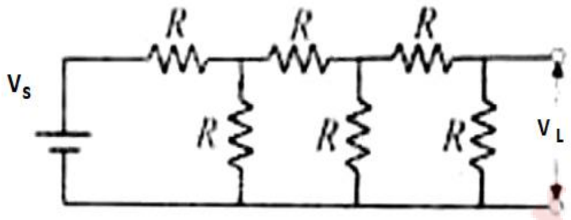
BEE QUESTION PAPER SOLUTION

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,

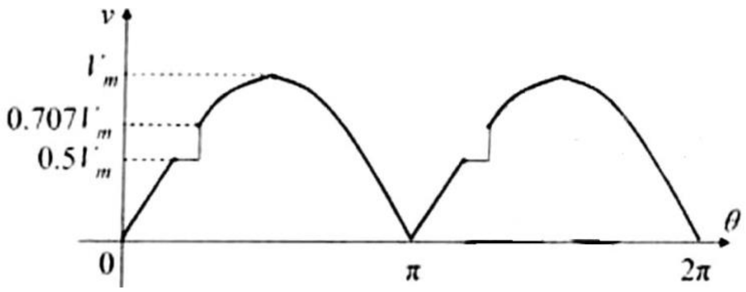
$R = \frac{1}{R} + \frac{2}{R} = \frac{R}{3}$

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

Hence we get the final ratio

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

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

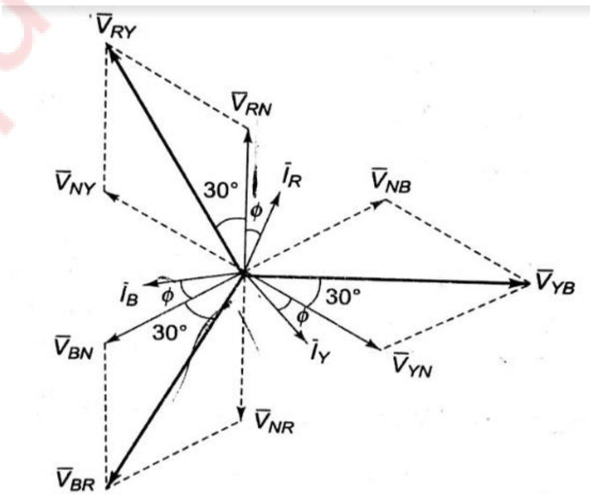
1. Average value of the waveform

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

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

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)**

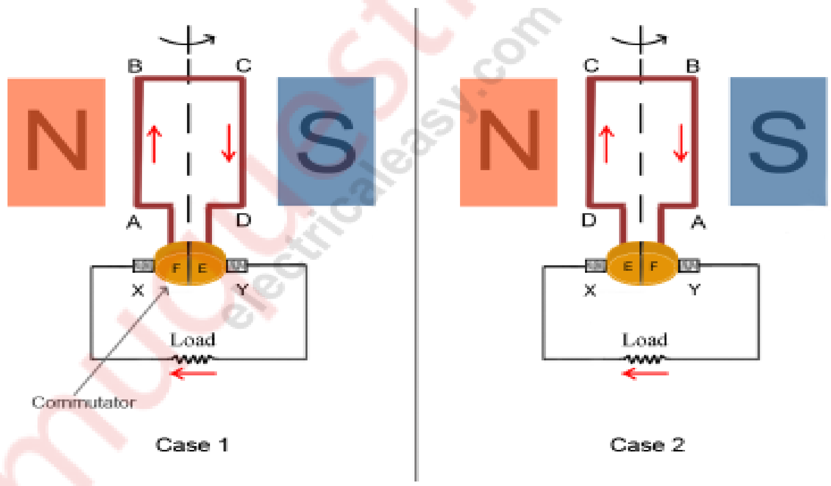
Solution:-

DC Generator

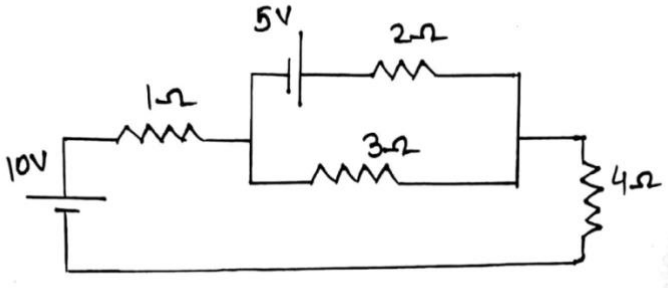
A dc generator is electrical machine which converts mechanical energy into direct current electricity. This energy conversion is based on the principle of production of dynamically induced emf. This article outlines basic construction and working of a DC generator.

