RULE, SLIDE, MILITARY,

FIELD ARTILLERY,

WITH CASE,

10-INCH

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WAR DEPARTMENT • *SEPTEMBER* 1945

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Washington 25, D. C., 15 September 1945

TM 6–240, Rule, Slide, Military, Field Artillery, With Case, 10-inch, is published for the information and guidance of all concerned.

[AG 300.7 (14 Jul 45)]

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Refer to FM 21-6 for explanation of distribution formula.

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III

CHAPTER I

INTRODUCTION

Section I.   GENERAL

1. Purpose and Scope

This manual describes the military slide rule for solving Field Artillery problems, including its use, adjustment, and care, and also gives solutions for typical problems.

2. References

The theory and principles of the Field Artillery problems in this manual are covered in FM 6–40 and FM 6–120.

Section II.   DESCRIPTION

3. General

The military slide rule (fig. 1) is a specially designed Mannheim-type slide rule for solving Field Artillery survey problems. It can also be used for other arithmetic and trigonometric calculations.

4. Component Parts

The rule consists of a body, a slide, and an indicator (fig. 2).

a. Body. The body includes the base, upper and lower guides, and table.

(1) *Base.* The base is a piece of mahogany to which the upper and lower guides and the table are fastened.

(2) *Upper guide.* The face of the upper guide is marked with two scales and three gauge points.

(*a*) *Scales.* Both guide scales are labeled OPPOSITE ANGLE. The upper scale is graduated in degrees and minutes; the lower, in mils. These scales are used with the APEX ANGLE scales on the slide to solve oblique triangles (par. 24).

(*b*) *Gauge points.* Three gauge points are used with the C scale on the slide and are marked SS = 369.2, DEG/MIL, and M/YD. The
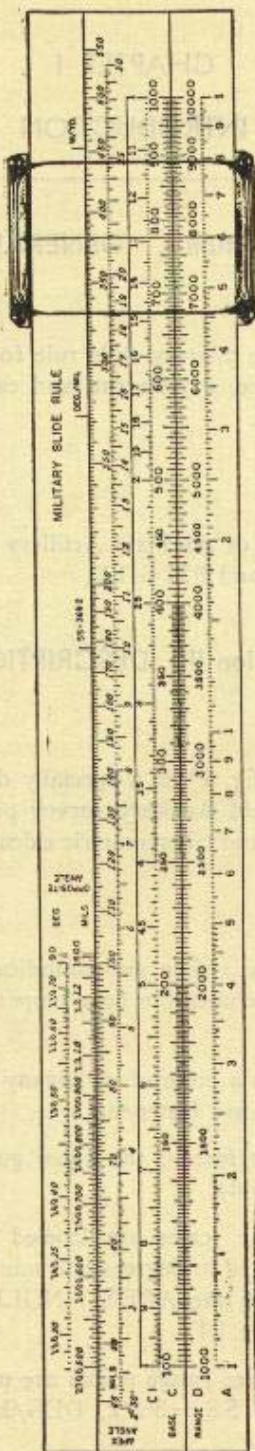
Figure 1. Military slide rule.

gauge point SS = 369.2 is used in sound range plotting (par. 30). The gauge point DEG/MIL is used in converting degrees to mils, and the M/YD gauge point is used in converting meters to yards (par. 18).

(3) *Lower guide.* The face of the lower guide is marked with the RANGE or D scale and the A scale.

(4) *Table.* The table on the back of the base contains trigonometric reference data which aids in solving Field Artillery survey problems.

b. SLIDE. The sliding part of the rule is called the slide. It is marked with scales on both the face and back.

(1) *Scales on face.* The face of the slide has four scales.

(*a*) *C scale.* The lower scale is the BASE or C scale and is used with the RANGE or D scale on the lower guide in multiplication and division and as a BASE scale in solving oblique triangles.

(*b*) *CI scale.* The scale above the C scale is labeled CI (inverted C scale). It is used with the D scale in multiplication and division.

(*c*) *APEX ANGLE scales.* The two upper scales on the face are the APEX ANGLE scales, used with the OPPOSITE ANGLE scales on the upper guide in solving oblique triangles. The upper scale is graduated in mils and the other in degrees and minutes.

(2) *Scales on back.* There are four additional scales on the back of the slide.

(*a*) *C scale.* The lower scale is labeled C and is identical with the BASE or C scale on the face of the slide.

(*b*) *SIN, SIN-TAN, and TAN scales.* The three scales above the C scale, labeled SIN, SIN-TAN, and TAN, are used in trigonometric calculations (pars. 19 to 22).

c. INDICATOR. The indicator consists of two guide bars and a glass with a vertical hairline engraved on the lower surface of the glass. It aids in reading and setting figures.
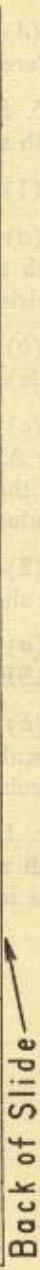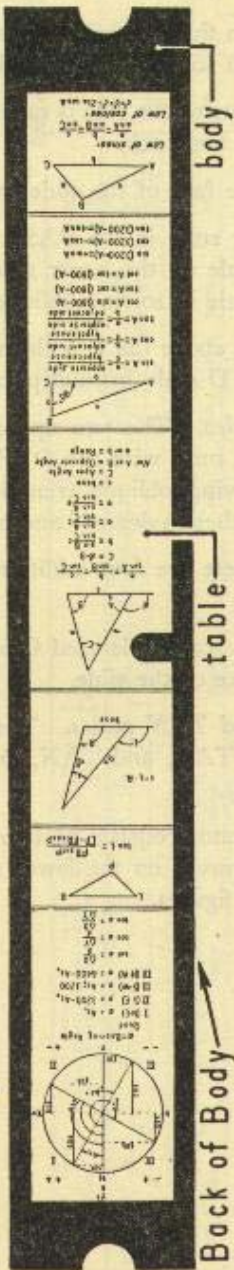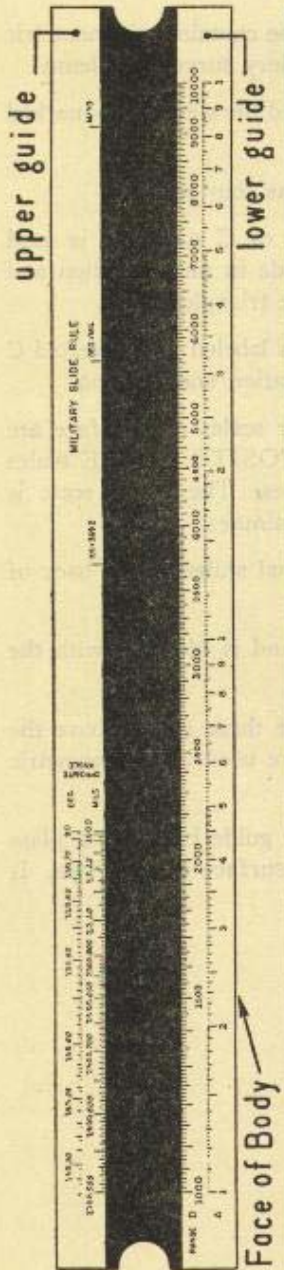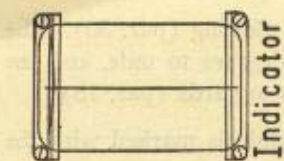
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Figure 2. Component parts of military slide rule.

CHAPTER 2

PRINCIPLES OF SLIDE RULE OPERATION

Section I. GENERAL

5. Scope

This chapter discusses in detail the various scales on the military slide rule and methods of using them to solve arithmetic and simple trigonometric problems. The solution of oblique triangles, the computation of traverses in surveying, and other problems in Field Artillery survey are discussed in chapter 3.

6. Suggestions to Student

While reading these chapters, the student should keep the rule before him, make all settings indicated in the illustrative examples, and compute answers for the exercises. The correct answers to each set of exercises are listed in the appendix.

Section II. SOLVING ARITHMETIC PROBLEMS

7. D Scale

The D scale is the basic slide rule scale (fig. 4).

a. PRIMARY DIVISIONS. The D scale is divided into nine parts by primary divisions numbered 1000, 2000, 3000, and up to 10000 (fig. 3). Each of these divisions represents the first digit of a number. Thus, the division numbered 3000 stands for 0.003, 0.03, 3, 30, or 3,000. The primary divisions numbered 1000 and 10000 are known as the *left* and *right indexes* of the scale.

b. SECONDARY DIVISIONS. The space between any two primary divisions is divided into ten parts by nine *secondary* divisions. Between primary divisions 1000 and 5000, the center secondary division is numbered (1500, 2500, and 3000). Each of these secondary divisions represents the second digit of a number. Thus, the third secondary division to the right of the primary division numbered 2000 represents 0.023, 0.23, 23, or 230.

c. TERTIARY DIVISIONS. (1) Finally, the space between any two secondary divisions is divided by *tertiary* divisions which aid in obtaining the third digit of a number. The number of tertiary divisions between adjacent secondary divisions varies along the scale. From 1000 to 2000 there are 10 divisions; from 2000 to 4000, 5 divisions; and from 4000 to 10000, 2 divisions.
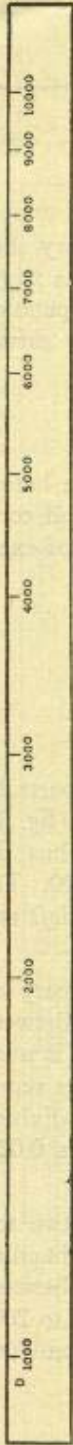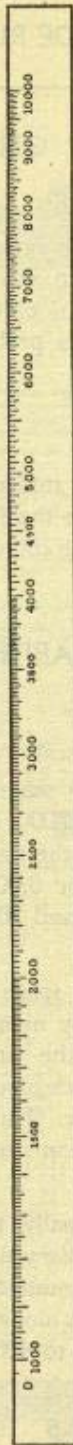
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Figure 3. Skeleton D scale.

