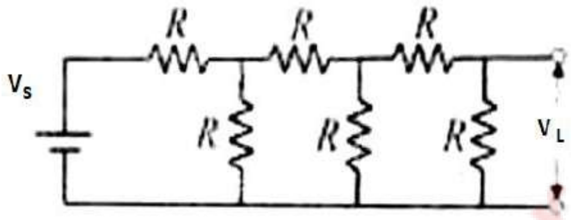
BEE QUESTION PAPER SOLUTION

MAY 2017 (CBCGS)

Q1] a) Find the ratio $\frac{V_L}{V_s}$ in the circuit shown below using Kirchoff's law (4)



Solution:-

As all the resistors are connected in parallel so total parallel resistance can be calculated as below:-

$R = \frac{1}{R} + \frac{1}{R} = \frac{R}{2}$

In this way calculating for whole circuit we get,

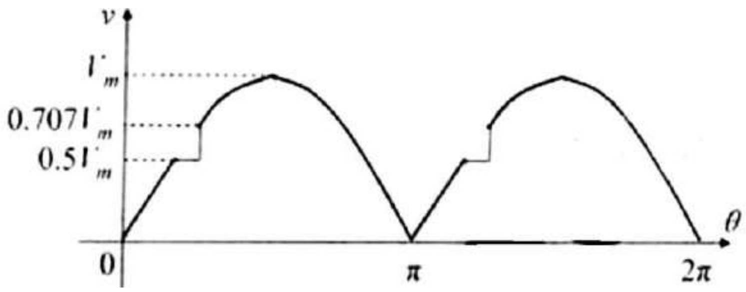
$R = \frac{1}{R} + \frac{2}{R} = \frac{R}{3}$

$R = \frac{1}{R} + \frac{3}{R} = \frac{R}{4}$

Hence we get the final ratio

$\frac{V_L}{V_s} = \frac{4}{R}$

Q1] b) Find the rms value for the following waveforms (4)



Solution:-

The equation of the waveforms is given by $v = V_m \sin(\theta + \varphi)$ where φ is the phase difference

When $\theta = 0$, $v = 0.7071V_m$, $v = 0.51V_m$

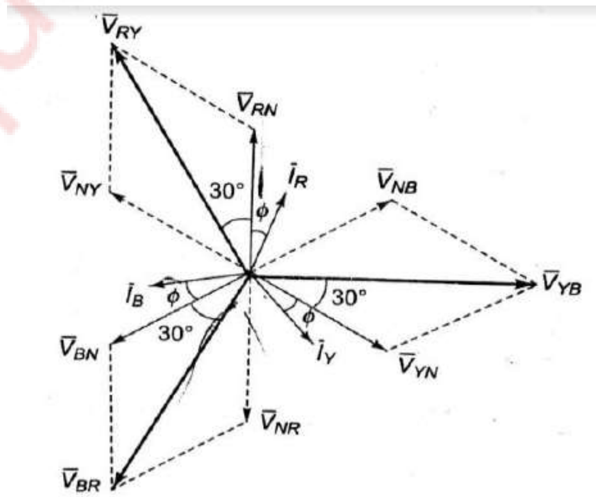
1. Average value of the waveform

$$V_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} v^2(\theta)d\theta} = \sqrt{\frac{1}{\pi}\left[\int_0^{\pi/4} V_M^2 sin^2\theta d\theta + \int_{\pi/4}^{3\pi/4}(0.707V_m)^2 d\theta + \int_{3\pi/4}^{\pi} 0.51^2 d\theta\right]}$$

$$V_{rms} = \sqrt{\frac{V_m^2}{\pi}\left\{[\frac{\theta}{2} - \frac{sin2\theta}{4}]_0^{\frac{\pi}{4}} + 0.499[\theta]_{\frac{\pi}{4}}^{\frac{3\pi}{4}} + [\frac{\theta}{2} - \frac{sin2\theta}{4}]_{3\pi/4}^{\pi}\right\}} = 0.584V_m$$

Q1] c) Draw the phasor diagram for a three phase star connected load with lagging power factor. Indicate all the line and phase voltages and current. (4)

Solution:-



Q1] d) A 5kVA 240/2400 V, 50Hz single phase transformer has the maximum value of flux density as 1 tesla. If the emf per turn is 10. Calculate the number of primary & secondary turns and the full load primary and secondary currents. (4)

Solution:-

kVA rating = 5kVA

$E_1 =$ 240 V

$E_2 =$ 2400 V

f = 50Hz

$e_m = 1T$

$\frac{E_1}{N_1} = 10$

1) Number of primary and secondary turns

   $\frac{E_1}{N_1} = 10 = \frac{240}{N_1}$

   $N_1 = 24$

   $\frac{E_2}{E_1} = \frac{N_2}{N_1}$

   $\frac{2400}{240} = \frac{N_2}{24}$

   $N_2 = 240$

2) Cross-sectional area of the core

   $E_2 = 4.44 f \varphi_m N_2$ = $4.44 f B_m A N_2$

   2400 = $4.44 \times 50 \times 1 \times A \times 240$

   A = 0.0450 m^2

3) Primary and secondary currents at full load for a transformer,

   $V_1 = E_1 = 240V$

   $V_2 = E_2 = 2400V$

$$I_1 = \frac{kVA\, rating \times 1000}{V_1} = \frac{5\times1000}{240} = 20.83A$$

$$I_2 = \frac{kVA\, rating \times 1000}{V_2} = \frac{5\times1000}{2400} = 2.08A$$

Q1] e) Explain the principle of operation of DC generator (4)

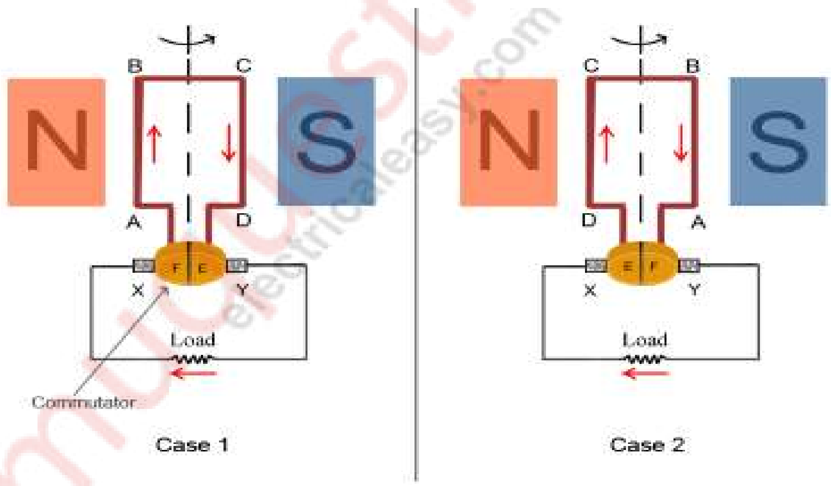
Solution:-

DC Generator

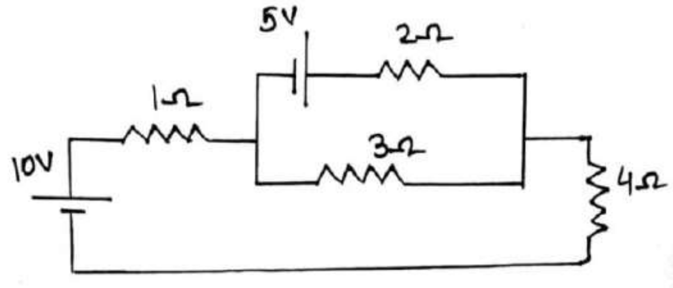
A dc generator is electrical machine which converts mechanical energy into direct current electricity. This energy conversion is based on the principle of production of dynamically induced emf. This article outlines basic construction and working of a DC generator.

PRINCIPLE

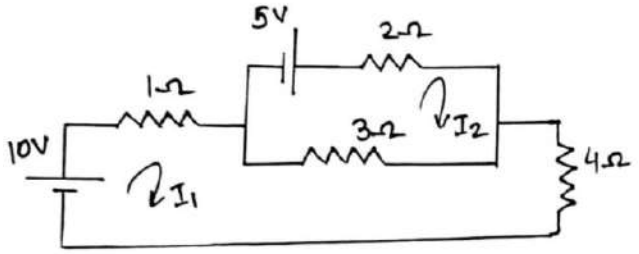
According to Faraday's laws of electromagnetic induction whenever a conductor is placed in a varying magnetic field (OR a conductor is moved in a magnetic field), an emf (electromotive force) gets induced in the conductor. The magnitude of induced emf can be calculated from the Emf equation of dc generator .If the conductor is provided with a closed path, the induced current will circulate within the path. In a DC generator, field coils produce an electromagnetic field and the armature conductors are rotated into the field. Thus, an electromagnetically induced emf is generated in the armature conductors. The direction of induced current is given by Fleming's right hand rule



Q2] a) Find the current through 3Ω resistor by mesh analysis (4)



Solution:-



Mesh 1

$10 - I_1 - 3(I_1 - I_2) - 4I_1 = 0$

$8I_1 - 3I_2 = 10$ ………(1)

Mesh 2

$5 - 2I_2 - 3(I_2 - I_1) = 0$

$3I_1 - 5I_2 = -5$ ………………(2)

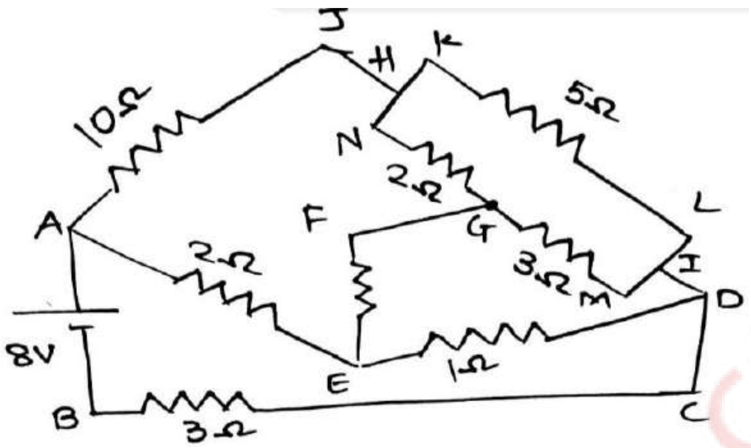
From (1) and (2) we get,

$I_1 = 2.096A$ $I_2 = 2.2580A$

$I = I_2 - I_1 = 2.2580 - 2.096 = 0.162$

$I = 0.162\Omega$

Q2] b) Find the current delivered by the source **(8)**



1) KVL to closed path ABCDEA

$8 - 2(I_2) - (I_2 - I_3) - 3(I_1 + I_2) = 0$

$-3I_1 - 6I_2 + I_3 = -8$

2) KVL to AEFGHJA

$-10I_1 - 2(I_2) - 4.4I_3 - 2I_4 = 0$

3) KVL to HKLIMNH

$-5(I_1 - I_4) - 3(I_3 - I_4) - 2I_4 = 0$

4) KVL to FEDIGF

$-(I_2 - I_3) - 4.4I_3 - 3(I_3 - I_4) = 0$

From 1), 2), 3) and 4) we get,

$I_1 = 4A$ $I_2 = 2.2A$ $I_3 = 3.1A$ $I_4 = 1.96A$

Current delivered = $I_1 + I_2$ = 4+2.2 = 6.2

I = 6.2A

Q2] c) The voltage and current in a circuit are given by $\overline{V} = 12\angle 30°$ V and $\overline{I} = 3\angle 60°$A. the frequency of the supply is 50Hz. Find

1. **Equation for voltage and current in both the rectangular and standard form**
2. **Impedance ,reactance and resistance**

3. Phase difference, power factor and power loss

Draw the circuit diagram considering a simple series of two elements indicating their values. (8)

Solution:-

$\bar{V} = 12\angle 30°$ $\bar{I} = 3\angle 60°$ f = 50Hz

1) Equation of volt & current in both the rectangular & standard form.

Voltage:-

$\bar{V} = 12\angle 30°$ $\therefore V = 10.392 + 6i$

Current:-

$\bar{I} = 3\angle 60°$ $\therefore I = 1.5 + 2.5980i$

2) Impedance, reactance and resistance.

V = IV

Z = $\frac{V}{I} = \frac{10.392+6i}{1.5+2.5980i}$ = 3.4641-1.9999i

Z = 3.4641-1.9999i

Comparing this with standard equation

Z = $R + jX_L$

$R = 3.4641\Omega$ $X_L = 1.9999$

3) Phase difference , pf and power loss.

Z = 3.4641-1.9999i = 4∠-29.99

Phase difference = 29.99

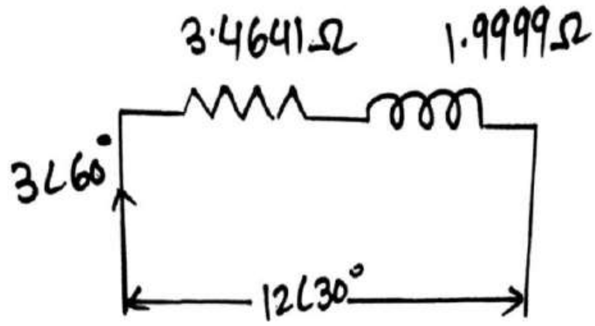
Pf = cosφ = cos(29.99)

Pf = 0.86611 (leading)

Power loss

P = VIcosφ = $12\times 3 \times 0.86611$

P = 31.1799W



Q3] a) Find the resultant voltage and its equation for the given voltages which are connected in series. (4)

$$\boldsymbol{e_1 = 2sin\omega t \quad e_2 = -cos\left(\omega t - \frac{\pi}{6}\right) \quad e_3 = 2cos\left(\omega t - \frac{\pi}{4}\right)}$$

$$\boldsymbol{e_4 = -2sin\left(\omega t + \frac{\pi}{3}\right)}$$

Solution:-

$\overline{E_1} = \frac{2}{\sqrt{2}}\angle 0° = 1.41\angle 0°$

$\overline{E_2} = \frac{-1}{\sqrt{2}}\angle -30° = -0.7071\angle -30°$

$\overline{E_3} = \frac{2}{\sqrt{2}}\angle -45° = 1.41\angle -45°$

$\overline{E_4} = \frac{-2}{\sqrt{2}}\angle 60° = -1.41\angle 60°$

$\bar{E} = \overline{E_1} + \overline{E_2} + \overline{E_3} + \overline{E_4}$

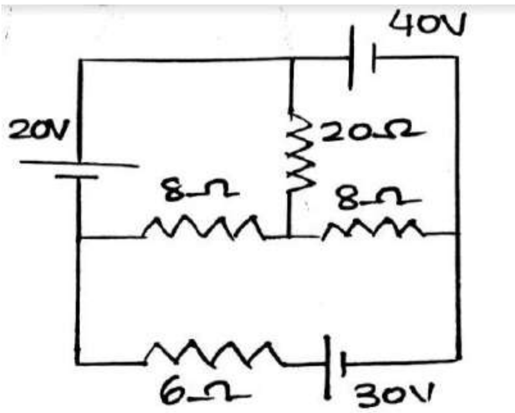
$\bar{E} = 1.41\angle 0° - 0.7071\angle -30° + 1.41\angle -45° - 1.41\angle -60°$

$\bar{E} = 2.1596\angle -59.69°$

e = $2.1596 \times \sqrt{2}\sin(\omega t - 59.69)$

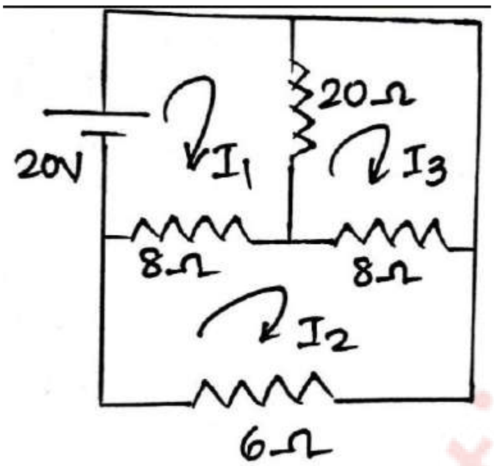
e = $3.0541\sin(\omega t - 59.69)$

Q3] b) Find the current through 20Ω resistor by using superposition theorem (8)



Solution:-

1. When 20V is active



Applying mesh analysis

Mesh 1

$-20 + 20(I_1 - I_3) + 8(I_1 - I_2) = 0$

$28I_1 - 8I_2 - 20I_3 = 20$ ....(1)

MESH 2

$6I_2 + 8(I_2 - I_1) + 8(I_2 - I_3) = 0$

$-8I_1 + 22I_2 - 8I_3 = 0$ ....(2)

Mesh 3

$8(I_3 - I_2) + 20(I_3 - I_1) = 0$

$-20I_1 - 8I_2 - 28I_3 = 0$ ....(3)

From (1), (2) and (3) we get,

$I_1 = 4.791A$

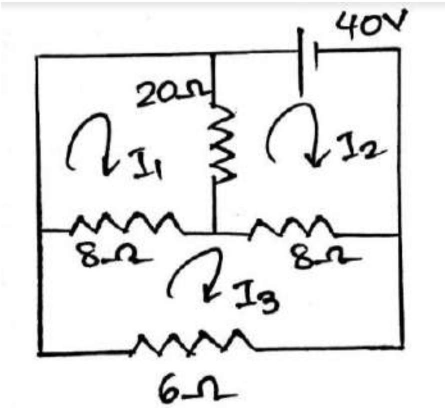
$I_2 = 3.33A$

$I_3 = 4.375A$

$I' = I_1 - I_3 = 0.416$

$I' = 0.416A$ ....(4)

2. When 40V is active



Applying mesh analysis to the circuit we get the equations as:-

Mesh 1

$28I_1 - 20I_2 - 8I_3 = 0$ ....(5)

Mesh 2

$-20I_1 + 28I_2 - 8I_3 = 40$ ....(6)

Mesh 3

$-8I_1 - 8I_2 + 22I_3 = 0$ ....(7)

From equation (5),(6) and (7) we get,

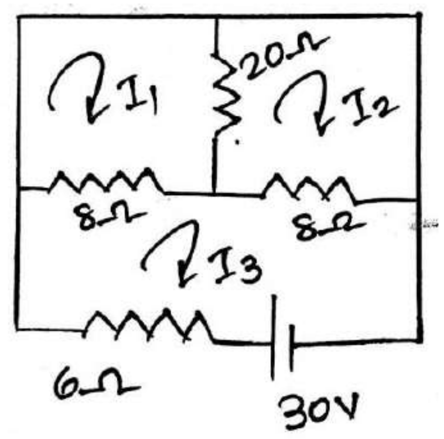
$I_1 = 8.75A$

$I_2 = 9.58A$

$I_3 = 6.667A$

$I'' = 0.833$ ....(8)

3. When 30V is active



Applying mesh analysis to the circuit we get the equations as:-

Mesh 1

$28I_1 - 20I_2 - 8I_3 = 0$ ....(9)

Mesh 2

$-20I_1 + 28I_2 - 8I_3 = 0$ ....(10)

Mesh 3

$-8I_1 - 8I_2 + 22I_3 = 30$ ....(11)

From (9),(10) and (11) we get,

$I_1 = 5A$

$I_2 = 5A$

$I_3 = 5A$

$I''' = 0A$ ....(12)

From (12), (8) and (4) we get,

$I(20\Omega) = 0 + 0.833 + 0.416$ = 1.249A

$I = 1.249A$

Q3] c) Two parallel branches of a circuit comprise respectively of 1) a coil having 5Ω resistance and inductance of 0.05H. 2) a capacitor of capacitance 100μF in series with a resistance of 10Ω. The circuit is connected to a 100V, 50Hz supply. Find

1) **Impedance and admittance of each branch**
2) **Equivalent admittance and impedance of the circuit**
3) **The supply current and power factor of the circuit**

Draw its equivalent series circuit using two elements indicating their values (8)

Solution:-

(1) Coil R= 5Ω and L = 0.05H
(2) C = 100μF series with R = 10Ω

V = 100V f = 50Hz

1. Impedance and admittance of each branch

R= 5Ω $X_L = 2\pi f L = 2 \times \pi \times 50 \times 0.05 = 15.7\Omega$

$\overline{Z_1} = R + jX_L = 5 + j15.7 = 16.4769\angle 72.3°$

$\overline{Y_1} = \frac{1}{\overline{Z_1}} = \frac{1}{16.4769\angle 72.3°} = 0.060\angle -72.33°$

$X_C = \frac{1}{2\pi f L} = \frac{1}{2\times 3.14\times 50\times 100\times 10^{-6}} = 31.8471\Omega$

$\overline{Z_2} = R - jX_C = 10 - j31.84 = 33.37\angle -72.56°$

$\overline{Y_2} = \frac{1}{\overline{Z_2}} = \frac{1}{33.37\angle 72.56°} = 0.299\angle 72.56°$

2. Equivalent admittance and impedance of circuit

$\bar{Z} = \frac{\overline{Z_1 Z_2}}{\overline{Z_1 + Z_2}} = \frac{(16.4769\angle 72.3°)\times(33.37\angle -72.56°)}{(16.4769\angle 72.3°)(33.37\angle -72.56°)} = 39.677\angle -64.543°$

Y = $\frac{1}{\bar{Z}} = \frac{1}{39.677\angle -64.543°} = 0.025\angle 64.543°$

3. Supply current and power factor

$I = \frac{V}{Z} = \frac{100\angle 0°}{39.677\angle -64.543°} = 2.520\angle 64.543$

Power factor = $\cos\varphi = \cos(-64.543) = 0.4298$

Pf = 0.4298

Q4] a) How are DC machines classified ? (4)

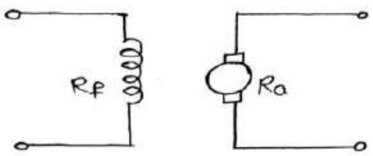
Solution:-

Depending upon the method of excitation of field winding ,DC machine are classified into two classes:-

1) Separately excited machines.
2) Self excited machines.

SEPARATELY EXCITED MACHINES

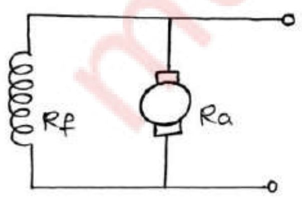
In separately excited machines the field winding is provided with a separate DC source to supply the field current as shown in figure.



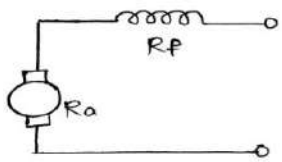
SELF EXCITED MACHINES

In case of self excited machines no, separate source is provided to drive the field current, but the field current is driven by its own emf generated across the armature terminals when the machine works as a generator self excited machine are further classified into the three types, depending upon the method in which the field winding is connected to the armature:

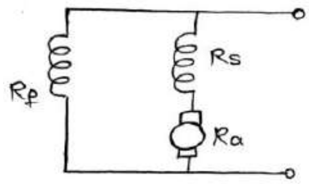
a) SHUNT WOUND MACHINES

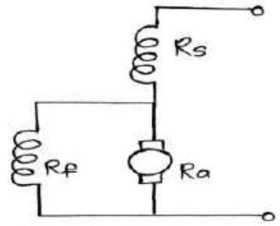


b) SERIES WOUND MACHINES

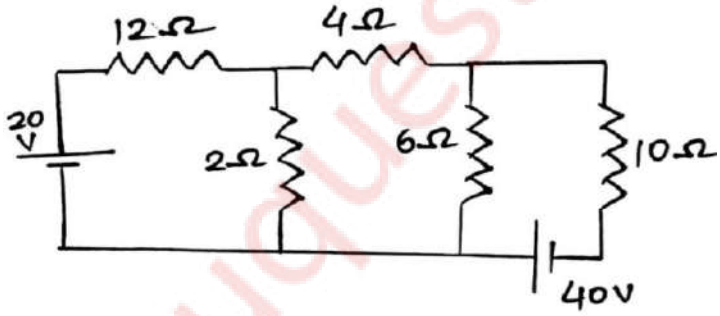


c) COMPOUND WOUND MACHINES

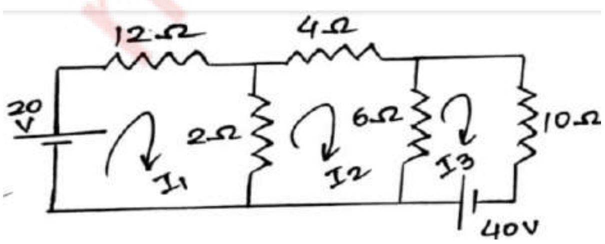




Q4] b)Find the current through 10Ω resistor by using Norton's theorem (8)



Solution:-



1. Calculation of I_N

Replacing 10Ω by short circuit

Mesh 1

$20 - 12I_1 - 2(I_1 - I_2) = 0$

$14I_1 - 2I_2 = 20$

Mesh 2

$-2(I_2 - I_1) - 4I_2 - 6(I_2 - I_3) = 0$

$2I_1 - 12I_2 + 6I_3 = 0$

Mesh 3

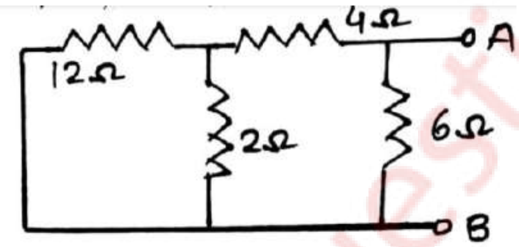
$40 - 6(I_3 - I_2) = 0$

$6I_2 - 6I_3 = -40$

From (1), (2) and (3) we get,

$I_1 = 2.5A \quad I_2 = 7.5A \quad I_3 = 14.166A$

$I_3 = I_N = 14.166A$



2. Calculation of R_N

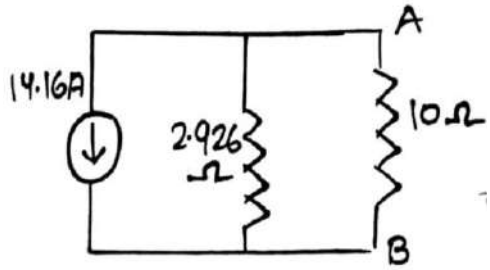
Replacing voltage source by short circuits

(12 || 2)Ω = 1.714Ω

1.714Ω + 4Ω = 5.714Ω

5.714Ω || 6Ω = 2.926

$R_N = 2.926\Omega$



1. Calculation of I_L

$I_L = 14.16 \times \frac{2.926}{10+2.926} = 3.2053A$

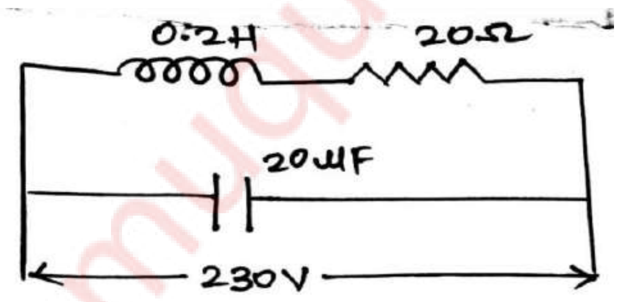
$I_L = 3.2053A$

Q4] c) An inductive coil has a resistance of 20Ω and inductance of 0.2H. It is connected in parallel with a capacitor of 20μF. This combination is connected across a 230 V supply having variable frequency. Find the frequency at which the total current drawn from the supply is in phase with the supply voltage. What is the condition called? Find the values of total current drawn and the impedance of the circuit at this frequency. Draw the phasor diagram and indicate the various currents & voltage in the circuit. (8)

Solution:-

$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{0.2\times20\times10^{-6}}} = 79.617Hz$

The frequency at which the total current drawn from the supply is in phase with the supply voltage, This condition is also called as resonance



$X_L = 2\pi fL = 2 \times 3.14 \times 79.617 \times 0.2 = 100\Omega$

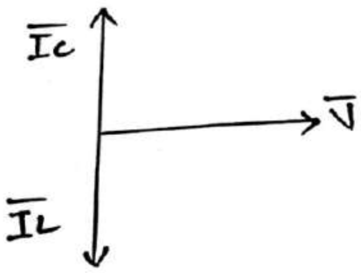
$X_c = \frac{1}{2\pi fC} = \frac{10^6}{2\times3.14\times79.617\times20} = 100\Omega$

$Z = R + (X_L - X_C)j = 20 + (100 - 100)j = 20$

Z = 20Ω

$V = IZ$

$I = \frac{V}{Z} = \frac{230}{20} = 11.5A$



Q5] a) A coil having a resistance of 20Ω and inductance of 0.2H is connected across a 230 V 50 Hz supply . Calculate:-

i) Circuit current
ii) Phase angle
iii) Power factor
iv) Power consumed. (4)

Solution:-

R = 20Ω $X_L = 0.2H$ V = 230V f = 50Hz

1) Circuit current

$Z = \sqrt{R^2 + X_L^2} = \sqrt{20^2 + 0.2^2} = 20.00$

$I = \frac{V}{Z} = \frac{230}{20.00}$ 11.5

2) Phase angle

$Z = R + jX_L$ = 20 + j0.2

$Z = 20\angle 0.5729°$

Phase angle = 0.5729°

3) Power factor

Pf = cosφ = cos(0.5729) = 0.9999

Power factor = 0.9999

4) Power consumed

P = VI cos$\varphi = 230 \times 11.5 \times 0.999$

P = 2644.73W

Q5] b) A balanced three phase delta connected load draws a power of 10 kW, with a power factor of 0.6 leading when supplied with an ac supply of 440 V, 50Hz. Find the circuit elements of the load per phase assuming a simple series circuit of two element. (8)

Solution:-

P = 10kW $V_L = 440V$ pf = 0.6 (leading)

For delta connected load,

1. Values of circuit elements,

$V_L = V_{ph} = 440V$

P = $\sqrt{3} V_L I_L cos\varphi$

$10\times 10^3 = \sqrt{3} \times 440 \times I_L \times 0.6$

$I_L = 21.86A$

$I_{ph} = \frac{I_L}{\sqrt{3}} = \frac{21.86}{\sqrt{3}} = 12.62A$

$Z_{ph} = \frac{V_{ph}}{I_{ph}} = \frac{440}{12.62} = 34.86\Omega$

$R_{ph} = Z_{ph} cos\varphi = 34.86 \times 0.6 = 20.916\Omega$

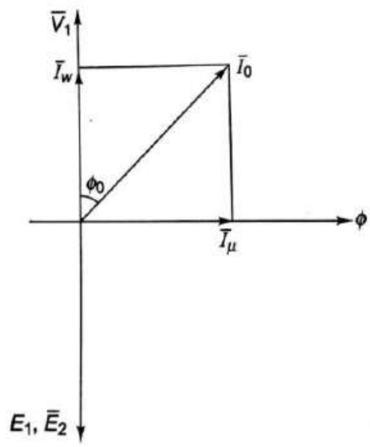
$X_{ph} = Z_{ph} sin\varphi = 20.916 \times \sin(cos^{-1} 0.6) = 16.73\Omega$

2. Reactive volt-amperes drawn

Q = $\sqrt{3} V_L I_L sin\varphi = \sqrt{3} \times 440 \times 21.860 \times 0.8 = 30.29kVAR$

Q5] c) Draw and explain the phasor diagram of a single phase transformer. (8)

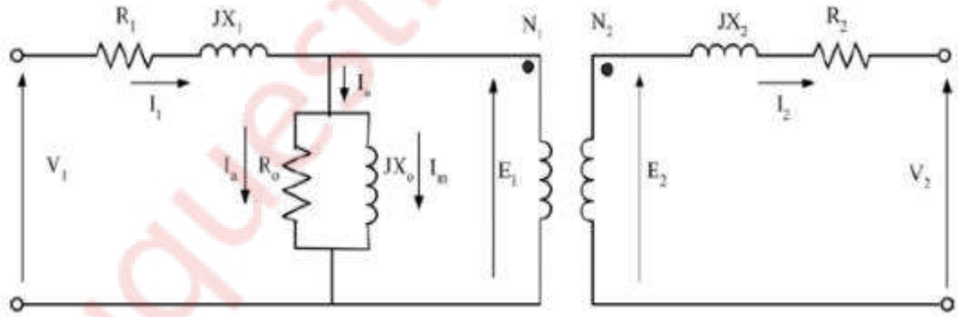
Solution:-



Phasor diagram:-

Since the flux φ is common to both the windings, φ is chosen as a reference phasor. From emf equation of the transformer, it is clear that E_1 and E_2 lag the flux by 90°. Hence , emf's

E_1 and E_2 are drawn such that these lag behind the flux φ by 90°. The magnetising component I_μ is drawn in phase with the flux φ. The applied voltage V_1 is drawn equal and opposite to E_1 as V_1. The active component I_w is drawn in phase with voltage V_1. The phasor sum of I_μ and I_w gives the no-load current I_0.

