★ NEW SCALE EFFICIENCY
★ NEW, CONVENIENT SIZE
★ FULLY GRADUATED SCALES

NEW POST 1445 STUDENT SLIDE RULES HAVE MANY FEATURES USUALLY FOUND ONLY IN EXPENSIVE RULES, BUT ARE DESIGNED FOR STUDENTS' ECONOMY AND CONVENIENCE.

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The all new 1445 is a new dimension in slide rules. Small enough to fit coat-pocket, notebook or purse, large enough to have all of the graduations of larger rules. Features such as the spring-loaded cursor, folded scales and lifetime construction make this eight-inch rule the outstanding value among slide rules today.

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Unique scale arrangement for a beginner's slide rule makes operation faster, and easier to learn.

CF and DF folded scales increase the speed of multiplication and division by as much as 30%; permit immediate multiplication by pi; and prevent running "off-scales."

TI and SI inverted trig scales permit direct multiplication or division by the numerical values of trigonometric functions, without reversing the slide in the rule. Trig scales are divided into degrees and decimals of degrees. This feature makes it easier to use with the newer trig textbooks, and makes transition to a professional rule easier.

NEW MANUAL

The 1445 Slide Rule is supplied with a 48 page instruction manual, written by a professional educator. This new booklet is ideal for use as a classroom text, yet simple enough for self-instruction . . . even for students with little math training.

NEW PRICE

Lifetime Bamboo Slide Rule, furnished in slip-cap desk-case, and including 48 page instruction manual is list priced at $3.75.

1486B $1.00

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SLIDE RULE INSTRUCTION MANUAL FOR 1445 SLIDE RULES

all new text makes self-instruction fast and easy

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ACKNOWLEDGEMENTS

The technology of the space-age has produced some remarkable conquests of our natural environment. They include the exploration of the inner nature of matter, as well as the reaches of outer space. These achievements have their origin in the minds of men, and in the tools of engineering.

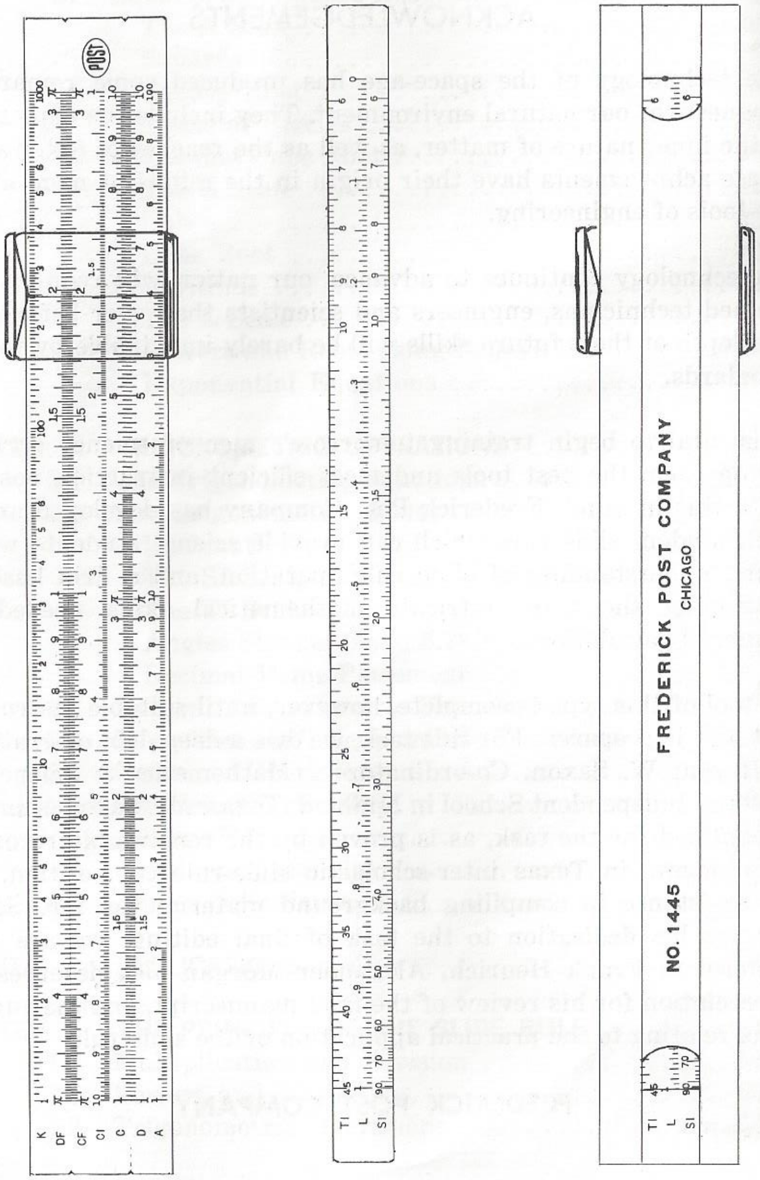
As technology continues to advance, our nation will require more trained technicians, engineers and scientists than ever before, and the depth of their future skills will be barely imaginable by today's standards.

It is vital to begin training tomorrow's men of science early by giving them the best tools and most efficient instruction possible. With this in mind, Frederick Post Company has developed an efficient student slide rule which can provide science students with a sound understanding of slide rule operation, and a firm base for developing the more intricate mathematical skills needed for advanced calculations.

No tool of this type is complete, however, until suitable instruction material is prepared. For this task, we owe a deep debt of gratitude to Bryant W. Saxon, Co-ordinator of Mathematics & Science, of Midland Independent School in Midland, Texas. Mr. Saxon is uniquely qualified for the task, as is proven by the remarkable record of his students in Texas inter-scholastic slide-rule competition. For his assistance in compiling background material for Mr. Saxon, and for his dedication to the task of final editing, we are most grateful to Frank Heurich. Alexander Morgan also deserves our appreciation for his review of the final manuscript, and his suggestions relating to the practical application of the slide rule.

FREDERICK POST COMPANY

STUDENT SLIDE RULE
1445, 1445 P



FACE OF 1445 — REVERSE SIDE OF SLIDE — REVERSE SIDE OF ENTIRE RULE

Figure 1.1

CHAPTER 1

INTRODUCTION TO THE STUDENT SLIDE RULE

The slide rule is an instrument which enables the user to solve simple and involved arithmetical problems with speed and confidence impossible with written computations.

This chapter covers the important topics of proper care and manipulation of the slide rule, a brief description of the scales, and the method of locating numbers and reading the basic scales. Reading the scales should be mastered before proceeding to multiplication and division.

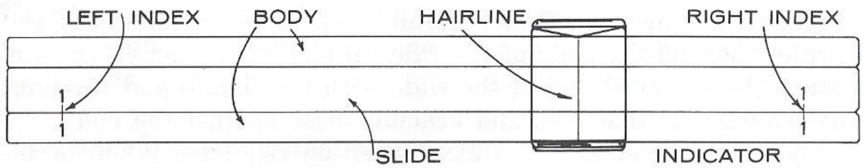


Figure 1.2

1.1 GENERAL DESCRIPTION

The construction of the slide rule is simple: essentially, there are three components; (1) the body, (2) the slide, and (3) the indicator. The body is comprised of the upper and lower fixed members. The slide is situated between these, and slides in the grooves in the body. Scales are deeply cut on the body, and on both front and back faces of the slide. The indicator (sometimes called the cursor) is composed of an unbreakable window with a red hairline. Two additional hairlines are provided on the back of the rule to be used with scales on back face of the slide.

The body and slide are made of laminated bamboo to which is permanently bonded the white plastic face. This type of construction offers the distinct advantages of insuring against warpage and providing exceptional dimensional stability, so that the rule will be accurate and operate smoothly over a wide range of weather conditions. Since bamboo is self-lubricating, the slide rule's action will improve with use.

1.2 CARE OF THE STUDENT RULE

It is important to keep the slide rule as clean as possible. Having clean hands and keeping the rule in its case when not in use will help. To clean the body and slide, a slightly moist cloth may be used. Keep the running surface of the slide and indicator clean, as dirt may accumulate here and cause an annoying "sticking" of the slide and indicator.

1.3 MANIPULATION

The following suggestions are offered for manipulation of the slide rule. With experience, the reader may develop his own variations.

Grasp the slide rule between the thumb and forefinger of one hand at the end of the rule.

In setting the slide, move it to the general neighborhood of the required setting. This will generally cause one end of the slide to project beyond the body of the rule. In making the precise setting, grasp the extended end of the slide with the thumb and forefinger of the hand at that end, and bracing these against the end of the body, move the slide to the exact position required. When neither end of the slide projects very far beyond the body of the rule, the two forefingers can push against both ends of the slide—pushing harder on one end than the other until the exact setting is reached.

In setting the hairline, the indicator is pushed to the neighborhood of the desired location. For precise positioning, place the thumbs of both hands against each end of the indicator frame and push harder with one thumb than the other as required to set the hairline.

1.4 DESCRIPTION OF THE SCALES

There are ten scales on the Student slide rule; seven on the front face and three on the reverse face of the slide. Each scale is designated by a letter or letters at the left end of the rule. Each scale and its function will be briefly described here. More detailed explanations will be found in the following chapters that deal with specific operations of the scales.

The **C** and **D** scales are the most basic and are most used. They are identical in markings and length; the C scale appearing on the slide, and the D scale on the lower body member. The C and D scales are used together for multiplication and division, and with each of the other scales for other computations.

The **CI** scale appears on the slide, and is identical to the C and D scales, except that its graduations and numbers run from the right to left. Those numbers appearing on the CI, or inverted scale, are reciprocals of those numbers directly opposite on the C scale. The reciprocal of a number is the quotient of the number and one. The number 2 on CI scale is in reality $1/2$, three on CI is $1/3$, etc. The CI scale is used with the D scale to provide efficient multiplication and division and with the other scales for various computations.

The **CF** and **DF** scales are folded scales. Their numbers and graduations are identical to those of the C and D scales, except that they begin and end with π (π, 3.1416). This arrangement results with the number 1 approximately at the center of the rule. The convenience of this arrangement for rapid work is explained in the following chapters.

The **A** scale is a scale for obtaining squares and square roots. It is a two section scale with a range from 1 to 100, and is used with the D scale.

The **K** scale is used for finding cubes and cube roots when used with the D scale. It is a three section scale with a range from 1 to 1,000.

The **L** scale is a uniformly divided scale for finding logarithms. A complete discussion will be provided later in this manual.

The **SI** scale is found on the back face of the slide. This scale is used to find the values of the sine and cosine functions of angles. It is graduated in degrees and decimals of degrees. The scale is graduated from right to left. Sine and cosine functions of angles on this scale are found on the D scale at the index on the C scale.

The **TI** scale is also found on the back face of the slide. This scale is used to obtain the values of the tangent function of angles from 5.7 to 84.3 degrees. Angles from 5.7 to 45 degrees are numbered from right to left on the TI scale. Tangent functions of angles on this scale are found on the D scale at the index on the C scale.

1.5 READING THE SCALES

The reading of the C and D scales is explained in detail. Applying these principles and noting the range and the direction of graduations, the reading of the other scales should be easily mastered.

The C and D scales are graduated into 10 major divisions—these graduations are numbered from 1 on the left to 10 on the right. Figure 1.3 shows the major divisions.

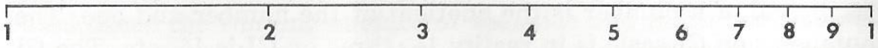


Figure 1.3

Since the slide rule is based on logarithms, the spaces between graduations are not uniform. (An understanding of logarithms is not important in the use of the slide rule. For a brief explanation of the principles, see Chapter 7.)

Each major division is divided into 10 secondary divisions. In the first major division, the mid-point of this division, 1.5, is also numbered.

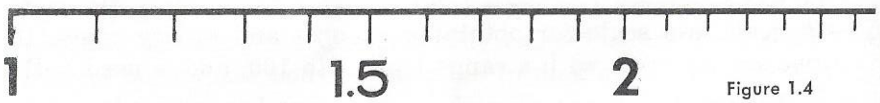


Figure 1.4

Each secondary division is also divided into still smaller divisions. These are the shortest graduations on the scale. Between major graduations 1 and 2, the secondary divisions are divided into 10 sub-divisions. Each division equals 1 in this part of the scale. Between major graduations 2 and 4, the secondary divisions are divided into 5 subdivisions. Each division equals 2 in this section of the scale. Between major graduation 4 and 10, the secondary divisions are divided into 2 subdivisions. Each division equals 5 in this part of the scale.

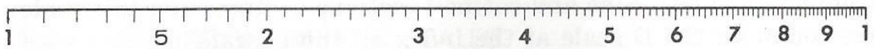


Figure 1.5

Locating numbers on the scale requires an understanding of significant figures. The first non-zero digit is called the first significant digit. The second and third digits, zero or not, become the second and third significant digits. In the number 237, the 2 is the first significant figure, the 3 is the second significant figure, and the 7 is the third significant figure. In the number 61, the 6 is the first significant figure and 1 is the second significant figure. There is no third significant figure. In the number 768,250, all we are concerned about is the 7, the 6 and the 8, which are the first, second, and third significant figures.

Are you ready for some practice? Find the *first, second* and *third* significant figures of the following numbers. a. 245 b. 564 c. 799 d. 888 e. 34 f. 65 g. 13 h. 104 i. 305 j. 1234 k. 134253954 l. .00100

In locating numbers on the slide rule the first significant figure helps us locate the general area in which to find a given number. For instance if the first significant figure is 2 then the number will be found in the space that includes the 2 and reaching just up to the big number 3. See fig. 1.6.

a. If the *first* significant figure is 1 then locate between 1 and 2.

b. If the *first* significant figure is 2 then locate between 2 and 3.

c. If the *first* significant figure is 3 then locate between 3 and 4.

d. If the *first* significant figure is 9 locate between 9 and the right index.