PRINCIPLE

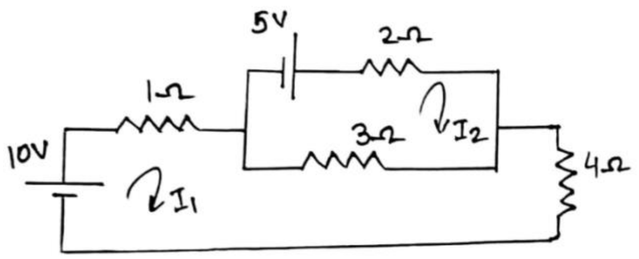
According to Faraday's laws of electromagnetic induction whenever a conductor is placed in a varying magnetic field (OR a conductor is moved in a magnetic field), an emf (electromotive force) gets induced in the conductor. The magnitude of induced emf can be calculated from the Emf equation of dc generator .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)

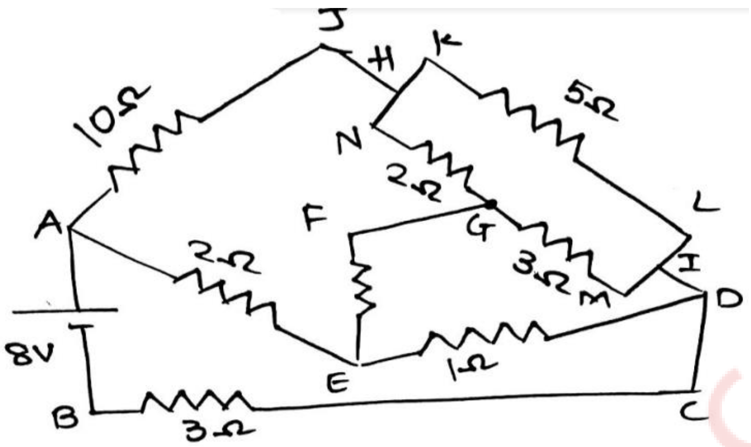
From (1) and (2) we get,

$I_1 = 2.096A \qquad I_2 = 2.2580A$

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

$I = 0.162\Omega$

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

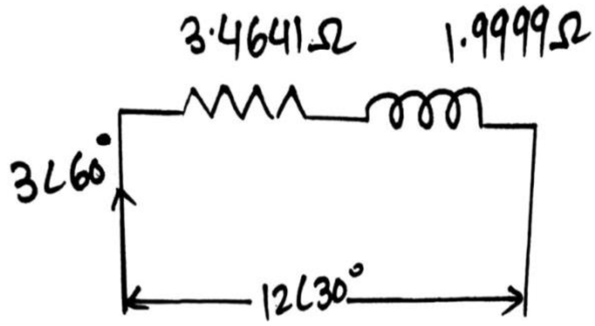
Pf = cosφ = cos(29.99)

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)

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

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

Solution:-

$\overline{E_1} = \frac{2}{\sqrt{2}}\angle 0°$ = 1.41∠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∠60°

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

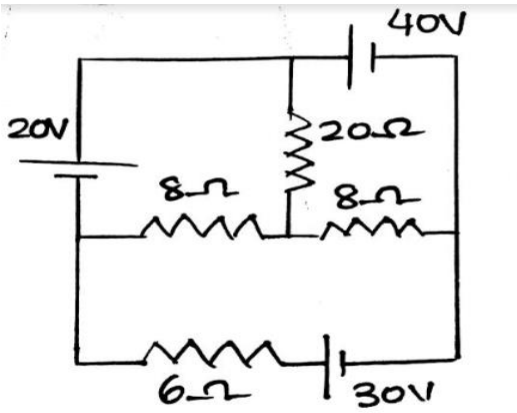
$\bar{E}$ = 1.41∠0° $-0.7071\angle -30°$ $+ 1.41\angle -45°$ $- 1.41\angle -60°$

$\bar{E} = 2.1596\angle -59.69°$

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

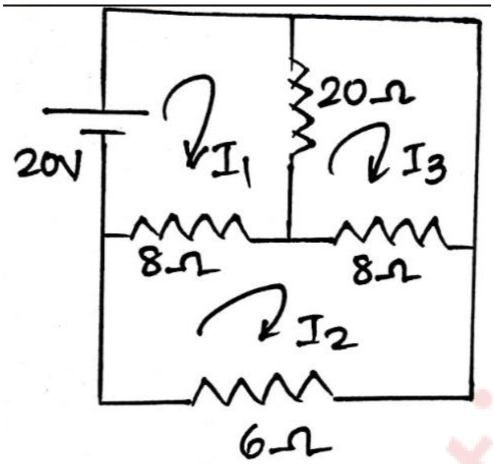
e = 3.0541sin($\omega t - 59.69$)