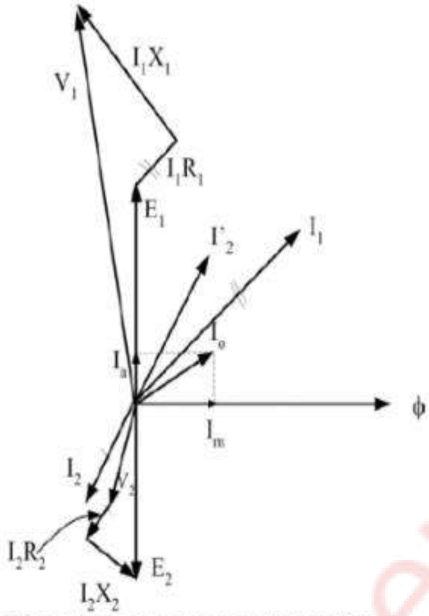


Transformer Equivalent circuit

1) Transformer when excited at no load, only takes excitation current which leads the working Flux by Hysteretic angle α.

2) Excitation current is made up of two components, one in phase with the applied Voltage V is called Core loss component (I_c) and another in phase with the working Flux Ø called Magnetizing Current (I_m).

3) Electromotive Force (EMF) created by working Flux Ø lags behind it by 90 degree.



phasor diagram of transformer on load condition

Q6] a) Explain the various losses of a single phase transformer (4)

Solution:-

There are two types of losses in a transformer:

1. Iron or core loss
2. Copper loss

IRON LOSS:

This loss is due to the reversal of flux in the core. The flux set-up in the core is nearly constant. Hence, iron loss is practically constant at all the loads, from no load to full load. The losses occurring under no-load condition are the iron losses because the copper losses in the primary winding due to no-load current are negligible. Iron losses can be subdivided into two losses:

1. Hysteresis loss
2. Eddy current loss

COPPER LOSS:

This loss is due to the resistance of primary and secondary windings

$W_{cu} = I_1^2 R_1 + I_2^2 R_2$

Where, R_1 = primary winding resistance

R_2 = secondary winding resistance

Copper loss depends upon the load on the transformer and is proportional to square of load current of kVA rating of the transformer.

Q6] b) Two wattmeter connected connected to measure power in a three phase circuit using the two wattmeter method indicate 1250W and 250W respectively. Find the total power supplied and the power factor to the circuit: when

i) Both the readings are positive.

ii) When the latter reading is obtained by reversing the connection of the pressure coil. (8)

Solution:-

$W_1 = 1250W \qquad W_2 = 250W$

1) Power factor of the circuit when both readings are positive

$W_1 = 1250W \qquad W_2 = 250W$

$\tan\varphi = \sqrt{3}\frac{W_1 - W_2}{W_1 + W_2} = \sqrt{3}\frac{(1250-250)}{(1250+250)} = 0.667$

$\varphi = 33.703°$

Power factor = $\cos\varphi = \cos(33.703) = 0.8319$

2) Power factor of the circuit when the latter reading is obtained after reversing the connection to the current coil of one instrument.

$W_1 = 1250W \qquad W_2 = -250W$

$\tan\varphi = \sqrt{3}\frac{W_1 + W_2}{W_1 - W_2} = \sqrt{3}\frac{(1250+250)}{(1250-250)} = 1.5$

$\varphi = 56.3099°$

Power factor = $\cos\varphi = \cos(56.3099°) = 0.5547$

Q6] c) A 200/400 V, Hz single phase transformer gave the following test results:

OC test: 200V 0.7A 70W (on lv side)

SC test: 15V 10A 85W(on hv side)

Obtain the parameters and draw the equivalent circuit of the transformer as referred to the primary. (8)

Solution:- 1) Equivalent circuit of the transform and parameters

From OC test(meters are connected on LV side i.e. primary)

$W_i = 70w \qquad V_1 = 200V \qquad I_0 = 0.7\text{Am}$

$\cos\varphi_0 = \frac{W_i}{V_1 I_0} = \frac{70}{200\times0.7} = 0.5$

$\sin\varphi_0 = (1 - 0.5^2)^{0.5} = 0.866$

$I_w = I_O cos\varphi_o = 0.7 \times 0.5 = 0.35$

$$R_O = \frac{V_1}{I_w} = \frac{200}{0.35} = 571.428\Omega$$

$I_\mu = I_o sin\varphi_o = 0.7 \times 0.866 = 0.6062\text{Am}$

$$X_o = \frac{V_1}{I_\mu} = \frac{200}{0.6062} = 329.924\Omega$$

From SC test (meters are connected on HV side i.e. secondary)

$W_{sc} = 85w \qquad V_{sc} = 15V \qquad I_{sc} = 10A$

$$Z_{02} = \frac{V_{sc}}{I_{sc}} = \frac{15}{10} = 1.5\Omega$$

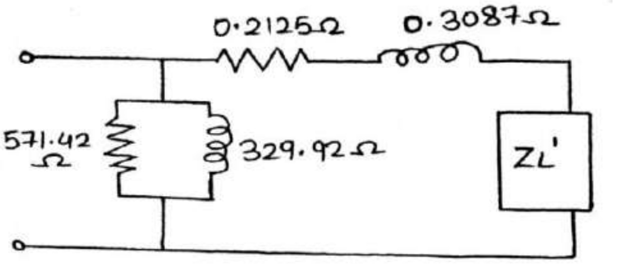
$$R_{02} = \frac{W_{sc}}{I_{SC}^2} = \frac{85}{10^2} = 0.85\Omega$$

$$X_{02} = ({Z_{02}}^2 - {R_{02}}^2)^{0.5} = (1.5^2 - 0.85^2)^{0.5} = 1.235\Omega$$

$$K = \frac{400}{200} = 2$$

$$R_{01} = \frac{R_{02}}{K^2} = \frac{0.85}{4} = 0.2125\Omega$$

$$X_{01} = \frac{X_{02}}{K^2} = \frac{1.235}{4} = 0.3087\Omega$$



BEE QUESTION PAPER SOLUTIONS

(CBCGS DEC 2017)

Q1] a) A voltage v(t) = 282.85sin100πt is applied to a coil, having resistance of 20Ω in series with inductance of 31.83mH. Find:- (4)

(1) RMS value of voltage.
(2) RMS value of current.
(3) Power dissipated in the coil and
(4) Power factor of the coil.

Solution:-

v(t) = 282.85sin100πt R = 20Ω $X_L = 31.83$mH = 0.03183H

(1) RMS value of voltage.

Comparing the given equation with the standard equation we get,

v(t) = 282.85sin100πt

v(t) = $V_m$sin2πft

V_m = 282.85V ω = 2πf => f = 50Hz.

$V_m = \frac{V_{rms}}{\sqrt{2}}$

$V_{rms} = \sqrt{2} \times V_m = \sqrt{2} \times 282.85$

$\boldsymbol{V_{rms}}$ **= 400.01V**

(2) RMS value of current.

Z(impedance) = $(R^2 + X_L^2)^{1/2}$ = $(20^2 + 0.03183^2)^{1/2}$ = 20.00Ω

V = IZ

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{400.01}{20.00} = 20.00Am$$

$$\boldsymbol{I_{rms} = 20.00Am}$$

(5) Power dissipated in the coil and

P = VIcosφ

$$\varphi = \tan^{-1}\left(\frac{X_L}{R}\right) = \tan^{-1}\left(\frac{0.03183}{20}\right) = 0.09118°$$

φ = 0.09118°

Power = $V_{rms} I_{rms} cos\varphi$

Power = 400.01$\times$ 20.00 $\times$ $cos 0.09118°$

Power = 8000 watts.

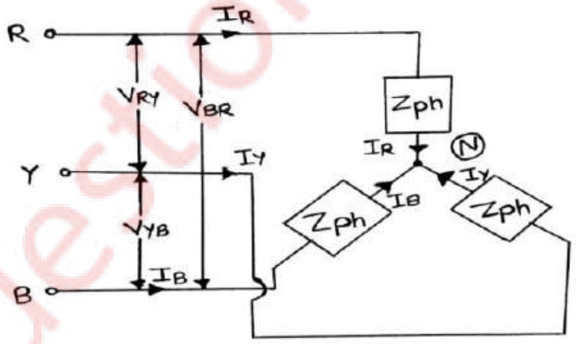
(6) Power factor of the coil.

Pf = cosφ = cos(0.09118)°

Pf = 0.9999

Q1] b) Derive the relation between line voltage and phase voltage in star connected three phase system. (4)

Solution:-



Since the system is balanced , the three-phase voltages V_{RN}, V_{YN}, V_{BN} are equal in magnitude and differ in phase from one another by 120°.

Let $V_{RN} = V_{YN} = V_{BN} = V_{ph}$

Where V_{ph}indicates the rms value of phase voltage .

$\overline{V_{RN}} = V_{ph} \angle 0°$

$\overline{V_{YN}} = V_{ph} \angle - 120°$

$\overline{V_{BN}} = V_{ph} \angle -240°$

Let $V_{RY} = V_{YB} = V_{BR} = V_L$

Where V_L indicates the rms value of line voltage.

Applying Kirchhoff's voltage law,

$\overline{V_{RY}} = \overline{V_{RN}} + \overline{V_{NY}} = \overline{V_{RN}} - \overline{V_{-YN}}$

$= V_{ph} \angle 0° - V_{ph} \angle -120°$

$= (V_{ph} + j0) - (-0.5V_{ph} - j0.866V_{ph})$

$= 1.5V_{ph} + j0.866V_{ph}$

$= \sqrt{3}\, V_{ph} \angle 30°$

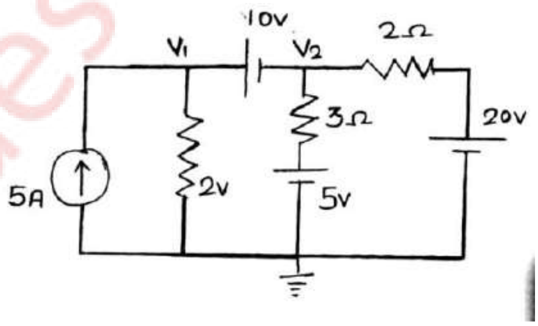
Similarly,

$\overline{V_{YB}} = \overline{V_{YN}} + \overline{V_{NB}} = \sqrt{3}V_{ph} \angle 30°$

$\overline{V_{BR}} = \overline{V_{BN}} + \overline{V_{NR}} = \sqrt{3}V_{ph} \angle 30°$

Thus in a star-connected, three phase system $\boldsymbol{V_L = \sqrt{3}\, V_{ph}}$ and line voltages lead respective phase voltages by 30°.

Q1] c) Find the nodal voltage V_2 by nodal analysis:- (4)



Solution:-

Applying KCL rule at node 1

$5 + \frac{V_1}{2} + V_1 - 10 - V_2 = 0$

$10 + V_1 + 2V_1 - 20 - 2V_2 = 0$

$3V_1 - 2V_2 = 10$ ……………………………………………….(1)

Applying KCL at node 2

$(V_2 - (-10) - V_1) + \frac{V_1 - 5}{3} + \frac{V_2 - 20}{2} = 0$

$$V_2 + 10 - V_1 + \frac{V_1 - 5}{3} + \frac{V_2 - 20}{2} = 0$$

Taking LCM we get,

$-4V_1 + 9V_2 = 10$ …………………………………………….(2)

Solving equation (1) and (2) we get,

V_1 = 5.789V and V_2 = 3.6842V.

Q1] d) A single phase transformer has a turn ration (N_1/N_2) of 2:1 and is connected to a resistive load. Find the value of primary current(both magnitude and angle with reference to flux) , if the magnetizing current is 1A and the secondary current is 4A. Neglect core losses and leakage reactance. Draw the corresponding phasor diagram. (4)

Solution:-

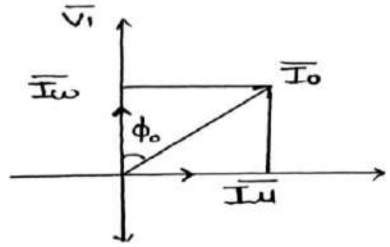
$\frac{N_1}{N_2} = 2:1$ magnetizing current = 1A $I_2 = 4A$

$I_2 = \frac{KVA\ rating \times 1000}{V_2}$

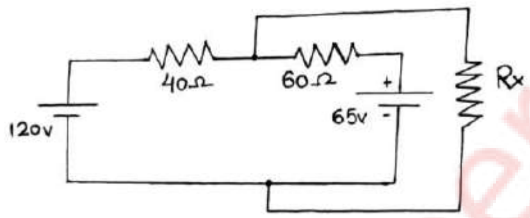
$\frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{E_2}{E_1} = K$

$$\frac{N_2}{N_1} = K = \frac{1}{2}$$

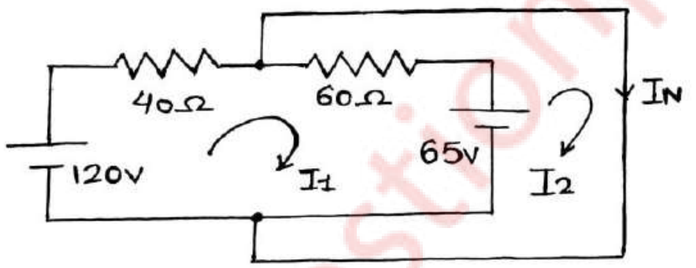
$\frac{I_1}{I_2} = K$ $\frac{I_1}{4} = \frac{1}{2}$ $I_1 = 2A$



Q1] e) Find the Norton's Equivalent of given circuit across R_X (4)



Solution:- Replacing R_X by short circuit



Applying KVL to mesh 1

$120 - 40I_1 - 60(I_1 - I_2) + 65 = 0$

$120 - 40I_1 - 60I_1 + 60I_1 + 65 = 0$

$100I_1 + 60I_2 = 185$ ……………………………………………(1)

Applying KVL to mesh 2

$65 - 60(I_2 - I_1) = 0$

$60I_1 - 60I_2 = -65$ ……………………………………………….(2)

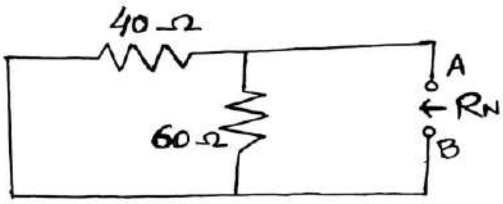
Solving equation (1) and (2) we get

$I_1 = 0.75$Am

$I_2 = 1.833$Am

$\boldsymbol{I_1 = I_N = 1.833}$**Am**

Calculation of R_N



Replacing voltage sources by short circuit

R_N = 60 || 40 = 24Ω

$\boldsymbol{R_N = 24\Omega}$

Norton's Equivalent Network.

Q1] f) A coil having a resistance of 20Ω and an inductance of 0.1H is connected in series with a 50μF capacitor. An alternating voltage of 250V is applied to the circuit. At what frequency will the current in the circuit be maximum? What is the value of this current? Also find the voltage across the inductor and quality factor? (4)

Solution:-

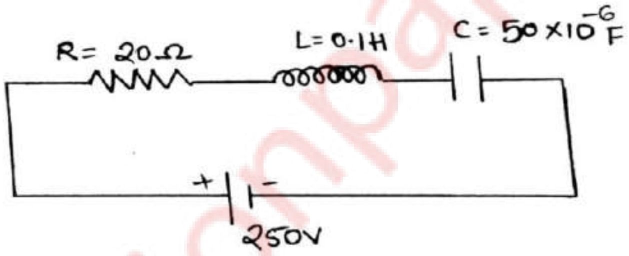
Given:- R = 20Ω $X_L = 0.1H$ $X_C = 50\mu F$ V = 250V.

Find :- 1) At what frequency (f) current is maximum = ?

2) current value = ?

3) voltage across Inductor=?

4) quality factor=?



(1) The frequency at which maximum current flows:-

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$$f_o = \frac{1}{2\pi\sqrt{0.1\times50\times10^{-6}}} = 71.17\text{Hz}$$

$$\boldsymbol{f_o = 71.17Hz}$$

(2) Current value

$$X_L = 2\pi fL = 2\pi \times 71.17 \times 0.1 = 44.717\Omega$$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 71.17 \times 50 \times 10^{-6}} = 45.45\Omega$$

$$\bar{Z} = R + jX_L - jX_C$$

$$\bar{Z} = 20 + j44.717 - j45.45$$

$$\bar{Z} = 20 - j0.77$$

$$\bar{Z} = 20.0148\angle - 2.2047$$

Current = $\frac{V}{Z} = \frac{250}{20.0148} = 12.49Am$

Max Current = 12.49Am.

(3) Quality Factor.

Pf = cosφ = cos(2.2047) = 0.9992

Pf = 0.9992

(4) Voltage across Inductor.

$X_L = 2\pi f L$

$X_L = 44.717\Omega$

V = I$X_L = 12.49 \times 44.717 = 558.51V$

V =558.51V

Q2] a) With necessary diagram prove that three phase power can be measured by only two wattmeter. Also prove that reactive power can be measured from the wattmeter readings. (10)

Solution:-

Given figure shows a balanced star-connected load, the load may be assumed to be inductive. Let V_{RN}, V_{YN}, V_{BN} be the three phase voltages. I_R, I_Y, I_B be the phase currents. The phase currents will lag behind their respective phase voltages by angle φ. Current through current coil of $W_1 = I_R$

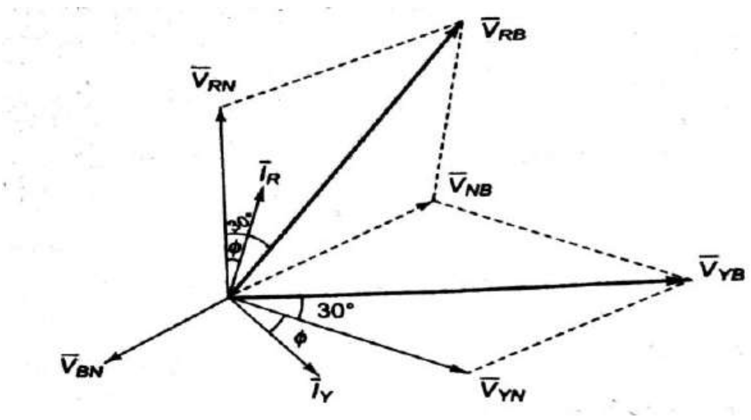
Voltages across voltage coil of $W_1 = V_{RB} = V_{RN} + V_{NB} = V_{RN} - V_{BN}$

From the phasor diagram, it is clear that the phase angle between V_{RB} and I_R is $(30° - \varphi)$

$W_1 = V_{RB} I_R \cos(30° - \varphi)$

Current through current coil of $W_2 = I_Y$

Voltage across voltage coil of $W_2 = V_{YB} = V_{YN} + V_{NB} = V_{YN} - V_{BN}$



From phasor diagram, it is clear that phase angle between V_{YB} and I_Y is $(30° + \varphi)$

$W_2 = V_{YB} I_Y \cos(30° + \varphi)$

But $I_R, = I_Y = I_L$

$V_{RB} = V_{YB} = V_L$

$W_1 = V_L I_L \cos(30° - \varphi)$

$W_2 = V_L I_L \cos(30° + \varphi)$

$W_1 + W_2 = V_L I_L \cos(30° - \varphi) + V_L I_L \cos(30° + \varphi)$

$W_1 + W_2 = V_L I_L (2cos30° cos\varphi)$

P(active power) = $W_1 + W_2 = \sqrt{3} V_L I_L (cos\varphi)$

Thus the sum of two wattmeter reading gives three phase power

For calculating reactive power :-

$W_1 - W_2 = V_L I_L \cos(30° - \varphi) - V_L I_L \cos(30° + \varphi)$

$W_1 - W_2 = V_L I_L \left[-2sin\left[\frac{30-\varphi+30+\varphi}{2}\right] sin\left[\frac{30-\varphi-30-\varphi}{2}\right]\right]$

$W_1 - W_2 = V_L I_L [-2\sin(30)\sin(-\varphi)]$

$W_1 - W_2 = V_L I_L (\sin\varphi)$

Q (reactive power) = $W_1 - W_2 = V_L I_L (\sin\varphi)$

Q2] b) A circuit has L = 0.2H and inductive resistance 20Ω is connected in parallel with 20μF capacitor with variable frequency , 230V supply. Find the resonant frequency and impedance at which the total current taken from the supply is in phase with supply voltage. Draw the diagram and derive the formula used(both impedance and frequency). Also the value of the supply current and the capacitor current. (10)

Solution:-

L = 0.2H $X_L = 20\Omega$ C = 200$\times 10^{-6}F$ V = 230V

RESONANT FREQUENCY :-

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi(0.2 \times 200 \times 10^{-6})^{0.5}} = 25.16Hz$$

IMPEDANCE :-

$Z_1 = jX_L$ $Z_2 = -jX_C$

$$X_C = \frac{1}{2\pi f C} = \frac{10^6}{2\pi \times 50 \times 200} = 15.915\Omega$$

$Z_1 = 20\Omega$ $Z_2 = -15.915\Omega$

$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{(20j)\times(-15.915j)}{(20j)-(15.915j)} = 77.9192\angle - 90$$

Z = $\mathbf{77.9192\angle - 90°}$

SUPPLY CURRENT:-

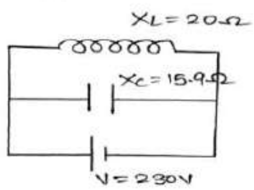
$$I = \frac{V}{Z} = \frac{230}{77.91929} = 2.95Am$$

I = 2.95Am

CAPACITOR CURRENT:-

$$I_C = \frac{V}{X_C} = \frac{230}{15.915} = 14.45Am$$

$I_C = 14.45Am$



Q3] a) Two impedances 14+j5 and 18+j10 are connected in parallel across 200V, 50Hz single phase supply. Determine, (10)

1) **Admittance of each branch in polar form.**
2) **Current in each branch.**
3) **Power factor in each branch.**
4) **Active power in each branch and,**
5) **Reactive power in each branch.**

Solution:-

Given :- $Z_1 = 14 + 5j\ \Omega$ $Z_2 = 18 + 10j\ \Omega$ connected in parallel across V = 200V

f = 50Hz.

1) Admittance of each branch in polar form

$\overline{Y_1} = \frac{1}{\overline{Z_1}} = \frac{1}{14+5j} = \frac{14}{221} - \frac{5}{221}i = 0.0672\angle -19.65°$

$\overline{Y_1} = 0.0672\angle -19.65°\ ℧$

$\overline{Y_2} = \frac{1}{\overline{Z_2}} = \frac{1}{18+10j} = \frac{9}{212} - \frac{5}{212}i = 0.048\angle 29.05°$

$\overline{Y_1} = 0.048\angle 29.05°\ ℧$

2) Current in each branch in polar form

$\overline{I_1} = \frac{\overline{V}}{\overline{Z_1}} = \frac{200}{14+5j} = 13.45\angle -19.65°$ Am

$\overline{I_2} = \frac{\overline{V}}{\overline{Z_2}} = \frac{200}{18+10j} = \frac{50\sqrt{106}}{53}\angle -29.05°$ Am

3) Pf of each branch.

$\cos\varphi_1 = \cos(-19.65°) = 0.9417$
$\cos\varphi_2 = \cos(-29.054°) = 0.8741$

4) Active power in each branch

$P_1 = VI_1\cos\varphi_1 = 200 \times 13.45 \times 0.9417 = 2533.173w$

$P_2 = VI_2\cos\varphi_2 = 200 \times 9.7128 \times 0.8741 = 1697.99w$

5) Reactive power in each branch
$Q_1 = VI_1 sin\varphi_1 = 200 \times 13.45 \times \sin(19.65) = 904.575w$

$$Q_2 = VI_2 sin\varphi_2 = 200 \times 9.7128 \times \sin(29.054) = 943.37w$$

Q3] b) Derive the emf equation of a single phase transformer. Find the value of the maximum flux in a 25KVA, 3000/240V single phase transformer with 500 turns on the primary. The primary winding is connected to 3000V, 50Hz supply. Find primary and secondary currents. Neglect all voltage drops.(6)

Solution:-

As the primary winding is excited by a sinusoidal alternating voltage, an alternating current flows in the winding sinusoidal varying flux φ in the core.

$\varphi = \varphi_m sin\omega t$

As per faradays laws of electromagnetic induction, an emf e_1 is induced in the primary winding

$$e_1 = -N_1\frac{d\varphi}{dt} = -N_1\frac{d}{dt}(\varphi_m sin\omega t) = -N_1\varphi_m\omega cos\omega t = N_1\varphi_m \sin(\omega t - 90°)$$

$e_1 = 2\pi f\varphi_m N_1 \sin(\omega t - 90°)$

Maximum value of induced emf = $2\pi f\varphi_m N_1$

Hence rms value of induced emf in primary winding is given by

$$E_1 = \frac{E_{max}}{\sqrt{2}} = \frac{2\pi f\varphi_m N_1}{\sqrt{2}} = 4.44 f\varphi_m N_1$$

$E_1 = 4.44 f\varphi_m N_1$

Similarly rms value of induced emf in the secondary winding is given by,
$E_2 = 4.44 f\varphi_m N_2$

$$\frac{E_1}{N_1} = \frac{E_2}{N_2} = 4.44 f\varphi_m$$

Thus emf per turn is same in primary and secondary winding and an equal emf I induced in each turn of the primary and secondary winding.

$E_1 = 3000$ $E_2 = 240$ KVA rating = 25KVA $N_1 = 500$

$E_1 = 4.44 f \varphi_m N_1$

3000 = $4.44 \times 50 \times 500 \times \varphi_m$

$$\varphi_m = \frac{3000}{4.44 \times 50 \times 500} = 0.027$$

$\mathbf{\varphi_m = 0.027Wb}$

<u>PRIMARY CURRENT AND SECONDARY CURRENT.</u>

$$\mathrm{I_1} = \frac{\text{KVA rating} \times 1000}{\mathrm{V_1}} = \frac{25 \times 1000}{3000} = 8.33\mathrm{Am}$$

$\mathbf{I_1 = 8.33Am}$

$$\mathrm{I_2} = \frac{\text{KVA rating} \times 1000}{\mathrm{V_2}} = \frac{25 \times 1000}{240} = 104.16\mathrm{Am}$$

$\mathbf{I_2 = 104.16Am}$

Q3] c) Compare core type and shell type transformer (any four point).(4)

Solution:-

CORE-TYPE TRANSFORMER	SHELL-TYPE TRANSFORMER
It consists of a magnetic frame with two limbs	It consists of a magnetic frame with three limbs
It has a single magnetic current.	It has a two magnetic current.
The winding encircles the core.	The core encircles most part of the winding.
It consists of cylindrical winding.	It consists of sandwich type winding.
It is easy to repair.	It is not easy to repair.
It provides better cooling since windings are uniformly distributed on two limbs.	It does not provides better cooling as the windings are surrounded by the core.
It is preferred for low-voltage transform.	It is preferred for high-voltage transform.

Q4] a) An alternating voltage is represented by v(t) = 141.4sin(377t)V. Derive the RMS value of this voltage. Find:- (8)

1) **Instantaneous value at t=3ms and**
2) **The time taken for the voltage to reach 70.7V for the first time.**

Solution:-

To calculate RMS value of this voltage

V(t) = 141.4sin(377t)

V = $V_m sin\theta$ 0< $\theta < 2\pi$

V_m = 141.4 $\theta = 377t$

$V_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} V_m^2 sin^2\theta d\theta$ = $\frac{1}{2\pi}\int_0^{2\pi} 141.4^2 sin^2\theta d\theta$ = $\frac{141.4^2}{2\pi}\int_0^{2\pi} sin^2\theta d\theta$

= $\frac{141.4^2}{2\pi}\int_0^{2\pi}\frac{(1-cos\theta)}{2}d\theta$ = $\frac{141.4^2}{2\pi}\int_0^{2\pi}[\frac{\theta}{2} - \frac{sin2\theta}{4}]_0^{2\pi}d\theta$ = $\frac{141.4^2}{2\pi}[\frac{2\pi}{2}]$ = 9996.98

$V_{rms} = \sqrt{9996.98} = 99.98$

$\mathbf{V_{rms} = 99.98V}$

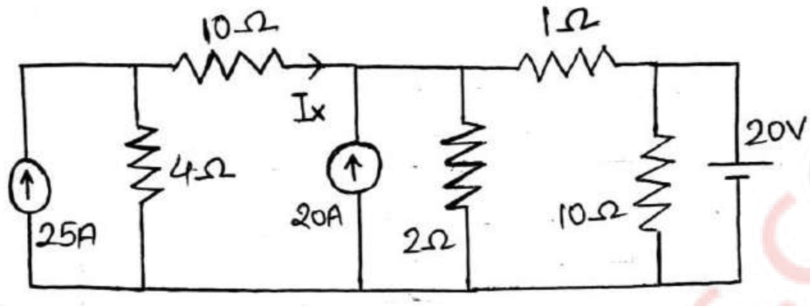
1) Instantaneous value at t = 3ms.
   t = $3 \times 10^{-3} = 0.003sec$
   V = $V_{rms}sin\theta$
   V = 141.4sin(337 x 0.003)
   V = 2.4949V
   Instantaneous voltage at t = 3ms is v = 2.494V.

