ALTERNATING CURRENT. G.B.Todd,RM1c
Weeks Number: Nine, Ten and Eleven.

37

QUESTION #1. What is meant by the term Alternating Current?

ANSWER #1. Alternating current is the name applied to an electric current which flows back and forth at regular intervals in a circuit.

QUESTION #2. Define: Cycle and Frequency.

ANSWER #2. The current has completed a cycle when it rises from zero to maximum in one direction, returns to zero, rises to maximum in the opposite direction and returns to zero.

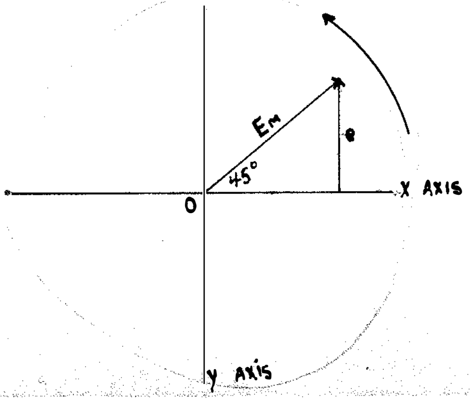
Frequency is the number of times per second that this series of events occurs. Frequency is stated in cycles per second.

QUESTION #3. Explain briefly a Vector Diagram. A Vector.

ANSWER #3. A vector diagram is a simple way of showing, or representing the relation of induced emf to the electrical angle, when the emf follows a sine curve. The sine curve may be thought of as a moving picture following the emf through the complete cycle, while a vector diagram may be thought of as a snapshot of the relations at some particular instant during the cycle. The diagram consists of a vertical and a horizontal axis. We may call the horizontal axis the x axis and the vertical, the y axis. The greatest value attained by the emf, during the cycle, may be represented by a line rotating counter clockwise around the intersection of the x and y axes. If the length of the vector (the line representing the maximum emf attained) stays the same, it is seen that a straight line dropped from the end of the vector to the x axis, will vary in length directly as the sine of the electrical angle, which angle is represented by the amount of rotation of the vector from the x axis. This straight line, or opposite side of the right angle triangle, represents the value of instantaneous emf at any instant during the cycle.

The line which represents the maximum value attained by the emf during the cycle is called a vector.

Vector diagrams are also used to represent the value of instantaneous current and for other purposes.



QUESTION #4. Define: Instantaneous value.

ANSWER #4. Instantaneous value is a term used when referring to the value of emf or current at any instant during a cycle. The emf is continually changing, therefore, in order to state its value it is necessary to state it for a given instant. At any other instant it will be greater or less than this value.

QUESTION #5. Give Algebraic Symbols and Equations for computing instantaneous values of EMF and instantaneous value of current.

ANSWER #5. When the voltage follows the sine wave, the equation for finding any instantaneous value of voltage in an alternating current is as follows:

$$e = \text{Em Sin } \phi$$

Where:
e = instantaneous voltage.
Em = maximum voltage.
ϕ = electrical angle (in degrees).

And for current:

$$i = \text{Im Sin } \phi$$

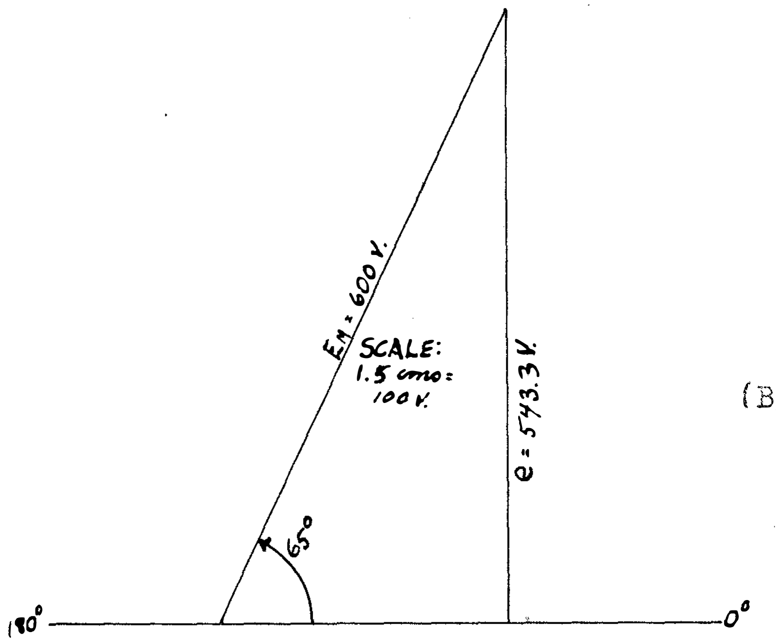
Where:
i = instantaneous current.
Im = maximum current.
ϕ = electrical angle (in degrees).

QUESTION #6. Compute by two methods for instantaneous value of emf when maximum value is 600 volts at 65°.

ANSWER #6. Formula: $e = \text{EM Sin } \phi$

Substituting: $e = 600 \times .906$ (By equation)

e = <u>543.6 volts. Ans.</u>



(By vector)

QUESTION #7. Define Average value of an Alternating Current.

ANSWER #7. The average value of an alternating current is the average of all instantaneous values regardless of signs If the average was found, taking into consideration the signs, the result would be zero, since the negative values are exactly equal to the positive values. But the signs only indication the direction of current flow, so, if the average was computed it would be found to be o.637 times the maximum value:

$$E_{av} = 0.637 E_m$$

and

$$I_{av} = 0.637 I_m$$

Where:
E_{av} = Average voltage
I_{av} = Average current
E_m = Maximum voltage
I_m = Maximum current
0.637 = Constant.

The average value is very seldom used. It is used only to compute the maximum value.

QUESTION #8. Define Effective value of an Alternating Current.

ANSWER #8. Alternating current is rated by its effective value, all meters in an alternating current circuit register effective values. A standard ampere in direct current is the current that will deposit a certain amount of silver in a certain time, but alternating current would deposit silver the first half of the cycle and take it off when the current reversed, so, it is necessary to rate alternating current by the heat that it will produce. It is rated in amperes and is found to be slightly greater than the average value, being 0.707 times the maximum value:

$$E = 0.707 E_m$$

and

$$I = 0.707 I_m$$

Where:
E = Effective voltage
I = Effective current
E_m = Maximum voltage
I_m = Maximum current
0.707 = Constant.

The reason the effective value is slightly greater than the average value is that the effective value is the square root of the average of the squares of the instantaneous values, while the average value is merely the average of the instantaneous values.

QUESTION #9. Compute for maximum value of current. A lamp which takes an alternating current of 0.45 ampere.

ANSWER #9. Formula: $I = 0.707 I_m$

Transposing: $I_m = \frac{I}{0.707}$

Substituting: $I_m = \frac{0.45}{0.707} =$ .63649 amperes. Ans.

QUESTION #10. How is Ohm's Law applied to an Alternating Current?

ANSWER #10. Ohm's Law is applied to Alternating Current exactly the same as Ohm's Law for Direct Current, provided voltage, current, and resistance only is taken into consideration. Resistance is always the opposition offered to the flow of current. Likewise reactance is an opposition to the flow of current. This opposition regardless of whether it is a result of resistance or reactance, is always stated in ohms. If the total opposition (in ohms) is found, Ohm's Law can then be applied exactly as in Direct Current. Of course the effective value of current must be taken into consideration if effective voltage is desired:

$$E = IR$$

where:
E = Effective voltage.
I = Effective current.
R = Resistance.

Maximum current must be used to compute maximum voltage:

$$Em = ImR$$

where:
Em = Maximum voltage
Im = Maximum current
R = Resistance

Average current must be used to compute average voltage:

$$Eav = IavR$$

where:
Eav = Average voltage.
Iav = Average current.
R = Resistance.

Instantaneous current must be used to compute instantaneous voltage:

$$e = iR$$

where:
e = instantaneous voltage
i = instantaneous current
R = Resistance

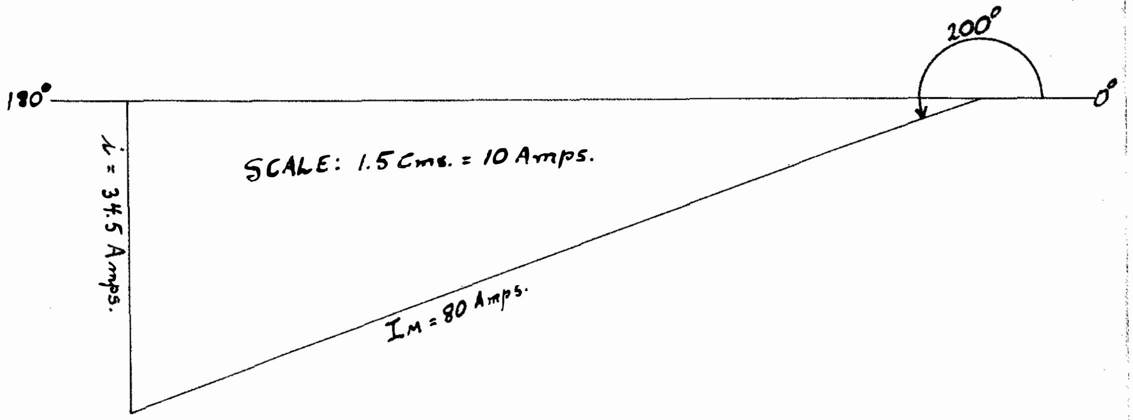
QUESTION #11. Solve by vector diagram: The maximum voltage is 200 volts, resistance is 2.5 ohms. What is the value of the current when the voltage is at the 200° point?

ANSWER #11. Formula: $Im = \frac{Em}{R}$

Substituting: $Im = \frac{200}{2.5} = 80$ amperes.

Solving for instantaneous current by vector:

(see next sheet)

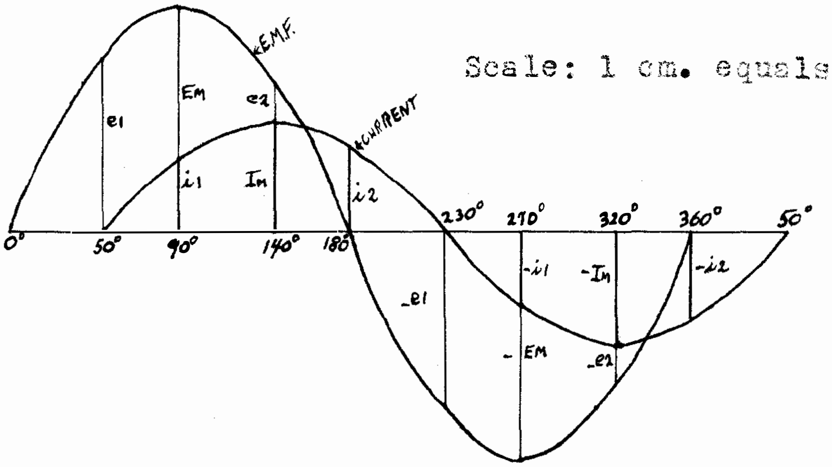


QUESTION #12. Define: Phase difference and Phase angle.

ANSWER #12. Phase angle represents the relation of the current to the voltage in an alternating current. There are three separate and distinct relations: When the current and voltage are in phase (when they rise and fall in unison), when the current lags behind the voltage, and when the current leads the voltage. Phase angle is represented by the symbol φ, the electrical angle. Phase difference is the difference in degrees between the phase angle of the current and the phase angle of the voltage. It is represented by the symbol θ.

QUESTION #13. Draw sine curve to scale in which the current lags 50° behind the voltage and explain.

ANSWER #13.



Scale: 1 cm. equals 40°

In this case the current lags behind the voltage by 50°. The voltage curve has a value of e1 at 50° while the current has a value of zero. The voltage curve reaches its maximum at 90°, while the current only has a value of i1. The current curve reaches its maximum at 140°. The voltage reaches zero again at 180° while the current has still a value of i2, and so on thru the entire curve. The difference of 50° between the voltage and the current is called the phase difference and is used in the equation to determine the phase angle for the current, so that the instantaneous current may be found. Of course the sine curve may be used to determine any instantaneous value but the result is not as accurate as by equation

QUESTION #14. What are the symbols and equations for a lagging current?

