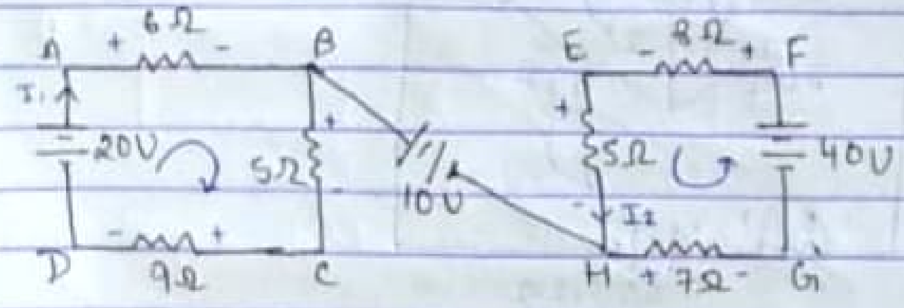
D.C. Circuits

REVIEW QUESTIONS:

1) For the given circuits below find the voltage across points C & F, & A & G



$$-6I_1 - 5I_1 - 9I_1 + 20 = 0$$

$$20 = 20I_1$$

$$\Rightarrow \boxed{I_1 = 1A}$$

$$-7I_2 + 40 - 8I_2 - 5I_2 = 0$$

$$40 = 20I_2$$

$$\boxed{I_2 = 2A}$$

$\therefore$ Now, $V_{CF} = V_F - V_C$

$$V_{CF} = -8I_2 - 5I_2 + 10 - 5I_1$$

$$= -13I_2 + 10 - 5I_1$$

$$= -26 + 10 - 5$$

$$\boxed{V_{CF} = -21V}$$

Now, $V_{AG} = V_G - V_A$

$$+7I_2 + 10 + 6I_1 = V_{AG}$$

$$14 + 10 + 6 = V_{AG}$$

$$\boxed{V_{AG} = 30V}$$

$+7 - I_1 - 2I_1 + I_2 + 2I_3 - 6 = 0$

$1 = 3I_1 - I_2 - 2I_3$ — (1)

$0 - I_2 - 2I_2 - 3I_2 + 3I_3 = 0$

$0 = 6I_2 - I_1 - 3I_3$ — (2)

$+6 - 3I_3 - I_3 - 2I_3 + 3I_2 + 2I_1 = 0$

$6 = 6I_3 - 3I_2 - 2I_1$ — (3).

$$\begin{bmatrix} 1 \\ 0 \\ 6 \end{bmatrix} = \begin{bmatrix} 3 & -1 & -2 \\ -1 & 6 & -3 \\ -2 & -3 & 6 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$I_1 = 3A$, $I_2 = 2A$, $I_3 = 3A$

Hence, current through

Resistor 1 = $I_1 - I_2 = 1A$

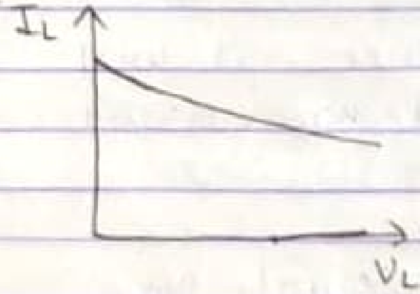
Resistor 2 = $I_2 = 2A$

Resistor 3 = $I_3 = 3A$

Resistor 4 = $I_3 - I_2 = 1A$

Resistor 5 = $I_1 - I_3 = 0A$

$\therefore$ current through shunt $= \dfrac{V_L}{R_{sh}}$

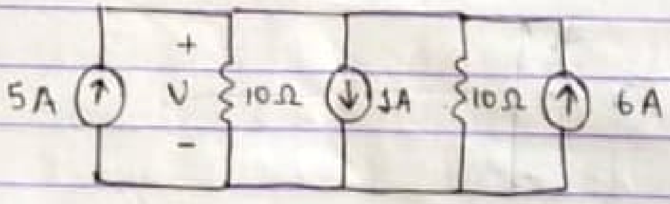


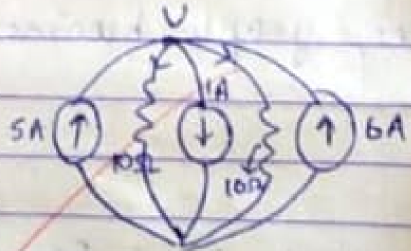
$$I_S = \frac{V_L}{R_{sh}} + I_L$$

$$\therefore \boxed{I_L = I_S - \frac{V_L}{R_{sh}}}$$

where, I_L is the load current.
I_S is the source current.

Q6:- Determine the voltage V.



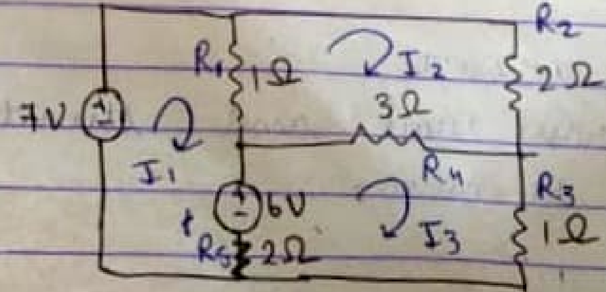


$$-5 - 6 + \frac{V}{10} + 1 + \frac{V}{10} = 0$$

$$\frac{2V}{10} = 10$$

$$\boxed{V = 50V}$$

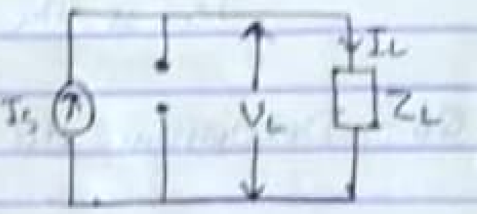
Q7. Use mesh analysis to determine the current through each resistor.



1) Ideal case:- For Ideal case of constant current generator, $R_{in} = 0$ $R_{sh} = \infty$.
Due to high value of resistance, it will behave as open circuit and no current will flow through it.

