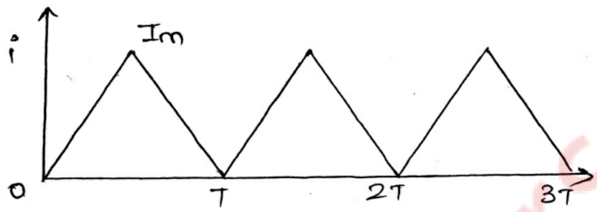
BEE SOLUTION OF QUESTION PAPER

(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,

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

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

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

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

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

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.

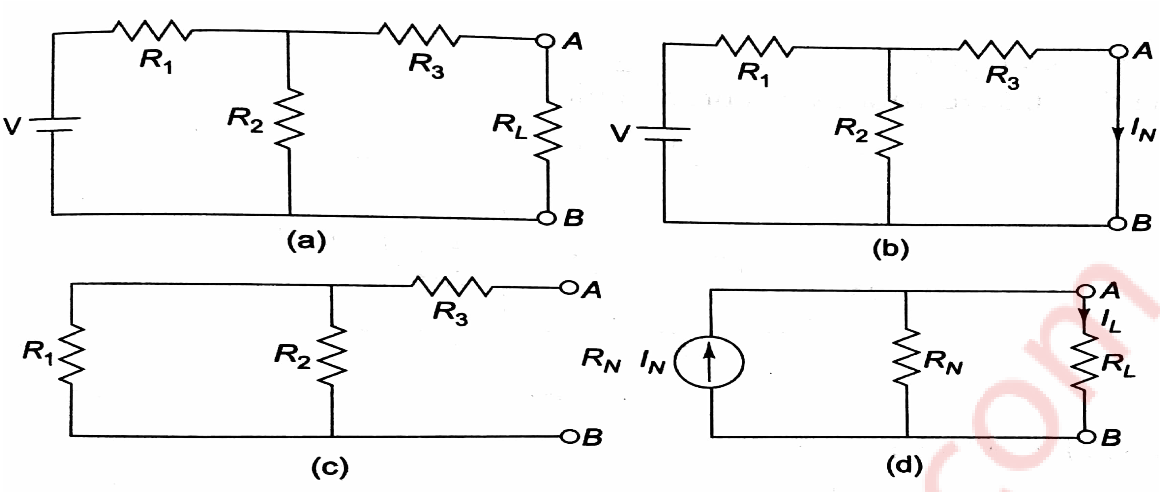


Diagram (d) from above shows the Norton's equivalent circuit.

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:-

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

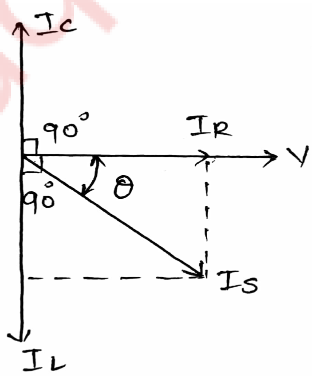
I_S be the source current.

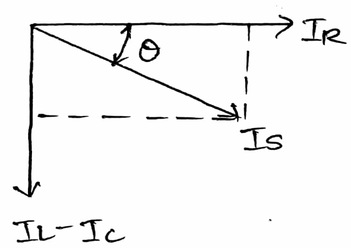
$I_S^2 = I_R^2 + (I_L - I_C)^2$

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

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

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.

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

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

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

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

Solution:-

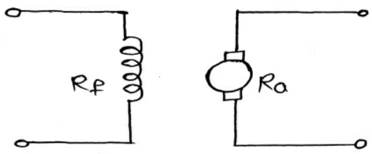
Depending upon the method of excitation of field winding ,DC machine are classified into two classes:-

1) Separately excited machines.

2) Self excited machines.

SEPARATELY EXCITED MACHINES

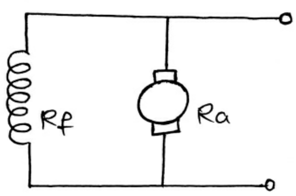
In separately excited machines the field winding is provided with a separate DC source to supply the field current as shown in figure.



