Introducing

The Slide Rule

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Simplified Instructions for Beginners

in the Use of the Slide Rule

REVISED EDITION

Published By

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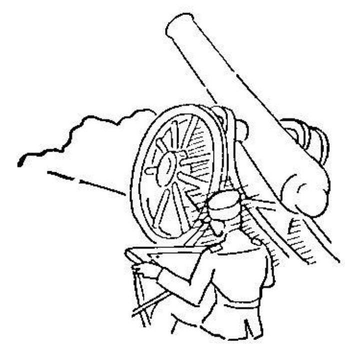
THE SLIDE RULE

To every individual who deals with numbers, the slide rule is important first of all as a labor saving device in computation and then as a check on work completed. To the engineer, merchant, chemist, draftsman, architect, physicist, accountant, contractor, army officer, shop foreman, in fact, to nearly every individual in the industrial or professional world the slide rule is an aid in solving the problems peculiar to his field.

The amazing powers of modern calculations are due to three inventions; the Hindu-Arabic numeral system with its use of zero, the decimal system, and logarithms. A Scotch mathematician, John Napier (1550-1617), invented logarithms and first showed how to use them in numerical computation. This invention made possible the slide rule, for it is really a logarithmic rule. The invention of the slide rule is credited by different authorities to two English clergymen who devoted most of their energies to the study of mathematics. One was William Oughtred (1574-1600); the other, Edmund Gunther (1581-1626).



Few changes were made with the rule until nearly a century later when Amedee Mannheim (1831-1906) of Paris, a French army officer, used the slide rule in calculation of artillery fire and standardized it; consequently our present most common type of rule is called the Mannheim Slide Rule.

Since the logarithms of numbers are not proportional to the numbers (i.e. log 1 = .0000, log 2 = .30103, log 3 = .47712), it will be noted that the main divisions on the slide rule are not spaced regularly as they are on the English and metric rules used for measurement. Like the metric rule, however, the smaller divisions are based on the decimal system and represent one unit or two units, depending on the space between the figures. Toward the left of the rule the spaces between main divisions are larger so they can be subdivided more closely; toward the right of the rule the space between main divisions is less and the division into fractional parts is not as close.

The best way to understand the slide rule is to observe its various parts and to practice making the settings and taking readings.

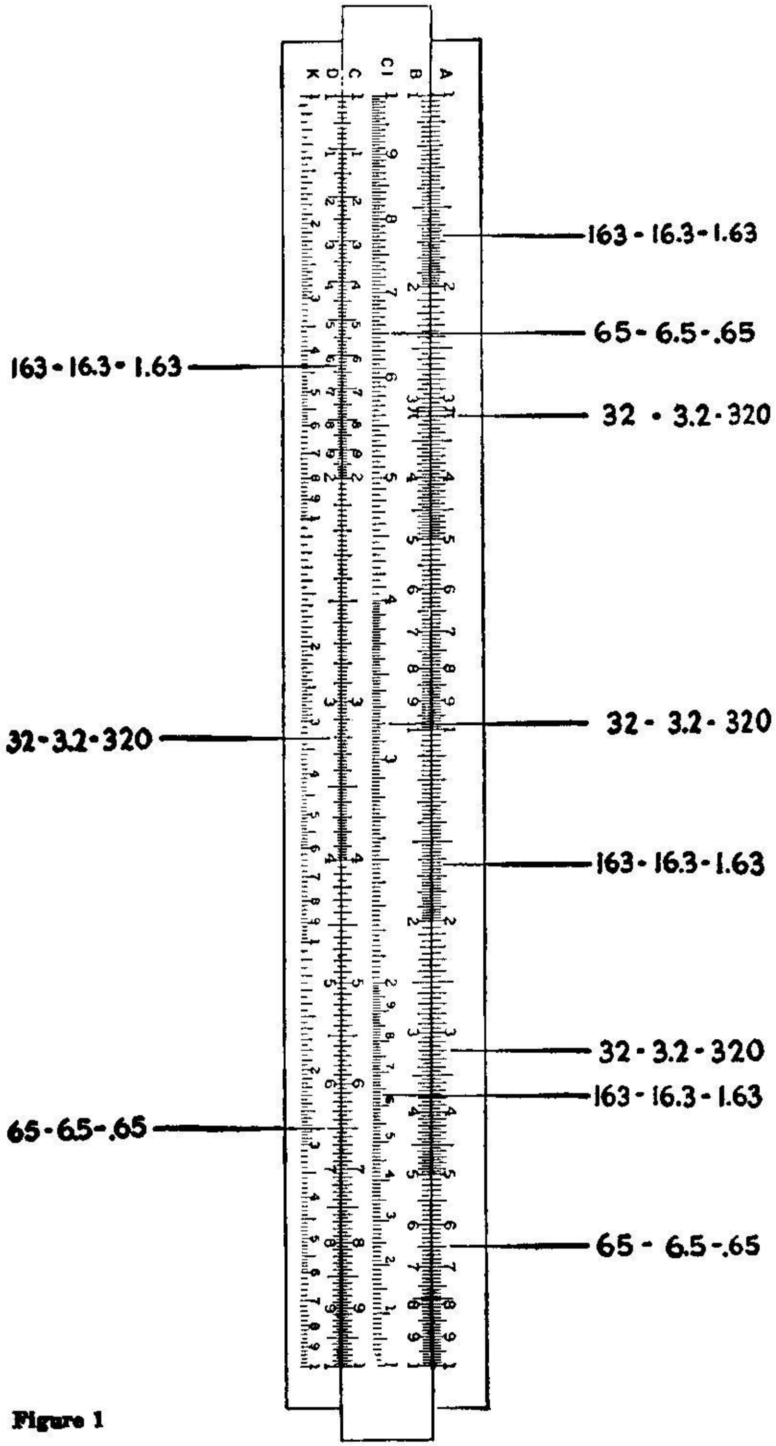


Figure 1

The slide rule consists of three parts: the rule, the slide, and the runner, also called the indicator or cursor. The scale, on some rules, is slightly longer than the rule and moves in the groove in the center of the face of the rule. The runner or indicator also slides on the face of the rule. It is provided with a fine line called a hair line which remains perpendicular to the axis of the rule. At either end of each scale is found the number 1 called the index. The one at the right is called the right index; at the left, the left index. These indexes may be read 1, 10, 100, 1000 etc. depending on the numbers of the problem.

Most slide rules contain four scales A, B, C, and D. Some others contain a CI and a K scale.

On the reverse of the slide on many rules are three other scales marked S, L, and T.

Take up your slide rule and note the following points:

(1) Scales A and B are alike; they are divided into two parts exactly the same.

(2) Scales C and D are alike, and they are constructed to a larger scale than A and B, i. e. it is farther between 1 and 2 on these scales than on A and B.

(3) Scale CI is the reverse of scale C.

(4) Scale K is the cube of the numbers directly above it on scale D.

(5) Scales S, L, and T are on the reverse of the slide. Scale S is used in considering sines, cosines, secants, and cosecants of angles; scale T for tangents and cotangents; and scale L is an equal parts scale for determining logarithms of numbers.

These scales on the reverse side of the rule may be used in either of two ways. By removing the slide from the groove, turning it over so that the underneath face is uppermost and inserting it into the groove with the indices coinciding, the trigonometric function of an angle or the logarithm of a number may be read directly from the rule. By leaving the slide in its usual position and using the marker corresponding to the hair line on the underneath side of the rule trigonometric functions and logarithms may be read directly from the rule. The latter method is sometimes preferable in calculation.

These various scales will be explained in greater detail as their uses in computation are considered.

The first thing to learn is to locate numbers on the rule. Numbers with more than three or four digits are located by the first three or four significant figures. (Significant figures are digits other than zeros or zeros both preceded and followed by other digits). Hence 36, 360, 3600, .0036, and 3.6 are all located the same. To locate these numbers you will note that the space between the numbers 3 and 4 on either part of the A and B scales or near the center of the C and D scales (not the small 3 and 4 near the left end of the C and D scales) is divided into ten parts. (Each of these parts is further subdivided, but these subdivisions refer to the third significant figure). Move the runner so that the hair-line coincides with the sixth of these ten divisions past 3. The runner is now set at any one of the above numbers.