Summary for *first* significant figures.

After locating the general area of the scale in which the first significant figure appears, the second significant figure can be located within that area:

a. Where a *second* significant figure of 2 could be.

b. Where a *second* significant figure of 3 could be.

c. Where a *second* significant figure of 9 could be.

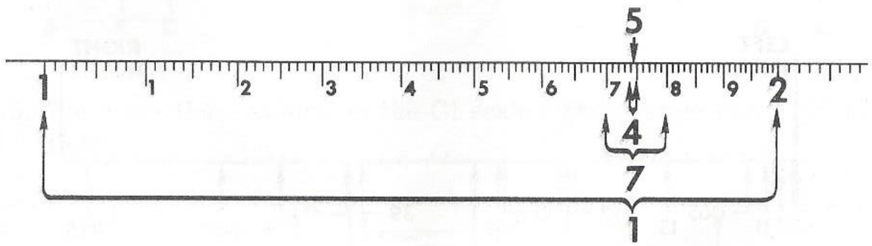


Figure 1.6

d. *And now one that causes more mistakes than all the others put together ! ! !* Where a *second* significant figure of 0 could be.

e. A second significant figure of 9 could be located as follows:

Two significant figures can always be located on a graduation while it is sometimes possible to locate three significant figures. Often however, the third significant figure must be estimated. If in locating the third significant digit 7, the space between the secondary graduation is sub-divided into spaces of two units each, the 7 would be half-way between the 6/10 and the 8/10 graduations. If the space between the secondary graduations is subdivided into 2 spaces, the 7 would be located 2/10 past the 5/10 graduation.

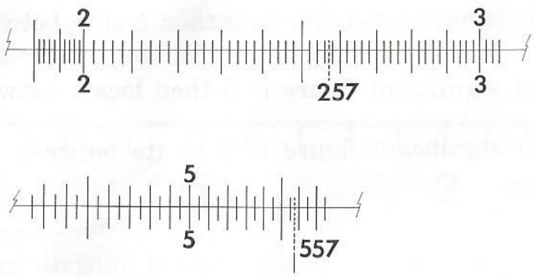


Figure 1.7

The location of the decimal point has no effect on the location of the number on the scale. All numbers that have the same digits (e.g. 274, 2.74, 27,400, and 0.00274) are located at the same point on the D scale regardless of the location of the decimal point. Several approaches to the decimal point placement are discussed in Chapter 2.

Figure 1. 8 shows several examples of numbers on the C or D scales. After reviewing these, practice locating the same numbers on the CI scale, and perform the exercises that follow.

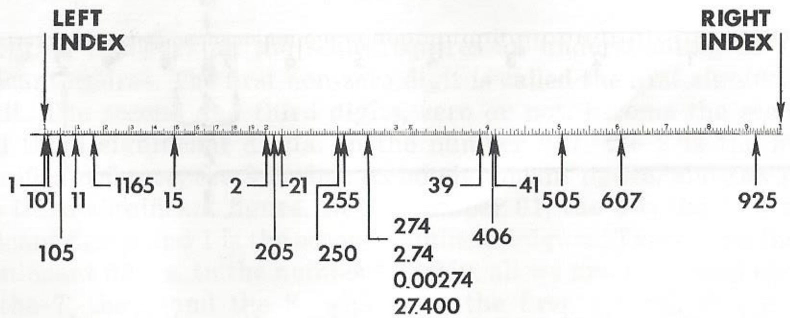
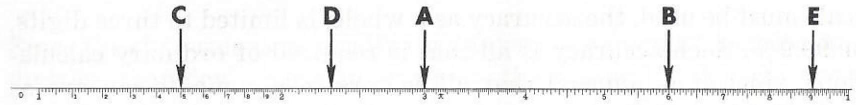


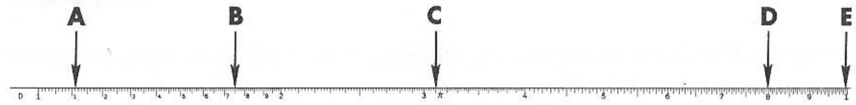
Figure 1.8

EXERCISES IN READING THE SCALE

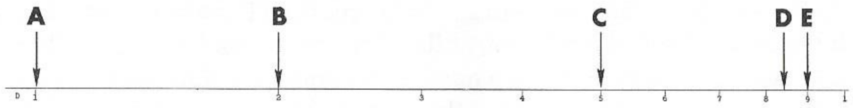
1. What are these values on the C or D scales? They range from 1 to 10. (Answers are located in the back of the book.)



2. What are these values on the C or D scales? They range from 10 to 100.



3. What are these values on the C or D scales? They range from .01 to .1.



4. What are these values on the CI scale? They range from 1 to 10.

5. What are these values on the CI scale? They range from 100 to 1,000.

1.6 ACCURACY

The graduations on the Student Rule are highly accurate, but the accuracy of the slide rule is limited to the ability of the user to see, set, and read the desired numbers. The scales can essentially only be read to an accuracy of three significant digits. Since the entire scale must be used, the accuracy as a whole, is limited to three digits, or 99.9%. Such accuracy is all that is required of ordinary calculations, since it is unusual that all factors in a computation are so accurate that no factor contains an error larger than one part in one thousand.

CHAPTER 2

MULTIPLICATION AND DIVISION

SIMPLE OPERATIONS

Since the slide rule is generally used far more for multiplication and division than for other computations, the Student Rule provides a selection of scales for optimum speed in any multiplication or division operation or series of computations. A familiarity of the alternates available can save time and steps in simple everyday computations, and a thorough understanding of the proper use of the scales is essential for efficient handling of a number of computations in a single problem.

This chapter and Chapter 3 present the scope of applications of the Student Rule to multiplication and division problems. The most efficient use of the rule is emphasized.

2.1 MULTIPLICATION: BASIC METHODS

The D and C Scales. The D and C scales are the most fundamental of the slide rule and are common to all types of rules, both simple and complex. Any multiplication or division operation may be performed solely through the use of these scales, though their exclusive use will not be the most efficient.

The following examples illustrate multiplication using the D and C scales.

Example 2.1

Problem: $2 \times 3 = 6$

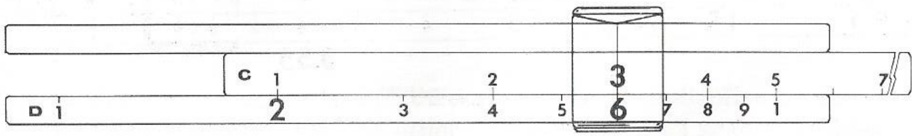


Figure 2.1

Operation: Move left index of C to 2 on D (i.e., opposite 2 on D).
Move hairline to 3 on C.
Read answer, 6, on D at hairline.

Use of the hairline in the first step is optional. Some people find it a convenience while learning to use the slide rule. The following examples omit this step.

Example 2.2
Problem: $9 \times 4 = 36$

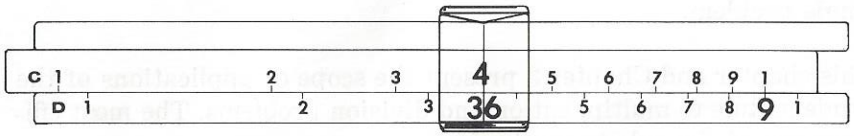


Figure 2.2

Operation: Set right index of C to 9 on D.
Move hairline to 4 on C.
Read product, 36, on D at hairline.

In this case, the right index must be used. Had the left index of the C scale been used, 4 on the C scale would project beyond the D scale and no answer could be obtained. Thus, the right index must obviously be used in this case. After a little practice, the selection of the proper index will become automatic.

Example 2.3
Problem: $1.5 \times 5.7 = 8.55$

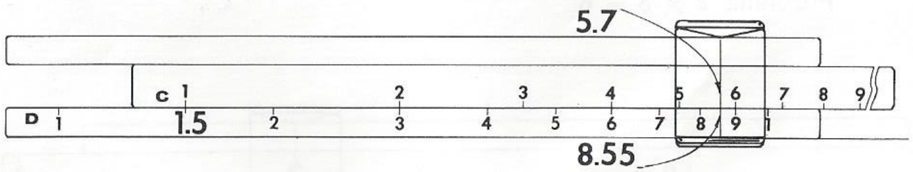


Figure 2.3

Operation: Set left index of C to 1.5 on D.
Move hairline to 5.7 on C.
Read 8.55 on D at hairline.

The topic of decimal point placement will be discussed later in this chapter.

From the examples above, a general procedure for multiplying using the D and C scales can be derived.

1. Move the slide until an index of C coincides with one of the numbers to be multiplied on D.
2. Move the hairline to the other number on C.
3. Read the product on D at the hairline.
4. If the slide extends beyond the body, to an extent that steps 3 and 4 cannot be performed, use the other index of C in step 2.

Since the D and C scales are adjacent, it is possible to multiply without the use of the indicator. The beginner is urged to make use of the indicator for it will save time and eliminate errors in reading the scale.

In multiplying numbers such as 4×9, the computation can be made by setting the right index of C at 4, moving the hairline to 9 on C, and reading 36 on D. However, considerable slide rule movement (and therefore time and effort) can be saved by reversing the problem to read 9×4 and solving as in Example 2.2.

The D and CI Scales. Multiplication using the D and CI scales is often more efficient than using the D and C scales. It is often preferred because it is not necessary to determine which index of the C scale to use. Experienced users will use both this method and the preceding method interchangeably, selecting the one most efficient for the particular problem. Remember that the values on the CI scale increase toward the left, while the values on the C scale increase toward the right. The procedure for multiplying using the D and CI scales follows:

1. Set the hairline to one of the numbers to be multiplied on D.
2. Move the slide until the other number on the CI scale coincides with the hairline.
3. Read the product of the two numbers on D at the index of C, (whichever index is adjacent to the D scale).

Example 2.4

Problem: $2 \times 3 = 6$

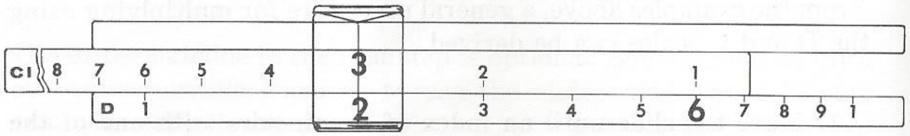


Figure 2.4

Operation: Set hairline at 2 on D.
Move 3 on CI to hairline.
Read 6 on D at right index of C.

Example 2.5

Problem: $52 \times 4 = 208$

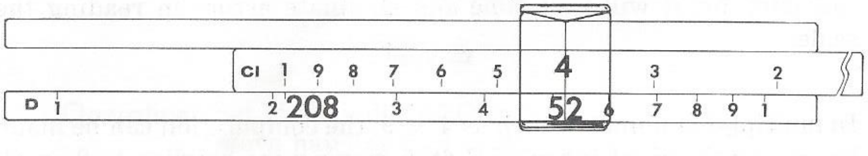


Figure 2.5

Operation: Set hairline to 52 on D.
Move 4 on CI to hairline.
Read 208 on D at left index of C.

Example 2.6

Problem: $64 \times .3 = 19.2$

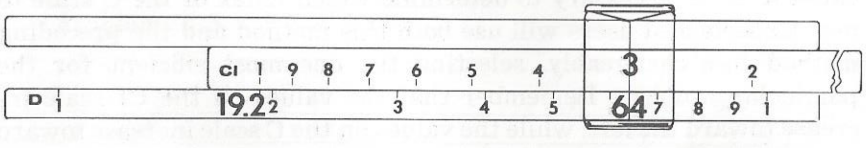


Figure 2.6

Operation: Set hairline to 64 on D.
Move .3 on CI to hairline.
Read 19.2 on D at index of C.

In this example, the solution must be less than 64 (since .3 is less than 1) and must be more than 6.4 (since .3 is more than .1). Therefore, the product of 64 and .3 must be 19.2.

Choice of the D and C, or the D and CI Scale Combinations. In general, choose the scale combination that would require the least slide movement as this is the most efficient scale combination. For some computations, the choice of scale combinations makes little difference in efficiency, while for others, there is a decided difference. Whenever one scale combination requires moving the slide more than one-half its length, use another combination.

Exercise in Multiplication. In performing the following exercises, indicate the most advantageous scale combination. A rough mental approximation will serve to locate decimal points. No attempt should be made to read results more accurately than the instrument allows. The accuracy is limited to three significant figures.

6.	8×3	12.	4×3
7.	12×7	13.	29×19.4
8.	6.1×7.3	14.	7.5×14.6
9.	1.37×27	15.	$.95 \times 1{,}07$
10.	812×8.02	16.	572×1.45
11.	7.92×6.4	17.	4.48×46.6

2.2 DIVISION: BASIC METHODS

The D and C Scales. The procedure for division using the D and C scales is as follows:

1. Set the hairline to the numerator on D.
2. Align the denominator on C with the hairline.
3. Read the quotient on D opposite the index of C.

Example 2.7

Problem: $\frac{6}{3} = 2$

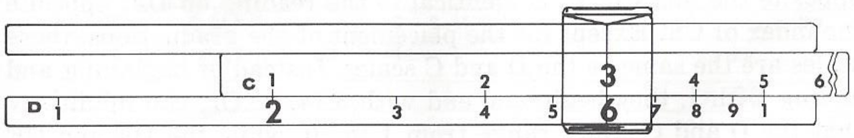


Figure 2.7

Operation: Set hairline to 6 on D.
Move 3 on C to hairline.
Read quotient, 2, on D at left index of C.