ANSWER #14. Formulae for lagging current:

$$e = Em \text{ Sin } \phi$$

$$i = Im \text{ Sin } (\phi - \theta)$$

where: ϕ = phase angle of voltage in degrees.
θ = difference in phase between Em and Im.

QUESTION #15. Compute by equation: In an inductive AC circuit, the current lags 30° behind the voltage. The maximum value of the current is 42.5 amperes. What is the instantaneous value of current when the voltage is at the 85° point, 125° point?

ANSWER #15. Formula:

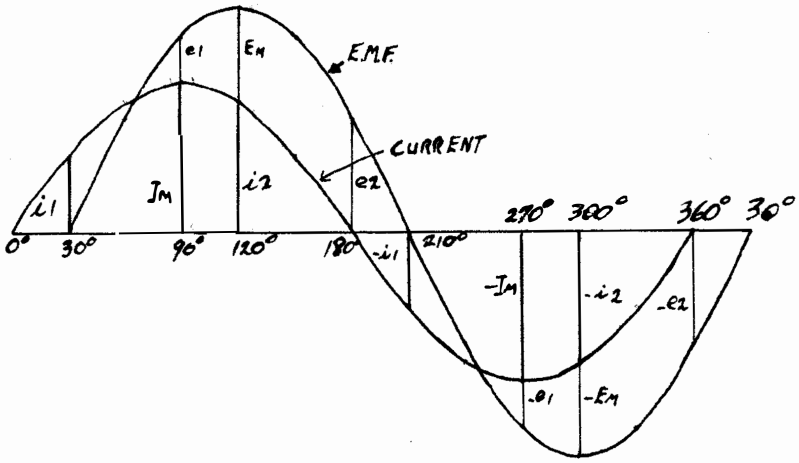
$i = Im \text{ Sin } (\phi - \theta)$
$i = Im \text{ Sin } (85° - 30°)$
$i = Im \text{ Sin } 55°$
$i = 42.5 \times .819$
$i = \underline{34.8075 \text{ amperes.Ans}}$

Formula:

$i = Im \text{ Sin } (\phi - \theta)$
$i = Im \text{ Sin } (125° - 30°)$
$i = Im \text{ Sin } 95°$
$i = Im \text{ Sin } (180° - 95°)$
$i = Im \text{ Sin } 85°$
$i = 42.5 \times .996$
$i = \underline{42.33 \text{ amperes. Ans.}}$

QUESTION #16. Draw sine curves showing current leading the voltage by 30° and explain.

ANSWER #16.



In this sine curve, the current leads the voltage by a phase difference of 30°. The current has attained a value of i1 at 30° while the voltage is zero. The current reaches its maximum at 90° but the voltage does not reach its maximum until the 120° point, showing a difference of 30° during the entire cycle. A curve of this sort is used mainly to get a general idea of the different phase relations, rather than to obtain the correct mathematical results. The correct result is obtained by vector diagram and by equation.

QUESTION #17. What are the symbols and equations for a leading current?

ANSWER #17. Formulae for leading current:

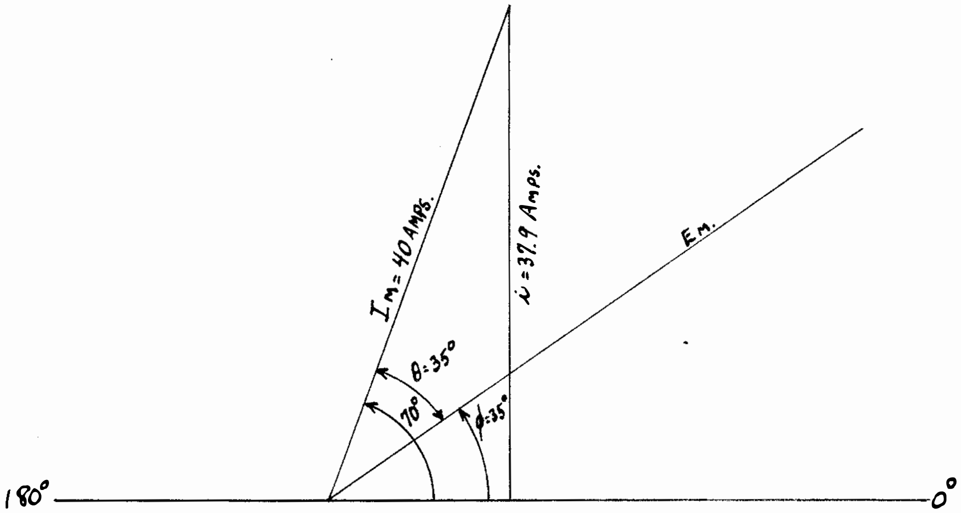
$$e = \text{Em Sin } \phi$$

$$i = \text{Im Sin } (\phi \text{ plus } \theta)$$

where:
ϕ = phase angle of voltage in degrees.
θ = difference in phase between Em and Im.

QUESTION #18. Compute by vector: The angle of lead of current is 35°. Maximum current is 40 amperes. What is the current value when the voltage is at the 35° point?

ANSWER #18.



QUESTION #19. What is the cause of a lagging current?

ANSWER #19. Inductive reactance is the cause of a lagging current in an alternating current. Lenz's Law tells us that in an electric circuit containing inductance an emf will be induced, the direction of which will oppose any change in the field which produced it. The current in an alternating current circuit is continually changing so there is always an emf induced which will oppose this continual change. When the current rises, the induced emf opposes the rise and the current is less than the result of the emf divided by the resistance. Therefore, the current rise takes place later than the rise in voltage. And the same when the current is falling. The direction of the current is such that it opposes the fall and tends to keep the value of current greater than the impressed emf alone would due. So it is seen that the current will lag behind the voltage throughout the entire cycle.

QUESTION #20. Compute: The maximum value of the current in an AC circuit containing inductance only is 26 amperes. The average value of the voltage is 119 volts. What is the Inductive Reactance?

ANSWER #20. Formula: $Xl = \frac{Em}{Im}$ $Em = \frac{Eav}{.637}$

$$Xl = \frac{Eav}{Im \times .637}$$

Substituting: $Xl = \frac{119}{26 \times .637}$

$Xl = $ 7.18512 Ohms. Ans.

QUESTION #21. What is inductive reactance? What is always the phase angle of current through inductive reactance only?

ANSWER #21. Inductive reactance is the opposition offered to the flow of alternating current by an inductance. It is measured in ohms, and has an effect of causing the current to lag behind the voltage. In a circuit containing inductance only (resistance negligible) the phase angle of the current will always be 90° behind the voltage. This is because the only voltage necessary is that requ-ired to overcome the induced emf. The induced emf would be greatest when the current was changing at the fastest rate. The current is changing most rapidly when it is passing through the zero value therefore the voltage is at its greatest when the current is zero. Since the voltage attains its maximum at a phase angle of 90° the current would be zero at the 90° angle. The voltage is least when the current is changing at its lowest rate. By inspecting a sine wave of current, it is seen that this happens when the current has a maximum value, so the voltage would be zero when the current is maximum. Since the current reaches its maximum at 180° (The voltage being at zero at 180°) it is seen that the current will lag 90° behind the voltage thruout the entire cycle.

QUESTION #22. A coil has an inductance of 10 Millihenries. What will be its reactance at a frequency of 500 cycles.

ANSWER #22. Formula: $X1 = 2 \text{ pi } f L$

Where:
$X1$ = inductive reactance in ohms.
2pi = 6.28
f = frequency in cycles.
L = inductance in henries.

1 millihenry = .001 henry
10 millihenry = 10 x .001 = .01 henry

$$X1 = 2 \text{ pi} \times 500 \times .01$$

$$X1 = 6.28 \times 500 \times .01$$

$$X1 = \underline{31.4 \text{ ohms. Ans.}}$$

QUESTION #23. What is the cause of a leading current?

ANSWER #23. Capacitive reactance is the cause of a leading curren Condensers in an alternating circuit act in much the same way as an air reservoir in a pump circuit, that is, they tend to oppose any change in pressure, and to keep the pressure constant. The condensers store electricity while the voltage is rising. When the voltage is falling the condensers tend to keep the current constant. Current will be flowing into the condenser as long as the voltage is rising. The largest current will be flowing when the voltage is rising most rapidly. The voltage rises most rapidly when it is passing the zero value, so the current is at a maximum at this point, 90° ahead, or in the lead, of the voltage. Similarly the current will flow out of the condensers when the voltage is falling at its fastest rate. This is seen to be at its 270° point, so the current is also at a maximum at this point, still 90° in advance of the voltage.

QUESTION #24. What is capacitive reactance? What is always the phas angle of current through capacitive reactance only?

QUESTION #24. Capacitive reactance is the opposition offered to the flow of an alternating current to to capacitiance in the circuit. It is measured in ohms. In an alternating circuit containing capacitance only, the current will always lead the voltage by 90° for reasons explained in the answer to Question #23.

QUESTION #25. What will be the capacitive reactance of a condenser of 0.001 mf at a frequency of 1000 cycles?

ANSWER #25. Formula: $$Xc = \frac{1}{2 \text{ pi } f C}$$

Where:
Xc = capacitive reactance in ohms.
f = frequency in cycles.
C = capacity in farads.

$$Xc = \frac{1,000,000}{6.28 \times 1000 \times .001}$$

$$Xc = \underline{159,235 \text{ ohms. Ans.}}$$

QUESTION #26. Three condensers of 10, 20, and 40 mf capacitance respectively are placed in parallel across a 25 cycle, Ac circuit, of 200 volts. What is the maximum current in the circuit? What would the current in the circuit be is the first and third condensers were hooked in series?

ANSWER #26. The capacitance of condensers joined in parallel is the sum of the capacitances of the separate condensers

$$C = C_1 \text{ plus } C_2 \text{ plus } C_3 \text{ and etc.}$$

Formula: $Im = \frac{Em}{Xc}$; $Em = E \times 1.414$; $Xc = \frac{1}{2 \text{ pi } f \ C}$

Therefore: $Im = \frac{E \times 1.414 \times 2pi \times f \times C}{1}$

$$Im = \frac{200 \times 1.414 \times 6.28 \times 25 \times .00007}{1}$$

$Im =$ 3.108007 amperes. Ans.

The reciprocal of the combined capacitance of condensers in series equals the sum of the reciprocals of the capacitances of the separate condensers.

$$\frac{1}{C} = \frac{1}{C_1} \text{ plus } \frac{1}{C_2} \text{ plus } \frac{1}{C_3} \text{ and etc.}$$

Formulae: $I = \frac{E}{Xc}$; $Xc = \frac{1}{2pi \ f \ C}$.

$$I = \frac{E \times 2pi \times f \times C}{1}$$

$$I = \frac{200 \times 6.28 \times 25 \times .000008}{1}$$

$I =$ .25105 amperes. Ans.

QUESTION #27. How does inductive reactance and capacitive reactance vary with changes in frequency?

ANSWER #27. Since the value of an inductive reactance in ohms is equal to 2pi times the frequency times the inductance it is seen that the inductive reactance will increase in direct proportion to an increase in frequency. The value of capacitive reactance in ohms is equal to the reciprocal of 2pi times the frequency times the capacitance, so, it is evident that an increase in frequency will decrease the capacitive reactance and vice versa, so, capacitive reactance varies inversely as the frequency.

QUESTION #28. What is reactance? Show symbols and express by an equation.

ANSWER #28. See next sheet.

ANSWER #28. Continued.

Reactance is the total opposition offered to a flow of alternating current due to the inductance and capacity in a circuit. Reactance is expressed in ohms, like resistance, but this opposition entails no loss of energy because it is due to a counter pressure and is not analogous to friction. Since the inductive reactance produces an opposition which is just the reverse of that produced by capacitive reactance they tend to neutralize each other. The combined effect is the algebraic difference between them.

$$X = Xl - Xc$$

Where:
X = reactance in ohms.
Xl = inductive reactance in ohms.
Xc = capacitive reactance in ohms.

