electronics

CLEVELAND INSTITUTE OF ELECTRONICS / CLEVELAND, OHIO

Electronics and Your Slide Rule Part I

3122-1

An AUTO-PROGRAMMED™ Lesson

ABOUT THE AUTHOR

Through over 15 years experience in helping students learn through home study, Mr. Geiger has obtained an intimate understanding of the problems facing home-study students. He has used this knowledge to make many improvements in our teaching methods. Mr. Geiger knows that students learn fastest when they actively participate in the lesson, rather than just reading it. Accordingly, you will find many "What Have You Learned?" sections in this lesson, to assist you in getting a firm grasp of each topic.

Mr. Geiger edits much of our new lesson material, polishing up the manuscripts we receive from subject-matter experts so that they are easily readable, contain only training useful to the student in practical work, and are written so as to teach, rather than merely presenting information.

Mr. Geiger's book, *Successful Preparation for FCC License Examinations* (published by Prentice-Hall), was chosen by the American Institute of Graphic Arts as one of the outstanding text books of the year.

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Electronics and Your Slide Rule

Step-by-step to Skillful Operation

By DARRELL L. GEIGER
Senior Project Director
Cleveland Institute of Electronics

In this lesson you will learn...

ELECTRONICS SLIDE RULE NO. 515
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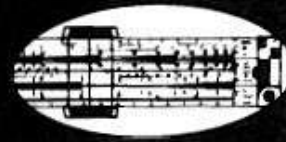


A chat with your instructor

This is the first of several lessons written specifically for the many electronics men who wish to improve their job efficiency and qualify for promotion by becoming skilled in the use of the slide rule. With electronic equipment rapidly increasing in complexity, a good knowledge of the slide rule is essential to all progressive-minded men of electronics.

Since you will be using this manual without the aid of a teacher, we have made every effort to make each step self-explanatory. Many illustrations are included to enable you to grasp each principle of slide rule operation. However, if you should come across any point which you cannot fully understand, please write to me so that I can explain it to you.

Topics 7 through 10 cover the most important subject of all... learning the proper reading of the scales. Don't be tempted to hurry through these topics in order to get to more interesting subjects. No matter how much you know about a slide rule, it is of no practical value unless you can properly read the scales. We have had much experience in training slide rule operators, and this experience shows that inability to properly read the scales cause beginners by far the most trouble. Not that it is hard to learn to read the scales--it is simply a matter of following the lesson step-by-step and working all the practice problems.

You should keep your slide rule before you at all times while reading this manual and go through all the steps described on the worked out examples. Since only practice will make you a slide rule expert, it is important that you work all the practice problems.

Slide rules stick and move by jumps unless properly held when setting. In Fig. A, the left hand squeezes the rule, binding the slide. Also, it leaves the setting of the slide entirely to the right hand.

Support the body of the rule between your left palm, and the thumb and second finger of the right hand (Fig. B). Note: no fingers around the rule! Move the slide with the left thumb and right forefinger. The two-way push prevents excess slide movement.

When the slide is far out of the body, support the body of the rule with the left hand and the second finger of the right hand (Fig. C). Do not wrap your fingers around the body. Adjust the slide with the right thumb and forefinger, and the thumb of the left hand.

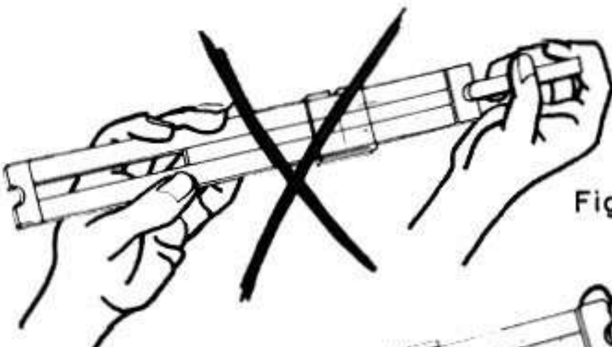


Fig. A Wrong way.

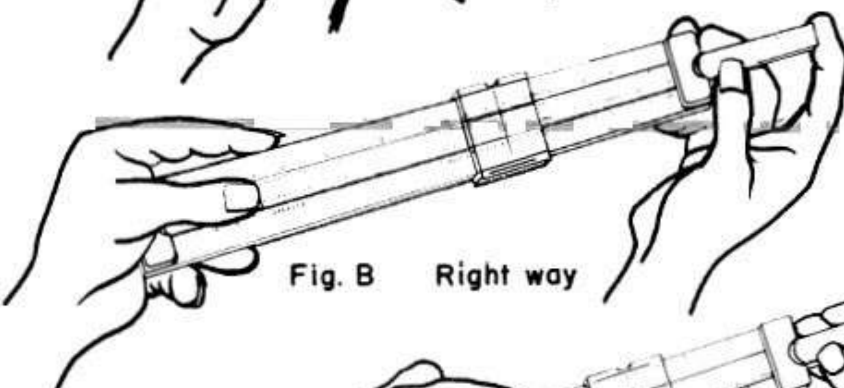


Fig. B Right way

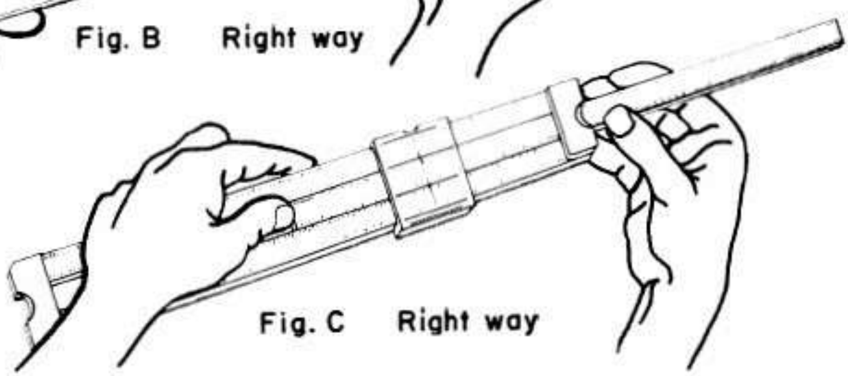
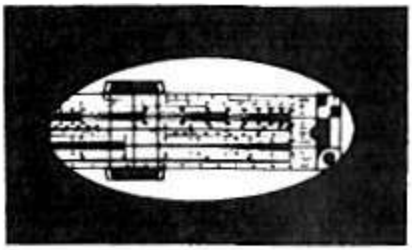


Fig. C Right way



Electronics and Your Slide Rule Part I

1 THE SCALES OF A SLIDE RULE...Any good slide rule carries a number of different scales, the exact number and type depending upon the purpose for which it is intended. The various scales are identified by letters placed to the left of each scale, which also indicate the purpose of the scales. The letter-identifying system is the same regardless of manufacturer.

On the front of your Electronics rule, notice first the C and D scales. They are identical, except that the D scale is on the stationary part of the rule and the C scale is on the sliding member. These are the basic and most important scales on a slide rule. The C and D scales are used directly for multiplying and dividing, and in conjunction with other scales of the rule for performing a multitude of operations.