Figure 4. Complete D scale.

Figure 5. Method of reading D scale (par. 7d).

(2) Thus, if the third and fourth secondary divisions to the right of the primary division 2000 represent 230 and 240, the four tertiary divisions between them represent 232, 234, 236, and 238. Likewise, if the third and fourth secondary divisions to the right of the primary division 5000 represent 530 and 540, the tertiary division between them represents 535. Readings between successive tertiary divisions must be estimated. Thus, a position halfway between tertiary divisions 131 and 132 is read 1315, a position halfway between tertiary divisions 326 and 328 is read 327, and a position two-fifths of the way from tertiary division 535 to secondary division 540 is read 537.

(3) Therefore, numbers to the left of primary division 2000 can be read to four digits and numbers to the right to three digits. Additional digits which cannot be read on the scale are disregarded.

d. ILLUSTRATIVE EXAMPLES. Read from figure 5 the numbers associated with the marks above the scale numbered (1), (2), (3), and so on, and compare your readings with the following:
(1) 2, (2) 5, (3) 17, (4) 26, (5) 137, (6) 244, (7) 363, (8) 525, (9) 748, and (10) 1614.

8. C Scale

The C scale, which is the bottom scale on each side of the slide, is divided into the same number of parts as the D scale. However, the divisions are numbered 100 to 1000 instead of 1000 to 10000. For convenience, the zeros are dropped in future reference to these scales. Thus, 200 on the C scale or 2000 on the D scale is referred to as 2.

9. Multiplication with D and C Scales

a. PROCEDURE. To mulitply with the D and C scales, proceed as follows:

(1) Move indicator hairline to either of the factors on the D scale. (with practice, this step can be omitted.)

(2) Set either the left or the right C scale index under the hairline or *opposite* the factor on the D scale directly if step (1) is omitted.

NOTE: Two positions are said to be *opposite* if the hairline can be brought to cover both positions at the same time without moving the slide.

(3) Move hairline to other factor on the C scale.

(4) Read product on the D scale under hairline.

NOTE: If the product cannot be read because the second factor is on that part of the slide projecting beyond the D scale, repeat above operations using other C scale index in step (2) above.

b. ILLUSTRATIVE EXAMPLES. (1) To multiply 2 by 4 (fig. 6), set left C index opposite 2 on D scale. Move indicator hairline to 4 on C scale and read product 8 under hairline on D scale.

(2) To multiply 3 by 5 (fig. 7), set right C index opposite 3 on D scale. Move indicator hairline to 5 on C scale and read product 15 under hairline on D scale.

NOTE: If left C index had been used, the second factor would have been on that part of the slide projecting beyond the D scale. Therefore, the right C index was used.

c. PLACING DECIMAL POINT. (1) To determine where the decimal point should be placed in the answer, round off the factors and multiply them.

(2) Table I shows sample calculations for placing the decimal point.

Table I. Sample calculations for placing decimal point

| To multiply— | Round off to— | The product is— | |
		Approximately	From rule
13.4 x 21.8	15 x 20	300	292
3.28 x 29.6	3 x 30	90	97.1
476. x 8.13	500 x 8	4000	3870
1.462 x 0.0724	1 x 0.08	0.08	0.1058

d. EXERCISES. Solve the following problems on the slide rule:

(1) 3×2
(2) 3.5×2
(3) 4.5×1.5
(4) 2×4.55
(5) 2.03×167.3
(6) 1.75×5.5
(7) 3×5

(8) 3.05×5.17
(9) 4.33×11.5
(10) 5.56×634
(11) 1.536×30.6
(12) 0.0756×1.093
(13) 1.876×926
(14) 1.876×5.32

(15) 0.495×0.0267
(16) 0.00205×4080
(17) 1.047×3080
(18) 5×2
(19) 1.756×1.756
(20) 4.98×4.98
(21) 3.14×3.14

10. Division with D and C Scales

a. PROCEDURE. To divide with the D and C scales, proceed as follows:

(1) Move indicator hairline to divident on D scale.

(2) Set divisor on C scale under hairline.

(3) Read quotient on D scale opposite C scale index.

b. ILLUSTRATIVE EXAMPLE. (1) To divide 8 by 4, move indicator hairline to 8 on D scale. Set 4 on C scale under hairline. Opposite C index, read quotient 2 on D scale. This operation is the reverse of the multiplication illustrated in figure 6.

(2) To divide 876 by 20.4, move indicator hairline to 876 on D scale. Set 204 on C scale under hairline. Opposite C index, read quotient 4 2 9 on D scale.

c. PLACING DECIMAL POINT. The decimal point is placed by approximate computation as described in paragraph 9c. For the problem
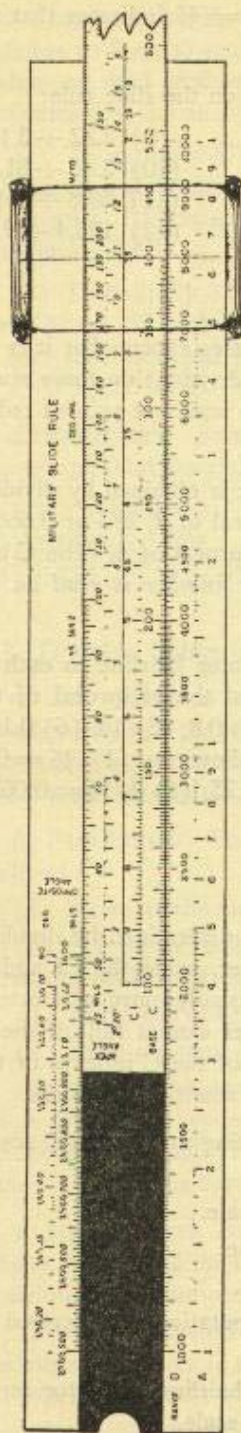
Figure 6. *Rule setting for illustrative problems (pars. 9b(1), 10b(1), and 12c(1)).*
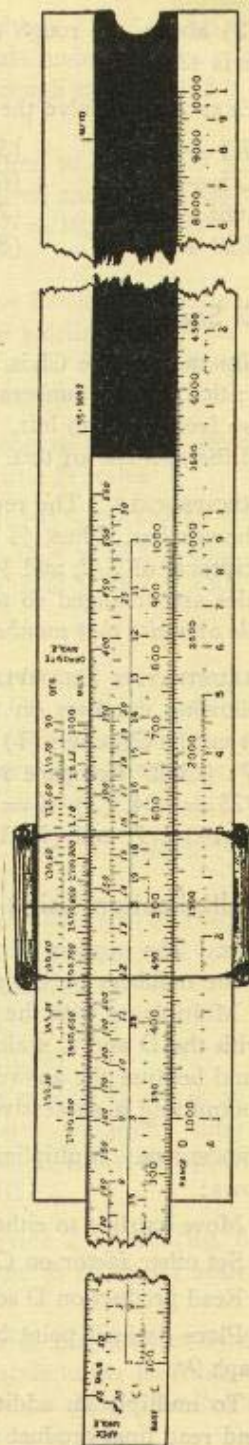
Figure 7. *Rule setting for illustrative problem (par. 9b(2)).*

in *b* (2) above, the rough calculation $900 \div 20 = 45$ indicates that the answer is 42.9.

d. EXERCISES.   Solve the following problems on the slide rule:

(1) $87.5 \div 37.7$	(5) $0.00377 \div 5.29$	(9) $2.72 \div 3.14$
(2) $3.75 \div 0.0227$	(6) $2875 \div 37.1$	(10) $3.42 \div 81.7$
(3) $0.685 \div 8.93$	(7) $8710 \div 0.468$	(11) $69.8 \div 3.49$
(4) $1029 \div 9.70$	(8) $8710 \div 9.83$	(12) $193.4 \div 9.34$

11. CI Scale

a. GENERAL.   The CI is like the C and D scales except that it is inverted; that is, the numbers represented by the divisions on these scales increase from right to left. The numbers on the scale are printed red to remind the operator of this.

b. RECIPROCALS.   The reciprocal of a number is obtained by dividing 1 by the number. Thus, ½ or 0.5 is the reciprocal of 2, 2/3 or 0.666 is the reciprocal of 3/2, and ¼ or 0.25 is the reciprocal of 4. The C and CI scales are arranged so *the reciprocal of any number is read on the CI scale opposite that number on the C scale.*

c. ILLUSTRATIVE EXAMPLES.   Move the indicator hairline to each of the following numbers on the C scale and read the reciprocal of the number on the CI scale: (1) 2, (2) 25, (3) 4, (4) 0.8, (5) 16, (6) 0.143, and (7) 0.362. Compare readings with the following: (1) $\frac{1}{2} = 0.5$, (2) $1/25 = 0.04$, (3) $\frac{1}{4} = 0.25$, (4) $1/0.8 = 1.25$, (5) $1/16 = 0.0625$, (6) $1/0.143 = 7$, and (7) $1/0.362 = 2.76$.