If the result is positive, the resultant effect is that of inductance, causing the current to lag. If the result is negative the effect is that of capacitance, causing the current to lead. Although, the result is always reactance in ohms, not inductive reactance, if positive prevails, or capacitive reactance if negative prevails.

$$X = 2\text{pi}\ f\ L - \frac{1}{2\text{pi}\ f\ C}$$

QUESTION #29. What is the reactance of a circuit containing 12 ohms inductive reactance in series with 15 ohms capacitive reactance?

ANSWER #29. Formula: $X = Xl - Xc$

$$X = 12 - 15$$

X = $\underline{-3 \text{ ohms.Ans.}}$

This indicates that the result is 3 ohms reactance, which will produce an effect of capacitance, that is, will cause the current to lead the voltage.

QUESTION #30. What is the reactance of a 60 cycle AC circuit containing 10 mf capacitance in series with 0.6 henry inductance? What current would flow in the circuit if voltage was 120 volts? Draw vector diagram and determine the value of current when voltage is at the 310° point.

ANSWER #30.

$$Xl = 2\text{pi}\ f\ L$$

$$Xl = 6.28 \times 60 \times .6$$

Xl = 226.08 ohms.

ANSWER #30. Continued.

$$Xc = \frac{1}{2pi\ f\ C}$$

$$Xc = \frac{\begin{matrix}1250\\ \cancel{2500}\\ \cancel{5000}\\ 1\cancel{00000}\end{matrix}}{\begin{matrix}\cancel{6.28} \times \cancel{60} \times .\cancel{000001}\\ \cancel{3.14} \quad\ \ 3 \qquad\qquad\\ 1.57 \qquad\qquad\qquad\end{matrix}} = \frac{1250}{4.71}$$

$$Xc = 265.39 \text{ ohms.}$$

$$X = Xl - Xc$$

$$X = 226.08 - 265.39$$

$X = \underline{-39.31 \text{ ohms (capacitive) Ans.}}$

$$I = \frac{E}{X}$$

$$I = \frac{120}{39.31}$$

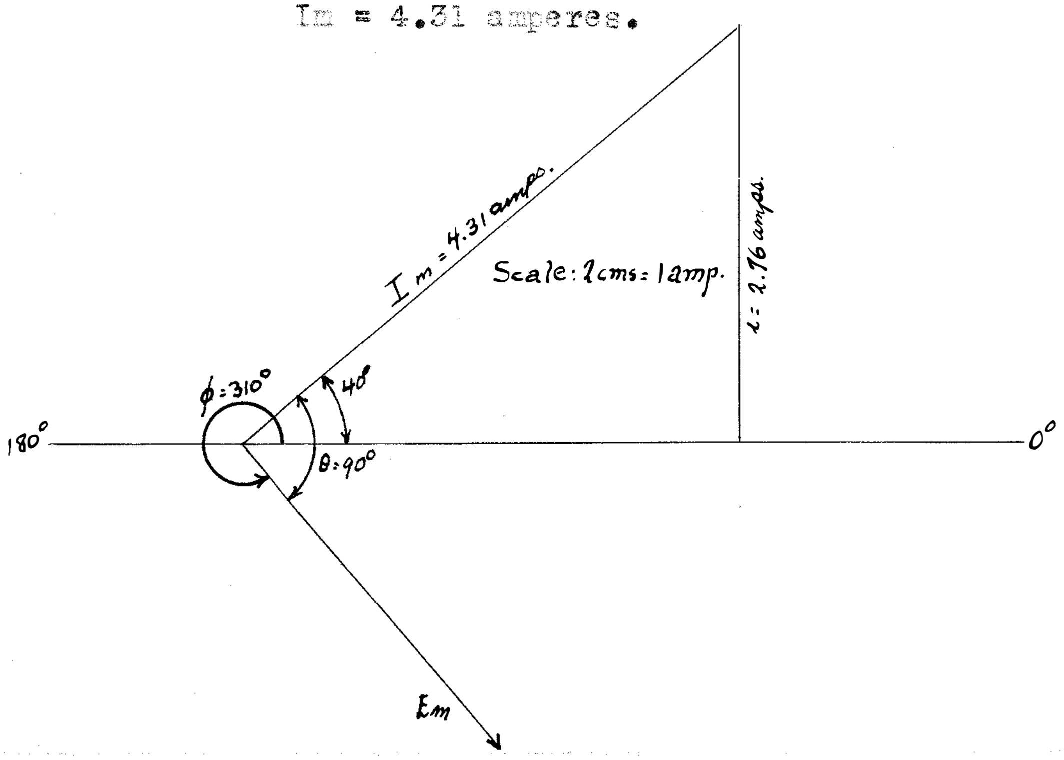
$I = \underline{3.05 \text{ amperes. Ans.}}$

If the voltage is at the 310° phase angle, the current would be at the 310° plus 90° or 400° - 360° equals 40° phase angle. In order to plot by vector the maximum current is needed:

$$Im = I \times 1.414$$

$$Im = 3.05 \times 1.414$$

$$Im = 4.31 \text{ amperes.}$$



QUESTION #31. What is Impedance? Why can it not be found by simple addition or subtraction?

ANSWER #31. Impedance is the combined effect of resistance and reactance. It is called this to distinguish it from its two components, resistance, which is that quantity which when multiplied by the current gives that component of the impressed emf which is in phase with the current, and reactance which is that quantity which when multiplied by the current gives that component of the impressed emf which is at right angles to the current. Impedance is the total opposition offered to the flow of an alternating current, and is due to the resistance and reactance of the circuit. Impedance is measured in ohms.

Impedance cannot be found by simple addition or subtraction because the reactance causes the current to either lead or lag the voltage by 90°, the effect thus being at right angles to the resistance effect.

QUESTION #32. Give symbols and equations for computing for Impedance.

ANSWER #32. Formula: $Z = \sqrt{R^2 \text{ plus } X^2}$

Where:
Z = impedance in ohms.
R = resistance in ohms.
X = reactance in ohms.

or $Z = \sqrt{R^2 \text{ plus } (Xl - Xc)^2}$

Where:
Xl = inductive reactance in ohms
Xc = capacitive reactance in ohms

QUESTION #33. Show Graphs and explain how impedance is computed when the reactance is Capacitive, Inductive.

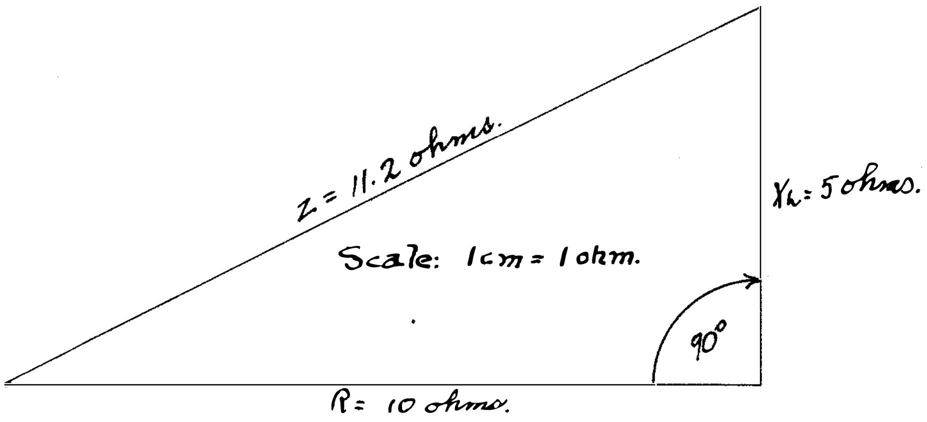
ANSWER #33. To find the result of a combination of resistance and inductive reactance in series by Graph method: First draw horizontal line to represent the resistance, then draw a line to scale at right angles to the R line, upward. A line drawn from the upper end of the reactance line to the left end of the resistance will be the impedance.

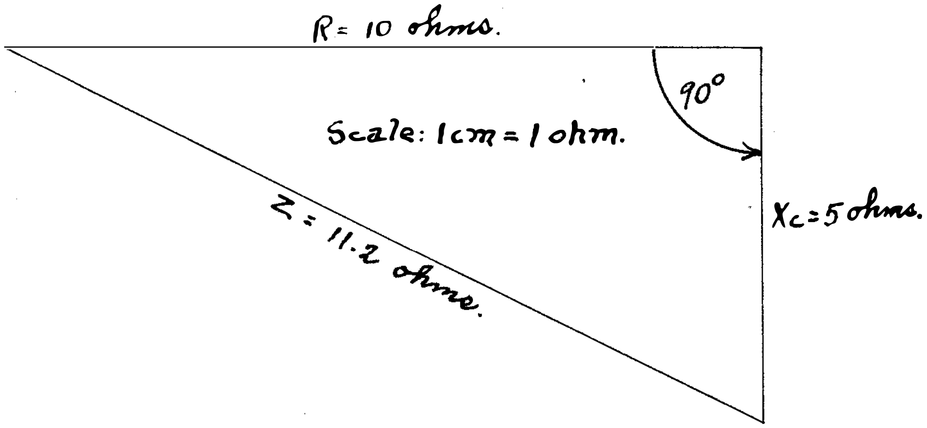
To find the result of a combination of resistance and capacitive reactance in series, by the Graph method: First draw a horizontal line to scale to represent the resistance, then draw a line from the right end of the resistance line at right angles and downward to represent an opposite effect than inductive reactance. A line drawn from the bottom end of the capacitive reactance line to the left end of the resistance line will be the impedance.

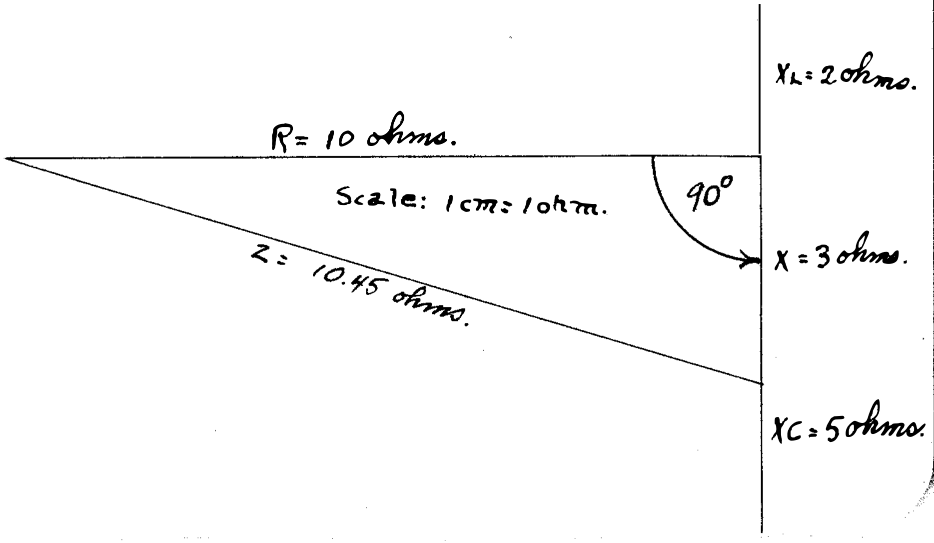
Resistance, inductive reactance, and capacitive may be represented on one Graph by first drawing the horizontal line to represent the resistance, a line at right angles and upward for inductive reactance and another at right angles and downward for capacitive reactance. Subtract one reactance line from the other and draw

ANSWER #33. Continued.

a line from the end of the resulting line to the left end of the resistance line, which will be the impedance. If the capacitive reactance prevails the effect will be capacitive and the impedance line will slant downwards from the left end of the resistance line. If the inductive reactance prevails, the effect will be inductive and the impedance line will slant upward. Inductive reactance is represented as positive and is drawn upward, while capacitive reactance as negative and drawn downward from the end of the resistance line







QUESTION #34. What is the General Law for Alternating current circuits: Show symbols and equations.

ANSWER #34. The General Law for Alternating current circuits is as follows: The current flowing in an alternating current circuit equals the quotient of the voltage divided by the impedance. This is evident when we remember that the impedance is the total opposition to the flow of the current.

