how to use ELECTRONIC TECHNICIANS SLIDE RULES

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PICKETT
THE WORLD'S MOST ACCURATE
SLIDE RULES
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PREFACE

A slide rule is not only a computing device, it is also a set of mathematical tables, and by proper arrangement of these tabular values and computational procedures it can be so arranged that many constants required for the solution of problems are automatically designed into the rule so that they do not have to concern the user. This is the case with the 535 Electronic Slide Rule. It is so arranged that a combination of these factors make a routine process out of a laborious arithmatical procedure.

There is a saying among engineers that the slide rule never makes a mistake, only the one who is pushing it. It is good to bear this in mind, for many times when a solution is found that appears to be the wrong answer, the difficulty is with the user, not the rule. Therefore, check procedures very carefully before deciding some error exists.

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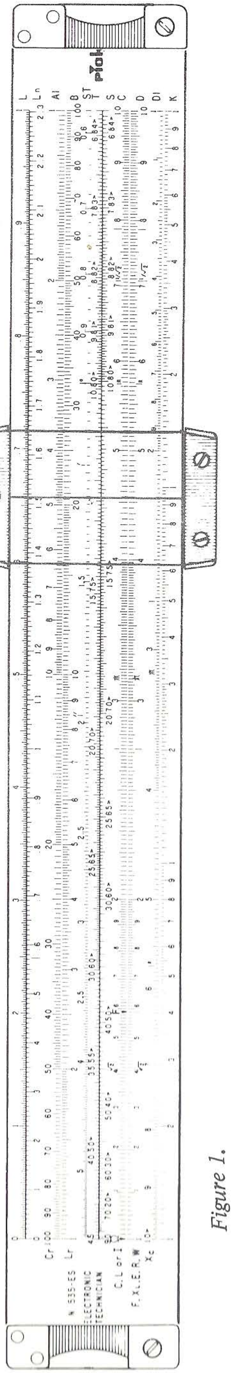


Figure 1.

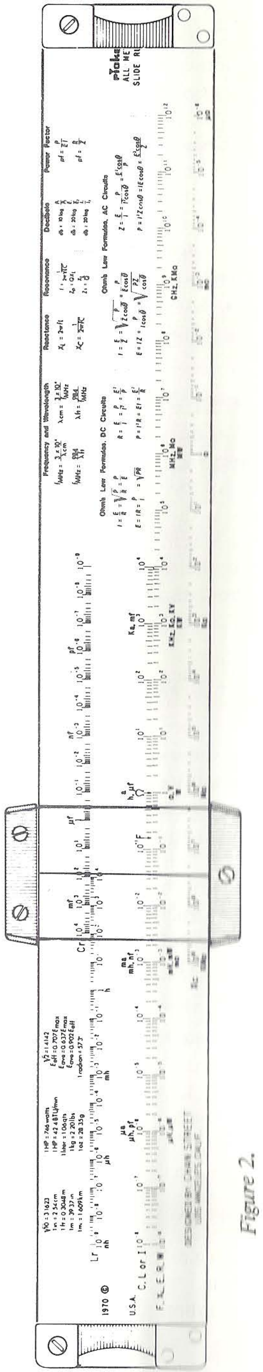


Figure 2.

1.00 GENERAL DESCRIPTION

The 535 Electronic Slide Rule has been specifically designed to solve the basic electronic problems of inductance and capacitive reactance and LC resonance. This has been accomplished on the front side of the slide rule as shown in Figure 1 in a way that permits the rule to remain substantially in the form of a conventional slide rule so that routine mathematical problems can be solved in addition to the special electronic functions. Due to the tremendous range of values utilized in electronics, it is laborious and time consuming to determine exactly where the numerical value, as solved by slide rule, will fall. To overcome this difficulty, the rear side of this rule, Figure 2, has been arranged so, in effect, the front side is repeated 20 times and each one of these powers of 10 are identified with a numerical guide as well as the "value names" used in electronic circuitry, such as henrys, millihenrys, kilohms and megohms. There is also included on the rear side of the rule the most commonly used relationships that are met with in basic circuit analysis.

1.10 FRONT SIDE SCALES.

The scales on the front of the rule, as shown in Figure 1, are essentially the same as those used in a conventional slide rule, excepting for the addition of certain reference marks and the reversal of some of the scales which will be discussed later in more detail. At the bottom of the rule is a conventional K scale. This consists of three decades within the full length of the rule, i.e., the calibration running from one to ten is repeated three times in the full length of the rule where the conventional scale is calibrated with the numbers from one to ten filling the length of the rule. This scale is used for finding cubes and cube roots. The next scale above the K scale is a DI scale. This scale is the same as the standard D scale excepting it is calibrated from right to left. The DI scale is used for division and for solving reciprocals. The next two scales, the D scale on the body of the rule and the C scale on the slider, are the same and are standard conventional slide rule scales.