Similarly, 11. 1.1, 1100, 110, and .0011 are located at the first of the ten major divisions between 1 (left index) and 2. On the C, D, and CI scales these sub-divisions are sometimes numbered; on others, due to lack of space, they are not.

For these numbers on the C or D scales, the hair line should, therefore, be brought to the small figure 1 immediately to the right of the left index. On the A and B scales the set would be at the first major division to the right of the left index. In this region on scales C, CI, and D, readings may be accurate to the third significant figure with the fourth estimated.

Consider the location of the following numbers as explained:

(Figure 1)

(1) 32	(2) 163	(3) 65
3.2	16.3	6.5
320	1.63	.65

Note that if in a given problem you must interpret 2 as 20, then 3 stands for 30, the 4 for 40 etc., and intermediate points lie proportionally between these figures. Numbers between the 1 and the large 2 (on C and D scales) are numbers between 10 and 20. The small 1 following the large 1 would be read 11 and the left index would be read 10. The first of the ten small divisions between the index and the first 1 would be read 10.1, the following 10.2, 10.3, etc. to the first marked subdivision which is 11.0. This first number may be .101, 1.01, 101, or 1010 depending on the problem. It is the sequence of the numbers that is important. Placing the decimal point correctly by inspection of the final answer gives the problem its correct value. As you go farther up the scale toward the right index, the numbers are closer together and the readings are less accurate.

The A and B scales are read in the same manner, but since they are double scales, the numbers are closer together. The A and B scales are less accurate than the C and D scales but more convenient for some work.

Take up your slide rule and locate the following numbers, remembering that the position of the decimal point does not affect the location of the number:

1. On scale C 198, 28, 4.75, .92.
2. On scale D 36, .38, 2.76, 87.
3. On scale A 5.9, 38, 20, 2.6.

As explained above, where there are ten subdivisions between two major divisions of the interval between two digits, the third significant figure may be read directly from the rule, and a fourth digit may be estimated. On other parts of the rule, it may be necessary to estimate the location of the third figure. For example on the D scale between numbers 250 and 260 there are five subdivisions. Each of these subdivisions represents an increment of two in the third figure. They correspond to 252, 254, etc. The number 253 will, therefore, be located half way between the first and second subdivision past 250. On the same scale between 430 and 440 there is only one dividing line. This line, therefore, corresponds to 435, and

432 would be estimated as 2/5 of the distance between 430 and 435. On the A scale there is no subdivision between 660 and 670. 663 is estimated as 3/10 of the distance between 660 and 670. A little practice will readily accustom you to deciding what digits must be estimated and what fraction of the space must be estimated. Example 1: On scale A locate the following numbers; 2.31, 473, 39.1, 221. Example 2: On scale C locate the following numbers: 235, 112.5, 655, 19.58.

It is well to emphasize at this point the importance of significant figures and correct interpretation of the accuracy of an answer, a topic which is too often neglected in courses in mathematics. Much of the data of arithmetic is approximate. Money can be counted and expressed accurately, but things that are weighed or measured are approximated with a degree of precision depending on the skill of the mechanic and the refinement of the tools with which he is equipped. A rod approximately 10 inches long may be measured with a foot rule graduated in eighths of an inch to a degree of accuracy expressible in three or, at most by an experienced operator, four significant figures. The same rod may be measured with a micrometer with five and possibly six significant figures of accuracy. A ton of coal weighed with an error not exceeding ten pounds represents three figure accuracy. To have the same degree of accuracy a two-pound box of candy must be weighed with an error less than one tenth of an ounce. When two approximate numbers or numbers with a given percentage of error in one of them are to be multiplied or divided, the result has at best no more significant figures of accuracy than the least accurate of the numbers involved. Since ordinary measurement is rarely carried out with more than three places of accuracy, the slide rule will furnish results which are satisfactory for most practical purposes. If greater accuracy is desired, a longer rule or a circular rule may be used which give results correct to one part in ten thousand.

You will use your slide rule to a much better advantage if you practice locating numbers on the scales until you can do this readily. The accuracy of your work will be limited by the length of the rule and by your own ability to estimate numbers that fall between the marks on the rule.

The arithmetical operations readily performed by the slide rule are multiplication, division, proportion, percentage, squares and cubes of numbers, square and cube roots, and problems in mensuration involving these operations. These operations will be taken up separately in order to familiarize you with the use of the rule.

MULTIPLICATION

In multiplication either the A and B or C and D scales may be used, but more accurate results can be obtained by using the C and D scales since they are constructed to a larger scale.

Example: 16×2.4= (Figure 2)

Place index 1 of scale C above 16 on scale D. Move the runner to 24 on scale C. Directly below on scale D you will find 384. Placing the decimal point by a rough mental calculation (2×16=32), one realizes that the answer is 38.4 and not 384 or 3.84 or .384.

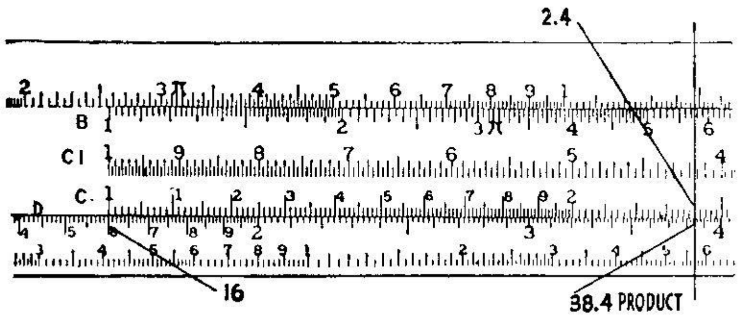


Figure 2

Example: 163×6.1=

Place index 1 on scale C directly above 163 on scale D. Move the indicator to 61 on scale C. Below 61, on scale D, you find 994. In estimating the product for the position of the decimal point, 160×6=960. So the answer is 994.

The above example may be solved using scales A and B. Place index 1 on scale B below 163 the first factor on scale A. Move the indicator to 61 on scale B. Above 61 on scale A you find 994. So the answer is 994.

It is well to mention that the process of multiplication is based on this fact of logarithms: The sum of the logarithms of numbers is the logarithm of their product.

Solve the following examples:

(1) 24×38=

(2) 16.2×8.1=

(3) 23.2×41=

(4) 84×65=

(5) 12×63=

(6) 16.3×2.3=

The product of a series of numbers can be obtained by the slide rule as follows: Example: Find the product of 24×3×16=

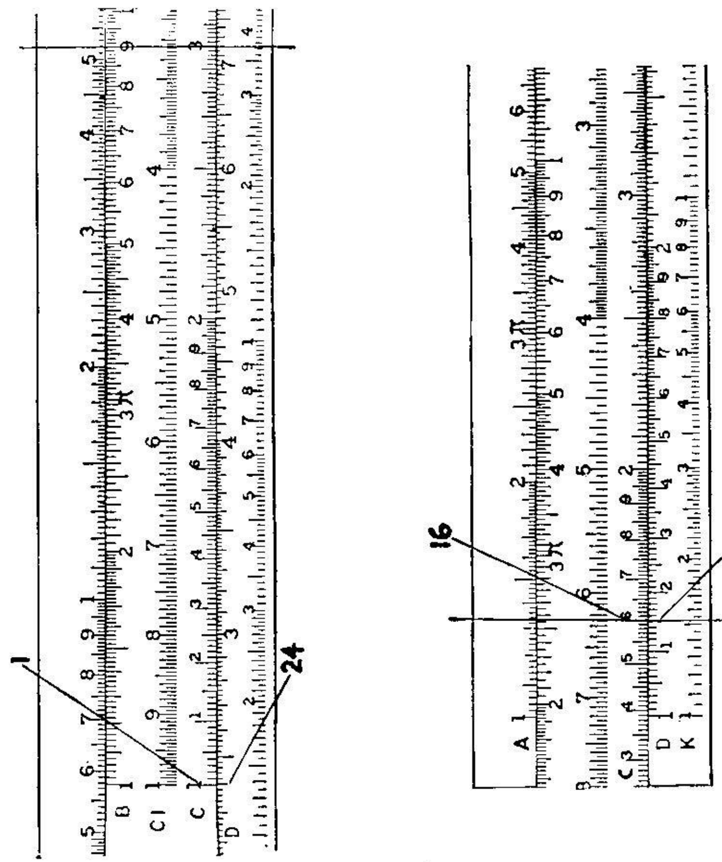


Figure 3

Move scale C until the index 1 is over the first factor 24 on scale D. Move the indicator to 3 on scale C. Move scale C until the index is on the hair line of the runner. 16, the next factor, on scale C now extends beyond scale D. Whenever this happens, move the slide back until the right index 1 of scale C is on the line of the runner where the left index had been. IN OTHER WORDS, CHANGE FROM LEFT TO RIGHT INDEX WHENEVER NECESSARY FOR THE READING OF THE SCALE. Now move the runner to 16 on scale C. Directly below 16 on scale C you will find, on scale D, 115. By estimation 20×3×20=1200. Therefore, the correct answer to three significant figures is 1150.

