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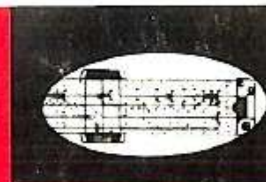
Electronics and Your Slide Rule Part III



An AUTO-PROGRAMMED™ Lesson

ABOUT THE AUTHOR

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

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

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

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Electronics and Your Slide Rule

Combined Operations with Electronic Applications

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

In this lesson you will learn...

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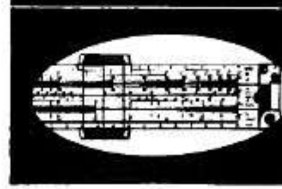
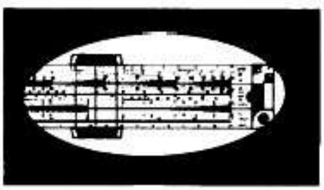


A chat with your instructor

In this lesson you learn how to use the special electronic scales on your slide rule, and also the trigonometric scales. Practical applications for the latter scales will be given in the next lesson.

In studying this lesson be sure to work all the practice problems. Practice is very important in learning slide rule operation. Don't limit your practice to the problems in your slide rule lessons. Always keep your rule handy, and use it for any needed calculations (whether business, personal or electronics) that comes up.



Electronics and Your Slide Rule Part III

25 REACTANCE AND RESONANCE DECIMAL POINT LOCATOR... Resonance frequency problems and problems concerning inductive and capacitive reactance are among the most commonly occuring problems that electronic technicians are required to work. Because of the rather involved formulas used for these problems and also because of the very large and very small values normally employed, locating the decimal point with certainty is a difficult task. For that reason special scales are provided on the back of your Electronics rule to enable the decimal point to be quickly and surely located in all problems involving reactance and resonance.

At the same time the scales also provide approximate solutions to these problems. This approximation is close enough for many requirements. When a more accurate answer is required it can be quickly obtained by the use of the H scale or the 2π scale on the front of the rule. The use of these two scales will be explained later.

The Decimal Point Locator scales have been designed so that it is unnecessary to convert from one unit to another in using these scales. This not only saves time but also eliminates a common source of errors in decimal point location. The next two sections will provide sufficient examples for you to easily understand the use of the decimal point locator scales.

26 DECIMAL POINT LOCATOR, RESONANCE PROBLEMS... To locate the decimal point in resonant frequency problems where C and L are given, set the value of either C or L (it makes no difference which one) on the Resonance Problems Scale of the slide opposite the other given value on the upper body scale. Then read the approximate frequency on the bottom body scale opposite the appropriate arrow on the slide.

As an example of how the decimal point is located in a resonant frequency problem, suppose an inductance of 40 mh is connected in parallel with a capacity of 0.03 μf. At approximately what frequency will this parallel circuit be resonant? Fig. 20 shows the setup for working this problem. Set the hairline over 0.03 μf on the upper body scale of the rule. This would be found on the scale marked Cμf and would be somewhere between the main division marks 0.01 and 0.1 on that scale. To assist in locating positions between main division marks, the space between each of the main divisions is marked by two subdivision marks, 2 and 5. For the space between the 0.01 and 0.1 marks on the Cμf scale, the 2 and the 5 marks would represent 0.02 μf and 0.05 μf respectively. Therefore, to represent 0.03 μf the hairline would be set between the 2 and 5 marks, and closer to the 2 mark than to the 5, as can be seen in Fig. 20.

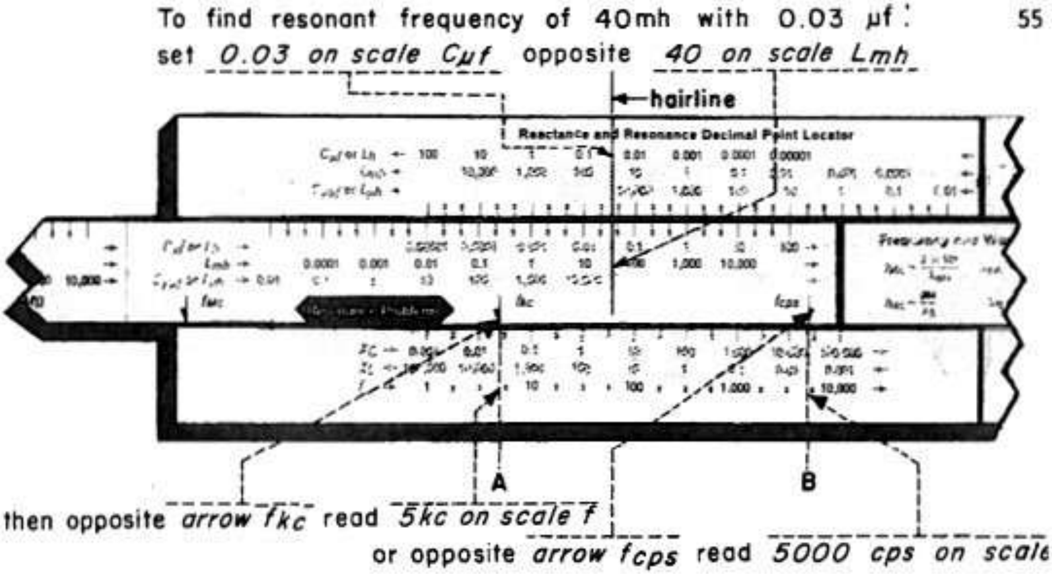


Fig. 20. Showing that 40 mh will resonate with 0.03 μf at approximately 5 kc or 5000 cps.

Now move the slide so that 40 mh on the section of the slide marked "Resonance Problems" is under the hairline. The scale used for this purpose would be the one on the slide marked L_{mh}. 40 on this scale would be located between the main division marks 10 and 100. The two subdivision marks, 2 and 5, between these two main divisions represents 20 mh and 50 mh on the L_{mh} scale. To represent 40 mh the hairline should therefore be between the 2 and 5 marks but closer to the 5 than to the 2. See Fig. 20. A high degree of accuracy is never necessary in setting values on the Decimal Point Locator scales.

The approximate resonant frequency is now read on the f scale of the lower body of the rule under the arrow marked f_{kc} if the answer is wanted in kilocycles, or under the arrow marked f_{cps} if the answer is wanted in cycles per second. To read the answer in kilocycles refer to dashed line A of Fig. 20. On scale f the dashed line is between the main divisions 1 and 10, which shows that the frequency lies somewhere between 0 and 10 kc.

To pin the frequency down closer notice that the dashed line is between the subdivision marks 3 and 6 on scale f. Hence, the resonant frequency of this circuit is between 3 and 6 kc. Since the dashed line is nearer the 6 subdivision than the 3, the frequency must be in the neighborhood of 5 kc. This is close enough for accurately locating the decimal point and also for many practical purposes. A more accurate answer can be obtained quickly by the use of the H scale on the front of the rule, as will be explained later.

Dashed line B shows where to read if the answer to the above problem is wanted in cycles per second. This dashed line shows that the arrow f_{cps} lies between 1,000 and 10,000 cps. Narrowing down the range, the arrow is between the subdivision marks 3 and 6, and the frequency is therefore between 3,000 and 6,000 cps. Since it is nearer to 6 than to 3 a good estimate of the frequency would be 5,000 cps.

In working the above problem the value of L could equally well have been set on the upper body scale and C on the slide. It makes no difference which of the scales is used for L and which for C.

Arrows are printed before and after each of the Decimal Point Locator scales. The purpose of these arrows is to indicate the direction of progression of the scales. For example, the values on the X_C scale on the lower part of the body become progressively larger from left to right. Hence, the associated arrows point in that direction. On the other hand the values on the X_L scale directly below become progressively larger from right to left, so the associated arrows point in the opposite direction from the arrows for the X_C scale. Knowing the direction of progression of the scales makes it easier to set and read values.

In the example above a parallel resonant circuit is involved. If the inductance and capacity were in series the problem would have been worked the same way, and the same answer obtained. In working any resonant frequency problem using either the Decimal Point Locator or the LC scale on the front of the rule the method is exactly the same whether series or parallel resonance is involved.