The next three scales are the T, S and ST scales. These scales are the same again as used on a standard slide rule excepting that on this particular rule they are calibrated from right to left instead of from left to right. The purpose of this will be explained in greater detail under Section 5.00, where the solution of right angle triangles is discussed. The B scale which is at the top of the slider is the same as that found on a conventional rule. This scale has two decades in the full length of the rule. The scale just across from this on the body of the rule labelled AI is the same as the B scale except inverted; in other words it reads from right to left. Above the AI scale there is an L and L_n scale used for finding the values of logarithms to the base 10 and to the base e.

The use of these scales in routine mathematical calculations is thoroughly covered in the accompanying handbook entitled *How to Use Trig Slide Rules.* Therefore, such techniques will not be covered in this handbook excepting where the special calibrations require some comment. On the left hand end of the rule the scales are differently identified than on the right hand end. The identifications on the right hand end are those that would be given to a slide rule not having a special purpose. The identification marks on the left end show the purpose for which the scales are used in the solution of electronic circuits. The C scale is marked L, C or I. This refers to the fact that values of inductance, capacitance or current will be read on this scale. There are several special marks on this scale not ordinarily included on a slide rule. At the left hand index there is an arrow labelled with Ω (omega). This symbol indicates that this is the reference mark used when setting to a value of resistance. The next special mark is the $\sqrt{2}$ which has a numerical value of 1.41421.

The next reference mark is again an arrow but labelled with F. The F in this case is the reference mark used to set to some value of frequency in electronic problems. This mark is at $\frac{1}{2\pi}$ whose numerical value is .15915. π is the next mark on this scale and equal to 3.14159. The next special reference mark is labelled with an R and is the number of degrees in one radian. Its numerical value is 57.29578. Just beyond 7 there is a calibration mark which is $\frac{1}{\sqrt{2}}$ and has a numerical value of .70711. The next and last special reference mark is $\frac{\pi}{4}$ which is used in solving areas of circles and has a value of .78540.

The marks as set forth on the C scale are repeated on the D scale excepting for the mark for F but without the identifying labels. The D scale is identified on the left hand end with F, X_L, E, R and W. These symbols stand for frequency, inductive reactance, voltage, resistance*. In the solution of problems, this is the scale on which these values will be found. The DI scale is identified by X_c and this refers to capacitive reactance. The K scale is not used for the solution of electronic circuit problems. The B scale is identified by L_r and this refers to the inductance of a resonant circuit. The AI scale is identified with C_r and this refers to the capacitance of a resonant circuit.

1.20 BACK SIDE SCALES.

As mentioned in the General Description, 1.00, the back of the rule is used for finding approximate solutions of electronic problems and these solutions will be estimated to two digits. In many problems this two digit accuracy is sufficient since often the components to be used can not be determined more closely. An example of this is the solution for a resistance where standard 5% composition types will be used. Assume that a solution using the back of the rule gave the answer as approximately 38kΩ and the more precise answer found by using the front of the rule was 39,850Ω. Since the two values on either side of 39kΩ are 36 and 43, it is obvious that the more exact solution might be interesting but of no great help in choosing the resistor to be used. In many routine circuit designs solutions with the back side of the rule will be sufficient and only in special circumstances will it be necessary to work out a more accurate solution using the larger scales on the front side. Only the DI, D, C, B and AI scales are placed on the back of the rule and they are identified with the same markings as the equivalent scales on the front. The technique of using the rule for electronic problems is the same regardless of which side is used for a solution.

2.00 CALCULATION OF REACTIVE IMPEDENCE.

2.10 INDUCTIVE REACTANCE.

The impedence offered to an alternating current by an inductance is called inductive reactance. The equation for this relationship is $X_L = \omega L$. Bear in mind when thinking of electrical relationships of networks that in nearly all functions defining their behavior, the value ω (angular velocity in radians) and not the frequency F appears as the basic factor. The relationship between frequency F and ω is $\omega = 2\pi F$. This conversion factor is handled on the rule by the use of the reference Mark ₣ as the place to which the frequency is set. This also gives a convenient way of converting the frequency of an alternating signal into its equivalent angular velocity, ω. To make this conversion, simply move the slides so that ₣ is set to the frequency on the D scale and at either index of the C scale read ω. The decimal point for this solution can be determined by simply being aware that ω is a little more than 6 times larger than the frequency. To solve for inductive reactance when frequency and inductance are known, move the slider so ₣ is at the frequency on the D scale. On the back of the rule the F scale is calibrated from .001 Hertz to 1000 gigihertz. For ease in marking the correct decade in which to make the setting, the value for kilihertz, megahertz and gigihertz are labeled with their appropriate symbols. With ₣ set to the frequency within the proper decade, move the indicator to the value L of the inductance. This scale is calibrated from .01μh to 1000h with microhenry, millihenry and henrys labeled for easy identification. With the