2) Time taken to reach till 70.7V for first time
   V = $V_{rms}sin\theta$
   V = 70.7V

   70.7 = 141.4sin(377t)
   0.5 = sin(337t)
   $\sin^{-1}(0.5) = 337t$
   30 = 337t
   t = 0.089sec.

   Time required to reach till 70.7V is 0.089sec

Q4] b) State Superposition theorem. Find I_x using Superposition theorem without using source transformation technique. (12)

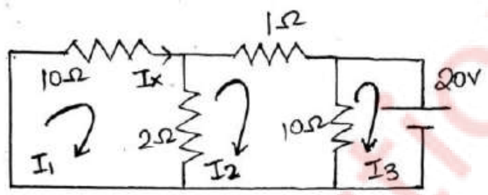


Solution:-

a. When 20V is acting alone other all sources are inactive.

4Ω is redundant, circuit becomes

Applying KVL to mesh 1



$$-10I_1 - 2(I_1 - I_2) = 0$$

$$-12I_1 + 2I_2 = 0$$

$$-6I_1 + I_2 = 0 \quad \text{.........(1)}$$

Applying KVL to mesh 2

$$-2(I_2 - I_1) - 1I_2 - 10(I_2 - I_3) = 0$$

$$-2I_2 + 2I_1 - I_2 - 10I_2 + 10I_3 = 0$$

$$2I_1 - 13I_2 + 10I_3 = 0 \quad \text{.........(2)}$$

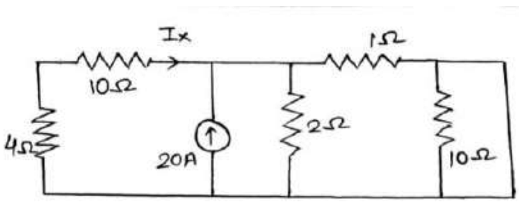
Applying KVL to mesh 3

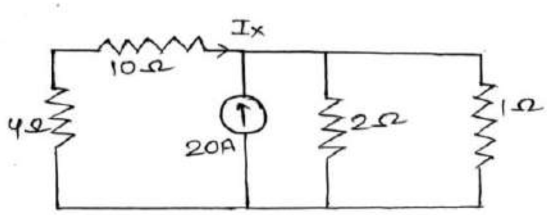
$$-10I_3 = -20$$

$$I_3 = 2A \quad \text{.........(3)}$$

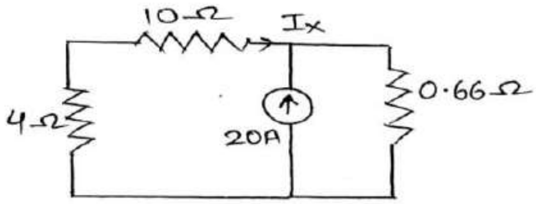
From (1), (2) and (3) we get, $I_X(1) = 0.26Am(\downarrow)$

When 20A is active and other all sources are inactive





10Ω is redundant hence the circuit will get modified. As shown above.



Resistor with 2Ω and 1Ω resistance are in parallel with each other

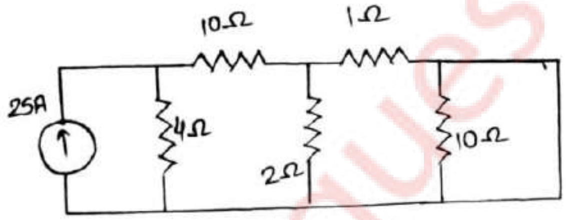
Hence total resistance we get , 0.66Ω

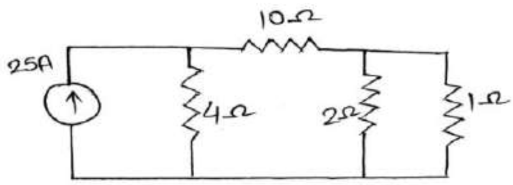
Current division rule,

$$I_X = 20 \times \frac{0.66}{14 + 0.66} = 0.90$$

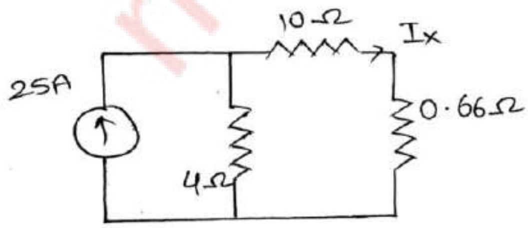
$$I_X(2) = -0.90Am$$

c. 25A active source and other all the inactive.





10Ω is redundant hence to get,



10+0.66 = 10.66Ω

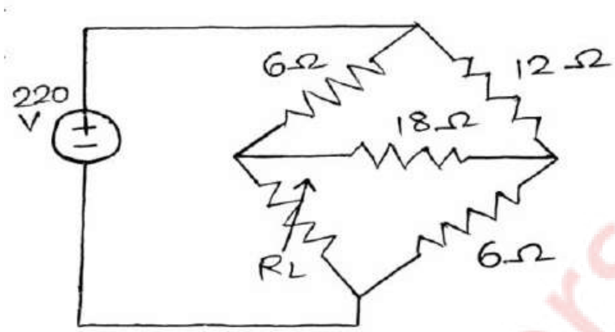
Current division rule,

$$I_X(3) = 25 \times \frac{4}{10.66 + 4} = 6.821A$$

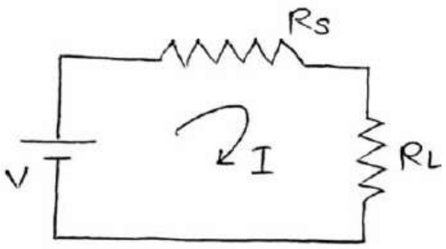
Total current $I_X = 6.821 + 0.26 - 0.90 = 6.181Am$

$I_X = 6.181Am$

Q5] a) State and prove maximum power transform theorem and find the value of R_L. **(10)**



Solution:-



$$I = \frac{V}{R_S + R_L}$$

Power delivered to load

$$R_L = P = I^2 R_L = \frac{V^2 R_L}{(R_S + R_L)^2}$$

To determine the value of $R_L$of maximum power to be transferred to the load,

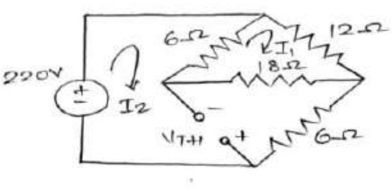
$\frac{dp}{dR_L} = 0$ => $\frac{dp}{dR_L} = \frac{d}{dR_L}\frac{V^2}{(R_S+R_L)^2}R_L$ => $\frac{V^2\left[(R_S+R_L)^2-(R_S+R_L)^1(2R_L)\right]}{(R_S+R_L)^4}$

$\frac{dp}{dR_L}$ = $(R_S + R_L)^2 - 2R_L(R_S + R_L)^1 = 0$

$R_S^2 + R_L^2 + 2R_SR_L - 2R_SR_L - 2R_L^2 = 0$

$R_L = R_S$

Hence the maximum power will be transferred to the load when load resistance is equal to the source resistance.



Applying KVL to mesh 1

$-18I_1 - 6(I_1 - I_2) - 12I_1 = 0$

$-18I_1 - 6I_1 + 6I_2 - 12I_1 = 0$

$-36I_1 + 6I_2 = 0$ ....(1)

Applying KVL to mesh 2

$220 - 6(I_2 - I_2) - 18(I_2 - I_1) - 6I_2 = 0$

$24I_1 - 30I_2 = -220$ ....(2)

From (1) and (2) we get, $I_1 = 1.410Am$ and $I_2 = 8.461Am$

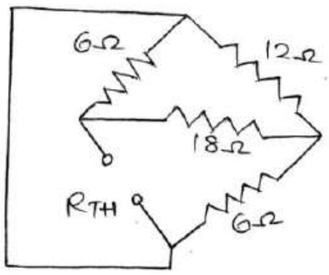
For calculation of V_{TH}

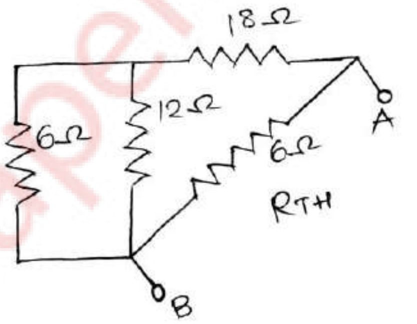
$V_{TH} - 18I_1 - 6I_2 = 0$

$V_{TH} = 6I_2 + 18I_1$

$\boldsymbol{V_{TH} = 76.146V}$

For calculation of R_{TH}



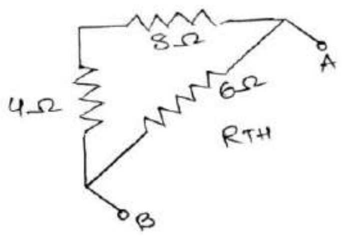


6Ω resistor is parallel with 12Ω gives resultant resistance 4Ω

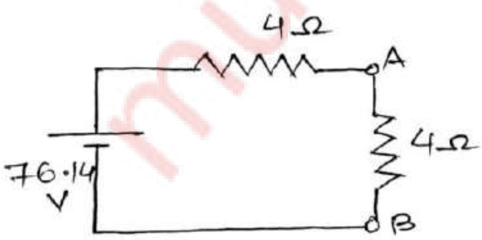
4Ω resistor is in series with 8Ω and is in parallel with 6 Ω gives resultant resistance 4Ω

[(4+8) || 6] = 4 Ω

$\boldsymbol{R_{TH} = 4\Omega}$



Calculation of P_{max}



$$P_{max} = \frac{V_{TH}^2}{4R_{TH}} = \frac{(76.146)^2}{16} = 362.38\,w$$

$\boldsymbol{P_{max} = 362.38}$

Q5] b) A balanced load of phase impedance 100Ω and power factor 0.8(lag) is connected in delta to a 400V, 3- phase supply . calculate :- (10)

(1) Phase current and line current.

(2) Active power and reactive power. If the load is reconnected in star across the same supply, find

(3) Phase voltage and line voltage .

(4) Phase current and line current. What will be the wattmeter readings if the power is measured by two wattmeter method(either star or delta).

Solution:-

1) Phase current and line current.

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{400}{100} = 4Am$

$\boldsymbol{I_{ph}} = 4$**Am …………………..(Phase current in delta connection)**

$\sqrt{3}I_{ph} = I_L$

$I_L = \sqrt{3} \times 4$

$\boldsymbol{I_L = 6.928}$**Am …………………..(Line current in delta connection)**

2) Active power and reactive power

Active power(P) = $\sqrt{3} \times V_L \times I_L cos\varphi$

Pf = 0.8

$0.8 = cos\varphi$

$\varphi = \cos^{-1} 0.8$

$\varphi = 36.86°$

$P = \sqrt{3} \times 400 \times 6.928 \times cos36.86°$

P = 3840.38 watts. ……………………..(Active power in delta connection)

Reactive power(Q) = $\sqrt{3} \times V_L \times I_L sin\varphi$

Q = $\sqrt{3} \times 400 \times 6.928 sin36.86°$

Q = 2879.2521 watts …………………….(Reactive power in delta connection)

<u>**FOR STAR CONNECTION**</u>

1) $V_{ph} =?$ And $V_L =?$

$V_L = \sqrt{3} \times V_{ph}$

$V_{ph} = 400V$
$V_L = \sqrt{3} \times 400 = 692.820V$

$\boldsymbol{V_{ph} = 400V}$ **And** $\boldsymbol{V_L = 692.820V}$

2) I_L =? And I_{ph} =?

$I_L = I_{ph}$
$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{400}{100} = 4\text{Am}$

$\boldsymbol{I_L = 4Am}$ **And** $\boldsymbol{I_{ph} = 4Am}$

WATTMETER READING

$w_1 = V_L I_L \cos(30 - \varphi)$

$w_1 = 692.820 \times 4 \times \cos(30 - 36.86)$

$w_1 = 2751.44\text{w}$

$w_2 = V_L I_L \cos(30 + \varphi)$

$w_2 = 692.820 \times 4 \times \cos(30 + 36.86)$

$w_2 = 1089.055\text{w}$

Wattmeter readings for star connection are as follows:-

$\boldsymbol{w_1 = 2751.44\text{w}}$

$\boldsymbol{w_2 = 1089.055\text{w}}$

Q6] a) The reading when open circuit and short circuit tests are connected on a 4KVA, 200/400V, 50Hz, single phase transformer are given below:-

1) **Find the equivalent circuit parameters and draw the equivalent circuit referred to primary.**
2) **Also find the transform efficiency and regulation at full load and half load for 0.8pf lagging. (12)**

OC test on LV side	**200V**	**0.7A**	**70w**
SC test on HV	**15V**	**10A**	**85w**

Solution:- 1) Equivalent circuit of the transform and parameters

From OC test(meters are connected on LV side i.e. primary)

$W_i = 70w$ $\quad\quad$ $V_1 = 200V$ $\quad\quad$ $I_0 = 0.7$Am

$\cos\varphi_0 = \frac{W_i}{V_1 I_0} = \frac{70}{200\times 0.7} = 0.5$

$\sin\varphi_0 = (1 - 0.5^2)^{0.5} = 0.866$

$I_w = I_O cos\varphi_o = 0.7 \times 0.5 = 0.35$

$$R_O = \frac{V_1}{I_w} = \frac{200}{0.35} = 571.428\Omega$$

$I_\mu = I_o sin\varphi_o = 0.7 \times 0.866 = 0.6062$Am

$$X_o = \frac{V_1}{I_\mu} = \frac{200}{0.6062} = 329.924\Omega$$

From SC test (meters are connected on HV side i.e. secondary)

$W_{sc} = 85w$ $\quad\quad$ $V_{sc} = 15V$ $\quad\quad$ $I_{sc} = 10A$

$$Z_{02} = \frac{V_{sc}}{I_{sc}} = \frac{15}{10} = 1.5\Omega$$

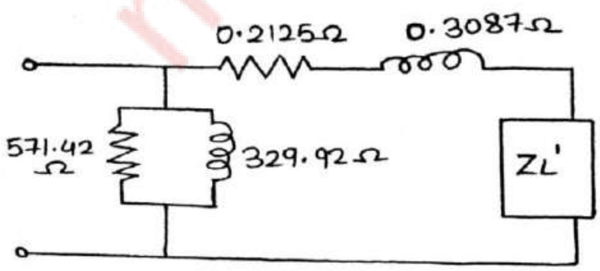
$$R_{02} = \frac{W_{sc}}{I_{SC}^2} = \frac{85}{10^2} = 0.85\Omega$$

$$X_{02} = ({Z_{02}}^2 - {R_{02}}^2)^{0.5} = (1.5^2 - 0.85^2)^{0.5} = 1.235\Omega$$

$$K = \frac{400}{200} = 2$$

$$R_{01} = \frac{R_{02}}{K^2} = \frac{0.85}{4} = 0.2125\Omega$$

$$X_{01} = \frac{X_{02}}{K^2} = \frac{1.235}{4} = 0.3087\Omega$$



2)Efficiency and regulation at full and half load for 0.8pf lagging

x = 0.5 pf = 0.8 $W_i = 70w = 0.70kw$ $W_{cu} = 85w = 0.85kw$

$$\%\eta = \frac{\text{x} \times \text{full load KVA} \times \text{pf}}{(\text{x} \times \text{full load KVA} \times \text{pf}) + \text{W}_\text{i} + \text{x}^2\text{W}_\text{cu}} \times 100$$

$$\%\eta = \frac{0.5 \times 4 \times 0.8}{(0.5 \times 4 \times 0.8) + (0.7) + (0.5)^2(0.85)} \times 100$$

$$\%\boldsymbol{\eta} = \mathbf{63.681}\%$$

On primary side ,

$$\%\ \text{regulation} = \frac{I_2(R_{02}cos\varphi + X_{02}sin\varphi)}{V_2} \times 100$$

$$I_1 = \frac{4 \times 1000}{400} = 10A$$

$cos\varphi = 0.8$ $sin\varphi = 0.6$

$$\%\ \text{regulation} = \frac{10(0.85 \times 0.8 + 1.235 \times 0.6)}{400} \times 100$$

$$\%\ \textbf{regulation} = \mathbf{3.55}\%$$

Efficiency at full load;

x = 1

$$\%\eta = \frac{\text{x} \times \text{full load KVA} \times \text{pf}}{(\text{x} \times \text{full load KVA} \times \text{pf}) + \text{W}_\text{i} + \text{x}^2\text{W}_\text{cu}} \times 100$$

$$\%\eta = \frac{1 \times 4 \times 0.8}{(1 \times 4 \times 0.8) + (0.7) + (0.5)^2(0.85)} \times 100$$

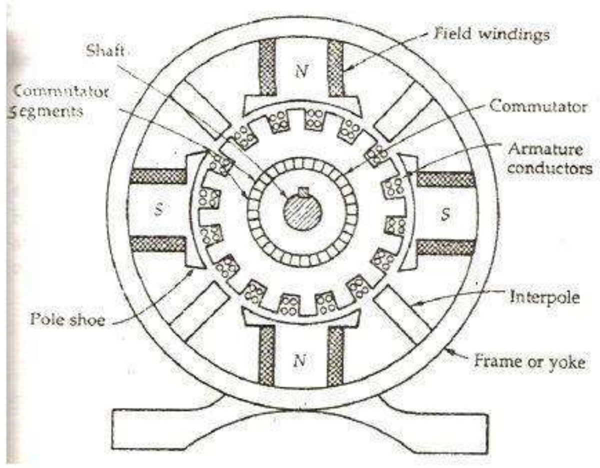
$$\%\boldsymbol{\eta} = \mathbf{67.36}\%$$

Q6] b) With neat diagram explain the main parts of a DC machine? Mention the functions of each part. (8)

Solution:-

A DC Generator is an electrical device which converts mechanical energy into electrical energy. It mainly consists of three main parts, i.e. Magnetic field system, Armature and Commutator and Brush gear. The other parts of a DC Generator are Magnetic frame and Yoke, Pole Core and Pole Shoes, Field or Exciting coils, Armature Core and Windings, Brushes, End housings, Bearings and Shafts.

The diagram of the main parts of a 4 pole DC Generator or DC Machine is shown below.



Magnetic Field System of DC Generator

The Magnetic Field System is the stationary or fixed part of the machine. It produces the main magnetic flux. The magnetic field system consists of Mainframe or Yoke, Pole core and Pole shoes and Field or Exciting coils. These various parts of DC Generator are described below in detail.

Magnetic Frame and Yoke

The outer hollow cylindrical frame to which main poles and inter-poles are fixed and by means of which the machine is fixed to the foundation is known as Yoke. It is made of cast steel or rolled steel for the large machines and for the smaller size machine the yoke is generally made of cast iron.

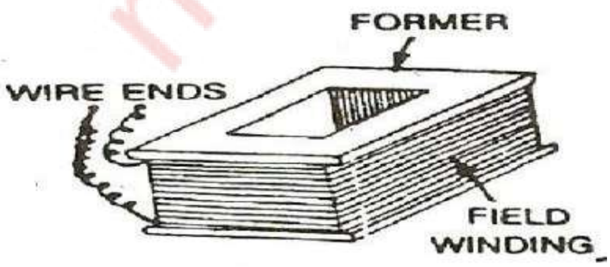
The two main purposes of the yoke are as follows:-

- It supports the pole cores and provides mechanical protection to the inner parts of the machines.
- It provides a low reluctance path for the magnetic flux.

Field or Exciting Coils

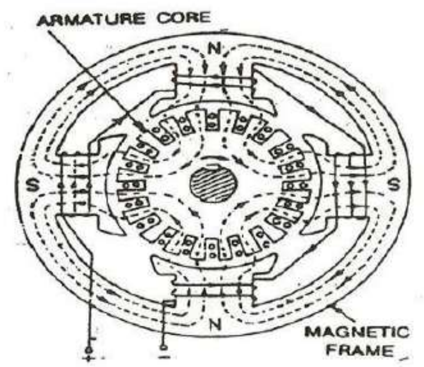
Each pole core has one or more field coils (windings) placed over it to produce a magnetic field. The enamelled copper wire is used for the construction of field or exciting coils. The coils are wound on the former and then placed around the pole core.

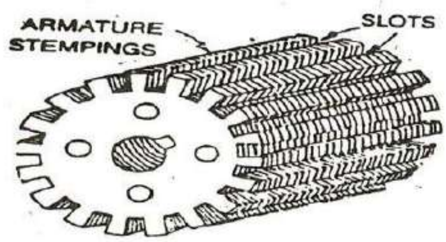
When direct current passes through the field winding, it magnetizes the poles, which in turns produces the flux. The field coils of all the poles are connected in series in such a way that when current flows through them, the adjacent poles attain opposite polarity.



Armature Core

The armature core of DC Generator is cylindrical in shape and keyed to the rotating shaft. At the outer periphery of the armature has grooves or slots which accommodate the armature winding as shown in the figure below.





The armature core of a DC generator or machine serves the following purposes.

- It houses the conductors in the slots.
- It provides an easy path for the magnetic flux.

As the armature is a rotating part of the DC Generator or machine, the reversal of flux takes place in the core, hence hysteresis losses are produced. The silicon steel material is used for the construction of the core to reduce the hysteresis losses.

The rotating armature cuts the magnetic field, due to which an emf is induced in it. This emf circulates the eddy current which results in Eddy Current loss. Thus to reduce the loss the armature core is laminated with a stamping of about 0.3 to 0.5 mm thickness. Each lamination is insulated from the other by a coating of varnish.

BEE QUESTION PAPER SOLUTION

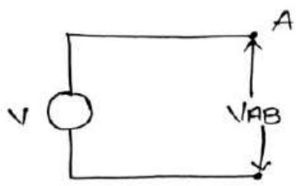
MAY 2018(CBCGS)

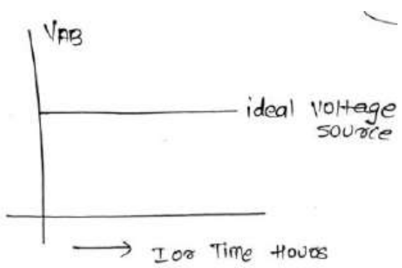
Q1] a) What is the difference ideal source and actual source? Illustrate the concept using the V-I characteristics of voltage and current source. (4)

Solution:-

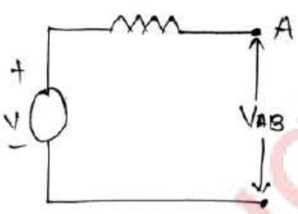
A voltage source is a two terminal device whose voltage at any instant of time is constant and is independent of the current drawn from it.

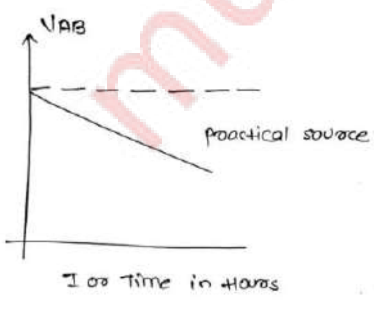
Ideal voltage source have zero internal resistance practically an ideal voltage source cannot be obtained.





Source having some amount of internal resistance are known as practical voltage source due to this internal resistance voltage drop takes place and it causes the terminal voltage to reduce.





Q1] b) In a balanced three phase circuit the power factor is 0.866. what will be the ratio of two wattmeter reading if the power is measured using two wattmeter (4)

Solution:-

Pf = 0.866

$\cos\varphi = 0.866$

$\varphi = \cos^{-1} 0.866$

$\varphi = 30.00$

$\tan\varphi = \tan(30.00) = 0.57735$

$\tan\varphi = \sqrt{3}\frac{(W_1 - W_2)}{(W_1 + W_2)}$

$\frac{0.57735}{\sqrt{3}} = \frac{(W_1 - W_2)}{(W_1 + W_2)}$

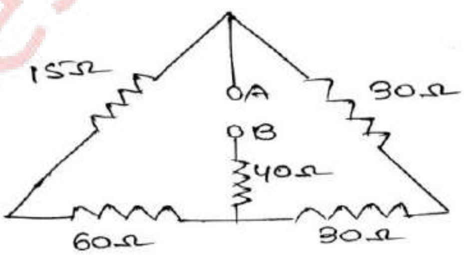
$0.333((W_1 + W_2) = (W_1 - W_2)$

$0.333W_2 + W_2 = W_1 - 0.333W_1$

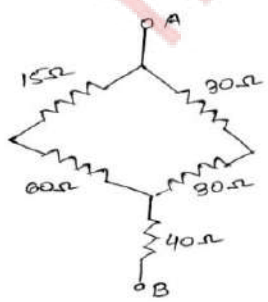
$\frac{W_1}{W_2} = \frac{1.333}{0.667}$

$\frac{W_1}{W_2} = 1.9985$

Q1] c)calculate R_{AB} (4)



Solution:-

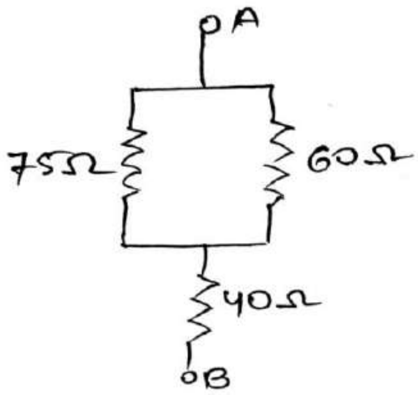


15+60 = 75Ω ………….(resistors are in series)

30+30 = 60Ω ……………..(resistors are in series)

Now, resistor 75Ω and 60Ω are in parallel,

75 || 60 = 33.33Ω



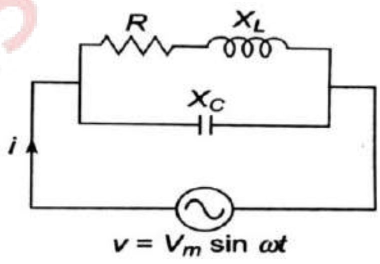
Now 33.33Ω and 40Ω are in series.

33.33 + 40 = 73.33Ω

R = 73.33Ω

Q1] d) Derive the equation for resonance frequency for a parallel circuit in which a capacitor is connected in parallel with a coil having resistance R and inductive reactance X_L. What is the resonance frequency if inductor is ideal? (4)

Solution:-



Consider a parallel circuit consisting of a coil and a capacitor as shown below. The impedances of two branches are:-

$\overline{Z_1} = R + jX_L$ $\overline{Z_2} = -jX_C$

$\bar{Y}_1 = \frac{1}{\overline{Z_1}} = \frac{1}{R+jX_L} = \frac{R-jX_L}{R^2+X_L^2}$ $\bar{Y}_2 = \frac{1}{\overline{Z_2}} = \frac{1}{-jX_C} = \frac{j}{X_C}$

Admittance of the circuit $\bar{Y} = \bar{Y}_1 + \bar{Y}_2$

$\bar{Y} = \frac{R-jX_L}{R^2+X_L^2} + \frac{j}{X_C} = \frac{R}{R^2+X_L^2} - j\left(\frac{X_L}{R^2+X_L^2} - \frac{1}{X_C}\right)$

At resonance the circuit is purely resistive. Therefore, the condition for resonance is.

$\frac{X_L}{R^2+X_L^2} - \frac{1}{X_C} = 0$

$\frac{X_L}{R^2+X_L^2} = \frac{1}{X_C}$

$X_L X_C = R^2 + X_L^2$

$\omega_0 L \frac{1}{\omega_0 C} = R^2 + \omega_0{}^2 L^2$

$\omega_0{}^2 L^2 = \frac{L}{C} - R^2$

$\omega_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$

$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$

Where f_0 is called as the resonant frequency of the circuit.

If R is very small as compared to L then

$\omega_0 = \sqrt{\frac{1}{LC}}$

$\boldsymbol{f_0 = \frac{1}{2\pi\sqrt{LC}}}$

DYNAMIC IMPEDANCE OF A PARALLEL CIRCUIT.

At resonance the circuit is purely resistive the real part of admittance is $\frac{R}{R^2+X_L^2}$. Hence the dynamic impedance at resonance is given by,

$$Z_D = \frac{R^2 + X_L^2}{R}$$

At resonance ,

$R^2 + X_L^2 = X_L X_C = \frac{L}{C}$

$\boldsymbol{Z_D = \frac{L}{CR}}$

Q1] e) What are the classification of DC motor? Specify one application for each one. (4)

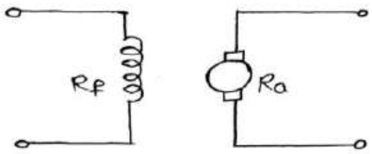
Solution:-

Depending upon the method of excitation of field winding ,DC machine are classified into two classes:-

1) Separately excited machines.
2) Self excited machines.

SEPARATELY EXCITED MACHINES

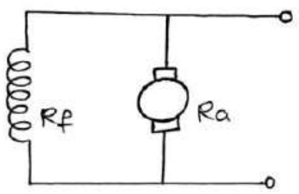
In separately excited machines the field winding is provided with a separate DC source to supply the field current as shown in figure.



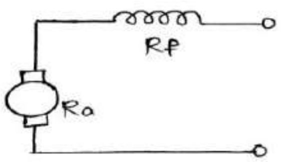
SELF EXCITED MACHINES

In case of self excited machines no, separate source is provided to drive the field current, but the field current is driven by its own emf generated across the armature terminals when the machine works as a generator self excited machine are further classified into the three types, depending upon the method in which the field winding is connected to the armature:

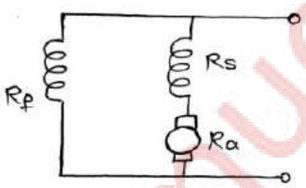
a) SHUNT WOUND MACHINES



b) SERIES WOUND MACHINES



c) COMPOUND WOUND MACHINES



Q1] f) Derive emf equation of a single phase transformer **(4)**

Solution:-

EMF EQUATION.