Example...31

Approximately what value of capacity should be used with an inductance of 350 μh in order to resonate at 200 kc?

Solution... Refer to Fig. 21

(1) Move the slide so that the slide arrow designated f-kc is opposite 200 on scale f on the lower body of the rule.

(2) Place the hairline over 350 on scale Lμh on the upper body of the rule.

(3) Under the hairline read 0.003 on scale Cμf on the slide. Hence, the answer is 0.003 μf.

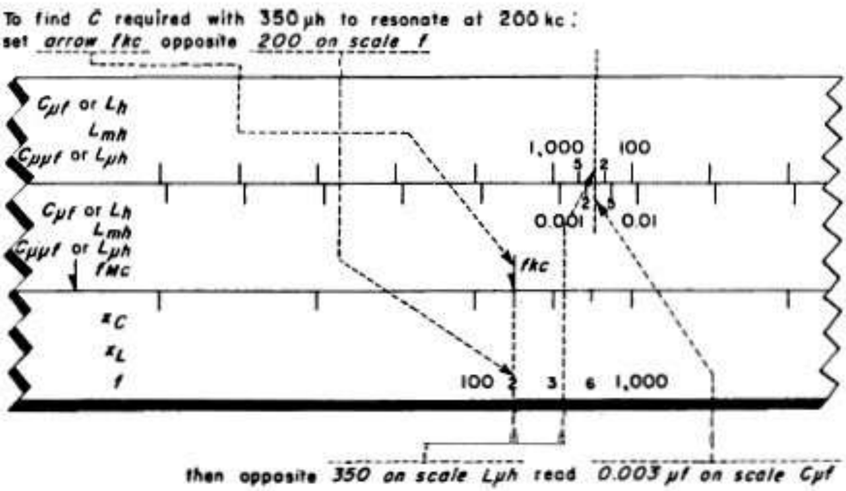


Fig. 21. Showing that for 350 μh to resonate at 200 kc, a capacitance of approximately 0.003 μf is required.

WHAT HAVE YOU LEARNED?

Using the Decimal Point Locator scales find the approximate frequency at which the following values of L and C will resonate:

1... L = 3 mh; C = 175 μμf

2...L = 340 μh; C = 0.0034 μf

3...L = 0.025 h; C = 2 μf

4...L = 700 μh; C = 500 μμf

Using the Decimal Point Locator scales find the approximate value of L or C needed to resonate at the given frequency:

5...f = 240 kc; C = 0.08 μf

6...f = 7,000 cps; L = 0.5 h

7...f = 40 mc; C = 550 μμf

8...f = 6500 kc; L = 425 μh

ANSWERS

1. 250 kc 2. 200 kc 3. 700 cycles 4. 300 kc
5. 8 μh 6. 0.001 μf 7. 0.03 μh 8. 2 μμf

27 REACTANCE PROBLEMS...In solving reactance problems the frequency on the part of the slide marked "Reactance Problems" is placed opposite the given value of inductance or capacity on the upper body of the rule. The reactance is then read on the proper scale on the lower body opposite the appropriate arrow of the slide.

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Example...32
Find the reactance of a 0.005 μf capacitor when used at 3 mc.

Solution...See Fig. 22.
(1) Set hairline over 0.005 on scale $C_{\mu f}$ on the upper body.
(2) Adjust slide so that 3 on scale f_{Mc} is under

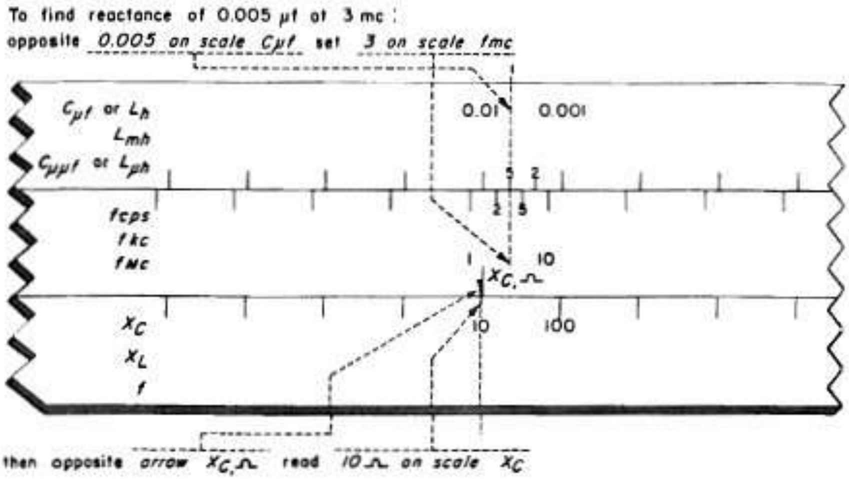

Fig. 22. Finding that the approximate reactance of a 0.005 μf capacitor at 3 mc is 10 ohms.

the hairline.

(3) Opposite arrow on slide marked X_c, Ω read 10 ohms on scale X_c on lower body of rule.

Hence, the reactance of this capacitor at this frequency is approximately 10 ohms.

Example...33

What approximate value of inductance will have a reactance of 4 megohms at a frequency of 3,000 kc?

Solution...

(1) Move slide so that arrow on slide marked X_LM Ω is opposite 4 on scale X_L on lower body of rule.

(2) Set hairline over 3,000 on scale f_{kc} on slide of rule.

(3) Under hairline on scale marked L_h on upper rule body read 0.3 henry, the approximate inductance value required.

Example...34

At what frequency will a 200 μμf capacitor have a reactance of 25 ohms?

Solution...

(1) Move slide so that slide arrow marked $X_C - \Omega$ is opposite 25 on scale X_C on lower body of rule.

(2) Set hairline over 200 on scale $C\mu\mu f$ on upper body of rule.

(3) Under hairline read 30 on scale F_{Mc} on slide.

Hence, the required reactance will be obtained at approximately 30 megacycles.

....

WHAT HAVE YOU LEARNED?

Use the Decimal Point Locator scales to find approximate answer to the following problems:

1...f = 2,300 kc; L = 250 mh; X_L = ?

2...f = 25 mc; C = 150 μμf; X_C = ?

3...f = 0.8 mc; L = 0.45 h; X_L = ?

4...f = 7,500 cps; C = 3.5 μf; X_C = ?

5...X_L = 3,000 Ω; L = 850 μh; f = ?

6...X_C = 6,500 Ω; C = 500 μμf; f = ?

7...f = 480 kc; X_L = 400 Ω; L = ?

8...f = 2.4 mc; X_C = 30,000 Ω; C = ?

ANSWERS

1. 3 megohms 2. 30 ohms 3. 2 megohms 4. 6 ohms
5. 700 kc 6. 60 kc 7. 0.2 mh 8. 2 μμf

28 THE 2π SCALE...If the hairline is over a certain value on the 2π scale, 2π times that value will appear under the hairline on the D scale. Or conversely, any number under the hairline on the D scale will be divided by 2π by merely reading under the

hairline on the 2π scale. This scale is very useful because the factor 2π widely occurs in electronics.

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Example... 35

How many degrees are in a radian? 2π radians are equal to 360°.

Solution...

Set the hairline over 360 on scale D and read 57.3°, the answer, under the hairline on scale 2π.

Example... 36

The armature of a generator is rotating at 1,800 revolutions per minute, which is 30 revolutions per second. What is its angular velocity, ω, in radians per second? The formula is $\omega = 2\pi r$, where r is revolutions per second.

Solution...

Set hairline over 30 on 2π scale. Read 188.8 radians per second, the answer, under the hairline on scale D.

....

The most important use of the 2π scale is in working capacitive and inductive reactance problems where better accuracy is required than is possible with the Decimal Point Locator scales. When using the 2π scale for this purpose the problem should also be worked on the Decimal Point Locator scales, so as to locate the decimal point.

