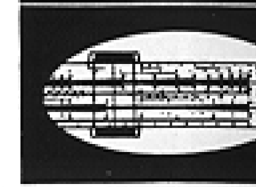
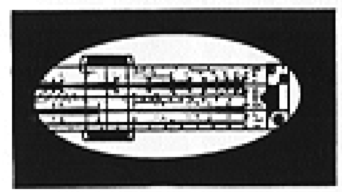
Pickett N-515-T
Cleveland Institute Of Electronics Slide Rule



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.

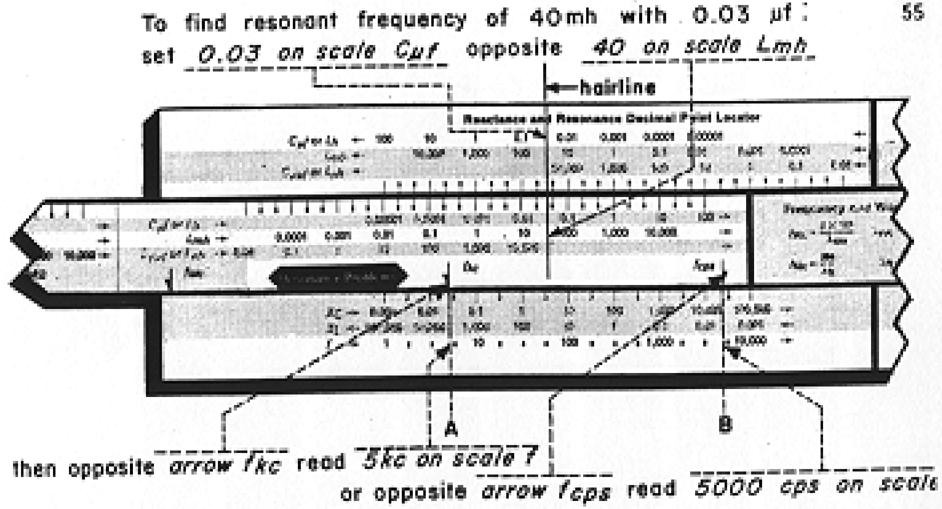


Fig. 20. Showing that 40 mh will resonate with 0.03 µf at approximately 5 kc or 5000 cps.

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 Lmh. 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 Lmh 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.

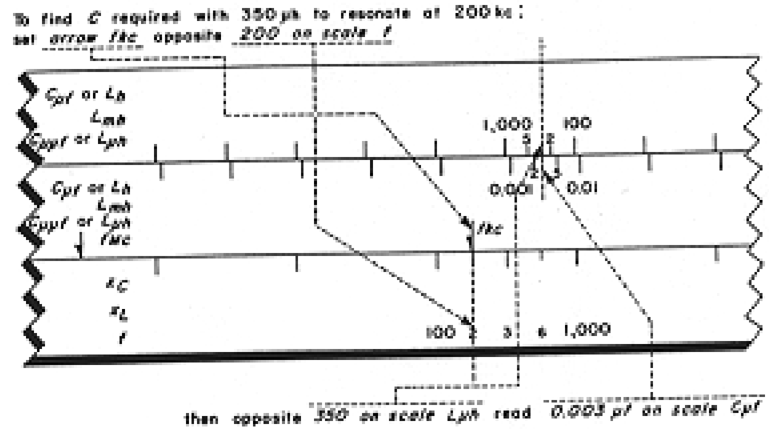


Fig. 21. Showing that for 350 μh to resonate at 200 kc, a capacitance of approximately 0.003 μf is required.

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

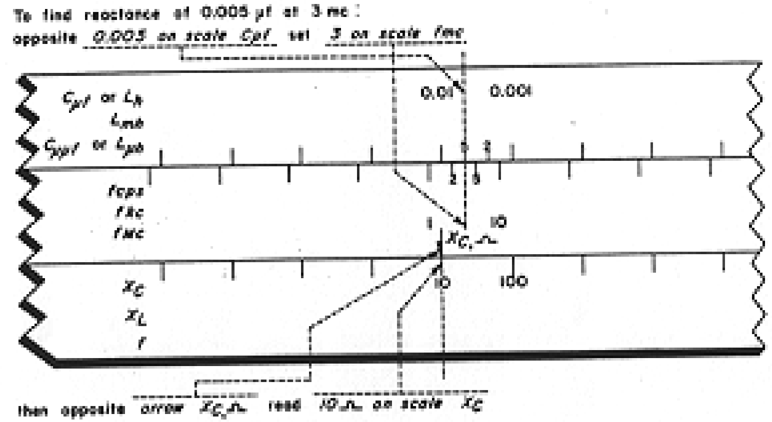

Fig. 22. Finding that the approximate reactance of a 0.005 µf capacitor at 3 mc is 10 ohms.

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.

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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.

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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.

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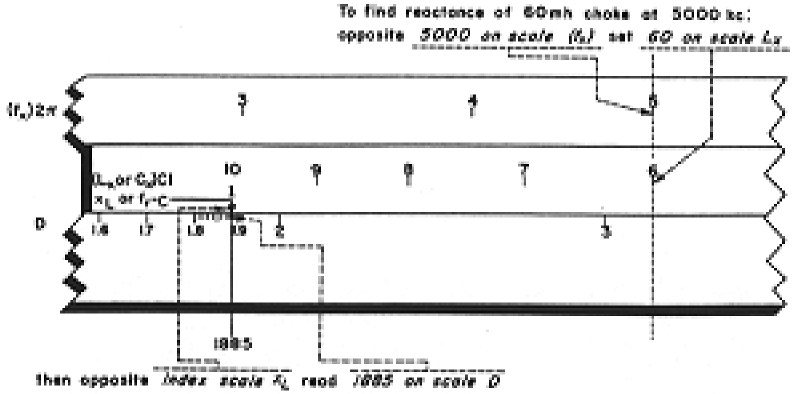

Fig. 23. Finding that a 60 mh choke at a frequency of 5000 kc has a reactance of 1.885 megohms.

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)2π.

(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.

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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.

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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.

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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. 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 μμf
3. 2.26 megohms	6. 49kc	9. 177,000 miles/sec.

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 nor 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 $H(L_r)$.

(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

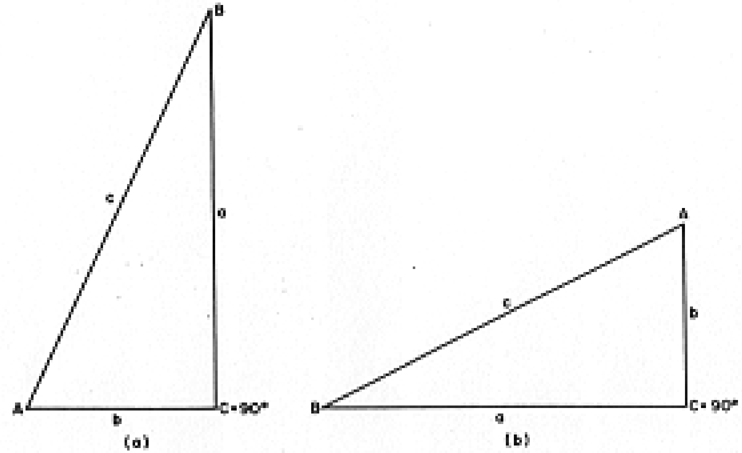

Fig. 24. The right triangle shown in two positions.

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...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:

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

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

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

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