As the primary winding is excited by a sinusoidal alternating voltage, an alternating current flows in the winding producing a sinusoidally varying flux φ in the core.

$$\varphi = \varphi_m sin\omega t$$

As per Faraday's law of electromagnetic induction an emf e_1 is induced in the primary winding.

$$e_1 = -N_1 \frac{d\varphi}{dt}$$

$$e_1 = -N_1 \frac{d}{dt}(\varphi_m sin\omega t)$$

$$e_1 = -N_1 \varphi_m \omega cos\omega t \quad = \quad -N_1 \varphi_m \omega \sin(\omega t - 90°) \quad = \quad 2\pi f N_1 \varphi_m \omega \sin(\omega t - 90°)$$

Maximum value of induced emf = $2\pi f \varphi_m N_1$

Hence, rms value of induced emf in primary winding is given by,

$$E_1 = \frac{E_{max}}{\sqrt{2}} = \frac{2\pi f N_1 \varphi_m}{\sqrt{2}} = 4.44 f N_1 \varphi_m$$

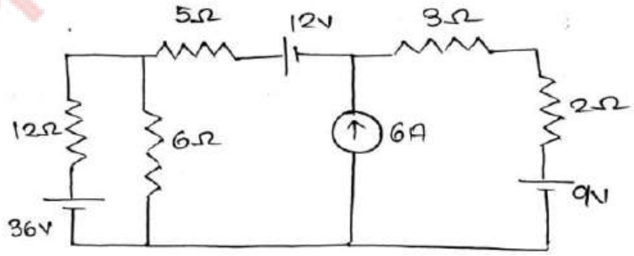
Similarly rms value of induced emf in the secondary winding is given by,

$$E_2 = 4.44 f N_2 \varphi_m$$

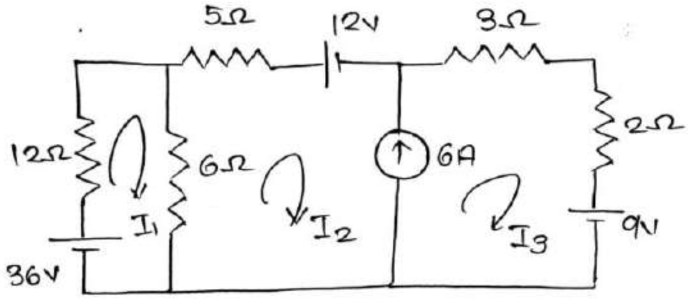
Also, $\frac{E_1}{N_1} = \frac{E_2}{N_2} = 4.44 f \varphi_m$

Thus emf per turn is same in primary and secondary winding and an equal emf is induced in each turn of the primary and secondary winding.

Q2] a)Using mesh analysis find current through 5Ω **(8)**



Solution:-



$I_3 - I_2 = 6$ ....(1)

Applying KVL to mesh 1

$-36 - 12(I_1) + 6(I_1 - I_2) = 0$

$-12I_1 + 6I_1 - 6I_2 = 36$

$-6I_1 - 6I_2 = 36$

$6I_1 + 6I_2 = -36$ ....(2)

Applying KVL to mesh 2

-6$(I_2 - I_1) + 5I_2 + 12 = 0$

$-6I_2 + 6I_1 + 5I_2 + 12 = 0$

$6I_1 - I_2 = -12$ ....(3)

From (1), (2) and (3)

$I_1 = -2.57A$, $I_2 = -3.428A$ and $I_3 = 2.571A$

Current through 5Ω = 3.428(←)A

Q2] b) An emf of 250V is applied to an impedance $Z_1 = (12.5 + j20)\Omega$. An impedance Z_2 is added in series with Z_1, the current become half of the origin and lead the supply voltage by 20°. Determine Z_2 (8)

Solution:-

V = 250∠0° $Z_1 = 12.5 + 20j$

$I_1 = \frac{\overline{V}}{\overline{Z_1}} = \frac{250\angle 0°}{12.5+20j} = \frac{250\angle 0°}{23.5849\angle 57.99}$

$I_1 = 10.600\angle -57.99$

$I_2 = \frac{250\angle 20°}{Z_2}$

$\frac{I_1}{2} = \frac{250\angle 20°}{Z_2}$

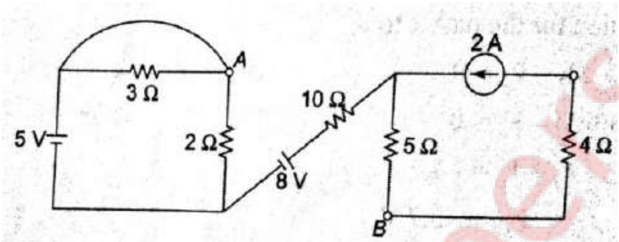
$Z_2 = \frac{500\angle 20°}{I_1}$

$Z_2 = \frac{500\angle 20°}{10.600\angle -57.99}$

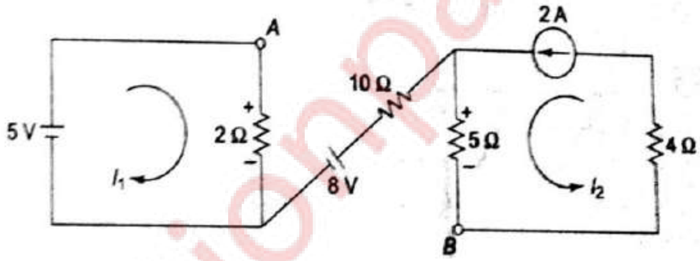
$Z_2 = 47.1698\angle 77.99$

$Z_2 = 9.815 + 46.131j$

Q2] c) Determine the potential difference V_{AB} for the given network **(4)**



Solution:-



The resistor of 3Ω is connected across a short circuit. Hence it gets shorted.

$I_1 = \frac{5}{2} = 2.5\text{A}$

$I_2 = 2A$

Potential difference, $V_{AB} = V_A - V_B$

Writing KVL equation for the path A to B,

$V_A - 2I_1 + 8 - 5I_2 - V_B = 0$

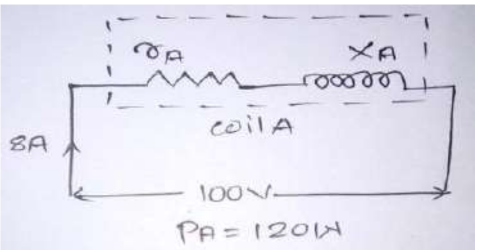
$V_A - 2(2.5) + 8 - 5(2) - V_B = 0$

$V_A - V_B = 7$

$V_{AB} = 7V$

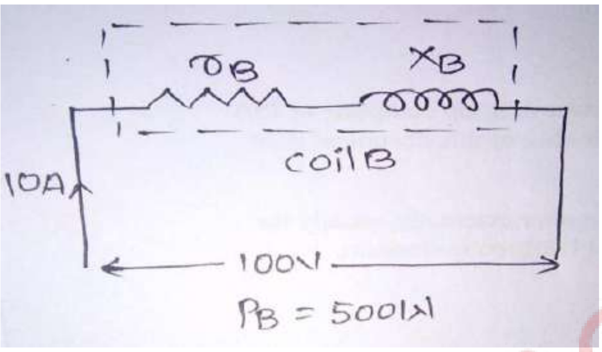
Q3] a) When a voltage of 100V, 50Hz is applied to an impedance A current taken is 8A lagging and power is 120W. When it is connected to an impedance B the current is 10A leading and power is 500W. what current and power will be taken if it is applied to the two impedances connected in series. (8)

Solution:-



Coil A : $V_A = 100V \quad I_A = 8A \quad P_A = 120W$

Coil B : $V_B = 100V \quad I_B = 10A \quad P_B = 500W$



For coil A , $Z_A = \frac{V_A}{I_A} = \frac{100}{8} = 12.5\Omega$

$P_A = I_A^2 r_A$

120 = $8^2 \times r_A$

$r_A = 1.875\Omega$

$X_A = \sqrt{12.5^2 - 1.875^2} = 12.36\,\Omega$

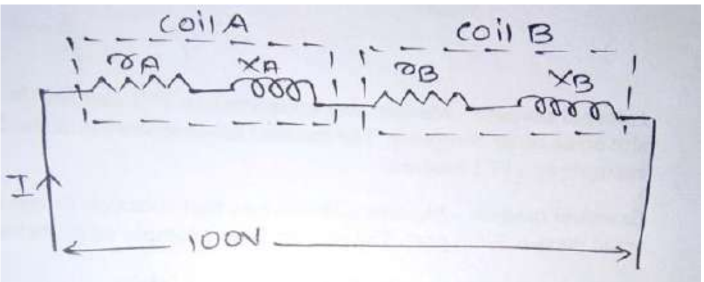
For coil B, $Z_B = \frac{V_B}{I_B} = \frac{100}{10} = 10\Omega$

$P_B = I_B^2 r_B$

500 = $10^2 \times r_B$

$r_B = 5\Omega$

$X_B = \sqrt{10^2 - 5^2} = 8.66\,\Omega$



When coils A and B are connected in series,

$\bar{Z} = r_A + jX_A + r_B + jX_B$

$\bar{Z} = 1.875 + j12.36 + 5 + j8.66$

$\bar{Z} = 6.875 + j21.02$

$\bar{Z} = 22.11\angle 71.89°$

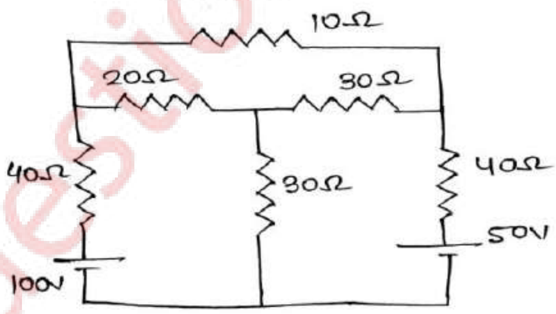
Z = 22.11Ω

$\varphi = 71.89°$

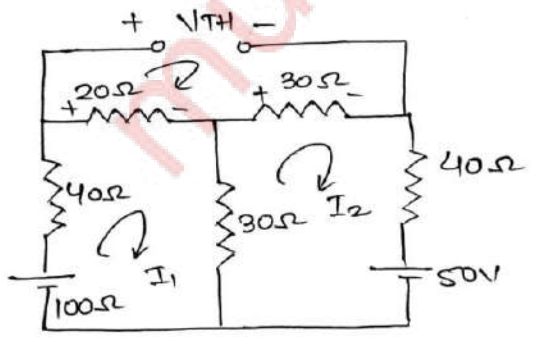
$I = \frac{V}{Z} = \frac{100}{22.11} = 4.52A$

P = $I^2(r_A + r_B)$ = $4.25^2 \times 6.875^2 = 140.64W$

Q3] b) Find current through 10Ω using Thevenin's theorem (8)



Solution:-



(1) Calculation of V_{TH}

Applying KVL to mesh 1

$-100 + 40I_1 + 20I_1 + 30(I_1 - I_2) = 0$

$40I_1 + 20I_1 + 30I_1 - 30I_2 = 100$

$90I_1 - 30I_2 = 100$ ………………(1)

Applying KVL to mesh 2

$30(I_2 - I_1) + 30I_2 + 40I_2 + 50 = 0$

$30I_2 - 30I_1 + 30I_2 + 40I_2 = -50$

$-30I_1 + 100I_2 = -50$

$30I_1 - 100I_2 = 50$ ……………………….(2)

From (1) and (2) we get

$I_1 = 1.049$ and $I_2 = -0.185$

V_{TH} equation:-

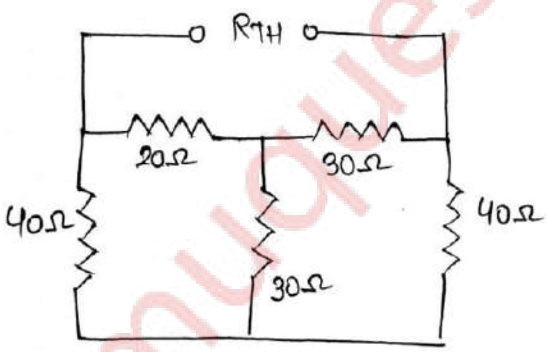
$V_{TH} - 30I_2 - 20I_1 = 0$

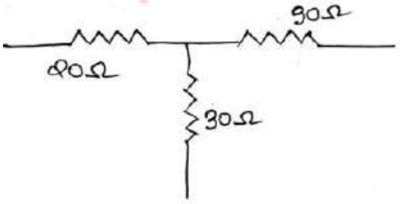
$V_{TH} - 30(-0.185) - 20(1.049) = 0$

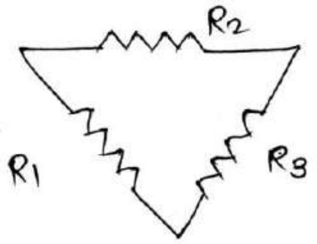
$V_{TH} = 15.43V$

(2) Calculation of R_{TH}

$R_1 = 20 + 30 + \frac{20\times30}{30} = 70\Omega$

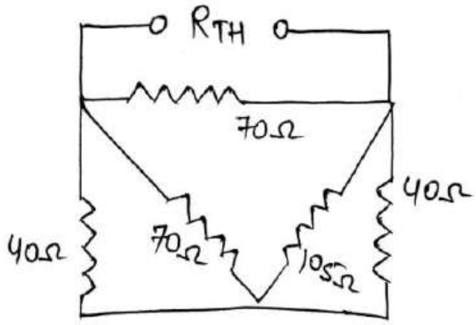






$R_2 = 20 + 30 + \frac{20\times30}{30} = 70\Omega$

$R_3 = 30 + 30 + \frac{30\times30}{20} = 105\Omega$



40 || 70 = 25.4545

105 || 40 = 28.9655

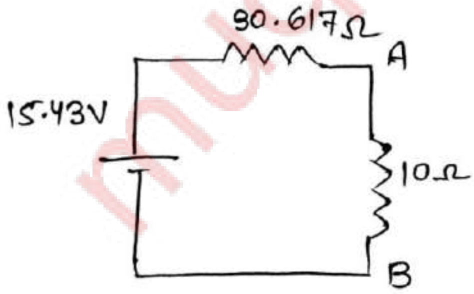
25.4545+28.9655 = 54.42Ω

$R_{TH} = 30.617\Omega$

(3) Calculation of I_L

$I_L = \frac{15.43}{30.617+10}$

$I_L = 0.3798A$



Q3] c) With the help of equivalent circuit of a single phase transformer show how total copper loss can be represented in primary of a transformer. (4)

Solution:-

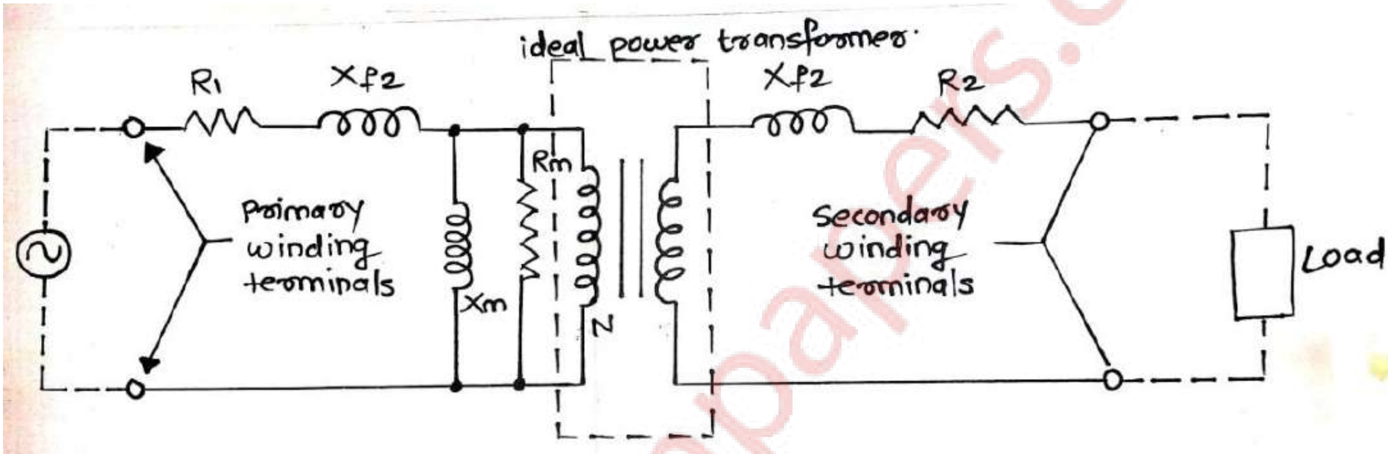
Copper Loss:- This loss is due to the resistances of primary and secondary windings.

$$W_{cu} = I_1^2 R_1 + I_2^2 R_2$$

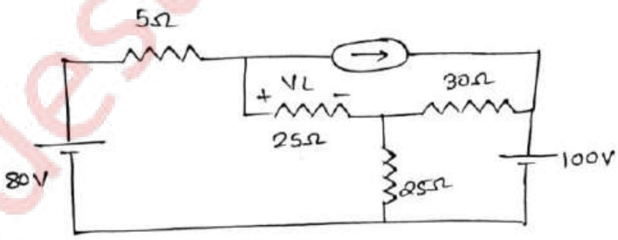
Where, R_1= Primary winding resistance

R_2 = secondary winding resistance.

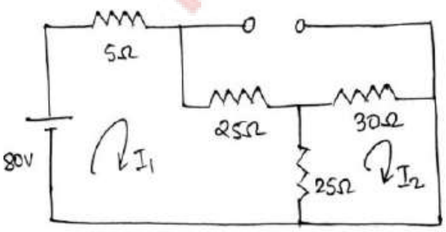
Copper loss depends upon the load on the transformer and its proportional to square of load current of kVA rating of the transformer.



Q4] a) Find V_L using super position theorem (8)



Solution:-



1) When 80V is active

Mesh analysis to mesh 1

$-80 + 5I_1 + 25I_1 + 25(I_1 - I_2) = 0$

$55I_1 - 25I_2 = 80$ ………………..(1)

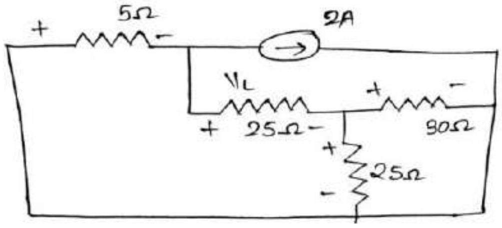
Mesh analysis to mesh 2

$-25(I_2 - I_1) + 30I_2 = 0$

$25I_1 + 5I_2 = 0$ ………………..(2)

From (1) and (2) we get,

$I' = 0.444A$

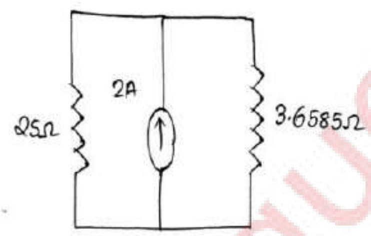


(2) when 2A is active

(25 || 30) = 13.6363Ω

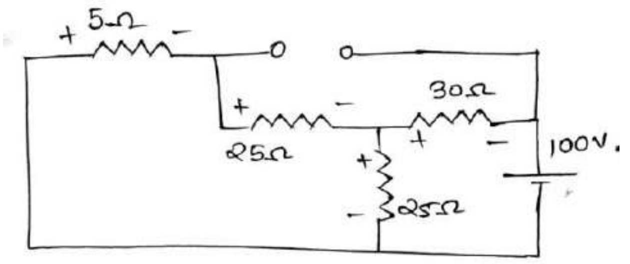
(13.6363 || 5) = 3.6585Ω

Hence we get



$I'' = 2 \times \frac{3.6585}{3.6585+25} = 0.25531A$

(3) when 100V is active



$5I_1 + 25I_1 + 25(I_1 - I_2) = 0$

$55I_1 - 25I_2 = 0$ …………………(1)

$-25(I_2 - I_1) + 30I_2 + 100 = 0$

$25I_1 + 5I_2 = -100$ ………………..(2)

From (1) and (2)

$I''' = \ -2.77A$

current through V_L is:

= 0.444 + 0.25531 – 2.77

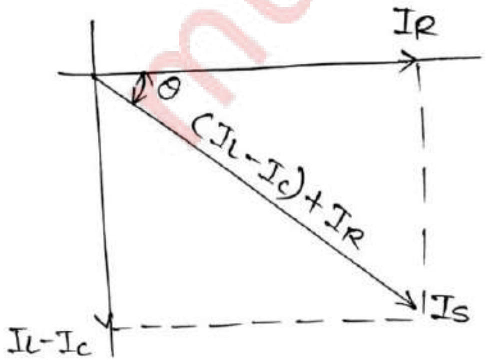
= -2.07069A

$I = 2.07069A$

Q4] b) In an R-L-C parallel circuit the current through resistor, inductor(pure) and capacitor are 20A, 15A and 40A respectively. What is the current taken from the supply? Draw phasor diagram. (4)

Solution:-

$I_R = 20A$, $I_L = 15A$ and I_C =40A



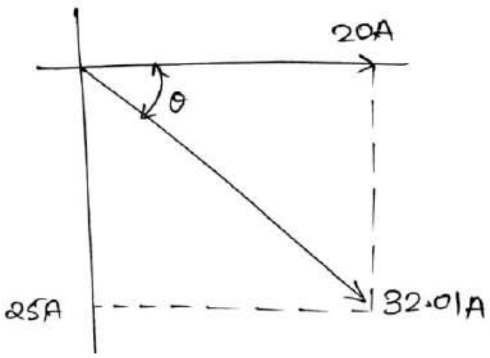
To calculate the source current according to phasor diagram,

$I_S^2 = I_R^2 + (I_L - I_C)^2$

$I_S^2 = 20^2 + (15 - 40)^2$

$I_S^2 = 1025$

$I_S = 32.01$ A



Q4] c) Two sinusoidal source of emf have rms value E_1 and E_2. When connected in series, with a phase displacement α the resultant voltage read on an electrodynamometer voltmeter 41.1V and with one source reserved 17.52V. When the phase displacement made zero a reading of 42.5V is observed. Calculate E_1, E_2 and α (8)

Solution:-

$\overline{E_1} = E_1\angle 0°$

$\overline{E_2} = E_2\angle \alpha°$

When two sources are connected in series,

$\sqrt{E_1^2 + E_2^2 + 2E_1E_2cos\alpha} = 41.1$

$E_1^2 + E_2^2 + 2E_1E_2cos\alpha = 1689.21$ ……………..(1)

When one of the source is reversed,

$\sqrt{E_1^2 + E_2^2 - 2E_1E_2cos\alpha} = 17.52$

$E_1^2 + E_2^2 - 2E_1E_2cos\alpha = 306.95$ ……………..(2)

When phase displacement is made zero,

$\sqrt{E_1^2 + E_2^2 + 2E_1E_2cos0} = 42.5$

$E_1 + E_2 = 42.5$

Adding eqn (1) and (2) we get,

$2(E_1^2 + E_2^2) = 1996.16$

$E_1^2 + E_2^2 = 998.08$

$(42.5 - E_2)^2 + E_2^2 = 998.08$

$1806.25 - 85E_2 + E_2^2 + E_2^2 = 998.08$

$E_2^2 - 42.5E_2^2 + 404.09 = 0$

Solving eq (2) from eq (1),

$E_2 = 28.14V$ or $E_2 = 14.36V$

$E_1 = 14.36V$ or $E_1 = 28.14V$

Subtracting eqn (2) from eqn (1),

$4E_1E_2cos\alpha = 1382.26$

$4 \times 14.37 \times 28.14cos\alpha = 1382.26$

$cos\alpha = 0.855$

$\alpha = 31.24°$

Q5] a) Prove that the power in a balanced three phase delta connected circuit can be deduced from the reading of two wattmeter. Draw relevant connections and vector diagrams. Draw a table to show the effect of power on wattmeter. (8)

Solution:-

Given figure shows a balanced star-connected load, the load may be assumed to be inductive. Let V_{RN}, V_{YN}, V_{BN} be the three phase voltages. I_R, I_Y, I_B be the phase currents. The phase currents will lag behind their respective phase voltages by angle φ. Current through current coil of $W_1 = I_R$

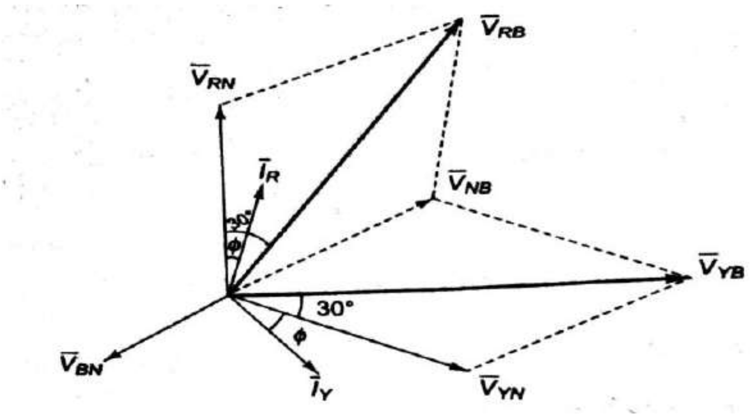
Voltages across voltage coil of $W_1 = V_{RB} = V_{RN} + V_{NB} = V_{RN} - V_{BN}$

From the phasor diagram, it is clear that the phase angle between V_{RB} and I_R is $(30° - \varphi)$

$W_1 = V_{RB}I_R\cos(30° - \varphi)$

Current through current coil of $W_2 = I_Y$

Voltage across voltage coil of $W_2 = V_{YB} = V_{YN} + V_{NB} = V_{YN} - V_{BN}$



From phasor diagram, it is clear that phase angle between V_{YB} and I_Y is (30° + φ)

$W_2 = V_{YB} I_Y \cos(30° + \varphi)$

But $I_R, = I_Y = I_L$

$V_{RB} = V_{YB} = V_L$

$W_1 = V_L I_L \cos(30° - \varphi)$

$W_2 = V_L I_L \cos(30° + \varphi)$

$W_1 + W_2 = V_L I_L \cos(30° - \varphi) + V_L I_L \cos(30° + \varphi)$

$W_1 + W_2 = V_L I_L (2cos30° cos\varphi)$

P(active power) = $W_1 + W_2 = \sqrt{3}\, V_L I_L (cos\varphi)$

Thus the sum of two wattmeter reading gives three phase power

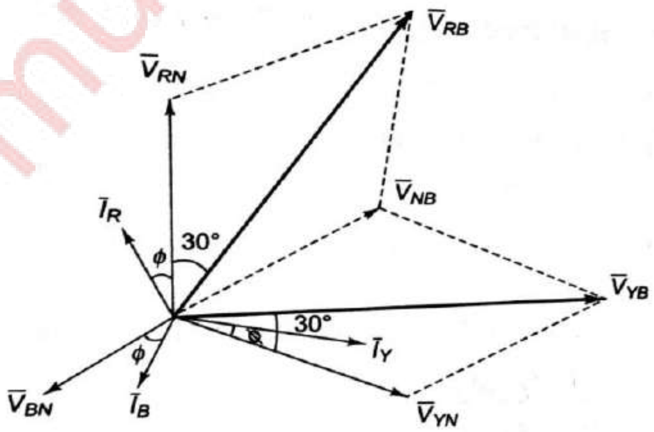
MEASUREMENT OF POWER FACTOR BY TWO-WATTMETER METHOD

(1) Lagging power factor

Pf = cos$\varphi = cos\left\{\tan^{-1}\left(\sqrt{3}\frac{W_1+W_2}{W_1-W_2}\right)\right\}$

(2) Leading power factor

(3) Pf = cos$\varphi = cos\left\{\tan^{-1}\left(-\sqrt{3}\frac{W_1+W_2}{W_1-W_2}\right)\right\}$



Q5] b) A 5kVA 200/400, 50Hz single phase transformer gave the following test results.

OC test on LV side	**200 V**	**0.7 A**	**60 W**
SC test on HVside	**22 V**	**16 A**	**120 W**

1. **Draw the equivalent circuit of the transformer and insert all parameter values.**
2. **Efficiency at 0.9 pf lead and rated load.**
3. **Current at which efficiency is maximum.** **(8)**

Solution:- 1) Equivalent circuit of the transform and parameters

From OC test(meters are connected on LV side i.e. primary)

$W_i = 60w$ $V_1 = 200V$ $I_0 = 0.7\text{Am}$

$\cos\varphi_0 = \frac{W_i}{V_1 I_0} = \frac{60}{200\times 0.7} = 0.43$

$\sin\varphi_0 = (1 - 0.43^2)^{0.5} = 0.9$

$I_w = I_O cos\varphi_o = 0.7 \times 0.43 = 0.3A$

$R_O = \frac{V_1}{I_w} = \frac{200}{0.3} = 666.67\Omega$

$I_\mu = I_o sin\varphi_o = 0.7 \times 0.9 = 0.63\text{Am}$

$X_o = \frac{V_1}{I_\mu} = \frac{200}{0.63} = 317.46\Omega$

From SC test (meters are connected on HV side i.e. secondary)

$W_{sc} = 120w$ $V_{sc} = 22V$ $I_{sc} = 16A$

$Z_{02} = \frac{V_{sc}}{I_{sc}} = \frac{22}{16} = 1.375\Omega$

$R_{02} = \frac{W_{sc}}{I_{SC}^2} = \frac{120}{16^2} = 0.47\Omega$

$X_{02} = ({Z_{02}}^2 - {R_{02}}^2)^{0.5} = (1.375^2 - 0.47^2)^{0.5} = 1.29\Omega$

$K = \frac{400}{200} = 2$

$R_{01} = \frac{R_{02}}{K^2} = \frac{0.47}{4} = 0.12\Omega$

$X_{01} = \frac{X_{02}}{K^2} = \frac{1.29}{4} = 0.32\Omega$

2)Efficiency at rated load and 0.9 pf leading

$W_i = 60w = 0.60kw$

Since meters are connected on secondary in SC test,

$I_2 = \frac{5\times1000}{400} = 12.5A$

$W_{Cu} = I_2^2 R_{02} = 12.5^2 \times 0.47 = 73.43W = 0.073kW$

x = 1   pf = 0

$$\%\eta = \frac{x \times \text{full load KVA} \times \text{pf}}{(x \times \text{full load KVA} \times \text{pf}) + W_i + x^2 W_{cu}} \times 100$$

$$\%\eta = \frac{1 \times 5 \times 0.9}{1 \times 5 \times 0.9 + 0.06 + 1 \times 0.073} \times 100$$

$\%\boldsymbol{\eta} = \mathbf{97.13}\%$

Regulation at rated load and 0.9 pf load,

$\cos\varphi = 0.9$

$\sin\varphi = 0.44$

$$\% \text{ regulation} = \frac{I_2(R_{02}cos\varphi - X_{02}sin\varphi)}{E_2} \times 100$$

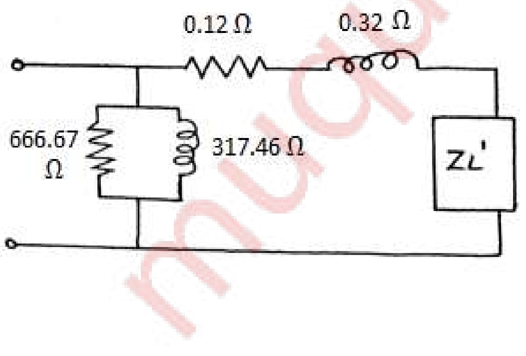
$$\% \text{ regulation} = \frac{12.5(0.47 \times 0.9 - 1.29 \times 0.44)}{400} \times 100$$

$\% \textbf{ regulation} = -\mathbf{0.45}\%$

Current at maximum efficiency,

$W_i = I_2^2 R_{02}$

$I_2 = \sqrt{\frac{W_i}{R_{02}}} = \sqrt{\frac{60}{0.47}} = 11.3$ A



Q5] c) Prove that if the phase impedance are same, power drawn by a balanced delta connected load is three times the power drawn by the balanced star connected load. (4)

Solution:-

Let a balanced load be connected in star having impedance per phase as Z_{ph}.