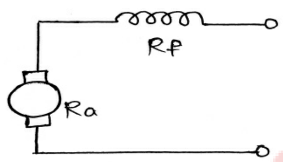
SELF EXCITED MACHINES

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:

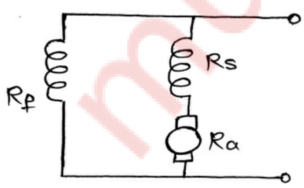
a) SHUNT WOUND MACHINES

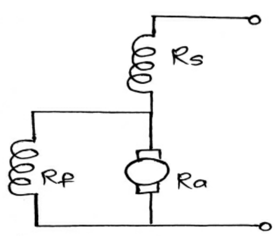


b) SERIES WOUND MACHINES



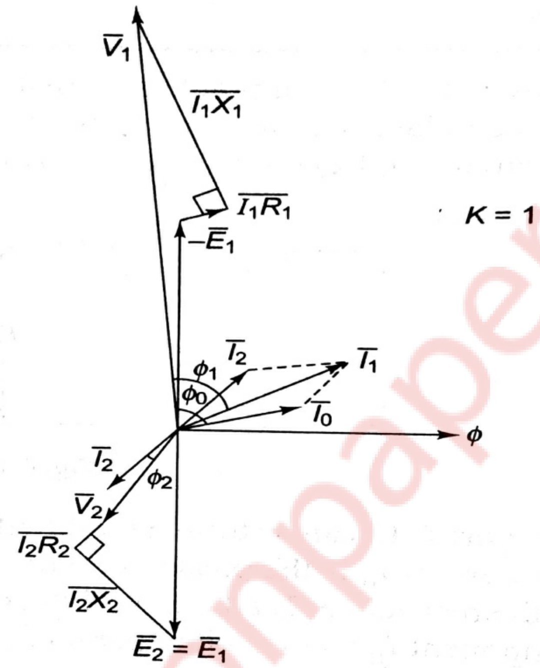
c) COMPOUND WOUND MACHINES





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 = $\cos\varphi = \cos(90°) = 0$

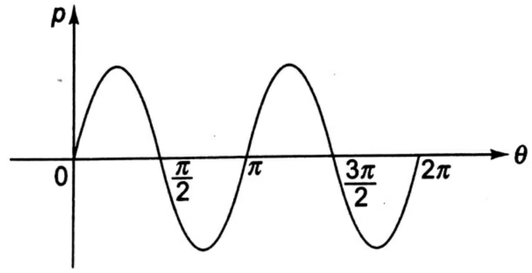
POWER

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)

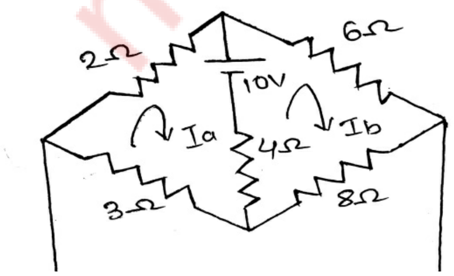
Solution:-

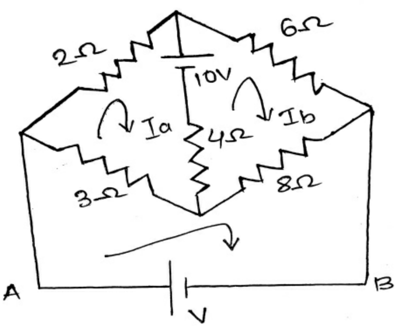
Applying KVL to mesh a

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

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

$9I_a - 4I_b = 10$ …………(1)





Applying KVL to mesh b

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

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

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

From (1) and (2) we get,

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

For voltage:-

Apply KVL to mesh

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

$V = 3I_a + 8I_b$

$V = 3 \times 1.5068 + 0.89 \times 8$

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

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

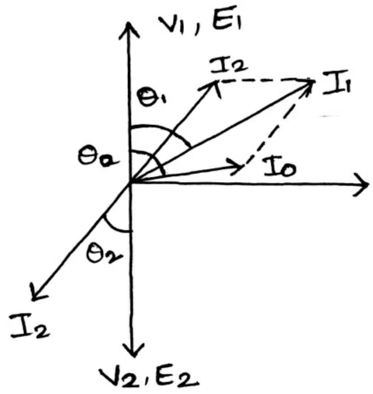
solve for horizontal and vertical components