If the A and B scales are used in multiplication, the process is exactly the same. The B scale takes the place of the C scale as explained and the A scale of the D scale.

To solve one of the simple problems of percentage, involving multiplication, follow exactly the same method: 16% of 36 is what number? .16×36=. As the steps are pointed out to you, do the work with your rule. (1) Place index 1 on scale C above 16 on scale D. (2) Follow runner along until the hair line is on 36 on scale C. (3) Below on scale D you find 576. (4) Placing the decimal point by inspection, the number is 5.76.

At first practice a few very simple multiplications until you gain skill. Learn to estimate the products and to place the decimal points correctly by inspection.

EXERCISES

Find the following products:

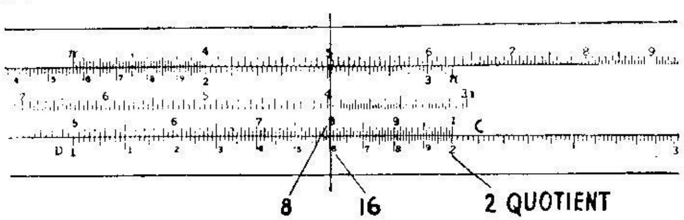
(1) 23×16=
(2) 3.15×2.81=
(3) 86×93=
(4) .28×.06=
(5) .063×1.58=
(6) How many cubic feet of water will fill a swimming pool 60 feet long and 30 feet wide to a depth of 7½ feet?

(7) At 27c a square foot find the cost of cementing a floor that is 18 feet long and 12 feet wide. (8) What number is 15% of 286? (9) If an article cost $2.83 and is sold at a profit of 25%, find the profit. Find the selling price. (10) A=bh. Solve when h=6.4, b=8.2.

DIVISION

Numbers are divided on the slide rule by subtracting distances on the scale which is just the reverse of the process of multiplication in which numbers are multiplied by adding distances on the scale. Division is based on the following rule: The logarithm of the quotient equals the logarithm of the dividend minus the logarithm of the divisor.

Using your own slide rule follow through the examples and learn to do the work of division.



Example: Find the quotient of 16÷8=. (Figure 4)

Figure 4

Locate 16 on scale D with runner. Place 8 on scale C directly above 16 on scale D. Directly below index 1 on scale C you find 2, the correct quotient, on D.

This process may be done using scales A and B.

Locate 16 on scale A with runner. Place 8 on scale B directly below 16 on scale A. Directly above index 1 on scale B you find 2, the correct quotient, on scale A.

In division as in multiplication either the left or right index may be used.

The advantages of using scales C and D were noted before; because of the spacing of graduations, C and D are accurate to a greater number of significant figures.

Example: 238÷2.6= Locate 238 on scale D. Place 26 on scale C directly above it. On scale D read the number directly below index 1 on scale C. The number is 915. Placing the decimal point by inspection 238÷2 is 119. The result is 91.5. The process would be exactly the same if scales A and B were used.

Now suppose you solve one of the common problems of percentage by the slide rule.

Example: 26 is what percent of 83? 26÷83=. Locate 26 on scale D. Directly above it place 83 on scale C. Directly below right index 1 of scale C, on scale D, you find 314. Placing the decimal point by inspection the quotient is .314 or 31.4%.

EXERCISES

Solve the following:

(1) 10÷3.5= (2) 14÷8.2= (3) 16÷8= (4) 7.28÷3.62= (5) 642÷83= (6) The area of a rectangle is 68.3 square feet. Its length is 16.2 feet. Find the width. (7) An automobile traveled 77.5 miles. If it averaged 15½ miles to the gallon of gas, how many gallons were needed for the trip? (8) $36.50 is what percent of $592?

Combining your knowledge of how to multiply and divide by using the slide rule, solve the following:

(1) $\frac{36\times 12}{1.8}=$ (4) $\frac{36\times 3\times 7}{2.3}=$

(2) $\frac{32\times 2[illegible]}{211}=$

(3) $\frac{2.8\times .36}{.91}=$ (5) $\frac{18\times 4\times .07}{6.3}=$

The labor involved in dividing a product of two or more factors by one or more factors is considerably reduced if the operations are alternated. Illustration:

$$\frac{12\times 7\times 23}{5\times 11}=$$

The process is: bring the hair line to 12 on scale D. Then bring 5 on the C scale to the hair line. The quotient, 2.4 is determined by the right index on C. Without reading this quotient it may be multiplied by 7 by bringing the hair line to 7 on scale C. This product 16.8 may be read on scale D. Without reading it, it may be divided by 11 by bringing 11 on scale C to the hair line. The left index number indicates the quotient 1.53. Again, without reading the quotient, it may be multiplied by 23 by bringing the hair line to 23 on scale C and reading on scale D. The product is 35.1.

Eliminating the explanation the process becomes:

Step 1—hair line to 12 on scale D.
" 2—5 on scale C to the hair line.
" 3—hair line to 7 on scale C.
" 4—11 on scale C to the hair line.
" 5—hair line to 23 on scale C.
" 6—read result on scale D.

Now repeat the five problems above using this method.

Problems involving percentage have been mentioned in the explanation of multiplication and division so it will suffice to say that to solve problems in percentage, first examine the problems to see if the process involved is multiplication or division and then follow the rules as explained for that process. The decimal point is placed by inspection and estimation.

If you consider these typical percentage problems, you can easily see how they should be solved by the aid of the slide rule. (1) 16 is 4% of what number? 16=.04X. X=16÷.04= (use division). (2) What number is 4% of 16? 16×.04= (use multiplication). (3) 16 is what percent of 640? 16=640X. X=16÷640 (use division). All percentage problems reduce themselves to one of the above types.

PROPORTION

The slide rule is particularly easy to use in solving problems of proportion. The A and B or C and D scales may be used in solution.

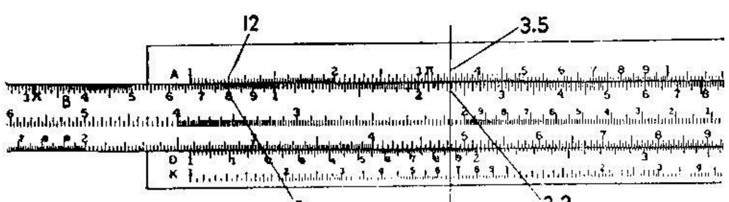


Figure 5

Example: $\frac{12}{8} = \frac{3.5}{X}$ (Figure 5)

Place 8 on scale B directly below 12 on scale A. Move the runner to 35 on scale A. Below it you will find the reading 23 on scale B. Placing the decimal point by inspection X=2.3.

Example: $\frac{6}{7} = \frac{X}{24}$

Below 6 on scale A place 7 on scale B. Follow the runner to 24 on scale B. Above 24, on scale A, you find 206 and placing the decimal point correctly X=20.6.

It becomes a case of placing term under term as

$\frac{16}{8} = \frac{12}{6}$ so $\frac{16 \text{ scale A}}{8 \text{ scale B}} = \frac{12 \text{ scale A}}{6 \text{ scale B}}$

The work in proportion may be done exactly the same by using scales C and D as follows:

Example: $\frac{6}{7} = \frac{X}{240}$ Place 6 on scale C above 7 on scale D.

Move the runner to 240 on scale D. Directly above 240 you will find 206 on scale C.