For a star-connected load

$V_{ph} = \frac{V_L}{\sqrt{3}}$

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{V_L}{\sqrt{3}Z_{ph}}$ => $I_{ph} = I_L = \frac{V_L}{\sqrt{3}Z_{ph}}$

Now, $P_Y = \sqrt{3}V_L I_L cos\varphi = \sqrt{3} \times V_L \times \frac{V_L}{\sqrt{3}Z_{ph}} \times cos\varphi = \frac{V_L^2}{Z_{ph}} cos\varphi$

For a delta-connected load

$V_{ph} = V_L$

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{V_L}{Z_{ph}}$ => $I_{ph} = \sqrt{3}I_L = \sqrt{3}\frac{V_L}{Z_{ph}}$

Now, $P_\Delta = \sqrt{3}V_L I_L cos\varphi = \sqrt{3} \times V_L \times \sqrt{3}\frac{V_L}{Z_{ph}} \times cos\varphi = 3\frac{V_L^2}{Z_{ph}} cos\varphi = 3P_Y$

$\boldsymbol{P_Y = \frac{1}{3} P_\Delta}$

Thus, power consumed by a balanced star-connected load is one third of that in the case of delta-connected load.

Q6] a) Three identical coils each having a reactance of 20Ω and resistance of 10Ω are connected in star across a 440V three phase line. Calculate for each method:

1. **Line current and phase current.**
2. **Active , reactive and apparent power.**
3. **Reading of each wattmeter connected to measure the power.** **(8)**

Solution:- $X_L = 20\Omega$ R = 10 Ω $V_L = 400$V

1. LINE CURRENT AND PHASE CURRENT.

$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94$ V

$\overline{Z_{ph}} = R + jX_L = 10 + j20$

$\overline{Z_{ph}} = 22.3606\angle 63.4349°$

$\varphi = 63.4349°$

Power factor = cos φ = cos(63.4349°) = 0.44721

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230.94}{22.3606} = 10.3279$A

$I_{ph} = I_L = 10.3279$ A

2. Active, Reactive and apparent power.

Reactive power(Q) = $\sqrt{3}I_L V_L sin\varphi \ = \sqrt{3} \times 400 \times 10.3279 \times \sin(63.4349)$

= 6399.962W

Active power(P) = $\sqrt{3}I_L V_L cos\varphi$ = $\sqrt{3} \times 400 \times 10.3279 \times \cos(63.4349)$

= 3199.957 W

Apparent power(S) = $\sqrt{3}I_L V_L$ = $\sqrt{3} \times 400 \times 10.3279$

= 7155.3790 W

3. Readings of 2 wattmeter

Active power(P) = $\sqrt{3}I_L V_L cos\varphi$ = $\sqrt{3} \times 400 \times 10.3279 \times \cos(63.4349)$

= 3199.957 W

$w_1 + w_2 = 3199.9570$ ………………(1)

Also, tan$\varphi = \sqrt{3}\frac{w_1 - w_2}{w_1 + w_2}$

tan(63.4349) = $\sqrt{3}\frac{w_1 - w_2}{3199.9570}$

$w_1 - w_2 = 3694.9841$ …………..(2)

From (1) and (2) we get,

$w_1 = 3447.47055$ w

$w_2 = 247.51355$ w

Q6] b) A series resonant circuit has an impedance of 500Ω at resonance frequency. The cut of frequency observed are 10kHz and 100Hz, Determine:

1. **Resonant frequency**
2. **Value of R,L and C.**
3. **Q factor at resonance** **(6)**

Solution:- R = 500Ω $f_1 = 100$Hz $f_2 = 10$kHz

1. RESONANCE FREQUENCY.

BW = $f_2 - f_1 = 10{,}000 - 10 = 9900Hz$

$f_1 = f_0 - \frac{R}{4\pi L}$ ……………….(1)

$f_2 = f_0 + \frac{R}{4\pi L}$ ……………….(2)

Adding (1) and (2),

$f_1 + f_2 = 2f_0$

$f_0 = \frac{f_1+f_2}{2} = \frac{10+10000}{2} = 5050Hz$

2. Values of R, L and C

R = 500Ω

BW = $\frac{R}{2\pi L}$

9900 = $\frac{500}{2\pi L}$

L = 8.038mH

$X_{L_0} = 2\pi f_0 L = 2\pi \times 5050 \times 8.038 \times 10^{-3} = 255.05\Omega$

At resonance , $X_{L_0} = X_{C_0} = 255.05\Omega$

$X_{C_0} = \frac{1}{2\pi f_0 C}$

$255.05 = \frac{1}{2\pi \times 5050 \times C}$

$C = 0.12\mu F$

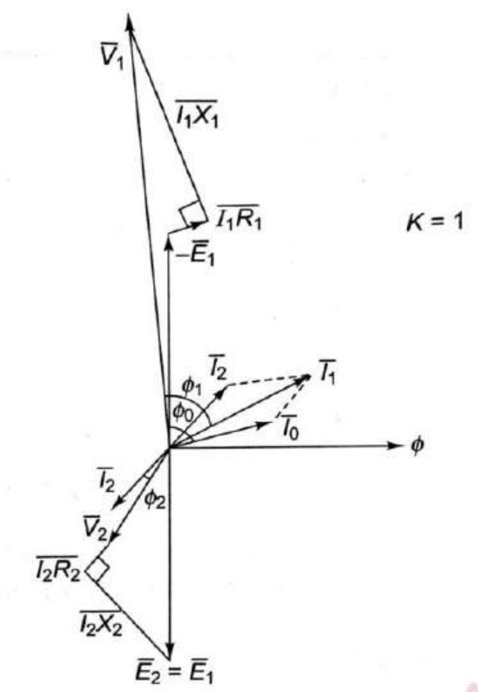
3. QUALITY FACTOR.

$Q_0 = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{500}\sqrt{\frac{8.038\times10^{-3}}{0.12\times10^{-6}}} = 0.5176$

$Q_0 = 0.5176$

Q6] c) Draw and illustrate transformer phasor diagram for lagging power factor. (6)

Solution:-

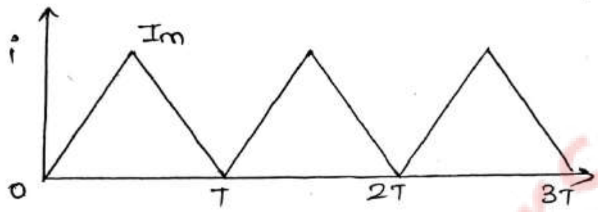


$\overline{V}_1$
$\overline{I_1X_1}$
$\overline{I_1R_1}$
$-\overline{E}_1$
$K = 1$
$\overline{I}_2$
$\overline{I}_1$
ϕ_1
ϕ_0
$\overline{I}_0$
ϕ
$\overline{I}_2$
ϕ_2
$\overline{V}_2$
$\overline{I_2R_2}$
$\overline{I_2X_2}$
$\overline{E}_2 = \overline{E}_1$

BEE SOLUTION OF QUESTION PAPER

(CBCGS DEC 2018)

Q1] 1) Find the RMS value of the waveform given below:- **(4)**



Solution:-

The rms value of the alternating current is given by,

$$I_{rms} = \sqrt{\frac{1}{t_2-t_1}\int_{t_1}^{t_2} i^2(t)dt}$$

$t_1 = T \qquad t_2 = 2T \qquad i = I_m \sin\theta t$

$$I_{rms} = \sqrt{\frac{1}{2T-T}\int_T^{2T}(I_m \sin\varphi t)^2(T)dt} \quad = \quad I_m\sqrt{\int_T^{2T}\sin^2\theta t dt} \quad = \quad I_m\sqrt{[\frac{\theta}{2}-\frac{\sin 2\theta}{4}]_T^{2T}}$$

$$I_{rms} = I_m\sqrt{[\frac{2T}{2}-\frac{\sin 4T}{4}-\frac{T}{2}+\frac{\sin 2T}{4}]}$$

$$I_{rms} = I_m\sqrt{\frac{T}{2}-\frac{\sin 4T}{4}+\frac{\sin 2T}{4}}$$

Q1]2) State Norton's theorem and draw the Norton's equivalent circuit. **(4)**

Solution:-

It states that 'Any two terminals of a network can be replaced by an equivalent current source and an equivalent parallel resistance.' The constant current is equal to the current which would flow in a short circuit placed across the terminals. The parallel resistance is the resistance of the network when viewed from these open-circuited terminals after all voltage and current have been removed and replaced by internal resistance.

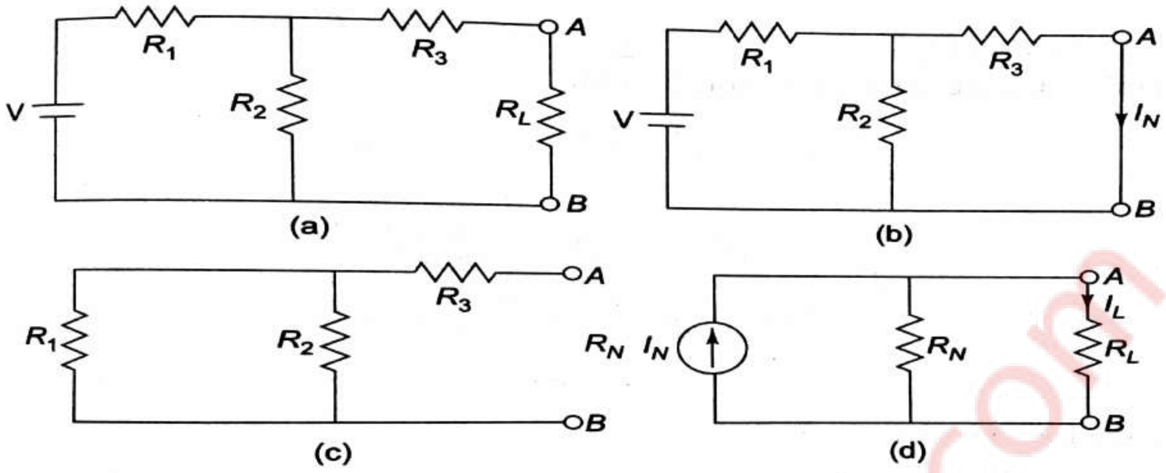


Diagram (d) from above shows the Norton's equivalent circuit.

Q1] 3) In an R-L-C parallel circuit the current through the resistor, inductor(pure), and capacitor (pure) are 20A, 15A and 40A respectively. What is the current from the supply ?draw the phasor diagram. (4)

Solution:-

$I_R = 20A \qquad I_L = 15A \quad I_C = 40A$

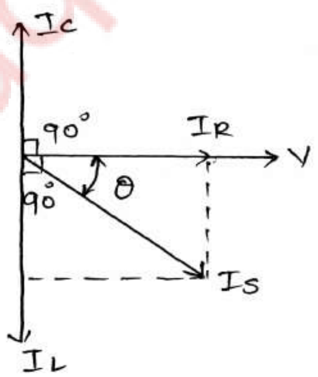
I_S be the source current.

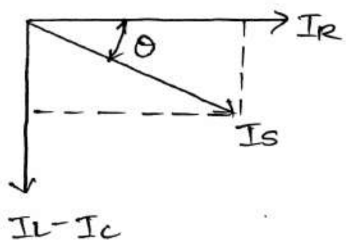
$I_S^2 = I_R^2 + (I_L - I_C)^2$

$I_S = \sqrt{I_R^2 + (I_L - I_C)^2}$

$I_S = \sqrt{20^2 + (15-40)^2} = \sqrt{20^2 + (-25)^2}$

I_S = 32.015 A





Q1] 4) A balanced 3 phase star connected load consists of three coils each consisting of R=6Ω and X_L= 8Ω . Determine the line current , power factor when the load is connected across 400V, 50Hz, supply (4)

Solution:-

R= 6Ω $X_L = 8\Omega$ V=400V f=50Hz

1) Power factor

.

$Z_{ph} = R + jX_L$ = 6 + j8 = 10∠53.13°

$Z_{ph} = 10\Omega$

$\varphi = 53.13°$

Pf = cos φ = cos(53.13) = 0.600

Power factor = 0.600

2) Line current.

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94V$$

$$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230.94}{10} = 23.094\text{ A}$$

$I_L = I_{ph}$ **= 23.09A**

Q1] 5) Briefly explain the classification of DC machine. (4)

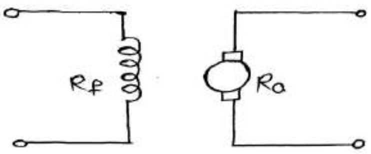
Solution:-

Depending upon the method of excitation of field winding ,DC machine are classified into two classes:-

1) Separately excited machines.
2) Self excited machines.

SEPARATELY EXCITED MACHINES

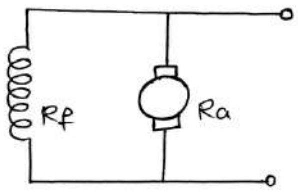
In separately excited machines the field winding is provided with a separate DC source to supply the field current as shown in figure.



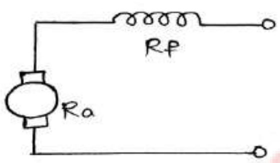
SELF EXCITED MACHINES

In case of self excited machines no, separate source is provided to drive the field current, but the field current is driven by its own emf generated across the armature terminals when the machine works as a generator self excited machine are further classified into the three types, depending upon the method in which the field winding is connected to the armature:

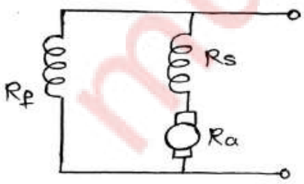
a) SHUNT WOUND MACHINES

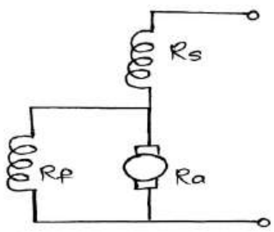


b) SERIES WOUND MACHINES



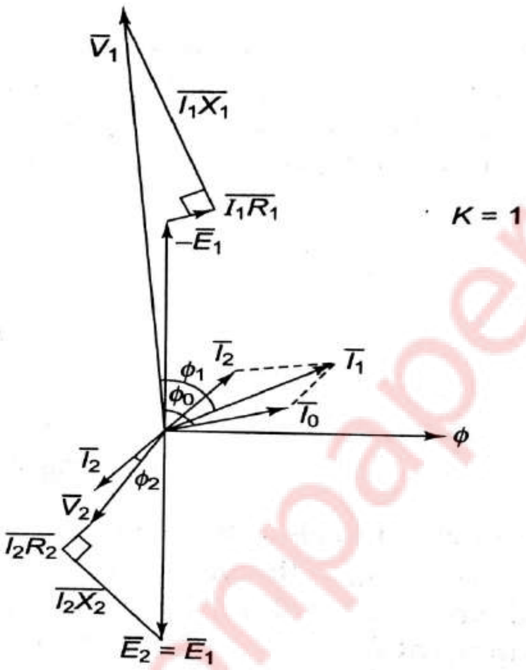
c) COMPOUND WOUND MACHINES





Q1]6) Draw the phasor diagram of a single phase transformer when it is loaded with a lagging power factor load. (4)

Solution:-



Q2] a) Prove that the average power taking by a pure capacitor fed with a sinusoidal ac supply in a circuit is zero. (10)

Solution:-

PHASE DIFFERENCE

It is the angle between the voltage and current phasors.

$\varphi = 90°$

POWER FACTOR

It is defined as the cosine of the angle between the voltage and current phasors.

Pf = $\cos\varphi = \cos(90°) = 0$

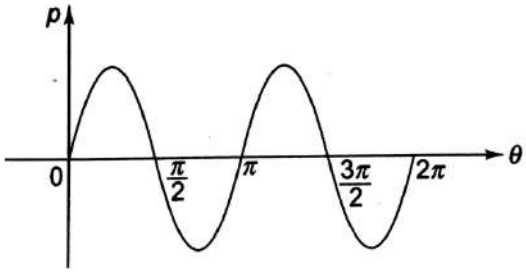
POWER

Instantaneous power P is given by,

$p = vi$

$p = V_m \sin\omega t I_m \sin(\omega t + 90)$

$p = V_m I_m \sin\omega t \cos\omega t$



$p = \frac{V_m I_m}{2} \sin 2\omega t$

The average power for one complete cycle, P =0

Hence, power consumed by a purely capacitive circuit is zero.

Q2] b) Using the mesh analysis find the mesh current in the direction shown and also find the voltage across A and B terminals . (10)

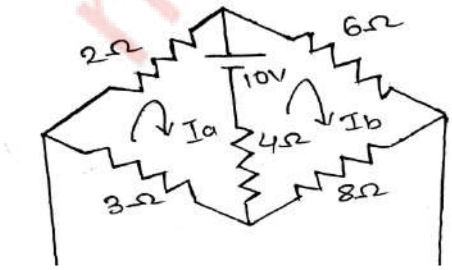
Solution:-

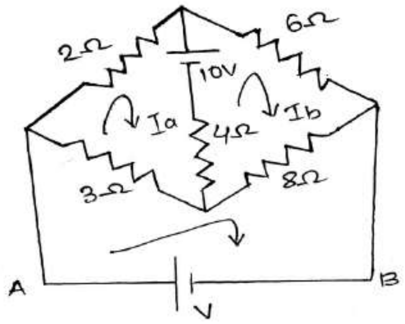
Applying KVL to mesh a

$-3I_a - 2I_a - 4(I_a - I_b) + 10 = 0$

$-3I_a - 2I_a - 4I_a + 4I_b + 10 = 0$

$9I_a - 4I_b = 10$ …………(1)





Applying KVL to mesh b

$-10 + 6I_a + 8I_b - 4(I_b - I_a) = 0$

$6I_b + 8I_b - 4I_b + 4I_a = 10$

$-4I_a + 18I_b = 10$ ....(2)

From (1) and (2) we get,

$I_a = 1.5068A$ and $I_b = 0.890A$

For voltage:-

Apply KVL to mesh

$-V + 3I_a + 8I_b = 0$

$V = 3I_a + 8I_b$

$V = 3\times1.5068 + 0.89\times8$

V = 11.640V

Q3] a) A single phase transformer has 1000 turns on the primary and 200 turns on the secondary. The no load current is 3A at a power factor of 0.2 lag and the secondary current is 280A at a power factor of 0.8 lag. Neglect R_2 and X_2 calculate (1) Magnetizing component and loss component of no load current. (2) primary current (3) input power factor .Draw phasor diagram showing all the currents.(10)

Solution:-

$$\frac{I_P}{I_S} = \frac{N_S}{N_P}$$

Therefore, $I_P = \frac{N_S}{N_P} \times I_S = \frac{200}{1000} \times 280 = 56A$

$\cos\varphi_2 = 0.8 \quad \cos\varphi_0 = 0.2 \quad \sin\varphi_2 = 0.6 \quad \sin\varphi_0 = 0.98$

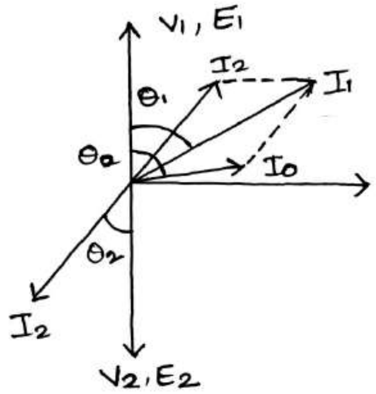
solve for horizontal and vertical components

$I_1\cos\varphi_1 = I_2\cos\varphi_2 + I_0\cos\varphi_0 \quad = (56\times0.8) + (3\times0.2) = 45.4A$

$I_1\sin\varphi_1 = I_2\sin\varphi_2 + I_0\sin\varphi_0 \quad = (56\times0.6) + (3\times0.98) = 36.54A$

$I_1 = \sqrt{45.4^2+36.54^2} = 58.3A$

I_μ **=** I_0**sin**φ_0 **=** (3×0.6) **= 1.8A**



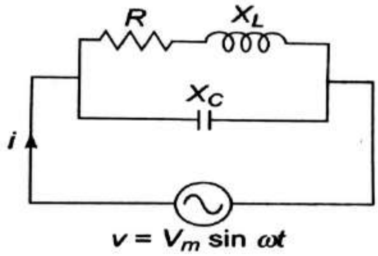
$\tan\varphi_1 = \frac{36.54}{45.4} = 0.805$

φ_1 **= 38°**

Power factor cosφ_1 **= cos38° = 0.78 lagging.**

Q3] b)Derive the formula for resonant frequency of the circuit with a pure capacitor in parallel with a coil having resistance and inductance. Find the expression for dynamic resistance of this parallel resonant circuit. (10)

Solution:-



Consider a parallel circuit consisting of a coil and a capacitor as shown below. The impedances of two branches are:-

$Z_1 = R + jX_L \qquad Z_2 = -jX_C$

$$Y_1 = \frac{1}{Z_1} = \frac{1}{R+jX_L} = \frac{R-jX_L}{R^2+X_L^2} \qquad Y_2 = \frac{1}{Z_2} = \frac{1}{-jX_C} = \frac{j}{X_C}$$

Admittance of the circuit $Y = Y_1 + Y_2$

$$Y = \frac{R-jX_L}{R^2+X_L^2} + \frac{j}{X_C} = \frac{R}{R^2+X_L^2} - j\left(\frac{X_L}{R^2+X_L^2} - \frac{1}{X_C}\right)$$

At resonance the circuit is purely resistive. Therefore, the condition for resonance is.

$$\frac{X_L}{R^2+X_L^2} - \frac{1}{X_C} = 0$$

$$\frac{X_L}{R^2+X_L^2} = \frac{1}{X_C}$$

$$X_L X_C = R^2 + X_L^2$$

$$\omega_0 L \frac{1}{\omega_0 C} = R^2 + \omega_0^2 L^2$$

$$\omega_0^2 L^2 = \frac{L}{C} - R^2$$

$$\omega_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

Where f_0 is called as the resonant frequency of the circuit.

If R is very small as compared to L then

$\omega_0 = \sqrt{\frac{1}{LC}}$

$f_0 = \frac{1}{2\pi\sqrt{LC}}$

DYNAMIC IMPEDANCE OF A PARALLEL CIRCUIT.

At resonance the circuit is purely resistive the real part of admittance is $\frac{R}{R^2+X_L^2}$. Hence the dynamic impedance at resonance is given by,

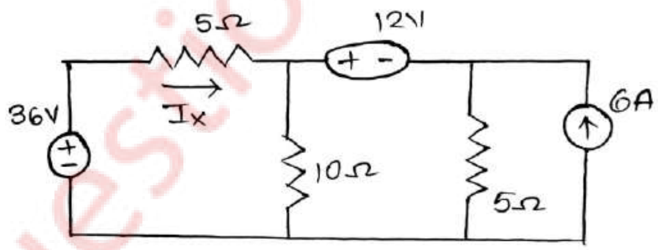
$$Z_D = \frac{R^2+X_L^2}{R}$$

At resonance ,

$R^2 + X_L^2 = X_L X_C = \frac{L}{C}$

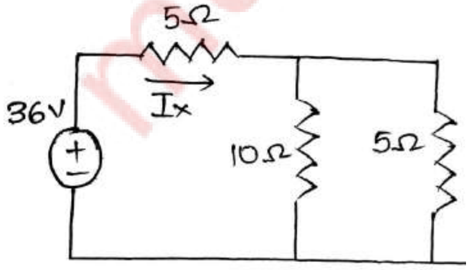
$Z_D = \frac{L}{CR}$

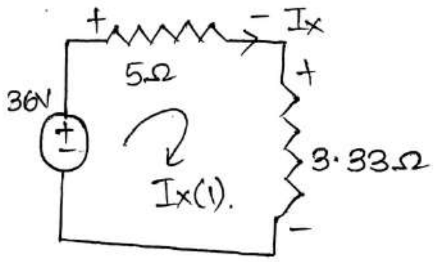
Q4] a) Find current I_X using Superposition theorem (10)

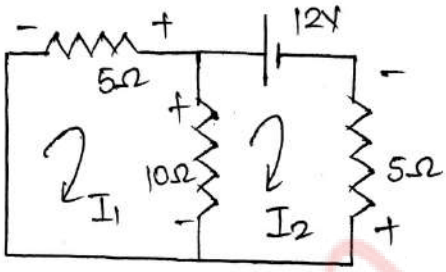


Solution:-

(1) 36V is active other all are inactive.







$10\Omega \,||\, 5\Omega = 3.33\Omega$

Applying KCL to the circuit.

$-36V + 5I_X + 3.33I_X = 0$

$8.33I_X = 36$

$I_X = 4.321$Am

(2) 12V is active other all are inactive.

Applying KVL at mesh 1

$-5I_1 + 10(I_1 - I_2) = 0$

$-5I_1 + 10I_1 - 10I_2 = 0$ ....(1)

Applying KVL at mesh 2

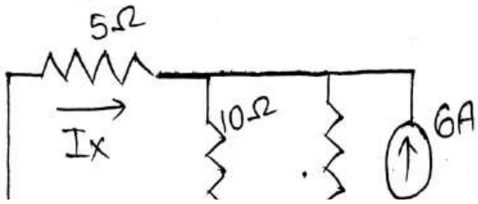
$12 - 5I_2 - 10(I_2 - I_1) = 0$

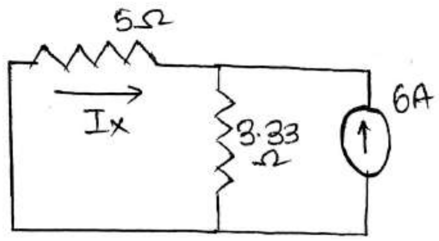
$12 = -10I_1 + 15I_2$ ....(2)

From (1) and (2) we get,

$I_1 = 2.142A$ and $I_2 = 1.0714A$

$I_X(2) = 2.142$ Am





(3) 6A is active and other all are inactive.

10Ω || 5Ω = 3.33Ω

$I_X(3) = 6\times\frac{3.33}{3.33+5} = 2.398$ Am

$I_X(3) = -2.398$ Am

$I_X = -2.398 + 2.142 + 4.32 = 4.065$

I_X **= 4.065 Am**

Q4] b) A resistance and a capacitor connected in series across a 250V supply draws 5A at 50Hz. When frequency is increased to 60Hz, it draws 5.8A. Find the values of R & C. Also find active power and power factor in both cases. (10)

Solution:-

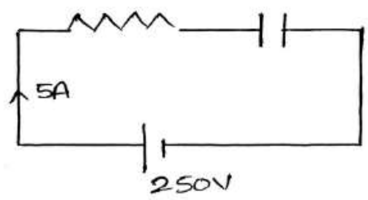
$I_1 = 5A$ V = 250V $f_1 = 50Hz$ $f_2 = 60Hz$ $I_2 = 5.8A$

(1) Values of R and C.

For $f_1 = 50Hz$ $Z_1 = \frac{V}{I_1} = \frac{250}{5} = 50\Omega$

$Z_1^2 = \left(R^2+(\frac{1}{2\pi f_1 C})^2\right) = (R^2 + (\frac{1}{100\pi C})^2)$

$R^2 + (\frac{1}{100\pi C})^2 = 2500$ ……………..(1)



For $f_1 = 60Hz$ $\quad Z_2 = \frac{V}{I_2} = \frac{250}{5.8} = 43.1\Omega$

$Z_2^2 = \left(R^2 + (\frac{1}{2\pi f_1 C})^2\right) \quad = \quad (R^2 + (\frac{1}{120\pi C})^2)$

$R^2 + (\frac{1}{120\pi C})^2 = 1857.9\Omega$ ....(2)

From (1) and (2) we get,

R = 19.96Ω C = 69.4µF

(2) Power draw in the both cases.

$P_1 = I_1^2 R = 5^2 \times 19.96 = 499w$ $\qquad P_2 = I_2^2 R = 5.8^2 \times 19.96 = 671.45w$

P_1 **= 499w and** P_2 **= 671.45w**

(3) Power factor in both cases:-

$P_1 = VI_1 \cos\varphi_1$

$499 = 250 \times 5 \times \cos\varphi_1$ => $\cos\varphi_1 = 0.3992$

φ_1 **= 66.471°**

$P_2 = VI_2 \cos\varphi_2$

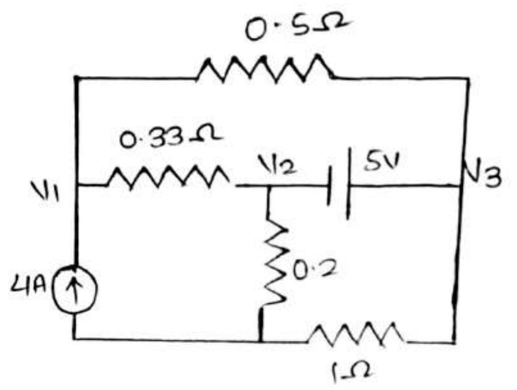
$671.45 = 250 \times 5.8 \times \cos\varphi_2$ => $\cos\varphi_2 = 0.463$

φ_1 **= 62.4146°**

Q5] a) Find the node voltages V_1,$V_2$and V_3 and current through 0.5Ω (10)

Solution:-

Assume that the currents are moving away from the nodes applying KCL at node 1,



$$4 = \frac{V_1 - V_2}{0.33} + \frac{V_1 - V_3}{0.5}$$

$$\left(\frac{1}{0.33} + \frac{1}{0.5}\right)V_1 - \frac{1}{0.33}V_2 - \frac{1}{0.5}V_3 = 4$$

$$5.03V_1 - 3.03V_2 - 2V_3 = 4$$

Nodes 2 and 3 will form a supernode.

Writing voltage equation for the supernode,

$$V_3 - V_2 = 5$$

Applying KCL at the supernode,

$$\frac{V_2 - V_1}{0.33} + \frac{V_2}{0.2} + \frac{V_3}{1} + \frac{V_3 - V_1}{0.5} = 0$$

$$-\left(\frac{1}{0.33} + \frac{1}{0.5}\right)V_1 + \left(\frac{1}{0.33} + \frac{1}{0.2}\right)V_2 + \left(1 + \frac{1}{0.5}\right)V_3 = 0$$

$$-5.03V_1 + 8.03V_2 + 3V_3 = 0$$

Solving eqs (1), (2) and (3)

$V_1 = 2.62V$

$V_2 = -0.17V$

$V_3 = 4.83V$

Q5] b) Describe the basic principle of operation of a single phase transformer and derive the emf equation. (10)

Solution:-

When an alternating voltage V_1 is applied to a primary winding, an alternating current I_1 flows in it producing an alternating flux in the core. As per Faraday's laws of electromagnetic induction, an emf e_1 is induced in the primary winding.