*and wattage

indicator properly set at the value of L, X_L will be read under the hairline on the D scale. Note that the D scale functions have more than a single purpose. In this case, it is used for frequency as well as reactive impedence, X_L, but at all times the scale reading will have the correct numerical value. As an example of this type of problem, assume that we wish to know X_L for a 40mh choke at a frequency of 30 kilihertz. Set ₣ to 30kHz on the F scale. This will be at the second division to the right of 10^4. This means the digit 3 times 10,000 which is equal to 30,000. 40mh is 4 times 10^{-2}h so the indicator will be set to the third division to the right of 10^{-2} on the L scale and at the hairline on the X_L scale read approximately 7.5 times $10^3\Omega$ or 7,500Ω. This setting is shown in Figure 3a. Notice that the hairline falls approximately one-half way between the graduations for 7 and 8, so therefore one uses as an estimate a value of 7.5. Now as a further extension of this example, let us find a more exact solution for the same problem on the front side of the rule. We know before we start that the answer will be approximately 7,000 Ω and all we are trying to do by the next solution is determine more precisely what this value is. Using the front side of the rule, set ₣ to 3 on the F scale and at 4 on the L scale read 7.54. Therefore the correct value for X_L is 7,540Ω. This setting is shown in Fig. 3b.

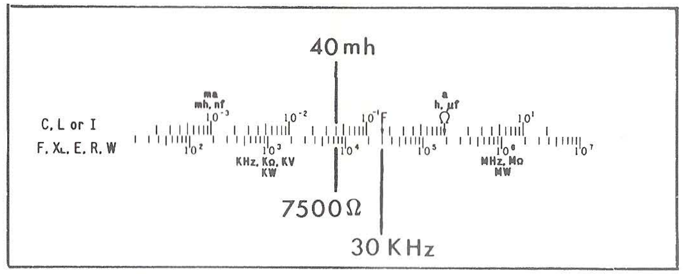


Figure 3a.

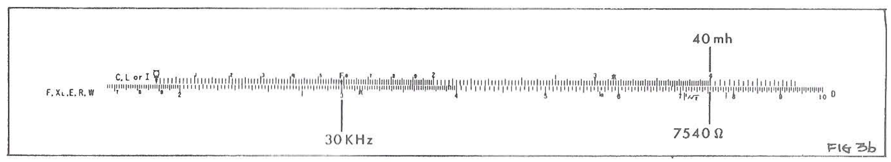


Figure 3b.

2.11 PRACTICE PROBLEMS FOR X_L

As practice in solving for X_L do the following problems:

1) A 10h choke at 120 cycles, what is X_L?
   Ans. 7.55kΩ.

2) At what frequency will a 5 μh coil have an impedence of 2,000 Ω. Ans. 63.6 megahertz. (In problem 2 when the final solution is made on the front side of the rule, it will be found that the 5 on the L scale is set opposite the 2 on the X_L scale. f will be off scale to the left so that it cannot be read. This situation may happen in many combinations of problems and the method of overcoming the difficulty is always the same, i.e., simply interchange the indexes. In this case notice that the right index of the L scale is opposite 4 on the X_L scale so by moving the slider out to the right side of the rule so that the left index is at 4, f will be at the value 6.36. Bear in mind that in using a slide rule the readings will always be duplicated whether the right or left index is set to the same number.)

3) What value of inductance is required to have an impedence of 600Ω at 350kHz? Ans. 273μh.

4) At what frequency will a 0.18μh inductance have an impedence of 500Ω? Ans. 440MHz.

2.20 CAPACITIVE REACTANCE.

Solutions for capacitive reactance are handled on this rule in exactly the same way as inductive reactance except that the value of X_c is read on the X_c scale. There are two things to be borne in mind when making this type of solution. One is that the C scale is calibrated in microfarads and not in farads. The other thing to notice is that the X_c scale is calibrated from right to left instead of from left to right as in the X_L scale so that one reads increasing values from right to left. The expression that solves for X_c is $X_c = \frac{1}{\omega C}$ which says that the impedence is inversely proportionate to ω, which is the same as being inversely proportionate to frequency. This means that the value of X_c decreases when either frequency or capacitance increases. As an example of solving for capacitive reactance, let us assume we wish to find the impedence offered by a 40μf condensor at the ripple of a full wave rectifier which is 120 Hertz where the line frequency is 60. Set f to 120Hz as shown in Figure 4 and move the indicator to 40μf on the C scale. At the hairline on the X_c scale read 30Ω. To solve this on the front of the rule, set f to 1.2 and the hairline of the indicator to 4. On the X_c scale the hairline should give a reading of 33.1Ω.

