "C" and "D" Scales for finding Logarithms.

READING THE SCALES

Before attempting to operate the slide rule, the beginner must first learn how to read the scales. When quick reading of the scales has been entirely mastered, the beginner will find that he can solve problems more rapidly.

Significant figures. A slide rule only enables one to work with significant figures of a number. The significant figures are the ones that remain after the zeros to the right or left of a given number have been removed.

For example:—The significant figures of the following numbers—0.001736; 1.736; 17.36; 173.6; 1736000—are all the same; namely one—seven—three—six; making a total of four significant figures. Due to the manner in which the slide rule is divided, it can only be read accurately to three significant figures.

To illustrate this, we will indicate the location of the three figure number 384 on the "C" and "D" scales in our explanation of the reading of the scales, as follows:

FIRST STEP: The scales on the slide rule are first divided into ten major divisions, numbered from 1 to 10, giving us our first significant figure. Fig. 2 illustrates the major divisions of the "C" and "D" scales, however the same explanation applies to the "A" and "B" scales.

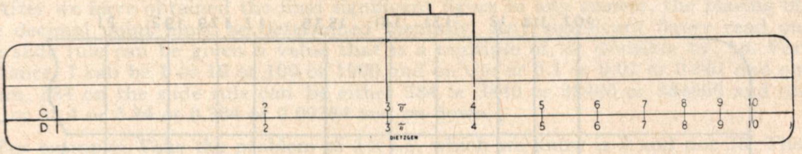

Fig. 2

If the first significant figure of a number is 1, the number will lie between the major division 1 and 2. If it is 2, the number will lie between 2 and 3. If it is 3, between 3 and 4, etc.

The number 384 lies between the major division 3 and 4 as indicated by the bracket (Fig. 2) since the first significant figure of the number is 3.

SECOND STEP: Each of these major divisions are subdivided into ten parts, or secondary divisions, giving our second significant figure (See Fig. 3).

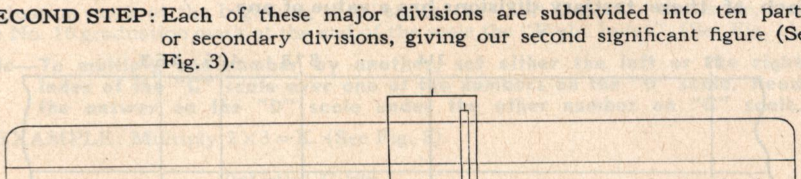

Fig. 3

In the number 384, the second significant figure—8—indicates that the location is between the 8th and 9th secondary division, as indicated by the bracket in Fig. 3. Note that Fig. 3 shows a skeleton scale with the major and secondary divisions filled in. On a 10″ rule, owing to lack of space, only secondary divisions between first and second major divisions are numbered.

THIRD STEP: Each of these secondary divisions is again subdivided into a third set of divisions (tertiary divisions) giving us our third significant figure (See Fig. 4).

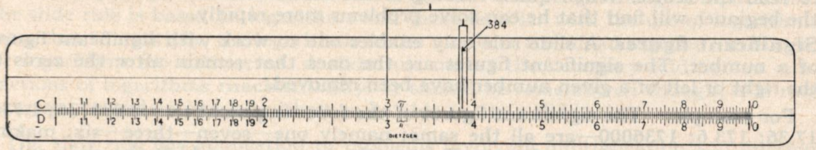

Fig. 4

In the number 384, the third significant figure—4—indicates that the location is the second tertiary division of the 8th secondary division of the third major division as indicated by the arrow in Fig. 4.

You will note that as each major division progressively decreases in size, as you read toward the right, the major divisions from 4 to 10 are not as finely subdivided into tertiary divisions as major divisions from 1 to 4. If space on the rule permitted, each secondary division would be divided into ten tertiary divisions. Therefore:—

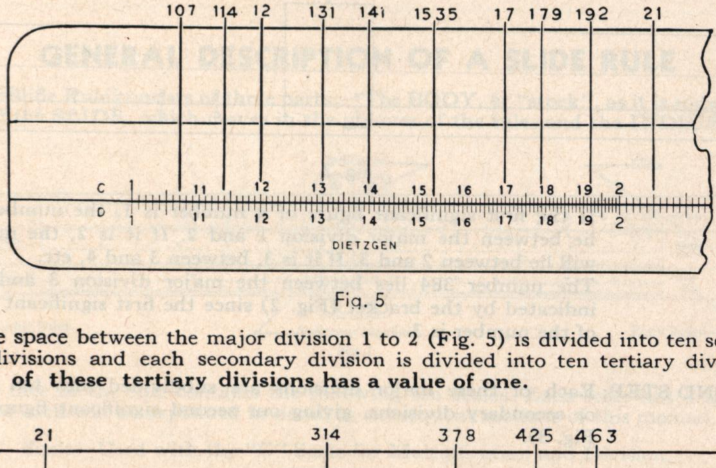

Fig. 5

The space between the major division 1 to 2 (Fig. 5) is divided into ten secondary divisions and each secondary division is divided into ten tertiary divisions. **Each of these tertiary divisions has a value of one.**