Formula: $I = \frac{E}{Z}$

Where:
I = effective current in amperes.
E = effective voltage in volts.
Z = impedance in ohms.

QUESTION #35. What current flows in an AC circuit if 120 volts is applied to 6 ohms impedance?

ANSWER #35. Formula: $I = \frac{E}{Z}$

Substituting: $I = \frac{120}{6}$

I = <u>20 amperes. Ans.</u>

QUESTION #36. What voltage would be required to force 7 amperes through 8 ohms impedance?

ANSWER #36. Formula: $I = \frac{E}{Z}$

Transposing: $E = IZ$

Substituting: $E = 7 \times 8$

E = <u>56 volts. Ans.</u>

QUESTION #37. Compute by equation: What is the impedance in a series circuit containing 30 ohms inductive reactance, 35 ohms capacitive reactance and 16 ohms resistance? Draw the circuit.

ANSWER #37. Formula: $Z = \sqrt{R^2 \text{ plus } (Xl - Xc)^2}$

Substituting: $Z = \sqrt{16^2 \text{ plus } (30 - 35)^2}$

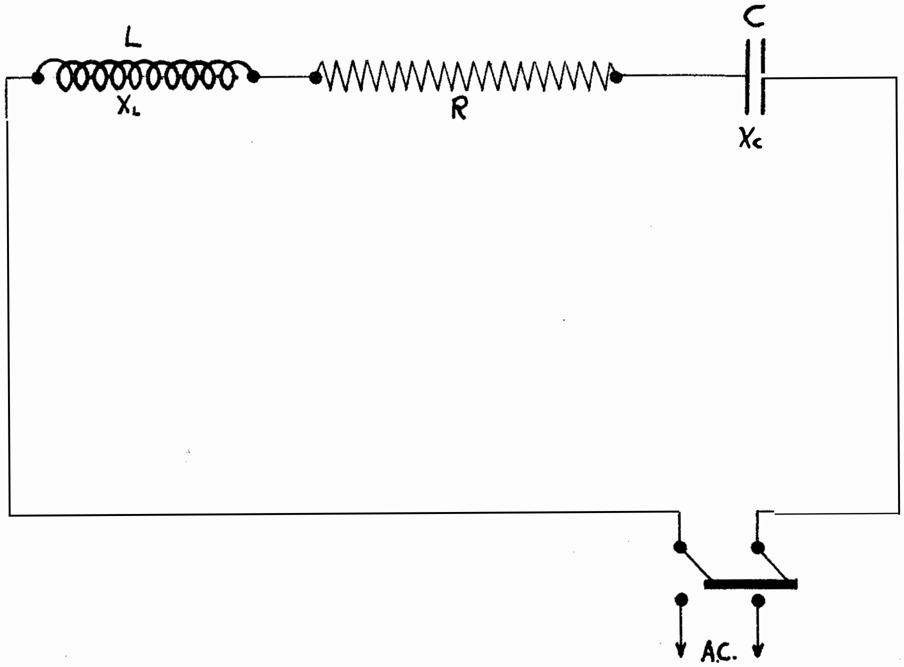
$Z = \sqrt{256 \text{ plus } 25}$

$Z = \sqrt{281}$

Z = <u>16.76 ohms. Ans.</u>

(See next sheet for circuit).

ANSWER #37. Continued.



Alternating Current circuit containing Inductive Reactance, Capacitive Reactance, and Resistance in series.

QUESTION #38. Compute by vector: A 60 cycle, 110 volt, AC circuit has 60 ohms resistance in series with 0.03 henry inductance and 30 mf capacity. Find impedance and current. What would be the impedance if the frequency were reduced to 25 cycles and the capacitance left out of the circuit?

ANSWER #38. Before computing by vector diagram for impedance, it is necessary to compute reactance by equation:

$$Xl = 2pi\ f\ L$$

$$Xl = 6.28 \times 60 \times .03$$

$$Xl = 11.304 \text{ ohms.}$$

- - - -

$$Xc = \frac{1}{2pi\ f\ C}$$

$$Xc = \frac{\cancel{1000000}\ 1250}{\underset{1.57}{\cancel{6}.2\cancel{8}} \times \underset{3}{\cancel{60}} \times 3\cancel{0}} = \frac{1250}{14.13}$$

$$Xc = 88.464 \text{ ohms.}$$

- - - -

$$X = Xl - Xc$$

$$X = 11.304 - 88.464$$

$$X = 77.16 \text{ ohms.}$$

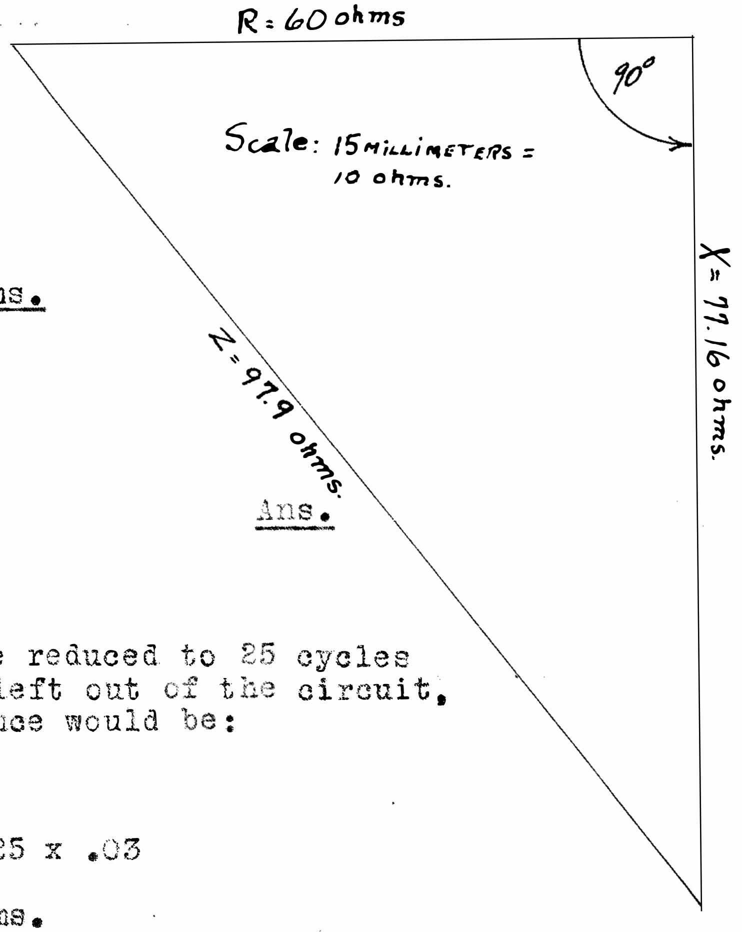
(See next sheet for vector)

ANSWER #38. Continued.

$$I = \frac{E}{Z}$$

$$I = \frac{110}{97.9}$$

I = <u>1.123 amperes. Ans.</u>



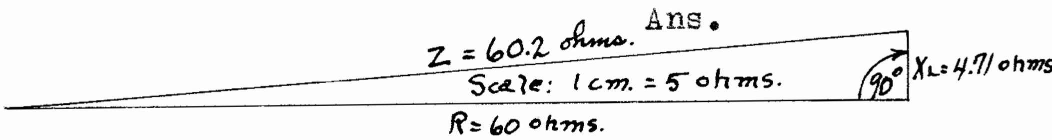
If the frequency were reduced to 25 cycles and the capacitance left out of the circuit, the inductive reactance would be:

Xl = 2pi f L

Xl = 6.28 x 25 x .03

Xl = 4.71 ohms.

Computing by vector diagram for the resultant impedance:



3.6

QUESTION #39. What is the relation of the total current through a series circuit to the current through each part?

ANSWER #39. The current through each part of a series circuit of an alternating current circuit is the same as the current flowing throughout. This is exactly the same as in direct current.

QUESTION #40. What is the relation of the total voltage drop to the voltage drops across the various parts of a series circuit?

ANSWER #40. It is remembered that the total voltage in a series direct current circuit, is the algebraic sum of the voltage drops across each part of the circuit. This is evident when we consider that the voltage flowing in a circuit depends on the opposition offered to the flow of current and to the current flowing. And that the current is always in phase with the voltage because there is no reactance in a direct current circuit. But in an alternating current circuit the inductive reactance causes the current to lag 90° behind the voltage and capacitive reactance causes the current to lead the voltage by 90° , so a voltage forcing a current through reactance, is acting at right angles to a voltage forcing a current through resistance, so it is seen that these two forces acting at right angles to each cannot be added algebraically.But if we find their vector sum we have the total voltage drop across the circuit, which makes apparent the rule: The voltage across a series combination equals the vector sum of the voltages across the separate parts.

QUESTION #41. What is meant by Vector Sum?

ANSWER #41. The length of the hypotenuse of a right triangle is the vector sum of the lengths of the altitude and the base. For instance if we wish to find the vector sum of a voltage drop across an inductive reactance and a voltage drop across a resistance, we draw a horizontal line to any scale representing the voltage drop across the resistance (which is E = IR), then from the left end of this horizontal line or at the intersection of the horizontal and vertical axes of the vector diagram we draw a vertical line upwards (upwards for inductive reactance and downwards for capacitive reactance) to the same scale as used to represent the voltage drop across the resistance, this time to represent the voltage drop across the reactance (which is E=IX1) a perfect rectangle is then completed from the end of the IR line and from the end of the IX1 line, then a diagonal line drawn from the intersection on the base line to the opposite corner of the rectangle will represent the voltage drop across the resistance and the reactance, or the voltage drop across the impedance (which is E = IZ). The divergence of this IZ line from the base line (IR line) will represent the angle of the voltage when the current is zero (The IR line representing the phase angle of the current, the current always being in phase with the resistance. This shows that the phase difference of a current flowing through reactance and resistance is always less than 90°.

QUESTION #42. The following pieces are hooked in series in an Ac circuit. An inductive reactance, capacitive reactance and resistance. The voltage drop across the inductive reactance is 15 volts, across the capacitive reactance 35 volts and 15 volts across the resistance. What is the vector sum of the voltage drops?

ANSWER #42. Computing by equation: Since the hypotenuse of a right triangle equals the square root of the sum of the squares of the base and the altitude, and, since the resistance is represented by the base, and the reactance by the altitude, the impedance may be found by this same equation, or, better we can represent the voltage drop across the resistance by the base line and the voltage drop across the reactance by the altitude, then the hypotenuse will represent the voltage drop across the entire circuit:

$$E = \sqrt{Ed_r^2 \text{ plus } Ed_X^2}$$

$$E = \sqrt{Ed_r^2 \text{ plus } (Ed_{X1} - Ed_{Xc})^2}$$

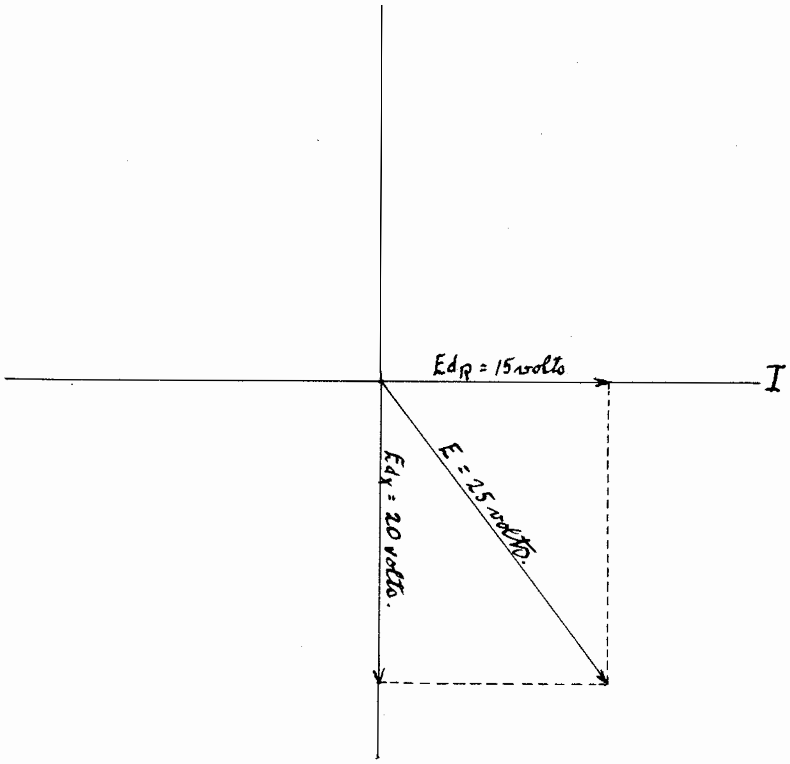
$$E = \sqrt{15^2 \text{ plus } (15 - 35)^2}$$

$$E = \sqrt{225 \text{ plus } 400}$$

$$\begin{array}{l} \quad\;\; 2\;\; 5.\;0\;\;0 \\ E = \sqrt{6'25.00'00} \end{array}$$

$$E = \underline{25 \text{ volts. Ans.}}$$

Computing by vector:



QUESTION #43. How is the phase difference in a series circuit computed by equation when the values of the reactance and resistance are known?