The advantage of using the C and D scales is the same as the advantage of using these scales in multiplication or division. Because of closer calibration a higher degree of accuracy is obtained. If there are decimals, estimate the result and place the decimal point correctly, or if there are a greater number of figures than can be shown on the rule accurately, estimate the product and add the correct number of zeros.

Suppose in the preceding example it had been $\frac{X}{2.4} = \frac{6}{7}$

Solving exactly as explained above you will find X=206, but estimating the value by inspection X=2.06, or if the proportion is $\frac{X}{2400} = \frac{6}{7}$ and directly above 24 on scale C you find 206, the number correct to three significant figures is 2060.

Inverse proportions may be solved by using the CI scale. Notice that the CI scale is in reverse order to the others. This enables one to set up an inverse proportion exactly as if it were a direct proportion.

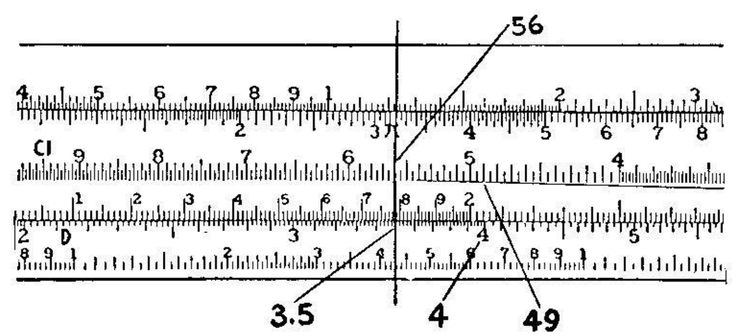


Figure 6

Example: If a car averaging 49 miles per hour requires 4 hours for a trip, how long will it take a car averaging 56 miles per hour? (Figure 6)

Place 49 on CI scale above 4 on scale D. Move runner to 56 on CI scale. Below on scale D you find the answer 3.5.

EXERCISES

(1) $\frac{A}{86}=\frac{51}{98}$ (3) $\frac{a}{.02}=\frac{9}{4.15}$

(2) $\frac{2.1}{.7}=\frac{9}{W}$ (4) $\frac{12}{n}=\frac{.09}{2.7}$

(5) If 9 men can do a piece of work in 5 days, in how many days can 6 men do the same task?

(6) If an automobile runs 103 miles on 7 gallons of gas, maintaining the same average rate, how many miles will it run on 5 gallons of gas?

(7) Mr. Brown's salary changed from $50 to $55 a week. If he formerly paid $40 a month rent, and his rent increases proportionately, what will he now have to pay?

(8) The taxes on a house worth $8,000 are $72. At the same rate what are the taxes on a house worth $10,000?

SQUARES AND SQUARE ROOTS

If you compare scales A and B and C and D, you will notice that the numbers on scales A and B are the squares of those directly below on C and D. This is due to the fact that the logarithms for scales A and B are laid off to a scale one half the size of the scale used for C and D.

To find the square of a number locate the number on scale D, move the runner to that point and read the number directly above on scale A. To find the square root of a number simply do the reverse. Locate the number on scale A; read the root directly below on scale D. In finding the square root, use the left half of scale A for numbers with an odd number of digits before the decimal point (1.63, 327, 238.36) and the right half of the scale for numbers with an even number before the decimal point (23.6, 28.4, 36.).

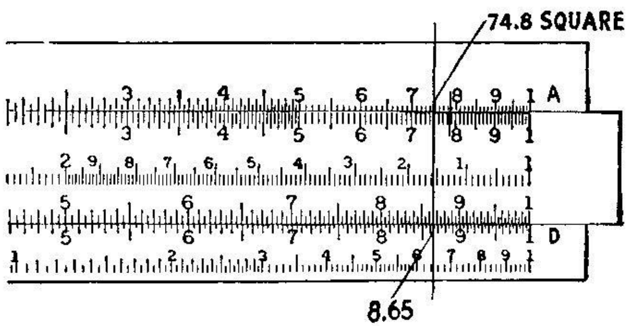


Figure 7

Example: Find the square of 8.65. (Figure 7).

Move the runner to 865 on scale D. Directly above on scale A you will find 748. Place the decimal point by inspection 8^2=64. The result is 74.8.

Example: Find the square of 24.3. Locate 24.3 on scale D. Directly above on scale A you have 59. Estimating the result 20^2=400. The result, correct to two significant figures, is 590.

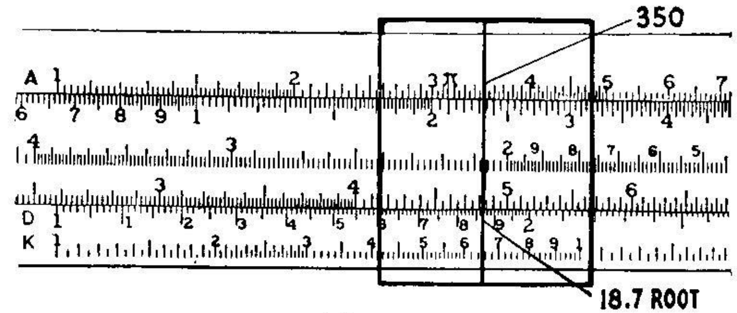


Figure 8

Example: Find the square root of 350. (Figure 8).

Using the left half of scale A, move the runner to 350 on scale A. Directly below on scale D you find 187. Place the decimal point by inspection. The result is 18.7.

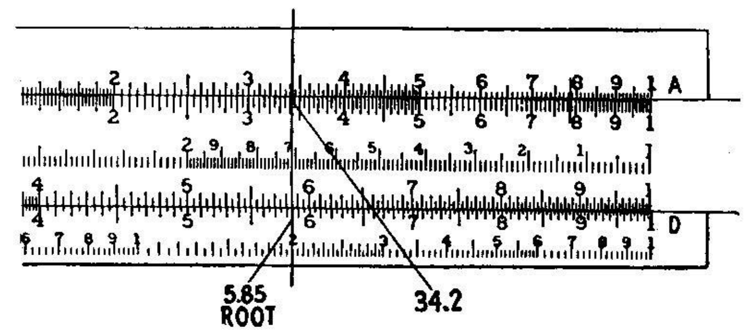


Figure 9

Example: Find the square root of 34.2. (Figure 9).

Using the right half of scale A, move the runner to 342 on scale A. Directly below on scale D you find the root 5.85.

EXERCISES

Find the square of (1) 38, (2) 2.63, (3) .23, (4) 86, (5) 56.3. Find the square root of (6) 14, (7) 26.8, (8) 2.42, (9) 591, (10) 85. (11) Find the hypotenuse of a right triangle if the other sides are 12 and 13 inches. (12) M=122$\sqrt{h}$. Solve when h=50.

CUBES AND CUBE ROOTS

If the rule you are using has, in addition to the A, B, C, and D scales mentioned, a K scale, you will have no difficulty in finding the cubes of numbers. If it contains just the four scales, A, B, C, and D, you will consider the cube of a number as a series of operations.

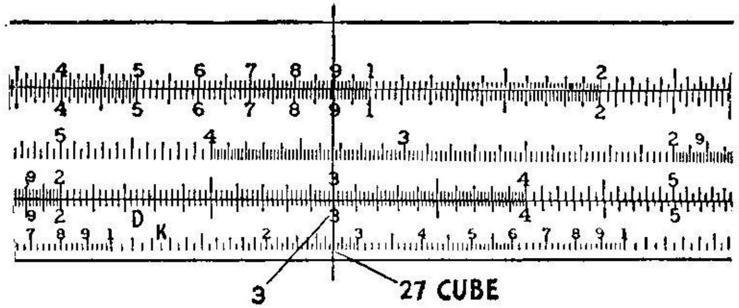


Figure 10

Example: In using the rule with a K scale: Find the cube of 3. (Figure 10).

Place the hair line of the indicator over 3 on scale D. Below on scale K you will find the cube 27.

On rules having only the A, B. C, and D scales change 3^3 to 3 squared times 3 ($3^2 \times 3$).

Move the runner to 3 on scale D. Move the slide until index 1 on scale B is directly above the 3 on scale D. Move the runner to 3 on scale B. Directly above on scale A you find the cube 27.