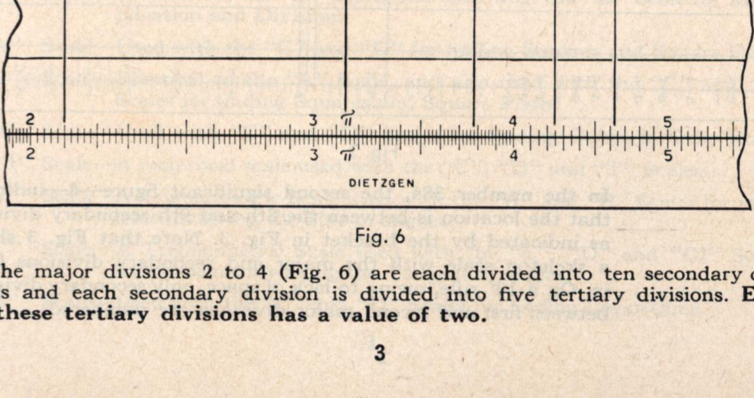

Fig. 6

The major divisions 2 to 4 (Fig. 6) are each divided into ten secondary divisions and each secondary division is divided into five tertiary divisions. **Each of these tertiary divisions has a value of two.**

The major divisions 4 to 10 (Fig. 7) are each divided into ten secondary divisions and each secondary division is divided into one tertiary division. **Each of these tertiary divisions has a value of five.**

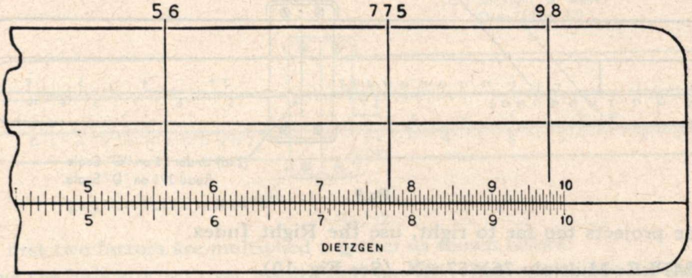

Fig. 7

If it is necessary to read to four significant figures, we are compelled to interpolate, or infer, this fourth figure, which falls between the tertiary divisions. This is illustrated by the number 1535 in Fig. 5 above.

After we have obtained the final significant figure in any answer, the placing of the decimal point must be determined mentally. Any significant figure read on the slide rule can be given a value that is a multiple of, or divisible by, 10. For instance, 1 can be 1 or 10 or 100 or 1000 and on up; or 0.1 or 0.01 or 0.001 and on down. 384 on the slide rule can be either 384 or 3840 or 38400 or 384000 and on up, or 38.4 or 3.84 or 0.384 or 0.00384 and on down.

For example: Take the problem of 2×1.5, which we know is 3 and not 30. The significant figure in the answer is 3, and it would be the same significant figure in the answer if we multiplied 20×150, which we know to be 3000. The setting on the slide rule would remain the same if we were multiplying, as suggested above, either 2×1.5, 20×150, or 200×15000, because all we are interested in is the significant figures in the problem. The number of zeros and the placing of the decimal point will have to be determined afterward.

MULTIPLICATION

To simplify the explanation of the use of the slide rule we will call the No. 1 graduation mark at the beginning of all scales, the "Left Index" of that scale, and the No. 10 graduation mark at the end of the scale the "Right Index". (See Fig. 1).

Rule—To multiply one number by another, set either the left or the right index of the "C" scale over one of the numbers on the "D" scale. Read the answer on the "D" scale under the other number on "C" scale.

EXAMPLE: Multiply 2×3 = X. (See Fig. 8).

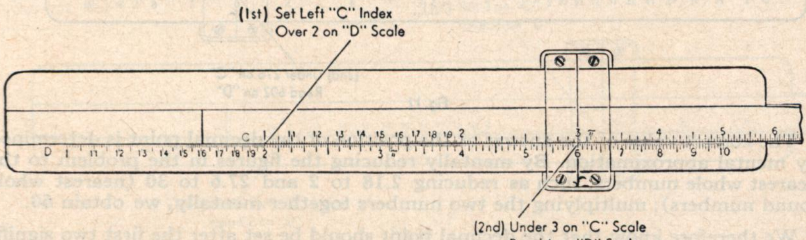

Fig. 8

EXAMPLE: Multiply 17×23=X. (See Fig. 9).

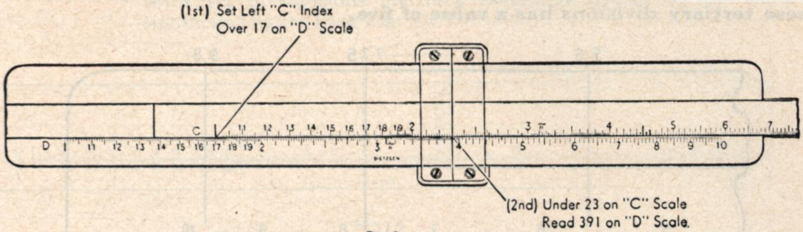

Fig. 9

If slide projects too far to right, use the Right Index.

EXAMPLE: Multiply 76×57=X. (See Fig. 10).