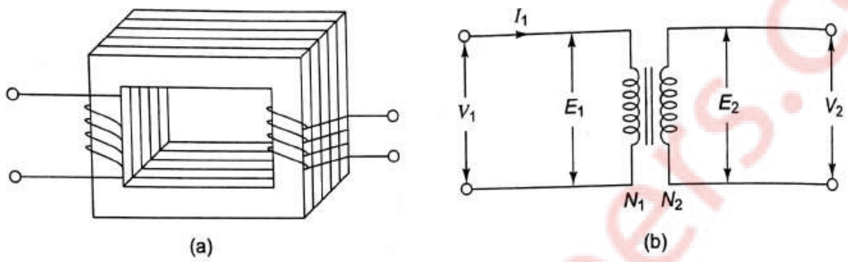


Fig. 6.5 *Working principle of a transformer*

$e_1 = -N_1 \frac{d\varphi}{dt}$

Where N_1 is the number of turns in the primary winding. The induced emf in the primary winding is nearly equal and opposite to the applied voltage V_1.

Assuming leakage flux to be negligible, almost the flux produced in primary winding links with the secondary winding. Hence, an emf e_2 is induced in the secondary winding.

$e_2 = -N_2 \frac{d\varphi}{dt}$

Where N_2 is the number of turns in the secondary winding. If the secondary circuit is closed through the load, a current I_2 flows in he secondary winding. Thus energy is transferred from the primary winding to the secondary winding.

EMF EQUATION.

As the primary winding is excited by a sinusoidal alternating voltage, an alternating current flows in the winding producing a sinusoidally varying flux φ in the core.

$$\varphi = \varphi_m \sin\omega t$$

As per Faraday's law of electromagnetic induction an emf e_1 is induced in the primary winding.

$$e_1 = -N_1 \frac{d\varphi}{dt}$$

$$e_1 = -N_1 \frac{d}{dt}(\varphi_m \sin\omega t)$$

$$e_1 = -N_1\varphi_m\omega\cos\omega t \quad = \quad -N_1\varphi_m\omega\sin(\omega t - 90°) \quad = \quad 2\pi f N_1\varphi_m\omega\sin(\omega t - 90°)$$

Maximum value of induced emf = $2\pi f\varphi_m N_1$

Hence, rms value of induced emf in primary winding is given by,

$$E_1 = \frac{E_{max}}{\sqrt{2}} = \frac{2\pi f N_1\varphi_m}{\sqrt{2}} = 4.44 f N_1\varphi_m$$

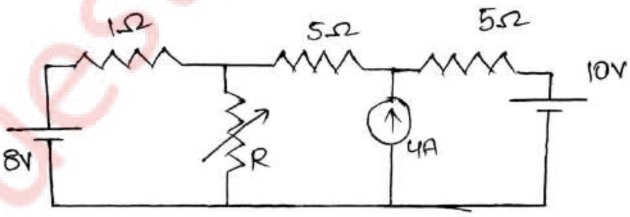
Similarly rms value of induced emf in the secondary winding is given by,

$$E_2 = 4.44 f N_2\varphi_m$$

Also, $\frac{E_1}{N_1} = \frac{E_2}{N_2} = 4.44 f\varphi_m$

Thus emf per turn is same in primary and secondary winding and an equal emf is induced in each turn of the primary and secondary winding.

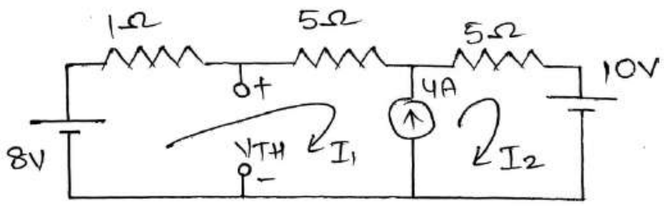
Q6] a) Determine the value of R for maximum power transfer and find the value of maximum transfer. (10)



Solution:-

(1) Calculation of V_{TH}

Removing the variable resistor R from the network



Mesh 1 and 2 will form A loop.

Writing current equation for the loop.

$I_2 - I_1 = 4$ ……………….(1)

Applying KVL to the loop,

$8 - I_1 - 5I_1 - 5I_2 - 10 = 0$

$-6I_1 - 5I_2 = 2$ ………..(2)

From (1) and (2) we get,

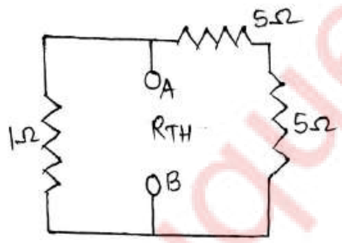
$I_1 = -2A$ and $I_2 = 2A$

Writing V_{TH} equation,

$8 - I_1 - V_{TH} = 0$ => $8 + 2 - V_{TH} = 0$

V_{TH} **= 10V**

(2) Calculation of R_{TH}



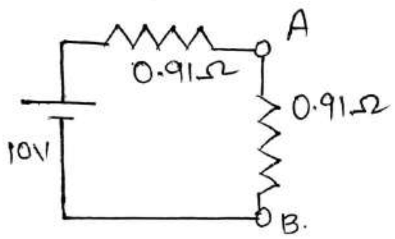
Replacing the voltage source by short circuits and current sources by an open circuit

R_{TH} = 10Ω || 1Ω = 0.91Ω

For maximum power transfer

(3) Calculation of P_{max}

$$P_{max} = \frac{V_{TH}^2}{4R_{TH}} = \frac{10^2}{4 \times 0.91} = 27.47w$$



Q6] b) The OC and SC test data are given below for a single phase, 5KVA, 200V/400V, 50Hz transformer

OC test from LV side	**200V**	**1.25A**	**150w**
SC test from HV side	**20V**	**12.5A**	**175w**

Determine the following :- **(10)**

1) **Draw the equivalent circuit of the transformer referred to LV side .**
2) **At what load or KVA the transformer is to be operated for maximum efficiency?**
3) **Calculate the value of maximum efficiency.**
4) **Regulation of the transformer at full load 0.8power factor lagging.**

Solution:-

(1) Approximate equivalent circuit.

From OC test (meters are connected on LV side i.e. secondary)

$$\cos\varphi_0' = \frac{W_0}{V_0 I_0'} = \frac{150}{200 \times 1.25} = 0.6 \qquad \sin\varphi_0' = 0.8$$

$$I_w' = I_0' \cos\varphi_0' = 1.25 \times 0.6 = 0.75A \qquad R_0' = \frac{V_0}{I_w'} = \frac{200}{0.75} = 266.6\Omega$$

$I'_\mu = I'_0 \sin\varphi'_0 = 1.25 \times 0.8 = 1A$ $\qquad X'_0 = \frac{V_0}{I'_\mu} = \frac{200}{1} = 200\Omega$

From SC test (meters are connected on the HV side i.e. primary)

$W_{SC} = 175w \quad V_{SC} = 20V \quad I_{SC} = 12.5A$

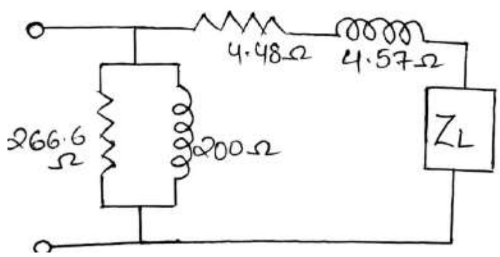
$Z_{01} = \frac{V_{SC}}{I_{SC}} = \frac{20}{12.5} = 1.6\Omega$ $\qquad R_{01} = \frac{W_{SC}}{I_{SC}^2} = \frac{175}{12.5^2} = 1.12\Omega$

$X_{01} = \sqrt{Z_{01}^2 - R_{01}^2} = \sqrt{1.6^2 - 1.12^2} = 1.1426\Omega$

$K = \frac{400}{200} = 2$

$R_{02} = K^2 R_{01} = 2^2 \times 1.12 = 4.48\Omega$

$X_{02} = K^2 X_{01} = 2^2 \times 1.1426 = 4.57\Omega$



(2) Maximum efficiency and load at which it occurs.

$W_{CU} = I_2^2 R_{02}$

$I_2 = \frac{5 \times 1000}{400} = 12.5$

$W_{CU} = 12.5^2 \times 4.48 = 700$

Load KVA = Full-load KVA$\times \sqrt{\frac{W_1}{W_{cu}}} = 5 \times \sqrt{\frac{150}{700}} = \mathbf{2.314KVA}$

<u>FOR MAXIMUM EFFICIENCY:-</u>

$W_i = W_{cu} = 150W = 0.150KW$

Pf =1

$$\%\eta_{max} = \frac{\text{load KVA} \times pf}{\text{load KVA} \times pf + W_i + W_i} \times 100$$

$$\%\eta_{max} = \frac{5 \times 1}{5 \times 1 + 0.15 + 0.15} \times 100$$

$\%\eta_{max}$ = 94.33%

(3) Regulation of transform at full load 0.8power factor lag.

$$\%\text{regulation} = \frac{I_2(R_{02}\cos\varphi + X_{02}\sin\varphi)}{E_2} \times 100$$

$$\%\text{regulation} = \frac{12.5(4.48 \times 0.8 + 4.57 \times 0.6)}{400} \times 100 = 19.76\%$$

%regulation = 19.76%

BEE Solutions May-2019

Q1.

(a) Explain the working principle of Single Phase Transformer. (4)

Ans: When an alternating voltage $V1$ is applied to a primary winding, an alternating current $I1$ flows in it producing an alternating flux in the core. As per Faraday's laws of electromagnetic induction, an emf $e1$ is induced in the primary winding.

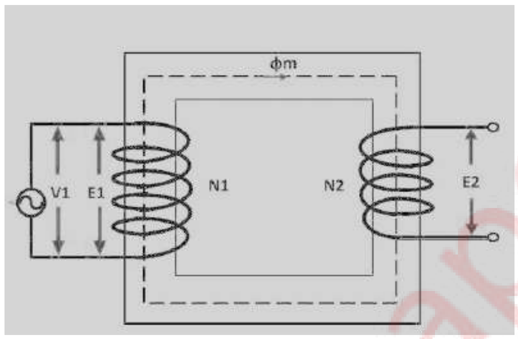


Fig.(a)

$e1 = -N1 \frac{d\varphi}{dt}$

Where $N1$ is the number of turns in the primary winding. The induced emf in the primary winding is nearly equal and opposite to the applied voltage $V1$.

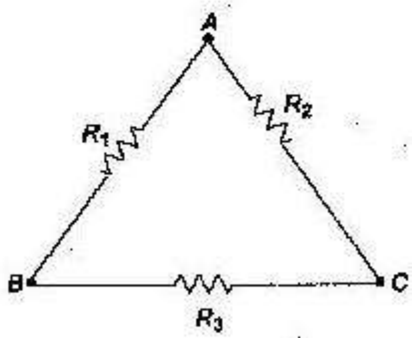
Assuming leakage flux to be negligible, almost the flux produced in primary winding links with the secondary winding. Hence, an emf $e2$ is induced in the secondary winding.

$e2 = -N2 \frac{d\varphi}{dt}$

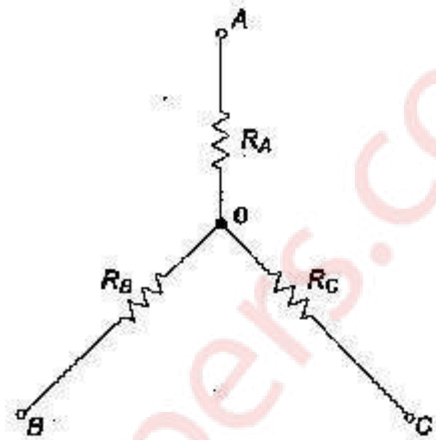
Where $N2$ is the number of turns in the secondary winding. If the secondary circuit is closed through the load, a current $I2$ flows in the secondary winding. Thus energy is transferred from the primary winding to the secondary winding.

(b) Derive the formulas to convert a Star circuit into equivalent Delta. (4)

Ans:



Fig(a)



Fig(b)

From the delta network shown,

The resistance between terminal 1 and 2 = $RC \mid\mid (RA + RB)$

$$= \frac{RC(RA+RB)}{RA+RB+RC} \qquad \text{.................... (1)}$$

From the star network shown above,

The resistance between terminals 1 and 2 = $R1 + R2$ .... (2)

Since the two networks are electrically equivalent.

$$R1 + R2 = \frac{RC(RA+RB)}{RA+RB+RC} \qquad \text{................... (3)}$$

Similarly,

$$R2 + R3 = \frac{RA(RB+RC)}{RA+RB+RC} \qquad \text{................ (4)}$$

And

$R1 + R3 = \frac{RB(RA+RC)}{RA+RB+RC}$ ………………. (5)

Subtracting Eq. (4) from Eq. (3)

$R1 - R3 = \frac{(RB*RC-RA*RB)}{RA+RB+RC}$ ……………… (6)

Adding Eq.(6) and Eq. (5)

$R1 = \frac{RB*RC}{RA+RB+RC}$

Similarly, $R2 = \frac{RA*RC}{RA+RB+RC}$

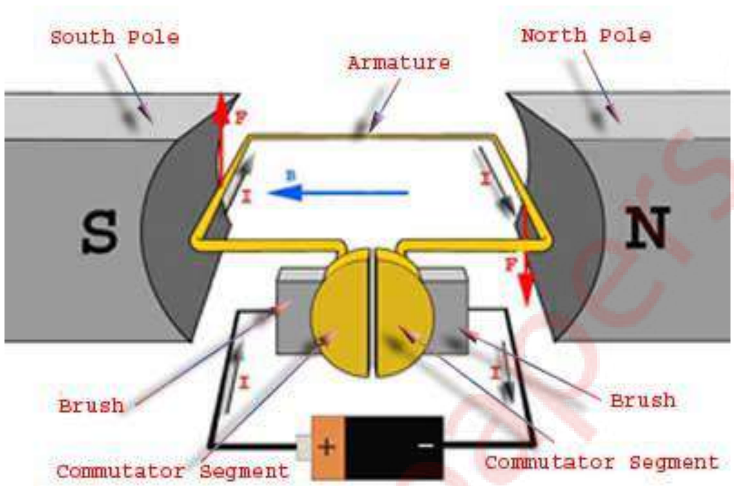
$R3 = \frac{RA*RB}{RA+RB+RC}$

Thus, star resistor connected to a terminal is equal to the product of the two delta resistors connected to the same terminal divided by the sum of the delta resistor.

(c) Explain the principle of operation of DC motor. (4)

Ans:

A machine that converts DC electrical power into mechanical power is known as a Direct Current motor.
DC motor working is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force.



The direction of this force is given by Fleming's left-hand rule and its magnitude is given by

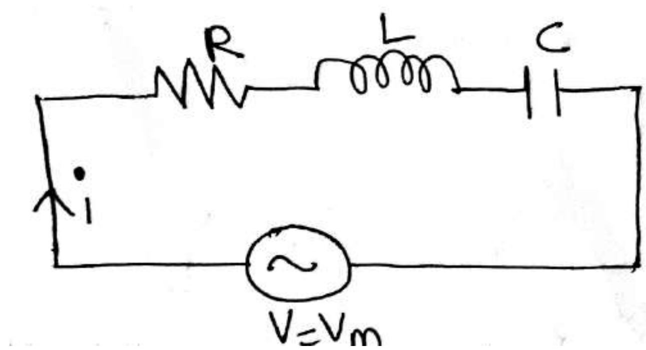
$$F = BIL$$

Where, B = magnetic flux density,
I = current
L = length of the conductor within the magnetic field.

(d) What is the necessary condition for resonance in series circuit? Derive the expression for resonance frequency. (4)

Ans:

A circuit containing reactance is said to be resonance if the voltage across the circuit is in phase with the current through it. At resonance the circuit thus behaves as a pure resistor and et reactance is zero.



Expression for Resonance is,

$Z = R + jX_L - jX_C$

$= R + j\omega L - j\frac{1}{\omega C}$

$= R + j(\omega L - \frac{1}{\omega C})$

At resonance,

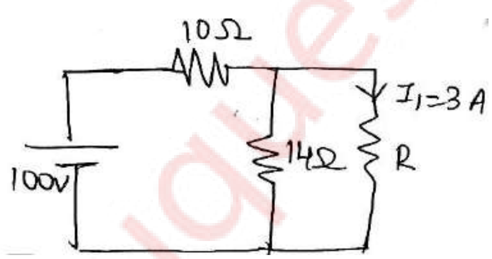
$\omega L - \frac{1}{\omega C} = 0$

$\omega = \omega_0 = \frac{1}{\sqrt{LC}}$

$f = f_0 = \frac{1}{2\pi\sqrt{LC}}$

Where f_0= resonant frequency

(e) Find the value of R in the following circuit. (4)



Ans:

By KCl,

Assume Voltage across R is V,

$\frac{V-100}{10} + \frac{V}{14} + 3 = 0$

By LCM and shifting,

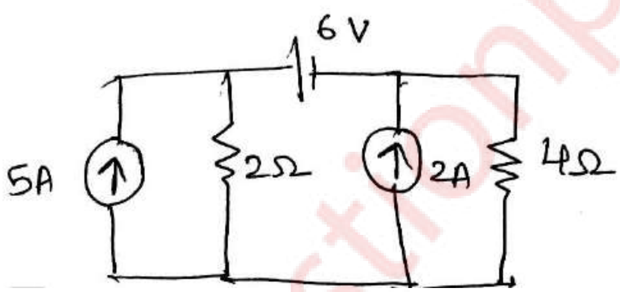
$\frac{6}{35}V = 7$

V = 40.33 v

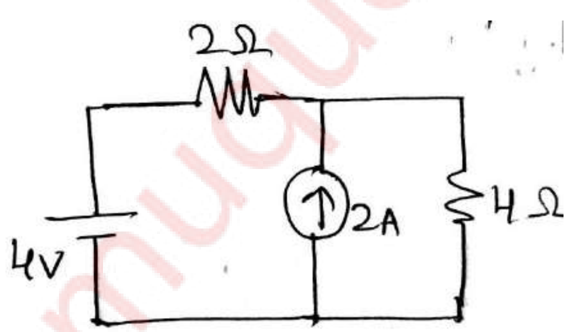
So value R is

$$R = \frac{40.833}{3} = 13.611\ \Omega$$

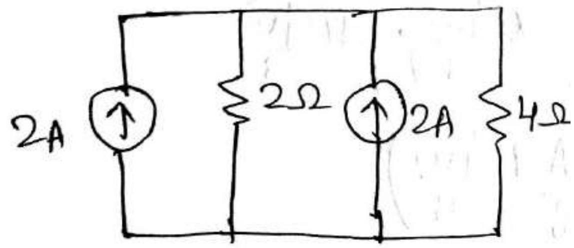
(f) Find the current through 4Ω resistor by source transformation in the following circuit. (4)



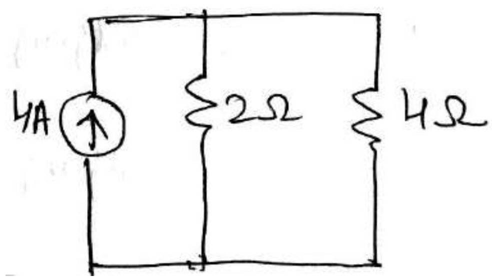
Ans:
By Source Transformation,



Again trasnforming 4V and 2Ω,



Adding 2A with 2A as they are in parallel,

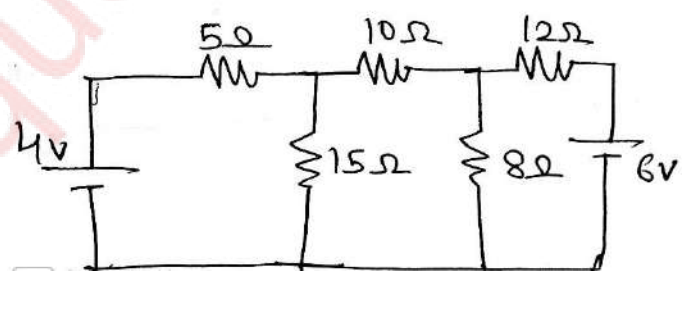


By Current Division Rule,

$I_{4\Omega} = 4\ X\ \frac{2}{2+4} = \frac{4}{3}\ A$

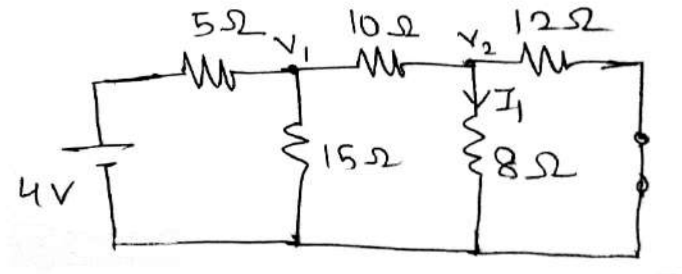
Q.2

(a) Determine the current through 8Ω resistor in the following network by superposition theorem: (8)



Ans:

When 4V is active and 6V is inactive



Applying KCl we get,

$$\frac{V1-4}{5}+\frac{V1-V2}{10}+\frac{V1}{15}=0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

And

$$\frac{V2-V1}{10}+\frac{V2}{8}+\frac{V2}{12}=0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

By solving eq (1),

$$\frac{11}{30}V1-\frac{V2}{10}=\frac{4}{5} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

By soving eq (2),

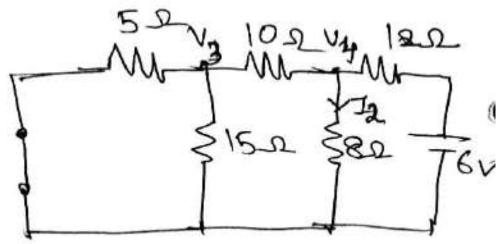
$$-\frac{V1}{10}+\frac{37}{120}V2=0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Solving eq (3) and (4) we get,

V1 = 2.4v V2 = 0.7763v

$$I1=\frac{V2}{8}=0.097A$$

Similarly, when 6v is active,



By KCL,

$$\frac{V3}{5} + \frac{V3 - V4}{10} + \frac{V3}{15} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$\frac{V4 - V3}{10} + \frac{V4 - 6}{12} + \frac{V4}{8} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

By solving eq (5) ,

$$\frac{11}{30}V3 = \frac{1}{10}V4 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

By solving eq. (6) ,

$$-\frac{1}{10}V3 + \frac{37}{120}V4 = \frac{1}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

Solving (7) and (8), we get

V3 = 0.485v V4 = 1.78v

$$I2 = \frac{V4}{8} = \frac{1.78}{8} = 0.225A$$

By Superposition Theorem,

$I_{8\Omega}$ = I1 + I2 = 0.097 + 0.225 = 0.322 A

(b) An inductive coil having inductance of 0.04H and resistance 25 Ω has been connected in series with another inductive coil of inductance 0.2H and resistance 15 Ω. The whole circuit is powered with 230V, 50Hz mains. Calculate the power dissipation in each coil and total power factor. (8)

Ans:

Coil 1 : $R_1 = 25\Omega$

$X_{L1} = 2\pi fL = 2 \times \pi \times 50 \times 0.04 = 12.566\ \Omega$

$Z_1 = \sqrt{R_1^2 + X_{L1}^2} = 27.98\ \Omega$

$\cos\phi_1 = \frac{R1}{Z1} = \frac{25}{27.98} = 0.8935$

$V1 = 230 \times \frac{Z1}{Z1+Z2} = 230\ x\ \frac{27.98}{27.98+64.6} = 69.511V$

Power Dissipated = $V_1 I \cos\phi_1 = \frac{V1xV1}{Z1}\ x\ cos\phi 1 = 152.3\ W$

Coil 2 : $R_2 = 15\Omega$

$X_{L2} = 2\pi fL = 2 \times \pi \times 50 \times 0.2 = 62.83\ \Omega$

$Z_2 = \sqrt{R_2^2 + X_{L2}^2} = 64.6\ \Omega$

$\cos\phi_2 = \frac{R2}{Z2} = \frac{15}{62.83} = 0.2387$

$V2 = 230 \times \frac{Z2}{Z1+Z2} = 230 \times \frac{64.6}{27.98+64.6} = 160.5V$

Power Dissipated = $V_2 I \cos\phi_2 = \frac{V2\ x\ V2}{Z2}\ x\ cos\phi 2 = 95.2W$

And Total PF,

$Req = R1 + R2 = 25 + 15 = 40\ \Omega$

$XLeq = XL1 + XL2 = 12.566 + 62.83 = 75.4\ \Omega$

$Z = \sqrt{R_{eq}^2 + X_{Leq}^2} = 85.35\ \Omega$

Power Factor(total) = $\cos\phi_{tot} = \frac{Req}{Zeq} = \frac{40}{85.35} = 0.468$

(c) What are the losses in transformer? Explain why the ratings of transformer in KVA not in KW? (4)

Ans: There are two types of losses in a transformer:

1. Iron or core loss
2. Copper loss

IRON LOSS:

This loss is due to the reversal of flux in the core. The flux set-up in the core is nearly constant. Hence, iron loss is practically constant at all the loads, from no load to full load. The losses occurring under no-load condition are the iron losses because the copper losses in the primary winding due to no-load current are negligible. Iron losses can be subdivided into two losses:

1. Hysteresis loss
2. Eddy current loss

COPPER LOSS: This loss is due to the resistance of primary and secondary windings

$Wcu = I_1^2 R1 + I_2^2 R2$

Where, $R1$ = primary winding resistance
$R2$ = secondary winding resistance

Copper loss depends upon the load on the transformer and is proportional to square of load current of kVA rating of the transformer.
So this is why, the ratings of transformer is in KVA and not in KW.

Q.3

(a) With necessary diagrams prove that three phase power can be measured by only two wattmeter. Also prove that reactive power can be measured from the wattmeter reading. (10)

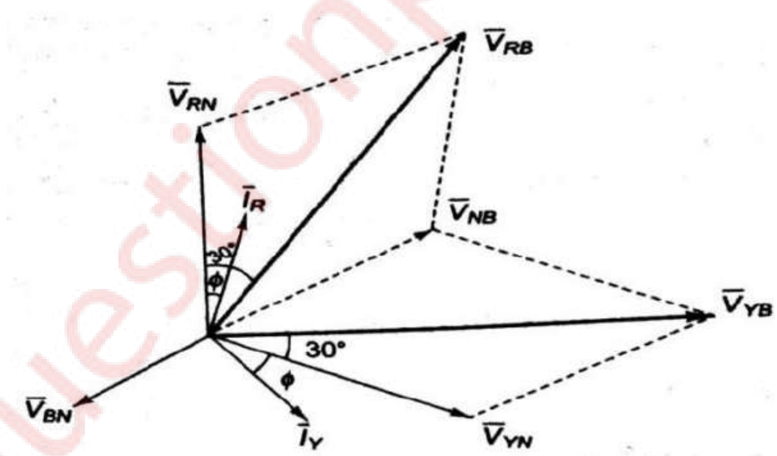
Ans:

Given figure shows a balanced star-connected load, the load may be assumed to be inductive. Let V_{RN}, V_{YN}, V_{BN} be the three phase voltages. I_R, I_Y, I_B be the phase currents. The phase currents will lag behind their respective phase voltages by angle φ. Current through current coil of $W1$ = I_R.

Voltages across voltage coil of $W1 = V_{RB} = V_{RN} + V_{NB} = V_{RN} - V_{BN}$

From the phasor diagram, it is clear that the phase angle between V_{RB} and I_R is $(30° - \varphi)$.

$W1 = V_{RB}\, I_R \cos(30° - \varphi)$ Current through current coil of $W2 = I_Y$ Voltage across voltage coil of $W2 = V_{YB} = V_{YN} + V_{NB} = V_{YN} - V_{BN}$



From phasor diagram, it is clear that phase angle between V_{YB} and I_Y is $(30° + \varphi)$

$W2 = V_{YB}\, I_Y \cos(30° + \varphi)$

But $I_R, = I_Y = I_L$

$V_{RB} = V_{YB} = V_L$

$W1 = V_L I_L \cos(30° - \varphi)$

$W2 = V_L I_L \cos(30° + \varphi)$

$W1 + W2 = V_L I_L \cos(30° - \varphi) + V_L I_L \cos(30° + \varphi)$

$W1 + W2 = V_L I_L (2cos30°cos\varphi)$

P(active power) = $W1 + W2 = \sqrt{3}\, V_L I_L (cos\varphi)$

Thus the sum of two wattmeter reading gives three phase power

For calculating reactive power :-

$W1 - W2 = V_L I_L \cos(30° - \varphi) - V_L I_L \cos(30° + \varphi)$

$W1 - W2 = V_L I_L [-2sin\,[\frac{30-\varphi+30+\varphi}{2}]\, sin\,[\frac{30-\varphi-30-\varphi}{2}]]$

$W1 - W2 = V_L I_L [-2 \sin(30) \sin(-\varphi)]$

$W1 - W2 = V_L I_L (\sin\varphi)$

Q (reactive power) = $W1 - W2 = V_L I_L (\sin\varphi)$

(b) An alternating voltage is represented by v(t)=141.4sin(377t) V. Derive the RMS value of the voltage.

Find:

1) **Instantaneous voltage value at t=3ms**
2) **The time taken for voltage to reach 70.7 V for first time (10)**

Ans:

To calculate RMS value of this voltage

$V(t) = 141.4\sin(377t)$

$V = V_m \sin\theta$ for $0 < \theta < 2\pi$

$Vm = 141.4$ for $\theta = 377t$

$V_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} V_m^2 \sin^2\theta d\theta = \frac{1}{2\pi}\int_0^{2\pi} 141.4^2 \sin^2\theta d\theta = \frac{141.42}{2\pi}\int_0^{2\pi} \sin^2\theta d\theta$

$\frac{141.42}{2\pi}\int_0^{2\pi} \frac{1-cos\theta}{2} d\theta = \frac{141.42}{2\pi}\left(\frac{\theta}{2} - \frac{sin2\theta}{2}\right)\ {}^{2\pi}{}_0 = \frac{141.42}{2\pi}\left[\frac{2\pi}{2}\right] = 9996.98$

$Vrms = \sqrt{9996.98} = 99.98$

$\mathbf{Vrms = 99.98V}$

1) Instantaneous value at t = 3ms

   $t = 3 \times 10^{-3} = 0.003sec$
   $V = V_{rms} \sin\theta$
   $V = 141.4\sin(337 \times 0.003)$
   V = 2.4949V

   Instantaneous voltage at t = 3ms is v = 2.494V

2) Time taken to reach till 70.7V for first time

   $V = V_{rms} \sin\theta$
   V = 70.7V

   $70.7 = 141.4\sin(377t)$
   $0.5 = \sin(337t)$
   $Sin^{-1}(0.5) = 337t$
   30 = 337t
   t = 0.089sec.