In finding the cube roots of numbers, scales D and K are used in just the reverse process to cubing the number.

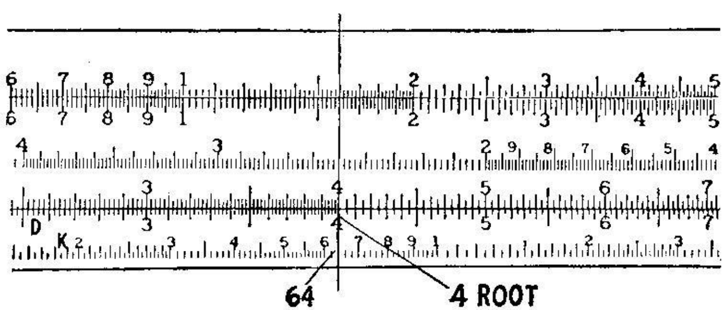
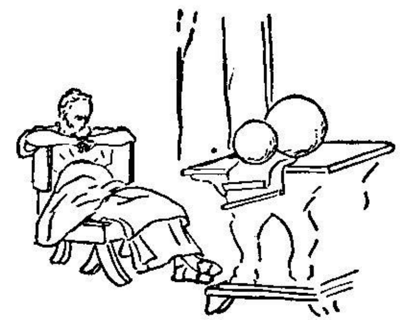


Figure 11

Example: Find the cube root of 64. (Figure 11).

Connect the indicator with the cube on scale K (64). Directly above on scale D you will find 4 the correct root.

The Circle and the Sphere



Computations concerning the circle occur in a great many problems dealing with familiar objects. The value π, the ratio of the circumference of a circle to its diameter, is marked on the rule as is also the value $\pi/4$ (.7854).

The common circle formulas are $C=\pi d$ or $2\pi r$ and $A=\pi d^2/4$ or πr^2. The area of a sphere ($A=4\ \pi r^2$) and the volume of a sphere ($V=4/3\ \pi r^3$) are also commonly used formulas.

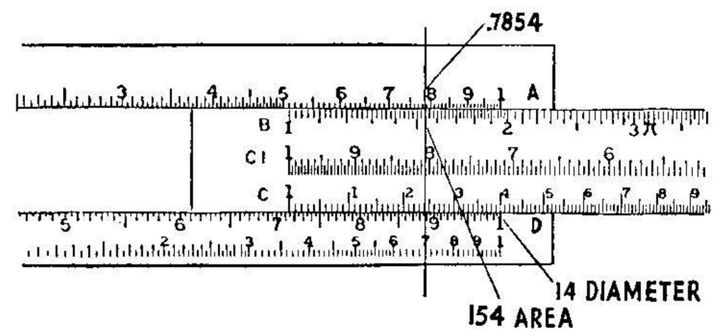


Figure 12

Example: Find the area of a circle whose radius is 7 inches. (Figure 12).

Move the diameter 14 on scale C to the right index 1 on scale D. Move the indicator to $\pi/4$ (.7854) on scale A. Directly below you will find 154 the correct area on scale B.

Example: Find the circumference of a circle whose radius is 7 inches. $r=7$, $d=14$. (Figure 13).

Problems:

$(42.93)^2$	Ans. 1840
$(305.2)^2$	Ans. 93100
$(.753)^2$	Ans. .567
$(613.4)^2$	Ans. 376,000

Square Root of a Number by Mental Survey Method

When we are going to find the square root of a number, we mean that we are to find a number which, when multiplied by itself, will equal the given number.

Whenever the sign ($\sqrt{\quad}$) is placed over a number it means that square root is required.

Before the square root can be found we must mark off the number into groups of two digits each starting from the decimal point. For example, 3148 which is a whole number will be marked off into two groups with 4 and 8 together and 3 and 1 together in this manner: $\sqrt{31|48|}$. Here the first group 31 has two digits. Another example 373 will be $\sqrt{3|73}$. with only one digit in the first group. Again in the numbers 538.42 and 6.471 they will be grouped as $\sqrt{5|38.42}$ and $\sqrt{|6.47|10}$.

In the answer to the square root of a number there will be as many numbers in the answer as there are groups in the number itself.

To find the square root of a number is the reverse operation of squaring therefore the A and D scales will be used again. If the first group has one number, as shown by 3|73 or 5|38.42|, set the hair line of the indicator over the number on the left half of the A scale and read the answer on the D scale. If the first group has two numbers as in 31|48. set the hair line of the indicator over 3148 on the right half of the A scale and read the answer under the hair line on the D scale.

Example 1: $\sqrt{48} = 6.93$

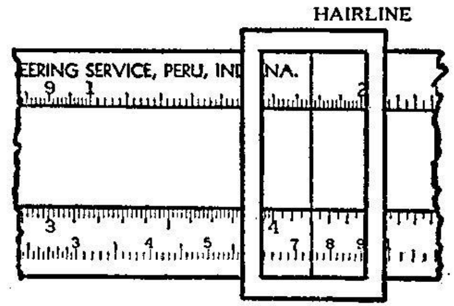
Since this group has two numbers, set the scale on 48 in the right half of the A scale and read 694 on the D scale. Here we have only one group, therefore we will have only one whole number in our answer; thus 6.94.

Example 2: $\sqrt{1|44} = 12$

Here we have one number in the first group, so we set 144 on the left half of the A scale and read the answer 12 under the hair line on the D scale. The number has two groups so we have two whole numbers in our answer.

Example 3: $\sqrt{17|64} = 42.1$

This number has two numbers in the first group so we set the indicator over 1764 on the right half of the A scale. This answer 421 is read under the hair line on the D scale. Our number has two groups, therefore we will have two whole numbers in our answer: thus 42.1. (See Fig. 17.)



SQUARE ROOT OF 17.64

FIG. 17

Problems:

$\sqrt{13|82.} = 37.2$

$\sqrt{5|48|17.} = 234.$

$\sqrt{7.38} = 2.72$

Square Root of a Number by the Integral Digit Method. (See page 21.)

When we say we are going to find the square root of a given number, we mean that we are going to find an unknown number which, when multiplied by itself, will be equal to the given number.

The sign ($\sqrt{\quad}$) when placed over a number signifies that the square root of that number is required.

Before we can take the square root of a number, we must first divide the number into groups of two digits each, beginning at the decimal point and point off to the right and left as the case may be. For example, the whole number 4257, we begin at the decimal and point off to the left in groups of two digits, thus |42|57. When pointing off, we place the marks above the number so that they will not become confused with the decimal points. In this number we then have the first group as 42 and the second group as 57.

In many cases we will have only one digit in the first group, as in the number 5|87|65. Here the first group is 5, the second group 87 and the third group 65.

Using the above method find the sine of 3°. You will notice that since the reading is on the left half of scale A the result is .052.

Now repeat the two above problems by the following method. Remove the slide from the groove and reverse it so that the underneath face is uppermost. Reinsert it in the groove with the indexes coinciding. The S scale is a scale for sines. Angles are given on scale S and opposite them on scale A their sines.

Opposite 40 on scale S is found its sine on scale A. It reads 643. Since this is on the right half of scale A, sine 40°= .643.

Opposite 3 on scale S is found its sine on scale A. It reads 52. Since this is on the left half of scale A, sine 3°= .052.

To solve a trigonometric problem involving sines set up the ratio and then use the slide rule to solve the problem.

$$\text{Sine } 40° = \frac{X}{25}$$

$$X = \text{sine } 40° \text{ times } 25$$

With the slide having scales B and C uppermost set 40° on scale S to the mark in the groove at the right end of the rule. Under 25 on scale A read the product 161 on scale B. Placing the decimal point by inspection X=16.1

Exercises: (1) Sine 30°= (2) Sine 23°= (3) Cos. 47°= (4) Cos. 16°= (5) Sine 8°= (6) The distance from the base to the top of a hill up a uniform incline of 12° is 230 yards. What is the height of the hill?

THE L SCALE

Logarithms represent the exponent or power which a number is of a given base, usually the base is 10. The logarithm of a number is divided into two parts, the characteristic and the mantissa. The mantissa is read directly from the rule on scale L. It is always a decimal part and remains the same for the same sequence of digits regardless of the position of the decimal point. The characteristic is determined by inspecting the number and following this rule:

(1) If the number is one or greater than one, the characteristic is positive and is one less than the number of digits before the decimal point (i. e. log 368, the characteristic is 2; log 36.8, the characteristic is 1; log 3.68 the characteristic is 0.)