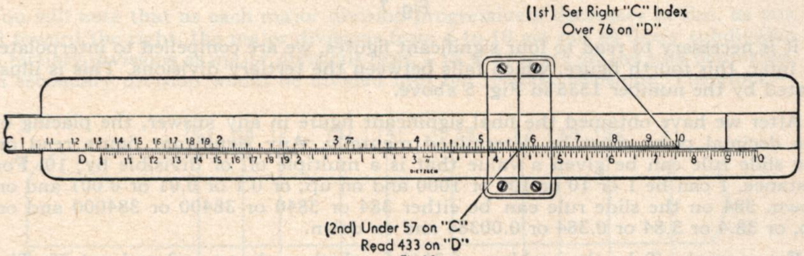

Fig.10

DECIMAL POINT

Heretofore we have not had problems involving decimal fractions. Below is an example of multiplying 2.18×27.6, both numbers containing decimal fractions.

In making this multiplication, treat these two numbers as if they did not contain a decimal point; that is, 218 and 276, and multiply them together. This multiplication would give you a reading on the slide rule of 602.

EXAMPLE: Multiply 2.18×27.6=(See Fig. 11).

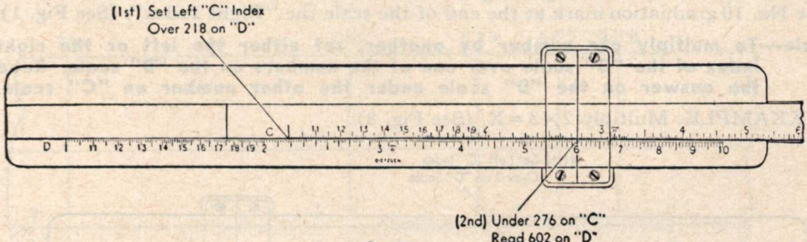

Fig. 11

The correct value of the answer or the position of the decimal point is determined by mental approximation. By mentally reducing the figures in the problem to the nearest whole numbers, such as reducing 2.18 to 2 and 27.6 to 30 (nearest whole round numbers); multiplying the two numbers together mentally, we obtain 60.

We therefore know that the decimal point should be set after the first two significant figures; namely, 60, and the correct answer is **60.2**.

MULTIPLICATION OF THREE OR MORE FACTORS

EXAMPLE: Multiply 71.3×36×0.0194 = X (See Fig. 12).

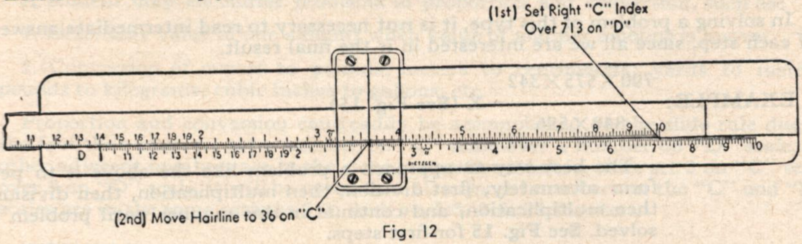

Fig. 12

The first two factors are multiplied together as shown before.

Leave the indicator set over result (256) on "D". There is no need of taking the product of these two numbers, as all we are interested in is the final result.

Bring the left index of "C" under the indicator hairline.

Move hairline to 194 on "C" read answer, 498, under hairline on "D". (Fig. 13).

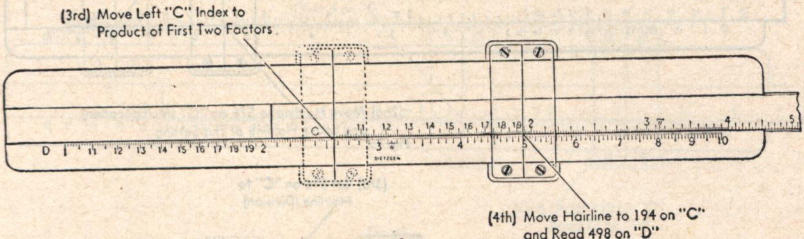

Fig. 13

Approximate the decimal point mentally multiplying 70×30×0.02, which is 42. Thus, decimal point is after first two significant figures and the answer is **49.8.**

Any number of factors can be multiplied together in a similar manner. For a more efficient way of multiplying three or more factors together, see "Multiplication Involving Three Factors" in the section "RECIPROCAL 'CI' SCALE".

DIVISION

Division is the reverse of multiplication.

Rule—To divide one number by another, set the divisor on the "C" scale over the dividend on the "D" scale, and read the quotient, answer, on the "D" scale under the index on the "C" scale.

Referring to Fig. 8 we note that 2×3 equals 6. By the same setting, 6÷3 equals 2.

EXAMPLE: 6÷3 = X (See Fig. 14).