   Time required to reach till 70.7V is 0.089sec

Q.4

(a)State and Prove Maximum Power Transfer Theorem. (8)

Ans:

It states that "The maximum power is delivered from a source to a load when the load resistance is equal to the source resistance".

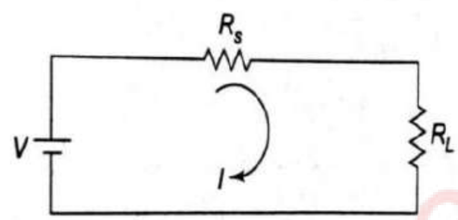


Fig: (a)

The maximum power will be transferred to the load when load resistance is equal to the source resistance.

Proof:

From the fig.(a)

$$I = \frac{V}{R_S + RL}$$

Power delivered to the load R_L = P = I^2 R_L = $\left(\frac{V}{(R_S + R_L)}\right)^2 R_L$

To determine the value of R_L for maximum power to be transferred to the load,

$$\frac{dP}{dRl} = 0$$

$$\frac{dP}{dRl} = \frac{d}{dRl}\left(\frac{V}{(R_S + R_L)}\right)^2 R_L$$

$$= \frac{V^2[(R_S + R_L)^2 - (2R_L)(R_S + R_L)]}{(R_S + R_L)^4}$$

$(R_S + R_L)^2 - 2R_L(R_S + R_L) = 0$

$R_S^2 + R_L^2 + 2R_L R_S - 2R_L R_S - 2R_L^2 = 0$

$R_S = R_L$

Hence, the maximum power will be transferred to the load when load resistance is equal to the source resistance.

Hence Proved.

(b)

A 5KVA 1000/200V, 50 Hz Single phase transformer gave the following test result

OC TEST(hv side): 1000V 0.24A 90 W

SC TEST(hv side) : 50V 5 A 110 W

Calculate :

1) **Equivalent circuit for transformer with circuit constant**
2) **Regulation at full load at 0.8 lagging**
3) **kVA load for maximum efficiency** **(12)**

Ans:

1) Equivalent circuit of the transform and parameters

From OC test(meters are connected on LV side i.e. primary)

$Wi = 90w$ $V1 = 1000V$ $I_0 = 0.24$Am

$\cos\varphi_0 = \frac{Wi}{V_1 \ I_0} = \frac{90}{1000 \times 0.24} = 0.38$

$\sin\varphi 0_0 = (1 - 0.38^2)^{0.5} = 0.732$

$Iw = I_0 \cos\varphi_0 = 0.24 \times 0.38 = 0.0912A$

$RO = \frac{V1}{Iw} = \frac{1000}{0.0912} = 10.96K\Omega$

$I\mu = Io\sin\varphi o = 0.24 \times 0.732 = 0.176$Am

$Xo = \frac{V1}{I\mu} = \frac{1000}{0.176} = 5.682K\Omega$

From SC test (meters are connected on HV side i.e. secondary)

$Wsc = 110w \quad Vsc = 50v \quad Isc = 5A$

$Z_{02} = \frac{Vsc}{Isc} = \frac{50}{5} = 10\Omega$

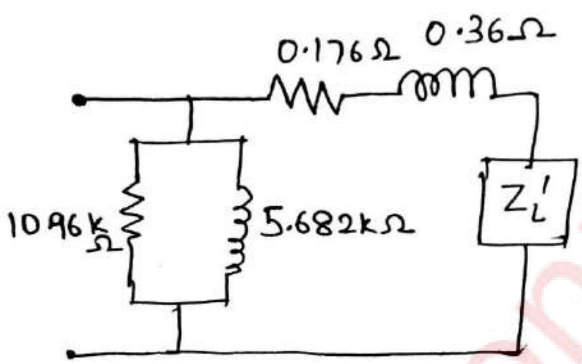
$R_{02} = \frac{Wsc}{Isc^2} = \frac{110}{25} = 4.4\Omega$

$X_{02} = (Z_{02}^2 - R_{02}^2)^{0.5} = (100 - 19.36)^{0.5} = 8.98\Omega$

$K = \frac{1000}{200} = 5$

$R_{01} = \frac{R_{02}}{K \times k} = 0.176\ \Omega$

$X_{01} = \frac{X02}{K^2} = 0.36\Omega$



2) <u>Efficiency at rated load and 0.8 pf lagging</u>

$Wi = 90w = 0.09kw$

Since meters are connected on secondary in SC test,

$I2 = (5\times1000)/400 = 12.5A$

$WCu = I_{22}\, R_{02} = 12.5^2 \times 4.4 = 687.5W = 0.687kW$

x = 1 pf = 0.8

$\%\eta = \frac{x \times \text{full load KVA} \times pf}{(x \times \text{full load KVA} \times pf) + Wi + x2\ Wcu} \times 100$

$\%\eta = \frac{1 \times 5 \times 0.8}{1 \times 5 \times 0.8 + 0.09 + 1 \times 0.687} \times 100$

$\%\eta = 83.73\%$

3) <u>Regulation at full load at 0.8 lagging is</u>

$$\%regulation = \frac{I_2(R_{02}\cos\phi + X_{02}\sin\phi)}{E_2} \times 100$$

$$= \frac{12.5(4.4\times0.8+8.98\times0.38)}{400} \times 100 = 21.66\ \%$$

Q.5

(a) Three similar coils having a resistance of 10Ω and inductance of 0.04H are connected in star across 3-phase 50Hz, 200v supply. Calculate the line current, total power absorbed, reactive volt amperes and total volt amperes. (8)

Ans:

R= 10Ω
L= 0.04H
V_L = 200V
F= 50Hz

For a star connected load,

$$V_{ph} = \frac{VL}{\sqrt{3}} = \frac{200}{\sqrt{3}} = 115.47$$

$X_L = 2\pi fL = 2\pi x50x0.04 = 12.6\ \Omega$

$Z_{ph} = R + jX_L$
$= 10+j12.6$
$= 16.08 < 51.56^o\ \Omega$

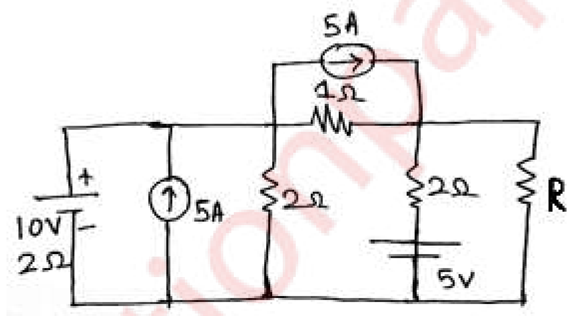
Power Factor = cos(51.56) = 0.273(lagging)

$I_{ph} = \frac{Vph}{Zph} = \frac{115.47}{16.08}$ = 7.2A

$I_L = I_{ph}$ = 7.2A

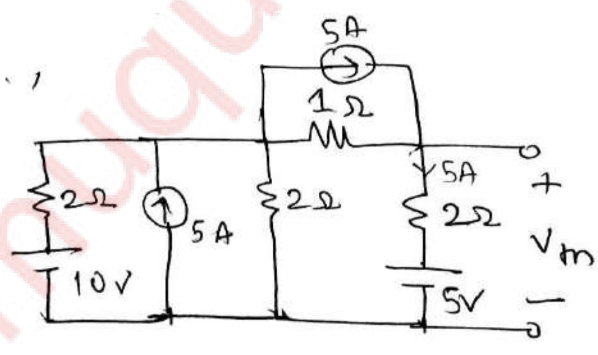
P = $\sqrt{3}V_LI_L\cos\phi$ = 1.73 x 200 x 7.2 x 0.273 = 680 W
Q = $\sqrt{3}V_LI_L\sin\phi$ = 1.73 x 200 x 7.2 x sin(51.56) = 2.4 KVAR
S = $\sqrt{3}U_L\,I_L$ = 1.73 x 200 x 7.2 = 2.5KVA

(b) In the following circuit find R for maximum power delivered to it. Also find maximum power delivered Pmax. (8)



Ans:

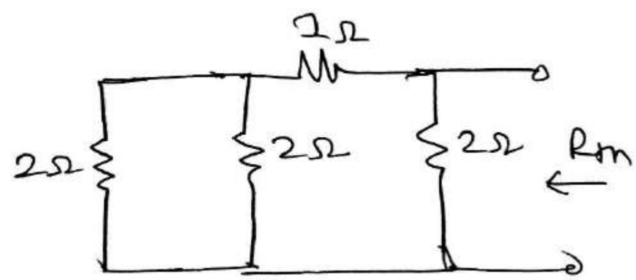
Calculate Vth ,



As 5A current of flowing through 2Ω branch, by applying KVL at outer loop, Vth – 5x2 – 5 = 0

Vth = 15V

Now to Calculate Rth, Short all voltage sources and open all current sources,



Solving above, we get

Rth = 1Ω

Now according to Maximum Power Transfer Theorem,

Rth = R

Thus, R=1Ω

And maximum power transferred is,

$$\text{Pmax} = \frac{\text{Vth}^2}{4 \text{ x Rth}} = \frac{15\ x\ 15}{4\ x\ 1} = \frac{255}{4} W$$

(c) Two impedance 12 + j16 Ω and 10-j20 Ω are connected in parallel across 230V, 50Hz. Single phase ac supply. Find kW, kVA and kVAR and power factor. (4)

Ans:

Z1 = 12 + j16 Ω Z2 = 10-j20 Ω

Admittance in each branch ,

$$\text{Y1} = \frac{1}{Z1} = \frac{1}{12 + \text{j}16\ \Omega} = 0.03 - j\,0.04 = 0.05\angle - 53.13°$$

$Y2 = \frac{1}{Z2} = \frac{1}{10 - j20\,\Omega} = 0.02 + 0.04j = 0.045\angle\ 63.43°$

Current in each branch,

$I_1 = V\ x\ Y1 = 200\ x\ Y1 = 10\angle - 53.13°$

I_2 = V x Y2 = 200 x Y2 = 9$\angle$ 63.43°

Power Factor,

$\cos\varphi 1 = \cos(-53.13°) = 0.6$

$\cos\varphi 2 = \cos(63.43°) = 0.45$

Active Power = P_1 = V x I_1 = 200 x 10 = 2KW
P_2 = V x I_2 = 200 x 9 = 1.8KW

Reactive Power = Q_1 = V x I_1 x $\cos\varphi 1$ = 200 x 10 x 0.6 = 1.2KVAR
Q_2 = V x I_2x $\cos\varphi 2$ = 200 x 9 x 0.45 = 0.81KVAR

Apparent Power = $S_1 = \sqrt{(P_1^2 + Q_1^2)}$ = 2.33 KVA
$S_2 = \sqrt{(P_2^2 + Q_2^2)}$ = 1.97 KVA

Q.6

(a)Draw and explain the phasor diagram for the practical transformer connected to lagging power factor. (6)

Ans :

When the transformer secondary is connected to an inductive load, the current flowing in the secondary winding is lagging w.r.t secondary terminal voltage. Let us assume that the current is lagging by an angle of θ_2.

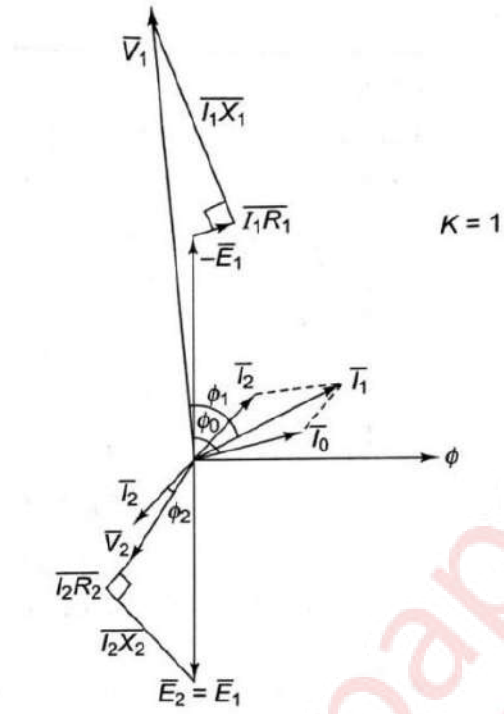
Let, R_1 = Primary winding Resistance

X_1 = Primary winding leakage Reactance

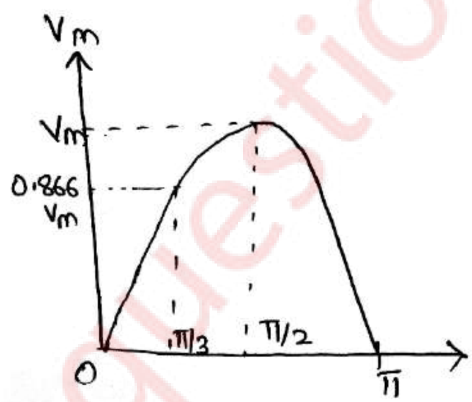
R_2 = Secondary winding Resistance

X_2 = Secondary winding leakage Reactance

The Phasor Diagram is as follows :



(b) Find 1) average value 2) rms value



(10)

Ans:

1) Average Value :

$$V_{DC} = \frac{Vm}{2\pi}\int_0^{\pi} \sin\omega t \, d\omega t$$

$= \frac{Vm}{2\pi}\ [-\cos\omega t]_0^{\pi}$

$= \frac{Vm}{2\pi}\ [-\cos\pi + \cos 0]$

$= \frac{Vm}{2\pi}\ [1+1]$

$= 2\ x\ \frac{Vm}{2\pi}$

$= \frac{Vm}{\pi}$

2) RMS Value

The RMS voltage is

$V_{RMS} = \sqrt{\frac{V_m^2}{2\pi}\int_0^{\pi} \sin 2\omega t\ d\omega t}$

$= \sqrt{\frac{V_m^2}{2\pi}\int_0^{\pi} \frac{(1-\cos 2\omega t)}{2}\ )\ d\omega t}$

$= \sqrt{\frac{V_m^2}{4\pi}}\ [\omega t - \frac{\sin 2\omega t}{2}\ ]_0^{\pi}$

$= \sqrt{\frac{V_m^2}{4\pi}}\ [\ \pi - \frac{(\sin\pi)}{2}\ - (0 - \frac{(\sin 0)}{2})]$

$= \sqrt{\frac{V_m^2}{4\pi}}\ x\ (\ \pi\ )$

$= \sqrt{\frac{V_m^2}{4}}$

$= \frac{Vm}{2}$

(c) State and explain Thevenins theorem and Nortons theorem. (4)

Ans:

Thevenin's Theorem states that "Any linear circuit containing several voltages and resistances can be replaced by just one single voltage in series with a single resistance or impedance connected across the load".

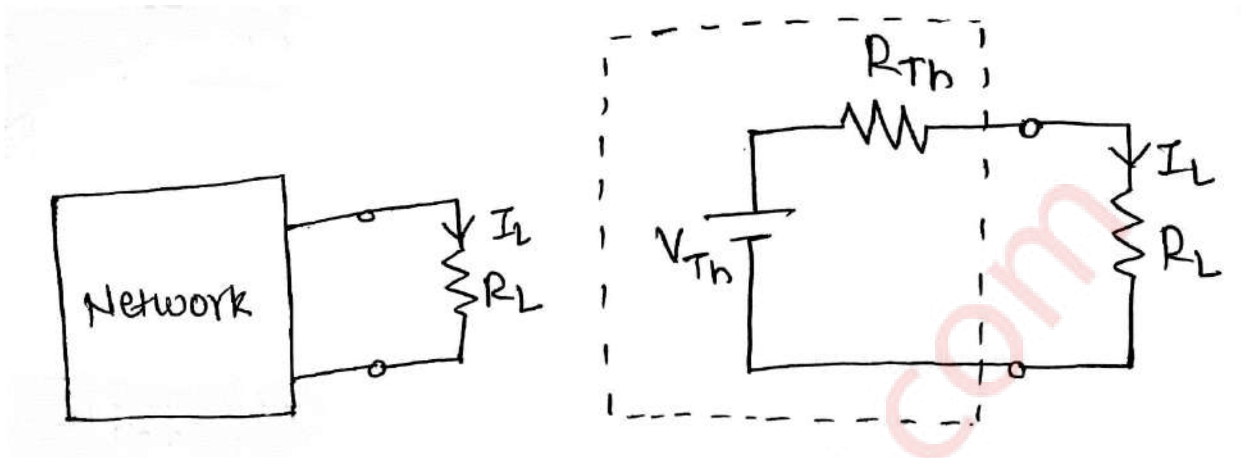


Fig (b) Thevenins Equivalent

Norton's Theorem states that – A linear active network consisting of independent or dependent voltage source and current sources and the various circuit elements can be substituted by an equivalent circuit consisting of a current source in parallel with a resistance. The current source being the short-circuited current across the load terminal and the resistance being the internal resistance of the source network.

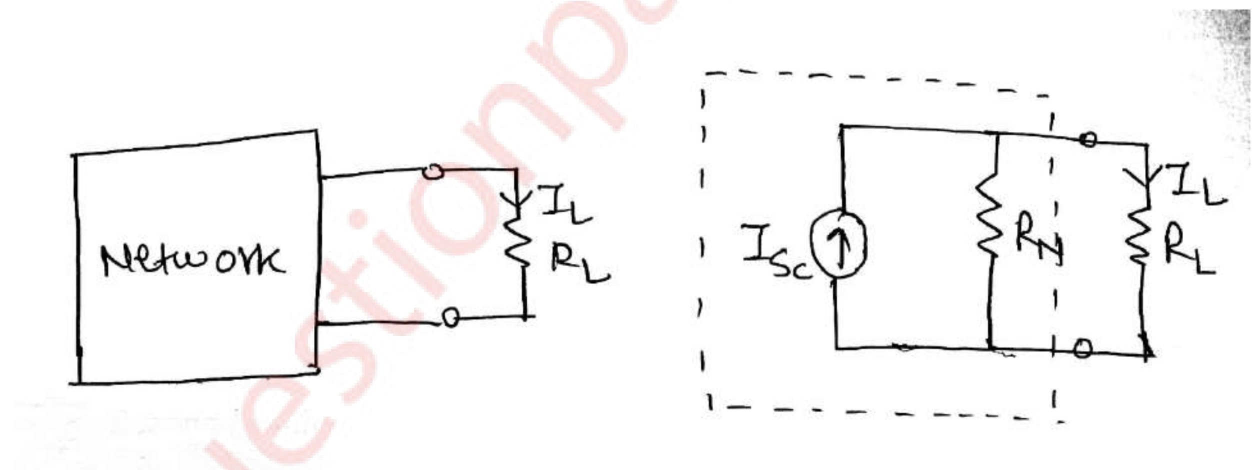


Fig (b) Norton Equivalent Circuit

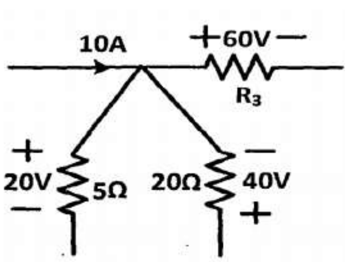
Q.P Code: 81620

BEE SOLUTION OF QUESTION PAPER

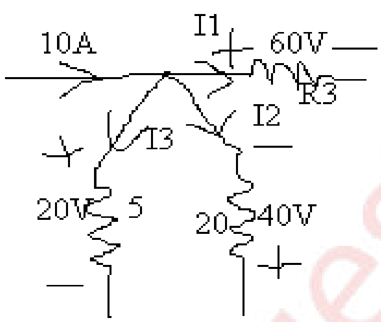
CBCGS (DEC-2019 Rev)

Q1. Answer any Five.

(i) Find the value of R_3 in the figure given below by applying Kirchhoff's Laws. **(4)**



SOLUTION: Apply Kirchhoff's current law (KCL)



$I_1+I_2+I_3 - 10=0$

$\frac{60}{R3} - \frac{40}{20} + \frac{20}{5} = 10$

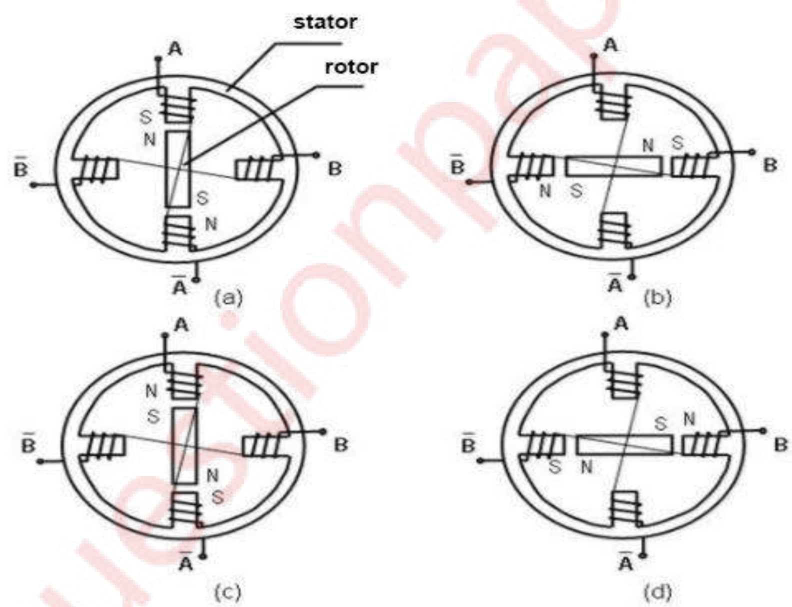
$\frac{60}{R3} - 2 + 4 = 10$

$R_3=7.5\Omega$

(ii) Briefly describe the operation of any one type of stepper motor.

SOLUTION: Permanent magnet stepper motor: **(4)**

The stepper motor rotor is a permanent magnet when the current flows through the stator winding, the stator winding to produce a vector magnetic field. The magnetic field drives the rotor to rotate by an angle so that the pair of magnetic fields of the rotor and the magnetic field direction of the stator are consistent. When the stator's vector magnetic field is rotated by an angle, the rotor also rotates with the magnetic field at an angle. Each time an electrical pulse is an input, the motor rotates one degree further. The angular displacement it outputs is proportional to the number of pulses input and the speed is proportional to the pulse frequency. Change the order of winding power, the motor will reverse. Therefore, it can control the rotation of the stepping motor by controlling the number of pulses, the frequency and the electrical sequence of each phase winding of the motor.



(iii) Two pure circuits elements in a series connection have the following current and applied voltage: V(t)=150sin(500t+10)v, i(t)=13.42sin(500t-53.3)A. Find the supply frequency(in Hz) and value of circuit elements. (4)

SOLUTION: Given $V(t)=150\sin(500t+10)v$ and , $i(t)=13.42\sin(500t-53.4)A$

$W=500=2\pi f$ therefore frequency is $f=\frac{500}{2\pi}$ **= 79.577Hz**

We can see that the current lagging the voltage,

V(t) =150∠10 i(t) =13.42∠-53.4

Impedance $\mathbf{Z} = (R+JX_L) = \frac{V(t)}{i(t)} = \frac{150\angle 10}{13.42\angle -53.4} = (5+j10)$

Resistance = R = 5Ω

And $X_L=10$ $wL=10$, therefore Inductance $\mathbf{L} = \frac{10}{500}$ **= 20mH.**

(iv) A three phase, three wire, 100V system supplies a balanced delta-connected load with per phase impedance of 20∠45 ohms. Determine the line current drawn and active power taken by the load. (4)

SOLUTION: Given Z = 20∠45

Since it is a delta connected load therefore,

$V_{ph} = V_L = 100V$

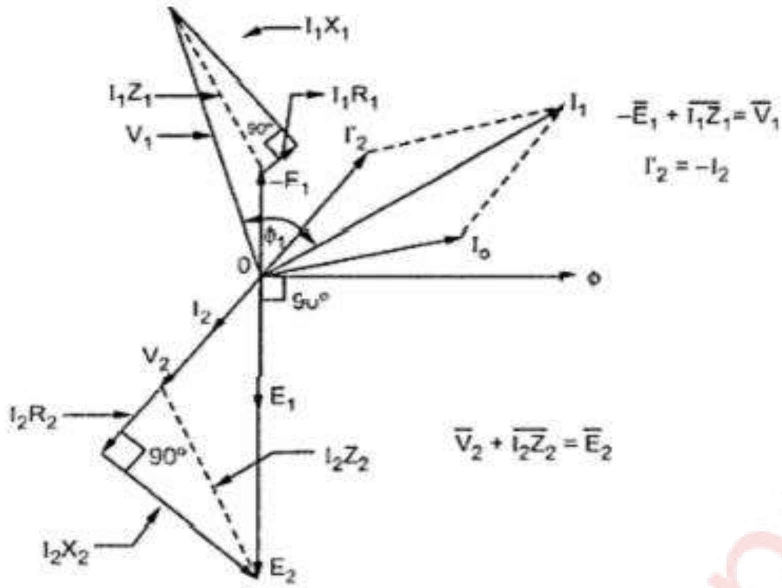
$I_{ph} = \frac{Vph}{Z} = \frac{100}{20\angle 45} = 3.535\angle -45\ A$

Line Current $I_L = \sqrt{3} \times I_{ph} = 6.12\angle -45A$

Active Power $P = \sqrt{3}\ V_L\ I_L \cos(-45) = 749.54W$

(v) Draw the phasor diagram of a single phase non ideal transformer feeding resistive load. (4)

SOLUTION:



(vi) Single phase induction motor is not self-starting . State true or false and justify your answer. (4)

SOLUTION: In induction machine a rotating magnetic field is required to produce torque.

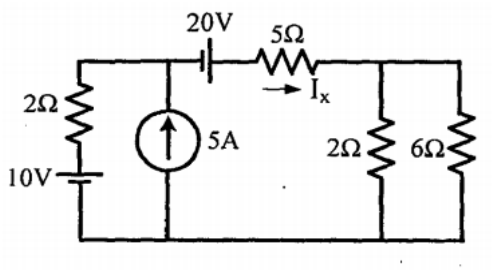
A rotating magnetic field can produced if we have balanced three phase supply and each phase is electrically spaced 120 to each other OR we have required minimum two phase

BUT in single phase induction motor there is single phase supply to the stator of motor , A SINGLE PHASE SUPPLY CANNOT PRODUCE A ROTATING MAGNETIC FIELD BUT IT PRODUCE A PULSATING MAGNETIC FIELD WHICH DOES NOT ROTATE.

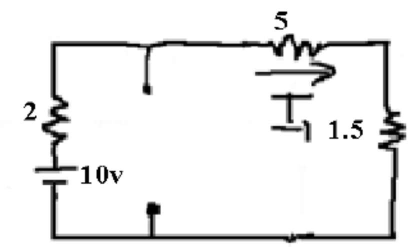
Due to this pulsating magnetic field torque cannot produce so motor is not self-start.

we can make single phase induction motor self-start by split single phase supply into two phase supply with the help of auxilliary winding.

Q2. (A) Find the current through 5Ω (I_X) using superposition theorem without using source transformation . (10)



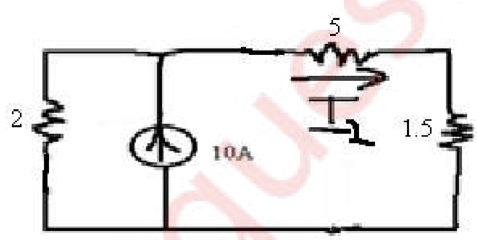
SOLUTION: (i) **Only 10V voltage source acting alone**:



Solving parallel resistors(2//6) $\frac{2\times6}{2+6}$ = **1.5Ω**

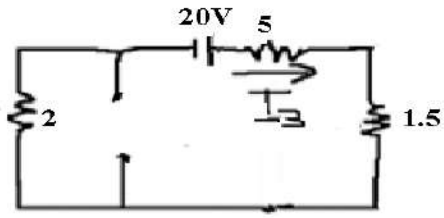
$$I_1 = \frac{10}{2+5+1.5} = 1.176A$$

(i) **Only 10A current source acting alone:**



Using current division rule: $I_2 = \frac{(2)\times10}{(2+1.5+5)}$ = **2.352A**

(i) **Only 20v voltage source acting alone**:



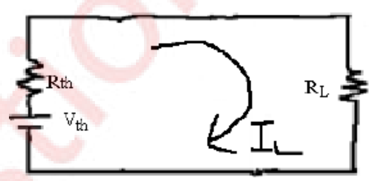
$$I_3 = \frac{20}{1.5+5+2} = 2.352A$$

By superposition theorem the total current through 5Ω resistor by 10v, 10A & 20v source will be,

$$I_X = I_1 + I_2 + I_3 = 1.176+2.352+2.352 = 5.88A$$

(B) State and prove Maximum Power Transfer Theorem. **(5)**

SOLUTION: The **maximum power transfer theorem** states that, to obtain **maximum** external **power** from a source with a finite internal resistance, the resistance of the load must equal the resistance of the source as viewed from its output terminals.



Proof: Power delivered to the load resistance,

$$P_L = I_L^{\ 2} \times R_L$$

$$= \left[\frac{V_{Th}}{R_{Th} + R_L}\right]^2 \times R_L$$

To find the maximum power, differentiate the above expression with respect to resistance R_L and equate it to zero. Thus,

$$\frac{dP(R_L)}{dR_L} = V_{Th}^2\left[\frac{(R_{Th}+R_L)^2 - 2R_L \times (R_{Th}+R_L)}{(R_{Th}+R_L)^4}\right] = 0$$

$$\Rightarrow (R_{Th}+R_L) - 2R_L = 0$$

$$\Rightarrow R_L = R_{Th}$$

The maximum power delivered to the load is,

$$P_{max} = \left[\frac{V_{Th}}{R_{Th}+R_L}\right]^2 \times R_L \Bigg|_{R_L = R_{Th}}$$

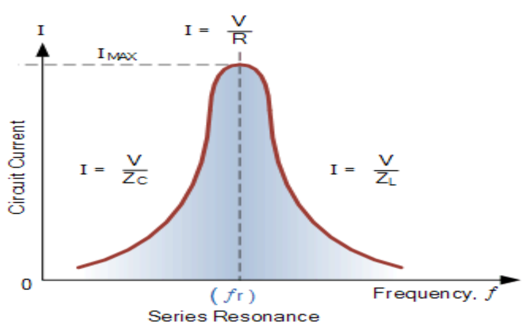
$$= \frac{V_{Th}^2}{4\,R_{Th}}$$

Thus in this case, the maximum power will be transferred to the load when load resistance is just equal to internal resistance of the battery.