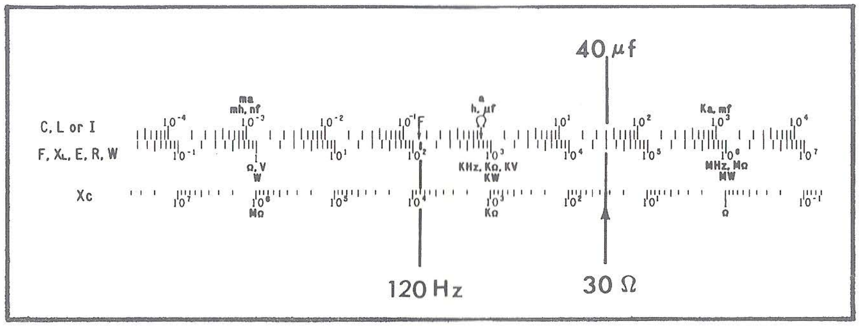


Figure 4.

2.21 PRACTICE PROBLEMS.

To become more proficient in determining capacitive reactance, solve the following problems:

1) What is X_c of a .01 condensor at 330Hz? Ans. 48.1kΩ.

2) What is the shunt reactance produced by 7.5pf at the input of a vacuum tube for a frequency of 270kHz? Ans. 78.5kΩ.

3) What size interstage coupling capacitor will be required to bring the low frequency cut off point to 30Hz where the grid resistor of the following tube is 470kΩ? Ans. .0113μf.

4) If one wished to make a low pass RC filter with the 3DB point 1200Hz what size capacitor would be used if the resistor is 4700Ω? Ans. .0282μf.

3.00 LC RESONANT CIRCUITS.

3.10 DESCRIPTION OF SCALES.

Referring to Figure 2 which shows the rear side of the rule, notice the two scales on the upper part of the body and slide, labeled C_r and L_r. These two scales are used for solving resonant circuits. The upper one being the capacitance value and the lower one the inductance value. To solve for a combination of inductance and capacitance that are resonant at a specific frequency, f is set to the desired frequency and then any combination of C and L that are opposite each other on the C_r and L_r scales will be the value of capacitance and inductance that will be resonant at that frequency for either series or parallel resonance. These scales are marked with their numerical values as well as the symbols normally used in electronic circuitry, such as microfarads (μf), picofarads (pf), which is one-millionth of a microfarad, henrys (h), millihenrys (mh), microhenrys (μh) and picohenrys (ph).

3.20 USE OF THE SCALES.

As an example of the use of these scales, let us assume that we wish to design a Hartley oscillator that will have a frequency of 200kHz. We set f to 200,000Hz on the F scale. This will be the first mark to the right of 10^5. On the C_r and L_r scales one may choose any combination of capacitance and inductance that appear opposite each other for this purpose. There are other factors determining what is a suitable combination, but in theory any of those shown will resonate at 200kHz. One of the factors that determines the combination of L and C used in a resonant circuit is that the inductance should have a self-resonant frequency greater than the frequency of the resonant system. Another factor, particularly for an oscillator, is that the coil should have a relatively high Q if the frequency is to be reasonably stable. So let us tentatively assume that the coil will have an inductance of 5mh. By setting the hairline to this value (fourth division to the right of 10^{-3}), we read on the C_r scale a value of 126pf. This combination will then be a resonant tank circuit at 200kHz. There, of course, will be some criterion as to what value of inductance and capacitance will be chosen out of the infinite number of combinations shown on the rule. As an example of an approximation of a suitable choice, we make a few assumptions. One of them is that it might be advisable in this example to have the resonant impedence, Z_L, have a value of approximately .2MΩ and that a reasonable Q to expect in the coil would be 30. Since the impedence of a resonant circuit is given by $Z_L = QX_L$ we can determine a suitable value for X_L. In this case this would be 6,660 Ω. Leaving the rule set as it was for solution of resonant frequency with $\digamma$ at 200kHz move the indicator so that the hairline is at 6,660Ω on the X_L scale and on the L scale read 5.3mh. Now by looking at the capacitance value on C_r opposite 5.3mh on L_r, we find that this inductance will resonate with a 120pf capacitor. The solution then is to use a 5.3mh coil with a 120pf condensor which will give us, if the Q of the coil is 30, a resonant frequency of 200kHz and a resonant impedence of .2MΩ.

To summarize the use of the resonant frequency scales is as follows: $\digamma$ is set to the desired frequency on the F scale and opposite each other on the L_r and C_r scales will be given the value of inductance and capacitance that will be either series or parallel resonant at the desired frequency. As a further example of using this set of scales let us assume that we wish to design the tank circuit of an RF power amplifier to operate a 1.5MHz. The output tube requires that the tank have a resonant impedence of 20,000Ω to give maximum power. Experience has shown that coils for this purpose usually have a Q of approximately 50 and we wish to know the inductance of the coil and value of the condensor to use in the output. Since $Z_L = QX_L$ we can determine X_L by

$$X_L = \frac{20{,}000}{50} = 400\Omega.$$

Using the rear side of the rule, place $\digamma$ at 1.5MHz and set the indicator to 400Ω on the X_L scale. At the hairline read approximately 40 μh. Without changing the setting of the slider, set the hairline to 40μh on L_r and on C_r read approximately 300pf.. These two values of inductance and capacitance are the approximate one that will fulfill the requirements of the tank circuit. This is shown in Figure 5. To determine more exactly the component values to use, we turn to the front side of the rule and set $\digamma$ at 1.5 on the F scale, at 4 on the X_L scale read 4.24 on the L scale. Without disturbing the setting of the slider, set the hairline to 4.24 on the L_r scale and read 2.65 on the C_r scale. The correct values for the circuit will thus be 42.4 μh for the coil and 265pf for the condensor. This setting is shown in Figure 6.