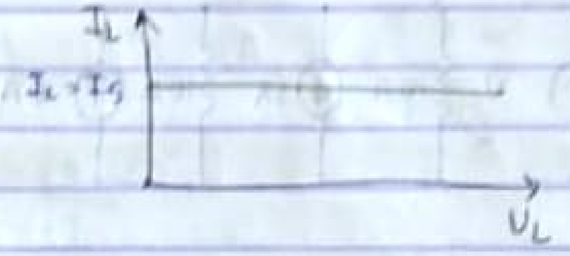
In ideal case, $R_{sh} = \infty$ so that equal am amount of current is supplied to all the loads.

$\therefore \boxed{I_L = I_S}$

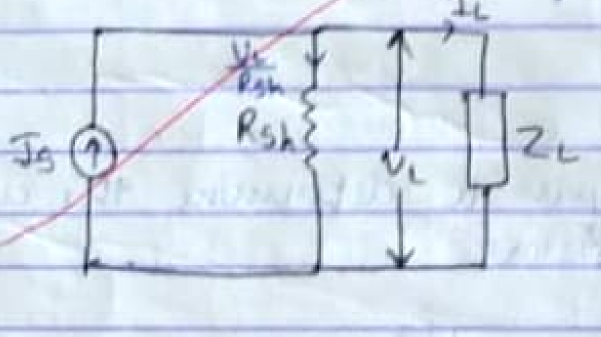


where, I_L = load current
I_S = source current

Hence, graph become



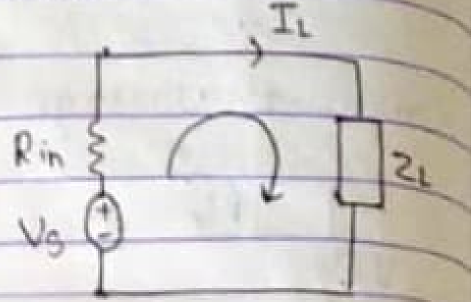
2) Practical case: For practical case of constant current generator, the shunt resistance 'R_{sh}' will have some finite values



Since it is a parallel circuit,
Hence voltage across load and shunt resistance will be same.

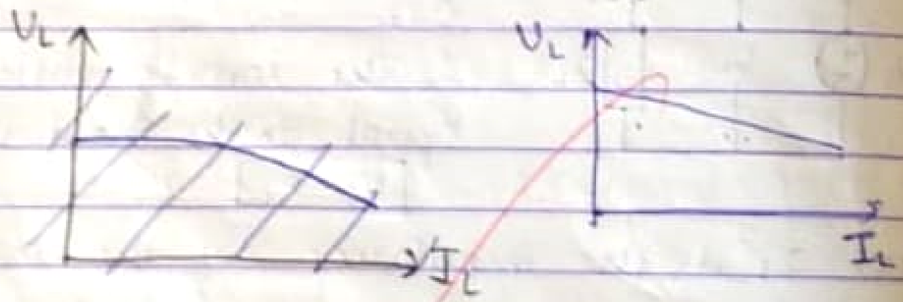
4 Hence by applying KVL to the circuit, the source voltage 'V_S' becomes

$$\boxed{V_S = R_{in} I_L + Z_L \times I_L}$$

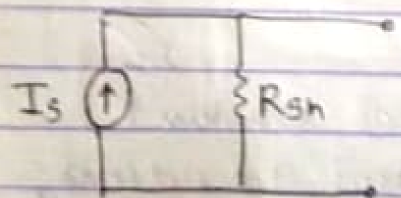


Hence, I_L is the current through the source. Since, load & R_{in} are connected in series. Therefore, the current through both of them will be same. And Z_L is the impedance of load.

Due to internal resistance of voltage source the graph of constant voltage generator in practical case becomes:



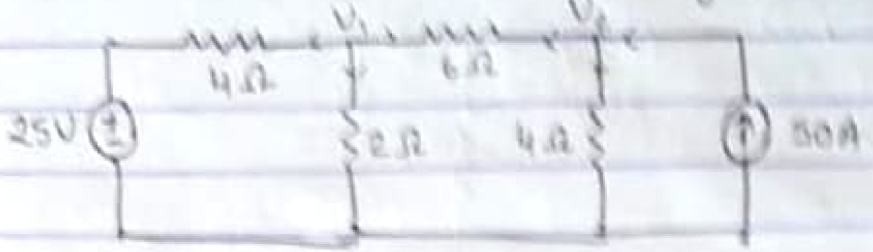
→ CONSTANT CURRENT GENERATOR:



In constant current generator, a ~~shett~~ shunt (resistance) is connected in parallel to the current source.

There are two cases of constant current generator:

4). Determine the node voltage



Applying KCL at node 1:-

$$\frac{V_1 - 25}{4} + \frac{V_1}{2} + \frac{V_1 - V_2}{6} = 0$$

$$V_1\left(\frac{1}{4} + \frac{1}{2} + \frac{1}{6}\right) - \frac{V_2}{6} = \frac{25}{4} \quad \text{--- (i)}$$

Applying KCL at node 2:

$$\frac{V_2 - V_1}{6} + \frac{V_2}{4} - 50 = 0$$

$$V_2\left(1/6 + 1/4\right) - \frac{V_1}{6} = 50 \quad \text{--- (ii)}$$

Now, $I = GV$

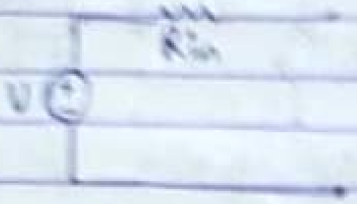
$$\begin{bmatrix} 25/4 \\ 50 \end{bmatrix} = \begin{bmatrix} 1/4 + 1/2 + 1/6 & -1/6 \\ -1/6 & 1/6 + 1/4 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$\begin{bmatrix} 6.25 \\ 50 \end{bmatrix} = \begin{bmatrix} 0.916 & -0.166 \\ -0.166 & 0.416 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$V_1 = 29.82V \approx 31V$
$V_2 = 131.66V$

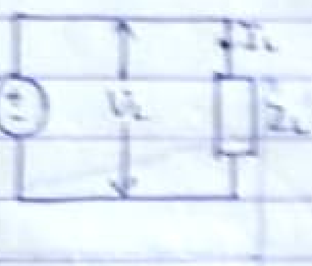
5) Explain constant voltage & constant current Generator.