ANSWER #43. Trigonometry tells us that, when the length of the adjacent side and the length of the opposite side are known and the angle is desired, divide the opposite side by the adjacent side and the result will be the tangent of the angle, look the tangent up in a table of tangents and the desired degree of angle will be found. Since the Reactance is represented by the opposite side and the resistance by the adjacent side of a right triangle we need only divide the reactance by the resistance to find the phase difference between the voltage and the current, since we always represent the current as being in phase with the resistance and the voltage in phase with the impedance.

Formulae: $\text{Tan } A = \frac{a}{b} = \frac{X}{R}$

Where:
a = opposite side of right triangle.
b = adjacent side of right triangle.
X = Reactance.
R = Resistance.

If the Capacitive Reactance prevails and the Reactance line is drawn downward from the base line, the phase difference represents the current as leading the voltage by that amount. If the Inductive Reactance prevails and the Reactance line is drawn upward from the base line, the phase difference represents the current as lagging the voltage by that amount, rotation being counter clockwise in the vector diagram.

QUESTION #44. A 60 cycle, AC circuit, consists of the following pieces:

(1) An inductance coil of 9 ohms inductive reactance and 8.2 ohms resistance.
(2) A capacitive reactance of 2.5 ohms.
(3) A 0.03 henry inductance coil with 0.4 ohms resistance.
(4) A 12 microfarad condenser.
(5) An inductive reactance of 10 ohms with 40 ohms resistance.

Find the voltage drop across the condenser if 2.5 amperes is flowing in the circuit. Find the total voltage drop across the combination. What is the impedance of the circuit? (Compute for phase difference and for impedance by vector).

ANSWER #44. Xl across (3) = 2pi f L

Xl = 6.28 x 60 x .03 = 11.304 ohms.

Total Xl = 9 plus 11.304 plus 10 = 30.304 ohms.

$$\text{Xc across (4)} = \frac{1000000}{6.28 \times 60 \times 12} = 221.66 \text{ ohms.}$$

Total Xc = 2.5 plus 221.66 = 223.66 ohms

(continued on next sheet)

ANSWER #44. Continued.

Total R = 8.2 plus 0.4 plus 40 = 48.6 ohms.

X = Xl - Xc

X = 30.304 - 223.667

X = 193.363 ohms (capacitive effect).

- - - - - - -

Voltage drop across condenser (4):

Ed = IXc

Ed = 2.5 x 221.16

Ed = 552.9 volts. Ans.

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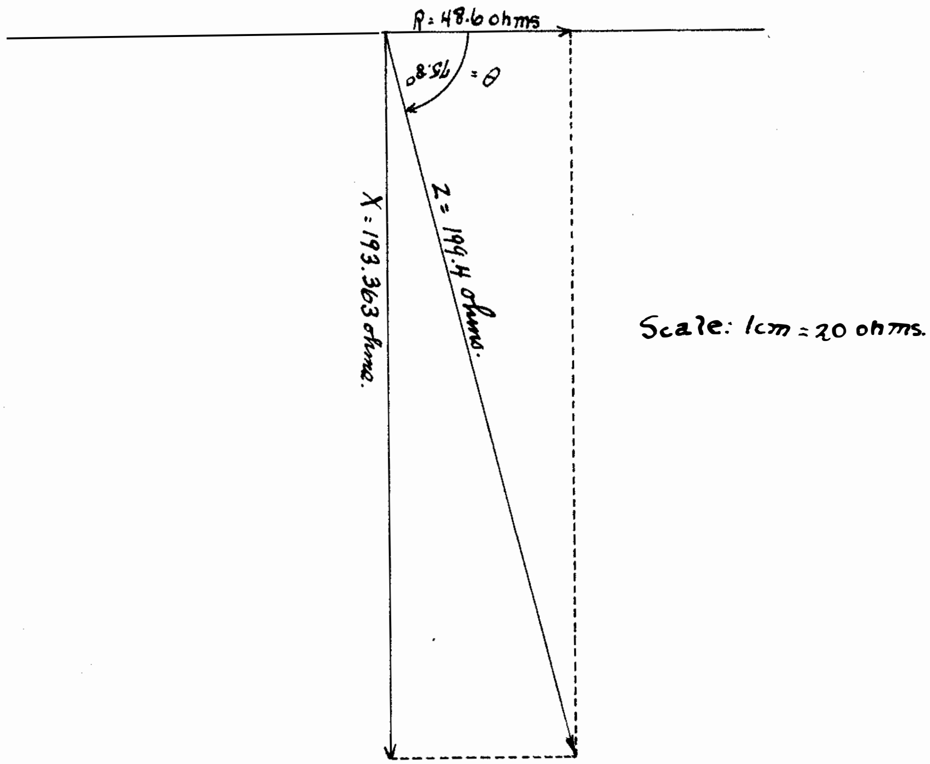
Computing by vector for impedance and phase difference



By vector, impedance = 199.4 ohms. Ans.

By vector, phase difference= 75.8° (current leading)Ans.

Total voltage drop across the combination:

E = IZ

E = 2.5 x 199.4

E = 498.5 volts. Ans.

QUESTION #45. When is a series circuit said to be in resonance?

ANSWER #45. In an alternating current circuit, when the capacitive reactance is equal to the inductive reactance, the circuit is said to be in resonance. That is, the reactance is zero and a maximum current will flow. An increase in frequency will decrease capacitive reactance and increase inductive reactance, therefore a circuit which is resonant (that is, offers least impedance) to one frequency will offer high impedance to a voltage of another frequency.

QUESTION #46. What impedance does a series circuit offer to the current when it is in resonance?

ANSWER #46. When a series alternating current is in resonance it will offer the least impedance to the flow of current. That is, it will allow a maximum current to flow. A combination of resistance and reactance will offer more opposition to the flow of current than will resistance alone, and, since inductive reactance has an opposite effect than capacitive reactance, one will neutralize the other, so, if the inductive reactance and the capacitive reactance balance each other the resulting reactance will be zero and the impedance of the circuit will be the resistance.

QUESTION #47. A series circuit has an inductance of 0.04 henry and a resistance of 2.5 ohms. How much capacitance must be added to produce resonance at 500 cycles per second? After the capacitance has been added to the circuit, how much more impedance will the circuit offer to impulses of a frequency of 200 cycles per second than to impulses of 500 cycles per second?

ANSWER #47. Formula: $Xl = 2pi\ f\ L$

$$Xl = 6.28 \times 500 \times .04$$

$$Xl = 125.6 \text{ ohms.}$$

For resonance: $Xl = Xc$

Therefore: $$2pi\ f\ L = \frac{1000000}{2pi\ f\ C}$$

Transposing: $$0 = \frac{\frac{1000000}{2pi\ f\ C}}{2pi\ f\ L}$$

$$0 = \frac{1000000}{2pi\ f\ C} \times \frac{1}{2pi\ f\ L}$$

Multiplying: $$0 = \frac{1000000}{2pi^2 \times f^2 \times L \times C}$$

Moving "C" to left side of equation: $$C = \frac{1000000}{2pi^2 \times f^2 \times L}$$

(Continued on next sheet)

ANSWER #47. Continued.

Square rooting both sides of equation:

$$\sqrt{C} = \frac{1000}{2pi \times f \times \sqrt{L}}$$

Squaring both sides of equation:

$$C = \left(\frac{1000}{2pi \times f \times \sqrt{L}}\right)^2$$

Substituting:

$$C = \left(\frac{1000}{6.28 \times 500 \times \sqrt{.04}}\right)^2$$

$$C = \left(\frac{\overset{\overset{1}{\cancel{2}}}{\cancel{1}\cancel{0}\cancel{0}\cancel{0}}}{\underset{3.14}{\cancel{6}.2\cancel{8}} \times \cancel{5}\cancel{0}\cancel{0} \times .2}\right)^2$$

$$C = \left(\frac{1}{.628}\right)^2$$

$$C = (1.5921)^2$$

$$C = \underline{2.53478241 \text{ microfarads.Ans.}}$$

The circuit would be resonant if this amount of capacitance were added to the circuit. Since the circuit is resonant, the capacitive reactance equals the inductive reactance. Therefore the resulting reactance is zero and the impedance of the circuit is equal to the resistance: 2.5 ohms.

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At a frequency of 200 cycles:

$$Xl = 6.28 \times 200 \times .04$$

$$Xl = 50.24 \text{ ohms.}$$

\- - - - - - -

$$Xc = \frac{\overset{625}{1\cancel{0}\cancel{0}\cancel{0}\cancel{0}\cancel{0}\cancel{0}}}{\underset{1.57}{\cancel{6}.2\cancel{8}} \times 2\cancel{0}\cancel{0} \times 2.53} = \frac{625}{1.99}$$

$$Xc = 313.49 \text{ ohms.}$$

\- - - - - - -

$$X = Xl - Xc$$

$$X = 50.24 - 313.49$$

$$X = -263.25 \text{ ohms}$$

\- - - - - - -

$$Z = \sqrt{R^2 \text{ plus } X^2}$$

$$Z = \sqrt{2.5^2 \text{ plus } 263.25^2}$$

$$Z = \sqrt{6.25 \text{ plus } 69300.5625}$$

(Continued on next sheet)

ANSWER #47. Continued.

```
           2  6  3. 2  6  1
   Z   = √6 93 06.81 25 00
          4
     46: 2 93
       : 2 76
    523:   17 06
       :   15 69
   5262:    1 37 81
       :    1 05 24
  52646:      32 57 25
       :      31 58 76
 526521:         98 49 00
       :         52 65 21
       :         45 83 79
```

Impedance at 200 cycles: 263.261 ohms
Impedance at 500 cycles: 2.5 ohms
260.761 ohms

Therefore, amount of impedance added by changing frequency to 200 cycles is 260.761 ohms. Ans.

QUESTION #48. What is the relation of the total current through a parallel AC circuit to the currents through its branches? What is the voltage relation?

ANSWER #48. In a parallel alternating current circuit, the total current is the vector sum of the current through each of the branches. The voltage across a parallel combination is the same as the voltage across each branch of the combination, just as in a direct current circuit. To compute the total current in a parallel circuit, when only the values of resistance and reactance are known, assume a voltage, divide the voltage by the impedance of each branch by the impedance of each separate branch. This will give the assumed current for that branch. Plot these resultant currents on a vector diagram according to their phase angle. For instance, if one branch of the parallel circuit contains inductance only (resistance negligible) the assumed current would be plotted as lagging the voltage by 90° and, if another branch of the circuit contained pure capacitance, the assumed current would be plotted as leading the voltage by 90°, and, if a third branch contained resistance only, the assumed current for that branch would be plotted on the base line which represents the phase angle of the voltage, that is, the resistance is such that the current flowing through it is always in phase with the voltage. If these lines are drawn to scale, rectangles completed, and resultant diagonals drawn the result will give the value of assumed current flowing through the combination, and the amount of divergence of this current line from the base, or voltage, line will give the phase difference. If below the line, lagging and if above the line leading.