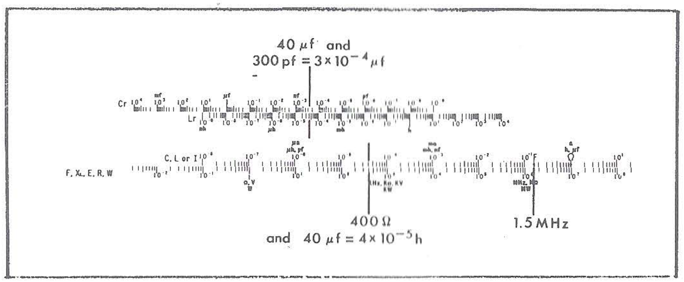


Figure 5.

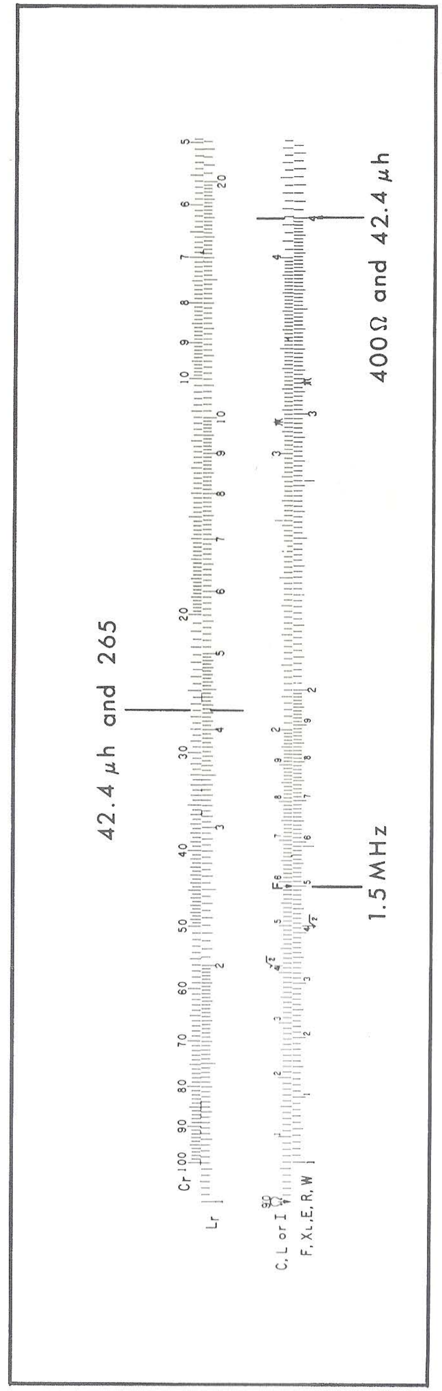


Figure 6.

3.21 PRACTICE PROBLEMS.

As practice problems in resonant frequency do the following exercises:

1) What inductance will be required to resonate with a 200pf condensor at 450kHz? Ans. .625mh.

2) What capacitance will be required to resonate a .05μh coil at 350MHz? Ans. 4.25pf.

3) We have tested a coil on the bench using an oscillator and a known condensor to find the frequency at which the pair will resonate. We wish to know the value of the coil. The condensor was a .001 μf and we found the frequency setting of the oscillator to be 33kHz at the point of maximum signal across the coil. What is the coil inductance? Ans. 0.232h.

4.00 Ohm's LAW.

4.10 DESCRIPTION OF SCALES.

The scales on the 535 Slide Rule are laid out in such a manner that they can be used to solve Ohm's Law. Of course, this is in itself a rather simple arithmetic relationship in which E = RI, but due to the range of values utilized in electronic work which covers generally about 20 magnitudes (one magnitude is considered to be an increase by a factor of 10 so that 20 magnitudes would be 100 million million million), the determination of the decimal point for all combinations of problems encountered can become very laborious. The 535 rule simplifies tremendously this particular problem, which on the whole is usually more of a nuisance than a difficulty. Referring to the back side of the rule, note that the digit on the scale labeled I has the symbol for Ohms, which is the Greek letter Ω (Omega). This is the reference mark for solving Ohm's Law just as F was for reactance problems. On the scale marked R, numbers represent the magnitude of a resistance as well as the magnitude of a voltage and these numbers have been identified with the generally accepted symbolism for resistance and voltage such as microvolts, millivolts, volts and kilovolts and ohms, kilohms and megohms. The scale on the slider identified by the letter I are values of current and have been labeled microamperes, milliamperes, amperes and kiloamperes. This range of numbers will cover most problems encountered in both vacuum and solid state electronics.