In working reactance problems in conjunction with the 2π scale, frequency is always set or read on scale 2π. To help you to remember this, the 2π scale is also marked (f_x). Inductance or capacity is always set or read on scale CI, which is shown by this scale also being identified as L_x or C_x. Capacitive reactance is always set or read opposite the appropriate index of scale D, which you can remember by the arrow at the index labeled X_C. Inductive reactance is always set or read opposite the appropriate index of scale C, which you can remember by the arrow at the index labeled X_L.

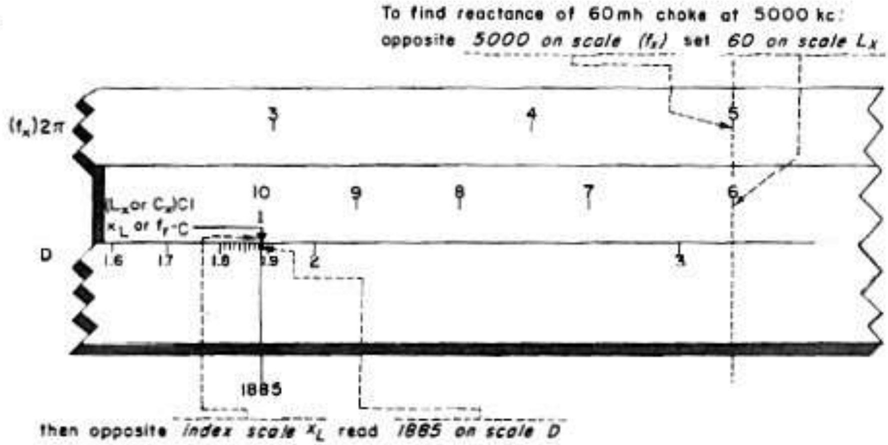

Fig. 23. Finding that a 60 mh choke at a frequency of 5000 kc has a reactance of 1.885 megohms.

Example... 37

Find accurately the reactance of a 60 mh choke coil at 5, 000 kc.

Solution...See Fig. 23

(1) Set the hairline over 5, 000 (which is the frequency) on scale $(f_X)2\pi$.

(2) Move the slide so that 60 (which is the inductance) on scale (L_X or C_X) CI is under the hairline.

(3) Opposite the index of scale X_L or f_r - C read 1, 885 (which is the inductive reactance) on scale D.

(4) Use the Decimal Point Locator scales on the back of the rule to obtain 1.5 megohm as the approximate reactance value.

Hence, the accurate reactance of the choke is 1.885 megohms.

....

Example...38

Find a more accurate value for the reactance of the capacitor in Example 32.

Solution...

(1) Set hairline over 3 (which is the frequency) on scale (f_X).

(2) Move slide so that 0.005 (which is the capacity) on scale C_X is under the hairline.
(3) Opposite the left index on scale X_C read 1061 (which is the capacitive reactance) on scale C. The approximate reactance has been found to be 10 ohms.

Hence, the exact reactance is 10.61 ohms.

Example...39

Find a more accurate value for the inductance in Example 33.

Solution...

(1) Set hairline over 3,000 on scale f_X
(2) Move slide so that right index of scale X_L is opposite 4 on scale D.
(3) Read 212 under the hairline on scale L_X.

The approximate inductance was previously found as 0.3 henry. Hence, the accurate value of the inductance is 0.212 henry.

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Any reactance problem can be worked without confusion if you remember these three points:

(1) Frequency is always set or read under the hairline on scale 2π, also marked (f_X).
(2) Inductance or capacity is always set or read under the hairline on scale CI which is therefore marked (L_X or C_X).
(3) Inductive reactance is always set or read opposite the C index on scale D, and this is indicated on the rule by the symbol x_L and an arrow on the C index pointing to the D scale. Capacitive reactance is always set or read opposite the D index on scale C and this is indicated by the symbol x_C and an arrow pointing to the C scale.

In working any reactance problem set up the known values in the positions on the rule indicated by the two applicable rules above, and then read the unknown value in accordance with the remaining rule.

Example...40

Find a more accurate value for the frequency in Example 34.

Solution...

Set up capacity and the reactance in accordance with Rules 2 and 3 above:

(1) By Rule 3 set the left index of scale D opposite 25 on scale C.

(2) By Rule 2 set the hairline over 200 on scale CI.

(3) By Rule 1 read the frequency, 318, under the hairline on scale 2π. The approximate frequency has previously been found to be 30 mc.

Hence, the accurate frequency is 31.8 mc.

....

WHAT HAVE YOU LEARNED?

1-8... Use the 2π scale to obtain accurate answers to the WHAT HAVE YOU LEARNED? section of Topic 27.

9... The velocity of propagation on a transmission line is given by the formula $v = \frac{\omega}{\beta}$, where v is the velocity of propagation, $\omega = 2\pi f$, and β is the wavelength constant (phase shift per mile). Find v when the frequency is 60 cps and β is equal to 0.00213.

ANSWERS

1.	3.61 megohms	4.	6.06 ohms	7.	0.133 mh
2.	42.5 ohms	5.	562 kc	8.	2.2 $\mu\mu$f
3.	2.26 megohms	6.	49kc	9.	177,000 miles/se

29 USING THE H SCALE... The H scale is used in solving resonant frequency problems when greater accuracy is required than is obtainable from the Decimal Point Locator scales. However, the problem must also be worked with the latter scales in order to locate the decimal point. This is much faster than the use of a rough calculation for this purpose. It is well known that the frequency at which a circuit will resonate is determined entirely by the product of the circuit

inductance and the circuit capacitance (called the LC product). If the hairline is set over the frequency on scale D, the required LC product for the circuit to resonate at this frequency is read under the hairline on scale H, and vice versa.

When using the H scale, frequency is always set or read opposite the index of scale C, on the D scale. For this reason the symbol f_r and an arrow on the C index pointing to the D scale appears on your rule.

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Example. . . 41

What must be the LC product in order that a circuit will resonate at 20 mc?

Solution. . .

First use the Decimal Point Locator scales on the back of the rule to obtain an approximate answer, as follows:

(1) Set arrow marked f-Mc on slide opposite 20 on scale f on lower body of rule.

(2) The LC product is now found by multiplying together any two opposite values on the upper body of the rule and the Resonance Problems portion of the slide. If 1 is one of the two opposite values no multiplication is required. If we take 1 on the scale Cμμf on the upper body of the rule then the value opposite on scale Lμh on the slide will be 70. Hence, the approximate value of the LC product is 70 when C is expressed in micromicrofarads and L in microhenries. Now the front of the rule is used to obtain a more accurate value for the LC product.

(3) Set the hairline over 20 on scale D. Then read 633 under the hairline on the H scale. Since the approximate value is 70, the accurate value will be 63.3, where C is in micromicrofarads and L is in microhenries.

Explanation...
When the hairline is over any frequency value on the D scale, the required LC product is under the hairline on the H scale.

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The reverse of the above problem (Example 41) is to find the frequency of resonance when the LC product is known. This, of course, would be done by setting the hairline over the LC product on scale H, and then reading the frequency under the hairline on scale D. However, any value can be set on scale H in two different positions, giving two different frequency readings on scale D.

Obviously only one of these readings can be correct. You should first determine the approximate frequency for the given LC product by the use of the Decimal Point Locator scales. Then the correct setting on the H scale is the one that gives a frequency value on the D scale that is near the approximate value previously determined.

The required value of C to go with a given value of L in order to resonate at a certain frequency can be found by dividing the LC product by the given L value. Or if C is known it can be divided into the LC product to give the required value of L to resonate at a certain frequency. However, the following examples show simpler ways of solving resonant frequency problems where the LC value is neither known or wanted, and this is generally the case.

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Example...**42**
Find a more accurate value for the capacity in the problem of Example 31.

Solution...

(1) Set the left index of scale C (which is marked f_r) opposite 200 (which is the frequency) on scale D.

(2) Set the hairline over 350 (which is the inductance) on scale $H(L_T)$.
(3) Read 181 (which is the required capacity) under the hairline on scale B.