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

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

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

$I_\mu = I_0\sin\varphi_0 = (3\times0.6) =$ **1.8A**



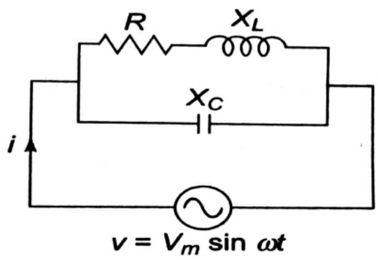
$\tan\varphi_1 = \frac{36.54}{45.4} = 0.805$

φ_1 **= 38°**

Power factor $\cos\varphi_1$ = 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,

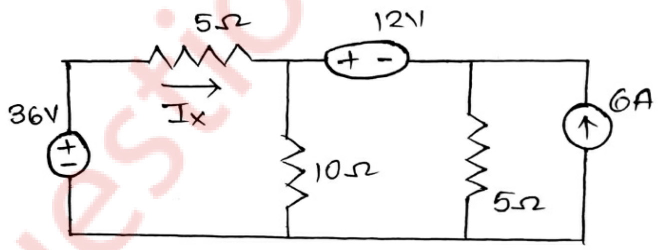
$$Z_D = \frac{R^2+X_L^2}{R}$$

At resonance ,

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

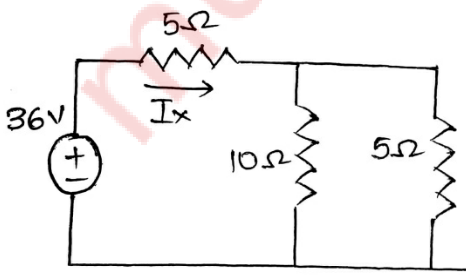
$Z_D = \frac{L}{CR}$

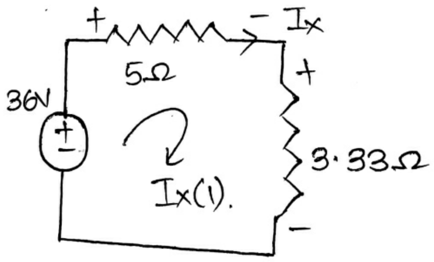
Q4] a) Find current I_X using Superposition theorem (10)

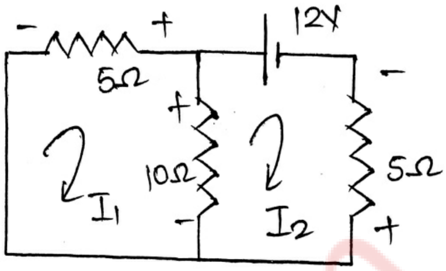


Solution:-

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







10Ω || 5Ω = 3.33Ω

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

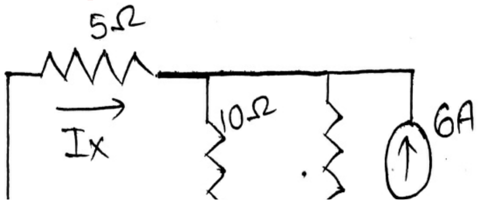
$12 - 5I_2 - 10(I_2 - I_1) = 0$

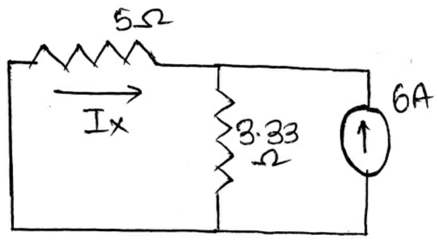
$12 = -10I_1 + 15I_2$ ....(2)

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:-

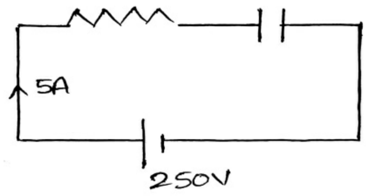
I_1 = 5A V = 250V f_1 = 50Hz f_2 = 60Hz I_2 = 5.8A

(1) Values of R and C.

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

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

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

$P_2 = VI_2 \cos\varphi_2$

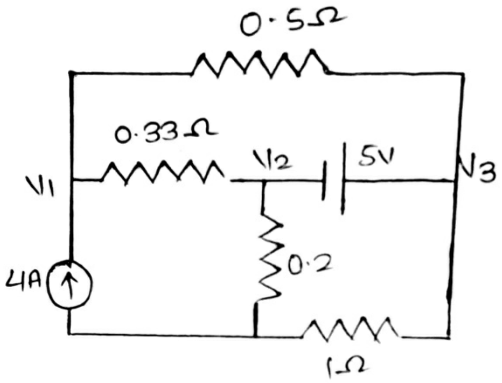
$671.45 = 250 \times 5.8 \times \cos\varphi_2$ => $\cos\varphi_2 = 0.463$

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.