Example 2.8

Problem: $\frac{342}{6} = 57$

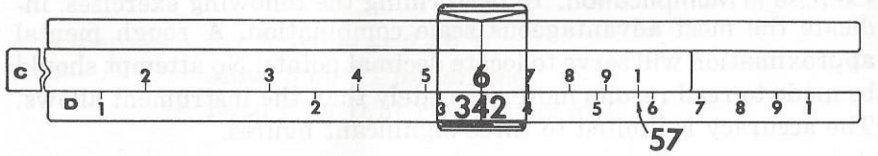


Figure 2.8

Operation: Set hairline to 342 on D.
Move 6 on C to hairline.
Read answer, 57, on D at right index of C.

Example 2.9

Problem: $\frac{9.56}{1.12} = 8.54$

Operation: Set hairline to 9.56 on D.
Move 1.12 on C to hairline.
Read quotient, 8.54, on D at left index of C.

The operation in Example 2.9 is grossly inefficient, because of the slide movement required. Using other scales, rather than the D and C scales for this and similar problems is preferable. Therefore, after mastering the use of the D and C scales for division, the use of the remaining scales should be studied.

The DF and CF Scales. These scales each have only one index (1 mark). Note that for any position of the slide, the reading on D, opposite the index of C, is identical to the reading on DF, opposite the index of CF. Except for the placement of the graduations, these scales are the same as the D and C scales. Instead of beginning and ending with 1, they begin and end with 3.14, π. Or, you might say that the D and C scales range from 1 to 10, while the DF and CF scales range from 3.14 to 31.4. In both multiplication and division, the DF scale is used like the D scale, and the CF scale is used like the C scale. The procedure for division using the DF and CF scales is the same as when using the D and C scales except the DF and CF scales are used in steps 1 and 2, as illustrated in examples 2.10, 2.11, and 2.12.

Example 2.10

Problem: $\frac{12}{6} = 2$

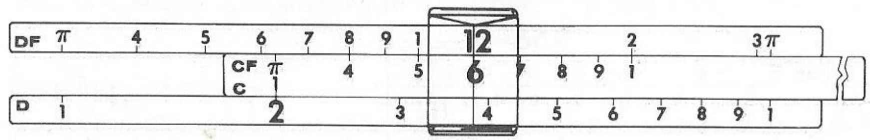


Figure 2.9

Operation: Set hairline to 12 on DF.
Move 6 on CF to hairline.
Read answer, 2, on D at index of C.

The answer can also be read on the DF scale opposite the CF index. However, developing the habit of looking for the answer in the same place (the D scale opposite the index of C) when using either the D and C or the DF and CF scale combinations simplifies the operation. Thus, even if the DF and CF combination is chosen when it is less efficient than the D and C combination and the CF index is not opposite the DF scale, the quotient can be read on the D scale without duplicating the operation on the D and C scales.

Example 2.11

Problem: $\frac{440}{5.5} = 80$

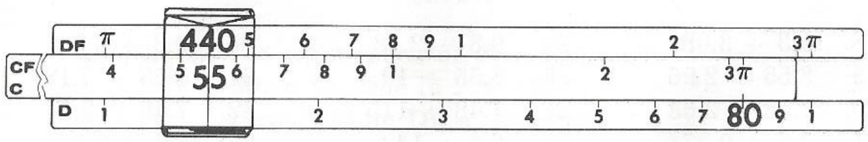


Figure 2.10

Operation: Set hairline to 440 on DF.
Move 5.5 on CF to hairline.
Read 80 on D at index of C.

(A quick mental calculation, $\frac{500}{5} = 100$, locates the decimal point.)

Example 2.12

Problem: $\frac{9.56}{1.12} = 8.54$

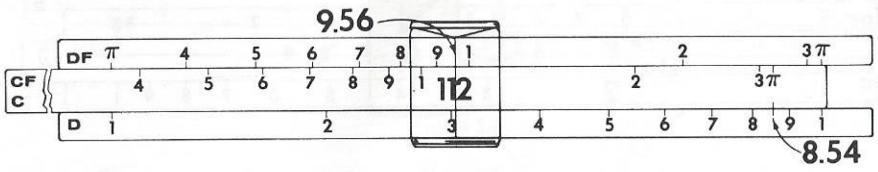


Figure 2.11

Operation: Set hairline to 9.56 on D.
Move 1.12 on CF to hairline.
Read 8.54 on D at index of C.

This is the same problem as Example 2.9, but is performed far more efficiently using the DF and CF scales.

Choice of the D and C, or DF and CF Scale Combinations. Again, choose the combination that requires the least slide movement. For some computations, there is no difference in efficiency, but for others, there is considerable difference. If the numerator and denominator are close to opposite ends of the D scale, choose the DF and CF combination. It should never be necessary to move the slide more than half its length.

Exercise in Division. Perform the following operation using different combinations of scales, and indicate the most advantageous scale combination.

18. 9.3 ÷ 3.08
19. 8.55 ÷ 2.96
20. 7.48 ÷ 2.63
21. 6.3 ÷ 0.27
22. 450 ÷ 19.2
23. 1950 ÷ 435
24. 9.3 ÷ 2.18
25. 8.55 ÷ 10.5
26. 7.48 ÷ 115
27. 6.3 ÷ 14.2
28. 450 ÷ 10.4
29. 1950 ÷ 94.5
30. 9.3 ÷ 6.5
31. 8.55 ÷ 5.12
32. 7.48 ÷ 3.54
33. 6.3 ÷ 7.5
34. 450 ÷ 57.2
35. 1950 ÷ 10.6

2.3 MULTIPLICATION: ALTERNATE METHOD

The DF and CF Scales. Multiplication can be performed strictly by using the DF and CF scales, but their more practical application is in conjunction with the D and C scales. Since every multiplication and division computation can be performed without moving the slide more than halfway out of the body of the rule, every value on a C scale (either C or CF) is opposite a value on a D scale (D or DF).

Multiplication using the DF and CF scales in conjunction with the D and C scales is illustrated in Examples 2.13 and 2.14.

Example 2.13

Problem: $21 \times 5 = 105$

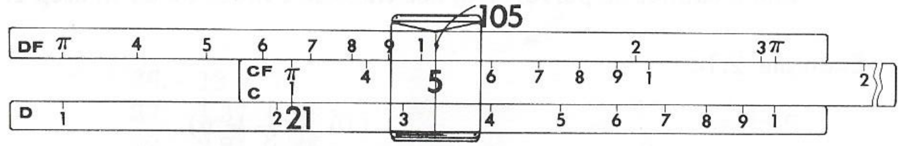


Figure 2.12

Operation: Set left index of C to 21 on D.
Move hairline to 5 on CF.
Read 105 on DF at hairline.

Example 2.14

Problem: $4.17 \times 2 = 8.34$

Figure 2.13

Operation: Set right index of C to 4.17 on D.
Move hairline to 2 on CF.
Read 8.34 on DF at hairline.

Multiplication using the DF and CF scales exclusively is demonstrated in the following example.

Example 2.15

Problem: $3 \times 6 = 18$

Operation: Set index of CF opposite 3 on DF.
Move hairline to 6 on CF.
Read 18 on DF at hairline.

DIVISION: ALTERNATE METHOD

The D and CI Scales. The procedure for dividing using the D and CI scale follows:

1. Set an index of the CI scale to the numerator on D.
2. Move the hairline to the denominator on the CI scale.
3. Read the quotient at the hairline on D.
4. If the slide extends beyond the body, to an extent that steps 2 and 3 cannot be performed, use the other index of CI in step 1.

Example 2.16

Problem: $\frac{15}{3} = 5 \qquad (15 \times \frac{1}{3} = 5)$

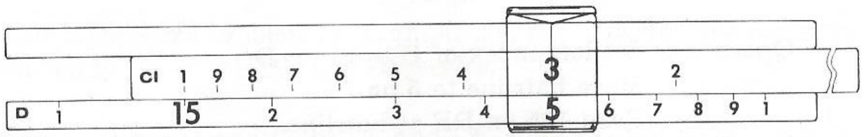


Figure 2.14

Operation: Move left index of CI to 15 on D scale.
Move hairline to 3 on CI.
Read quotient, 5, on D at hairline.

Example 2.17

Problem: $\frac{3.94}{19.05} = .207$

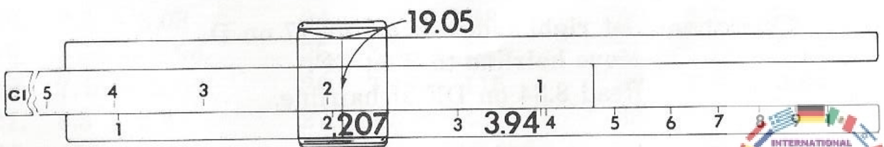


Figure 2.15

Operation: Move right index of CI to 3.94 on D.
Move hairline to 19.05 on CI.
Read .207 on D at hairline.

Notice that the procedure using the D and CI scales is the sa
used for multiplication using the D and C scales. Since the CI
is a reciprocal scale, this method is, in effect, division by multi
tion of the numerator by the reciprocal of the denominator.

Exercise in Multiplication and Division. In performing the follo
multiplication exercises, use the DF and CF scales in conjun
with the D and C scales; then check the answer using both the D
C scales, and then D and CI scale combinations. Notice the mos
vantageous scale combination. A rough approximation will ser
locate the decimal.

36. 12×7
37. 1.37×96
38. 2.84×45
39. $.95 \times 10{,}015$
40. 572×1.4510
41. 41×23

In performing the following division exercises, use the D an
scales; then check the answers using both the D and C scales an
DF and CF scale combinations. Again, notice the most advant
ous scale combinations.

42. $4 \div 3$
43. $9 \div 4$
44. $13 \div 3$
45. $75{,}000 \div 25$
46. $2 \div 6$
47. $892 \div 24$

2.5 DECIMAL POINT LOCATION

Thus far, the topic of the location of the decimal point has
briefly mentioned. Since the slide rule has no provision for "car

along" the decimal point in a given problem, some method must be adopted. Three methods are suggested. In all probability, all will be used at one time or another, depending on the complexity of the particular problem. Therefore, all three methods should be thoroughly understood.

The Common Sense Approach. For many problems, the combination of factors is simple enough that by inspection, the location of the decimal point is obvious. For instance, in the computation 9.2 ÷ 2, the slide rule reads 46, which certainly must be 4.6. Even for other problems, which may be comprised of many factors and be more complicated mathematically, the result may be only reasonably interpreted in one way. For example, if the result of a calculation of the speed of an automobile in miles per hour was the digits 234, the correct speed would reasonably be 23.4 mph, not 234.0 or 2.34 mph.

The Standard Form Approach. This is the most exact method and is recommended for problems too complicated to be easily handled through the common sense method. It is particularly helpful when dealing with numbers of very large or very small size.

Placing a number in its standard form entails placing the decimal point after the first non-zero digit of the number and indicating the true location of the decimal point by multiplying it by the appropriate power-of-ten. The magnitude of the appropriate power-of-ten is determined by the number of digits that the decimal point was moved to place it after the first non-zero digit of the number. If the number is larger than 10, the decimal point is moved to the *left*, and the power-of-ten is *positive*. If the number is larger than 1, but less than 10, the decimal point is not relocated, and the power-of-ten is therefore zero, ($10^0 = 1$). If the number is smaller than 1, the decimal point is moved to the *right*, and the power-of-ten is *negative*. The following examples are presented for clarification.

	NUMBER		STANDARD FORM
(a)	100	=	1×10^2
(b)	735	=	7.35×10^2
(c)	4,360,000	=	4.36×10^6
(d)	.0001354	=	1.354×10^{-4}
(e)	.0862	=	8.62×10^{-2}
(f)	26.9	=	2.69×10^1
(g)	.326	=	3.26×10^{-1}
(h)	7.1	=	7.1×10^0

When multiplying numbers in their standard form, the exponents are added; when dividing, they are subtracted. Thus, $7{,}000 \times .0006 = (7 \times 10^3)\ (6 \times 10^{-4}) = 42 \times 10^{-1} = 4.2$. Note also that $\frac{1}{10^{-3}} = 10^3$, etc. Using this method makes the slide rule solution of problems like the following quick and free of error.

$$\frac{26 \times 79{,}800 \times .00633}{.0081 \times 7{,}800{,}000} = \frac{(2.6 \times 10^1)\ (7.98 \times 10^4)\ (6.33 \times 10^{-3})}{(8.1 \times 10^{-3})\ (7.8 \times 10^6)}$$

$$= \frac{2.6 \times 7.98 \times 6.33 \times 10^2}{8.1 \times 7.8 \times 10^3}$$

$$= 2.08 \times 10^{-1}$$

$$= .208$$

While the simple and direct slide rule computation for this type of problem has not yet been explained, the solution would read 208, which is correctly interpreted as .208. Chapter 3 shows the solution to this computation with just two settings of the slide.

Approximation. The position of the decimal point can be pre-determined by approximate mental calculations. In rounding off each factor to the nearest hundred and mentally computing an approximate answer the decimal point can be accurately placed.

Example:

$$\frac{389 \times 47 \times 8.072}{.912 \times 432 \times 1.87} = \frac{4.0 \times 5.0 \times 8.0 \times 10^3}{1.0 \times 4.0 \times 2.0 \times 10^1}$$

A quick mental calculation would give $\frac{160}{8} \times 10^2$ or 2000.0

Answer: App. 2000

2.6 MULTIPLICATION AND DIVISION: SUMMARY

There are three pairs of scales generally used for multiplication and division; they are D and C, D and CI, DF and CF. There are two procedures of using these scales: (1) aligning the two factors and reading the answer opposite an index, and (2) aligning one factor and an index, and reading the answer opposite the other factor. Following the rule that numerators and answers are read on a D scale (D or DF), the three pairs of scales and two procedures of using them result in six combinations; three yield multiplication, and three yield division. These six combinations are tabled below.