The approximate value of C has been previously found to be 0.003 μf. Hence, the accurate value is 0.00181 μf.

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When C is given and L is to be found the method is the same as in Example 42 above. Whether finding L or C an index of the C scale is placed opposite the frequency on the D scale. Then with the hairline over the given value of L on scale H, the unknown value of C is read on scale B under the hairline. Or alternately, the known value of L or C can be set on scale B and the unknown value then read on scale H.

The following example illustrates the method when L and C are known and the frequency is to be found:

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Example. . .43

An inductance of 40 mh is connected in parallel with a capacitance of 0.03 μf. At what frequency will this circuit resonate?

Solution. . .

(1) Find the approximate resonant frequency using the Decimal Point Locator scales. This was done in Topic 26 and was found to be 5000 cps.
(2) Set hairline over 40 on scale H.
(3) Adjust slide so that 3 on scale B is under the hairline.
(4) Read opposite the index of scale C on scale D. Depending upon which halves of scales H and B were used for setting the values, the reading obtained on scale D may be either 1452 or 459. Since the approximate frequency is known to be 5000 cps, the accurate frequency is 4590 cps. The value 1452 is spurious because it is far different from the known approximate frequency. If the reading 1452 is obtained, move the slide so that 3 on the other half of the B scale is under the hairline.

Then 459 will read opposite the C index on scale D.

Discussion...
The B scale and the H scale are both of the repeating type, so any value can be set on either of these two scales in two different positions. In problems in which the frequency is known and L or C is to be found, as in Example 42, the correct answer is obtained no matter which of the possible positions are used on the H and B scales. However, when L and C are known and the frequency is to be found, there are two different results possible, depending upon the sections of the H and B scales used.

Only one of the results can be correct. To determine if the result obtained is correct, see if it is in agreement with the approximate value, which should have been previously determined. If not, move the slide so that the other half of the B scale is used for setting the B scale value.

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WHAT HAVE YOU LEARNED?

1-8...Use the H scale to find accurate answers to the WHAT HAVE YOU LEARNED? section of Topic 26.

9...What is the required LC product to resonate at 5 megacycles, L being in microhenries and C in microfarads?

ANSWERS

1. 220 kc 2. 148 kc 3. 710 cycles 4. 269 kc 5. 5.5 μh
6. 0.00103 μf 7. 0.0287 μh 8. 1.41 μμf 9. 0.001014

Using the Trigonometric Scales

It is necessary to be familiar with logarithms and trigonometry before studying the remainder of this manual. If you are not familiar with these subjects, your slide rule training is now

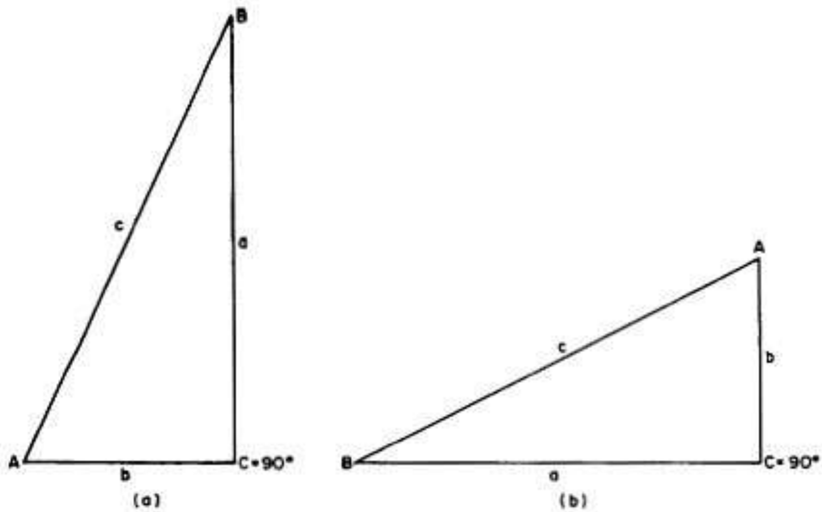

Fig. 24. The right triangle shown in two positions.

completed. However, the author hopes you will eventually be able to acquire a knowledge of these subjects and then complete the remainder of this manual.

30 THE TRIGONOMETRIC FUNCTIONS

THE TRIGONOMETRIC FUNCTIONS...A review of trigonometry, particularly those sections dealing with the right triangle, will help you understand the following sections. The trigonometric functions are defined by the sides of a right triangle. Figure 24(a) shows a right triangle with sides of length a, b, and c and two acute angles labeled A and B (angles less than 90 degrees are called acute angles), and also the right angle C. The sine, cosine, tangent, and cotangent of angle A are defined as follows:

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

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

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

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

 The tangent and cotangent are reciprocal quantities:

$$\tan A = \frac{1}{\cot A}; \qquad \cot A = \frac{1}{\tan A}.$$

If you know one of the two acute angles, the other can be found by subtracting the known angle from 90°. Thus in Fig. 24(a) A = 90° - B and B = 90° - A. For example, if A were 30°, then B would be 90° - 30° = 60°. When A is 45° then B = 90° - 45° = 45° and the acute angles are then equal.

Since the angles A and B of the right triangle depend upon each other (their sum must be 90°), then the trigonometric functions of these two acute angles also depend upon each other. Figure 24(b) shows the same triangle as in Fig. 24(a), but turned over so that the functions of angle B can be found more easily. From Fig. 24(b) the sine of angle B is found as:

$$\sin B = \frac{\text{opposite side}}{\text{hypotenuse}} = \frac{b}{c}$$

Since cos A is also equal to $\frac{b}{c}$, sin B equals cos A. In the same way, you can find that cos B = $\frac{a}{c}$ = sin A. This type of relationship is also true for the tangent and cotangent, and so the trigonometric functions of the acute angles of a right triangle are related as follows: The sine of one angle equals the cosine of the other and the tangent of one angle equals the cotangent of the other. Thus in Fig. 24, if A = 30° and B = 60°, then sin 30° = cos 60°, cos 30° = sin 60°, tan 30° = cot 60°, and cot 30° = tan 60°. This principle can be extended a bit further. Since angle B is always 90° minus angle A, the previous rule can be written as:

$$\sin A = \cos B = \cos (90° - A)$$
$$\cos A = \sin B = \sin (90° - A)$$
$$\tan A = \cot B = \cot (90° - A)$$
$$\cot A = \tan B = \tan (90° - A)$$

These formulas relate the functions of angle A to those of 90° - A and can be used, for example, to find the sine of an angle when only cosines are available. If the sin 10° was needed, it could be obtained by finding cos (90° - 10°) = cos 80°.

1...In Fig. 24(a), let B = 36.8°, a = 4, b = 3, and c = 5.

(a) What is angle A?

(b) Find sin B, cos B, tan B, and cot B from the sides of the triangle.

(c) Find sin A, cos A, tan A, and cot A from the sides of the triangle and compare these results with part (b). Which functions of angle A equal which functions of angle B?

2...Some slide rules only give the value of the tangent of angles between 0 and 45°. How could you use such a slide rule to find cot 65°?

ANSWERS

1...(a) A = 53.2°

(b) $\sin B = \frac{\text{opposite side}}{\text{hypotenuse}} = \frac{3}{5} = 0.60$

cos B = 0.80; tan B = 0.75; cot B = 1.33

(c) sin A = 0.80; cos A = 0.60; tan A = 1.33; cot A = 0.75

Sin A = cos B; cos A = sin B; tan A = cot B; cot A = tan B.

2...The cot 65° can be found by looking up tan 25°, since cot 65° = tan (90° - 65°) = tan 25°.