12. Multiplication Using CI Scale

a. USE.   The product of two numbers can be determined by dividing one of the numbers by the reciprocal of the other, using the CI and D scales. Multiplying with the CI and D scales is usually more satisfactory than with the D and C scales, because the answer cannot fall off the D scale, and because the answer falls opposite one of the C indexes of the slide, permitting a successive operation without resetting the slide.

b. PROCEDURE.   Multiplication is performed using the CI and D scales as follows:

(1) Move hairline to either of factors on D scale.

(2) Set other factor on CI scale under hairline.

(3) Read product on D scale opposite C index.

(4) Place decimal point by approximate computation as described in paragraph 9c.

(5) To multiply an additional factor, move hairline to factor on C scale and read final product under hairline on D scale.

c. ILLUSTRATIVE EXAMPLES. (1) To multiply 8×2.5 (fig. 6), move hairline to 8 on D scale. Set 25 on CI scale under hairline opposite C index and read product 2 on D scale. The rough calculation $8 \times 2 = 16$ indicates that the answer is 20.

(2) To multiply 876×20.4, move hairline to 876 on D scale. Set 204 on CI scale under hairline opposite C index, and read product 1 7 8 7 on D scale. The rough calculation $900 \times 20 = 18,000$ indicates that the answer is 17,870.

(3) To multiply $3.65 \times 76.2 \times 218$, move hairline to 365 on D scale. Set 762 on CI scale under hairline. Move hairline to 218 on C scale. Under hairline, read product 6 0 6 on D scale. The rough calculation $4 \times 70 \times 200 = 56,000$ indicates that the answer is 60,600.

d. EXERCISES. Solve the following problems and the exercises in paragraph 9 on the slide rule, using the CI and D scales.

(1) $4.2 \times 25 \times 0.03$ (4) $793 \times 2.64 \times 52.3$
(2) $52.5 \times 2 \times 70$ (5) $63.4 \times 22.3 \times 22.2$
(3) $0.173 \times 1.51 \times 93.4$ (6) $25.7 \times 25.7 \times 730$

13. Division Using CI Scale

a. USE. Division can be done on the CI scale by multiplying the dividend by the reciprocal of the divisor. This is especially convenient when dividing a quotient determined by a previous operation or a product determined on the CI and D scales.

b. PROCEDURE. To divide using the CI and D scales, proceed as follows:

(1) Move hairline to divident on D scale. (This step may be omitted.)

(2) Set either left or right C index under hairline, or opposite dividend on D scale directly if step (1) is omitted.

(3) Move hairline to divisor on CI scale.

(4) Read quotient on D scale under hairline.

(5) If quotient cannot be read because second factor is on part of slide projecting beyond D scale, repeat above operations using other C index in step (2). However, in this case, it is usually preferable to use the C scale as described in paragraph 10.

c. ILLUSTRATIVE EXAMPLES. (1) To divide 2 by 25 (fig. 6), set C index opposite 2 on D scale. Move hairline to 25 on CI scale. Under hairline, read quotient 0.08 on D scale.

(2) To divide 468 by 278 and then divide the quotient by 63, move hairline to 468 on *D* scale. Set 278 on C scale under hairline. Opposite C index, read first quotient 1.685 on D scale. Move hairline to 63 on CI scale and read second quotient 0.0267 on D scale.

(3) To multiply 631 by 7.68 and then divide the product by 5.29, move hairline to 631 on D scale. Set 768 on CI scale under hairline. Opposite C index, read product 4850 on D scale. Move hairline to 529 on CI scale. Under hairline, read quotient 916 on D scale.

d. EXERCISES. (1) Using C and D scales, divide 169.5 by 5.66. Using CI scale, divide above quotient by 1.25.

(2) Using C and D scales, divide 4.81 by 0.172. Using CI scale, divide above quotient by 8.46.

(3) Using CI and D scales, multiply 7.23 by 221. Using CI scale, divide above product by 23.1.

14. A Scale

The scale below the D scale on the lower guide consists of two identical scales, referred to as A left and A right. It is used only with the D scale for determining squares and square roots of numbers. When the hairline is set to a number on the D scale, the square of that number is read under the hairline on the A scale.

15. Squares of Numbers

The square of a number can be determined either by multiplication using the C and D scales, or the CI and D scales, or directly using the A and D scales. Use of the C and D or CI and D scales is explained in paragraphs 9 and 12.

a. PROCEDURE. To determine the square of a number using the A and D scales, move hairline to number on D scale, and read square of that number under hairline on A scale.

b. ILLUSTRATIVE EXAMPLES. (1) To find 3^2, move hairline to 3 on D scale. Under hairline, read square 9 on A scale.

(2) To find 7^2, move hairline to 7 on D scale. Under hairline, read square 49 on A scale.

(3) To find 378^2, move hairline to 378 on D scale. Under hairline, read 1 4 3 on A scale. The rough calculation $400 \times 400 = 160,000$ indicates that the answer is 143,000.

c. EXERCISES. Determine the following squares using both the D and A scales and the CI and D scales.

(1) 25^2	(5) 89^2	(9) 1.753^2
(2) 32^2	(6) $.733^2$	(10) 0.334^2
(3) 61^2	(7) 472^2	(11) 0.00356^2
(4) 75^2	(8) 2.08^2	(12) 0.953^2

16. Square Roots of Numbers

Square roots can best be determined with the A and D scales. The first step is to point off groups of two digits starting at the decimal point. If the number is greater than 1, the number of places in the root is equal to the number of groups. If the number is less than 1, there are as many zeros between the decimal point and the first significant figure as there are groups of double zeros. Determine the greatest square root which can be extracted from the leftmost group containing significant figures. This is the first figure of the desired square root.

a. PROCEDURE. To determine the square root using the A and D scales, divide the number into groups. If there is only one figure in the first group to the left, move hairline to number on A *left* scale and read square root under hairline on D scale. If there are two numbers in the first group to the left, move hairline to number on A *right* scale and read square root under hairline on D scale.

b. ILLUSTRATIVE EXAMPLE. (1) To determine square root of 67,431, divide number into groups, (6) (74) (31). Since there are three groups of figures, there are three figures to the left of the decimal point in the root. The first digit in the root is 2. Since there is only one figure (6) in the first group to the left, move hairline to 674 on A *left* scale. Under hairline, read 2 5 9 5 on D scale. The desired root is 259.5.

(2) To determine square root of 3461.8, divide number into groups (34) (61).8. Since there are two groups of figures, there are two figures to the left of the decimal point in the root. The first digit in the root is 5. There are two figures in the first group to the left. Therefore, move hairline to 346 on A *right* scale. Under hairline, read 5 8 8 on D scale. The desired root is 58.8.

(3) To determine square root of 0.00034618, divide number into groups 0.(00) (03) (46) (18). Since there is one group of double zeros, there is one zero to the right of the decimal in the root. The first digit in the root is 1. There is only one figure in the leftmost group containing significant figures. Therefore, move hairline to 346 on A *left* scale. Under hairline, read 1 8 6 on D scale. The desired root is 0.0186.

17. Proportions

a. GENERAL. The ratio of two numbers can be written as a fraction. A statement of equality of two or more ratios such as $2/3 = 6/9$, $x/5 = 7/11$, and $2/3 = x/5 = 7/y = 9/z$ are proportions. Proportions may be solved using the C and D scales.

b. PROCEDURE. If the numerator of any ratio in a proportion is set on the C scale opposite the denominator of the same ratio on the D

scale, then the numerator of any other ratio in that proportion falls on the C scale opposite the denominator of the other ratio on the D scale. If the desired number falls off the range of the scale, move hairline to C index and then shift other C index under hairline.

c. ILLUSTRATIVE EXAMPLE. In the proportion $3.15/5.29 = x/4.35 = 57.6/y = z/14$, determine x, y, and z.

(1) Set 315 on C scale opposite 529 on D scale.

(2) Opposite 435 on D scale, read $x = 2.59$ on C scale.

(3) Opposite 576 on scale, read $y = 96.7$ on D scale.

(4) Move hairline to left C index.

(5) Set right C index under hairline.

(6) Opposite 14 on D scale, read $z = 8.34$ on C scale. To determine positions of decimal points, notice that each denominator must be less than twice its associated numerator, since in original fraction 5.29 is less than twice 3.15.

18. Special Proportions

a. CONVERTING METERS TO YARDS. The gauge point on the upper guide marked M/YD is used to convert meters to yards. The gauge point is opposite 0.9144 on the D scale, the number of meters equivalent to 1 yard. The procedure is as follows:

(1) Set C index opposite M/YD gauge point.

(2) Move hairline to value in meters on D scale.

(3) Read value on C scale under hairline. The solution is that of the proportion $0.9144/1 = M/YD$.

b. CONVERTING DEGREES TO MILS. (1) Using C and D scales. The gauge point on the upper guide marked DEG/MIL is used to convert degrees to mils. This gauge point is opposite 0.0562 on the D scale, the number of degrees equivalent to 1 mil. The procedure is as follows:

(a) Convert minutes to decimal parts of a degree.

(b) Set C index opposite DEG/MIL gauge point.