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,

$I_1 = 4.791A$

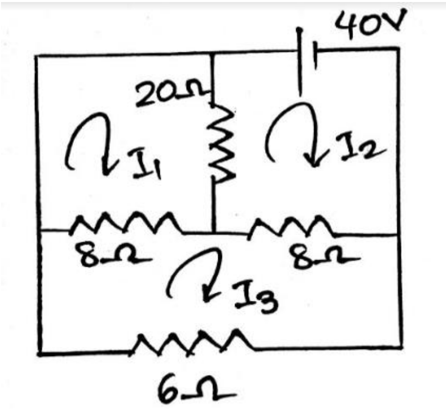
$I_2 = 3.33A$

$I_3 = 4.375A$

$I' = I_1 - I_3 = 0.416$

$I' = 0.416A$ ………………(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,

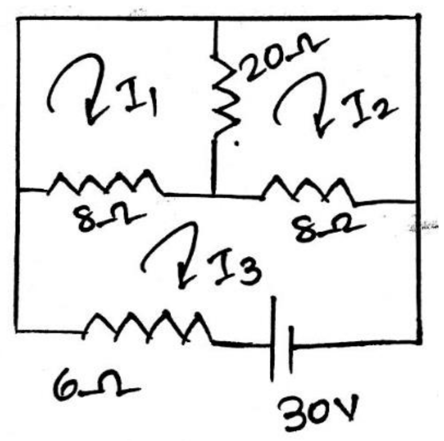
$I_1 = 8.75A$

$I_2 = 9.58A$

$I_3 = 6.667A$

$I'' = 0.833$ ………………(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

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

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)

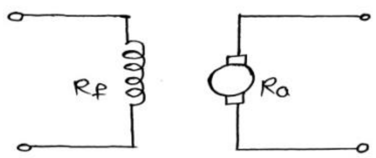
Solution:-

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

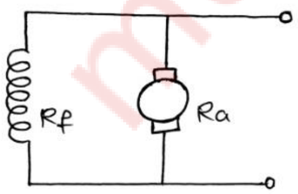
In separately excited machines the field winding is provided with a separate DC source to supply the field current as shown in figure.



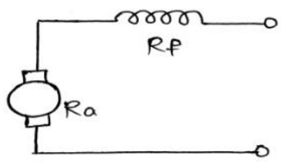
SELF EXCITED MACHINES

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:

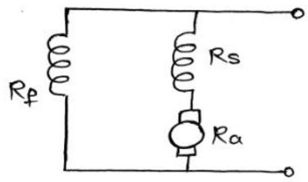
a) SHUNT WOUND MACHINES

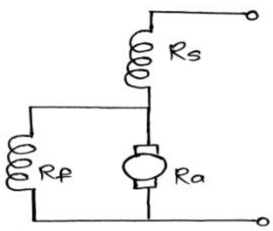


b) SERIES WOUND MACHINES

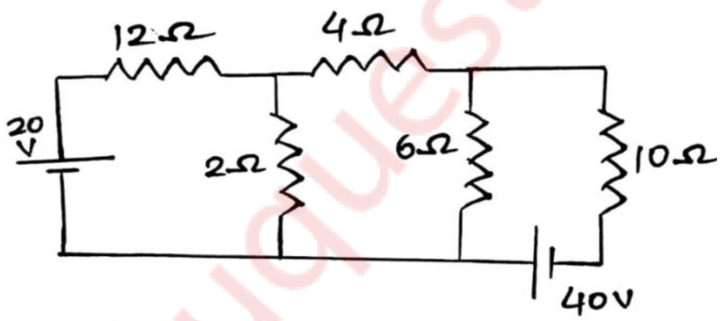


c) COMPOUND WOUND MACHINES

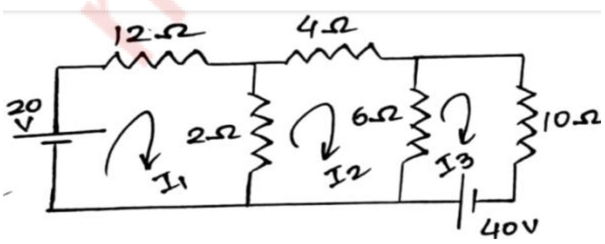




Q4] b)Find the current through 10Ω resistor by using Norton's theorem (8)