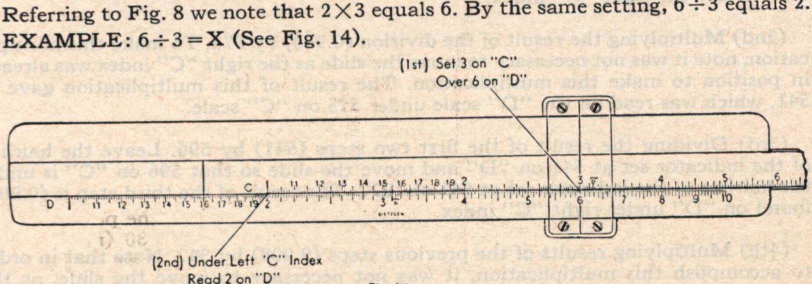

Fig. 14

The decimal point is again determined mentally by approximation.

PROBLEMS INVOLVING BOTH MULTIPLICATION AND DIVISION

In solving a problem of this type, it is **not** necessary to read intermediate answers of each step, since all we are interested in is the final result.

EXAMPLE: $\frac{790\times575\times342}{840\times596} = X$ (See Fig. 15)

The best way to approach a problem like the above is to perform alternately, first division, then multiplication, then division, then multiplication, and continue in this manner until problem is solved. See Fig. 15 for first steps.

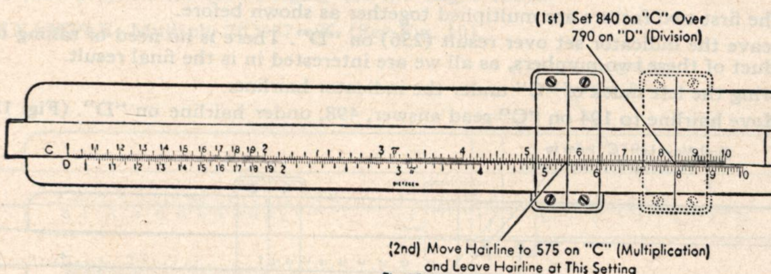

Fig. 15

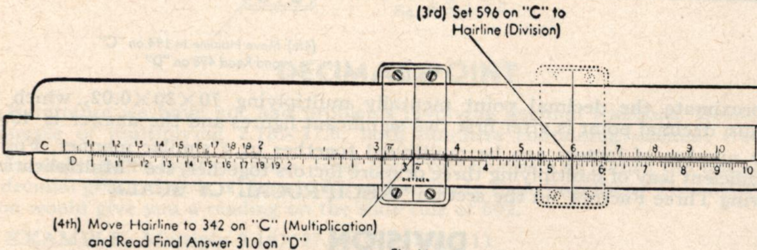

Fig. 16

You will note that the above problem required four steps:

(1st) Dividing 790 by 840. The result (0.940) of this division was found on "D" scale under the right "C" index.

(2nd) Multiplying the result of the division (0.940) by 575. To make this multiplication, note it was not necessary to move the slide as the right "C" index was already in position to make this multiplication. The result of this multiplication gave us 541, which was read on the "D" scale under 575 on "C" scale.

(3rd) Dividing the result of the first two steps (541) by 596. Leave the hairline of the indicator set at 541 on "D" and move the slide so that 596 on "C" is under the hairline of the indicator set at 541 on "D". The result of the third step is (0.908) found on "D" under right "C" index.

(4th) Multiplying results of the previous steps (0.908) by 342. Note that in order to accomplish this multiplication, it was not necessary to move the slide, as the right "C" index was already in position over (0.098) on "D", and the final result 310 was read on "D" under 342 on "C".

PROPORTION

A student may encounter problems in proportion and conversion, such as:

1. Determine value of one amount when value of another amount is known.

2. Conversion of ounces to pounds; meters to centimeters; yards to meters; pounds to kilograms; cubic inches to gallons, etc.

Proportion and conversion can readily be accomplished on the slide rule due to the fact that when we set a number on "C" scale over a number on "D" scale, all other adjacent numbers are in the same proportion; that is, if we set 3 on "C" scale over 9 on "D" scale, it will be noted that all adjacent numbers on the "C" and "D" scales are in the same ratio as 3:9; such as, 1:3. 2:6. 25:75; etc.

EXAMPLE in proportion:

If we know that 231 cubic inches equals 4 quarts and we wish to ascertain the number of quarts contained in 410 cubic inches, we set 231 on "C" over 4 on "D" and under 410 on "C", we read 7.1 quarts on "D" (See Fig. 17).

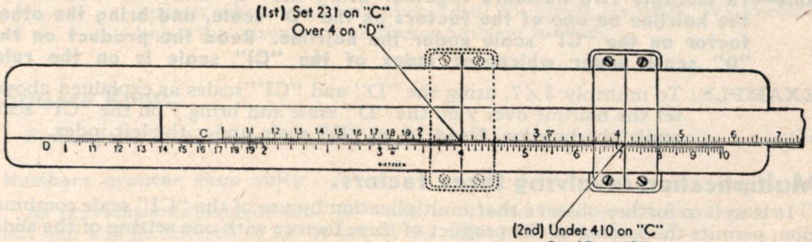

Fig. 17

It will be noted from the above setting that for any number of given cubic inches on scale "C", the corresponding number of quarts in same can be read on scale "D". For instance, 260 cubic inches equal 4½ quarts, etc.

RECIPROCAL "CI" SCALE

The "CI" scale on the face of the slide is an inverted "C" scale and is in reverse relation to the scales "C" and "D".