→ Constant voltage generator –



Two cases are there for constant voltage generator.

I. Ideal Case: For ideal voltage source, the internal resistance becomes 0Ω



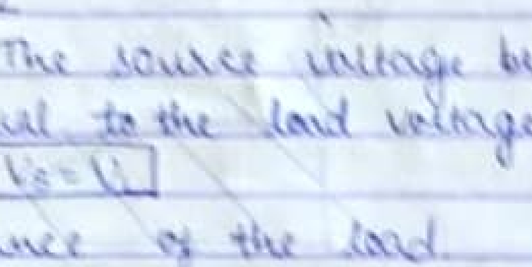
∴ The source voltage becomes equal to the load voltage

$\boxed{V_S = V_L}$

Here Z_L is the impedance of the load.

Eg.

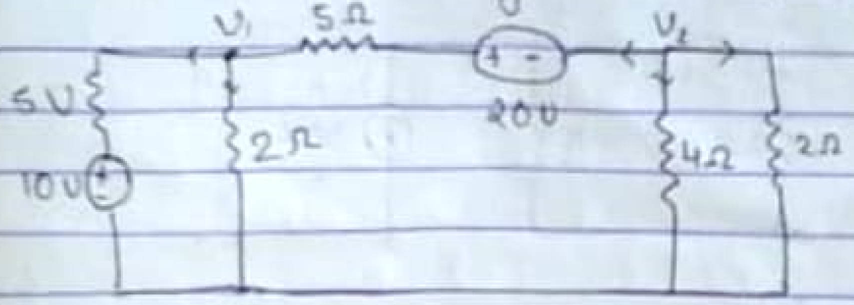
V_L	I_L	Z_L
10V	5A	2Ω
10V	2A	5Ω



Hence, we can conclude that for a constant voltage generator, to be in ideal conditions, there will be constant voltage throughout the load.

II. Practical Case: In practical case, the voltage source have some internal resistance. Hence, ~~By applying~~

3. Obtain node voltage V_1 & V_2



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

$$\frac{V_1}{5} + \frac{V_2}{2} + \frac{V_1}{5} - \frac{V_2}{5} = 6$$

$$V_1\left(\frac{1}{5}+\frac{1}{2}+\frac{1}{5}\right) - \frac{V_2}{5} = 6 \quad -(1)$$

Applying KCL at node -2 :- we get.

$$\frac{V_2}{2} + \frac{V_2}{4} + \frac{V_2+20-V_1}{5} = 0$$

$$V_2\left(\frac{1}{2}+\frac{1}{4}\right) + \frac{V_2}{5} - \frac{V_1}{5} = -4$$

$$V_2\left(\frac{1}{2}+\frac{1}{4}+\frac{1}{5}\right) - \frac{V_1}{5} = -4 \quad -(2)$$

Now, $I = GV$

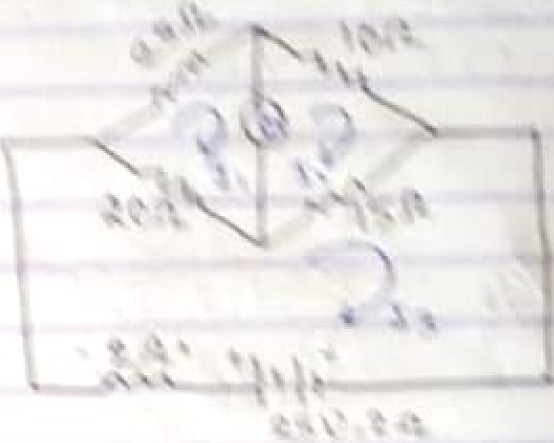
$$\begin{bmatrix} 6 \\ -4 \end{bmatrix} = \begin{bmatrix} 1/5 + 1/2 + 1/5 & -1/5 \\ -1/5 & 1/2 + 1/4 + 1/5 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$\begin{bmatrix} 6 \\ -4 \end{bmatrix} = \begin{bmatrix} 0.9 & -0.2 \\ -0.2 & 0.95 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$V_1 = 6.0122$ V

$V_2 = -2.9447$ V

2) Find the current through the galvanometer 'G' in the wheatstone bridge shown in fig (a). Assume galvanometer resistance to be 5Ω.



For loop 1

$20I_3 + 0 - 25I_1 - 5I_1 - 20I_1 + 5I_2 = 0$

$0 = 50I_1 - 5I_2 - 20I_3$ —(1)

For loop 2:

$0 - 10I_2 - 15I_2 - 5I_2 + 15I_3 + 5I_1 = 0$

$0 = -5I_1 + 30I_2 - 15I_3$ —(2)

For loop 3

$25 - 2I_3 - 20I_3 + 20I_1 - 15I_3 + 15I_2 - 2I_3 = 0$

$25 = 39I_3 - 20I_1 - 15I_2$ —(3)

Using Mesh Analysis →

$$\begin{bmatrix} 0 \\ 0 \\ 25 \end{bmatrix} = \begin{bmatrix} 50 & -5 & -20 \\ -5 & 30 & -15 \\ -20 & -15 & 39 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$I_1 = 0.539\,A$

$I_2 = 0.679\,A$

$I_3 = 1.179\,A$

∴ Current through galvanometer $= I_2 - I_1$

$= 0.14\,A$

A.C. CIRCUITS

Q1:- Define the terms: rms, average value, form factor of sinusoidal varying quantities

Sol:-

- rms value: It is defined as the root mean square value of an alternating quantity.

$$V_{rms} = \sqrt{\frac{\int_0^{2\pi} v^2 d\theta}{2\pi}}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{2\pi} V_m^2 \sin^2\theta \, d\theta}$$

$$= \sqrt{\frac{V_m^2}{2\pi}\int_0^{2\pi} \left(\frac{1-\cos 2\theta}{2}\right) d\theta}$$

$$= \sqrt{\frac{V_m^2}{4\pi}\left[\frac{\theta - \sin 2\theta}{2}\right]_0^{2\pi}}$$

$$= \sqrt{\frac{V_m^2}{4\pi}(2\pi - 0) - (\sin 2\pi - \sin 0)}$$

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

$$= 0.707 V_m$$

Similarly

$$I_{rms} = \frac{I_m}{\sqrt{2}} = 0.707 I_m$$

Where V_m = max^n voltage

I_m = max^n current

- Average Value: It is defined as the average of all instantaneous values during one alternation.