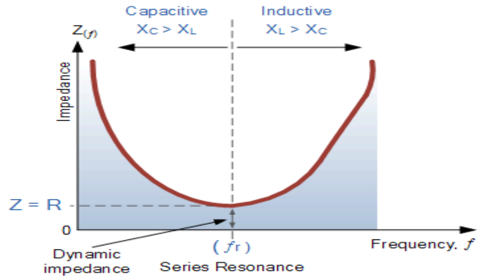
(C) Plot the variation of current, impedance, resistance, inductive reactance and capacitive reactance when supply frequency is varied in R-L-C series circuit. (5)

SOLUTION:

(i) Variation of current with frequency:

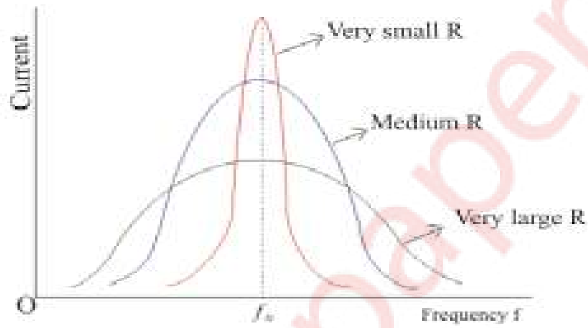


(ii) Variation of impedance with frequency:

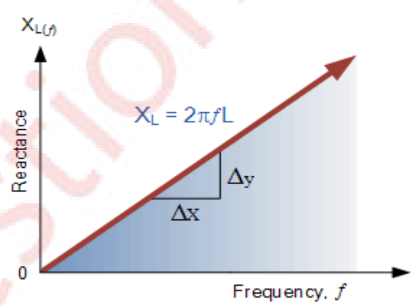


(iii) Variation of resistance with frequency:

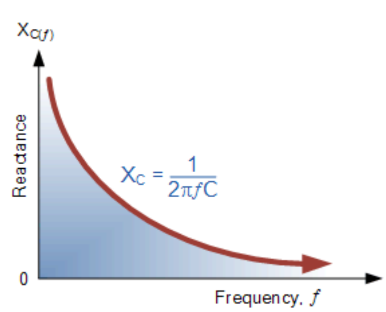
Resistance is independent of frequency, so it remains constant with change in frequency.



(iv) Variation of inductive reactance with frequency:



(v) Variation of capacitive reactance with frequency:



Q3. (A) The open Circuit(OC) and Short Circuit(SC) tests on a 5KVA, 200/400 V, 50 Hz single phase transformer gave the following results:

OC: 200V, 1A, 100W(lv side), SC: 15V, 10A, 85W(hv side). Draw the equivalent circuit referred to primary and put all values. **(10)**

<u>SOLUTION:</u>

From OC test,

No load(or OC) power factor $\cos\phi_o = \frac{100}{200 \times 1} = 0.5$

$$\phi_o = \cos^{-1}(0.5) = 60^o$$

Hence, $\sin\phi_o = 0.866$

Magnetizing component, $I_{m1} = (I_O \times \sin\phi_o) = 1 \times 0.866 = 0.866A$

Core Loss component, $I_{c1} = (I_O \times \cos\phi_o) = 1 \times 0.5 = 0.5A$

Therefore Magnetizing Reactance $X_{m1} = \frac{VO}{Im1} = \frac{200}{0.866} = \mathbf{230.94\Omega}$

Resistance representing core loss $R_{c1} = \frac{VO}{Ic1} = \frac{200}{0.5} = \mathbf{400\Omega}$

From SC test,

$$W_{sc} = (I_{sc})^2 r_{e2}$$

$$r_{e2} = \frac{Wsc}{(Isc)2} = \frac{15}{10 \times 10} = \mathbf{0.15\Omega}$$

Now SC Impedance $Z_{sc} = \frac{Vsc}{Isc} = \frac{15}{10} = \mathbf{1.5\Omega}$

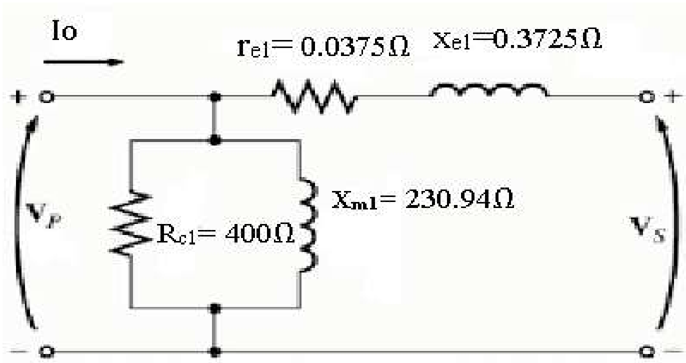
Thus $x_{e2} = \sqrt{(Zsc)2 - (re2)2} = \sqrt{(1.5)2 - (0.15)2} = \sqrt{2.25 - 0.0225} = 1.49\Omega$

Now equivalent circuit referred to primary side,

Turns ratio, $a = 200/400 = 0.5$

$$\mathbf{r_{e1} = a^2 r_{e2} = 0.5^2 \times 0.15 = 0.0375\Omega}$$

$$x_{e1} = a^2 x_{e2} = 0.5^2 \times 1.49 = 0.3725\Omega$$



Equivalent circuit referred to primary side

(B) Derive the EMF equation of DC motor. **(5)**

SOLUTION:

Let

Φ - flux/ pole in weber

Z – Total number of armature conductors.

P - Number of poles

A - Number of parallel paths in armature

N - Speed of armature in r.p.m

Flux cut by one conductor = dΦ = PΦ

Time taken to complete one revolution = dt = 60/N seconds

Average induced E.M.F in one conductor = e = PΦ/dt

e = PΦN/60 Volt

Number of conductors connected in series in each parallel path = Z/A

Average induced EMF across each parallel path that is across armature terminals, E = e *Z/A

= (PΦN/60) *Z/A

E = (ΦZN/60)* P/A

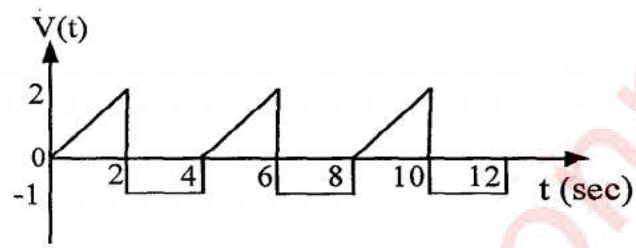
For a wave wound machine A = 2

E = ΦZNP/120 Volt

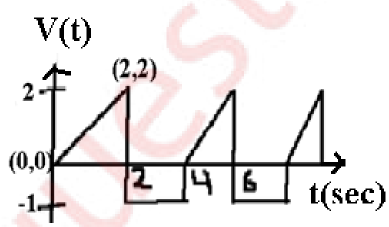
Lap wound machine A =P

E = ΦZN/60 Volt

(C) Find the Root Mean Square Value (RMS) value of the following waveform. (5)



SOLUTION:



For triangular waveform slope of line m= $\frac{2}{2}$ = 1

From o<t<2

Y = mx + c , V=1t + 0=t

From 2<t<4

V= -1

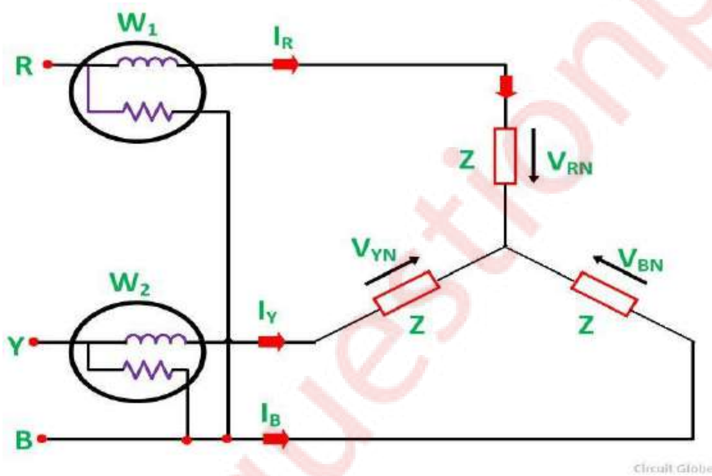
$\int_0^4 v^2(t) = \int_0^2 t^2 dt + \int_2^4 (-1)^2 dt = [\frac{t3}{3}]_0^2 + [1]_2^4 = (\frac{8}{3} + 2) = 4.67$

$$\mathbf{V_{rms}} = \sqrt{\frac{Area\ of\ Waveform\ over\ full\ cycle}{Period\ of\ the\ waveform}} = \sqrt{\frac{4.67}{4}} = \sqrt{1.167} = 1.08V$$

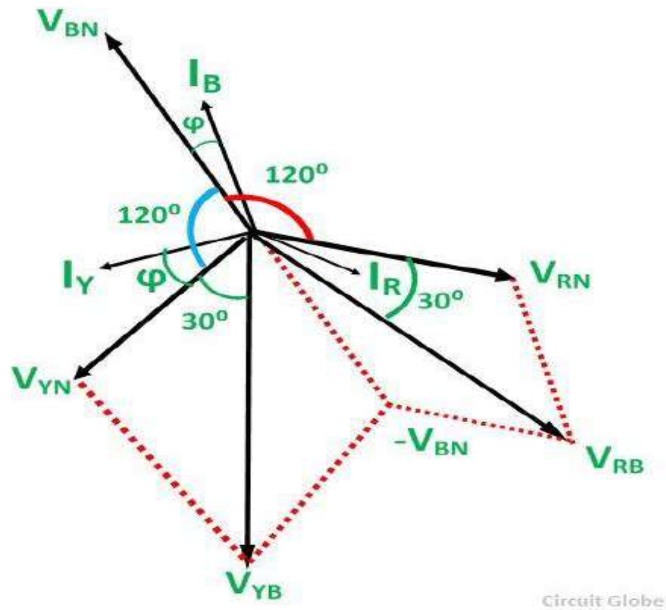
Q4. (A)With a neat circuit diagram and phasor diagram, prove that by two wattmeter method active power and reactive power of a three phase load can be measured. (10)

SOLUTION:

The connection diagram of a 3 phase balanced load connected as Star Connection is shown below.



The load is considered as an inductive load, and thus, the phasor diagram of the inductive load is drawn below.



The three voltages V_{RN}, V_{YN} and V_{BN}, are displaced by an angle of 120 degrees electrical as shown in the phasor diagram. The phase current lag behind their respective phase voltages by an angle ϕ.

Now, the current flowing through the current coil of the Wattmeter, W_1 will be given as

$$W_1 = I_R$$

Potential difference across the pressure or potential coil of the Wattmeter, W_1 will be

$$W_1 = V_{RB} = V_{RN} - V_{BN}$$

To obtain the value of V_{YB}, reverse the phasor V_{BN} and add it to the phasor V_{YN} as shown in the phasor diagram above. The phase difference between V_{RB} and I_R is $(30^o - \phi)$

Therefore, the power measured by the Wattmeter, W_1 is

$$W_1 = V_{RB} I_R \cos(30^0 - \phi)$$

Current through the current coil of the Wattmeter, W_2 is given as

$$W_2 = I_Y$$

Potential difference across the Wattmeter, W_2 is

$$W_2 = V_{YB} = V_{RN} - V_{BN}$$

The phase difference V_{YB} and I_Y is $(30^o + \phi)$.

Therefore, the power measured by the Wattmeter, W_2 is given by the equation shown below.

$$W_2 = V_{YB} I_Y \cos(30^0 + \phi)$$

Since, the load is in balanced condition, hence,

$$I_R = I_Y = I_B = I_L \text{ and}$$

$$V_{RY} = V_{YB} = V_{BR} = V_L$$

Therefore, the wattmeter readings will be

$$W_1 = V_L I_L \cos(30^0 - \phi) \text{ and}$$

$$W_2 = V_L I_L \cos(30^0 + \phi)$$

Now, the sum of two Wattmeter readings will be given as

$$W_1 + W_2 = [V_L I_L \cos(30^0 - \phi) + V_L I_L \cos(30^0 + \phi)]$$

$$W_1 + W_2 = V_L I_L[\cos 30^0 \cos\phi + \sin 30^0 \sin\phi + \cos 30^0 \cos\phi - \sin 30^0 \sin\phi]$$

$$W_1 + W_2 = V_L I_L(2\cos 30^0 \cos\phi)$$

$$W_1 + W_2 = V_L I_L (2\frac{\sqrt{3}}{2} \cos \phi)$$

$$W_1 + W_2 = \sqrt{3} V_L I_L \cos \phi = P \text{ ....(1)}$$

The above equation (1) gives the Active power absorbed by a 3 phase balanced load.

As we know that,

$$W_1 + W_2 = \sqrt{3} V_L I_L \cos \phi$$

Now,

$$W_1 - W_2 = [V_L I_L \cos (30^0 - \phi) - V_L I_L \cos (30^0 + \phi)]$$

$$W_1 - W_2 = V_L I_L [\cos 30^0 \cos \phi + \sin 30^0 \sin \phi - \cos 30^0 \cos \phi + \sin 30^0 \sin \phi]$$

$$W_1 - W_2 = 2 V_L I_L \sin 30^0 \sin \phi$$

$$W_1 - W_2 = V_L I_L \sin \phi \text{ ....(2)}$$

Determination of Reactive Power by Two Wattmeter Method

To get the reactive power, multiply equation (2) by $\sqrt{3}$

$$\sqrt{3} (W_1 - W_2) = \sqrt{3} V_L I_L \sin \phi = P_r$$

Therefore, the Reactive Power is given by the equation shown below.

$$P_r = \sqrt{3} (W_1 - W_2)$$

(B) A sinusoidal voltage v(t)=200sin(wt) is applied to a series R-L-C circuit with R=20Ω, l=100mH, and C=10μF. Find (i) the resonant frequency, (ii) RMS value of current at resonance (iii) Quality factor of the circuit, (iv) voltage across the inductor at resonance frequency and (v) phasor diagram at resonance. (10)

SOLUTION: **$L = 100mH = 100\times10^{-3} = 0.1H$**

$C = 10\mu F = 10\times 10^{-6} = 10^{-5}$

(i) The resonant frequency $\mathbf{f_o} = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} = \frac{1}{2\pi}\sqrt{\frac{1}{0.1\times10^{-5}}} = 159.15Hz$

(ii) At resonance $(X_L - X_C)^2 = 0$, $Z = \sqrt{R^2 + (X_L - X_C)^2} = R$

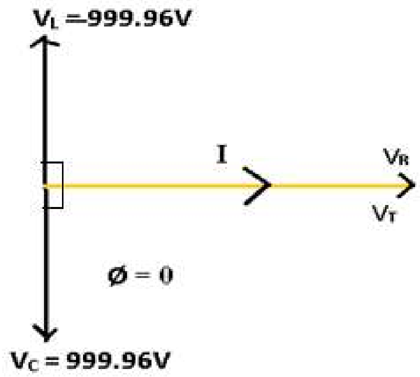
$I_{rms} = \frac{V}{Z} = \frac{200}{20} = 10A$

(iii) Q factor = $\frac{W\times L}{R} = \frac{2\pi\times159.15\times0.1}{20} = 5$

(iv) At resonance, the voltage across the inductor is,

$V_L = I_{rms}X_L = (10)\times(2\pi\times159.15)\times(0.1) = 999.96V$

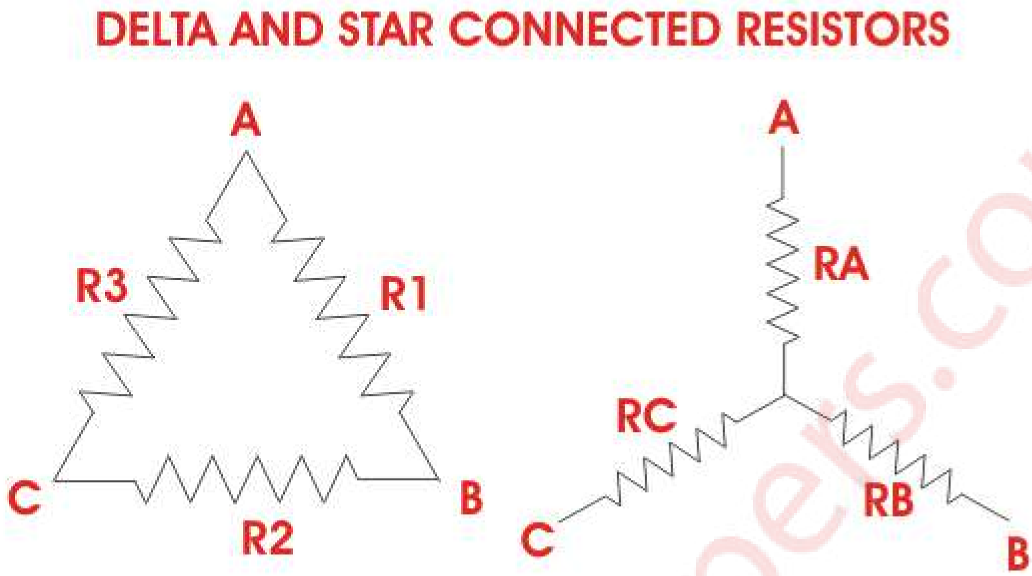
(v) At resonance $X_L = X_C$ and $V_L = V_C = 999.96V$ And circuit becomes Resistive . And phase difference between voltage and current will be zero i.e ($\phi = 0$) such that $V(t) = V_T = V_R = 200V$.



Q5. (A) Derive the transformation formula to convert a delta network of resistors to an equivalent star network and star network of resistors to an equivalent delta network. (10)

<u>SOLUTION:</u> Delta To Star Conversion:

The replacement of delta or mesh by equivalent star connection is known as **delta – star transformation**. The two connections are equivalent or identical to each other if the impedance is measured between any pair of lines. That means, the value of impedance will be the same if it is measured between any pair of lines irrespective of whether the delta is connected between the lines or its equivalent star is connected between that lines.



Consider a delta system that's three corner points are A, B and C as shown in the figure. Electrical resistance of the branch between points A and B, B and C and C and A are R_1, R_2 and R_3 respectively.

$$\mathbf{R_{AB} = R_1 \,||\, (R_2 + R_3) = \frac{R_1.(R_2 + R_3)}{R_1 + R_2 + R_3}}$$

Now, one star system is connected to these points A, B, and C as shown in the figure. Three arms R_A, R_B and R_C of the star system are connected with A, B and C respectively. Now if we measure the resistance value between points A and B, we will get,

$$\mathbf{R_{AB} = R_A + R_B}$$

Since the two systems are identical, resistance measured between terminals A and B in both systems must be equal.

$$\mathbf{R_A + R_B = \frac{R_1.(R_2+R_3)}{R_1+R_2+R_3}} \quad \ldots\ldots\ldots\text{(i)}$$

Similarly, resistance between points B and C being equal in the two systems,

$$\mathbf{R_B + R_C = \frac{R_2.(R_3+R_1)}{R_1+R_2+R_3}} \quad \ldots\ldots\ldots\text{(ii)}$$

And resistance between points C and A being equal in the two systems,

$$\mathbf{R_C + R_A} = \frac{R_3.(R_1+R_2)}{R_1+R_2+R_3} \text{ .... (iii)}$$

Adding equations (I), (II) and (III) we get,

$$\mathbf{2(R_A + R_B + R_C)} = \frac{2.(R_1.R_2+ R_2.R_3+ R_3.R_1)}{R_1+ R_2+R_3}$$

$$\mathbf{R_A + R_B + R_C} = \frac{R_1.R_2+ R_2.R_3+ R_3.R_1}{R_1+ R_2+R_3} \text{ ....(iv)}$$

Subtracting equations (I), (II) and (III) from equation (IV) we get,

$$\mathbf{R_A} = \frac{R_3.R_1}{R_1+ R_2+R_3} \text{ ....(v)}$$

$$\mathbf{R_B} = \frac{R_1.R_2}{R_1+ R_2+R_3} \text{ ....(vi)}$$

$$\mathbf{R_C} = \frac{R_2.R_3}{R_1+ R_2+R_3} \text{ ....(vii)}$$

For **star – delta transformation** we just multiply equations (v), (VI) and (VI), (VII) and (VII), (V) that is by doing (v) × (VI) + (VI) × (VII) + (VII) × (V) we get,

$$\mathbf{R_AR_B + R_BR_C + R_CR_A} = \frac{R_1R_2^2R_3+ R_1R_2R_3^2+R_1^2\,R_2R_3}{(R_1+ R_2+R_3)^2}$$

$$\mathbf{R_AR_B + R_BR_C + R_CR_A} = \frac{R_1R_2^2R_3+ R_1R_2R_3^2+R_1^2\,R_2R_3}{(R_1+ R_2+R_3)^2}$$

$$= \frac{R_1 R_2 R_3 (R_1 + R_2 + R_3)}{(R_1 + R_2 + R_3)^2}$$

$$= \frac{R_1 R_2 R_3}{R_1 + R_2 + R_3} \quad \text{........ (viii)}$$

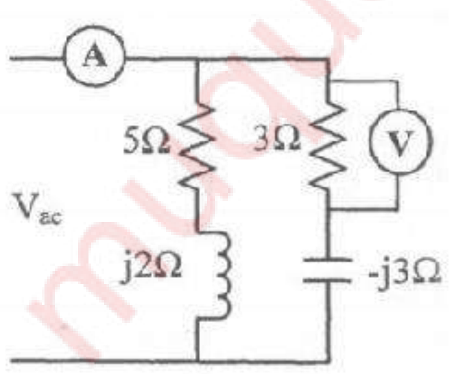
Now dividing equation (VIII) by equations (V), (VI) and equations (VII) separately we get,

$$\mathbf{R_2} = \frac{R_A R_B + R_B R_C + R_C R_A}{R_A}$$

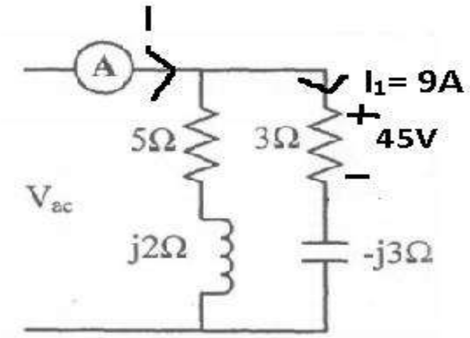
$$\mathbf{R_3} = \frac{R_A R_B + R_B R_C + R_C R_A}{R_B}$$

$$\mathbf{R_1} = \frac{R_A R_B + R_B R_C + R_C R_A}{R_C}$$

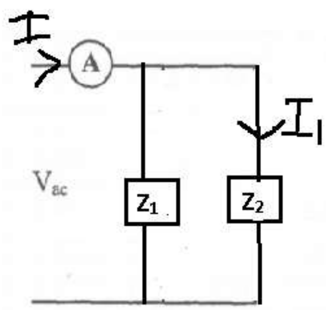
(B) In the parallel circuit, voltmeter across 3 Ω resistor reads 45V. What is the indication on the ammeter? Also find input power factor. (10)



SOLUTION:



$$I_1 = \frac{45}{5} = 9A$$



$Z_1 = 5 + j2 = 5.385 \angle 21.8$, $Z_2 = 5 - j3 = 5.83 \angle -30.96$

Applying Current Division rule,

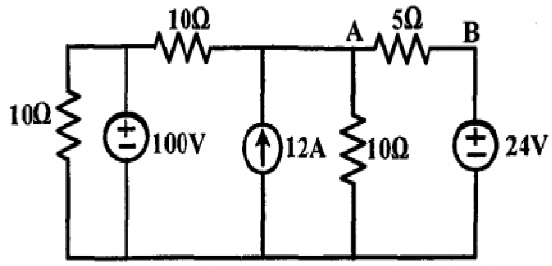
$$I_1 = \left(\frac{Z1}{Z1 + Z2}\right) I$$

Therefore $I = \frac{Z1 + Z2}{Z1} \times I_1 = \left(\frac{5.385 \angle 21.8 + 5.83 \angle -30.96}{5.385 \angle 21.8}\right) \times 9 = 1.866\angle -27.5A$

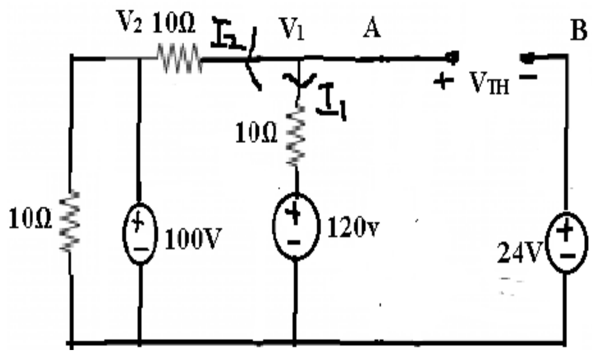
Ammeter reading is 1.866A

And input power factor is cos(-27.5) = 0.887 lagging

Q6. (A) Find current through 5Ω from A to B using Thevenin's theorem.(10)



SOLUTION: Using source transformation the equivalent circuit is,



To find V_{TH}

Now using nodal analysis at V_1

V_2=100v

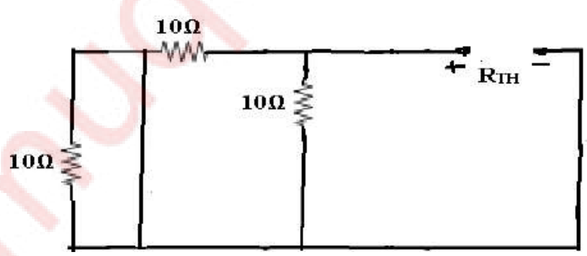
$$\frac{V1-V2}{10}+\frac{V1-120}{10}=\frac{V1-100}{10}+\frac{V1-120}{10}=0$$

$V_1 - 100 + V_1 - 120 = 2V_1 - 220 = 0$

$V_1 = 110v$

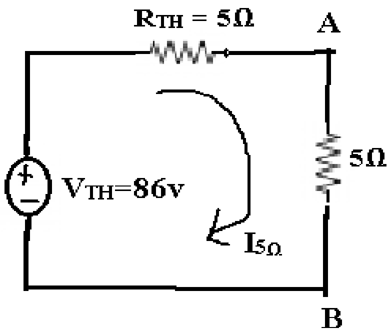
$V_{TH} = 110 - 24 = 86v$

To find R_{TH},



$$R_{TH} = (10//10) = \frac{10\times10}{10+10} = 5\Omega$$

The Thevenin's equivalent circuit,



The current through 5Ω Resistor will be,

$$I_{5\Omega} = \frac{86}{5+5} = 8.6A$$

(B) A 20KVA Transformer has iron loss of 450W and full load copper loss of 900W. Assume power factor of load as 0.8 lagging. Find full load and half load efficiency of the transformer. **(5)**

<u>SOLUTION</u>: Given $W_i = 450W$, $W_{cu} = 900W$

At full load $x = 1$

$$\%\eta = \frac{(x \times full\text{-}load\ KVA \times pf)}{(x \times full\text{-}load\ KVA \times pf) + W_i + x^2[W_{cu}]} \times 100$$

$$= \frac{(1 \times 20 \times 0.8)}{(1 \times 20 \times 0.8) + 0.45 + 1^2 \times 0.9} \times 100 = 92.21\%$$

At half load $x = 0.5$,

$$\%\eta = \frac{(0.5 \times 20 \times 0.8)}{(0.5 \times 20 \times 0.8) + 0.45 + 0.5^2 \times 0.9} \times 100 = 83.33\%$$

(C) Briefly explain the principle of operation of three phase induction motor. What are the types of three phase induction motor? (5)

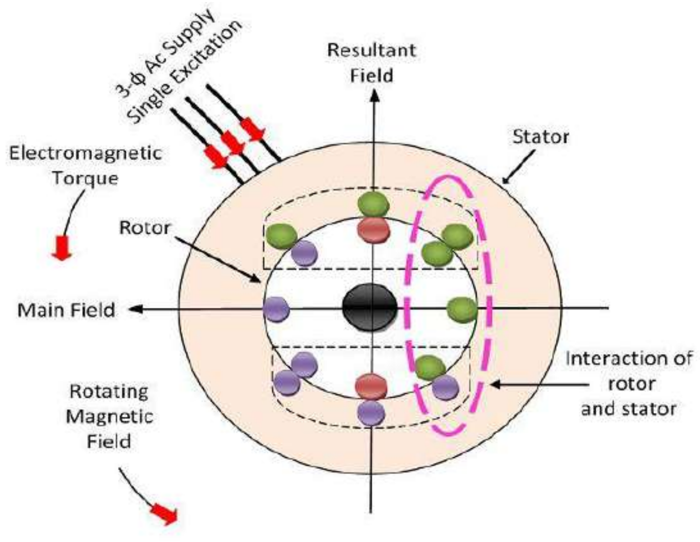
<u>SOLUTION</u>:

The motor which works on the principle of electromagnetic induction is known as the induction motor. The electromagnetic induction is the phenomenon in which the electromotive force induces across the electrical conductor when it is placed in a rotating magnetic field.

The stator and rotor are two essential parts of the motor. The stator is the stationary part, and it carries the overlapping windings while the rotor carries the main or field winding. The windings of the stator are equally displaced from each other by an angle of 120°.

The induction motor is the single excited motor, i.e., the supply is applied only to the one part, i.e., stator. The term excitation means the process of inducing the magnetic field on the parts of the motor.

When the three phase supply is given to the stator, the rotating magnetic field produced on it. The figure below shows the rotating magnetic field set up in the stator.



Three Phase Induction Motor

Consider that the rotating magnetic field induces in the anticlockwise direction. The rotating magnetic field has the moving polarities. The polarities of the magnetic field vary by concerning the positive and negative half cycle of the supply. The change in polarities makes the magnetic field rotates.

The conductors of the rotor are stationary. This stationary conductor cut the rotating magnetic field of the stator, and because of the electromagnetic induction, the EMF induces in the rotor. This EMF is known as the rotor induced EMF, and it is because of the electromagnetic induction phenomenon.

The conductors of the rotor are short-circuited either by the end rings or by the help of the external resistance. The relative motion between the rotating magnetic field and the rotor conductor induces the current in the rotor conductors. As the current flows through the conductor, the flux induces on it. The direction of rotor flux is same as that of the rotor current. Now we have two fluxes one because of the rotor and another because of the stator. These fluxes interact each other. On one end of the conductor the fluxes cancel each other, and on the other end, the density of the flux is very high. Thus, the high-density flux tries to push the conductor of rotor towards the low-density flux region. This phenomenon induces the torque on the conductor, and this torque is known as the electromagnetic torque.

The direction of electromagnetic torque and rotating magnetic field is same. Thus, the rotor starts rotating in the same direction as that of the rotating magnetic field.

There are two types of 3 phase Induction motors,

- Squirrel Cage **Induction Motor**.
- Slip Ring **Induction Motor** or Wound Rotor **Induction Motor** or **Phase** Wound **Induction Motor.**