QUESTION #49. How is the impedance of a parallel AC circuit computed

ANSWER #49. The General Law for Alternating Current circuits state that the current flowing in an alternating current circuit equals the quotient of the voltage divided by the impedance, therefore, the impedance is equal to the voltage across a parallel combination divided by the current through the combination. If the voltage is not known, the best rule is to assume a voltage. The impedances of each branch is found separately by method explained under series circuits, at the same time finding the phase angle of the current through each particular branch. Then the assumed voltage is divided, in each case by the impedance of that particular branch, and these values are plotted to scale on a vector diagram, with the proper phase angle for each particular branch. After the rectangles are completed, the resultant diagonal will measure to scale the value of the current flowing through the combination. Then it is only necessary to divide the assumed voltage by the value of current found to find the impedance of the combination (It is well to remmember to use the same assumed voltage throughout the problem).

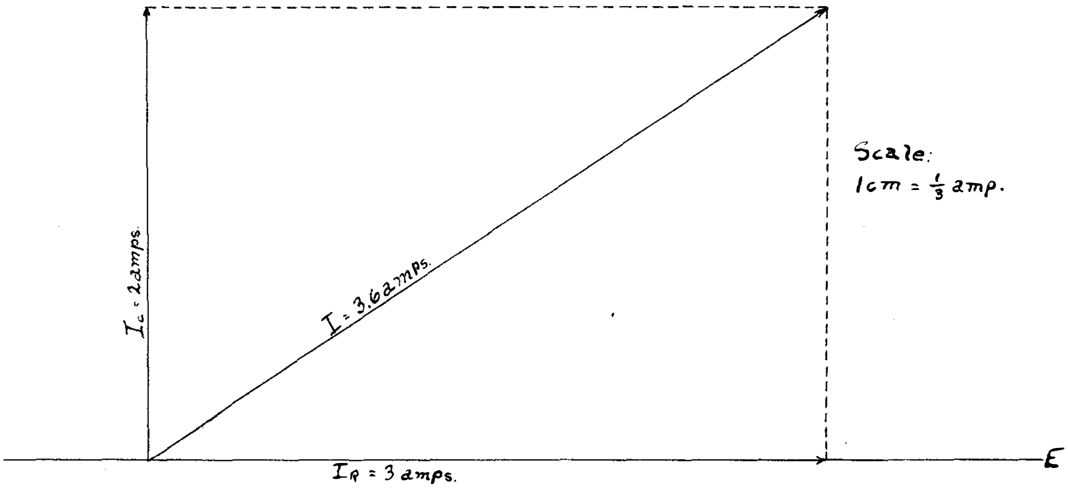
QUESTION #50. A capacitive reactance of a parallel AC circuit is 6 ohms and a resistance is 4 ohms. What is the impedance of the circuit?

ANSWER #50. Assuming a voltage of 12 volts:

$$Ic = \frac{E}{Xc} = \frac{12}{6} = 2 \text{ amperes.}$$

$$Ir = \frac{E}{R} = \frac{12}{4} = 3 \text{ amperes.}$$

The current through the capacitive reactance is at a 90° angle to the current through the resistance. Plotting by vector for the resultant current:



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ANSWER #50. Continued.

Checking by equation:

Since the current through Xc is acting at right angles to the current through R, the resultant current can be found by triangle formula:

$$c^2 = a^2 \text{ plus } b^2$$

Therefore: $I^2 = Ic^2 \text{ plus } Ir^2$

and $I = \sqrt{Ic^2 \text{ plus } Ir^2}$

Substituting: $I = \sqrt{2^2 \text{ plus } 3^2}$

$$I = \overset{3.605}{\sqrt{13.000000}}$$

For impedance:

$$Z = \frac{E}{I}$$

$$Z = \frac{12}{3.6}$$

$Z =$ <u>3.33 ohms. Ans.</u>

QUESTION #51. An inductive reactance of 9 ohms with 3 ohms resistance is placed in parallel with a 7 ohms resistor. What is the current through the circuit if the voltage drop across the circuit is 12o volts, 60 cycles, AC? What is the phase relation of the current and voltage?

ANSWER #51. Computing by equation for impedance of first branch:

$$Z_1 = \sqrt{R_1{}^2 \text{ plus } Xl_1{}^2}$$

$$Z_1 = \sqrt{9^2 \text{ plus } 3^2}$$

$$Z_1 = \sqrt{81 \text{ plus } 9}$$

$$Z_1 = \overset{9.\ 4\ \ 8}{\sqrt{90.00'00}}$$

$Z_1 = 9.48$ ohms.

Angle of lag thru first branch:

$$\text{Tan } \theta = \frac{Xl}{R}$$

$$\text{Tan } \theta = \frac{9}{3} = 3.0000$$

$$\theta = 71.5667° \text{ lag}$$

Since the second branch contains resistance only, the impedance is equal to the resistance.

$Z_2 = 7$ ohms. Current in phase with voltage.

We are given a voltage of 120 volts, but it simplifies calculation if we assume a convenient voltage:

Assuming voltage of 9.48 x 7 volts:

$$I_1 = \frac{E}{Z_1} = \frac{9.48 \times 7}{9.48} = 7 \text{ amperes.}$$

(continued on next sheet)

ANSWER #51. Continued.

$$I_2 = \frac{E}{Z_2} = \frac{9.48 \times 7}{7} = 9.48 \text{ amperes.}$$

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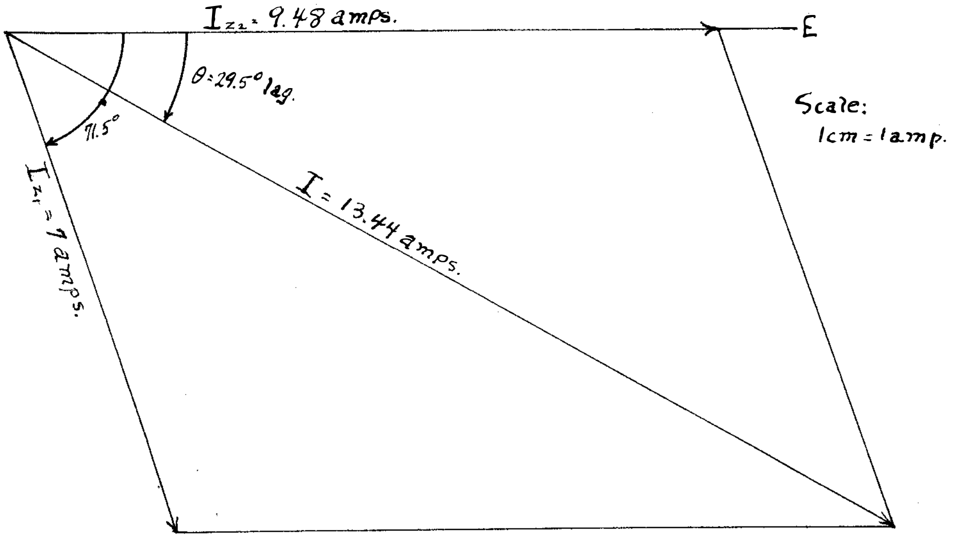
Plotting by vector for resultant current:



Computing for impedance:

$$Z = \frac{E}{I} = \frac{\overset{2.37}{\cancel{9.48}} \times 7}{\underset{3.36}{\cancel{13.44}}} = \frac{16.59}{3.36} = 4.937 \text{ ohms.}$$

Resultant current if voltage drop across circuit is 120V:

$$I = \frac{E}{I} = \frac{120}{4.937} = \underline{24.3 \text{ amperes. Ans.}}$$

Phase relation of the current and voltage through the combination:

The current is <u>lagging the voltage by 29.5° Ans.</u>

QUESTION #52. A parallel combination consisting of three branches, A, B, and C. Branch A consists of an inductive reactance of 40 ohms with 30 ohms resistance. Branch B has 70 ohms resistance. Branch C contains a capacitive reactance of 30 ohms and a resistance of 20 ohms.

(a) What current flows thru the circuit if the combination is placed across a 220 volt, 60 cycle, AC circuit?

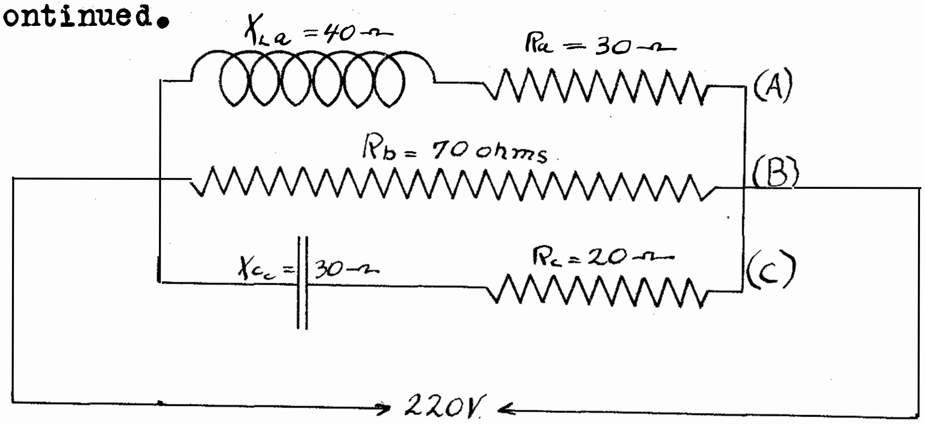
(b) What is the phase relation between the voltage and current?

(c) What impedance does the circuit offer to the current?

Draw the circuit.

(Answer on next sheet)

ANSWER #52. Continued.



$$Z_a = \sqrt{R_a^2 \text{ plus } Xl_a^2}$$

$$Z_a = \sqrt{30^2 \text{ plus } 40^2}$$

$$Z_a = \sqrt{900 \text{ plus } 1600}$$

$$Z_a = \sqrt{\overset{5\ \ 0}{2500}}$$

Z_a = 50 ohms.

$$\text{Tan } \theta_a = \frac{Xl_a}{R_a}$$

$$\text{Tan } \theta_a = \frac{40}{30}$$

$$\text{Tan } \theta_a = 1.3333$$

θ_a = 53.1333° lagging

$Z_b = R_b$ = 70 ohms.

θ_b= 0°, or "in phase"

$$Z_c = \sqrt{R_c^2 \text{ plus } Xc_c^2}$$

$$Z_c = \sqrt{20^2 \text{ plus } 30^2}$$

$$Z_c = \sqrt{400 \text{ plus } 900}$$

$$Z_c = \sqrt{\overset{3\ \ \ 6.\ 0\ \ \ 5\ \ \ 5}{13'00.00'00'00}}$$

Z_c = 36.055 ohms.

$$\text{Tan } \theta_c = \frac{Xc_c}{R_c}$$

$$\text{Tan } \theta_c = \frac{30}{20}$$

$$\text{Tan } \theta_c = 1.5000$$

θ_c = 56.3167°

$$I_a = \frac{E}{Z_a} = \frac{220}{50} = 4.4 \text{ amperes.}$$

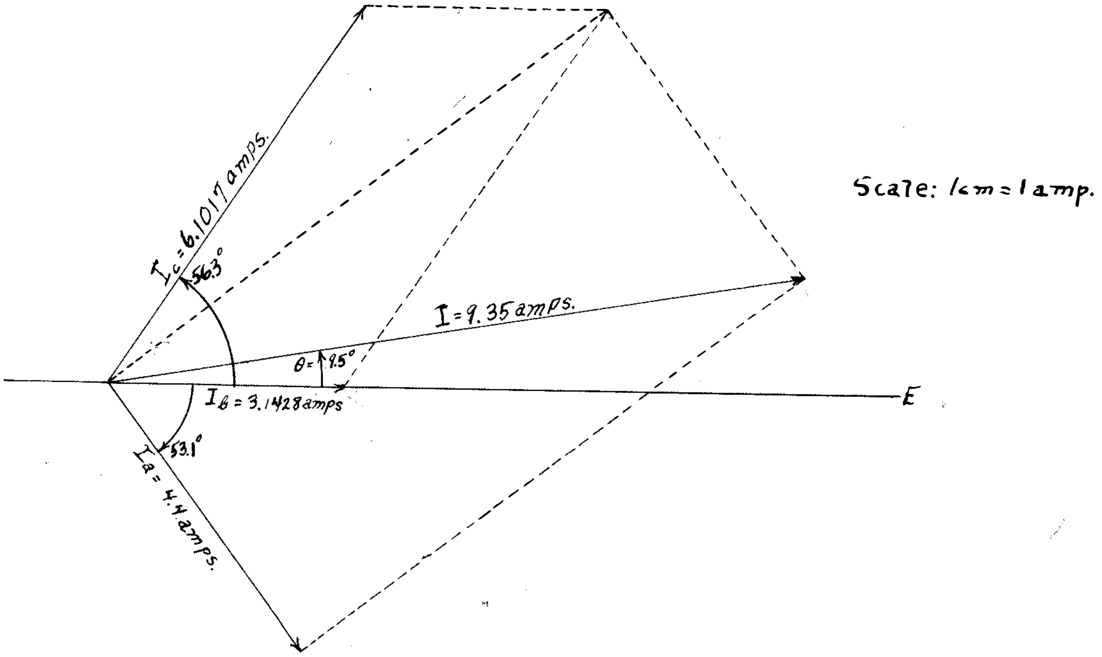
$$I_b = \frac{E}{Z_b} = \frac{E}{R} = \frac{220}{70} = 3.1428 \text{ amperes.}$$

$$I_c = \frac{E}{Z_c} = \frac{220}{36.055} = 6.1017 \text{ amperes.}$$

I is equal to the vector sum of I_a, I_b, and I_c

(Continued on next sheet)

ANSWER #52. Continued.   Plotting by vector for resultant current:



(a) When combination is placed across a 220 volt, 60 cycle AC circuit, the current flowing thru the circuit is 9.35 amperes. Ans.