(c) Move hairline to value in degrees on D scale.

(d) Read value in mils on C scale.

(e) To place decimal point, remember that 1 degree equals 17.77 mils or approximately 20. The solution is that of the proportion $0.0562/1 = DEG/MIL$.

(2) Using APEX ANGLE or OPPOSITE ANGLE scales. To convert angles greater than 2° 30' directly to mils, move hairline to value in degrees on APEX ANGLE or OPPOSITE ANGLE scale in degrees and read value in mils under hairline on corresponding APEX ANGLE or OPPOSITE ANGLE scale.

Section III. TRIGONOMETRIC PROBLEMS

19. SIN Scale

Black numbers on the SIN scale are used in determining sines of angles from 100 to 1600 mils. Red numbers are used in determining cosines of angles from 0 to 1500 mils (the black 1600 being used as the 0 point). The method used to divide the scale is similar to that for the D scale (par. 7).

a. Use. (1) To find the sine of an angle, move hairline to *black* number representing angle in mils, and read sine under hairline on C scale. If C and D scale indexes coincide, the sine may be read on the D scale.

(2) To find the cosine of an angle, move hairline to *red number* representing angle in mils, and read cosine under hairline on C scale.

(3) Since sine of 1600 mils (90°) is 1.0, right index of C scale is 1.0 and left index is 0.1 when reading sines of angles set on SIN scale.

b. ILLUSTRATIVE EXAMPLES. Determine (1) sine 600 mils, (2) sine 160 mils, (3) sine 523 mils, (4) sine 400 mils, (5) cosine 1200 mils, and (6) cosine 1362 mils. Compare the answers with (1) 0.556, (2) 0.1564, (3) 0.491, (4) 0.383, (5) 0.383, and (6) 0.2315.

20. SIN-TAN Scale

Numbers on the SIN-TAN scale represent angles from 10 to 105 mils. Since the tangent approximately equals the sine for angles less than 100 mils, the SIN-TAN scale can be used to determine either the sine or the tangent of an angle.

a. Use. (1) To find the sine or tangent of an angle, move hairline to number representing angle in mils, and read sine or tangent under hairline on C scale. If C and D scale indexes coincide, the sine or tangent may be read on the D scale. To determine the sine or tangent for angles less than 10 mils, move hairline to an angle 10 times the desired angle. .

(2) Since sine or tangent of 100 mils is approximately 0.1, right index of C scale is 0.1 and left index is 0.01 when reading sines or tangents of angles greater than 10 mils set on SIN-TAN scale. For angles less than 10 mils, right index is 0.01 and left index is 0.001.

(3) To determine cosines of angles greater than 1500 mils, set the complement of the angle on the SIN-TAN scale. Thus, the cosine of 1578 mils = sine 22 mils, and the cosine of 1593 mils = sine 7 mils.

b. ILLUSTRATIVE EXAMPLES. Determine (1) sine 40 mils, (2) tangent 52.5 mils, (3) sine 3.4 mils, (4) tangent 5.8 mils, (5) cosine 1543 mils, and (6) cosine 1591 mils. Compare answers with (1) 0.0392, (2) 0.0515, (3) 0.00334, (4) 0.00570, (5) 0.0559, and (6) 0.00884.

21. TAN Scale

Numbers on the TAN scale represent angles from 100 to 800 mils and angles from 800 to 1500 mils. Black numbers are used in determining tangents between 100 and 800 mils, and red numbers in determining cotangents between 800 and 1500 mils. The tangent of angles greater than 800 mils is found by first determining the cotangent. Then convert by the relation that the tangent of an angle is the reciprocal of the cotangent of that angle ($\tan \alpha = 1/\cot \alpha$). The tangent of an angle greater than 800 mils can also be read directly using the TAN scale and C and D scales.

a. Use. (1) To find the tangent of an angle, move hairline to black number representing angle in mils, and read tangent under hairline on C scale.

(2) To find the cotangent of an an angle, move hairline to red number representing angle in mils, and read cotangent of angle under hairline on C scale.

(3) To find the tangent of an angle greater than 800 mils, move hairline to either D index, set angle on *red* numbers of TAN scale under hairline, and read tangent on D scale opposite C index.

(4) Since tangent of 800 mils (45°) is 1.0, right index of C scale is 1.0 and left index is 0.1 when reading tangents of angles set on TAN scale.

b. Illustrative Examples. Determine (1) tangent 300 mils, (2) tangent 555 mils, (3) tangent 1350 mils, and (4) tangent 1422 mils. Compare answers with (1) 0.303, (2) 0.606, (3) 3.99, and (4) 5.66.

22. ARCTAN

The expression "arctan 0.341" means the angle which has a tangent of 0.341. Knowing the tangent, the angle can be determined. If the tangent is less than 1.0, the angle is less than 800 mils.

a. Procedure. (1) To determine an angle less than 800 mils when tangent is known, set hairline at tangent on C scale. For tangents between 0.1 and 1.0, read angle on TAN scale. For tangents between 0.01 and 0.1, read angle on SIN-TAN scale. For tangents between 0.001 and 0.01, angle is one-tenth of value read on SIN-TAN scale.

(2) If tangent is between 1.0 and 10, set either C index opposite value of tangent on D scale, move hairline to D index, and read angle on *red* divisions of TAN scale under hairline. If tangent is between 10 and 100, read value on SIN-TAN scale and subtract from 1600 mils. If tangent is between 100 and 1000, read value and subtract one-tenth of value on SIN-TAN scale from 1600 mils.

b. ILLUSTRATIVE EXAMPLES. Determine angles corresponding to (1) arctan 0.400, (2) arctan 0.462, (3) arctan 0.668, (4) arctan 0.0668, (5) arctan 2.45, (6) arctan 24.5, and (7) arctan 245.0. Compare answers with (1) 388 mils, (2) 441 mils, (3) 600 mils, (4) 68.1 mils, (5) 1205 mils, (6) 1538.4 mils, and (7) 1595.8 mils.

Section IV.   ACCURACY

23. Limits of Accuracy

Accuracy of the military slide rule depends on how exactly the *least accurate* figure in the problem can be set on the rule. If *none* of the figures in the problem can be set as accurately as they were measured, another method of calculation must be used. However, if *any one* figure can be set on the rule as accurately as it was measured, accuracy of the slide rule answer cannot be improved.

a. ILLUSTRATIVE EXAMPLES. (1) In solving an oblique triangle, the angles are measured as 2231.4 mils and 2152.9 mils to within ± 0.1 mil and the base is measured as 893.2 yards to within ± 0.1 yard. The angles can only be set on the slide rule to within ± 3 mils and ± 0.2 mils approximately, and the length of base to within ± 1 yard. Since *not one item* can be set as accurately as measured, a more accurate answer can be obtained using natural functions or five-place logarithms.

(2) If the length of the base in the example above were measured as 893 yards to within ± 1 yard, this *one item* of the problem could be set on the rule as accurately as measured. The accuracy of the answer could not be improved by any other computation method.

b. DETERMINING METHODS OF COMPUTATION. To decide whether a value determined on the rule should be used as a final answer or merely as a check on more accurate methods of computation, consider both the accuracy of the data and the accuracy required in the answer. For example, in locating a target, the accuracy obtained using the slide rule is usually adequate. On the other hand, if the location of a survey control point is being determined, a highly accurate answer is required and the slide rule probably would not be accurate enough.

FIELD ARTILLERY SURVEY PROBLEMS

Section I. GENERAL PROBLEMS

24. Solving Short Base Problem

The OPPOSITE ANGLE and APEX ANGLE scales are used in conjunction with the BASE or C and RANGE or D scales for solving the short base problem. The fourth section of the table on the back of the rule (fig. 8) is a convenient reference. Designation of angles used by the field artillery observation battalion for this problem is illustrated in figure 9.

a. DETERMINATION OF b WHEN ANGLES A^1 AND B AND SIDE c ARE KNOWN. (1) If angles A^1 and B and side c are known, b is computed by solving the proportion $b/c = \mathrm{Sin}\ B\ /\mathrm{Sin}\ C$. Apex angle C is determined as $A^1 - B$.

(2) To find value of b, if c = 636 yards, A^1 = 830 mils, and B = 712 mils: Subtract B from A^1 to find C (830 — 712 = 118). Move hairline to 712 on OPPOSITE ANGLE scale. Set 118 under hairline on APEX ANGLE scale. Move hairline to 636 on BASE scale. Under hairline, read b = 3540 on RANGE scale.

b. DETERMINATION OF a WHEN ANGLES A^1 AND B AND SIDE c ARE KNOWN. (1) If angles A^1 and B and side c are known, side a is computed by solving the proportion $a/c = \mathrm{Sin}\ A/\mathrm{Sin}\ C$.

(2) To find value of a, if c = 872 yards, A^1 = 2332 mils, and B = 2094 mils: Subtract B from A^1 to find C (2332 — 2094 = 238). Move hairline to 2332 on OPPOSITE ANGLE scale. Set 238 under hairline on APEX ANGLE scale. Move hairline to 872 on BASE scale. Under hairline, read a = 2835 on RANGE scale.

c. DETERMINATION OF a WHEN ANGLES A AND B AND SIDE c ARE KNOWN. (1) If angles A and B and side c are known, side a is computed by solving the proportion $a/c = \mathrm{Sin}\ A/\mathrm{Sin}\ C$.