Numbers on the "CI" scale are reciprocals of numbers directly below on "C" scale.

Rule—To find the reciprocal of a given number (1 divided by the number), or $\frac{1}{n}$ set the hairline on the given number on the "C" scale and read its reciprocal under the hairline on the "CI" scale.

EXAMPLE: To find the reciprocal of 4, set the hairline on 4 on the "C" scale and read its reciprocal 0.25 under the hairline on the "CI" scale.

Multiplication by use of the "CI" scale.

The "CI" scale besides permitting the reading of reciprocal numbers, can be used in multiplication and division in conjunction with the "D" scale.

Rule—To multiply two numbers together using the "D" and "CI" scales, set the hairline on one of the factors on the "D" scale, and bring the other factor on the "CI" scale under the hairline. Read the product on the "D" scale under whichever index of the "CI" scale is on the rule.

EXAMPLE: To multiply 2×7, using the "D" and "CI" scales as explained above, set the hairline over 2 on the "D" scale and bring 7 on the "CI" scale under the hairline. Read 14 on "D" scale under the left index.

Multiplication involving three factors.

It is well to further observe that multiplication by use of the "CI" scale combination, permits the finding of the product of three factors with one setting of the slide.

Rule—To find the product of three factors, set the hairline over one factor on the "D" scale and bring the other factor on the "CI" scale under the hairline. Move the indicator hairline to the third factor on the "C" scale and read the product under the hairline on the "D" scale.

EXAMPLE: To multiply 2×7×4, set hairline over 2 on the "D" scale, bring the 7 on the "CI" scale under hairline. Move hairline to 4 on the "C" scale and read the product 56 under the hairline on the "D" scale.

Division by use of the "CI" scale.

Rule—To divide one number by another using the "CI" scale, set the index of the "CI" scale over the number to be divided on the "D" scale, move the hairline to the divisor on the "CI" scale and read the quotient on the "D" scale.

EXAMPLE: To divide 6 by 3, set the right hand index of the "CI" scale over 6 on the "D" scale, move the hairline to 3 on the "CI" scale and read the quotient 2 under the hairline on the "D" scale.

SQUARES AND SQUARE ROOTS

Problems involving Squares and Square Roots are worked on the "A" and "B" scales in conjunction with the "C" and "D" scales.

Squares.

The "A" and "B" scales are each logarithmic scales of two identical parts—each part being one-half as long but identical to the "D" scale. Therefore, if the indicator hairline is set over a number on the "D" scale, the Square of the number will be found on the "A" scale under the indicator hairline.

Rule—To find the Square of a number, set the indicator hairline over the number to be Squared on the "D" scale, and read the Square of the number on the "A" scale under the indicator hairline.

EXAMPLE: Find the Square of 81.5 (See Fig. 18).

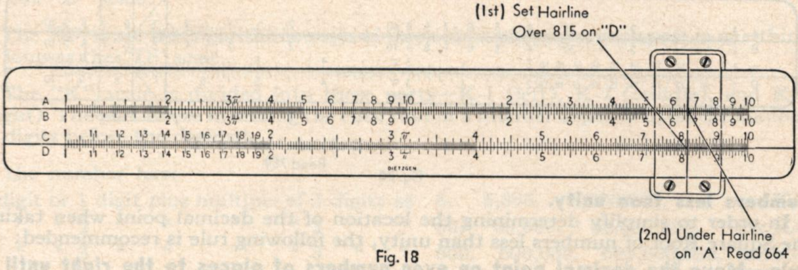

Fig. 18

The decimal point is determined by mentally Squaring 80, (the nearest whole round number, to 81.5), giving us 6400. We therefore know the answer to the above problem is **6640.**

Square Roots.

Finding the Square Root is essentially the reverse process of Squaring a number.

Numbers greater than unity

As previously explained, the "A" scale is divided into two identical parts. The left half will be referred to as "A-Left", the right half as "A-Right".

Rule—To find the Square Root of a number greater than unity—if there are an odd number of figures before the decimal point, set the hairline over the number on "A-Left" and read the Square Root under the hairline on the "D" scale. If the number has an even number of figures before the decimal point, set the hairline over the number on "A-Right" and read the Square Root under the hairline on the "D" scale. Determine the location of the decimal point by mental approximation.

EXAMPLE: Find the Square Root of 567 (See Fig. 19).

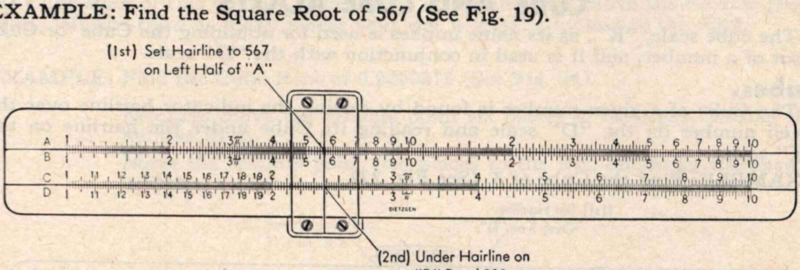

Fig. 19

Use "A-Left" since there are an odd number of figures before the decimal point. By mental approximation locate the decimal point after the second significant figure, making the answer **23.8.**