Operation	*Scales*	*Procedure*
Multiplication	D & CI	1
Multiplication	D & C	2
Multiplication	DF & CF	2
Division	D & C	1
Division	DF & CF	1
Division	D & CI	2

The object in perfecting more than one method for multiplying and one for dividing is to greatly increase the potential speed and efficiency. For both multiplication and division, two basic procedures should be mastered and used interchangeably to limit slide movement to half its length and so that no more than half of the slide projects beyond the body scales. Two alternate procedures should be learned for rapid handling of sequences and combinations of computations with the minimum number of settings.

The procedures recommended here are efficient, easily learned by beginners, and preferred by many teachers of the slide rule. The important thing is that *all* of the procedures are understood and are used when required, and that the procedures selected as the basic ones are used efficiently and without error.

CHAPTER 3

MULTIPLICATION AND DIVISION

COMPOUND OPERATIONS

A great advantage of the slide rule is that a number of calculations can be performed in one continuous operation. It is not necessary to record the answers to intermediate steps of a compound problem. A complete understanding of Chapter 2, however, is required.

3.1 COMBINED OPERATIONS

Multiplying or Dividing a Series of Numbers. Using two procedures for multiplication and two pairs of scales, a series of factors can be multiplied together with minimum time and effort. In the following examples, notice that the products of the intermediate calculations are available, but can be disregarded.

Example 3.1

Problem: $4.7 \times 5.24 \times 10.12 = 249$

Operation: Set hairline to 4.7 on D.
Move 5.24 on CI to hairline.
Move hairline to 10.12 on C.
Read 249 on D at hairline.

Example 3.2

Problem: $3.25 \times 4.28 \times 9.13 = 127$

Operation: Set hairline to 3.25 on D.
Move 4.28 on CI to hairline.
Move hairline to 9.13 on CF.
Read 127 on DF at hairline.

On the slide rule, division is just as easy as multiplication. As previously mentioned, division of a number only requires multiplication by the reciprocal of the denominator, and thus the procedure of dividing a series of numbers is evident. Again, full use must be made of the various methods of division for efficient operation, as demonstrated in the following example.

Example 3.3

Problem: $\dfrac{1}{3.25 \times 4.28 \times 6.13} = .01173$

Operation: Set 3.25 on C to right index of D.
Move hairline to 4.28 on CI.
Move 6.13 on C to hairline.
Read .01173 on D at left index of C.

Multiplying and Dividing a Series of Numbers. The process of combining multiplication and division in a series of computations is as simple as combining the operations just illustrated. In the example that follows, two sequences of operations are described.

Example 3.4

Problem: $\dfrac{2.5 \times 5.85 \times 16.4}{4.35 \times 13.9 \times 3.36} = 1.18$

Operation (A): Set hairline to 2.5 on D.
Move 5.85 on CI to hairline.
Move hairline to 16.4 on C.
Move 4.35 on C to hairline.
Move hairline to 13.9 on CI.
Move 3.36 on C to hairline.
Read 1.18 on D at left index of C.

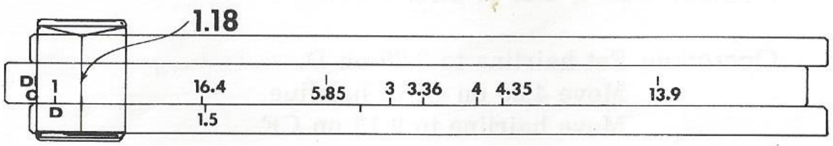


Figure 3.1

Problem: $\dfrac{2.5 \times 5.85 \times 16.4}{3.36 \times 13.9 \times 4.35}$

Operation (B): Set hairline to 2.5 on D.
Move 4.35 on C to hairline.
Move hairline to 5.85 on C.
Move 13.9 on C to hairline.
Move hairline to 16.4 on C.
Move 3.36 on C to hairline.
Read 1.18 on D at left index of C.

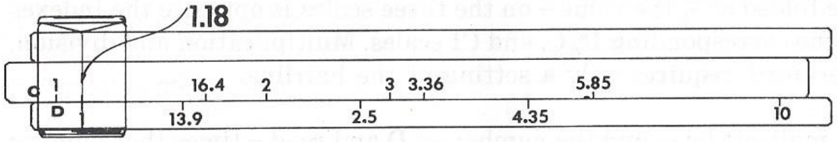


Figure 3.2

While there is no difference in the efficiency of the two sequences of operations, the first sequence, Operation A, is recommended. It is believed that fewer errors result by first using all factors in the numerator, then next using all factors in the denominator. In this way, one first concentrates on continuous multiplication, then on continuous division without alternating from one process to the other. Therefore, the first method shown for solving the last example is followed in the next examples.

Example 3.5

Problem: $\dfrac{120 \times 8.25 \times 19.1 \times 9.6}{40.5 \times 3.24 \times 50.4 \times 25} = 1.098$

Operation: Set hairline to 120 on D.
Move 8.25 on CI to hairline.
Move hairline to 19.1 on C.
Move 9.6 on CI to hairline.
Move hairline to 40.5 on CI.
Move 3.24 on C to hairline.
Move hairline to 50.4 on CI.
Move 25 on C to hairline.
Read 1.098 on D at left index of C.

Example 3.6

Problem: $\dfrac{26 \times 79{,}800 \times .00633}{.0081 \times 7{,}800{,}000} = .208$

Operation: Set hairline to 26 on D.
Move 79,800 on CI to hairline.
Move hairline to .00633 on CF.
Move .0081 on CF to hairline.
Move hairline to 7,800,000 on CI.
Read .208 on D at hairline.

Multiplying and Dividing by π. Since the folded scales (DF and CF) are folded at π, the value π on the three scales is opposite the indexes of the corresponding D, C, and CI scales. Multiplication and division, therefore, requires only a setting of the hairline.

To multiply by π, find the number on D and read π times that number on DF. To divide by π, find the numerator on DF and read the quotient on D. The C and CF scales can be used in a similar manner to multiply and divide by π.

Example 3.7

Problem: $18\pi = 56.5$

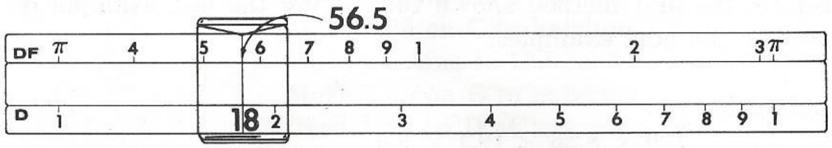


Figure 3.3

Operation: Set hairline to 18 on D.
Read 56.5 on DF at hairline.

Example 3.8

Problem: $\frac{13}{\pi} = 4.14$

Operation: Set hairline to 13 on DF.
Read 4.14 on D at hairline.

Example 3.9

Problem: $\frac{5.9 \times 2.2\pi}{25} = 1.63$

Operation: Set hairline to 5.9 on D.
Move 2.2 on CI to hairline.
Move hairline to 25 on CI.
Read 1.63 on DF at hairline.

Exercises in Combined Operations:

48. $12.1 \times 2.36 \times 4.25$

49. $5.72 \times 6.25 \times 7.13$

50. $7.48 \times 802 \times 920$

51. $\frac{1}{1.04 \times 1.71 \times 9.25}$

52. $\frac{18.6}{4.1 \times 3.64 \times 2.04}$

53. $\frac{8.24 \times 9.13}{10.12 \times 14.7}$

54. $\frac{7.85 \times 204 \times 82.6}{6.55 \times 101.5 \times 71.9}$

55. 89.2π

56. $\frac{6}{\pi}$

57. $\frac{37\pi}{93}$

58. $\frac{37}{9.3\pi}$

59. $\frac{16.9 \times 1.14 \times 7.05\pi}{50.2 \times 2.6 \times 2.17}$

3.2 MULTIPLICATION AND DIVISION OF A SINGLE FACTOR BY A SERIES OF NUMBERS, AND DIVISION OF A SERIES OF NUMBERS BY A SINGLE FACTOR.

It is frequently necessary to obtain the products or quotients of several different numbers, each multiplied or divided by a constant. For multiplication with a single setting of the slide, it is only necessary to move the hairline to perform the successive computations. For division with a single setting of the hairline, it is only necessary to move the slide to perform the successive operation. Remembering that the slide need not be moved more than one-half of its length, and since 3.16 is located approximately at its mid-point of the scale, neither index of the C scale should cross 3.16 on the D scale.

Multiplication. Use the D and C, and the DF and CF scale combinations. Set an index of the C scale at the constant located on the D scale, move the hairline to the various numbers on the C or CF scale, and read the products on the D or DF scale at the hairline.

Example 3.10

Problem: Multiply 1.27 in turn by 3.16, 4.28, 6.55, 8.4, and 9.85.

Operation: Set the left index of C to 1.27 on D.
Move hairline to 3.16 on C.
Read 4.01 on D.
Move hairline to 4.28 on C.
Read 5.44 on D.
Move hairline to 6.55 on C.
Read 8.32 on D.
Move hairline to 8.4 on CF.
Read 10.67 on DF.
Move hairline to 9.85 on C.
Read 12.51 on DF.

Division. For division of a single factor by a series of numbers, use the C, D and CI scale combination. Set an index of the CI scale to the constant located on the D scale, move the hairline to the various numbers on the CI scale, and read the quotients on the D or DF scale at the hairline.

Example 3.11

Problem: Divide 41.5 in turn by 12.4, 20.8, 44.5 and 92.

Operation: Set the hairline to 41.5 on DF.
Move 12.4 on CF to hairline.
Read 3.35 under C index on D.
Move 20.8 on CF to hairline.
Read 1.99 under C index on D.
Move 44.5 on CF to hairline.
Read 0.933 under CF index on D.
Move 92 on C to hairline.
Read 0.451 under CF index on D.

Likewise, a series of numbers can be divided by a single factor, simply by multiplying each number in the series by the reciprocal of the single factor.

Example 3.12

Problem: Divide 3.65, 30.5, 95.2, and 6.95, each by .561.

Operation: Set .561 on C to the right index of D.
Move hairline to 3.65 on C.
Read 6.51 on D.
Move hairline to 30.5 on C.
Read 54.4 on D.
Move hairline to 95.2 on CF.
Read 169.7 on DF.
Move hairline to 6.95 on CF.
Read 12.39 on DF.

Exercises in Multiplication and Division of a Series by a Single Factor.

60. Multiply 320 successively by 1.15, 2.42, 3.18, 4.5, 5.42, 6.88, 7.96, 8.05, and 9.6
61. Divide 7.18 successively by 1.02, 2.15, 3.29, 4.18, 5.67, 6.41, 7.85, 8.76, and 9.34.
62. Divide 107, 181, 257, 294, 352, 671, 707, 775, 988, each by 358.

3.3 PROPORTION

The slide rule is very effective in solving simple equations in the form of a proportion, without the algebraic manipulation of terms. In a proportion such as $\frac{d}{c}=\frac{x}{c'}$, the known value d is located on a D scale.

(D or DF), the known values of c and c′ are located on a C scale (C or CF), and the unknown x is located on a D scale (D or DF). The folded scales are used for part or all of the proportion to limit slide movement to half its length.

Example 3.13

Problem: $\frac{8}{12}=\frac{x}{21}$;x = 14

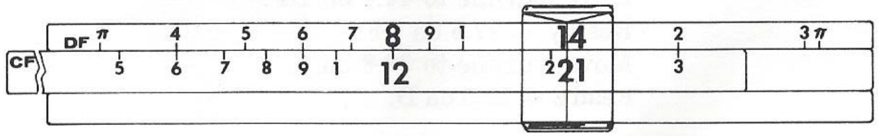


Figure 3.2

Operation: Set hairline to 8 on DF.
Move 12 on CF to hairline.
Move hairline to 21 on CF.
Read 14 on DF at hairline.

In Example 3.13, notice that the physical form of the proportion is exactly duplicated on the slide rule when the DF and CF scales are used. For problems that lend themselves exclusively to the D and C scales for solution, it is sometimes convenient to mentally invert the equation by locating the numerators on the C scale and the denominators on the D scale. Both solutions are shown for the following example.

Example 3.14

Problem: $\frac{639}{725} = \frac{x}{318}$; $x = 280$

Operation (A): Set hairline to 725 on D.
Move 639 on C to hairline.
Move hairline to 318 on D.
Read 280 on C at hairline.

Operation (B): Set hairline to 639 on D.
Move 725 on C to hairline.
Move hairline to 318 on C.
Read 280 on D at hairline.

Example 3.15

Problem: $\frac{8.7}{15.2} = \frac{x}{27.6} = \frac{44.4}{y} = \frac{z}{39.3}$

Operation: Set hairline at 8.7 on DF.
Move 15.2 on CF to hairline.
Move hairline to 27.6 on CF.
Read $x = 15.8$ on DF.
Move hairline to 44.4 on DF.
Read $y = 77.5$ on CF.
Move hairline to 39.3 on C.
Read $z = 22.5$ on D.

A large number of so-called "word problems" are in fact, equivalent expressions and lend themselves to solution by the proportional principle.

Example 3.16

Problem: A speed of 60 mph is equivalent to 88 ft./sec.

What is the speed in ft./sec. corresponding to a speed of 37 mph?