(2) To find value of a, if c = 428 yards, A = 638 mils, and B = 2481 mils. Subtract $A + B$ from 3200 mils to find C (3200 — (638 + 2481) = 81). Move hairline to 638 on OPPOSITE ANGLE scale. Set 81 under hairline on APEX ANGLE scale. Move hairline to 428 on BASE scale. Under hairline, read a = 3158 on RANGE scale.

d. SOLUTION WHEN BASE LENGTH FALLS OFF THE RANGE SCALE. (1) If base length falls off RANGE scale, change C indexes and exercise care in placing decimal point.

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

$$C = A^{I} - B$$
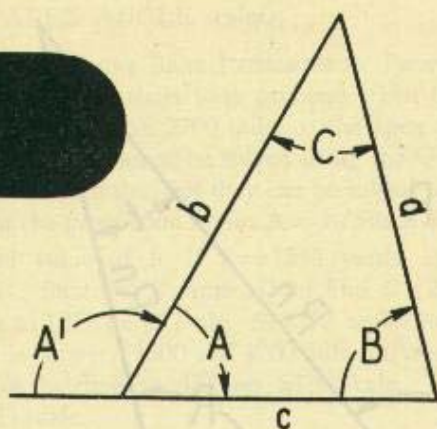
$$b = \frac{\sin B}{\sin C} c$$

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

$$a = \frac{\sin A^{I}}{\sin C} c$$

$$c = base$$

$$C = Apex \ Angle$$

$$A^{I} or \ A \ or \ B = Opposite \ Angle$$

$$a \ or \ b = Range$$

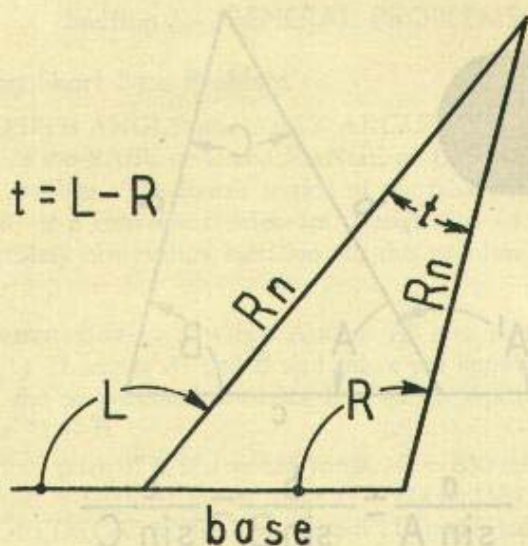*Figure* 8. *Short base triangle and formulas (from table on reverse of rule).*

Figure 9. Short base triangle for use of field artillery observation battalion (from table on reverse of rule).

(2) To find value of b, if c = 393 yards, A^1 = 1419 mils, and B = 1042 mils. Subtract B from A^1 to find C (1419 — 1042 = 377). Move hairline to 1042 on OPPOSITE ANGLE scale. Set 377 under hairline on APEX ANGLE scale. Move hairline to right C index. Set left C index under hairline. Move hairline to 393 on BASE scale. Under hairline, read b = 928 on RANGE scale.

e. DETERMINATION OF c WHEN ANGLES A^1 AND B AND SIDE b ARE KNOWN. (1) If angles A^1 and B and side b are known, length of side c is computed by solving the proportion b/c = Sin B/Sin C.

(2) To find value of c, if b = 5622 yards, A^1 = 2467 mils, and B = 2343 mils: Subtract B from A^1 to find C (2467 — 2343 = 124). Move hairline to 2343 on OPPOSITE ANGLE scale. Set 124 under hairline on APEX ANGLE scale. Move hairline to 5622 on RANGE scale. Under hairline, read c = 916 on BASE scale.

f. SOLUTION FOR ANGLE MEASURED IN DEGREES AND MINUTES. If angles are measured in degrees and minutes, solve short base problems listed above using degree and minute graduations on OPPOSITE ANGLE and APEX ANGLE scales.

g. SOLUTION OF SHORT BASE PROBLEMS BY PROPORTION. (1) It may be necessary to solve a short base problem when the opposite angle is less than 500 or more than 2700 mils, or the apex angle is less than 45 mils. These problems cannot be solved using the OPPOSITE ANGLE and APEX ANGLE scales, but they can be solved on the C, D, and SIN scales by using the proportion $a/\sin A = b/\sin B = c/\sin C$.

(2) To find value of b, if $c = 1213$ yards, $A^1 = 2940$ mils, and $B = 2763$ mils: Subtract B from A^1 to find C ($2940 - 2763 = 177$). Move hairline to 1213 on D scale. Set 177 under hairline on SIN scale. Since angle B is between 1600 and 3200 mils, supplement ($3200 - 2763$) is used. Move hairline to 437 on SIN scale. Under hairline, read $b = 2918$ on D scale.

h. EXERCISES. Solve the following problems for the side indicated:

	Angle A	Angle A¹	Angle B	a	b	c
(1)	..	1067 mils	940 mils	..	?	785 yards
(2)	..	1540 mils	1327 mils	?	..	656 yards
(3)	665 mils	..	2432 mils	..	?	933 yards
(4)	..	1391 mils	1192 mils	..	?	1282 yards
(5)	..	2345 mils	2024 mils	..	?	324 yards
(6)	..	975 mils	848 mils	..	5120 yards	?
(7)	..	2332 mils	2181 mils	8625 yards	..	?
(8)	..	2122.5 mils	2059.2 mils	?	..	868 yards
(9)	..	593 mils	473 mils	..	?	941 yards

25. Computation of Coordinates

When bearing and length of a line are known, the X-component (departure) of the line is determined by multiplying the distance by the sine of the bearing. Also the Y-component (latitude) is determined by multiplying the distance by the cosine of the bearing.

a. BEARINGS. The bearing of a line is the acute angle between the line and the Y-axis (north-south line). In figure 10, line A in the first quadrant has a bearing of N700ᴱ (read north 700 east), line B in the second quadrant has a bearing of S900ᴱ, line C in the third quadrant has a bearing of S1100W, and line D in the fourth quadrant has a bearing of N600W. Bearings in mils are always expressed as indicated above, giving first the letter N or S indicating from which end of the north-south axis the line deviates, then the angular deflection in mils, and finally the letter E or W indicating the direction of deviation. Bearings of lines having azimuths of 0, 1600, 3200, and 4800 mils are expressed as north, east, south, and west.
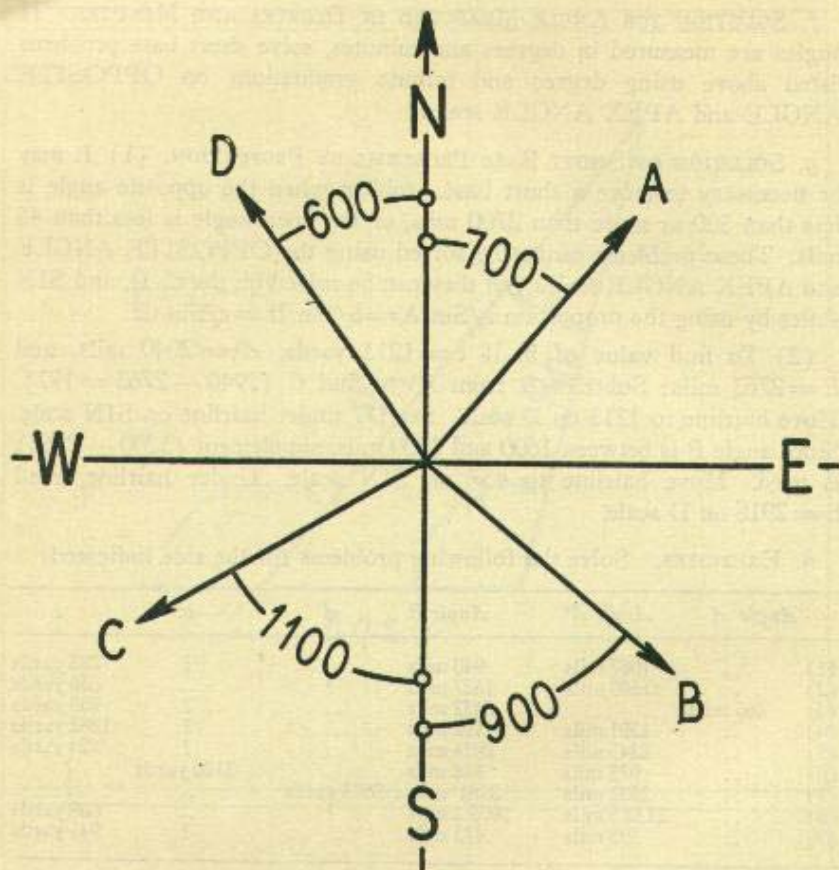
Figure 10. *Method of designating bearings.*