EXAMPLE: Find the Square Root of 5760 (See Fig. 20).
Use "A-Right" since there are an even number of figures before the

decimal point. By mental approximation, locate the decimal point after the second significant figure, making the answer **75.9.**

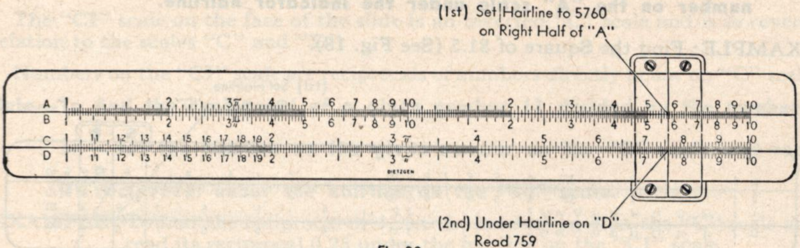

Fig. 20

Numbers less than unity.

In order to simplify determining the location of the decimal point when taking the Square Root of numbers less than unity, the following rule is recommended:

Rule—Move the decimal point on *even* numbers of places to the *right* until a number between 1 and 100 is obtained. Find the Square Root of the number thus obtained, as explained above. Move the decimal point to the *left* one-half as many places as it was originally moved to the *right*.

EXAMPLE: Find the Square Root of 0.0956 (See Fig. 21).

Move the decimal point two places to the right, thus obtaining 9.56. Use "A-Left" because there are now an odd number of figures before the decimal point. Move the decimal one place to the left, making the answer **0.309.**

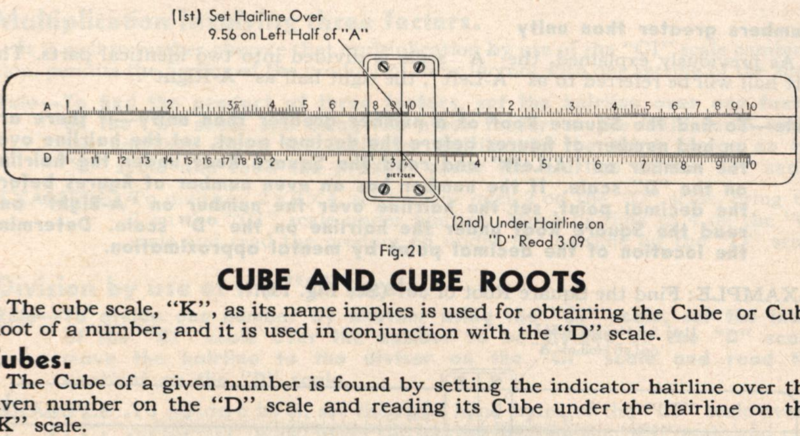

Fig. 21

CUBE AND CUBE ROOTS

The cube scale, "K", as its name implies is used for obtaining the Cube or Cube Root of a number, and it is used in conjunction with the "D" scale.

Cubes.

The Cube of a given number is found by setting the indicator hairline over the given number on the "D" scale and reading its Cube under the hairline on the "K" scale.

EXAMPLE: Find the Cube of 3. (See Fig. 22).

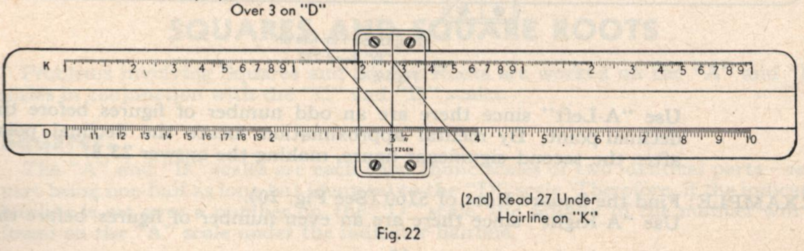

Fig. 22

Cube Roots.

Conversely, the Cube Root of a given number is found by setting the indicator over the given number on the "K" scale and reading its Cube Root under the hairline on the "D" scale.

The "K" scale is a logarithmic scale of three identical parts, each part is one-third as long as the "D" scale.

The "K" scale is divided into three parts—K-1 (left), K-2 (middle), and K-3 (right). The part to use in finding the cube root of a number depends upon the number of digits before the decimal.

If the number has:

1 digit or 1 digit plus multiple of 3 digits as	6,	6,000,	6,000,000,	use K-1
2 " " 2 " " " " 3 " "	60,	60,000,	60,000,000,	use K-2
3 " " 3 " " " " 3 " "	600,	600,000,	600,000,000,	use K-3

EXAMPLE: Find the cube root of 34.56 (See Fig 23).

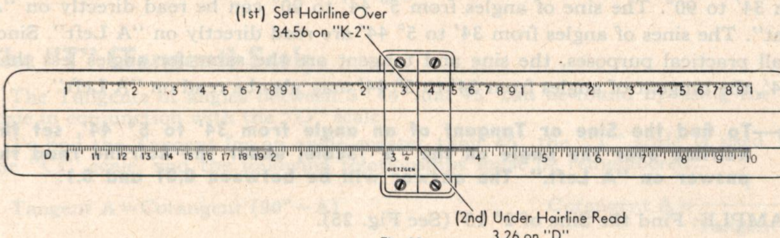

Fig. 23

Cube Roots of Numbers Less than Unity.