Operation: The problem is set up in the following form:

$$\frac{60 \text{ mph}}{88 \text{ ft./sec.}} = \frac{37 \text{ mph}}{x} ;\ x = 54.3 \text{ ft./sec.}$$

Set hairline to 60 on DF.
Move 88 on CF to hairline.
Move hairline to 37 on DF.
Read 54.3 on CF at hairline.

Exercises in Proportion:

63. $\frac{21.4}{195} = \frac{x}{12.1}$

64. $\frac{71}{705} = \frac{18.25}{x}$

65. $\frac{7.18}{x} = \frac{32.4}{17.9}$

66. $\frac{356}{51} = \frac{42.5}{x} = \frac{x}{y} = \frac{y}{z}$

CHAPTER 4

POWERS AND ROOTS—LOGARITHMS

4.1 SQUARES AND SQUARE ROOT

The A Scale. The A scale can be used for square and square root calculations. It ranges from 1 to 100. The A scale is, in effect, two short D scales placed end to end, and that is approximately how it is used. The simple mathematical relationship of the A and D scales may be expressed as $D^2 = A$.

Squares. The square of numbers on the D scale are directly opposite on the A scale. The left half of the A scale is associated with odd numbers of significant digits, and the right half with an even number of digits.

Example 4.1

Problem: $(24.8)^2 = 615$

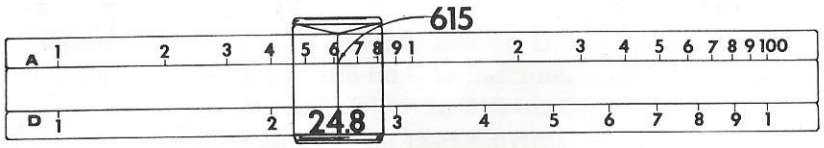


Figure 4.1

Operation: Set hairline to 24.8 on D.
Read 615 on A at hairline.
$(2.48 \times 10^1)^2 = 6.15 \times 10^2 = 615$

Example 4.2

Problem: $(417)^2 = 174{,}000$

Operation: Set hairline to 417 on D.
Read 174,000 on A at hairline.
$(4.17 \times 10^2)^2 = 17.4 \times 10^4 = 174{,}000$

Example 4.3

Problem: $(0.0196)^2 = 0.000384$

Operation: Set hairline to .0196 on D.
Read .000384 on A at hairline.
$(1.95 \times 10^{-2})^2 = 3.84 \times 10^{-4} = 0.000384$

Example 4.4

Problem: $(0.822)^2 = 0.676$

Operation: Set hairline to .822 on D.
Read .676 on A at hairline.

To locate the decimal point place the number in the standard form and multiply the power of 10 by 2. Adjust the position of the decimal in the squared number.

$$(8.22 \times 10^{-1})^2 = 67.6 \times 10^{-2} = 0.676)$$

Example 4.5

Problem: $\left(\frac{4.1}{6.95 \times 0.233}\right)^2 = 6.4$

Operation: Set hairline to 4.1 on D.
Move 6.95 on C to hairline.
Move hairline to .233 on CI.
Read 6.4 on A at hairline.

Square Root. The square roots of numbers on the A scale are directly opposite on the D scale. The procedure is essentially the reverse of finding squares using the A scale, but in locating numbers on the A scale, the position of the decimal point is important since the A scale ranges from 1 to 100. Exponents can also be used. If the exponents of the number is even, the left hand A scale is used; if the exponent is odd, the right hand A scale is used.

Example 4.6

Problem: $\sqrt{5{,}480} = 74.0$

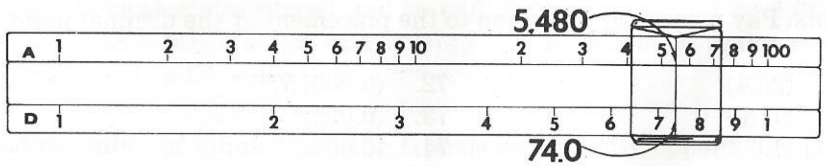


Figure 4.2

Operation: The exponent is 3 and odd.
Set hairline to 5,480 on right half of A.
Read 74.0 on D at hairline.

To locate the decimal point. Divide the power of 10 by 2 and adjust the position of the decimal in the root found.

$$(54.80 \times 10^2)^{1/2} = 7.40 \times 10^1 = 74.0$$

Example 4.7

Problem: $\sqrt{54,800} = 234$

Operation: The exponent is 4 and even.
Set hairline to 54,800 on left half of A.
Read 234 on D at hairline.
$(5.48 \times 10^4)^{1/2} = 2.34 \times 10 = 234.$

Example 4.8

$$(17.6 \times 10^{-6})^{1/2} = 4.2 \times 10^{-3} = .0042.$$

Operation: The exponent is -5 and odd.
Set hairline to .0000176 on right half of A.
Read .0042 on D at hairline.
$(17.6 \times 10^{-6})^{1/2} = 4.2 \times 10^{-3} - .0042.$

Example 4.9

Problem: $\sqrt{0.000176} = 0.01327$

Operation: The exponent is -4 and even.
Set hairline to .000176 on left half of A.
Read .01327 on D at hairline.
$(1.76 \times 10^{-4})^{1/2} = 1.327 \times 10^{-2} = 0.01327.$

Exercises in Square and Square Root. The following exercises are provided to gain proficiency in finding squares and extracting square roots. Pay particular attention to the placement of the decimal point.

67. $(20.4)^2$
68. $(715)^2$
69. $(1,070)^2$
70. $(125.4)^2$
71. $(0.85)^2$
72. $(0.000157)^2$
73. $(0.094)^2$
74. $(0.0076)^2$
75. $\sqrt{27}$
76. $\sqrt{925}$

77. $\sqrt{820,000}$
78. $\sqrt{1,265}$
79. $\sqrt{71,500}$
80. $\sqrt{51,000,000}$
81. $\sqrt{1,970,000}$
82. $\sqrt{660}$
83. $\sqrt{0.424}$
84. $\sqrt{0.0875}$
85. $\sqrt{0.00097}$
86. $\sqrt{0.00725}$
87. $\dfrac{17\sqrt{676}}{3.19 \times 12}$
88. $\left(\dfrac{\sqrt{811} \times 4}{2.36}\right)^2$

Areas of Circles. A special gauge mark is located near the left end of the C scale. It is marked by a letter c and represents the constant $\dfrac{4}{\pi}$. Using this mark and with a single setting of the slide, it is possible to determine the diameter of a circle when the area is known, or the area when the diameter is known. Set "c" mark opposite the left index of D, and at any diameter on the C scale, the area is opposite on the A scale.

Example 4.10

Problem: Find the area of a circle whose diameter is 4.84 ft.
Area = 18.4 sq. ft.

Operation: Set hairline to left index of A.
Move "c" mark on C to hairline.
Move hairline to 4.84 on C.
Read area, 18.4, on A at hairline.

Exercises in Areas of Circles.

89. Find the area of circles whose diameters are known:
a) 7.1; b) .42; c) 1.09; d) .0495; e) 1,700.
90. Find the diameter of circles whose areas are known:
a) 5; b) 50; c) 760; d) .0106; e) .601.

4.2 CUBES AND CUBE ROOT

The K Scale. The K scale is used with the D scale for finding cubes and cube root. It is a three segment scale which may be thought of as three short D scales placed end to end. It ranges from 1 to 1,000. The simple mathematical relationship of the D and K scales may be expressed as $D^3 = K$.

Cubes. Cubes of numbers on the D scale are directly opposite on the K scale. For numbers between 1 and 10, the location of the decimal point is indicated by the K scale, since it ranges from 1 to 1,000.

Example 4.11

Problem: $(6.1)^3 = 227$

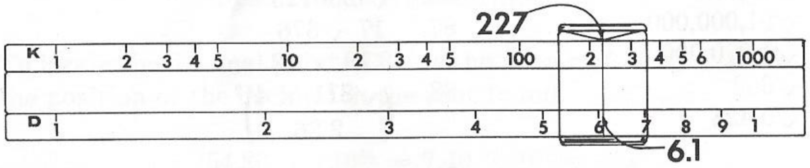


Figure 4.3

Operation: Set hairline to 6.1 on D.
Read 227 on K at hairline.

For numbers larger than 10 and smaller than 1, the location of the decimal point is not as obvious, and the use of the standard form is again recommended. Briefly, since $(N \times 10^n)^3 = N^3 \times 10^{3n}$, the K scale is used for finding the cube of N and the power of ten for relocating the decimal point.

Example 4.12

Problem: $(1{,}214)^3 = 1{,}790{,}000{,}000$

Operation: Express problem as $(1{,}214 \times 10^3)^3$.
Set hairline to 1.214 on D.
Read 1.79 on K at hairline.
Answer: $1.79 \times 10^9 = 1{,}790{,}000{,}000$.

Example 4.13

Problem: $(0.0721)^3 = 0.000375$

Operation: Express problem as $(7.21 \times 10^{-2})^3$.
Set hairline to 7.21 on D.
Read 375. on K at hairline.
Answer: $375 \times 10^{-6} = .000375$

Cube Root. Cube roots of numbers on the K scale are directly opposite on the D scale. Therefore, the cube root of numbers between 1 and 1,000 range between 1 and 10.

For numbers larger than 1000 and smaller than −1000, the location of the number on the scale is not so obvious, and the use of the power of the number is again recommended. Assign names to the three sections of the K scale as indicated in the drawing below.

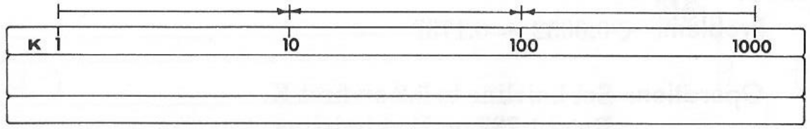


Figure 4.4

Any time the power of the number is zero or differs from 0 by a multiple of 3, $(0 \pm 3n)$, the first K scale is used. i.e. $(6.14 \times 10^{2, 3, 6, 9, \ldots 3n})$. Any time the power of the number is 1 or differs from 1 by a multiple of 3, $(1 \pm 3n)$, i.e. $(6.14 \times 10^{1, 4, 7, 10, \ldots (1+3n)}$ the middle K scale is used. Any time the characteristic of the number is 2 or differs from 2 by a multiple of 3, (2 ± 3), i.e. $(6.14 \times 10^{2, 5, 8, 11, \ldots (2+3n)}$ the third K scale is used.

Example 4.14

Problem: $\sqrt[3]{5.2} = 1.73$

Operation: Power is 0.
Set hairline to 5.2 on K.
Read 1.73 on D at hairline.

To Locate Decimal. Move the Decimal to the right or left three positions each move until one, two, or three digits appear in front of the decimal.

i.e.
$$5{,}167.0 = 5.167 \times 10^3$$
$$51{,}670.0 = 51.67 \times 10^3$$
$$516{,}700.0 = 516.7 \times 10^3$$
$$1{,}610{,}000{,}000.0 = 7.61 \times 10^9$$

Multiply the exponents of 10 by ⅓ and adjust the position of the root found.

i.e. $\sqrt{8370000} = (8.37 \times 10^6)^{1/3} = 2.13 \times 10^2 = 213.0$

Example 4.15

Problem: $\sqrt[3]{26{,}400} = 29.8$

Operation: Power is $1 + 3(1)$
Set hairline to 26.4 on middle K.
Read 2.8 on D at hairline.
Answer: $2.98 \times 10^1 = 29.8$

Example 4.16

Problem: $\sqrt[3]{0.0052} = 0.1732$

Operation: Set hairline to 5.2 on first K.
Read 1.732 on D at hairline.
Answer: $1.732 \times 10^{-1} = .1732$.

Example 4.17

Problem: $\dfrac{\sqrt[3]{0.000475}}{4.6} = 0.01696$

Operation: Set hairline to 475. on third K.
Move 4.6 on C to hairline.
Read 1.696 on D at index of C.
Answer: $1.696 \times 10^{-2} = 0.01696$

Exercises in Cubes and Cube Root. Perform the operations indicated using the K and D scales.

91. $(1.26)^3$
92. $(2.715)^3$
93. $(5.85)^3$
94. $(41)^3$
95. $(750)^3$
96. $(3.2)^3$
97. $\sqrt[3]{6}$
98. $\sqrt[3]{24}$
99. $\sqrt[3]{270}$
100. $\sqrt[3]{1{,}720}$
101. $\sqrt[3]{29{,}000}$
102. $\sqrt[3]{560{,}000}$
103. $(0.245)^3$
104. $(0.036)^3$
105. $(0.0048)^3$
106. $\sqrt[3]{0.32}$
107. $\sqrt[3]{0.041}$
108. $\sqrt[3]{0.0075}$

4.3 LOGARITHMS

The L Scale. The L scale is a uniformly divided scale, graduated and numbered from right to left, and ranging from 0 to 1. The logarithm of a number is the power to which the base of the logarithm must be raised to equal the number. Logarithms to the base 10, called common logarithms, are read on the L scale. The common logarithm of a number N is designated as $\log_{10}N$ or simply, as log N.

The logarithm consists of two parts, (a) the *characteristic* which is to the left of the decimal point, and (b) the *mantissa* which is to the right of the decimal point. The mantissa is located on the L scale at the hairline when the index of C scale is placed at the number on the D scale.