- Average value for one completly cycle:

$$Avg = \frac{\int_0^{2\pi} v \cdot d\theta}{2\pi}$$

$$= \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\theta \, d\theta$$

$$= \frac{V_m}{2\pi}\left[-\cos\theta\right]_0^{2\pi}$$

$$= \frac{V_m}{2\pi}\left(\cos 0 - \cos 2\pi\right)$$

$$= \frac{V_m}{2\pi}\left(1-1\right) = 0$$

Hence, average value i.e V_{avg} for one complete cycle is 0.

\# For Half Cycle:

$$Avg. = \frac{\int_0^{\pi} V\,d\theta}{\pi}$$

$$= \frac{V_m}{\pi}\int_0^{\pi} \sin\theta\,d\theta$$

$$= -\frac{V_m}{\pi}\left[\cos\theta\right]_0^{\pi}$$

$$= -\frac{V_m}{\pi}\left[\cos\pi - \cos 0\right] = -\frac{V_m}{\pi}\left[-1-1\right]$$

$$\boxed{Avg. = \frac{2V_m}{\pi}} = 0.637\,V_m$$

Similarly, $I_{avg} = 0.637\,I_m$.

- form factor: It is defined as the ratio of the rms value to average value of an alternating quantity

$$V_{rms} = 0.707\,V_m$$

$$V_{avg} = 0.637\,V_m$$

$$\therefore \text{form factor} = \frac{0.707\,V_m}{0.637\,V_m} = 1.11$$

Peak factor: It is defined as max^m value of to the rms value of an alternating quantity.

Peak factor $= \dfrac{V_m}{0.707\,V_m} = 1.414$

Q2. Obtain an expression for power in a series RL & RC circuits and also draw the phasor diagram and waveforms.

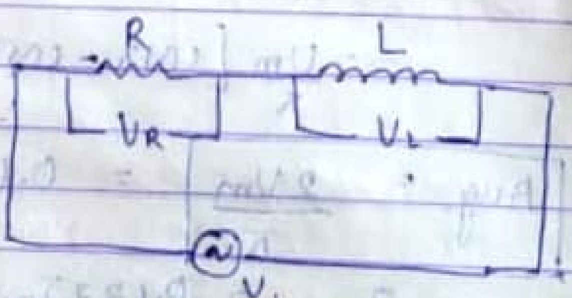
* RL - Circuit

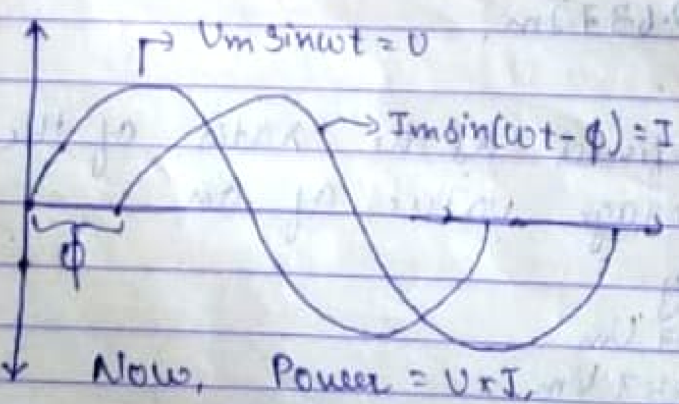
Let us consider a circuit with 'V' as the rms voltage. There is a resistance 'R' and inductor with inductance 'L'. Since R & L are in series, the current through both will be same.

Now, let the voltage drop across 'R' be V_R & 'L' be V_L

$V_R = IR$

$V_L = IX_L$





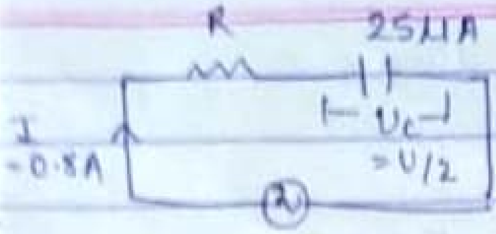
For a practical R-L circuit, current lacks by ϕ

Now, Power $= V \times I$

$= V_m \times \sin\omega t \; I_m \sin(\omega t - \phi)$

$= V_m I_m \sin\omega t \sin(\omega t - \phi)$

$\sin A \sin B = \frac{1}{2}\left[\cos(A-B) - \cos(A+B)\right]$



$V_c = V/2$

$$X_c = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 50 \times 25} \times 10^6$$
$$= 127.323\,\Omega$$

$$V_c = I X_c$$
$$\frac{V}{2} = \frac{0.8}{\pi} \cdot \frac{\times 10^6}{2500\pi}$$
$$V = 203.7183\,V$$

$$\therefore \quad V_c = \frac{203.71}{2} = 101.85\,V$$

$$V = IZ$$
$$Z = \frac{V}{I} = \frac{203.17}{0.8}$$
$$= 254.625\,\Omega$$

$$Z^2 = R^2 + X_c^2$$
$$64496.9514 = R^2 + 16211.38$$
$$\boxed{R = 220.5\,\Omega}$$

$$\tan\phi = \frac{X_c}{R} = 0.5774$$
$$\phi = 30.0035^\circ$$
$$\cos\phi = 0.8659 \quad \rightarrow \text{p.f (leading)}$$

$$P = VI\cos\phi$$
$$= 203.71 \times 0.8 \times 0.8659$$
$$P = 140.15 \text{ Watts.}$$

Let us consider two magnets which are acting as north pole & south pole. Three armature coils viz. RR', YY' & BB' are suspended b/w the magnets.