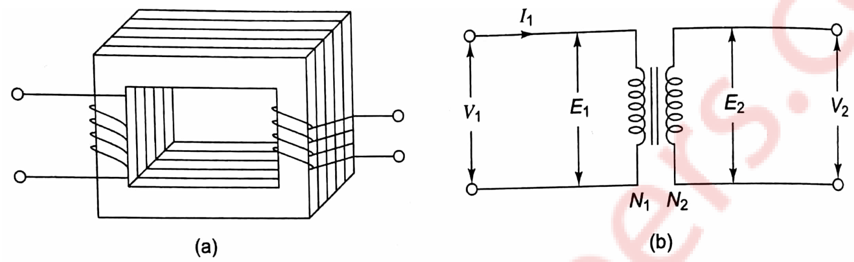


Fig. 6.5 *Working principle of a transformer*

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

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.

<u>EMF EQUATION.</u>

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,

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

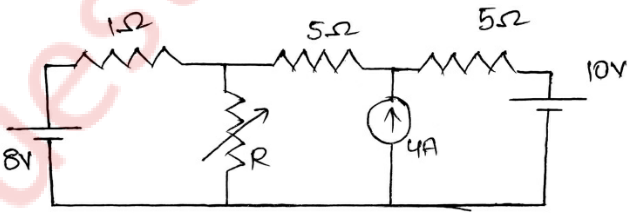
Similarly rms value of induced emf in the secondary winding is given by,

$$E_2 = 4.44 f N_2\varphi_m$$

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.

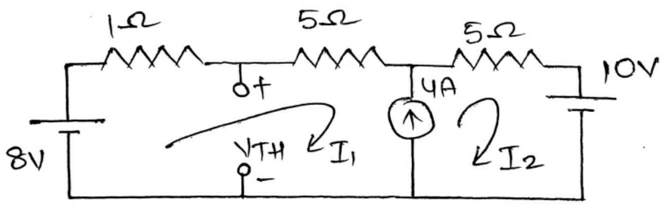
Q6] a) Determine the value of R for maximum power transfer and find the value of maximum transfer. (10)



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,

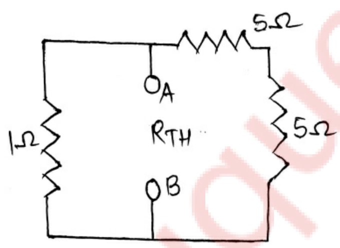
$I_1 = -2A$ and $I_2 = 2A$

Writing V_{TH} equation,

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

V_{TH} **= 10V**

(2) Calculation of R_{TH}



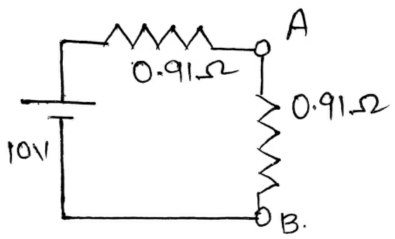
Replacing the voltage source by short circuits and current sources by an open circuit

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)

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

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

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

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

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

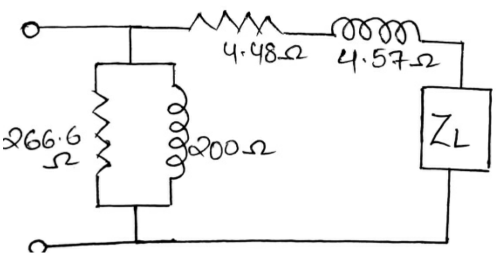
$Z_{01} = \frac{V_{SC}}{I_{SC}} = \frac{20}{12.5} = 1.6\Omega$ $\quad\quad R_{01} = \frac{W_{SC}}{I^2_{SC}} = \frac{175}{12.5^2} = 1.12\Omega$

$X_{01} = \sqrt{Z^2_{01} - R^2_{01}} = \sqrt{1.6^2 - 1.12^2} = 1.1426\Omega$

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

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

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



(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× $\sqrt{\frac{W_1}{W_{cu}}} = 5 \times \sqrt{\frac{150}{700}} = \mathbf{2.314KVA}$

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

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

Pf =1

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

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

$\%\eta_{max}$ = 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%