Example 4.18

Problem: $\log 164.3 = 2.216$

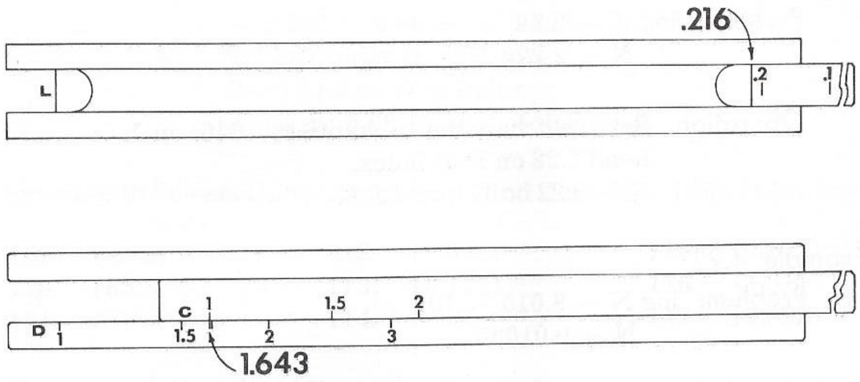


Figure 4.5

Operation: Characteristics = 2.
Set left index to 1.643 on D.
Read mantissa, .216, on L at hairline.
Answer = 2.216

Example 4.19

Problem: $\log 8.47 = 0.928$

Operation: Characteristic = 0.
Set right index to 8.47 on D.
Read mantissa, .928, on L at hairline.
Answer = 0.928.

Logarithms of numbers less than one have negative characteristics. Since the mantissa is always positive and less than one (as indicated by the above procedure), negative logarithms are usually expresses in a positive form, as $\log .001 = \log (1 \times 10^{-3}) = 0.000 - 3$ or $7.000 - 10$.

Example 4.20

Problem: $\log 0.0718 = 8.856 - 10$

Operation: Characteristics = $-$ 2.
Set right index to 7.18 on D.
Read mantissa, .856, on L at hairline.
Answer = $8.856 - 10$.

Example 4.21

Problem: $\log N = 3.46$

$N = 2{,}220$

Operation: Set right hairline to mantissa, .346, on L.
Read 2.22 on D at index.
$N = 2.22 \times 10^3$, or 2.220.

Example 4.22

Problem: $\log N = 8.015 - 10.$

$N = 0.01035$

Operation: Set hairline to mantissa, .015 on L.
Read 1.035 on D at index.
$N = 1.035 \times 10^{-2}$, or 0.01035

Powers and Roots Using Logarithms. Since the relationship $N^n = n \log N$ exists, any number N may be raised to any power n by multiplying the log of the number N by the power n. This involves finding the logarithm, multiplying, and finding the anti-logarithm.

Example 4.23

Problem: $(28.6)^{1.26} = 68.4$

Operation: Express number as 2.86×10^1.
Characteristic = 1.
Set either index of C scale to 2.86 on D.
Read mantissa, .456, on L at hairline.
Log 28.6 = 1.456.
Product of log and power: $1.456 \times 1.26 = 1.835$.
Set left hairline to 8.35 on L.
Read 6.84 on D at right index.
Answer: $6.84 \times 10^1 = 68.4$

Example 4.24

Problem: $(0.513)^{0.85} = 0.566$

Operation: Express number as 5.13×10^{-1}.
Characteristic = − 1 or 9. − 10.
Set right index to 5.13 on D.
Read mantissa, .710, on L at hairline.
Log 0.513 = 9.710 − 10 = − 0.290.

Product of log and power:
$-0.290 \times 0.85 = -0.247 = 9.753 - 10.$
Set left index to .753 on L.
Read 5.66 on D at index.
Answer: $5.66 \times 10^{-1} = 0.566$.

Exercises in Powers Using Logarithms. Find the value of the following:

109. $(1.95)^{2.7}$	112. $(0.568)^{9.1}$	115. $(0.877)^{-2.5}$
110. $(650)^{0.5}$	113. $(0.114)^{0.252}$	116. $(1.31)^{-3.2}$
111. $(31)^{0.845}$	114. $(415)^{-0.75}$	117. $(0.992)^{4.1}$

Exponential Equations. Equations in the form $N^p = A$, in which N and A are known quantities, may be solved for the unknown exponent p. The problem may be stated as: To what exponent p must N be raised so that the result is A? This can be expressed as $p = \frac{\log A}{\log N}$

An example follows:

Example 4.25

Problem: $(2.4)^p = 180$

$p = 5.94$

Operation: Set left index to 2.4 on D.
Read mantissa, .380 on L at hairline.
Log 2.4 = 0.380
Express other number as 1.8×10^2.
Set left index to 1.8 on D.
Read mantissa, .255 on L at hairline.
Log 180 = 2.255.
Therefore 0.380p = 2.255.
Set hairline to 2.255 on D.
Move 0.380 on C to hairline.
Read 5.94, on D at index of C.

Exercises in Exponential Equations. In the following equations, solve for p.

118. $(9.1)^p = 16.4$	121. $(0.915)^p = 0.614$
119. $(25.5)^p = 17.5$	122. $(0.425)^p = 0.0174$
120. $(3.25)^p = 71.5$	

CHAPTER 5

TRIGONOMETRIC OPERATIONS

5.1 THE TRIGONOMETRIC FUNCTIONS

There are six basic trigonometric functions, or relations between the sides of a right triangle Each angular function is expressed as the ratio of a particular pair of sides of the triangle. These six ratios are the sine, cosine, tangent, cotangent, secant, and cosecant of an angle.

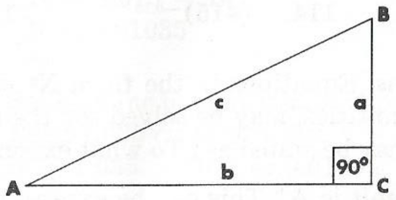


Figure 5.1 The Right Triangle

The six basic trigonometric functions may be written as:

$$\text{sine } A = \sin A = \frac{a}{c} = \frac{\text{opposite side}}{\text{hypotenuse}} = \frac{1}{\text{cosec } A}$$

$$\text{cosine } A = \cos A = \frac{b}{c} = \frac{\text{adjacent side}}{\text{hypotenuse}} = \frac{1}{\sec A}$$

$$\text{tangent } A = \tan A = \frac{a}{b} = \frac{\text{opposite side}}{\text{adjacent side}} = \frac{1}{\cot A}$$

$$\text{cotangent } A = \cot A = \frac{b}{a} = \frac{\text{adjacent side}}{\text{opposite side}} = \frac{1}{\tan A}$$

$$\text{secant } A = \sec A = \frac{c}{b} = \frac{\text{hypotenuse}}{\text{adjacent side}} = \frac{1}{\cos A}$$

$$\text{cosecant } A = \csc A = \frac{c}{a} = \frac{\text{hypotenuse}}{\text{opposite side}} = \frac{1}{\sin A}$$

Note the reciprocal nature between the first and last three functions. The first set of three (sine, cosine, and tangent) find the most frequent application. Consequently scales for finding values of these functions for any given angle are found on the slide rule. Should other ratios (cotangent, secant, cosecant) be required, they may be obtained through the use of a convenient reciprocal scale.

5.2 THE TRIGONOMETRIC SCALES

Designation. The two trigonometric scales are located on the back side of the slide and are designated as TI and SI. They are divided in degrees and decimals of degrees. Each set of graduations is numbered from right to left.

The SI Scale. The SI scale is numbered from right to left. The sine varies from 1.0 to 0.10 for angles varying from 5.74 to 90 degrees. Therefore all sine functions for angles shown on the SI scale vary from 0.10 to 1.0.

In order to find the sine of an angle, move the value of the angle on the SI scale to the hairline. Then flip the rule and read the sine function on the D scale at the index of C .

The SI scale may also be used to find the cosine function. The cosine of any angle is equal to the sine of its complement; therefore the identity $\text{Cos } \Theta = \text{Sin } (90° - \Theta)$ is utilized in finding the cosine. To find the cosine of any angle, first subtract the value of the angle from 90° and then proceed to find the sine of this difference.

The TI Scale. The TI scale is used to find the tangents of angles. The tangent varies from 0.10 to 1.0 for angles ranging from 5.7° to 45°. Therefore the scale increases from right to left for angles with values from 5.7° to 45°. In order to find the tangent function of any angles with values in this range, draw the value on the TI scale under the hairline, then flip the rule and read the tangent on the D scale at the index of C.

For tangents of angles greater than 45°, the identities $\text{Cot } \Theta = \tan (90 - \Theta)$ and $\tan \Theta = \frac{1}{\text{Cot } \Theta}$ in that order are used. For the tangent of an angle greater than 45°, first subtract its value from 90°. Then find the cotangent of this value on the TI scale and read the tangent of the original angle on the C scale at the index of the D scale.

Angles Smaller Than 5.7°. Since sine and tangent of angles smaller than 5.7° are the same to two significant digits, the first two digits of these functions can be easily obtained by a multiplication factor. For all angles in this range (0° to 5.7°), the first two digits of the sine or tangent function can be obtained by multiplying the angle by .0175. In this manner, these functions are found using only the C and D scales. For example:

Sin 2° = 2 × .0175 = .035
Sin 4° = 4 × .0175 = .070
Tan .733° = .733 × .0175 = .014
Tan .5° = .5 × .0175 = .0087

$$\text{Tan } 85^\circ = \frac{1}{\text{Tan } (90^\circ - 85^\circ)} = \frac{1}{\text{Tan } 5^\circ} = \frac{1}{5 \times .0175} = 11.4$$

Decimal Point Placement. The problem of locating the decimal point when dealing with trigonometric functions is resolved with the knowledge of the range of values of the functions corresponding to the range of angles on the trig scales. These values are summarized in the following table.

Trigonometric Functions	Range: Angular	Range: Numerical
Sine	0.57° — 5.74°	0.01 — 0.10
Sine	5.7° — 90°	0.10 — 1.0
Cosine	0° — 84.3°	1.0 — 0.10
Tangent	0.57° — 5.74°	0.01 — 0.10
Tangent	5.7° — 45°	0.10 — 1.0
Tangent	45° — 84.3°	1.0 — 10.0
Tangent	84.26° — 89.43°	10.0 — 100

5.3 NATURAL TRIGONOMETRIC FUNCTIONS

The determination of natural trigonometric functions requires only a setting of the hairline and a little knowledge of the numerical range of the function.

Example 5.1

Problem: sin 35° = 0.574

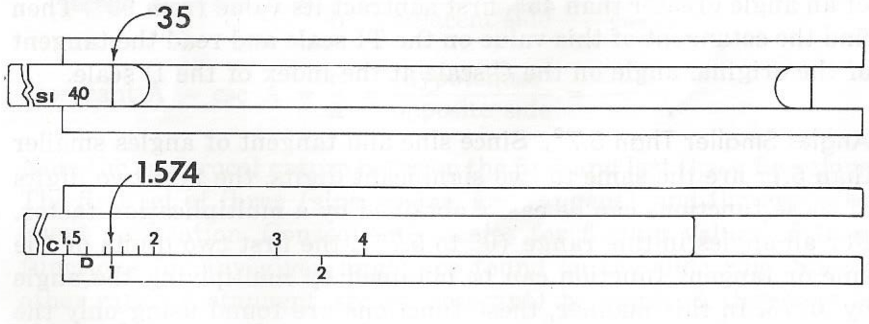


Figure 5.2

Operation: Set hairline to 35° on SI.
Read the sine, .574, on D at index of C.

Example 5.2

Problem: sin Θ = 0.182
Θ = 10.5°

Operation: Set left index of C to .182 on D.
Read angle, 10.5°, on SI at hairline.

Example 5.3

Problem: cos 16° = 0.961

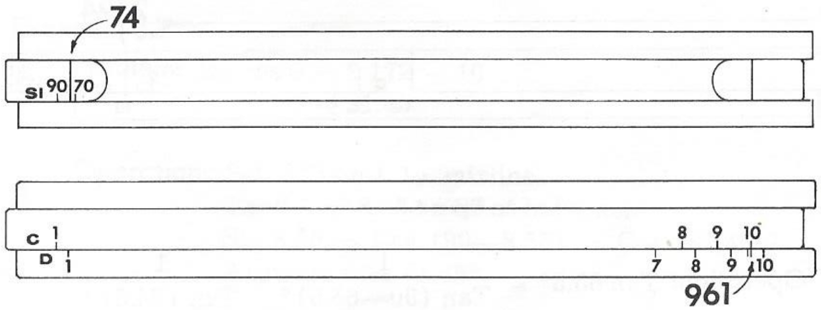


Figure 5.3

Operation: cos 16° = sin (90—16) ° = sin 74°
Set 74° on SI to left hairline.
Read cosine, .961, on D at index of C.

Example 5.4

Problem: tan 8° = 0.1405

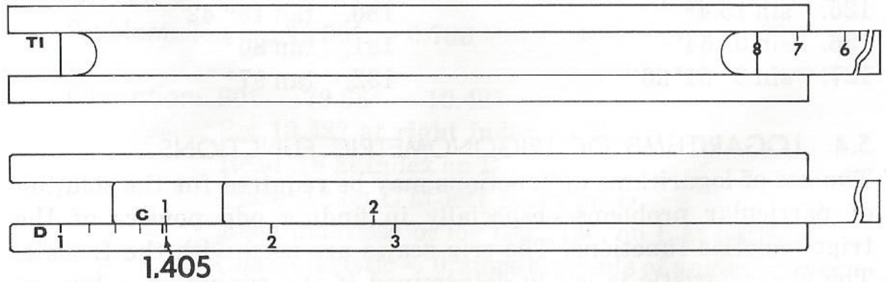


Figure 5.4

Operation: Set hairline to 8° on TI.
Read tangent, 0.1405, on D at index of C.