b. CONVERTING AZIMUTHS TO BEARINGS. In field artillery survey, the direction of a line is usually expressed as an azimuth. The first section of the table on the back of the rule (fig. 11) is a convenient reference for converting azimuths to bearings and determining coordinates. In figure 12, which shows a small portion of figure 11, the Roman numeral II indicates the second quadrant. The signs + — under the numeral II indicate that the X-component is + and the Y-component is —. In figure 11, the — + signs over the numeral IV indicate that the X-component is — and the Y-component is +. The solid line with *cos* printed alongside indicates that the Y-component is equal to the distance multiplied by the cosine of the bearing. The dotted line with *sin* printed underneath indicates that the X-component is equal to the distance multiplied by the sine of the bearing. There are four equations under the diagram in figure 11. Under the abbreviation *Quad*, the quadrant designations are given by number and by compass direction.
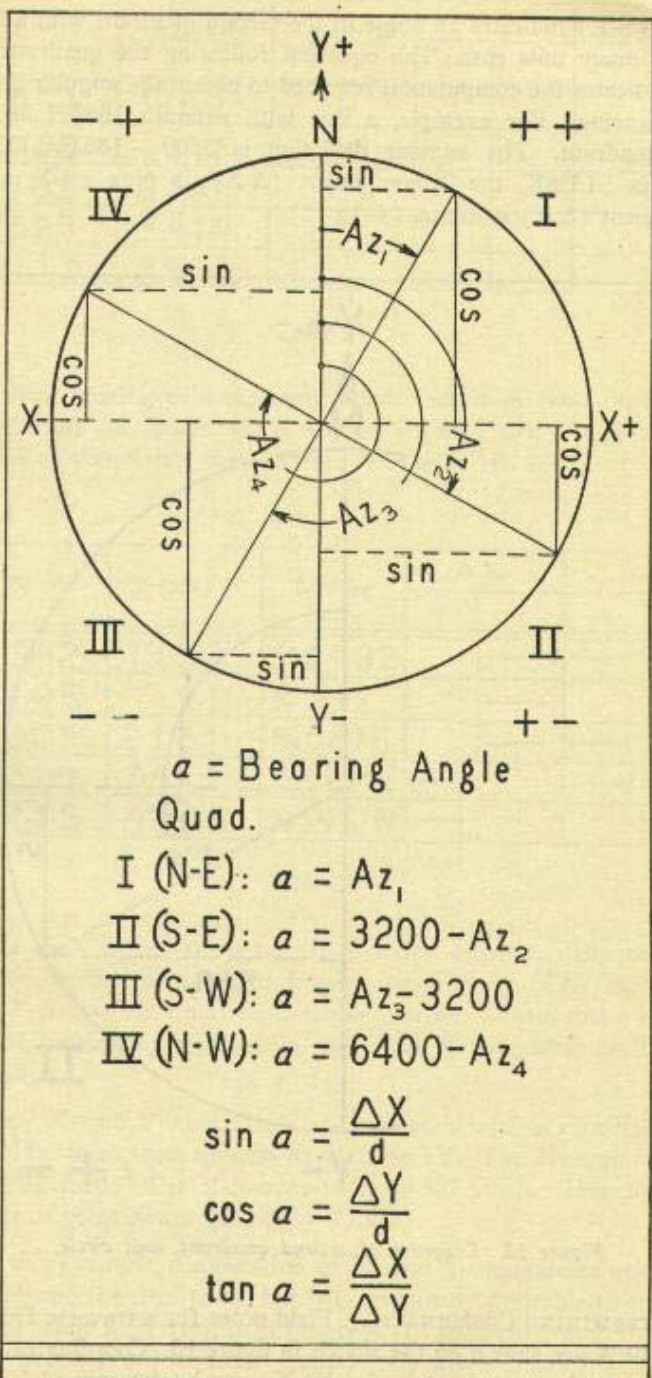
a = Bearing Angle

Quad.

I (N-E): $a = Az_1$

II (S-E): $a = 3200 - Az_2$

III (S-W): $a = Az_3 - 3200$

IV (N-W): $a = 6400 - Az_4$

$$\sin a = \frac{\Delta X}{d}$$

$$\cos a = \frac{\Delta Y}{d}$$

$$\tan a = \frac{\Delta X}{\Delta Y}$$

Figure 11. *Unit-circle diagram for converting azimuths to bearings (from table on reverse of rule).*

Thus II (S-E) indicates an angle in the second quadrant with a bearing south so many mils east. The equation following the quadrant designation indicates the computation required to obtain the angular deviation of the bearing. For example, a line with azimuth 1862 falls in the second quadrant. The angular deviation is $3200 - 1862 = 1338$, the bearing is S1338E, the X-component (ΔX) is plus $(+)$, and the Y-component (ΔY) is minus $(-)$.
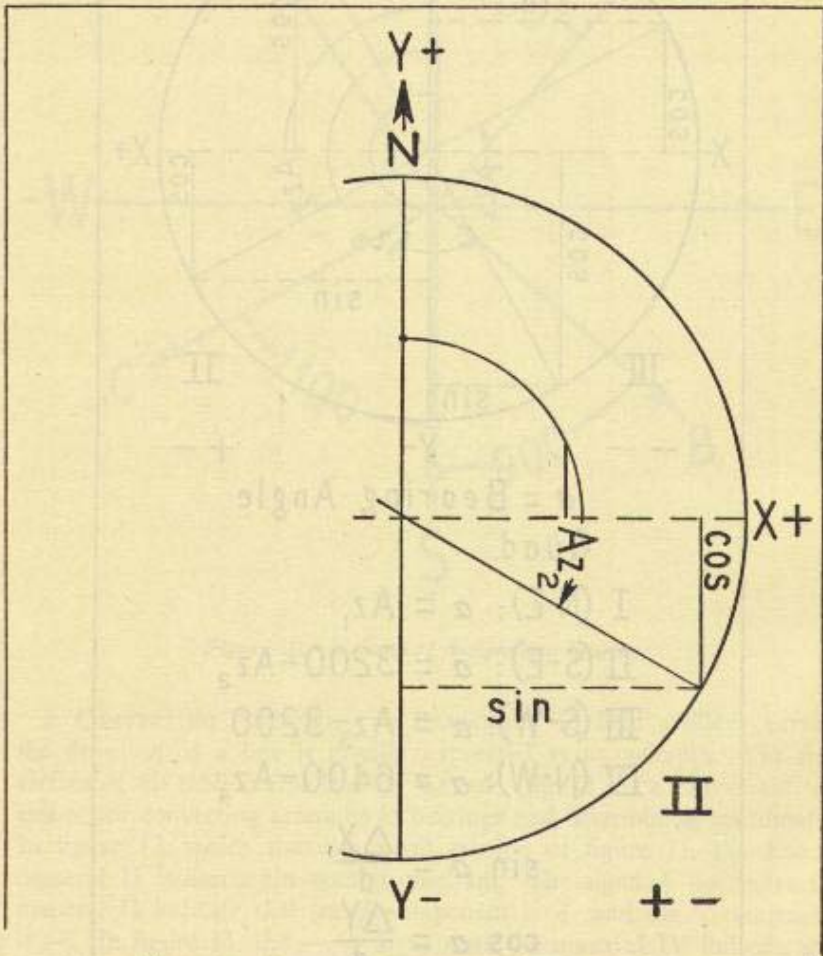

Figure 12. Diagram of second quadrant, unit circle.

c. DETERMINING COORDINATES. Field notes for a traverse from point A to point X are shown on the sketch in figure 13. Coordinates of point A are known, but coordinates of point X must be determined.

(1) First, tabulate data in a convenient way such as in Table II.

Leg	Distance	Y-Azimuth	Bearing	ΔX +	ΔX −	ΔY +	ΔY −
A-1	542	1952					
1-2	105	91					
2-3	405	2131					
3-4	329	3414					
4-X	115	4943					

Table II

(2) Fill in bearing column, using upper section of table on back of slide rule. Line out spaces which will not be used in Δ X and Δ Y columns. The tabulated data then appears as in table III.

Leg	Distance	Y-Azimuth	Bearing	ΔX +	ΔX −	ΔY +	ΔY −
A-1	542	1952	S1248E		—	—	
1-2	105	91	N 91E		—		—
2-3	405	2131	S1069E		—	—	
3-4	329	3414	S214W	—		—	
4-X	115	4943	N1457W	—			—

Table III

(3) For each leg of traverse, set C index opposite distance on D scale, move hairline to value of bearing on SIN or SIN-TAN scale, and read X-component on D scale under hairline. Then, move hairline to value of bearing on COS scale, and read Y-component on D scale under hairline.

(4) Total X- and Y-components and add each total to coordinates of point A. The form then appears as in table IV. The X-component of $\overline{AX}$ is + 687 yards. The Y-component is — 587 yards. Therefore, the coordinates of point X are (28.687 — 73.413).

(5) In this example, computation of X- and Y-components was made after completing the field work, but it is frequently desirable to compute the traverse while field work is in progress. In such case, coordinates of successive points are determined immediately after measuring the distance and azimuth of each leg. This requires only slight modification of the procedure.