(b) The phase relation of the voltage and current is: The current leads the voltage by 9.5° Ans.

(c) The impedance offered to the current by the circuit:

$$Z = \frac{E}{I} = \frac{220}{9.35} = 23.52 \text{ ohms. Ans.}$$

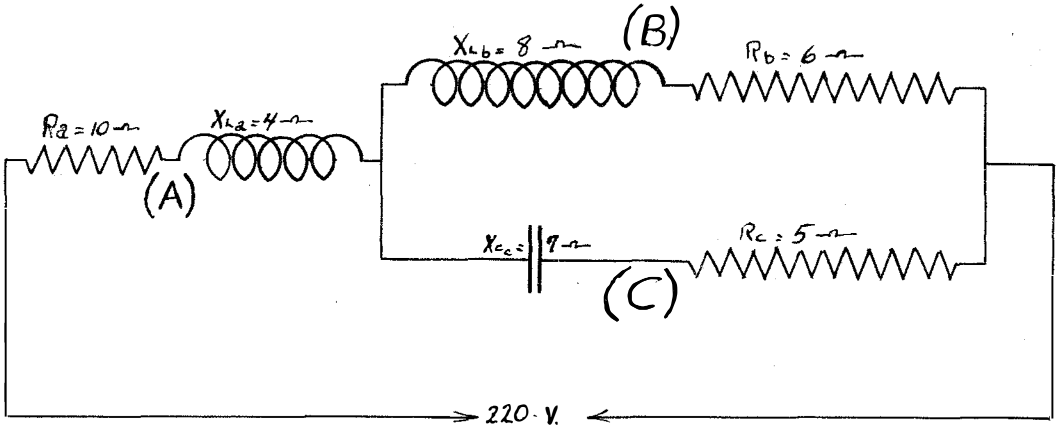
QUESTION #53. A series parallel combination consisting of a series branch A which has 10 ohms resistance and 4 ohms inductive reactance. Parallel combination made up with two branches B and C. Branch B has 8 ohms inductive reactance and 6 ohms resistance. Branch C has a resistance of 5 ohms and 7 ohms capacitive reactance. The voltage drop across the circuit is 220 volts. Draw the circuit. Find:

(a) Impedance of the combination.
(b) Current through the combination.
(c) Phase relation between voltage and current.
(d) Current thru branches A, B, and C.
(e) Voltage drop across series branch; parallel.
(f) Current thru branch B and C.

ANSWER #53.

(See next sheet for diagram of circuit).

ANSWER #53. Continued.



$Z_b = \sqrt{R_b{}^2 \text{ plus } Xl_b{}^2}$

$Z_b = \sqrt{6^2 \text{ plus } 8^2}$

$Z_b = \sqrt{36 \text{ plus } 64}$

$Z_b = \overset{1\ 0.}{\sqrt{100.}}$

$Z_b = 10$ ohms.

$\text{Tan } \theta_b = \dfrac{Xl_b}{R_b}$

$\text{Tan } \theta_b = \dfrac{8}{6}$

$\text{Tan } \theta_b = 1.3333$

$\theta_b = 53.1333°$ lagging.

- -

$Z_c = \sqrt{R_c{}^2 \text{ plus } Xc_c{}^2}$

$Z_c = \sqrt{5^2 \text{ plus } 7^2}$

$Z_c = \sqrt{25 \text{ plus } 49}$

$Z_c = \overset{8.\ 6\ \ 0\ \ 2}{\sqrt{74.00'00'00}}$

$Z_c = 8.602$ ohms.

$\text{Tan } \theta_c = \dfrac{Xc_c}{R_c}$

$\text{Tan } \theta_c = \dfrac{7}{5}$

$\text{Tan } \theta_c = 1.4000$

$\theta_c = 54.4667°$ leading.

- -

Although any voltage can be assumed, it is more convenient to assume a product of the two impedances: 10 x 8.602:

$$I_b = \frac{E}{Z_b} = \frac{\cancel{10} \times 8.602}{\cancel{10}} = 8.6\cancel{0}\cancel{2} \text{ amperes.}$$

$$I_c = \frac{E}{Z_c} = \frac{10 \times \cancel{8.602}}{\cancel{8.602}} = 10 \text{ amperes.}$$

- -

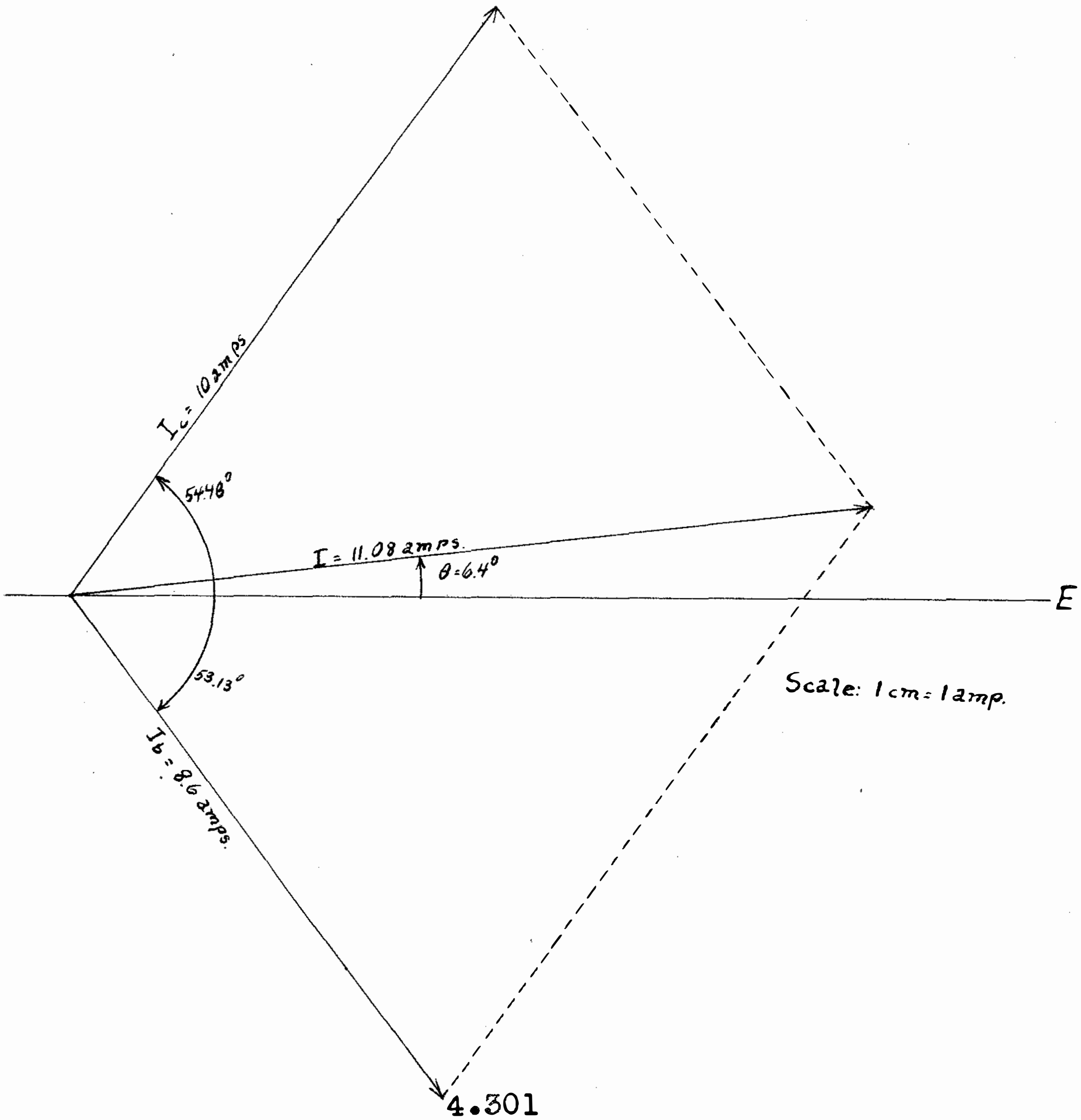
The current through the parallel branch is the vector sum of the current through each branch.

- -

(See next sheet for vector diagram).

ANSWER #53. Continued.

Plotting for resultant current by vector:



$$Z_{bc} = \frac{E}{I_{bc}} = \frac{\overset{4.301}{\cancel{1}0 \times \cancel{8}.\cancel{6}0\cancel{2}}}{\begin{array}{c}\cancel{1}\cancel{1}.0\cancel{8}\\ \cancel{1}.\cancel{1}0\cancel{8}\\ .554\end{array}} = 7.761 \text{ ohms. } \theta_{bc} = 6.4° \text{ leading.}$$

- -

$Z_a = \sqrt{R_a{}^2 \text{ plus } Xl_a{}^2}$

$Z_a = \sqrt{10^2 \text{ plus } 4^2}$

$Z_a = \sqrt{100 \text{ plus } 16}$

$Z_a = \overset{1\ 0.\ 7\ 7}{\sqrt{116.0000}}$

$Z_a = 10.77$ ohms.

$\text{Tan } \theta_a = \frac{Xl_a}{R_a}.$

$\text{Tan } \theta_a = \frac{4}{10}$

$\text{Tan } \theta_a = .4000$

$\theta_a = 21.8°$ lagging

- -

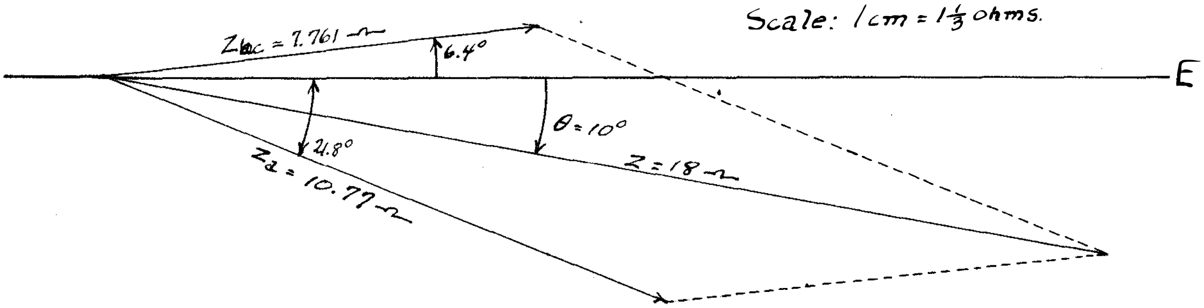
We have now resolved the series parallel circuit down to a simple series circuit, with two impedances in series. AC laws tell us that the impedance of a series circuit is the vector sum of the separate impedances.