(2) If the number is less than one, the characteristic is negative and numerically one more than the number of zeros between the decimal point and the first no zero figure (i. e. log .368, the characteristic is —1; log .0368, the characteristic is —2; log .00368, the characteristic is —3.)

Example: log 6 = 0.778
log 60 = 1.778
log 600 = 2.778
log .6 = .778—1
log .006 = .778—3

The mathematical processes that may be solved by logarithms are multiplication, division, and powers and roots of numbers. To multiply numbers using logarithms add the logs of the numbers and find the antilog of the result. Finding the antilog means to find the number when the log is given. You will find the process explained in the examples which follow. To divide numbers using logarithms subtract the logarithm of the divisor from the logarithm of the dividend. The result gives the log of the quotient. The quotient is found by finding the antilog. To find any given power of a number multiply the log of the number by the power and find the antilog of the result. To find any root of a number divide the log of the number by the given root and find the antilog of the result.

The L scale lies on the reverse of the slide between the scales marked S and T. On most rules the L scale is numbered from left to right. The work may be done with the slide reversed so that the L scale is uppermost or with the slide in its usual position.

Example: Find log 60.

With slide reversed so that S, L, and T scales are uppermost and indexes coinciding, move hair line of runner to 6 on scale D. Directly above on scale L read .778. Prefixing the characteristic log 60=1.778.

Example: Find log 60.

With the slide in the usual position with the L scale underneath set 6 on scale C opposite the right index of D. On scale L opposite the right index on the underside of the rule you find .778. Prefixing the correct characteristic, log 60=1.778.

If the slide rule you are using has the scale of equal parts numbered from right to left use the left index. Place the left index of scale C over 6 on scale D and read the result from the L scale on the underneath side of the rule.

To find the antilog of a given log (i. e. to find the number when the log is given) reverse the process as explained above.

Example: Find n if log n = 0.699.

With the scale in reverse place the hair line of the indicator over .699 on scale L. Read the number 5 below on scale D. Following the rule for characteristics N = 5.

Again, with the slide in the usual position place .699 opposite the right index on the under side of the rule. On the face of the rule above the index of scale D you find 5 on scale C. The number is 5.

Exercises: (1) Find log of 62, 51.3, 280, .023, 2.36.
(2) Find N if log N=1.602, 2.800, 1.661, .143-1, .480-2.
(3) Solve $(3.2)^3$, $\sqrt{2.4}$, 46÷239.

THE T SCALE

The T scale is used for finding tangents and cotangents of an angle. When the slide is reversed and the T scale uppermost, this scale gives readings for angles whose tangents are found opposite on scale D.

Example: Find tan 40°.

Opposite 40° on scale T find 839 on scale D. Placing the decimal point tan 40° = .839.

Example: Find tan 40°.

With the slide in the usual position (scales B and C uppermost) set 40 on the T scale to the index mark on the underside of the rule and opposite 1 on scale D read 839 on scale C.

This latter method is preferable when solving problems involving trigonometric ratios.

Example: $\tan 40° = \frac{X}{150}$

$150 \tan 40° = X$

(1) Place 40° to index mark on T scale on underside of the rule.

(2) Opposite 1 on scale D read 839 on C.

(3) Without changing set of rule move runner to 150 on scale D. Above on scale C find 126 the correct result.

It may be necessary after the set for the tan has been made to shift scale C so that the right index takes the place of the left index in order to complete the problem.

The T scale carries angle markings to 45°. The tangents of all angles from 0° to 45° are less than 1 (tan 45°=1.000) so the first significant figure comes in the first decimal point.

For angles greater than 45° use the formula $\tan A = \frac{1}{\tan(90°-A)}$

Find the tan of 70°.

$$\tan 70° = \frac{1}{\tan(90°-70°)}$$

$$\tan 70° = \frac{1}{\tan 20°}$$

(1) Set 20° on T scale opposite index mark on underside of the rule.

(2) Opposite left index of C read 275 on scale D.

(3) To place the decimal point remember tan 45° = 1.

$\frac{20°}{45°}$ = roughly ½ $\quad \frac{1}{½} = 2$

(4) Tan 70° = 2.75

Cotangents of angles may be found by finding the tangent of the complement of the angle.

cot A = tan (90° - A)

cot 70° = tan (90° - 70°)

cot 70° = tan 20°

You will note on the rule that on the T scale the angles begin at 6°. For angles less than 6° the sine scale may be used since sine and tangent are the same to three significant figures for small angles.

Exercises: Find (1) tan 24°. (2) cot 36°. (3) tan 80°. (4) cot 64°. (5) If a post subtends an angle of 20° from a point on the ground 60 feet away, what is the height of the post? (6) A post 44 feet high casts a shadow 16 feet long. Find the angle of the sun.

The Slide Rule As A Check

The slide rule is not only a tool for solving but also provides a method of checking work. Suppose you were solving a problem on the area of a circle by the formula $A = \pi r^2$. First you would square the radius, then multiply the result by 3.1416, and the answer would be the required area. You can check your answer by one set of the slide rule. Now suppose you find your answer in error. There are two places you might have erred; each of which you can check very readily with the rule. The error might be (1) in squaring r; check it; (2) in multiplying $r^2 \times 3.1416$; check it. By these two checks you can readily find the error in the work. Remember that the satisfaction gained from solving a problem is doubled if you know from your check that you have solved the problem and your solution is correct.

HIGH SCHOOL SUBJECTS

ALGEBRA

The slide rule becomes of value in algebra wherever arithmetical computations occur. For example: If 9 men can do a piece of work in 21 days, how long will it take 7 men to do the same work? This is an inverse proportion; that is, the fewer the men working, the longer the time required to do the work. Setting up the proportion you write $\frac{9}{7} = \frac{X}{21}$. Using the slide rule scales A and B as explained for proportion X=27. Again you might have solved the problem by cross multiplying.

7X=189. X=27.

Then in one setting of the rule, check the answer. Again you might have solved the problem using scales CI and D and setting it up as a direct proportion.

Another type of problem found in first year algebra involves substitution in formulas:

$(h^2 = a^2 + b^2)$ $\quad (h^2 = 16^2 + 8^2)$

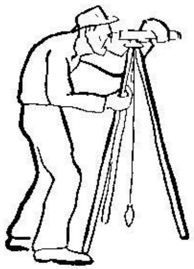
a=16, b=8. Using the slide rule as instructed for squaring numbers $16^2 = 256$, $8^2 = 64$, so $h^2 = 320$. Using the slide rule to find $\sqrt{320}$, h=17.9.

EXERCISES

(1) Find the principal which will yield $75 interest in 4 years at 5%. (2) $a^3 + b^3 + c^3$. Evaluate when a=3, b=4, c=5. (3) Divide a board 54 inches long into two parts in the ratio of seven to eleven. (4) Find the diagonal of a rectangle 18 feet long and 12 feet wide.

GEOMETRY

The slide rule can be used effectively in geometry. Recent textbooks feature an abundance of exercises and problems of a practical nature showing the direct application of theorems studied.



In the following typical geometry problems you can see how much of the work is done quickly and accurately by the slide rule: (1) What is the cost of constructing a cement walk 2 feet wide around a circular pool 40 feet in diameter at a cost of $2.80 per square yard?

First of all draw a figure for the problem and consider the proper line of reasoning. You see using the slide rule detracts in no way from the application of geometry and the steps in geometric reasoning.

The two circles will be concentric with AD, diameter of larger, cutting the smaller circle at B and C. BC=40, AB=CD=2. (1) Area of large circle — area of small circle=area of walk in sq. ft. (2) Area in sq. ft.÷9=area in sq. yards. (3) Area in sq. yds. times $2.80 equals total cost.

Now to use the slide rule for a quick and accurate solution. Following the method learned for the area of a circle: Area of circle 44 feet in diameter=1520 sq. ft. Area of circle 40 feet in diameter =1255 sq. ft.; area of walk =1520 — 1255=265 sq. ft.