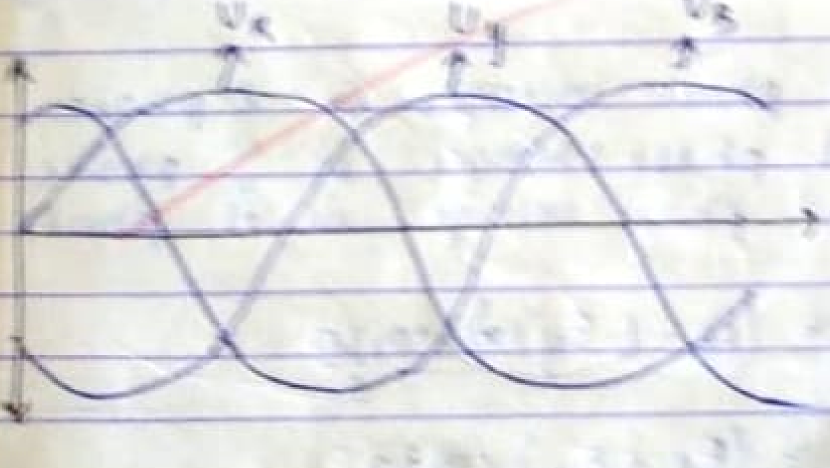
In accordance with the Faraday's law of electromagnetism, whenever a flux is cut inside the conductor an emf is said to be induced.

Hence, in fig I, RR' cuts max^m flux & therefore max^m amount of voltage is induced in RR'.

Similarly in fig II, YY' will have max^m induced voltage & in fig III, BB' will have max^m induced voltage.

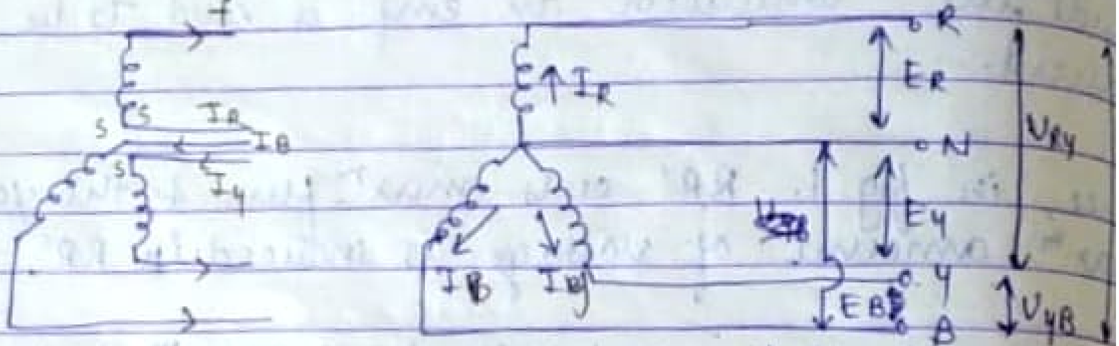
Hence, Instantaneous Voltage Equations can be written as:

$$V_R = V_m \sin \omega t$$
$$V_Y = V_m \sin(\omega t - 120°)$$
$$V_B = V_m \sin(\omega t - 240)$$



Q15. Derive the ~~expression~~ relationships b/w line & phase values of voltages & currents in star & delta connected balanced loads.

1. For STAR CONNECTION



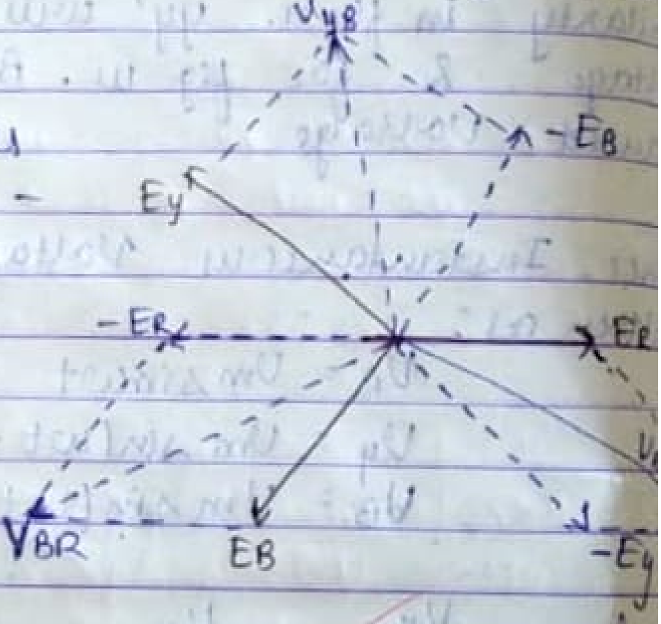
Now, line voltages can be written as -

$V_{RY} = E_R - E_Y$

$V_{YB} = E_Y - E_B$

$V_{BR} = E_B - E_R$

$E_R = E_Y = E_B = E_{ph}$



where,

E_R = induced phase voltages in R phase

E_Y = Induced phase voltages in Y phase

E_B = induced phase voltage in B phase

Now, $V_{RY} = (E_R - (-E_Y)) \times \cos\frac{60}{2}$

$= (E_R + E_Y)\cos 30$

$= 2E_{ph} \times \frac{\sqrt{3}}{2}$

$\boxed{V_{RY} = \sqrt{3}E_{ph}}$

For three phase

$P = 3 \times I_{ph}^2 \times R$

$120 \times 10^3 = 3 \times (85)^2 \times R$

$R = \frac{120 \times 10^3}{3 \times (85)^2}$

$R = 5.53\Omega$

$Z^2 = R^2 + X_L^2$

$Z_{ph} = \frac{V_{ph}}{I_{ph}} = \frac{635.08}{85} = 7.47\,\Omega$

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

$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{1100}{\sqrt{3}} = 635.08V$