4.20 SOLUTION OF Ohm's LAW.

As an example of how these scales are used for the solution of Ohm's Law, let us assume we wish to know the current that will flow in a 2.4kΩ resistor if the voltage drop across it is 15v. Move the slider till Ω is at 2.4kΩ which will be a little to the right of the first division to the right of 10^3 on the R scale (10^3 is marked kΩ). Now move the hairline until it is lined up with 15 on the scale marked E and just above it on the scale marked I, read approximately 6.5ma. This technique is used for any combination of R, I and E. By knowing or assuming two of these values, the third may be found. As a further example let us find the value of a resistor which will drop 120v with a current of 3 μa. To solve this move the hairline to 120 on the E scale. This will be a little to the right of 10^2. Now move the slider so that the value of 3 μa is at the hairline. This will be the second mark to the right of 10^{-6} which is marked μa. At Ω read 40MΩ. This mark will be the third mark to the right of 10^7 on the scale marked R.

As a summation of this type of problem, remember that resistance is always read at Ω and at any setting of the slide any combination of current and voltage opposite each other on the E and I scale will be a solution for the value of resistance to which Ω is set. This makes the solution of Ohm's Law rather straight forward since one can determine all possible combinations of voltage and current for any given value of resistance.

Just as in the problems of reactance a more precise solution can be obtained by turning the rule over and using the front side after the approximation has been made on the rear of the rule. The same principle holds in that Ω is always set to the resistance value and combinations of current and voltage are read on the I and E scale.

4.21 PRACTICE PROBLEMS.

1) What value of resistance shall we put on the collector of a transistor so that it will have a voltage drop of 12v for a current of 4ma? Ans. 3,000Ω.

2) We wish to determine the value of the plate resistor of a high gain pentode where the B supply is 250v and one-third of this is to be dropped across the load resistor. The operating current at the quiescent point is to be 1.2ma. Ans. 69.5kΩ.

3) We need a divider network to split a supply for a transistor circuit into three equal parts. The supply voltage is 20v and we want the network to draw 3ma. Ans. 2.22kΩ.

4) What will be the base current of a grounded emitter silicon transistor where R_b = 82kΩ is connected to the supply which is 18v. Ans. 210 μa (Note: The base offset of a silicon transistor is usually about 0.8v).

4.30 SOLUTION OF DC POWER.

DC power problems may be solved with the rule if the current and voltage are known. Power solutions involving resistance can not be solved directly because this would require a scale specially for this purpose and since one usually wishes to know both current and voltage as well as power, the two step method was felt justified, particularly since the most bothersome part of this type of problem is again determining the decimal point which the back of the rule will solve for directly. In this case the mark Ω is set to the voltage that is dropped across the load and at the current on the I scale one reads the power on the scale marked W. As an example of this, let us solve for the wattage dissipated in the resistor calculated in Problem 2) of Section 4.20. Move the slider till Ω is at 83v ($\frac{250}{3}$ = 83v).

With this setting move the hairline to the current specified in Problem 2), namely 1.2ma and read approximately .1w. Now that we know the approximate magnitude of the wattage we can repeat the problem on the front side of the rule and find the more exact value of .102w. This process is the one of using the rear of the rule to find an approximate value and placing the decimal point, and then repeating the solution as in other problems on the front of the rule to determine the answer to approximately three places. As a further example, let us solve for the wattage dissipated in the collector resistor of Problem 1). In this problem both the voltage and current are specified, namely 12v with a current of 4ma. Using the rear side of the rule, set Ω to 12 on the E scale and the hairline to .004 (4ma) and read approximately .05w. A more exact solution will give .048w.

4.31 PRACTICE PROBLEMS.

For practice in this particular type of problem, solve the following examples:

1) A relay coil is to operate from a 24v supply and the minimum current to produce closure is 125ma and the maximum allowable wattage dissipation for this particular relay is 7w. Determine the wattage dissipated in the minimum current and the

current required at the maximum permissible dissipation. Using the back of the rule, set Ω to 24 on the E scale and set the hairline to .125 (125ma) and read 3w on the W scale directly below. To determine the current required to produce maximum dissipation, move the hairline to 7 on the W scale and directly above it read approximately 300ma. A more precise determination using the front of the rule will show that these two values are 3w for the lower limit and 291ma for the maximum permissible current.

2) We wish to put a 1.0Ω resistor as a current limiter in series with a diode used as a half wave rectifier where the maximum current will be 2.5a. What wattage resistor must we use? Ans. 6.25w minimum.