Example 5.5

Problem: Tan 65.5° = 2.194

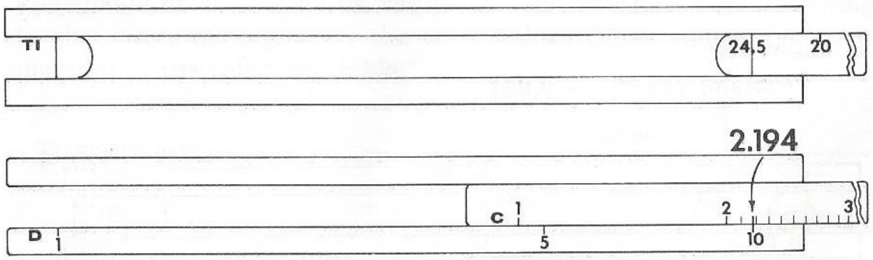


Figure 5.5

Operation: $\text{Tan } 65.5° = \dfrac{1}{\text{Tan } (90—65.5)°} = \dfrac{1}{\text{Tan } (24.5)°}$
Place 24.5° on TI at right hairline.
Read 2.194 on C at right index of D.
Answer Tan 65.5° = 2.194

Exercises in Natural Functions. Determine the following natural functions. Angles expressed in minutes and seconds require conversion to decimals of degrees.

123.	sin 76°	128.	cos 34.5°
124.	sin 54.5°	129.	cos 74.7°
125.	sin 15.4°	130.	tan 15° 42′
126.	sin 0° 54′	131.	tan 80°
127.	sin 3° 51′ 36″	132.	tan 97°

5.4 LOGARITHMS OF TRIGONOMETRIC FUNCTIONS

The use of logarithms of functions may be required for the solution of particular problems—especially in finding odd powers of the trigonometric functions. The trig scales are used with the L scale. The characteristic is easily determined if the ranges of values of each scale are kept in mind.

For angles on trigonometric scales
1. Set the back hairline to the angle on the trigonometric scale.
2. Read the mantissa on the L scale at the hairline.

Example 5.6

Problem: log sin 28.2° = 9.674 − 10

Operation: Set 28.2° on SI to hairline.
Read mantissa of log sin, .674, on L at hairline.
Characteristic = −1, since sines of angles between 5.7° and 90° range between 0.1 and 1.
Answer: 9.674 − 10

Example 5.7

Problem: log cos Θ = 9.172 − 10
Θ = 81.45°

Operation: Set .172 on L to hairline.
Read Θ = 8.55 on SI at hairline.
Sin 8.55 = Cos (90—8.55) = Cos (81.45°)
Answer: Θ = 81.45°

Example 5.8

Problem: log tan 15.6° = 9.446 − 10

Operation: Set 15.6° on TI to hairline.
Read mantissa of log tan, .446, on L at hairline.
Characteristic = −1, since tangents of angles between 5.7° and 45° range between 0.1 and 1.
Answer = 9.446 −10

Example 5.9

Problem: log tan 79.58° = 0.736

Operation: 90° − 79.58° = 10.42°
Set 10.42° at right index on TI.
Read .18 at index on D.
Place .18 on C at left index on D.
Read mantissa of log tan, .736, on L at hairline.
Characteristic = 0, since tangents of angles between 45° and 84.3° range between 1 and 10
Answer: log tan 79.58° = 0.736.

Exercises in Logarithms of Trigonometric Functions. Find the logarithm of the function in Exercises 133 through 137 and Θ in Exercises 138 through 142.

133.	log sin 76°	138.	log sin Θ = 9.424 − 10
134.	log sin 0.9°	139.	log cos Θ = 9.421 − 10
135.	log cos 34.5°	140.	log tan Θ = 9.449 − 10
136.	log tan 77.5°	141.	log tan Θ = 1.554
137.	log tan 2.4°	142.	log tan Θ = 0.654

5.5 COMBINED OPERATIONS

Calculations involving products and quotients of trigonometric functions may be performed using the trigonometric scales. An example of this type of computation follows.

Example 5.10

Problem: 9.2 Sin 43° Cos 70.46° = 2.1

Operation: Set 43° at hairline on SI.
Read .682 at index on D.
Cos 70.46° = Sin (90 − 70.46°) = Sin 19.54°
Set 19.54° at left hairline on SI.
Move hairline to .682 on C.
Move 9.2 on CI to hairline.
Read 2.1 on D at hairline.

5.6 SOLUTION OF TRIANGLES

In this section, a typical trigonometric application involving right triangles is illustrated. A familiarty of the trigonometric functions defined in Section 5.1 and a thorough understanding of the numerical ranges of the trigonometric scales as tabled in Section 5.2 is essential.

Right Triangles.

Example 5.11

Problem: Find the length of the hypotenuse (side c) of the triangle in Figure 5.6

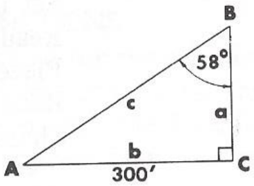


Figure 5.6

Operation: $\sin 58° = \frac{300'}{C}$
Set hairline to 300′ on D.
Move 58° on SI to left hairline.
Read c, 354′ on C at hairline.

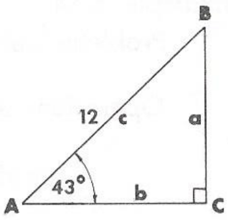


Figure 5.7

Example 5.12

Problem: Solve the triangle in Figure 5.7 for a, b and B.

Operation: a = c sin A
b = c cos A
B = 90° − A
Set 43° on SI to left hairline.
Move hairline to 12 on CF.
Read a = 8.18 on DF at hairline.
Cos 43° = Sin (90° − 43°) = Sin 47°
Set 47° on SI to left hairline.
Move hairline to 12 on CF.
Read b = 8.76 on DF at hairline.
B = 90° − A = 90° − 43° = 47°

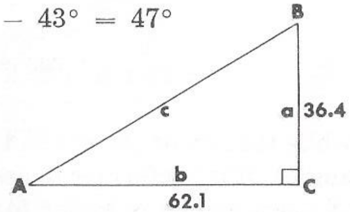


Figure 5.8

Example 5.13

Problem: Solve the triangle in Figure 5.8 or a, b, and c.

Operation: $\text{Tan } a = \frac{36.4}{62.1}$
Tan b = 90° − A
$\text{Tan } c = \frac{36.4}{\text{Sin } A}$
Set hairline to 36.4 on D.
Move 62.1 on C to hairline.
Read a = 30.4° on TI at hairline.
b = 90° − 30.4° = 59.6°.
Move 30.4° on SI to left hairline.
Read c = 72 on C at hairline.

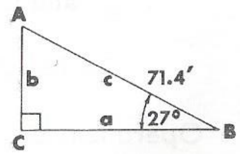


Figure 5.9

Example 5.14

Problem: Solve the triangle in Figure 5.9 for A, a and b.

Operation: Applying the law of sines, which may be written:

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

solve as a proportion.

$$\frac{a}{\text{Sin }(90^\circ - 27^\circ)} = \frac{b}{\text{Sin }27^\circ} = \frac{71.4'}{\text{Sin }90^\circ}$$

Set 90° on SI to left hairline.
Set hairline to 71.4′ on CI.
Move 63° (90° − 27°) on SI to left hairline.
Read a = 63.6′ on CI at hairline.
Move 27° on SI to left hairline.
Read b = 32.4′ on D at hairline.

Oblique Triangles. The law of sines, illustrated in Example 0.00 is applicable to any triangle—right or oblique. When the three sides are given, the angles can be determined using the law of cosines, which is:

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

while the law of cosines can be written in three forms (one for each angle), it is preferable to use it to find just one angle and use the law of sines, which is easier to calculate, for finding the other angles.

Example 5.15

Problem: Solve the triangle in Figure 5.10 for A, B, and C.

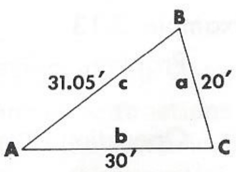


Figure 5.10

Operation: $\text{Cos A} = \frac{900 + 964 - 400}{2(30)31} = \frac{1464}{1860}$

Set hairline to 1464 on D.
Move 1860 on C to hairline.
Read Sin A = 51.8° on SI at left hairline.
Cos A = 90° − 51.8° = 38.2°.
38.2°

$$\frac{20'}{38.2^\circ} = \frac{30'}{\text{Sin B}} = \frac{31'}{\text{Sin C}}$$

Set 38.2° on SI to left hairline.
Set hairline to 20′ or CI.
Move 30′ on CI to hairline.
Read B = 68.1° on SI at left hairline.
Move 31′ on CI to hairline.
Read 73.7° on SI at left hairline.
C can be accurately determined also by 180° − A − B = 73.7°.

5.7 ANGLES IN RADIANS

Angles in radians may be converted to angles in degrees by use of a multiplication factor. Since one radian is equal to $\frac{180}{\pi} = 57.3^\circ$, the angle in radians multiplied by 57.3 equals the angle in degrees.

Example 5.16

Problem: Convert to degrees; 0.53, 2.19 and 1.43 radians.

Operation: Set right index of C to 57.3 on D.
Move hairline to 0.53 on C.
Read 30.4° on D at hairline.
Move hairline to 2.19 on C.
Read 125.5° on D at hairline.
Move hairline to 1.43 on CF.
Read 82° on DF at hairline.

Example 5.17

Problem: Convert to radians; 30.4°, 125.5°, and 82°.

Operation: Set 57.3 on C to right index of D.
Move hairline to 30.4° on C.
Read 0.53 on D at hairline.
Move hairline to 125.5° on C.
Read 2.19 on D at hairline.
Move hairline to 82° on CF.
Read 1.43 on DF at hairline.

CHAPTER 6

APPLICATIONS

In this chapter, ten applications are given. They have been chosen to give examples of the use of each scale on the rule. Each operation is given without explanation for choice of scales. The reader is urged to follow the operations and decide for himself why each operation, as shown, achieves the desired results. In some cases the operations are chosen to show some unique property of the arrangement of the scales.

When the reader is able to explain the reasoning behind each operation, a more thorough understanding of the rule will be developed, and a complete mastery of its operations should soon be achieved.

1. The area of a square is 220 square feet. How long is a side?

   Solution: $x = \sqrt{220}$

   The characteristic of 220 is 2 and even.
   Set hairline at 220 on left A scale.
   Read answer 14.8 feet on D scale.

2. The volume of a cube is 4913. How long is an edge?

   Solution: $x = \sqrt[3]{4913}$

   The characteristic of 4913 is $^{0} + 3(1)$.
   Set hairline at 491 on left K scale.
   Read answer 17 on D scale.

3. A stationary gunner leads a moving target 260 yards away by 4.6°. By how many yards does he lead the target?

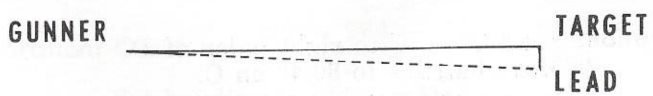


Figure 6.1

Solution: $\text{Tan } 4.6° = \dfrac{\text{Lead}}{260}$

Lead = 260 Tan 4.6°.
Answer = (260) (.0175) (4.6).
Set hairline at 260 on D.
Move .0175 on CI to hairline.
Move hairline to 4.6 on C.
Read answer 20.9 yards on D.

4. At 8:00 p.m. the moon is 232,000 miles directly overhead. At a later time, the line of sight to the moon and the vertical makes an angle of 3.85°. How far has the moon traveled assuming a straight line path?

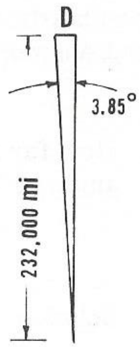


Figure 6.2

$x = 232{,}000 \text{ Sin } 3.85°$

Answer: $x = (232{,}000)\ (.0175)\ (3.85)$

Set hairline at 232,000 on D.
Move .0175 on CI to hairline (no extension).
Move hairline to 3.85 on C.
Read answer 15,630 miles on D at hairline.

5. Find the height of a rocket tower that has a shadow 44 feet long when the sun's rays make a 37° angle with the ground.

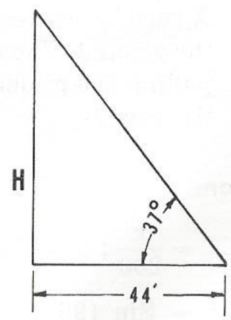


Figure 6.3

Solution: $\tan 37° = \dfrac{x}{44}$

$x = 44 \tan 37°$

Set 37° on TI scale at left hairline.
Move hairline to 44 on C.
Read answer 33′ at hairline on D.
Height of tower is 33 feet.

6. From the bank of a river 50 wide, the angle of the elevation of a cliff on the opposite shore is 60°. How high is the cliff?

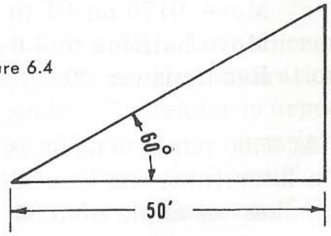


Figure 6.4

Solution: $\text{Tan } 60° = \frac{x}{50}$

$x = 50 \tan 60°$

Set $(90 - 60)° = 30°$ on TI at left hairline.
Move hairline to 50 on D.
Read answer 87′ on C at hairline.

7. How far from a 40′ pole must a guy wire be tied to make an angle of 75° with the ground?

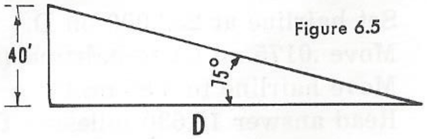


Figure 6.5

Solution: $\text{Cot } 75° = \frac{x}{40}$

$x = 40 \cot 75°$
$\text{Cot } 75° = \tan (90 - 75) = \tan 15°$

Set 15° on TI scale at right hairline.
Move hairline to 40 on CF.
Read answer 10.7′ on DF.