Notice next the CI scale on your rule. The CI scale is the same as the C scale except reversed; that is, the numbering is from right to left instead of from left to right as on the C and D scales. CI means "C Inverted". Inverted scales are printed in red on most slide rules, so the user will not forget while reading the scales that they progress from right to left. The CI scale is used directly for finding reciprocals. In conjunction with other scales it simplifies computations in many ways.

A and B scales are used with problems involving squares and square roots. These two scales are identical, except that the A scale is on the body of the rule, while the B scale is on the slide. The left half of the A or B scale (the part numbered from 1 to 10) is similar to the C or D scale, but scaled down to be only half as long. The right half of the A or B scale (the part numbered from 10 to 100) is identical to the left half, except for the higher numbering used.

The L scale is used for finding logarithms. It is particularly useful in electronics for working decibel problems. The L scale is different from all the rest of the scales in that it is linearly (that is, evenly) divided.

The S and T scales are used when working problems in trigonometry. Their most important use to the electronic technician is in working alternating current-circuit problems. The S scale is used when working with sines and cosines, and the T scale with tangents and cotangents.

2 SPECIAL SCALES... The scales so far discussed are found on all good slide rules intended for engineering or technical applications. In addition, the Electronics rule has several scales intended specifically to facilitate working many common types of electronic problems. These scales, of course, would not be found on slide rules intended for general engineering applications.

One of these special scales is the H scale, the top scale on the front of your Electronic rule. This scale is used for solving the various types of resonant frequency problems. Since this, as you will notice, is an inverted scale, it is printed in red. Below the H scale is the 2π scale. This scale is used in solving problems involving inductive or capacitive reactance, or in any type of problem where the factor 2π appears.

On the back side of your Electronics rule, you will find an additional set of scales. These scales are used for quickly and accurately locating the decimal point in many frequently occurring types of electronic problems. These scales are one of the most valuable features of the Electronics rule for men working in electronics.

3 THE PARTS OF YOUR SLIDE RULE... The names of the various parts of a typical slide rule are shown in Fig. 1. It is important to know these in order to follow the instructions for using the instrument. The slide is the movable central part of the rule. The stationary part of the rule, in which the slide slides, is called the body.

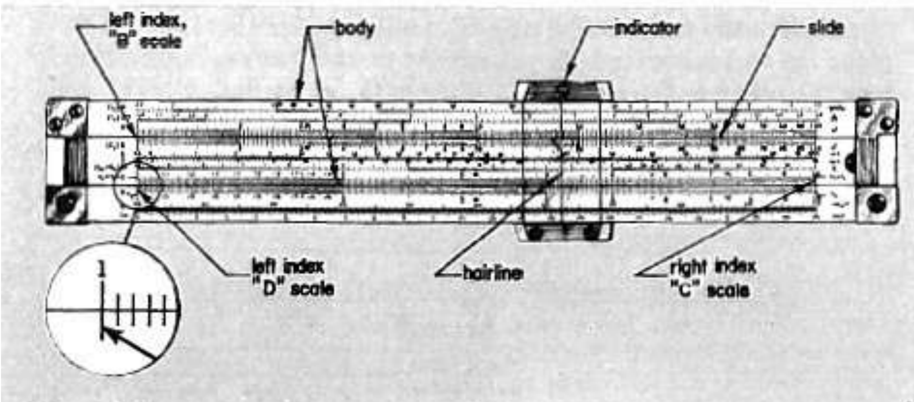


Fig. 1. The parts of a slide rule.

The transparent runner that is free to move along the body is called the indicator or cursor. In the center of the indicator is a long fine line perpendicular to the scales of the rule. This is called the hairline, and is used for accurately locating and reading positions on the scales. Screws in the cursor on most slide rules make it possible to adjust the hairline, if it should become necessary, so as to maintain it exactly perpendicular to the scales. Screws in the body of the rule, at the ends, allow the tension of the slide to be adjusted.

Of special importance with reference to the A, B, C, CI, and D scales is the end scale markings on these scales, called the index marks. Each of these scales has an index on each end. In addition, the 10 marks at the centers of the A and B scales are also called indexes.

4 A SLIDE RULE FOR ADDING AND SUBTRACTING...A slide rule is inherently a device for adding and subtracting. But by putting properly graduated scales on the rule, the results of this adding and subtracting can be directly read as products of multiplication or as quotients of division. In fact, scales for actually adding and subtracting are seldom placed on practical slide rules, because such simple operations can be performed quicker with a pencil and paper.

However, the best way to learn to use a slide rule and to understand its principles of operation is to learn to use an adding and subtracting slide rule. You can construct such a rule by cutting out with a pair of scissors the two centimeter scales at the end of this lesson. Then place the two calibrated edges together so that one edge can slide along the other to form a simple slide rule, as in Fig. 2.

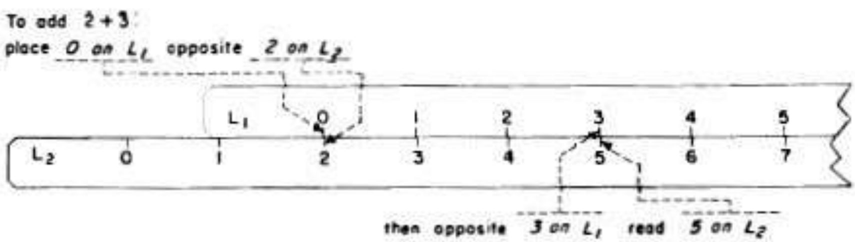


Fig. 2. Using a linear slide rule to show that 2 + 3 = 5.

The scales on your paper slide rule are different from most of the scales of your regular slide rule in that the divisions of the former are linearly (that is, evenly) spaced, while the spacing between the divisions of the latter is uneven. However, there is one linear scale on your regular slide rule, the L scale. If your regular rule had another L scale on its slide, it could be used for adding and subtracting. To add or subtract, both of the scales used must be linear.

Fig. 2 shows how to use your linear slide rule to find that 2 + 3 = 5. The principle of operation is quite simple. Since the numbered divisions on the scales are in fact centimeter marks, in adding by the method of Fig. 2 you actually show that 2 centimeters plus 3 centimeters is equal to 5 centimeters.

You are measuring out two centimeters and from that point measuring on three centimeters more, making a total length of 5 centimeters. You should now add various numbers together on your paper slide rule until you understand clearly the principle of addition by this method. This will be very helpful in learning to operate a regular slide rule.

Adding and subtracting on your linear paper slide rule are not limited to simple whole numbers. Fig. 3(a) shows how to add 2.3 and 3.4. The 0 mark (index) of L_1 is placed opposite the mark for 2.3 centimeters on scale L_2. This position is found by noting that there are 10 minor division marks between the main centimeter marks 2 and 3. Hence, each of the minor division marks represents one tenth of a centimeter, so that 2.3 centimeters will be three minor division marks to the right of the main division mark 2, as shown in Fig. 3(a).