3) We wish to design a heater coil for a small oven. Other factors indicate that we should dissipate approximately 100w. Our supply voltage is 120v, rms, 60Hz. What will be the current required for the oven when it reaches equilibrium? Ans. .833a.

4) A sonar transducer is being excited at resonance with a 360v pulse of ultra sonic frequency. The current to achieve this is .560ma. What is the instantaneous power input to the transducer? Ans. 202w.

5.00 TRIGONOMETRIC SCALES.

By examining Figure 1 and the 535 Slide Rule, it will be noticed that the sine and tangent functions are calibrated from right to left instead of the conventional manner of left to right. The reason for this is that the solution of right angle triangles is greatly simplified over the conventional method and once the procedure is practiced and memorized, it will be found to be extremely rapid and simple. This technique is especially applicable to electrical problems where the solving of the phase angle of reactive circuits is required. The simplest case and one it is advisable to remember is the 3-4-5 triangle which can always be used as a test to determine how a particular rule can be most efficiently handled. This is the triangle shown in Figure 7 where the base is 4 units, the height is 3 and the hypotenuse will therefore be exactly 5,

$$5 = \sqrt{4^2 + 3^2} \ .$$

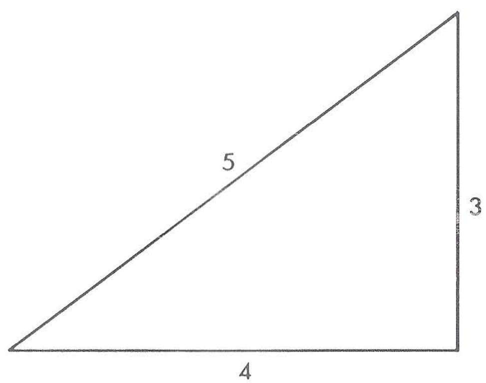
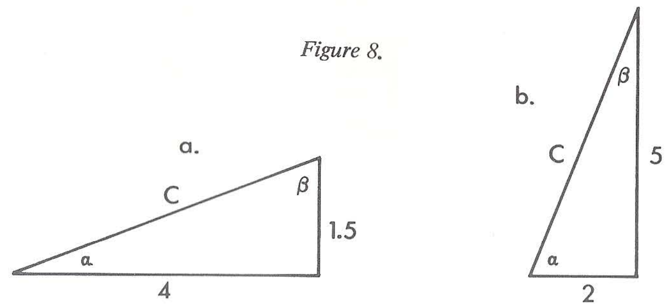


Figure 7.

As an example of understanding the use of the rule, let us solve this triangle trigonometrically. In the mathematical use of the slide rule, we will refer to the conventional scale designations as shown on the right hand end of the front of the rule. Move the slider until the left hand index of the C scale is set at 3 on the D scale. Move the hairline to 4 on the D scale. At the hairline on the tangent scale marked T read 36.9° (precise value is 36.870°). Move the hairline to 36.9 on the sine scale and beneath it on the D scale read 5. This method of solution has in one setting of the slide given us both of the angles of the triangle, 36.9° and its compliment 53.1° as read on the red figures and the value of the hypotenuse. As a trial let us assume the triangle had a height of 2 and a base length of 3. Move the slider inwards until the left index is at 2 on the D scale and with the hairline on 3 read 33.7° on the T scale. To find the length of the hypotenuse simply move the hairline to 33.7° on the S scale and read on the D scale beneath it 3.6. With these two trials in mind let us examine the rules that apply so that right angle triangles can be solved readily without confusion as to how the rule should be set or which angle is to be read. Examining Figure 8, there are shown two triangles and we wish to solve in both cases for angle α . The rule to follow in all cases is as follows: Either the left or right hand index of scale C is set to the numerical value of the shorter side on the D scale.

Figure 8.



Move the hairline to the value of the longer side on scale D and above on the T scale read the angle α . In the case as shown in Fig. 8(a) where α is between the longer side and the hypotenuse, the angle is read on the black figures of scale T, and the complimentary angle, β is read on the red figures. In the example of Fig. 8(b) where α is between the hypotenuse and the shorter side, α is read on the red figures of scale T and the complimentary angle, β, on the black figures. In both of these cases one finds the hypotenuse by shifting the hairline so that it is set to the same angle on the sine scale as was read on the T scale and the value of the hypotenuse will be read on the D scale. If these rules are studied and a few practice problems worked with, it will be found that the solution of right angle triangles is quite rapid and easily handled. The solution of the triangle in Fig. 8(a) will be α = 20.6°, β = 69.4° and C = 4.27. To solve Fig. 8(b) set the left index of C at 2 on the D scale, the hairline at 5 and on the T scale read 68.2° for α and 21.8° for β. Move the hairline to 68.2° as read on the red figures of the S scale and on the D scale read 5.39 for the hypotenuse. Let us examine the situation where the hypotenuse and one of the sides of the triangles are given. In Fig. 9 we have two triangles very similar to those shown in Fig. 8 but here the hypotenuse in Fig. 9(a) is 7 and the height is 3.5 and we wish to solve for the base B and the angle α.