$X_C = \sqrt{Z^2 - R^2}$

$= \sqrt{(7.47)^2 - (5.5)^2}$

$= 5.05\,\Omega$

$X_C = \frac{1}{2\pi f C} = 5.05\,\Omega$

$C = \frac{1}{2 \times \pi \times 50 \times 5.05}$

$\boxed{C \approx 630\mu F}$

$\cos\phi = R/Z$

$= \frac{5.5363}{7.4715}$

$\cos\phi = 0.7409$ leading

Q17. Three coils each of 16 Resistance & 12 inductive reactance are connected in delta across 400V, 50Hz supply. Determine

(vi) Power loss in each phase

$P = I^2 R$

$= I_{ph}^2 \times R_{ph}$

$= (20)^2 \times 16$

$P_{loss} = 6400$ Watts $\longrightarrow$ For 1 phase

Total Power Loss

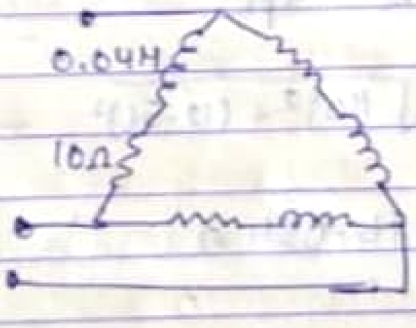
$P_{Total} = 3 \times P_{Loss}$

$= 3 \times 6400$

$= 19200$ Watts.

Q18. Three inductive coils, each with a resistance of 10 & an inductance of 0.04H are connected i) in star ii) in delta to a 3-ph's 400V, 50Hz supply. Calculate for each of the case a) phase current & line current & b) total power absorbed.

Delta Connecⁿ.



$R = 10\Omega$

$L = 0.04H$

$X_L = 2\pi f L$

$= 2\pi \times 50 \times 0.04$

$= 12.5663\Omega$

$V_L = V_{ph}$

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

$|Z_L| = \sqrt{(10)^2 + (12.5663)^2}$

$= 16.059\,\Omega$

$I_{ph} = \dfrac{V_{ph}}{Z_{ph}} = \dfrac{400}{16.059} = 24.91\,A$

$I_L = \sqrt{3}\, I_{ph}$
$= \sqrt{3} \times 24.91$
$= 43.155\ A$

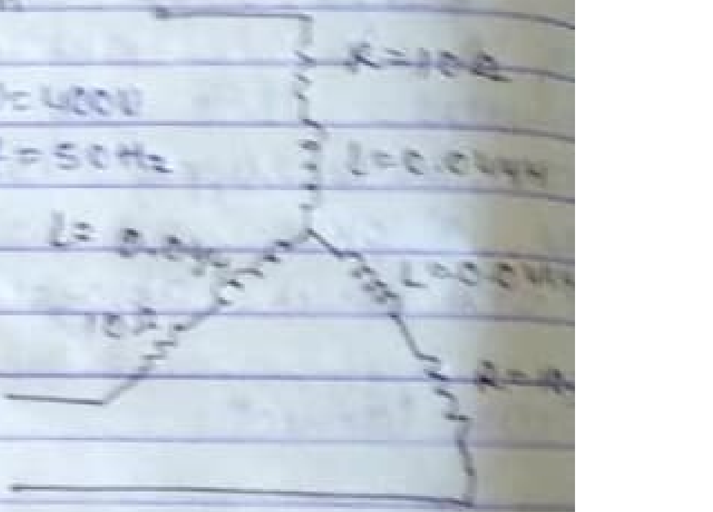
→ Power Absorbed

$P = \sqrt{3}\, I_L V_L \cos\phi$
$= \sqrt{3} \times 43.155 \times 400 \times 0.62$
$= 18536$ Watts

$\cos\phi = \dfrac{R}{Z}$

$\cos\phi = 0.62$

→ In Star Connection



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

$I_L = I_{ph}$

$Z_{ph} = R_{ph} + jX_L$

$|Z_{ph}| = \sqrt{R^2 + X_{ph}^2}$

$|Z_{ph}| = \sqrt{(10)^2 + (12.56)^2}$

$|Z_{ph}| = 16.054\ \Omega$

$V_{ph} = \dfrac{V_L}{\sqrt{3}} = \dfrac{400}{\sqrt{3}} = 230.9\ V$

$I_{ph} = \dfrac{V_{ph}}{Z_{ph}} = \dfrac{230.9}{16.059} = 14.38\ A$

$I_L = 14.38 A$

$\cos\phi = R/Z = 10/16.059 = 0.62$

Power consumed or absorbed

$P = \sqrt{3} \times V_L I_L \cos\phi$
$= \sqrt{3} \times 400 \times 14.38 \times 0.62$
$= 6176.9$ Watts.

Now, $I_{L_1} = (I_R - (-I_B)) \cos 60/2$

$= (I_R + I_B) \cos 30°$

$= 2 I_{ph} \sqrt{3}/2$

$\boxed{I_{L_1} = \sqrt{3} I_{ph}}$

$I_{L_2} = ((I_Y) - (-I_R)) \cos 60/2$

$= 2 I_{ph} \times \sqrt{3}/2$

$\boxed{I_{L_2} = \sqrt{3} I_{ph}}$

$I_{L_3} = (I_B - (-I_Y)) \cos 60/2$

$= (I_B + I_Y) \cos 30°$

$= 2 I_{ph} \times \sqrt{3}/2$

$\boxed{I_{L_3} = \sqrt{3} I_{ph}}$

In case of delta connecⁿ, line voltage is equal to phase voltage due to absence of neutral

$\boxed{V_L = V_{ph}}$

Q16:- A balanced 3-ph star connected load of 120 KW takes a leading current of 85A wh connected across a 3ph, 1100V, 50Hz suppl Obtain the values of resistance, Impedance and capacitance of the load per phase & al Calculate the power factor of the load.