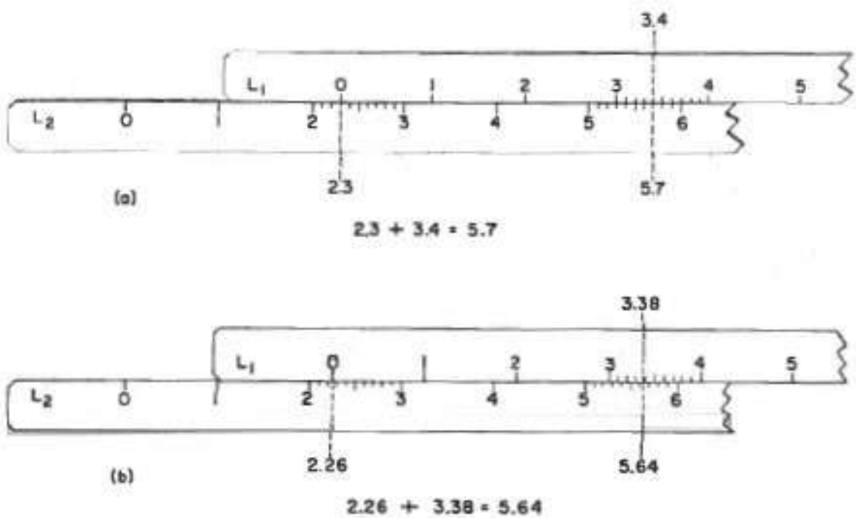


Fig. 3. Adding two and three digit numbers with a linear slide rule.

Opposite 3.4 centimeters on scale L_1, read 5.7 centimeters on scale L_2. Hence, 2.3 + 3.4 = 5.7. Since the sum of 23 + 34 is equal to the sum of 2.3 + 3.4, except for the location of the decimal point, the setting of Fig. 3(a) can equally well be used to show that 23 + 34 = 57. Or as another example, the same setting can be used to show that 230 + 340 = 570, or that

0.023 + 0.034 = 0.057. It is characteristic of most slide rule scales that the same setting can be used for different locations of the decimal point if the digit values are the same, as in the above examples.

Adding 226 to 338 provides another example. Except for the position of the decimal point in the answer, this is the same as adding 2.26 to 3.38, which is shown in Fig. 3(b). The zero mark on scale L_1 is placed opposite 2.26 centimeters on scale L_2. To locate 2.26 on scale L_2, the minor division mark representing 2.2 is first located. On past 2.2, six tenths of the distance to the following minor mark, is 2.26. We must estimate with our eye to locate this last position, keeping in mind that 6 is slightly over half of the distance between the two minor marks. With practice, such estimates can be made fairly accurately on a regular slide rule, but not here because of the lack of precision in the printing process. Opposite 3.38 on scale L_1 the sum, 5.64, is read on scale L_2. Thus 226 + 338 = 564. You may get a value for the last digit considerably different from 4, due to the inaccuracies of the paper scales.

Subtracting on your paper slide rule is merely a matter of working backwards from the process used for addition. Thus, to subtract 3 from 5 set 3 on scale L_1 opposite 5 on scale L_2, and then opposite 0 on scale L_1 read the answer, 2, on scale L_2. The scale settings are exactly the same as for adding 2 + 3, as shown in Fig. 2. Similarly, by setting 3.4 of scale L_1 opposite 5.7 on scale L_2, the difference between the two, 2.3, is read on scale L_2 opposite 0 on scale L_1 The setting is the same as in Fig. 3(a).

You should practice adding and subtracting with your paper slide rule until the principles and methods are clear to you. It is important not just to learn how to add or subtract, but also to understand why the sums and differences are obtained when the operations are performed as described.

One way to add 2 + 3 would be to measure off two feet on the floor from some starting point and there make a mark. From this mark, measure off three feet more in the same direction and make a second mark. Now measuring the distance from the starting point to the second mark, it is found to be five feet, so that $2 + 3$ must equal 5. Your paper slide rule is just a somewhat less clumsy method of adding two distances in the same way.

5 MULTIPLYING AND DIVIDING BY ADDING AND SUBTRACTING...Since a slide rule is inherently capable only of adding and subtracting, multiplication and division must be reduced to addition and subtraction if a slide rule is to be used for the purpose. If you have studied logarithms, you will probably remember that it is possible to do this, but you need not be familiar with logarithms to understand how.

In algebra, it is shown that numbers with the same base can be multiplied together by adding their exponents. Thus, $3^2 \times 3^3 = 3^{2+3} = 3^5$. For proof, note that $3^2 = 3 \times 3 = 9$, $3^3 = 3 \times 3 \times 3 = 27$, and $3^5 = 3 \times 3 \times 3 \times 3 \times 3 = 243$. Since $9 \times 27 = 243$, $3^2 \times 3^3$ is proved equal to 3^5. As another example, $2^4 \times 2^5 = 2^9$, which you may verify as an exercise. As a further example, take $10^2 \times 10^3 = 10^5$, which shows that $100 \times 1{,}000 = 100{,}000$. In this last example, the base is 10. More advanced mathematics shows that any number can be written as 10 with the proper exponent. Here are some examples:

$100 = 10^2$	$500 = 10^{2.699}$	$2 = 10^{0.301}$
$131.23 = 10^{2.118}$	$762 = 10^{2.882}$	$3 = 10^{0.477}$
$200 = 10^{2.301}$	$1{,}000 = 10^3$	$6 = 10^{0.778}$

The exponents in the examples above are called <u>logarithms.</u> Thus in the expression, $762 = 10^{2.882}$, 2.882 is said to be the logarithm of 762. Logarithms are found by consulting <u>tables of logarithms</u>, constructed for that purpose, but how this is done need not concern us. The important point at this time is that any two or more numbers can be multiplied together by adding their logarithms. Thus, since $131.23 = 10^{2.118}$ and $762 = 10^{2.882}$, we can multiply 131.23 by 762 by merely adding the exponents of the powers of 10 (logarithms). Hence, $131.23 \times 762 = 10^{2.118 + 2.882} = 10^5 = 100{,}000$.

Working in a similar manner, $2 \times 3 = 10^{0.301} \times 10^{0.477} = 10^{0.778} = 6$. Providing we know the logarithms of the numbers involved, the process of multiplication thus reduces to one of simple addition. And since division is the opposite of multiplication, the process of division reduces to one of subtraction.

6 MULTIPLYING WITH THE SLIDE RULE...Using the paper slide rule you have constructed, you can multiply 2 by 3 by adding their logarithms, 0.301 and 0.477, and then noting that their sum, 0.778, is the logarithm of 6. Since we would ordinarily not know the logarithms of the numbers to be multiplied or divided without looking them up in tables, this method is certainly impractical. However, by marking directly on the slide rule the numbers to which the logarithms correspond, the necessity of knowing or referring to logarithms is eliminated, as you will see shortly.