8. A rope being used to pull a glider makes an angle of 42° with the ground. The shadow of the glider is 200 feet from the car pulling the glider. The sun is directly overhead. How long is the rope?

Solution:

$\text{Sec } 42° = \frac{x}{200}$; $x = 200 \text{ Sec } 42°$

$\text{Cos } 42° = \text{Sin } (90 - 42°) = \text{Sin } 48°$

$\text{Sec } 42° = \frac{1}{\text{Cos } 42°} = \frac{1}{\text{Sin } 48°}$

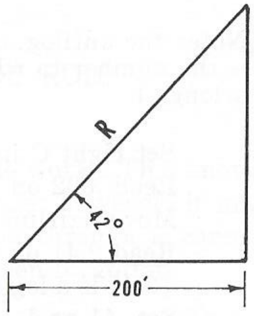


Figure 6.6

Set 48° on SI at left hairline.
Move hairline to 2 on D.
Read answer 269′ on C at hairline.

9. Joe can complete his math notebook in 12 working hours, and Mary can complete her notebook in 18 hours. If the teacher allows them to work together and hand in one notebook, how long must they work?

Solution: $\frac{1}{12} + \frac{1}{18} = \frac{1}{x}$

$$\frac{18 + 12}{(12)\ (18)} = \frac{1}{x}$$

$$\frac{30}{(12)\ (18)} = \frac{1}{x}$$

Set 12 on C to left index of D.
Move hairline to 3 on C.
Move 18 on C to hairline.
Read answer 7.2 hours on C scale at D index.
Note this reading constitutes an extension since by reading the answer on the C scale, we have used the reciprocal of x which is at the C index on the D scale.

10. What is the volume of a ball with an 8-inch diameter?

$$V = \frac{4}{3} \pi R^3$$

$$V = \frac{4}{3} \pi 4^3$$

$$V = \frac{4^4 \pi}{3}$$

$$\frac{[\text{antilog. } (4 \text{ Log })]}{3} \pi = V$$

(Note: the antilog. of a log
is the number to which the log
belongs.)

Set right C index to 4 on D.
Read .602 on L at hairline.
Move hairline to .602 on C.
Read 2.41 on D scale at index of C.
(2.41 is a logarithm with characteristic 2 and mantissa .41).
Set .41 on L scale to left hairline.
(Notice 257 at C index on D, decimal located per characteristic.)
Move hairline to 3 on CI.
(Notice no extension here.)
Read answer 269 on DF at hairline.

CHAPTER 7

THE PRINCIPLE OF THE SLIDE RULE

This chapter briefly describes how the slide rule works. This knowledge is not essential for efficient use of the rule; however, it may satisfy one's curiosity or enable one to reason through a correct computation when the exact procedures have been forgotten.

7-1 Multiplication and Division. Those who have a little facility with mathematics will recognize that the slide rule is based on logarithms. Multiplication and division can be accomplished by the addition and subtraction of logarithms of numbers. $N_1 \times N_2 = \log N_1 + \log N_2$. Using the slide rule to multiply and divide is, in effect, the addition and subtraction of logarithms—actually, the addition and subtraction of logarithmic lengths of the scales. The graduations of the C and D scales are measured lengths (from the left index), proportional to logarithms of numbers between 1 and 10. Or, more generally, the graduations of the C and D scales are lengths proportional to the mantissa of common logarithms of all numbers.

Several simple examples of the addition and subtraction of logarithmic lengths using the slide rule follow. Similar addition and subtraction can be applied to more involved computations. Use the L scale to verify these examples.

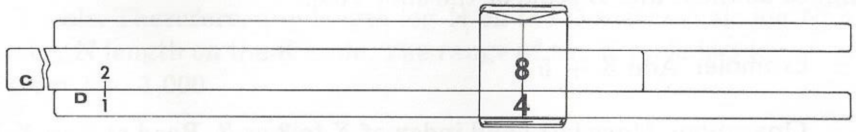


Figure 7.1

Example 7.1

Problem: $2 \times 4 = 8$

Solution: $\log 2 + \log 4 = \log 8$
$0.301 + 0.602 = 0.903$

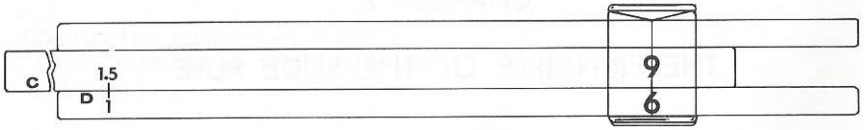


Figure 7.2

Example 7.2

Problem: $1.5 \times 6 = 9$

Solution: $\log 1.5 + \log 6 = \log 9$
$0.176 + 0.778 = 0.954$

Example 7.3

Problem: $\frac{9}{6} = 1.5$

Solution: $\log 9 - \log 6 = \log 1.5$
$0.954 - 0.778 = 0.176$

Since the characteristic of logarithms of numbers on the slide rule is not represented, the operator must keep track of it. Use of the standard form, as described in Section 2.5 is recommended—especially for involved calculations and when working with very large and small numbers.

Addition & Subtraction. Addition and subtraction of numbers can be accomplished by means of two twelve inch rulers with their scales aligned as the C and D scale of the slide rule.

Example: Add 3 + 5

Operation: Move left hand index of X to 3 on Z. Read at 5 on X 8 on the D scale.

Answer: 8.

Any number or "X" can be added to 3 and the answer read on "Y"

Construction of the inverted scale, CI, is the same as the C except that distances are measured from the right index rather than the

left. With a correction of the decimal point, at any setting of the hairline, values M on the CI scale are reciprocals of values N on the C scale. Since log N + log M = log 10, the entire scale length, then $\log N = \log \frac{10}{M}$, and $N = \frac{10}{M}$.

The construction of the C and D scales is such that the reciprocal of the number below the C scale index on the D scale appears above the D scale index on the C scale. The converse is also true. Knowledge of this fact is often valuable. Problems 6 and 7 in Chapter 6 are examples of its use.

The folded scales are simply C and D scales that start at π rather than 1. At any setting of the hairline, N on the D scale is opposite πN on the DF scale.

7.2 Powers and Roots. Numbers on the A scale are squares of numbers opposite on the D scale. Therefore, any length log N on the D scale equals log N^2, or 2 log N length on the A scale. Thus, the range of the A scale is 2 log 10, or from 1 to 100.

Example 7.4

Problem: $3^2 = 9$

Solution: $2 \log 3 = \log 9$
$2 \times 0.477 = 0.954$

Numbers on the K scale are third powers of numbers opposite on the D scale. Therefore, any length log N on the D scale equals log N^3 or 3 log N length on the K scale. The range of the K scale is 3 log 10, or from 1 to 1,000.

7.3 Trigonometric Operations. As described in Chapter 5, trigonometric scales are simply C1 scales renumbered. The trigonometric scales are not divided in 10 major divisions, but graduated in degrees and decimals of degrees of the mantissa of the logarithm of the trigonometric function represented. Therefore, any length log N on the CI scale, is equal to the log sin Θ on the SI scale, etc.

APPENDIX I

THE STANDARD FORM — SHORT CUT

In applying the standard form method of keeping track of the decimal point location to the slide rule, a short cut variation is suggested. With this method, the only number that has value here is the exponent associated with the power of ten used. Examples are: with 214 we associate the number 2, with 67834 the number 4, with 0.003 the number −3. This associated number is known as its characteristic.

When multiplying numbers, the characteristics are added; when dividing they are subtracted.

Example: With 3219 × 467 characteristics are 3 and 2; thus 5 is the characteristic of the product.

With 3219 ÷ 467 we associate the characteristic 3 − 2 or 1.

This characteristic may be written down or mentally retained. As the slide rule computation is performed, note is taken of the location of the left hand C scale index. If the left hand index of the C scale is off scale, an extension is noted. For a left hand extension in division, one is subtracted from our original characteristic; for each extension in multiplication one is added to our characteristic. The number remaining after all rule movements is the characteristic that is associated with the answer for decimal location. In using the CI scale, right hand extensions are counted, and left hand extensions ignored. The CF and DF scales require a mental analysis to determine if the operation would constitute an extension if the C and D were used.

$$\frac{\overset{(1)}{26} \times \overset{(4)}{79{,}800} \times \overset{(-3)}{.00233}}{\underset{(-3)}{.0081} \times \underset{(6)}{7{,}800{,}000}}$$

The characteristic associated with each number of the problem is in parenthesis. The characteristic for the entire problem is [1 + 4 + (−3)] − [(−3) + 6] = 2 − 3 = −1. As we divide 8.1 into 2.6, an extension occurs; thus our characteristic becomes (−1) − 1 = −2. The hairline can be moved to 7.98 on C as the next operation.

An extension occurs in this multiplication operation; thus our characteristic is now −2 + 1 = −1. 7.8 is now drawn to the hairline, and an extension for division is noted. The characteristic now is (−1) − (1) = −2. As a final operation, the hairline is moved to 2.33 on the CF scale. It is noted here that had this operation been done on C and D, no extension would occur. The final characteristic then is −2. On the DF at hairline, 765 is read, and the decimal is placed according to the characteristic −2. The answer is .0765.

APPENDIX II

ANSWERS

ANSWERS TO EXERCISES

SIGNIFICANT DIGITS

	First	Second	Third
a	2	4	5
b	5	6	4
c	7	9	9
d	8	8	8
e	3	4	—
f	6	5	—
g	1	3	—
h	1	0	4
i	3	0	5
j	1	2	3
k	1	3	4
l	1	0	0

READING THE SCALES— PAGE 11

1.	a	3	b	6	c	1.5	d	2.3	e	9.05
2.	a	11.1	b	17.5	c	31	d	79.9	e	99.7
3.	a	.01005	b	.02	c	.051	d	.0842	e	.0902
4.	a	1.1	b	9.9	c	7	d	1.31	e	8.03
5.	a	150	b	200	c	41	d	499	e	835

MULTIPLICATION— PAGE 17

6.	24	12.	12
7.	84	13.	563
8.	44.5	14.	109.5
9.	37.0	15.	1,020
10.	6,510	16.	831
11.	50.7	17.	209

DIVISION— PAGE 20

18.	3.02	24.	4.27	30.	1.431
19.	2.89	25.	0.814	31.	1.670
20.	2.84	26.	0.0650	32.	2.11
21.	23.3	27.	0.444	33.	0.840
22.	23.4	28.	43.3	34.	7.87
23.	4.48	29.	20.6	35.	184.0

MULTIPLICATION AND DIVISION— PAGE 23

36.	84	39.	955	42.	1.33	45.	3,000
37.	131.5	40.	831	43.	2.25	46.	.333
38.	127.8	41.	943	44.	4.33	47.	37.2

COMBINED OPERATIONS— PAGE 31

48.	121.4	54.	2.77
49.	255	55.	280
50.	5,520,000	56.	1.91
51.	.0608	57.	1.25
52.	.611	58.	1.267
53.	.506	59.	1.507

MULTIPLICATION AND DIVISION OF A SERIES BY A SINGLE FACTOR— PAGE 33

60. 368; 774; 1,018; 1,440; 1,734; 2,200; 2,550; 2,580; 3,070.
61. 7.04; 3.34; 2.18; 1.718; 1.266; 1.120; 0.915; 0.820; 0.769.
62. 0.299; 0.506; 0.718; 0.821; 0.983; 1.874; 1.975; 2.16; 2.76.

PROPORTION— PAGE 35

63. 1.328
64. 181.2
65. 3.97
66. x = 6.09; y = .872; z = .125

SQUARE & SQUARE ROOT— PAGE 38, 39

67.	416	74.	.0000578	81.	1,404
68.	511,000	75.	5.20	82.	25.7
69.	1,145,000	76.	30.41	83.	0.651
70.	15,730	77.	906	84.	0.2958
71.	.722	78.	35.57	85.	0.03115
72.	.0000000246	79.	267.4	86.	0.0851
73.	.00884	80.	7,140	87.	11.53
				88.	2,330

AREAS AND DIAMETERS OF CIRCLES— PAGE 39

89. a) 39.6; b) .1385; c) .8; d) .01924; e) 2,270,000.
90. a) 2.522; b) 7.98; c) 31.1; d) .1162; e) .875

CUBES AND CUBE ROOT— PAGE 42

91.	2	97.	1.817	103.	.0147
92.	20	98.	2.88	104.	.0000467
93.	200	99.	6.46	105.	.000000111
94.	69,000	100.	11.98	106.	.684
95.	422,000,000	101.	30.7	107.	.345
96.	32.8	102.	82.4	108.	.1957

POWERS USING LOGARITHMS— PAGE 45

109.	6.08	112.	0.0058	115.	1.387
110.	25.5	113.	0.578	116.	0.421
111.	18.2	114.	0.0109	117.	0.968

EXPONENTIAL EQUATIONS— PAGE 45

118.	1.267	121.	5.50
119.	0.884	122.	4.74
120.	3.62		

NATURAL FUNCTIONS— PAGE 50

123.	0.970	128.	0.824
124.	0.814	129.	0.264
125.	0.266	130.	0.281
126.	0.0157	131.	
127.	0.0673	132.	

LOGARITHMS OF TRIGONOMETRIC FUNCTIONS— PAGE 52

133.	9.987 − 10	137.	8.622 − 10	140.	15.7°
134.	8.196 − 10	138.	15.4°	141.	88.4°
135.	9.916 − 10	139.	74.7°	142.	77.5°
136.	0.654				