Cost $\frac{265 \times \$2.80}{9}$ (using rule)=$82.44. In this case the work of computation may be further shortened by first writing the area as a formula: $\frac{\pi \times 22^2 - \pi \times 20^2 \times 280}{9}$. Factoring, the computation thus becomes one that can be entirely carried out on the slide rule.

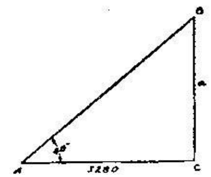
(2) Two chords AB and CD of a circle intersect at R. If AR=1.2, RB=3.1, and CR=4.2, find RD.

This exercise depends on the following theorem: If two chords intersect within a circle, the product of the segments of one equals the product of the segments of the other. The segments of the first are AR and RB; the segments of the second are CR and RD. (1) AR times RB equals CR times RD. (2) 1.2 times 3.1 equals 4.2 times RD. (3) Using the slide rule for multiplication: 3.72=4.2 RD. (4) Using the slide rule for division .88=RD.

TRIGONOMETRY

The slide rule is an aid in solving the problems of trigonometry and also in checking results of problems solved by logarithms. Sometimes it is necessary to get greater than three figure accuracy in solving a problem, and in that case logarithms should be used; otherwise the slide rule is satisfactory for all types of work. In as much as the uses of the S and T scales have been discussed, it will only be necessary to give some examples of typical trigonometric problems solved by using the slide rule.

Example: A barrage balloon tethered one mile away from an observer bears an angle of elevation of 40°. What is the height of the balloon?



$$\tan 40^\circ = \frac{A}{5280}$$

(1) Place 40° to index mark on scale T on underside of rule.

(2) Opposite 1 on scale D, read 839 on C.

(3) Without changing the set of the rule move runner to 5280 on scale D. Above on scale C find 443. Estimating the result correctly A=4430 feet.

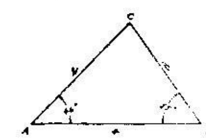
In addition to problems involving the right triangle the student in trigonometry is concerned with problems involving oblique triangles (triangles none of whose angles are right angles). The solution of these is based on the fundamental laws of sines, cosines, and tangents, and their solution by using the slide rule in no way changes the student's understanding or fundamental approach to the problem.

Example: Two people observing a balloon are 4 miles apart. The balloon is in the same vertical plane with the observers and has an angle of elevation from the observers of 46° and 55° respectively. What is the distance from the balloon to each observer?

Angle C = 180° - (46°+55°)

Angle C = 79°

$$\frac{4}{\sin 79^\circ} = \frac{a}{\sin 46^\circ} = \frac{b}{\sin 55^\circ}$$



The problem may then be solved as a proportion problem in one set of the rule. With the slide reversed so that the S scale is uppermost place 79° on scale S directly below 4 on scale A (Using right half of scale A). Move the hair line of indicator to 46 on scale S. Directly above on scale A find 293, directly above 55° on scale S, you find 334 on scale A. Placing the decimal point by inspection, the results are:

Angle C = 79°	c=4 miles
Angle B = 55°	b=3.34 miles
Angle A = 46°	a=2.93

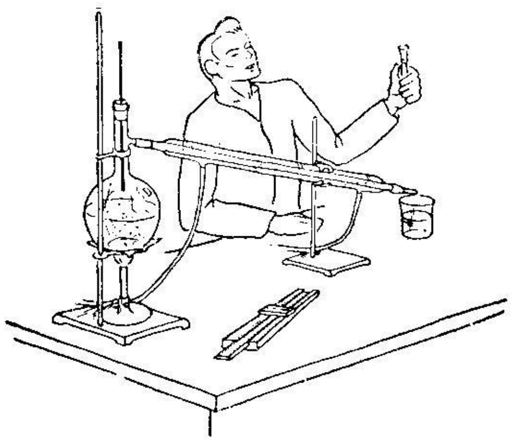
Often in trigonometry it is necessary to change radians to degrees or degrees to radians.

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

The problem is a proportion problem. Using the scales A and B set the problem up as follows: opposite π on scale A set 180 on scale B; opposite radians on scale A read degrees on scale B.

CHEMISTRY

Probably no one uses the slide rule more constantly than the chemist. It lends itself very readily to solving many types of chemical problems, examples of which are given below.



(1) The most common type of chemical problem is that involving weight reactions only. Example: What weight of silver chloride can be made by treating 25 grams of Ag NO_3 with H Cl? First write the equation as follows and place an X under the formula of the compound, the weight of which is to be found, and place the given weight under the known factor Ag N O_3. Over the formulas of these two substances place the molecular weights of the compounds.

$$\overset{170}{\underset{25}{Ag\ N\ O_3}} + H\ Cl = \overset{143.5}{\underset{X}{Ag\ Cl}} + H\ N\ O_3$$

This type of problem is set up on the slide rule exactly as it appears in the equation. Over 25 on scale D place 170 on scale C; then with the runner find 143.5 on scale C. Directly below it on scale D will be the answer 21+ grams.

(2) Percentage composition: Example: Find the percentage of oxygen in K Cl O_3. This is solved by dividing the multiple atomic weight of oxygen in the compound ($3\times16=48$) by the molecular weight of the compound, K Cl O_3; K 39.1+Cl 35.5+O_3 48=122.6 48÷122.6=. follow the method as explained for division. By inspection the answer is found to be 39.2%.

(3) Problems involving gases: In these problems it is unnecessary to first find the weight of the gas and then to find the volume, as the problems are solved using the gram molecular volume (22.4 liters). Example: What volume of H Cl gas is produced by treating 50 grams of sodium chloride with sulphuric acid according to the equation

$$\overset{58.5}{\underset{50}{Na\ Cl}} + H_2SO_4 = Na\ HSO_4 + \overset{2.4}{\underset{X}{H\ Cl}}$$

Place 58.5 on scale C over 50 on scale D. Locate 22.4 on scale C. Directly under it on scale D is 19.3. The answer is 19.3 liters of H Cl.

(4) Problems involving gas laws:

(a) Boyle's Law: If a given mass of gas has a volume of 1500 liters under a pressure of 740 millimeters of mercury, what volume will it occupy at standard pressure (760 mm)? By inspection note that the pressure has increased slightly; therefore, the result will be slightly less than 1500. Use Boyle's Law formula as follows: $\frac{V_1}{V_1}=\frac{P_2}{P_2}$ substituting $\frac{1500}{X}=\frac{760}{740}$ Solve as a proportion problem using A, B, or C, D scales: X=1460.

(2) Charles Law: A given mass of gas, pressure remaining constant, has a volume of 1460 cubic centimeters at a temperature of 20° C. Find its volume at standard temperature (0°C). Change the temperature reading to absolute by adding 273 and substitute in Charles Law formula written as follows: $\frac{V_1}{V_2}=\frac{T_1}{T_2}$ $\frac{1460}{X}=\frac{293.}{273}$

Note by inspection that the temperature decreases, and, therefore, the volume decreases slightly. Solving the proportion by using the slide rule X=1362.

PHYSICS

Since mathematics is the most important tool of the physicist, many students of physics find the work burdensome because of the computations involved. Probably in no science does the use of the slide rule save more time. The following physical laws and problems concerning them will give you practice in using the rule.

(1) LAW OF FRICTIONLESS MACHINES.

(a) Lever: If a 100 lb. weight is placed 2 feet from the fulcrum of a lever of the first class, find the effort required if the distance from the fulcrum to the other end is 30 inches. ED=RD (cf. proportion).

(b) Hydraulic Press: The area of the large piston is 100 square inches and the area of the small piston is 20 square inches. Find the effort needed to lift one ton.

$$\frac{a}{A}=\frac{E}{R} \quad \text{(cf. proportion)}$$

(2) LAW OF PENDULUM $T=\frac{\pi\sqrt{L}}{g}$

Find the period of a pendulum if it is 64 centimeters long at a latitude where g=32.16.

(3) LAW OF HEAT EXCHANGE: Heat lost = heat gained.

Find the temperature of a 20 gram piece of copper if when placed in one liter of water it raises the temperature of the water from 10°c to 25°c.

$M\times t\times s=M_1\times t_1\times s_1$. Where M=mass of metal, t=change in temperature, s=specific heat of metal=.09, M_1=mass of water, t_1=change in temperature of water, s_1=specific heat of water=1.