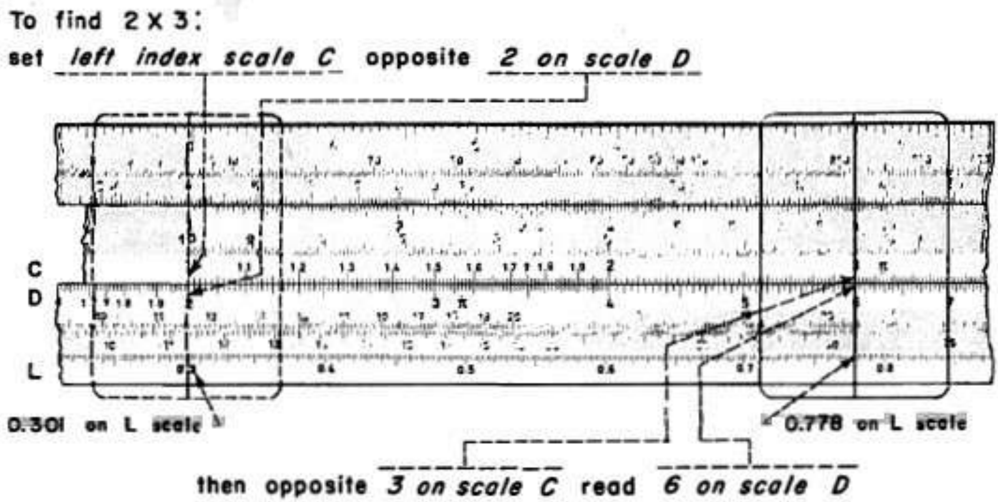


Fig. 4. Finding $2 \times 3 = 6$ (or finding $6 \div 3 = 2$).

We will now multiply 2×3 using your Electronics slide rule. On the body of the rule there is one linear scale, the L scale, corresponding to the L_1 scale of your paper slide rule. To multiply 2×3, it is necessary to add 0.301 to 0.477. Set the hairline of the indicator over 0.301 on the L scale, and then set the left index of the C scale under the hairline, as shown in Fig. 4, the dashed line indicating the position of the hairline at this time. But notice that the hairline is also over 2 on scale D. Hence, it was not necessary to first know the logarithm of 2 and then set the hairline to this value on scale L. You can accomplish the same thing by setting the index of scale C opposite 2 on scale D.

Our next step is to set the hairline over 0.477 on a linear scale on the slide. But since the slide does not have a linear scale, this cannot be done. However, if it did have one, 0.477 would come opposite 3 on scale C. Hence, set the hairline over 3 on scale C, as shown by the indicator position in Fig. 4. Reading under the hairline on scale L, 0.778 is found to be the sum, which is the logarithm of 6. Hence, $2 \times 3 = 6$. Again, it is not necessary to consider the logarithm 0.778, because the answer 6 can be read directly on the D scale.

The slide rule manufacturer has marked on the C and D scales the natural numbers, each number being located on the rule at the point where the logarithm would fall on a linear scale. In that way, it is not necessary to refer to logarithms when using a slide rule to multiply or divide.

To summarize: To multiply 2 by 3, set the left index of scale C opposite 2 on scale D. Then opposite 3 on scale C, read 6, the answer, on scale D. Or another way: Set the left index of scale C opposite 3 on scale D. Then opposite 2 on scale C, read 6 on scale D.

As another example, to multiply 1.5 by 3, set the left index of scale C opposite 1.5 on scale D. Then opposite 3 on scale C, read the answer 4.5 on scale D. See Fig. 5. We get 4.5 as our reading on scale D, because the hairline sits on the half mark between 4 and 5.

Dividing is, of course, just the opposite of multiplying. To divide 6 by 3, place 3 on scale C opposite 6 on scale D. Then opposite the left index of scale C, read 2 on scale D. See Fig. 4. Or to divide 4.5 by 3, first set the hairline over 4.5 on scale D. Then set 3 on scale C under the hairline. The answer, 1.5, is then read opposite the left index of the C scale on the D scale. See Fig. 5. The purpose of using the hairline is to fix the point 4.5 on scale D, so we won't lose it while locating 3 on scale C and bringing it to the proper location.

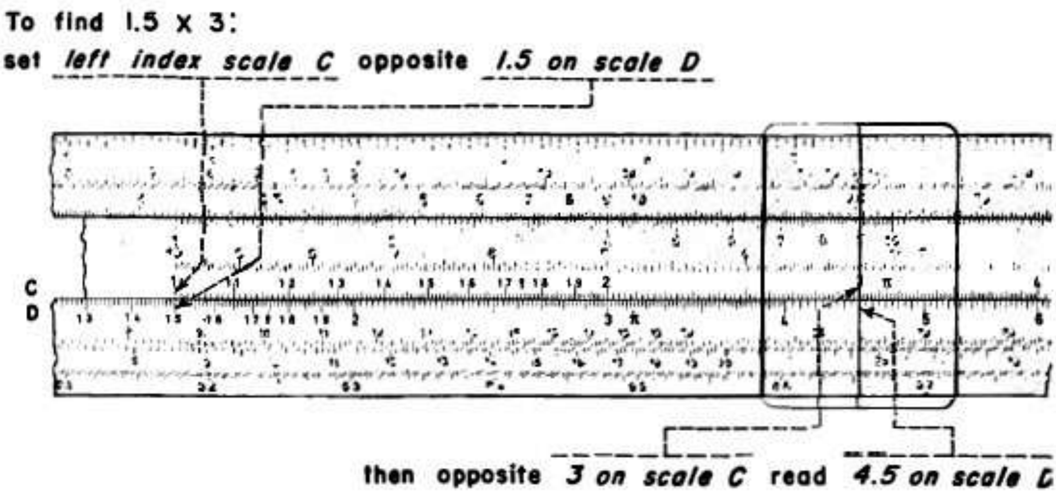


Fig. 5. Finding 1.5 $\times$ 3 = 4.5 (or finding 4.5 $\div$ 3 = 1.5).

7 **READING THE SLIDE RULE SCALES...** Before the slide rule can be put to any practical use, it is first necessary to learn to read any value from the scales. We will begin first with the C and D scales, which are identical. Slide rule scales are somewhat more difficult to read than simple linear scales because of the unequal spacing between divisions. Consider first, readings that fall between 1 and 2 on the scales C and D.

A view of this part of scale D appears in Fig. 6. The vertical dashed lines represent various positions of the hairline. This section of the rule is divided into 10 main subdivisions, marked 1.1, 1.2, 1.3, etc. For example, the hairline at position G reads 1.7 on scale D.

Each of the main subdivisions just discussed is further divided into 10 secondary subdivisions. For example, you will find the space between 1.2 and 1.3 on your rule divided into 10 parts. These are not numbered because the division marks are too close together to permit it. These secondary subdivisions between 1.2 and 1.3 make it possible to read values from the slide rule between 1.2 and 1.3.