To find the Cube Root of numbers less than 1 (unity), move the decimal point to the right three places at a time until a number greater than 1 is obtained. Solve for the Cube Root of this number as explained above and then move the decimal point to the left one-third as many places as it was originally moved to the right.

EXAMPLE: Find the Cube Root of 0.0000315 (See Fig. 24).

Mentally move the decimal point six places to the right, making the number 31.5.

Move the decimal point two places to the left, obtaining the answer 0.0316.

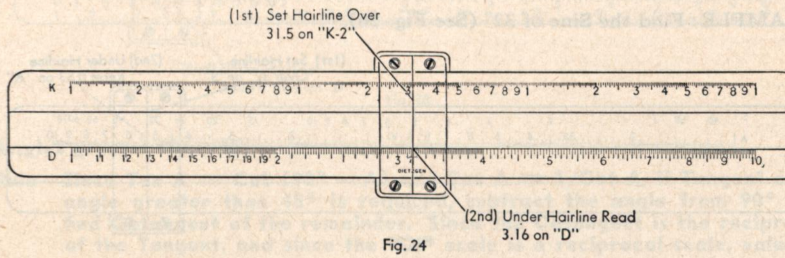

Fig. 24

TRIGONOMETRY

The following section on Trigonometry does not apply to the No. 1772A, Pocket Slide Rule, since it does not have Trigonometric Scales.

The two trigonometric scales, namely the "S" (Sine) Scale; and the "T" (Tangent) Scale, are used with other scales on the rule for problems involving trigonometric functions.

It will be noted that the "S" and "T" Scales are divided into Degrees and Minutes. For example, on the "S" Scale between 15° and 16° there are six spaces and consequently, each division represents ten minutes (10′). By similar reasoning, the value of each division for any part of any of the trigonometric scales can be determined.

The "S" (Sine) Scale.

The "S" Scale is used with the "A" and "B" Scales for finding the sines of angles from 34′ to 90°. The sine of angles from 5° 44′ to 90° can be read directly on "A Right". The sines of angles from 34′ to 5° 44′ are read directly on "A Left". Since for all practical purposes, the sine and tangent are the same for angles less than 5° 44′, the tangent of angles from 34′ to 5° 44′ may also be read on "A Left".

Rule—To find the Sine or Tangent of an angle from 34' to 5° 44', set the hairline over the angle on the "S" Scale, under the hairline read the answer on "A Left." The answer will be between 0.01 and 0.1.

EXAMPLE: Find the Sine of 2° 15′ (See Fig. 25).

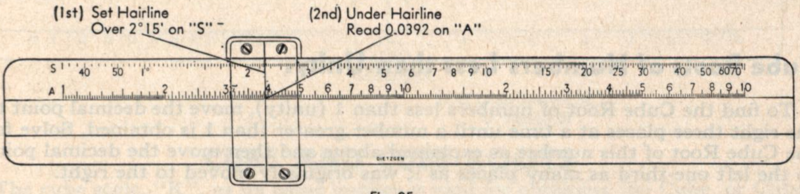

Fig. 25

It should be remembered that .0392 is also the value of the tangent of 2° 15′.

Rule—To find the Sine of an angle from 5° 44' to 90°, set the hairline over the angle on the "S" Scale, under the hairline read the answer on "A Right." The answer will be between 0.1 and 1.0.

EXAMPLE: Find the Sine of 32° (See Fig. 26).

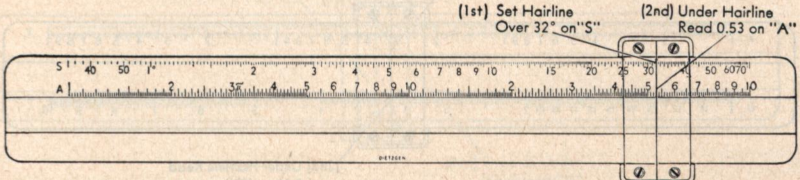

Fig. 26

By remembering the following trigonometric equations, the Cosine, Secant and Cosecant can be found by using the "S" Scale with the "A" and "CI" Scales.

$$\text{Sin A} = \text{Cos } (90° - \text{A}); \qquad \text{Cosine A} = \text{Sin } (90° - \text{A})$$

$$\text{Secant A} = \frac{1}{\text{Cos A}}; \qquad \text{Cosecant A} = \frac{1}{\text{Sin A}}$$

EXAMPLE: Find the Cosine of 37° (See Fig. 27).

$$\text{Cos } 37° = \text{Sin } (90° - 37°) = \text{Sin } 53°$$

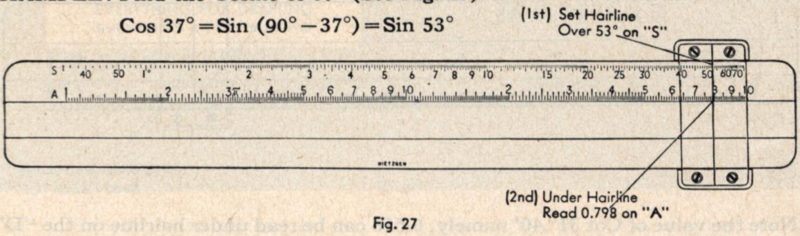

Fig. 27

The "T" (Tangent) Scale.