31 FINDING SINES AND COSINES WITH THE S SCALE...The sine and cosine of any angle between 5.75° and 90° can be found by means of the S scale on your slide rule. Notice that each major division of the S scale has a pair of numbers side by side. To find the sine of an angle, ignore the red number of each pair and find the value of the angle on the S scale reading only the black numbers. Place the hairline over the angle on the S scale and read the sine of the angle below on the C scale. When finding the sine by means of the S scale (angles between 5.75 and 90 degrees), always place the

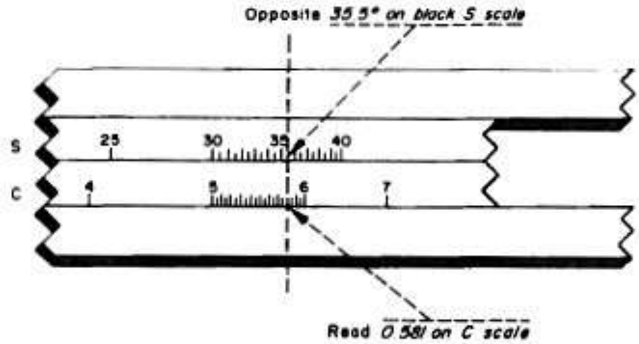

Fig. 25. Finding sin 35.5° by means of the C scale and black S scale.

decimal directly in front of the first digit of the value read on the C scale. Figure 25 shows the S scale with the left numbers of each pair omitted and the hairline set on 35.5°. The sin 35.5° is then read on the C scale as 0.581.

To find the cosine of an angle, ignore the black numbers of each pair and find the angle on the S scale reading only the red numbers. The cosine of the angle can then be read directly below on the C scale. The decimal again should be placed in front of the first digit. Figure 26 shows the S scale with the black numbers of each pair omitted and the hairline set on 49.5°. (Note that when you are reading the red numbers of each pair, the scale begins at 84.25° and decreases to 0° at the right index.) From the C scale cos 49.5° is found to be 0.649.

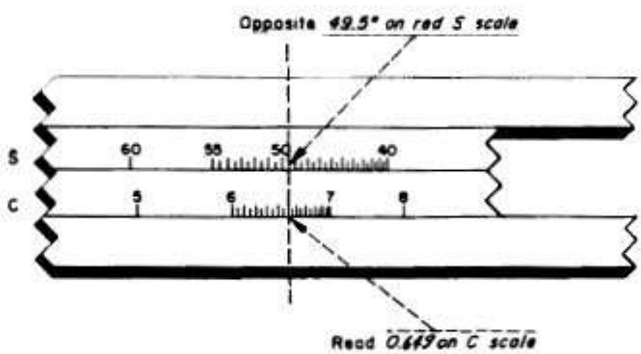

Fig. 26. Finding cos 49.5° by means of the C scale and red S scale.

Find the following values by means of the S scale.

1...sin 6.3° = ?

2...sin 75.8° = ?

3...cos 18.9° = ?

4...sin 43.6° = ?

5...cos 45° = ?

6...cos 31.6° = ?

7...sin 25.3° = ?

8...cos 54.7° = ?

9...sin 48.6° = ?

10...cos 28.7° = ?

ANSWERS

1...0.109	2...0.970	3...0.946	4...0.690	5...0.707
6...0.852	7...0.427	8...0.578	9...0.750	10...0.877

You may have noticed that the right number of each black and red pair on the S scale is exactly 90° minus the left number of that pair. In the preceding section it was shown that cos A = sin (90° - A). When finding a cosine of an angle by the method given above, you are in reality finding the sine of 90° minus that angle by means of the black numbers which you ignore. This is why only one scale is needed to find both sines and cosines.

Often it is desired to work backwards and find the angle when the sine or cosine of that angle is known. If the value of the sine or cosine has its decimal in front of the first digit, you know that the angle is between 5.75° and 90° and so can be found on the S scale. Knowing the sine of the angle, set the hairline over this value on the C scale and read the angle on the S scale, ignoring the red numbers of each pair. When the cosine of the angle is given, the process is identical except that the black numbers, rather than the red, must now be ignored in reading the angle.

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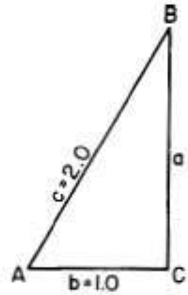

Fig. 27. Figure for use with Example 44.

Example...44

Given the right triangle shown in Fig. 27, what is angle A?

Solution...

(1) Find cos A from the sides of the triangle.

$$\cos A = \frac{\text{adjacent side}}{\text{hypotenuse}} = \frac{1}{2}$$

(2) Knowing cos A, find A by means of the S scale. Set the hairline over 500 on the C scale. Ignore the black numbers and read 60° (not 30°) on the S scale.

Hence, A = 60°.

....

WHAT HAVE YOU LEARNED?

Find the angle A in each of the following problems.

1...sin A = 0.242

2...cos A = 0.888

3...cos A = 0.954

4...sin A = 0.648

5...cos A = 0.578

6...sin A = 0.895

7...cos A = 0.818

8...sin A = 0.488

9...cos A = 0.233

10...sin A = 0.985

1...14.0°	2...27.4°	3...17.4°	4...40.4°	5...54.7°
6...63.5°	7...35.1°	8...29.2°	9...76.5°	10...80.0°

32 FINDING TANGENTS BY MEANS OF THE T SCALE...The tangents of angles between 5.71° and 84.29° can be found by means of the T scale. Like the S scale, the T scale also is made up of pairs of red and black numbers. The black numbers on the right of each pair form a scale which starts with 5.71° at the left index and increases to 45° at the right index. To find the tangent of an angle between 5.71° and 45°, ignore the red numbers and place the hairline over the value of the angle on the scale formed by the black numbers. The tangent of the angle can then be read below on the C scale. The decimal again goes in front of the first digit of the value read on the C scale. For example, to find tan 35°, place the hairline over 35 on the black numbered portion of the T scale and read tan 35° = .700 on the C scale.

The red numbers of the T scale form a scale which starts with 84.29° at the left index and decreases to 45° at the right index. To find the tangent of an angle between 45° and 84.29°, place the hairline over the value of the angle as found on this red scale. In this case, the value of the tangent must be read below on the CI scale. For angles between 45° and 84.29°, the value of the tangent lies between 1 and 10, hence, the decimal must be placed between the first and second digit of the value read on the CI scale. Refer to Fig. 28 which shows the hairline set at 71° on the red T scale. The value 290 is read on the CI scale and since the decimal point goes after the first digit, tan 71° = 2.90.

Here again your slide rule is using one scale for two purposes. The black numbers are 90° minus the red numbers as was the case with the S scale. When you find the tangent of say, 70°, you place the hairline on the red value 70. Since the black number next to 70 is 90° - 70° = 20°, the hairline automatically sets up the tan 20° on the C scale. From the formulas previously given you can see that

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

so that $\tan 70° = \frac{1}{\tan 20°}$

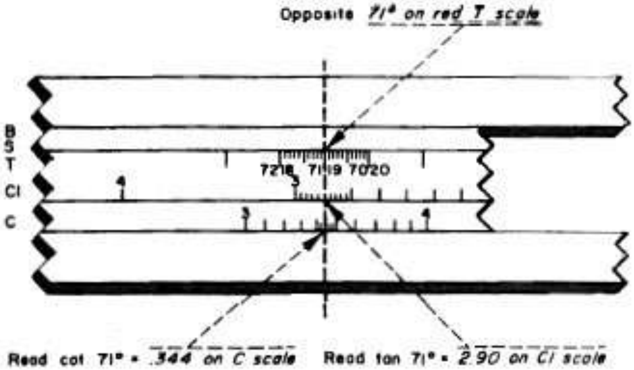

Fig. 28. Finding tan 71° and cot 71° by means of the red T scale.

The final answer which appears on the CI scale is the reciprocal of tan 20° and hence the tan 70°.

WHAT HAVE YOU LEARNED?

Find the tangents of the following angles by means of the T scale.

1...7.33° 2...45.0° 3...59.1° 4...19.6° 5...70.3°
6...49.0° 7...33.2° 8...74.7° 9...26.5° 10...68.4°

ANSWERS

1...0.1287 2...1.00 3...1.671 4...0.356 5...2.79
6...1.150 7...0.654 8...3.655 9...0.499 10...2.53

To find the angle when its tangent is known, you must reverse the above process. First inspect the value of the tangent, noting the position of the decimal point. If the decimal is in front of the first digit, the angle must lie between 5.71° and 45°. Place the hairline over the value of the tangent on the C scale and read the angle on the black T scale. For example, if the value of the tangent is 0.415, set the hairline over 415 on the C scale and read the angle as 22.5° on the black T scale.