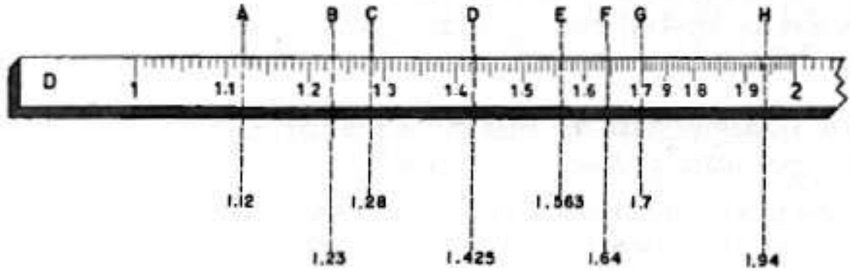


Fig. 6. Reading the section of the C or D scale between 1 and 2.

For example, when the hairline is in position B of Fig. 6, the reading is 1.23. The last digit 3 is obtained by noting that the hairline is 3 secondary subdivision marks past 1.2. Similarly, the reading for the hairline at point C is 1.28 (here the hairline is 8 secondary subdivisions past 1.2). As further examples, the reading for hairline A is 1.12, for position F is 1.64, and for position H 1.94. Reading positions D and E will be explained in the next topic. You should, of course, set the hairline of your slide rule to these various positions as you study the text.

WHAT HAVE YOU LEARNED?

Referring to Fig. 7, read the nine different settings of the hairline.

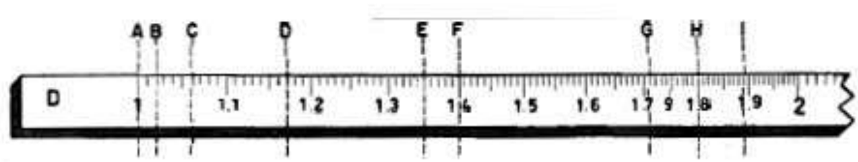


Fig. 7.

ANSWERS

A. 1.00 B. 1.02 C. 1.06 D. 1.17 E. 1.35
F. 1.40 G. 1.71 H. 1.80 I. 1.89

8 READING WITH HAIRLINE BETWEEN MARKS...

When the hairline is in position D of Fig. 6, it does not coincide with any of the marks on the rule, but is halfway between the mark for 1.42 and 1.43. The reading therefore is 1.425, the last digit 5 showing that the hairline is past the mark for 1.42 by 0.5 of the distance from 1.42 to 1.43.

In position E of Fig. 6 the hairline is between 1.56 and 1.57. By careful inspection we might estimate it to lie to the right of 1.56 by 0.3 of the distance between 1.56 and 1.57. With that assumption, the reading obtained for this setting would be 1.563. The last digit 3 here is only an estimate. Someone else equally experienced with a slide rule might estimate 2 for the last digit. A third person might estimate 4. Thus the reading for position E might be variously given by different operators as 1.562, 1.563, and 1.564. This is characteristic of a slide rule; the last digit in the reading is often subject to a slight error. However, for practical applications the accuracy of a slide rule is nearly always sufficient.

From the above it is evident that the accuracy of results with a slide rule depends to some extent upon the ability of the user to properly estimate values when the hairline does not coincide exactly with any of the division marks on the rule. You can quickly obtain this necessary skill with practice, providing you are careful to always do the best estimating job you can.

WHAT HAVE YOU LEARNED?

Referring to Fig. 8, read the different settings of the hairline. Take care in estimating the final digit. An experienced reader will get one of the acceptable readings given in the answers to this exercise. Since you are a beginner, you may be farther in error than these answers allow. Providing you are doing the best you can, you need not be concerned about this.

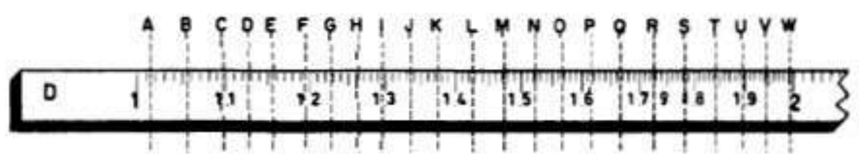


Fig. 8.

The best answer for each reading is given first, but all of the answers given are acceptable, even for an experienced slide rule operator.

A. 1.014, 1.013, 1.015 B. 1.056, 1.057 C. 1.096, 1.097
D. 1.128, 1.127 E. 1.155 F. 1.195, 1.196
G. 1.228, 1.227, 1.229 H. 1.263, 1.262, 1.264
I. 1.297, 1.296, 1.298 J. 1.336, 1.335, 1.337
K. 1.373, 1.372, 1.374 L. 1.426, 1.427 M. 1.472, 1.473
N. 1.523, 1.522, 1.524 O. 1.566, 1.567 P. 1.615
Q. 1.668, 1.667 R. 1.726, 1.727 S. 1.783, 1.782, 1.784
T. 1.844, 1.843, 1.845 U. 1.895, 1.896 V. 1.943, 1.942
W. 1.992, 1.991, 1.993

9 READING OTHER PARTS OF THE SCALES C AND D

...We will now consider reading that portion of scales C and D of the slide rule between 4 and 10. Fig. 9 is a view of that section. Each of the principal divisions in this part of the rule is divided into 10 subdivisions. Because of lack of space these subdivisions are not numbered. Each subdivision is further divided into two secondary subdivisions to assist in estimating the final digit when the hairline lies between two subdivision marks.

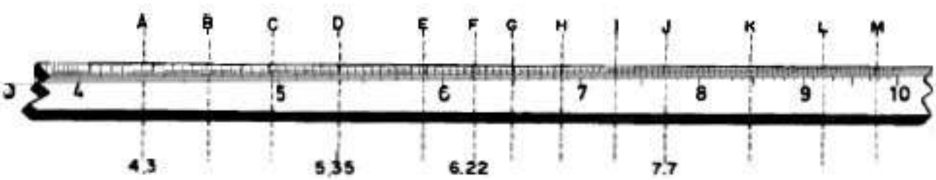


Fig. 9. Reading the portion of the C and D scales between 4 and 10.

The reading of A in Fig. 9 is 4.3, since the hairline lies 3 subdivision marks to the right of 4. Similarly, the reading of J is 7.7. The reading of D is 5.35, since the hairline lies on the mark that divides the space between 5.3 and 5.4 in half. The reading F is 6.22, the final 2 being, of course, estimated.

In reading the position of the scales C and D between 2 and 4 you will notice that each principal subdivision is further divided into five secondary subdivisions. Figure 10 shows this part of the rule. The reading for position E is 2.6 and for position N 3.8. Position F reads 2.74, position K reads 3.28, position A reads 2.15 and position I reads 3.07.

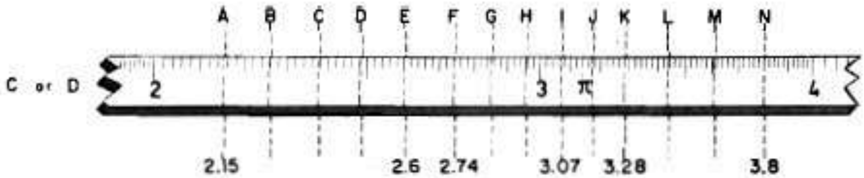


Fig. 10. Reading the portion of the C and D scales between 2 and 4.