The Tangents of angles between 5° 44′ and 45° can be found by using the "T" scale in conjunction with the "D" scale.

To find the Tangent for an angle greater than 45° the "T" scale is used with the "CI" scale, and the following relationships must be remembered:

$$\text{Tangent A} = \text{Cotangent } (90° - \text{A}) \qquad \text{Cotangent A} = \frac{1}{\text{Tangent A}}$$

Angles less than 45°

Rule—To find the Tangent of an angle from 5° 44' to 45°, set the hairline over the angle on the "T" scale, under the hairline read the answer on the "D" scale. The range of the value of the answer will be between 0.1 and 1.0.

EXAMPLE: Find the Tangent of 7° 40′ (See Fig. 28).

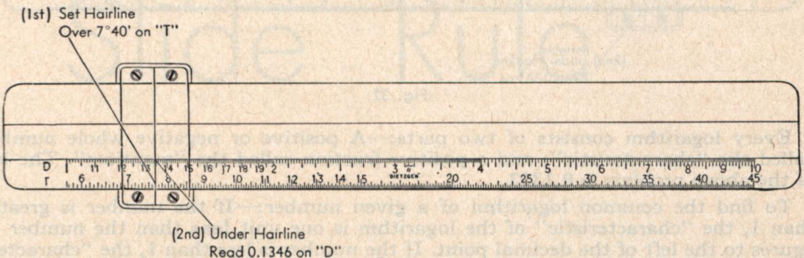

Fig. 28

Angles greater than 45°

Rule—Since Tan A = Cot (90° − A) and Tan A = 1/Cot A, if Tangent of an angle greater than 45° is required, subtract the angle from 90° and find Cotangent of the remainder. Since the Cotangent is the reciprocal of the Tangent, and since the "CI" scale is a reciprocal scale, value of

Tangent can be read directly on the "CI" scale when the rule is closed, i.e. the indices of the "C" and "D" scale are in alignment. The range of the value of the answer will be between 1.0 and 10.0.

EXAMPLE: Find the Tangent of 58° 20′ (See Fig. 29).
Tan 58° 20′ = Cot (90° − 58° 20′) = Cot 31° 40′

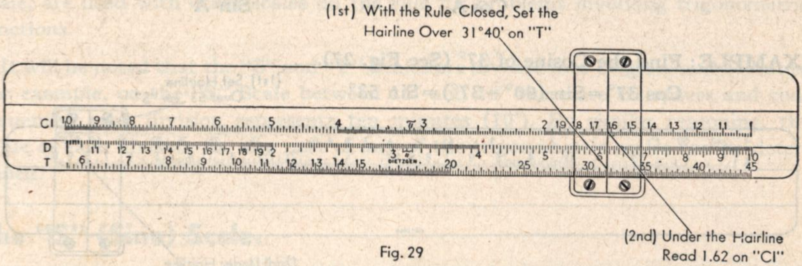

Fig. 29

Note the value of Cot 31° 40′ namely, 0.616 can be read under hairline on the "D".

LOGARITHMS

The "L" scale (a scale of equal parts) permits the reading of the logarithm (mantissa) of numbers on the "D" scale.

Rule—Set the hairline over the number on the "D" scale and read the logarithm (mantissa) under the hairline on the "L" scale.

EXAMPLE: Find the log of 1.35 (See Fig. 32).

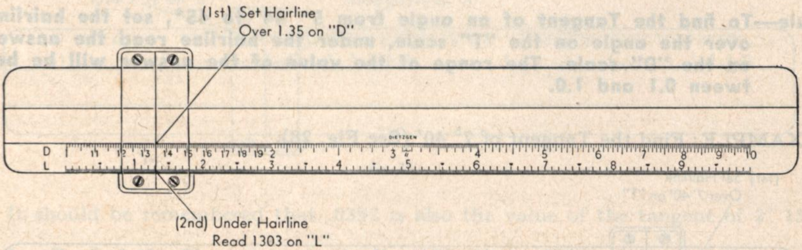

Fig. 32

Every logarithm consists of two parts:—A positive or negative whole number called the "characteristic"; and a positive fraction called the "mantissa". The log of the above problem is **0.1303.**

To find the common logarithm of a given number:—If the number is greater than 1, the "characteristic" of the logarithm is one unit **less** than the number of figures to the left of the decimal point. If the number is less than 1, the "characteristic" of the logarithm is negative and one unit **more** than the number of zeros between the decimal point and the first significant figure of the given number.

To find the number corresponding to a given common logarithm:—If the "characteristic" is positive, the number of figures before the decimal point is one more than the number of units in the "characteristic". If the "characteristic" is negative, the number of zeros between the decimal point and the first significant figure is one less than the number of units in the "characteristic".

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