If the decimal lies between the first and second digit of the value of the tangent, the angle lies between 45° and 84.29°. In this case, place the hairline over the value of the tangent on the CI scale and read the angle on the red T scale. Thus if the value of the tangent is 4.15, set the hairline over 415 on the CI scale and read the angle as 76.45° on the red T scale.

WHAT HAVE YOU LEARNED?

Find the angle A in each of the following problems.

1...tan A = 0.418	6...tan A = 0.762
2...tan A = 0.615	7...tan A = 2.19
3...tan A = 1.54	8...tan A = 0.966
4...tan A = 0.178	9...tan A = 1.23
5...tan A = 4.40	10...tan A = 0.294

ANSWERS

1...22.7° 2...31.6° 3...57.0° 4...10.1° 5...77.2°
6...37.3° 7...65.45° 8...44.0° 9...50.9° 10...16.4°

33 FINDING COTANGENTS WITH THE T SCALE...The cotangent of an angle can always be found by taking the reciprocal of the tangent. No additional slide rule operation is required for this purpose, since the values on the C scale are reciprocals of those on the CI scale and vice versa. To find the cotangent of an angle between 5.71° and 45°, set the hairline as if you were finding the tangent of that angle. Now instead of reading the tangent below on the C scale, read the cotangent, which is the reciprocal of the tangent, above on the CI scale. The value of the tangent of angles between 5.71° and 45° lies between .1 and 1, hence the cotangent of these angles must lie between 1 and 10. The decimal must then go between the first and second digit. For example, to find the cotangent of 36°, set the hairline on 36 of the black T scale. Read cot 36° = 1.376 on the CI scale.

For cotangents of angles between 45° and 84.29°, the operation is similar. Set the hairline as if you were finding tangent but read the answer on the C scale instead of the CI scale. Since the tangent of these angles has its decimal between the first and second digit, the cotangent will have its decimal in front of the first digit. Again refer to Fig. 28. Here the hairline is set on 71° and tan 71° = 2.90 appears on the CI scale. The cot 71° $= \frac{1}{\tan 71^\circ}$ is seen to be 0.344 below on the C scale.

WHAT HAVE YOU LEARNED?

Find the cotangents of the following angles:

1...24.1°	6...30°
2...32.8°	7...66.4°
3...75.9°	8...40.7°
4...55.4°	9...52.7°
5...45°	10...11.3°

ANSWERS

1...2.24	2...1.552	3...0.2512	4...0.690	5...1.000
6...1.732	7...0.437	8...1.163	9...0.762	10...5.01

34 COMBINED OPERATIONS - MULTIPLICATION. . .In most practical problems, finding the value of a trigonometric function is seldom an end in itself. More often than not, you will be required to find the product or quotient of a trigonometric value and some other value which occurs in the problem. Instead of first finding the value of the trigonometric function then carrying out the multiplication or division as two separate operations, both these operations can be combined to yield the answer directly.

To see how this is done, consider the problem of finding the value of 1.5 sin 30°. This value could be found by first finding sin 30°. (Placing the hairline on the black 30 of the S scale, sin 30° = 0.5 is then read on the C scale.) The desired answer would then be obtained by multiplying 1.5 by .50 to give 1.5 sin 30° = 1.5 × 0.50 = .75. This process is not too efficient. Besides obtaining the answer to the problem, we have wasted our time in finding sin 30°, which was not asked for. This same problem can be worked more easily by the following method.

Place the left index of the slide over 1.5 on the D scale. Next set the hairline as if you were finding sin 30° by means of the S and C scales. That is, set the hairline over black 30° on the S scale. Now instead of reading sin 30° = .50 on the C scale, the answer, 1.5 sin 30° = .75, can be read directly under the hairline on the D scale. The location of the decimal point is found by recognizing that sin 30° lies between .1 and 1. Hence 1.5 sin 30° lies between .15 and 1.5.

It is easy to see why this method works. To multiply 1.5 by a number, you set the index over 1.5 on the D scale, set the hairline on the number you are multiplying by on the C scale, and read the answer on the D scale. In the above example, when you put the slide over 30° on the S scale, this automatically put the hairline over the value of sin 30° on the C scale, and this was the number you wished to multiply 1.5 by.

When finding the value of the sine, cosine, or tangent of an angle less than 45°, or the cotangent of an angle greater than 45°, the value of the trigonometric function is always read on the C scale. The above method will then work for all these functions since placing the hairline over the correct angle on the S or T scale sets up the value of the function on the C scale for multiplication. Also, for these functions, the trigonometric value always lies between .1 and 1 and the decimal can be placed accordingly. In general, to multiply a number by a sine, cosine, or tangent of an angle less than 45°, or by a cotangent of an angle greater than 45°, place the index of the slide over the number and set the hairline over the angle on the S or T scale as if you were finding the value of the trigonometric function. The answer can then be read under the hairline on the D scale. This operation is the same as any ordinary multiplication problem, except the angle, which is the multiplier, is set on the S or T scale, while in ordinary multiplication problems the multiplier is set on the C scale.

This method will not work for the tangent of angles greater than 45° or the cotangent of angles less than 45° since the values of these functions are normally read on the CI scale. A combined operation for these functions is explained later.

....

Example...**45**

Solving for the two legs of a right triangle when the hypotenuse and one acute angle is known involves combined multiplication operations. With reference to Fig. 29, where the hypotenuse c is 16.3 and angle A is 38.5°, find the value of the two legs a and b.

Solution...

1...To find leg a we use the formula a = c sin A. Thus a = 16.3 sin 38.5°. Set the right index of the slide over 16.3 on the D scale and set the hairline over 38.5° on the black S scale. Read 1015 on the D scale--since the value of a lies between 1.63 and 16.3, a = 10.15.

2...To find the value of leg b we use the formula b = c cos A, so that b = 16.3 cos 38.5°. Keep the right index of the slide over 16.3 on the D scale

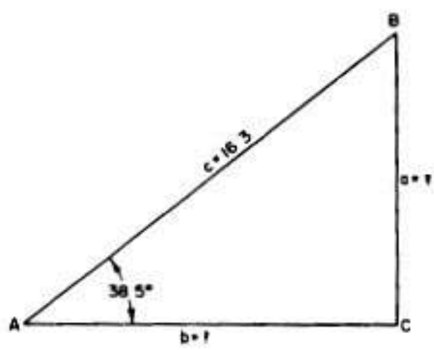

Fig. 29. Figure to be used with Example 45.

and set the hairline over 38.5 on the red S scale. Read the value b = 12.75 on the D scale under the hairline.

....

WHAT HAVE YOU LEARNED?

1... Find the following values by the combined multiplication operation:

(a) $2.31 \sin 35° = ?$

(b) $14.6 \cos 11.7° = ?$

(c) $129 \tan 26.4° = ?$

(d) $.864 \cot 63.8° = ?$

(e) $22.6 \sin 73.4° = ?$

(f) $1.39 \cot 67.1° = ?$

(g) $287 \sin 7.5° = ?$

(h) $72.6 \cos 13.4° = ?$

(i) $49.3 \cos 80° = ?$

(j) $0.439 \tan 33.1° = ?$

2... Refer to example 45 and Fig. 29. Using the formulas $a = c \sin A$ and $b = c \cos A$, find a and b in the following cases:

(a) $c = 12.6$, $A = 22°$

(b) $c = 43.9$, $A = 51.3°$

(c) $c = 1.02$, $A = 66.1°$

(d) $c = 14.9$, $A = 18.6°$

3... Circuit power is given by the formula, $P = EI \cos \Theta$, where Θ is the angle of lead or lag between current and voltage. Find the circuit power when $\Theta = 18°$, E = 120 volts and I = 3.4 amperes.