WHAT HAVE YOU LEARNED?

Read the hairline positions B, C, E, G, H, I, K, L, and M in Fig. 9 and positions B, C, D, G, H, J, L, and M in Fig. 10.

ANSWERS

Figure 9...
B. 4.62, 4.63 C. 4.96, 4.97 E. 5.88, 5.87 G. 6.48, 6.49
H. 6.86, 6.85 I. 7.28, 7.27 K. 8.47, 8.48 L. 9.20
M. 9.77, 9.76

Figure 10...
B. 2.26 C. 2.37, 2.38 D. 2.48 G. 2.85 H. 2.95, 2.96
J. 3.17 L. 3.43 M. 3.60, 3.61

10 READING OTHER SCALES...The principles of slide rule reading brought out above in learning to read scales C and D will enable you without further study to read the other scales on

the slide rule. However, in reading the CI scale it must be remembered that this scale is the C or D scale in reverse, and therefore must be read from right to left, rather than from left to right as for the other scales. For example, the reading of position B on scale CI in Fig. 11(a) would be 8.9.

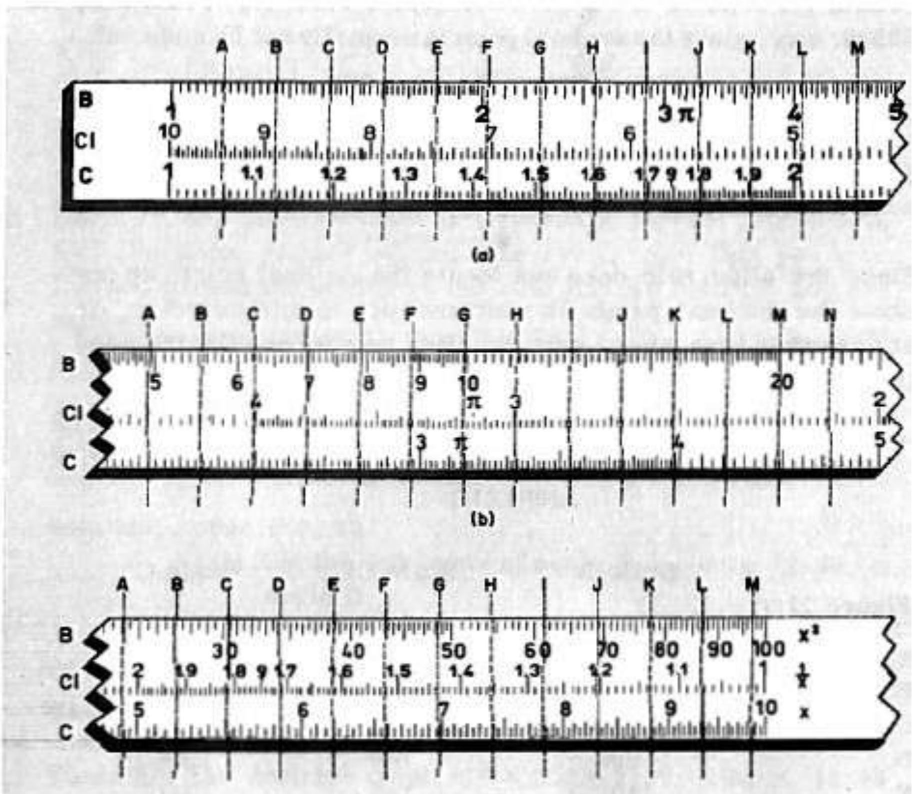


Fig. 11.

11 **DECIMAL POINT IN SLIDE RULE OPERATION...** In reading the hairline position in problems and examples up to this point, the decimal point has always been considered. This was done to help you understand the theory of reading positions on the rule. In actual problems the position of the decimal point is generally ignored (except when finding square root) during the slide rule manipulations. After the digits forming the answer

are obtained from the rule, the correct decimal point position is found by some non-slide rule method. Various examples in the remainder of this manual will show how this is done.

While position D of Fig. 9, for example, has been stated as the setting for 5.35, it is also the setting for 0.00535, 0.535, 535, 53500, etc., since the decimal point is normally not considered.

WHAT HAVE YOU LEARNED?

Read the B, the CI and the C scales for each of the hairline positions A through G in Fig. 11(a), (b), and (c).

Since the slide rule does not locate the decimal point, do not show the decimal points in your answers to this exercise, or at any other time when using the slide rule unless the intended position for the decimal point is known or can be determined.

ANSWERS

	Scale B	Scale CI	Scale C
Figure 11(a)			
A.	1126	944	1060
B.	1266	889	1125
C.	1425	839	1193
D.	1606	790	1266
E.	1802	746	1341
F.	202	704	1421
G.	227	664	1507
Figure 11(b)			
A.	493	449	222
B.	553	425	235
C.	622	401	249
D.	702	378	265
E.	788	356	281
F.	884	337	297
G.	994	318	315

Figure 11(c)

A.	241	204	492
B.	271	1921	521
C.	304	1813	552
D.	341	1711	585
E.	383	1614	620
F.	431	1523	657
G.	485	1436	697

12 PRACTICAL MULTIPLYING...You have already learned to multiply some simple values, like 2 × 3. Now that you have learned to read the scales on the rule you can multiply any two numbers.

....

Example... 1
Multiply 12.46 by 236

Solution... See Fig. 12

(1) Set the left index of scale C opposite 12.46 on scale D.
(2) Set the hairline of the indicator over 236 on scale C.
(3) Read the digits of the answer, 294, under the hairline on scale D.

To locate the decimal point: 10 × 250 = 2500. Hence, 12.46 × 236 = 2940, ans.

Explanation...

In making the settings required in steps (1) and (2), the decimal points in the original problem are ignored. This is true also in reading the digits making up the answer in step (3).

Fig. 12(a) shows the setting for steps (1), (2), and (3) in skeleton form, and Fig. 12(b) is a photograph of the portion of the rule covering this setting.