Leg	Distance	Y-Azimuth	Bearing	ΔX		ΔY	
				+	−	+	−
A-1	542	1952	S1248E	510	—	—	184
1-2	105	91	N 91E	9	—	105	—
2-3	405	2131	S1069E	351	—	—	202
3-4	329	3414	S 214W	—	69	—	322
4-X	115	4943	N1457W	—	114	16	—

$$+870 -183 \quad +121 -708$$
$$-183 \qquad\qquad +121$$
$$\overline{+687} \qquad\qquad \overline{-587}$$
$$28.000 \qquad\qquad 74.000$$

$$\text{Coords. Pt.X} = \frac{28.000}{28.687} \quad - \quad \frac{74.000}{73.413}$$
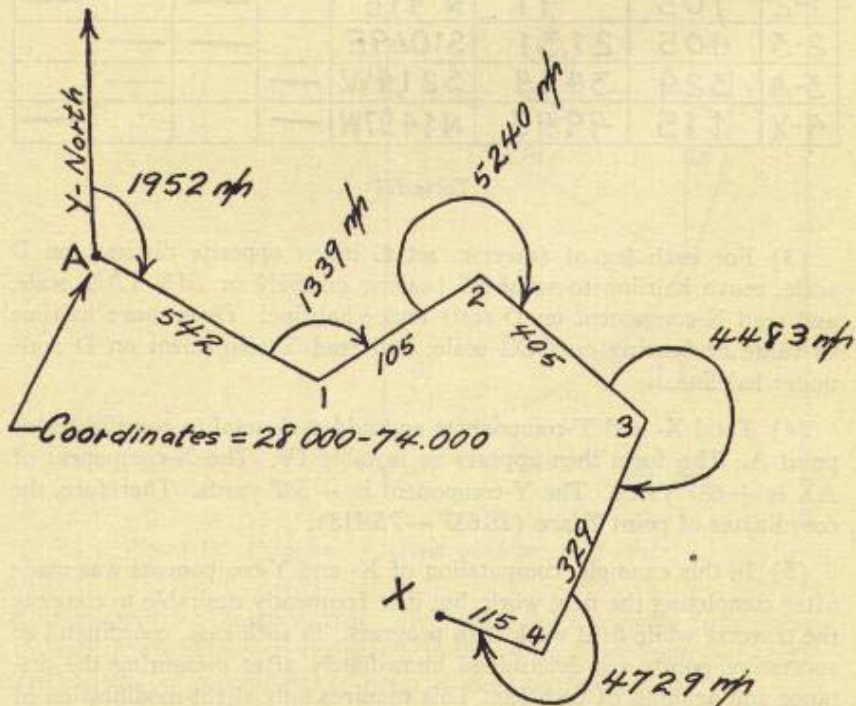
Table IV.

Figure 13. *Survey field notes.*

26. Determining Direction

a. DETERMINATION OF BEARING. When X- and Y-components of a line are known, the bearing of the line is determined using the TAN or SIN-TAN scale.

(1) When ΔX is less than ΔY, the bearing is less than 800 mils. For this case, the relation tan $\alpha = \Delta X / \Delta Y$ (fig. 11) is used. Dividing this equation by ΔX results in the following proportion:

$$\frac{\tan \alpha}{\Delta X} = \frac{1}{\Delta Y}$$

Therefore, *to determine bearings less than 800 mils (ΔX less than ΔY),* set C index opposite Y-component on D scale and move hairline to X-component on D scale. Read bearing directly from TAN or SUN-TAN scale. For tangent of bearing, read under hairline on C scale.

(2) When ΔX is greater than ΔY, the bearing is greater than 800 mils. For this case, the relations Cot $\alpha = \Delta Y / \Delta X$ and cot $\alpha =$ tan $(1600 - \alpha)$ are used. By combining these two equations, the following is obtained:

$$\cot \alpha = \tan (1600 - \alpha) = \Delta Y / \Delta X$$

Dividing this equation by ΔY results in the following proportion:

$$\frac{\cot \alpha}{\Delta Y} = \frac{\tan (1600 - \alpha)}{\Delta Y} = \frac{1}{\Delta X}$$

Therefore, *to determine bearings greater than 800 mils (ΔX greater than ΔY),* set C index opposite X-component on D scale and more hairline to Y-component on D scale. Cotangent of bearing angle is then under hairline on C scale. Read complement angle of bearing $(1600 - \alpha)$ directly from TAN or SIN-TAN scale. To determine bearing, subtract angle read from 1600. Bearing can be read directly on TAN scale, using red figures which represent complementary angles.

(3) *To determine a bearing, set C index opposite larger component on D scale and move hairline to smaller component on D scale. If X-component is less than Y-component, read bearing directly from black figures on TAN or SIN-TAN scale. If Y-component is less than X-component, read bearing directly from red figures on TAN scale or subtract value read on SIN-TAN scale from 1600 mils. If ratio ΔX/ ΔY or ΔY/ ΔX falls between 0.1 and 1, read bearing on TAN scale. If ratio ΔX/ ΔY falls between 0.01 and 0.1, read bearing from SIN-TAN scale. If ratio ΔX/ ΔY falls between 0.001 and 0.01, bearing is one-tenth of value read from SIN-TAN scale.*

b. DETERMINATION OF AZIMUTH. After bearing is determined, calculate the azimuth as follows: In first quadrant, bearing and azimuth are the same. In second quadrant, azimuth is the bearing subtracted from 3200. In third quadrant, azimuth is the bearing plus 3200. In fourth quadrant, azimuth is the bearing subtracted from 6400.

c. Exercises. Determine bearing and azimuth of each of the following lines:

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔX+123	—298	+89.3	+ 241	+ 36	—598	+ 4.6	+896
ΔY+298	+123	+ 241	—89.3	—598	— 36	+ 896	— 4.6

Continue traverse computations in paragraph 25 by solving for bearing and azimuth of $\overline{AX}$.

27. Determining Distance

a. Procedure. When coordinates of two points are known, the length of the line between points is determined as follows:

(1) First, find X- and Y-components by subtracting coordinates of one point from those of other point,

(2) Next, determine bearing of line, using components as described in paragraph 26.

(3) To find length of line, divide X-component by sine of bearing (SIN $\alpha = \Delta X/d$ or $d = \Delta X/SIN \alpha$) as follows: Set value of bearing on SIN scale opposite value of X-component on D scale, and read length of line opposite index on D scale. Since cos $\alpha = \Delta Y/d$, length of line can also be found by dividing Y-component by cosine of bearing.

b. Illustrative Example. Continue traverse computations from paragraph 25 to find distance $\overline{AX}$. The X-component of $\overline{AX}$ is + 687 yards, and bearing of $\overline{AX}$ is S880E (par. 26c(9)). Therefore, length of $\overline{AX}$ is 687 / sin 880. Move hairline to 687 on D scale. Set 880 on SIN scale under hairline. Opposite C index, read distance 904 yards on D scale. If Y-component (— 587 yards) is used, length of $\overline{AX}$ is 587/cos 880 = 904 yards.

c. Exercises. Determine distance between two points in following exercises. For 1 through 8, use bearings determined in paragraph 26.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔX + 123	— 298	+ 89.3	+ 241	+ 36	— 598	+ 4.6	+ 896
ΔY + 298	+ 123	+ 241	— 89.3	— 598	— 36	+ 896	— 4.6

	Coordinates point A	Coordinates point B
(9)	852.937 — 1292.631	853.229 — 1292.971
(10)	50.194 — 200.631	49.831 — 199.322
(11)	103.298 — 500.162	101.007 — 501.298

28. "Point P" Method of Determining Length of Short Base

a. Procedure. The following method is used to find the distance between two observation posts which are not visible to each other. L is the left observation post, R is the right observation post, and P is a point

that is located so both L and R are visible and the distances $\overline{LP}$ and $\overline{PR}$ can be taped or computed.

(1) *Determining angle L.* Measure distances $\overline{LP}$ and $\overline{PR}$ and angle *P*; then, compute angle *L* by the formula:

$$\text{Tan } L = \frac{\overline{PR} \text{ Sin } P}{\overline{LP} - \overline{PR} \text{ cos } P}$$

In applying the above equation, remember that the cosine of an angle less than 1600 mils is *positive,* and the cosine of an angle between 1600 and 3200 is *negative.* If cos *P* is positive and quantity $(\overline{PR} \text{ cos } P)$ is greater than $\overline{LP}$, then tan *L* is negative and angle *L* is greater than 1600 mils. The second section on the back of slide rule (fig. 14) has this formula for ready reference.
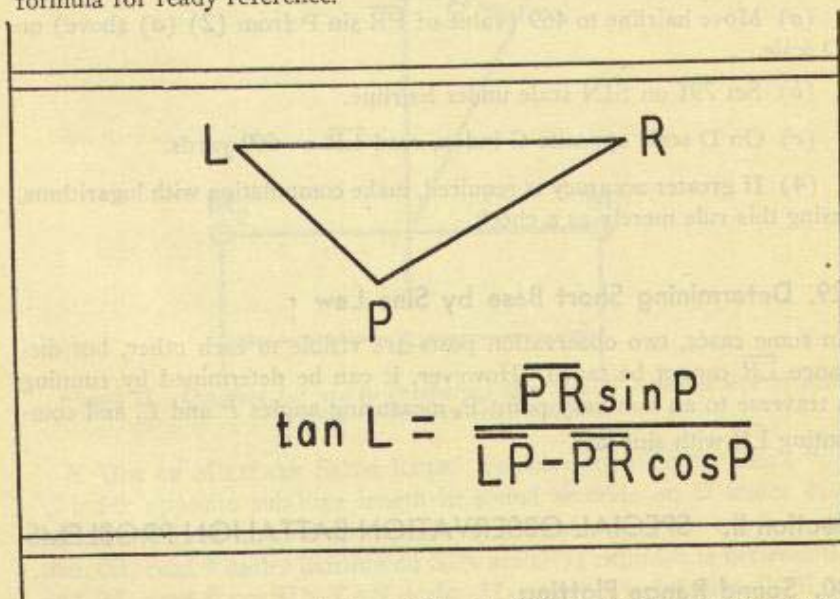
Figure 14. Diagram for use in "point P" method (from table on reverse of rule).