$P = 120$ KW (Low) → load

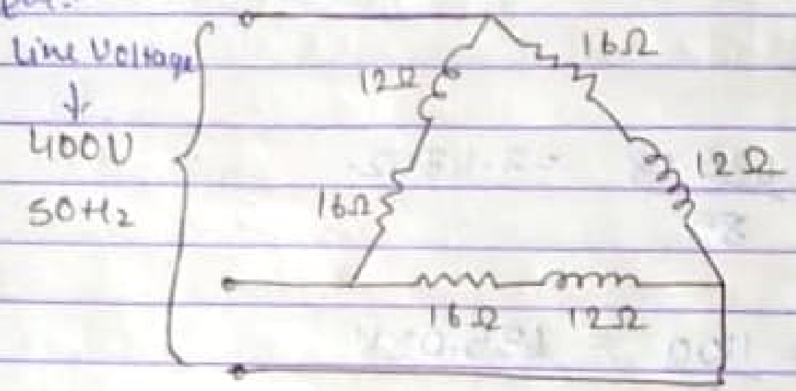
$I_L = 85A = I_{ph}$ (Star, $I_L = I_{ph}$)

$V = 1100V$.

$P = I_{ph}^2 R$ ⟶ Single Phase

a) Impedance per phase b) phase current
c) line current d) p.f. of the circuit
e) phase difference f) power loss in each phase g) total power loss.

Sol:-



In Delta connecⁿ

$V_L = V_{ph} = 400V$

$Z_{ph} = R + X_L j$

$|Z_{ph}| = \sqrt{R^2_{ph} + X^2_{Lph}}$

$= \sqrt{(16)^2 + (12)^2}$

$= 20$

$\boxed{Z_{ph} = 20\Omega}$

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{400}{20} = 20A$

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

$= 20\sqrt{3}\ A$

$I_L = 34.6A$

$\cos\phi = \frac{R}{Z}$

$\cos\phi = \left(\frac{16}{20}\right) = 0.8$

$\phi = \tan^{-1}\left(\frac{12}{16}\right) = 36.86°$

- $V_{BR} = (E_B - (-E_R)) \cos 60/2$
$= (E_B + E_R) \cos 30^\circ$
$= 2 \times E_{ph} \times \sqrt{3}/2$

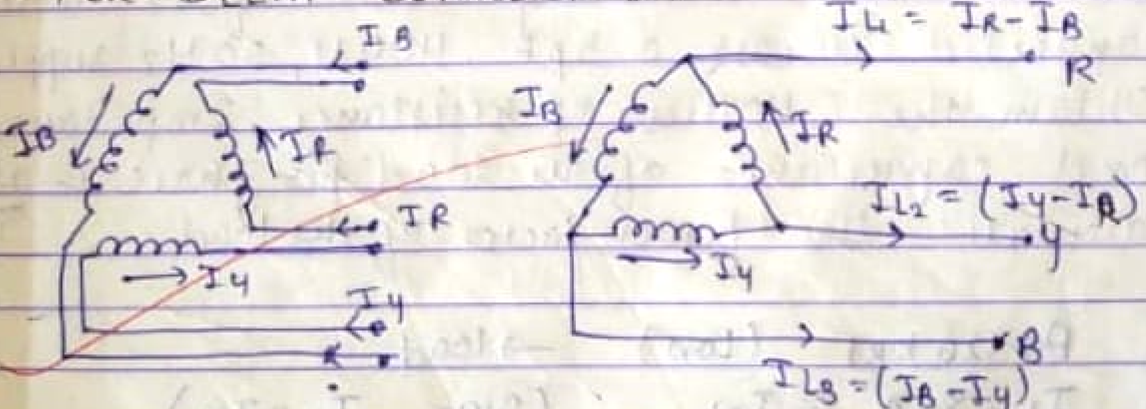
$\boxed{V_{BR} = \sqrt{3} E_{ph}}$

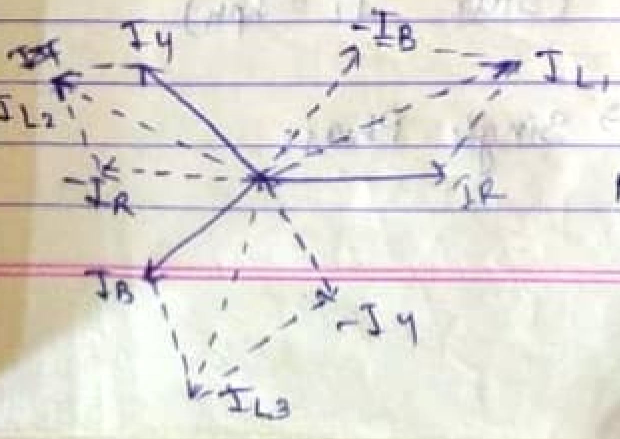
- $V_{YB} = (E_Y - (-E_B)) \cos 60/2$
$= (E_Y + E_B) \cos 30^\circ$
$V_{YB} = 2 \times E_{ph} \times \sqrt{3}/2$
$\boxed{V_{YB} = \sqrt{3} E_{ph}}$

Now, for star connection line current are equal to the phase current.
Applying ~~KV~~ KCL, $I_R + I_Y + I_B = 0$
$\therefore I_R = I_Y = I_B = I_{PL}$

where, I_R = current flowing through 'R' phase.
I_Y = current flowing through 'Y' phase
I_B = current flowing through 'B' phase
I_L = line current.

2. FOR DELTA CONNECTION —





Now, $I_{L1} = I_R - I_B$
$I_{L2} = I_Y - I_R$
$I_{L3} = I_B - I_Y$

$\cos\phi = 0.9839$

$P_{total} = 250 \times 33.1654 \times 0.983$
$= 8157.8592$ Watts.