To locate the decimal we round off very roughly the values of the original problem. Thus 12.46 is roughly equal to 10, and

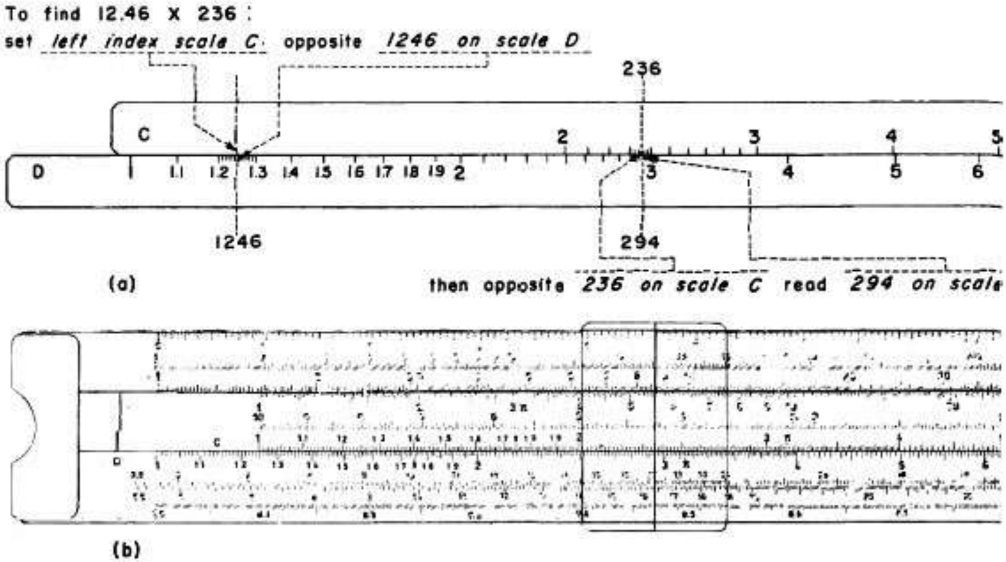


Fig. 12. Using slide rule to show that 12.46 X 236 = 2940 (or finding that 2940 ÷ 236 = 12.46).

236 is roughly equal to 250. Since 10 × 250 = 2500, the answer to the original problem must be of the order of 2500, which would make it 2940.*

Multiplying 12.46 by 236 with a pencil gives an exact answer of 2940.56. Rounding this value off to three significant figures gives 2940, the same as the slide rule answer above. You should not suppose that the slide rule answer of 2940 is usually a less satisfactory answer than the exact answer 2940.56. It is only less satisfactory if the nature of the problem requires an accuracy greater than three significant figures, and this is seldom the case in electronics work.

Example... 2
Multiply 0.004728 by 8.62

Solution... See Fig. 13
(1) Set the right index of scale C opposite 862 on scale D.

*Locating the decimal point by means of a rough calculation, as shown here, is the method used by all expert slide rule users. Mechanical methods of locating the decimal point, as occasionally taught, have serious disadvantages and will not be explained in this course.

(2) Set the hairline of the indicator over 473 on scale C.
(3) Read the digits of the answer, 408, under the hairline on scale D.

To locate the decimal point: 0.005 × 9 = 0.045. Hence, 0.004728 × 8.62 = 0.0408.

Explanation...
The procedure in this example differs from that of Example 1 in that the right index of scale C is used for this example, while the left index was used for Example 1. You should try to work this problem using the left index as in Example 1. You will find that part of the slide needed extends beyond the body of the rule so that a reading cannot be obtained.

In step (2) the number 4728 is rounded off to 473, since this part of the scale will not read to four figures.

To locate the decimal point, 0.004728 is rounded off to 0.005 and 8.62 is rounded off to 9. Hence, the correct answer is somewhere around 0.045. We place the decimal point in the answer digits, 408, in the position that makes the answer closest to 0.045. That would be 0.0408.

....

The examples above show that both the left and the right indexes on the C scale are used in working problems in multiplication.

If the wrong index is chosen for any particular problem, it will not be possible to set the hairline on the desired position on scale C, because that part of the scale extends beyond the body of the rule. In that case the problem must be started over again using the other index. With a very little experience you will know at once which index to use for most problems. However, even an experienced operator sometimes finds he has chosen the wrong index.

Example 2 above was worked by placing the index of scale C opposite 862 on scale D. This problem could also have been worked by placing the index of C opposite 473 on D, and then the hairline over 862 on scale C. You should work the problem in this manner, verifying that the answer is the same as

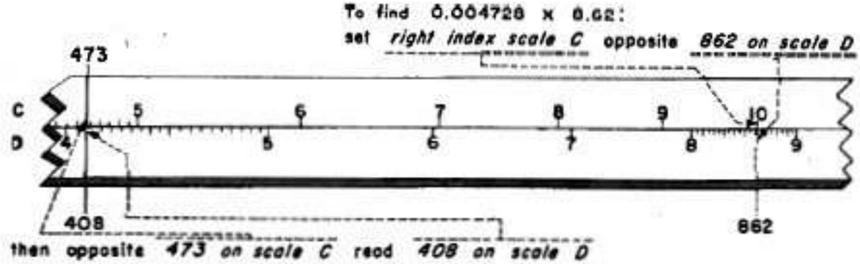


Fig. 13. Using slide rule to show that 0.004728 X 8.62 = 0.0408.

obtained in Example 2. There are thus two ways of multiplying any two numbers together.

One method results in the slide being moved farther out of the body of the rule than does the other method. While it would make little or no difference in the simple problems so far given, it is generally the best practice to choose that method which results in the slide being moved the least distance out of the body of the rule. In more involved problems this will sometimes result in a saving of labor.

WHAT HAVE YOU LEARNED?

Perform the indicated multiplications:

1...3 × 277	5...11.18 × 0.46
2...2.41 × 3.87	6...8,624 × 3,719
3...69.5 × 5.78	7...743 × 0.597
4...426,000 × 0.00888	8...1.003 × 474

9...27 horsepower is equal to how many watts? (Refer to back of slide rule to find number of watts in a horsepower.)

10...A current of 138 ma flows through a resistance of 4,700 ohms. What is the voltage drop across the resistor?

11...The diameter of a circle is 12.342 inches. Find its circumference, using the formula, $C = \pi D$, where C is the circumference and D is the diameter, both in the same units.

12...The list price of a radio component is $41.80. If you are allowed a discount of 37%, what will this item cost you?

13...An antenna is 38.2 feet long. What is its length in meters? (See back of slide rule for relation of meters to feet.)

14...480 volts are applied to the final stage of a transmitter. The stage draws 320 ma. What is the input power to the stage?

15...A scope shows the peak amplitude of a sinusoidal wave to be 260 volts. What is the effective value of this voltage? (Refer to back of rule for conversion factors.)

ANSWERS

1. 831	3. 402	5. 5.14	7. 444
2. 9.33	4. 3780	6. 32,100,000	8. 475

9. 20,100 watts (back of slide rule shows that one horsepower equals 746 watts.)

10. 649 volts

11. 38.8 inches

12. $26.33; this cost is 100 − 37 = 63% of the list price; $0.63 \times 41.8 = \$26.33$.

13. 11.64 meters (back of slide rule shows that one foot equals 0.3048 meter).

14. 153.6 watts

15. 183.8 volts

13 MULTIPLYING MORE THAN TWO FACTORS...As problems become more complex the labor saved by using a slide rule greatly increases. We see this to some extent in the following relatively simple type of problem where more than two factors are to be multiplied together. Notice that it is not necessary to read from the rule the results of the intermediate steps; only the final result needs to be read. Later in this lesson you will find that by using the CI scale the labor on this type of problem can be further decreased. Reducing labor does more than increase speed; by reducing the number of steps, the possibility of mistakes is also reduced.