ANSWERS

1... (a) 1.326 (b) 14.3 (c) 64.0 (d) 0.425 (e) 21.65
(f) 0.587 (g) 37.45 (h) 70.6 (i) 8.56 (j) 0.286
2... (a) A = 4.72 b = 11.68 (b) a = 34.25 b = 27.4
(c) a = 0.932 b = 0.413 (d) a = 4.75 b = 14.14
3... $P = 120 \times 3.4 \cos 18° = 388$ watts

35 COMBINED OPERATIONS - DIVISION...The division of a number by a sine, cosine, or tangent of an angles less than 45°, or by a cotangent of an angle greater than 45° can also be accomplished by means of a combined operation. Set the hairline over the number on the D scale. Now move the slide until the hairline is set on the angle of the S or T scale as if you were finding the value of the trigonometric function. The answer can then be read on the D scale under the index of the slide. To find $\frac{1.6}{\tan 24°}$, set the hairline at 1.6 on the D scale. Move the slide so that the hairline also covers 24 on the black T scale. This is where the hairline would be if you were finding the value of tan 24°. The answer is read on the D scale below the right index of the slide; 1.6/tan 24° = 3.60. The decimal is placed by noting that the reciprocal of the sine, cosine, and tangent of angles less than 45°, and the cotangent of angles greater than 45°, lies between 1 and 10. In this example it is then seen that 1.6/tan 24° must lie between 1.6 and 16, giving the position of the decimal

This method of division works in a manner similar to the multiplication operation previously discussed. When you move the slide so that the hairline covers the angle on the S or T scale, you are actually setting the value of the trigonometric function on the C scale directly above the value of the dividend on the D scale. This is just the usual method of division, but here again the trigonometric value is set up on the C scale indirectly by means of the T or S scale.

Dividing a value into a trigonometric function is no different than any other division problem, except that the angle which is the dividend is set on the S or T scale, while in ordinary division problems the dividend is set on the D scale.

....

Example...**46**

When one acute angle and one leg of a right triangle are known, the hypotenuse can be found by a combined division operation. In Fig. 30 the triangle is shown with b = 12.3, a = 5.66 and A = 24.7°. Find the value of the hypotenuse c in two different ways.

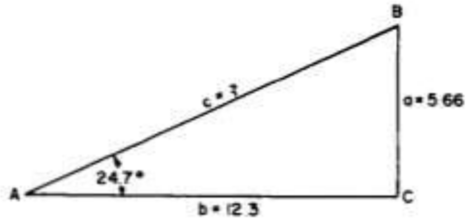

Fig. 30. Figure for use with Example 46.

Solution...

1... One way of finding c is to use side a and angle A in the formula c = a/sin A, so that c = 5.66/sin 24.7°. Set the hairline over 5.66 on the D scale and move the slide so that the hairline covers 24.7° on the black S scale. Read 1355 on the D scale under the left index of the slide. Since c must lie between 5.66 and 56.6, c = 13.55.

2... The hypotenuse c can also be found using side b and angle A by means of the formula c = b/cos A, so that c = 12.3/cos 24.7°. Set the hairline over 12.3 on the D scale and move the slide so that the hairline covers 24.7° on the red S scale. Read c = 13.55 under the right index of the slide.

....

WHAT HAVE YOU LEARNED?

Find the following values by the combined division operation.

1...

(a) $\frac{3.8}{\cos 10.4°} = ?$

(b) $\frac{16.4}{\sin 28.7°} = ?$

(c) $\frac{747}{\sin 43.6°} = ?$

(d) $\frac{1.31}{\cot 62.5°} = ?$

(e) $\frac{47.8}{\tan 16.1°} = ?$

(f) $\frac{86.4}{\cos 30°} = ?$

(g) $\frac{1.83}{\cot 75.5°} = ?$

(h) $\frac{393}{\tan 20.4°} = ?$

(i) $\frac{28.7}{\sin 7.3°} = ?$

(j) $\frac{3.34}{\cos 57.8°} = ?$

2...Refer to example 46 and Fig. 30. Use the formulas $c = a/\sin A$ and $c = b/\cos A$ to find c in the following cases:

(a) $a = 12.4$, $A = 51.5°$ (c) $b = 69.4$, $A = 14.6°$

(b) $b = 1.16$, $A = 21.8°$ (d) $a = 109$, $A = 44.1°$

3...An a-c circuit is consuming 10 watts of power. If the input current is 0.504 amperes and the phase angle Θ is 26°, compute the input voltage using the formula $E = \frac{P}{I \cos \Theta}$.

ANSWERS

1...(a) 3.862 (b) 34.2 (c) 1083 (d) 2.52 (e) 166 (f) 99.8 (g) 7.07 (h) 1056 (i) 226 (j) 6.275

2...(a) $c = 15.85$ (b) $c = 1.25$ (c) $c = 71.7$ (d) $c = 156.6$

3... $E = \frac{10}{0.504 \cos 26°} = 22.1$ volts

36 COMBINED OPERATIONS FOR THE TANGENT AND COTANGENT...

Combined operations for the tangent of angles greater than 45° and the cotangent of angles less than 45° are obtained by using the fact that the tangent and cotangent are reciprocals. Multiplying a number by the tangent of an angle is the same as dividing that number by the cotangent of the same angle. If you are required to multiply a number by the tangent of an angle greater than 45°, you can obtain this result by dividing that number by the cotangent of the same angle. In the previous section it was shown how to divide by the cotangent of an angle greater than 45°, so you already know how to perform this operation. For example, to find 32.1 tan 51°, find 32.1/cot 51° by the method given in the previous section. Similarly, if it is required to divide by the tangent of an angle greater than 45°, you can multiply instead by the cotangent of the same angle and get the same result.

This reciprocal technique also holds true when multiplying or dividing by the cotangent. To multiply by the cotangent, divide by the tangent and vice versa. Some examples of the conversion which must be made to perform the combined operations are shown below:

$$\frac{3.5}{\tan 71^\circ} = 3.5 \cot 71^\circ$$

$$\frac{7.6}{\cot 18^\circ} = 7.6 \tan 18^\circ$$

WHAT HAVE YOU LEARNED?

1... Find the following values by means of combined operations.

(a) $37.4 \cot 31^\circ = ?$

(b) $\frac{1.43}{\tan 56.7^\circ} = ?$

(c) $\frac{12.8}{\cot 24.3^\circ} = ?$

(d) $3.92 \tan 74.4^\circ = ?$

(e) $187 \tan 54.3^\circ = ?$

(f) $.874 \cot 39^\circ = ?$

(g) $\frac{21.6}{\cot 44^\circ} = ?$

(h) $\frac{75.2}{\tan 61.2^\circ} = ?$

2... The resistance, R, and the total reactance, X, of a series circuit are related by the formulas, $R = X \cot \Theta$ and $X = R \tan \Theta$, where Θ is the phase angle between the current and applied voltage. Find R and X in the following cases by means of these formulas.

(a) $X = 53.1\ \Omega$, $\Theta = 15^\circ$

(b) $R = 1{,}500\ \Omega$, $\Theta = 28.4^\circ$

(c) $R = 293\ \Omega$, $\Theta = 56.3^\circ$

(d) $X = 139\ \Omega$, $\Theta = 28.1^\circ$

ANSWERS

1... (a) $37.4 \cot 31^\circ = \frac{37.4}{\tan 31^\circ} = 62.3$

(b) $\frac{1.43}{\tan 56.7^\circ} = 1.43 \cot 56.7^\circ = 0.939$

(c) 5.78 (d) 14.04 (e) 260.3 (f) 1.079 (g) 20.86
(h) 41.3

2... (a) $R = 198.2\ \Omega$ (b) $X = 811\ \Omega$ (c) $X = 439\ \Omega$
(d) $R = 260.3\ \Omega$

LESSON 3124-1

SLIDE RULE

EXAMINATION

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

1. Which one of the following statements is not correct with respect to a right triangle?
    1. The sine of one of the acute angles is equal to the cosine of the other
    2. The tangent of one of the acute angles is equal to the cotangent of the other.
    3. $\text{Sin } A = \dfrac{1}{\cos A}$
    4. The longest side is always the side opposite the right angle.