(2) *Determining distance LR.* After angle *L* is determined, find distance $\overline{LR}$ by applying the law of sines in the following way:

$$\overline{LR} = \frac{\overline{PR} \text{ Sin } P}{\text{Sin } L}$$

b. ILLUSTRATIVE EXAMPLE. (1) $\overline{LP}$ is 362.4 yards, $\overline{PR}$ is 482.6 yards, and angle *P* is 1843.8 mils.

(2) Determine angle *L* from formula

$$\tan L = \frac{\overline{PR} \text{ Sin } P}{\overline{LP} - \overline{PR} \text{ cos } P} \text{ as follows}$$

(*a*) Set C index opposite value of $\overline{PR}$, 483, on D scale. Move hairline to 1356 (3200 — 1843.8) on SIN scale, using black figures. Under hairline, read $(\overline{PR} \text{ sin } P)$ equals 469 yards on D scale.

(*b*) Move hairline to 1356 on SIN scale, using red figures. Under hairline, read ($\overline{PR}$ cos P) equals — 114.8 yards on D scale.

(*c*) Subtract —114.8 from 362.4 (362.4 — (—114.8) = 477.2)

(*d*) Set C index opposite 477 on D scale. Move hairline to 469 on D scale.

(*e*) Since ΔX or ($\overline{PR}$ sin P) is less than ΔY or ($\overline{LP}$ — $\overline{PR}$ cos P), read angle L under hairline on black figures of TAN scale as 791 mils.

(3) Determine distance LR from formula

$$\overline{LR} = \frac{\overline{PR} \sin P}{\sin L} \text{ as follows:}$$

(*a*) Move hairline to 469 (value of $\overline{PR}$ sin P from (2) (*a*) above) on D scale.

(*b*) Set 791 on SIN scale under hairline.

(*c*) On D scale opposite C index, read $\overline{LR}$ = 669 yards.

(4) If greater accuracy is required, make computation with logarithms, using this rule merely as a check.

29. Determining Short Base by Sine Law

In some cases, two observation posts are visible to each other, but distance $\overline{LR}$ cannot be taped. However, it can be determined by running a traverse to an auxiliary point P, measuring angles *P* and *L*, and computing $\overline{LR}$ with sine law.

Section II. SPECIAL OBSERVATION BATTALION PROBLEMS

30. Sound Range Plotting

The direction used in sound range plotting with a range-deflection fan can be computed with the military slide rule. (For additional details of theory and practice consult FM 6–120.)

a. THEORY. The time of arrival of a sound (gun or shell burst) at each microphone is recorded. The difference between times of arrival in seconds (t) is computed. The direction to the source of sound, an angle Θ measured from the perpendiclar bisector of the line connecting a pair of microphones, is determined from the equation:

$$\frac{\text{Sine } \theta}{t} = \frac{1}{s}$$

Where s is the distance $M_1 M_2$ (sub-base fig. 15) is expressed in sound seconds. One sound is 369.2 yards. A ray is then plotted in the correct direction with a range-deflection fan. The ray is plotted to the right if

the time interval is positive (sound arrives at M_1 first) and to the left if the time interval is negative (sound arrives at M_2 first).

NOTE: Corrections (see FM 6-120) must be applied to the *measured* time interval (t) before a final plot is made.
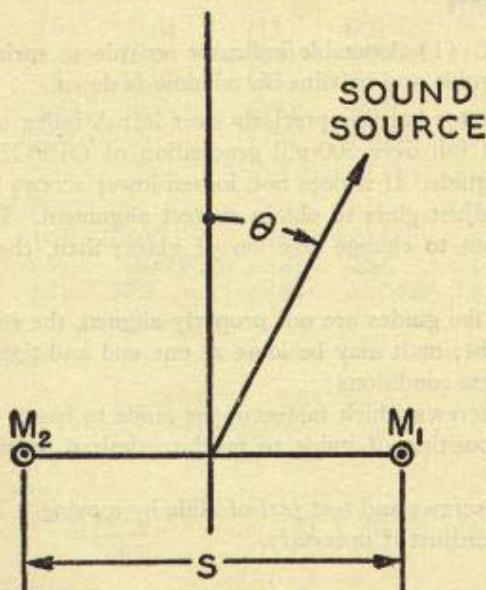

Figure 15. Diagram for use in computing direction of sound source of field artillery observation battalion.

b. USE OF MILITARY SLIDE RULE. To solve equation for angle Θ, set C index opposite sub-base length in sound seconds on D scale. Move hairline to time interval in seconds on D scale. If ratio t/s is greater than 0.1, read Θ under hairline on SIN scale. If ratio t/s is between 0.01 and 0.1, read Θ on SIN-TAN scale. If ratio t/s is between 0.001 and 0.01, Θ is one-tenth of value read on SIN-TAN scale.

c. ILLUSTRATIVE EXAMPLE. A sub-base of a sound-ranging base is 923.0 yards. The value of s is 2.5 sound seconds (923.0/369.2 = 2.5). The measured time interval t is 1.137 seconds. Angle Θ is found as follows: Set C index opposite 25 on D scale. Move hairline to 1.137 on D scale. Under hairline, read $\Theta = 481$ mils on SIN scale.

CHAPTER 4

ADJUSTMENTS AND CARE

31. Adjustments

a. INDICATOR. (1) Assemble indicator on rule so spring slides along edge of upper guide and hairline on window is down.

(2) Set indicator hairline precisely over left A index on lower guide. Hairline should fall over 500-mil graduation of OPPOSITE ANGLE scale on upper guide. If it does not, loosen lower screws holding indicator glass and adjust glass to obtain correct alignment. Tighten screws, being careful not to change position of glass; then, check adjustment again.

b. SLIDE. If the guides are not properly aligned, the slide may be too loose or too tight; or it may be loose at one end and tight at the other. To eliminate these conditions:

(1) Loosen screws which fasten upper guide to base.

(2) Adjust position of guide to produce desired amount of friction on slide.

(3) Tighten screws and test *feel* of slide by moving it back and forth a few times. Readjust if necessary.

32. Care

a. PRECAUTIONS IN HANDLING. (1) Avoid rough handling to prevent chipping or denting face and edges of scales or defacing scale graduations.

(2) Do not jam indicator against stops which prevent indicator from sliding off rule. Be especially careful when inserting or removing rule from carrying case.

(3) Avoid abrasion, bending, or impact because indicator glass is brittle.

(4) Do not expose rule to excessive heat. Temperatures above 120° F. injure nitrocellulose scales.

b. LUBRICATION. (1) When slide is new or movement sticks, lubricate by rubbing edges with talcum powder. Issue foot powder is satisfactory.

(2) *NEVER* use oil, grease, or tallow as a lubricant.

c. CLEANING. (1) If scales are dirty, wash with cloth moistened slightly with soapy water. After scales are clean, remove all traces of soap with clean slightly damp cloth, and dry carefully with tissue or soft clean cloth.

(2) Do not clean scales with commercial solvents such as alcohol or acetone, and avoid using too much water.

APPENDIX

ANSWERS TO EXERCISES

Paragraph 9d, page

(1)	6.00	(6)	9.62	(11)	47.0	(16)	8.37
(2)	7.00	(7)	15.0	(12)	0.0826	(17)	3225.
(3)	6.75	(8)	15.77	(13)	1737.	(18)	10.0
(4)	9.10	(9)	49.8	(14)	9.98	(19)	3.08
(5)	340.	(10)	3525.	(15)	0.1322	(20)	24.8
						(21)	9.87

Paragraph 10d, page

(1)	2.32	(4)	106.1	(7) 18,610.	(10)	0.0419
(2)	165.2 .	(5)	0.000713	(8) 886.	(11)	20.0
(3)	0.0767	(6)	77.5	(9) 0.866	(12)	20.7

Paragraph 12d, page

(1)	3.15	(3)	24.4	(5)	31,500
(2)	7350.	(4)	109,500	(6)	482,000

Paragraph 13d, page

(1) 29.9	(2) 27.9	(3) 1,598.	(4) 39,400.
23.9	3.3	4,410.	1,708.

Paragraph 15d, page

(1)	625.	(4)	5,625.	(7) 204,000.	(10) 0.1116
(2)	1,024.0	(5)	7,920.	(8) 4.33	(11) 0.00001267
(3)	3,720.	(6)	537,000.	(9) 3.08	(12) 0.908

Paragraph 24h, page

(1) b = 5,033 yards	(4) b = 6,081 yards	(7) c = 1,692 yards
(2) a = 3,155 yards	(5) b = 956 yards	(8) a = 12,178 yards
(3) b = 6,327 yards	(6) c = 861 yards	(9) b = 3,585 yards

Paragraph 26c, page

(1) N399E, 399	(5) S61.3E, 3138.7	(9) S880E, 2320
(2) N1201W, 5199	(6) S1539W, 4739	
(3) N361E, 361	(7) N5.2E, 5.2	
(4) S1239E, 1961	(8) S1594.8E, 1605.2	

Paragraph 28c, page

(1) 322.3	(5) 599.	(9) 488.
(2) 322.3	(6) 599.	(10) 1358.
(3) 257.0	(7) 900.	(11) 2557.
(4) 257.0	(8) 900.	

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