....

Example... **3**

Find the product of 3.31 × 0.065 × 1.456 × 82.3

Solution...

Start out by multiplying 331 by 65 in the usual way. To do this place the right index of scale C opposite 65 on scale D, and then move the hairline so that it is over 331 on scale C. Now the product will be under the hairline on scale D. However, it is not necessary to read this product. Instead, move the slide until the left index of scale C is under the hairline.

The left index is now opposite the product of 331 by 65, and therefore is in the proper position for multiplying this product by 1456. Set the hairline over 1456 on scale C. The product of 331 by 65 by 1456 now appears under the hairline on scale D. Again this product need not be read. Instead, move the slide so that the right index of scale C is under the hairline, and therefore opposite the product of 331 by 65 by 1456. Then move the hairline so that it is over 823 on scale C. Read the digits of the final product, 258, under the hairline on scale D.

To find the decimal point we take 3 × 0.06 = 0.18, or nearly 0.2. 0.2 × 1.5 = 0.3. 0.3 × 80 = 24. Hence, the answer to the problem is 25.8.

Perform the indicated multiplications:

1...$12 \times 41.3 \times 0.0081$

2...$63.7 \times 0.501 \times 2,628$

3...$3.9 \times 81,700 \times 2.4 \times 0.662$

4...$955 \times 2.06 \times 501 \times 1,009$

5...The inductance of a coil is 43 microhenries. Find its reactance when the frequency is 31.1 megacycles.

ANSWERS

1. 4.01 2. 83,900 3. 506,000 4. 994,000,000
5. Using the formula on the back of the rule, $X_L = 2\pi fL =$ $6.28 \times 31.1 \times 10^6 \times 43 \times 10^{-6} = 8,400\ \Omega$, ans.

14 DIVISION...Since division is the opposite of multiplication, no new principle on the slide rule is involved when dividing. It is just a matter of working the steps required in multiplying in reverse order.

....

Example...**4**
2940/236 = ?

Solution... See Fig. 12
(1) Set the hairline over 294 on scale D.
(2) Move the slide until 236 on scale C is under the hairline.
(3) Opposite the left index of scale C read on scale D, 1246, the digits of the answer.

To locate the decimal point: 3000/200 = 15. Hence, the decimal point belongs in 1246 at the position that gives a value close to 15. That would be 12.46. Hence, 2940/236 = 12.46.

Fig. 12 illustrates the set-up for this problem.

....

Perform the indicated divisions:

1...85.7/73.7

2...1095/5.7

3...4.65/2.38

4...34.7/874

5...0.0083/0.000648

6...18.65/0.003862

7...4.63/0.576

8...1000/3.1416

9...The voltage across a circuit is 350 volts. If the impedance of the circuit is 4,250 ohms, find the current flowing.

10...A 175 ampere-hour storage battery is discharged. If the battery charger puts out 2.4 amperes, find the length of time required to charge this battery.

11...An antenna is 3.69 meters long. What is its length in feet and inches?

ANSWERS

1. 1.163 2. 192.1 3. 1.954 4. 0.0397 5. 12.81
6. 4830 7. 8.04 8. 318 9. 0.0824 amperes 10. 72.9 hrs.
11. 12 ft., 1.32 in.; 3.69/0.3048 = 12.11 ft., 0.11 ft. = 0.11 × 12 in. = 1.32 in.

LESSON 3122-1

SLIDE RULE

EXAMINATION

Circle the number of the correct answer for each question that follows. Then transfer the answers to the answer sheet by putting X's in the proper squares. When the graded answer sheet is returned to you, correct in this book any questions you may have missed. You will then have a record of the correct answers to all questions.

Be sure you have answered everyone of the What Have You Learned? problems before doing this examination. Unless you have that practice, you are going to make mistakes in reading the various scales.

Be sure to use the Request for Assistance sheet we have furnished you if you have any questions. Never write questions on the back of your exam sheet—we may not see them, so that they will not be answered.

1. In Fig. 11(b) on page 17, what is the reading on the C scale when the hairline is in position J?

1. 372	2. 3725	3. 374
4. 3745	5. 375	6. 383

2. In Fig. 11 (c) on page 17, what is the reading on the CI scale when the hairline is in position I?

1. 1208	2. 1253	3. 1256
4. 1280	5. 1302	6. 1320

3. In Fig. 11(c) on page 17, what is the reading on the C scale when the hairline is in position I?

1. 7535	2. 7565	3. 772
4. 7805	5. 783	6. 785

4. In Fig. 11 (a) on page 17, what is the reading on the B scale when the hairline is in position G?

1. 2208	2. 2255	3. 226
4. 227	5. 229	6. 255

5. In Fig. 11(a) on page 17, what is the reading on the CI scale when the hairline is in position H?

1. 6025	2. 6205	3. 621
4. 625	5. 771	6. 775

6. In Fig. 11(a) what is the reading on the C scale when the hairline is in position G?

1. 1501	2. 1505	3. 1508
4. 151	5. 155	6. 158

7. In Fig. 11(a) what is the reading on the C scale when the hairline is in position L?

1. 202	2. 205	3. 210	7. 220
4. 211	5. 2126	6. 215	

8. Using your slide rule, find the product 0.01743 × 63.2.

1. 1.102 2. 11.01 3. 11.2 4. 110.3 5. 111.3

9. Using your slide rule, find the product of 1908 × 0.405.
   1. 77.3 2. 77.6 3. 80.2 4. 89.1
   5. 773 6. 776 7. 802 8. 891

10. Using your slide rule, find 0.678 ÷ 27.4.
    1. 0.00186 2. 0.0187 3. 0.00242
    4. 0.0247 5. 0.025 6. 0.246

11. How much power does the final stage of a transmitter draw if the supply voltage is 645 volts and the plate current 325 ma?
    1. 201 watts 2. 209 watts 3. 215 watts
    4. 285 watts 5. 290 watts 6. 295 watts

12. What size cathode bias resistance should you use to develop a grid bias of -6 volts, if the cathode current is 35 ma? (The grid bias voltage equals the voltage drop across the cathode bias resistor.)
    1. 171.4 ohms 2. 210 ohms 3. 212 ohms
    4. 583 ohms 5. 1713 ohms 6. 2100 ohms

13. What horsepower is equal to 6300 watts?
    1. 0.118 hp 2. 0.845 hp 3. 4.7 hp
    4. 8.44 hp 5. 47 hp 6. 83.5 hp

14. An antenna is 35.3 meters long. What is its length in feet?
    1. 0.896 ft 2. 10.77 ft 3. 11.58 ft
    4. 89.6 ft 5. 107.7 ft 6. 115.8 ft

15. The principle of multiplying or dividing with a slide rule is that of
    1. mechanically adding or subtracting logarithms.
    2. using a mechanical multiplication table.
    3. using logarithms in exponential form to represent the value involved.
    4. using reciprocating scales.

END OF EXAM

(Do not tear this page from your book, but cut at this dotted line.)

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