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

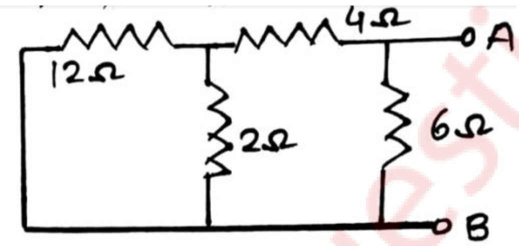
$40 - 6(I_3 - I_2) = 0$

$6I_2 - 6I_3 = -40$

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

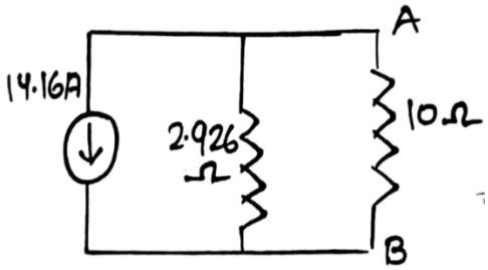
Replacing voltage source by short circuits

(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

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

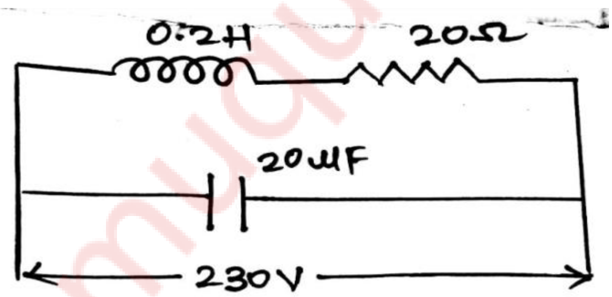
$I_L = 3.2053A$

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



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

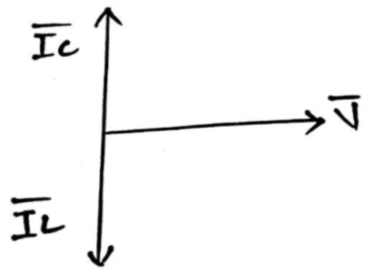
$X_c = \frac{1}{2\pi fC} = \frac{10^6}{2\times3.14\times79.617\times20} = 100\Omega$

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

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

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

$I_L = 21.86A$

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

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

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

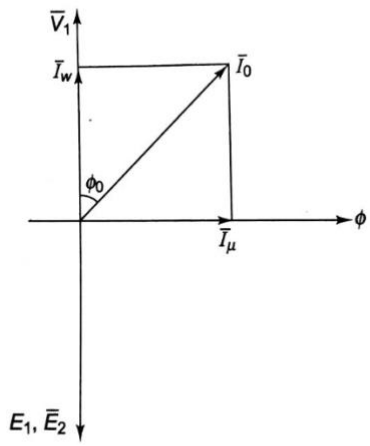
$X_{ph} = Z_{ph}sin\varphi = 20.916 \times \sin(cos^{-1} 0.6) = 16.73\Omega$

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)

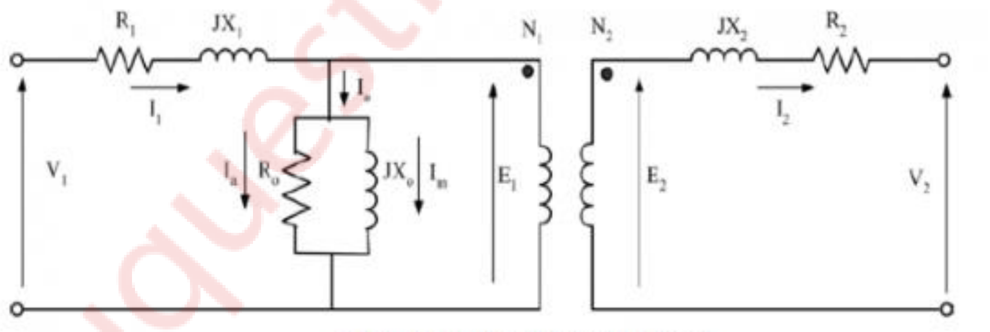
Solution:-



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.

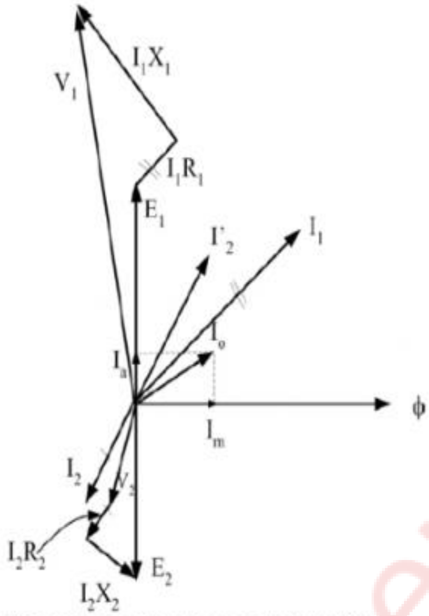


Transformer Equivalent circuit

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)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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