Figure 9.

If in the problem it is not too obvious that the side given is the shorter of the sides, it can be quickly checked by using the reference point of $\sqrt{2}$ shown on the C scale. By setting this reference point opposite 7 on the D scale we find that 7 divided by the $\sqrt{2}$ is a little more than 4.9 and since this is obviously larger than the value given, α must be less than 45°. So, again, you set the left index of C to 3.5, the hairline to 7 on the D scale and above on the sine scale, we find 30° which is the value of α. We now move the hairline to 30° on the T scale and read 6.06 on the D scale which is the value of B. It will be noticed that this is exactly the same process used for solving the triangles in Figure 8, excepting that we worked backwards from the relationship of the hypotenuse and the sine of α instead of solving for them. So, using this principle, we can solve any right angle triangle in one setting as long as any two values are given. This relationship is shown using the triangle in Figure 9(b) where the base of the triangle is B, the height is A and the hypotenuse is C and the relative position of reading these values on the slide rule is shown in Figure 10.

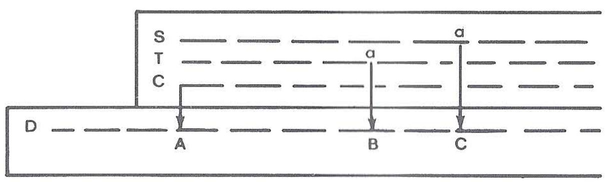


Figure 10.

With the index of C at A, B is opposite α on the T scale and C is opposite α on the S scale. Notice one other fact from basic trigonometry that

$$\text{Cos}\,\alpha = \frac{\text{Sin}\,\alpha}{\text{Tan}\,\alpha},$$

therefore the distance on the rule between the angle α on the T scale and the angle α on the S scale is equal to the Cos of α.

5.10 PRACTICE PROBLEMS.

To become proficient a number of problems should be solved. A few practice problems will be given here but one should make up numerous ones of his own to extend the practice until the technique is fully in mind.

1) The hypotenuse of a right angle triangle is 5.5 and α is 35.5°. What are the values of A and B? Ans. A = 3.19 and B = 4.47.

2) The base of a right angle triangle is 15.5" and its height is 6.25". What is the value of α and the length of the hypotenuse? Ans. $\alpha = 21.9^\circ$ and the hypotenuse is 16.7".

3) The base of a right angle triangle is 23.5cm and α is 9.5°. What will be the height of the triangle and the length of its hypotenuse? Ans. C = 23.8 and B = 3.93.

5.20 SOLUTIONS WITH SMALL ANGLES.

In all of the foregoing discussion, we have worked with angles whose tangent is greater than 0.1. These angles are all calibrated on the S and T scales. There is on the rule an additional scale marked ST that is used for solving triangles with smaller angles. At angles less than approximately 5.7° the sine and tangent of the angles are so nearly alike that for all practical purposes in slide rule calculation they can be considered the same. This also means that in a triangle where α is less than 5.7°, the base and the hypotenuse are so nearly the same that we do not attempt to distinguish the small difference that does exist between them. But very useful calculations can be performed on a rule determining the height of triangles having small angles. The 535 slide rule is calibrated to solve these problems where α is as small as approximately $.6^\circ$. It can readily be determined whether the reading will be made on the S or T scale or on the ST scale. This will be indicated wherever a height of a triangle is less than one-tenth of the base. As an example of this, let us solve the triangle as shown in Figure 11 where the base is 22.4 and the height is 1.07.

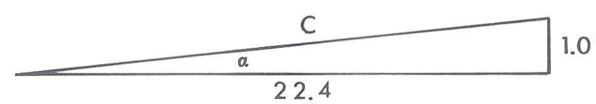


Figure 11.

Simply by shifting the decimal point we can determine that the height is obviously less than one-tenth the base. To solve for this set the index of C to 1.07 on the D scale and the hairline to 22.4. At the hairline on the ST scale, read 2.74° for the value of α. For all intents and purposes, the hypotenuse C will be equal to 22.4. To show that this type of solution is satisfactory for practically all routine problems, the exact solution of this triangle is as follows: $\alpha = 2.7345^\circ$ and C = 22.42556. The error in this case in assuming that the base and hypotenuse are the same is only 0.114%. To follow up on the use of the ST scale, let us solve the example of a triangle whose base is 56.5 and α is equal to 1.64. What will be the height of the triangle? Set the hairline to 565 on the D scale and move the slider until 1.64 is under the hairline on the ST scale. At the left index of the C scale, read 1.62 for the height.

It is strongly suggested that the use of this slide rule and the solution of right angle triangles be thoroughly practiced since experience has shown that this particular combination of scales, which is the same as used on the N-16 electronic slide rule, is extremely versatile and rapid.