(4) OHM'S LAW AND ELECTRICAL POWER:

(a) Find the cost of operating a 20 ohm electric iron for 10 hours 110 volts at 8c per K. W. H.

$$\text{Cost} = \frac{\text{volts} \times \text{amps} \times \text{hours} \times \text{rate}}{1000}$$

(b) Find the heat developed by a heating coil drawing 5 amperes from a 110 volt line for ½ hour. $H\ (\text{cal}) = I^2 R \times .24 \times t$.
(t=time in seconds).

(5) LENS FORMULA:

Di=distance to image, Do=distance to object, F=focal length of lens.

$$\frac{1}{Di} + \frac{1}{Do} = \frac{1}{F}$$

(a) If an object is 73.5 centimeters from a lens and an image is formed 31.6 centimeters away, what is the focal length of the lens?

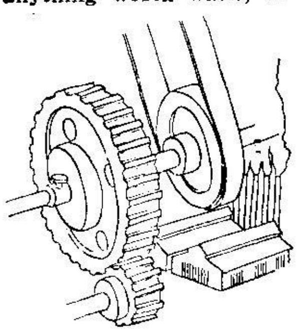
$$\frac{So}{Si} = \frac{Do}{Di}$$

So=size of object, Si=Size of image, Do=distance of object, Di=distance of image.

(b) If an object is 6 feet high and 10 feet from a lens, find the size of the image 9" from the lens.

INDUSTRIAL ARTS

The work of industrial subjects and the related professions is not entirely a work of construction. Before the builder can make anything worth while, he must plan his work, study carefully the required specifications, understand the strength of materials, and calculate the cost of construction. Because of this constant dealing with numbers the slide rule is indespensable. Consider the following problems of a practical nature, and see how the slide rule saves time in solving them.



Example: A 32 inch pulley making 200 r. p. m. turns a 24 inch pulley. Find the r. p. m. of the 24 inch pulley.

$$\frac{\text{r. p. m. of the large wheel}}{\text{r. p. m. of the small wheel}} = \frac{\text{diameter of smaller}}{\text{diameter of larger}}$$

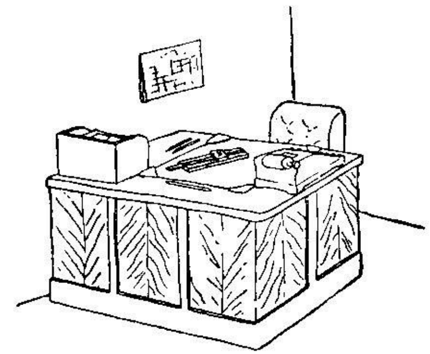
$\frac{200}{X} = \frac{24}{32}$. Solving by the slide rule as explained for proportion $X = 267$.

EXERCISES

(1) A machinist drills a hole in the center of a circular piece of metal which is 2 inches in diameter. The hole is 1 inch deep and 7/8 inch in diameter. Calculate the volume of metal removed.

(2) Calculate the number of board feet in the following lumber bill: 8 pieces, 2"×6"—14'.
Board Feet: Number of pieces times thickness times width times length (in inches) divide by 144.

COMMERCIAL SUBJECTS



In the business office there arise many problems involving more than addition and subtraction for which the adding machine is not sufficient. Many of these are quickly solved by the slide rule.

Examples:

(1) Find the interest on $400 at 6½% for 2 years.
Using the slide rule as explained for multiplication:

$$I = Prt. \qquad I = \frac{400 \times 6.5 \times 2}{100} = \$52$$

(2) What is the rate of income of stock costing $80 a share and paying $4 a year per share in dividend?
Using the slide rule for division: 4÷80=.05 or 5%.

EXERCISES

(1) Complete the paymaster's schedule given below:

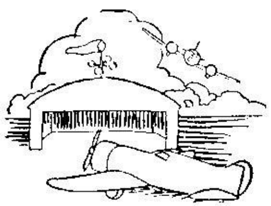
Rate	50	51	52	53	54	55	56	57
Hours								
¼	.12							
½	.25							
¾	.37							
36	18.00							
37	18.50							
38	19.00							
39	19.50							
40	20.00							

(2) Which pays a higher rate of income, a 5% bond of $1000 face value that can be bought for $950 or a 6% bond of $500 face value that can be bought for $550?

You will notice in solving these problems of special subjects that you must understand the problem and its application. The use of the rule takes away the mechanical work which often becomes burdensome.

Finally, this may be said concerning the slide rule; it is not a crutch or prop to lean upon. Its proper use definitely demands a clear understanding of the principles of the problem involved, and its value lies in the saving of time and the eliminating of the drudgery of repetition.

REVIEW EXERCISES



The following exercises will check your knowledge of the material covered before you take the mastery tests. Use the manual for reference and review carefully the solution of those exercises which you find difficult.

(1) $45 \div 5 =$

(2) $2.93 \times 6.39 =$

(3) $3 \times 16 \times 11 =$

(4) $\dfrac{16 \times 8}{18 \times 5} =$

(5) $\dfrac{41}{X} = \dfrac{5}{8}$ $X =$

(6) Find the interest on $200 at 4⅛% for 3 years. I=Prt.

(7) Find the area and circumference of a circle 3 inches in diameter. $A = \pi r^2$, $C = 2\pi r$.

(8) $48.50 is what percent of $296?

(9) $16ab =$ $a = 13$ $b = 2.3$

(10) $\sqrt{1.63} =$

(11) $(2.3)^2 =$

(12) $\sqrt[3]{293} =$

(13) $\dfrac{13.6 \times 24.1}{6.3}$

(14) $\dfrac{PV}{T} = \dfrac{P_1V_1}{T_1}$

$P = 740$, $T = 15°C$, $V = 450$.

$P_1 = 760$, $T_1 = 5°C$, $V_1 =$

(15) Find the height of a cliff if the angle of elevation of the top is 63° from a point 500 feet from the base of the cliff.

(16) An observer in an airplane 5,000 feet above point A observes point B on a line with A at an angle of depression of 54°. How far is it from A to B?

Mastery Test I

Name ——————————.

(1) $\sqrt{618} =$

(2) $.36 \times 2.3 \times .06 =$

(3) $.19 \div .0036 =$

(4) $.063 \times 1.21 =$

(5) Find the area of a rectangle with a length of 19.3 feet and width of 8.11 feet. ——————

(6) $\sqrt[3]{217.} =$

(7) I=Prt. P=$456 r=4% t=5 months. Find I. ——————

(8) $\dfrac{321}{X} = \dfrac{214.}{7}$ $X =$

(9) A makes $35 a week and B makes $42 a week. After a proportional raise in salary, B makes $50. What is A's new salary? ——————

(10) Find the area of a circle with a radius of 6.32 inches. ——————

(11) $(32)^3 =$

(12) $\dfrac{abc}{a^3 + b^2} =$ $a = 2$, $b = 3$, $c = 7$.

(13) Find the circumference of a circle with a diameter of 9.2 centimeters. ——————

(14) $\dfrac{8 \times 23 \times 6.3}{2.4 \times .21} =$

(15) Find the log of 69.3.

(16) Find the height of a cliff if the angle of elevation of the top is 63° from a point 200 feet from the base of the cliff.

Mastery Test II

Name ——————————.

(1) tan $36°30' =$

(2) $36.7 \times 28.4 =$

(3) $(3.62)^2 =$

(4) $\dfrac{9 \times 21}{15 \times 18} =$

(5) $\dfrac{36}{9} = \dfrac{a}{4}$

(6) $324 \div 8 \div 4 =$

(7) $3 \times 27 \times 1.56 =$

(8) $18 \div 76 =$

(9) $A = \dfrac{abc}{4r}$ $a = 3$, $b = 2$, $c = 5$, $r = 4$

$A =$ ————

(10) $396 \div 3.3 =$

(11) If 500 feet of wire weigh 29 pounds, what will a mile of the same wire weigh? ————

(12) Find the area of a circle with radius 7 inches. ————

(13) $\sqrt[3]{739} =$

(14) $\sqrt{137} =$

(15) Find the log of 824. ————

(16) Find the area of a sphere with a radius of 8 inches. ————