- -

(See next sheet for vector diagram).

ANSWER #53. Continued.

Plotting by vector for total impedance:



(a) Impedance of combination: 18 ohms Ans.

(b) Current thru combination: $I = \frac{E}{Z} = \frac{220}{18}$

$I = 12.222$ amps. Ans.

(c) Phase relation: Current lags voltage by 10° Ans.

(d) Current thru A: The current throughout a series circuit is the same thru each part. 12.222 amps Ans

Current thru B: $I_b = \frac{Ed_b}{Z_b} = \frac{94.854}{10} = 9.4854$ amps Ans

Current thru C: $I_c = \frac{Ed_c}{Z_c} = \frac{94.854}{8.602} = 11.015$ amps Ans

(e) Voltage drop in series branch: $Ed_a = IZ_a$

$Ed_a = 12.222 \times 10.77$

$Ed_a = 131.63$ volts

Voltage drop in Parallel: $Ed_{bc} = IZ_{bc}$

$Ed_{bc} = 12.222 \times 7.761$

$Ed_{bc} = 94.854$ volts Ans.

(f) Current through the parallel combination is the same as the current through the whole combination being the vector sum of the currents in each branch of the parallel circuit, therefore, $I_{bc} = 12.222$ am

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SEVENTEENTH WEEK.
ALTERNATING CURRENT.

QUESTION #54. When is a parallel A.C. circuit said to be in resonance?

ANSWER #54. When the lagging component of current equals the leading component, the parallel circuit is said to be in resonance.

QUESTION #55. What impedance does it offer to the current when it is in resonance?

ANSWER #55. When a parallel circuit is in resonance it offers a maximum impedance to the flow of current, therefore, for a given voltage the current will be minimum.

QUESTION #56. A parallel circuit consists of the following pieces: A resistance of 50 ohms and an inductive reactance of 30 ohms in parallel with a resistance of 25 ohms and a capacitive reactance which is unknown. What value must the capacitive reactance have at this frequency in order to produce resonance in the parallel circuit?

(b) If the 25 ohms resistance is left out of the capacitive branch, what value must the capacitive reactance have if the current through the combination is to be minimum when 1000 volts are applied?

ANSWER #56.

R_1 = 50 ohm resistor in inductive branch.
$X1$ = inductive reactance.
R_2 = 25 ohm resistor in capacitive branch.
Xc = capacitive reactance.
Z_1 = impedance of inductive branch.
Z_2 = impedance of capacitive branch.
$I1$ = current through inductive branch.
I_2 = current through capacitive branch.
i_1 = instantaneous current through inductive branch
i_2 = " " through capacitive branch.

$$Z_1 = \sqrt{R_1^2 \text{ plus } X1^2}$$

$$Z1 = \sqrt{50^2 \text{ plus } 30^2}$$

$$Z1 = \sqrt{2500 \text{ plus } 900}$$

$$Z1 = \sqrt{3400}$$

$$Z1 = 58.31 \text{ ohms.}$$

$$I1 = \frac{E}{Z_1} = \frac{500}{58.31} \text{ (assumed voltage)}$$

$$I1 = 8.575 \text{ amps.}$$

$$\text{Sin } \theta = \frac{X1}{Z_1}$$

ANSWER #56. Continued.

$$i_1 = I_1 \text{ x } \text{Sin } \theta$$

$$i_1 = I_1 \text{ x } \frac{X1}{Z_1}$$

$$i_1 = \frac{8.575 \text{ x } 30}{58.31} = \frac{257.25}{58.31}$$

$$\underline{i_1 = 4.4115 \text{ amps.}}$$

For resonance: $i_1 = i_2$

$$i_1 = I_2 \text{ x } \frac{Xc}{Z_2}$$

$$i_1 = \frac{E}{\sqrt{R_2{}^2 \text{ plus } Xc^2}} \text{ x } \frac{Xc}{\sqrt{R_2{}^2 \text{ plus } Xc^2}}$$

$$4.4115 = \frac{500}{\sqrt{25^2 \text{ plus } Xc^2}} \text{ x } \frac{Xc}{\sqrt{25^2 \text{ plus } Xc^2}}$$

$$4.4115 = \frac{500Xc}{625 \text{ plus } Xc^2}$$

Transposing:

$$625 \text{ plus } Xc^2 = \frac{\overset{100}{\cancel{500}}Xc}{\underset{.8823}{\cancel{4.4115}}}$$

$$625 \text{ plus } Xc^2 = 113.34Xc$$

Transposing to take the form of: ax^2 plus bx plus c = 0.

$$Xc^2 - 113.34Xc \text{ plus } 625 = 0.$$

Solving the affected quadratic equation of the form:

$$ax^2 \text{ plus } bx \text{ plus } c = 0.$$

Where:
a = coefficient of x^2
b = coefficient of x
c = coefficient of terms not containing x.

By use of the formula:

$$x = \frac{-b \begin{smallmatrix}\text{plus}\\ \text{minus}\end{smallmatrix} \sqrt{b^2 - 4ac}}{2a}$$

ANSWER #56. Continued.

Substituting:

$$x = \frac{113.34 \substack{\text{plus} \\ \text{minus}} \sqrt{(-113.34)^2 - 4(1 \times 625)}}{2 \times 1}$$

$$x = \frac{113.34 \substack{\text{plus} \\ \text{minus}} \sqrt{10345.9556}}{2}$$

$$x = \frac{113.34 \substack{\text{plus} \\ \text{minus}} 101.71}{2}$$

$$x = \frac{113.34 \text{ plus } 101.71}{2}$$

$$x = \underline{107.525 \text{ ohms. Ans.}}$$

$$x = \frac{113.34 \text{ minus } 101.71}{2}$$

$$x = \underline{5.815 \text{ ohms. Ans.}}$$

Therefore, the circuit will be resonant if the capacitive reactance has a value of either 107.525 ohms, or 5.815 ohms.

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(b)

E across branch = 1000 volts.

$$I_1 = \frac{E}{Z_1} = \frac{1000}{58.31} = 17.149 \text{ amps.}$$

For resonance:

$$i_1 = i_2$$

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$$i_1 = I_1 \times \sin \theta$$

$$i_1 = 17.149 \times \frac{30}{58.31} = \frac{514.470}{58.31}$$

$$i_1 = 8.823 \text{ amps.}$$

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Since there is no resistance in the capacitive branch, I_2 is equal to i_2, and for resonance i_2 is equal to i_1 therefore i_2 = 8.823 amps.

$$Xc = Z_2. \quad Z_2 = \frac{E}{I_2}$$

$$\therefore \quad Xc = \frac{Ec}{I_2} = \frac{1000}{8.823} = \underline{113.34 \text{ ohms. Ans.}}$$

QUESTION #57. Explain briefly resonance in series parallel circuits.

ANSWER #57. Series resonance produces minimum impedance and parallel resonance produces maximum impedance. Therefore, if the two are combined in one circuit, the parallel branch can be tuned so that it is resonant to the frequency which is desired to be shut out, while the series part may be tuned so that it is resonant to the desired frequency. This feature is made use of in radio work and such a circuit is called a filter. The proper procedure is to connect a coil and resistor in parallel with a condenser, the tuning of the parallel circuit being accomplished by means of the variable condenser. In the series part there is another variable condenser, which is tuned to provide series resonance, or minimum impedance to the desired frequency, thus allowing a maximum current to flow.

QUESTION #58. What is meant by power factor? Where obtained?

ANSWER #58. The cosine of the angle of lead or lag of the current is called the power factor and it is the factor by which the apparent power must be multiplied in order to obtain the true power. The reason for this is that when the voltage and current are out of phase part of the power is being returned to the generator at such instants as the voltage is positive and the current negative or vice versa. It can be seen that the instantaneous power is always the product of the instantaneous current and the instantaneous voltage. If the current is in phase with the voltage, the voltage and current change from positive to negative at the same instant, therefore, the power is always positive, since like signs produce a positive product. But if the current and voltage are out of phase, the current will be either positive or negative with respect to the voltage for an instant, thus their product will be negative at that instant, which indicates that part of the power is being returned to the generator. The power in any circuit is the power consumed overcoming resistance, and, since part of this power is being returned to the generator, the power consumed must be only a part of the total power generated. To find this, it is necessary to determine the component of the current in phase with the voltage, or:

$$P = EI_r$$

but: $I_r = I \cos \theta$

therefore: $P = EI \cos \theta$

QUESTION #59. Explain briefly reactive or wattless component of current

ANSWER #59. Since there is no power consumed in forcing the reactive component of current Ix through the circuit, this component is sometimes called the wattless component of the current. The reason why it requires no power to force the wattless component thru the circuit can be understood if we consider that the power taken by this current is used either to charge a condenser or to set up a cemf in a coi which of course helps to send the current back to the generator as the emf reverses.

QUESTION #60. How does the phase angle affect the power in an A.C. circuit?

ANSWER #60. The phase angle of lag or lead of the current determines the power consumed. The more the reactance in the circuit the greater will the phase angle be, and the greater the angle the less will the power be. This is evident when one considers that the power is the product of the voltage times the current times the cosine of the angle. From a table of cosines, it can be seen that when the angle is 0° the cosine will be unity and thus the power will be maximum, while as the angle increases the cosine decreases, thus the power decreases.

QUESTION #61. An AC circuit is operated at 85% power factor. What is the relation between the voltage and the current?

ANSWER #61. Power factor is always expressed in percent, as the power in a circuit where the current is out of phase, is always a certain percent of the total current, or the product of the effective current and effective voltage. To change the power factor expressed in % back to a decimal, the cosine of the angle, divide by 100.

$$\cos \theta = \frac{\text{power factor in \%}}{100}$$

$$\cos \theta = \frac{85}{100}$$

$$\cos \theta = .85$$

$$\theta = \underline{31.7833^\circ \text{ Ans.}}$$

Therefore, the current either leads or lags the voltage by 31.7833°

QUESTION #62. There are 9 amperes flowing in an AC circuit under a pressure of 220 volts. If the current is leading the voltage by 35°, what would be the power consumed in the circuit?

ANSWER #62. Formula: $P = EI\cos\theta$

$$\cos 35^\circ = .819$$

$$P = 220 \times 9 \times .819$$

$$P = \underline{1621.620 \text{ watts. Ans.}}$$

QUESTION #63. What is the resultant power in a circuit if the current leads or lags the voltage by 90°?

ANSWER #63. If the current leads or lags the voltage by 90°, it indicates that the circuit contains pure capacity or pure inductance, with negligible resistance, thus there is no current in phase with the voltage, and, since the only power used or consumed is that used to overcome resistance the power is zero.

Formula: $P = EI\cos\theta$. $\cos 90^\circ = 0$.

$P = E \times I \times 0 = 0$. Ans.

QUESTION #64. A 0.15 henry inductance coil with 4 ohms resistance is placed on a 60 cycle, 110 volt, AC circuit. What is the power factor? What power is consumed by the coil?

ANSWER #64. Formula: $Xl = 2\pi fL$

$Xl = 6.28 \times 60 \times 0.15$

$Xl = 56.52$ ohms.

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$Z = \sqrt{R^2 \text{ plus } Xl^2}$

$Z = \sqrt{4^2 \text{ plus } 56.52^2}$

$Z = \sqrt{3210.5104}$

$Z = 56.66$ ohms.

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$I = \frac{E}{Z} = \frac{110}{56.66}$

$I = 1.9414$ amps.

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$\text{Tan } \theta = \frac{Xl}{R} = \frac{56.52}{4}$

$\text{Tan } \theta = 14.13$

$\theta = 85.958°$ lag.

$\text{Cos } \theta = .07063$

Power factor $= .07063 \times 100 =$ 7.063% Ans.

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$P = EI\cos\theta$

$P = 110 \times 1.9414 \times .07063$

$P =$ 15.0833 watts. Ans.