2. Which of the following statements is correct with reference to using the S and T scales?
    1. The black numbers are for setting sines and tangents, the red numbers for cosines and cotangents.
    2. If an angle value is set on black S or T scale, the corresponding trigonometric value should be read on the C scale, if an angle is set on a red S or T scale, the value should be read on the CI scale.
    3. The red numbers on the S scale are for setting cosines, and on the T scale for setting tangents and cotangents greater than 45 degrees.
    4. Same as selection 3 except delete the words "and cotangents."

3. What is the tangent of 16.65 degrees?

1. 0.299	2. 0.346	3. 0.380
4. 2.89	5. 2.98	6. 3.08

4. What is the cosine of 27.6 degrees?

1. 0.224	2. 0.246	3. 0.283
4. 0.445	5. 0.886	6. 1.084

5. To multiply the tangent of 53 degrees by 4.26 you would proceed as follows:
   1. Place the right index of the slide opposite 4.26 on scale D. Then with the hairline over 53 degrees on the T scale, read the answer on the D scale.
   2. With hairline over 4.26 on scale D, adjust slide until 53 degrees on scale T is under hairline. Then read answer on scale D opposite right index of scale C.
   3. With hairline over 4.26 on scale D, adjust slide until 53 degrees on scale T is under hairline. Then read answer opposite the D index on scale C.
   4. With 4.26 on scale CI opposite the left index of scale D, read answer on scale D opposite 53 degrees on scale T.

6. The power factor of a circuit is equal to the cosine of the angle of lead or lag between current and voltage. If this angle is 77.3°, what is the power factor?
   1. 0.220 2. 0.225 3. 0.239
   4. 9.444 5. 0.455 6. 0.975

7. What value of inductance would you use with a 25 pf capacitor in order to resonate at 65 mc?*
   1. 0.232 μh 2. 0.24 μh 3. 2.32 μh
   4. 23.2 μh 5. 24 μh 6. 0.24 mh

8. What is the required LC product for a circuit to resonate at 4300 kc? Assume that L is in microhenries and C is in microfarads?
   1. 0.00135 2. 0.00137 3. 0.0136
   4. 0.0137 5. 0.136 6. 0.137

9. Capacitive reactance is inversely proportional to frequency. If the reactance of a capacitor is 3300 ohms at 665 kc, what will be its reactance at 475 kc?
   1. 357 ohms 2. 463 ohms 3. 915 ohms
   4. 3570 ohms 5. 4630 ohms 6. 9150 ohms

10. Using the formula $R = X \cot \phi$, which is a formula for finding R in a series circuit, find the value of R if X is 34,600 ohms and ϕ is 63°.
   1. 1765 ohms 2. 6800 ohms 3. 7620 ohms
   4. 17,650 ohms 5. 67,900 ohms 6. 76,100 ohms

*In questions 7, 12, and 15, pf is the abbreviation for picofarad which is replacing the term micromicrofarad (μμf) in the technical literature.

11. At what frequency will a circuit resonate that has an inductance of 400 μh and a capacity of 0.2 μf?
    1. 17.8 kc
    2. 56.4 kc
    3. 178 kc
    4. 564 kc
    5. 17.8 mc
    6. 56.4 mc

12. At what frequency will a circuit resonate that has an inductance of 0.55 h and a capacitance of 700 pf?
    1. 2.56 kc
    2. 8.11 kc
    3. 25.6 kc
    4. 81.1 kc
    5. 256 kc
    6. 811 kc

13. What reactance does a 3.2 μf capacitor have when used at a frequency of 470 kc?
    1. 0.102 ohms
    2. 0.106 ohms
    3. 10.2 ohms
    4. 10.6 ohms
    5. 1020 ohms
    6. 1060 ohms

14. What is the largest value of inductor you could use if it should have a reactance not greater than 20 ohms when used at 9.35 Mc?
    1. 0.340 μh
    2. 0.343 μh
    3. 3.40 μh
    4. 34.3 μh
    5. 340 μh
    6. 343 μh

15. What value of capacitor has a reactance 0.8 megohm at 4500 cps?
    1. 4.43 pf
    2. 4.48 pf
    3. 44.3 pf
    4. 44.8 pf
    5. 44.3 μf
    6. 44.5 μf

END OF EXAM

Notes

"To err is human,
but it takes a better excuse the second time."

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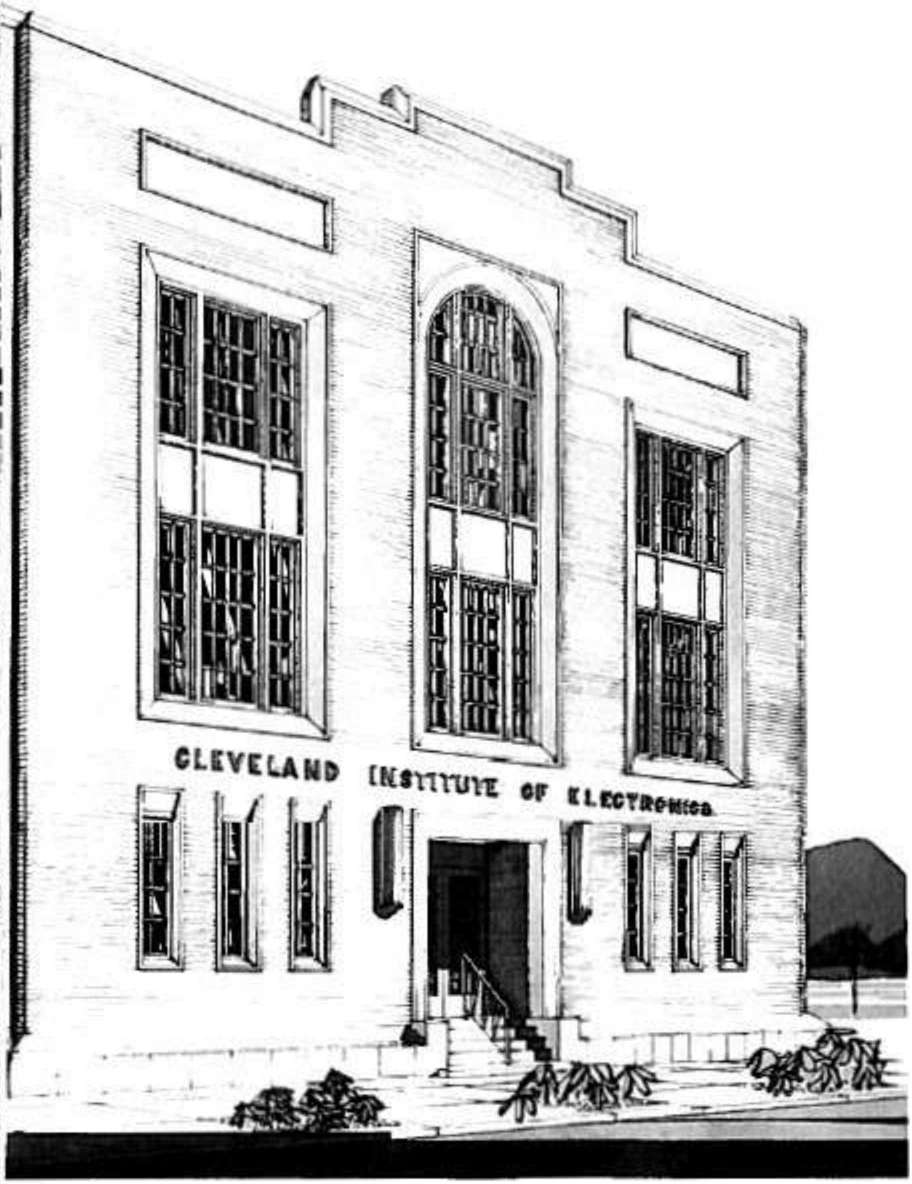

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