Q13. List the advantages of 3phases ac system over single phase ac systems :

1. Power factor of single phase AC motors, is lower than the three phase AC motor for same output ~~p~~ & speed.

2. Single phase AC motors are not self-starting i.e. they require auxiliary apparatus for their starting but three phase AC motors are self starting

3. For a given size, output of three phase AC machine is greater than the single phase supply motor.

4. For a given amount of power at a given voltage, 3 phase supply system requires $3/4^{th}$ ~~of~~ weight of copper of single phase system.

Q.14. Explain the generation of three phase voltages?

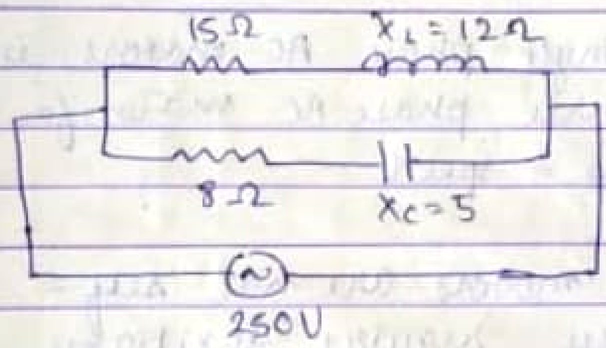
Q12. Two impedances $Z_1 = 15 + j12\,\Omega$ & $Z_2 = 8 - j5\,\Omega$ are connected in parallel. if the potential differences across one of the impedance is 250V, calculate.

i) total current & branch currents.

ii) total power & power consumed in each branch

iii) Overall p.f.

12:-



$Z_1 = 19.2093\,\Omega$

$Z_2 = 9.433\,\Omega$

$\therefore\ I_1 = \dfrac{V}{Z_1} = 13.0145A$

$I_2 = 26.5001A$

$\cos\phi_1 = \dfrac{15}{Z_1} = 0.7808$

$\cos\phi_2 = \dfrac{8}{Z_2} = 0.8480$

$I_A = I_1\cos\phi_1 + I_2\cos\phi_2$

$= 32.6339A$

$I_R = I_2\sin\phi_2 - I_1\sin\phi_1$

$= 14.0449 - 8.1312$

$= 5.9137A$

$I = \sqrt{I_A^2 + I_R^2}$

$= 33.1654A$

$P_1 = I_1V_1\cos\phi_1 = 2540.4304$ Watts.

$P_2 = V_2I_2\cos\phi_2 = 5618.0212$ Watts.

$P_{total} = P_1 + P_2$

Now for resistance of the lamp —

$$P = \frac{V^2}{R} = \frac{100 \times 100}{R}$$

$$R = \frac{100 \times 100}{750} = \frac{40}{3} = 13.33\,\Omega$$

Now, Impedance of circuit :

$$Z = \frac{V}{I} = \frac{230}{7.5} = 30.67\,\Omega$$

Now, $Z = \sqrt{R^2 + X_C^2}$

$$X_C = \sqrt{Z^2 - R^2}$$

$$X_C = 27.62\,\Omega$$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2 \times 3.14 \times C \times 60} = 27.62$$

$$\therefore C = \frac{1}{2 \times 3.14 \times 60 \times 27.62}$$

$$= 960 \times 10^{-5}$$

$$= 96.0 \times 10^{-6}\,F$$

$$\boxed{C = 96\,\mu F}$$

Now, $\tan\theta = \frac{X_C}{R} \Rightarrow \theta = \tan^{-1}\left(\frac{27.62}{13.33}\right)$

$$\boxed{\theta = 64.27^\circ}$$

Q11:- An adjustable resistor R in series with a capacitance of 25µF draws a current of 0.8A, when connected across 50Hz supply. Calculate (i) the value of resistor so that the voltage across the capacitor is half the supply voltage (ii) the power, and (iii) p.f.

Reactive Power = $V \times I \times \cancel{\cos} \sin\theta$
$= 250 \times 22.36 \times \sin(63.4349)$
$= 4999.84$ VAr

Active Power = $V \times I \times \cos\theta$
$= 250 \times 22.36 \times 0.4472$
$= 2499.84$ Watts

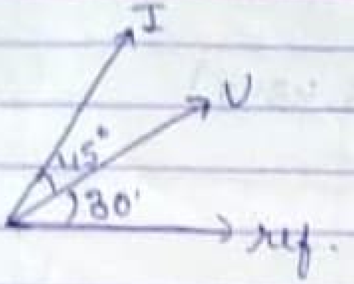
Q9. A two element series circuit consumes 700W & has p.f. = 0.707 leading. If applied voltage is $V = 141.4 \sin(314t + 30)$. find the circuit constants.

Sol:- P.f = 0.707 leading
∵ The circuit consists a capacitor
∴ It is a R-C Network.
$P = 700W$
$P.f. = 0.707$ (Lead)
$V = 141.4 \sin(314t + 30^\circ)$ → voltage is making 30° with reference.
$V = V_m \sin(\omega t)$

∴ $V_m = 141.4$
$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{141.4}{\sqrt{2}} = 100V$
$\boxed{V_{rms} = 100V}$

$P = V_{rms} \times I_{rms} \times \cos\phi$
$700 = 100 \times I_{rms} \times 0.707$
$I_{rms} = \frac{7}{0.707} = 9.9A$

$\cos\theta = 0.707$
$\theta = \cos^{-1}(0.707)$
$\boxed{\theta = 45^\circ}$ → ∴ Angle b/w voltage & current is 45°.
↓
Here current leads because R-C network.



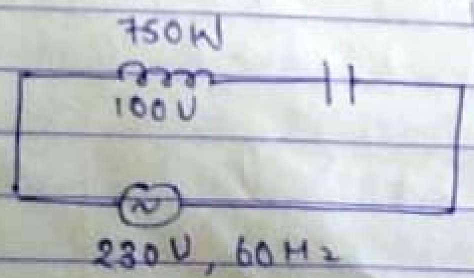
$$Z = \frac{V}{I} = \frac{(100\angle 30^\circ)}{(9.9\angle 75^\circ)}$$
$$= 7.1424 - 7.14j$$
$$Z = 10.10 \angle -45^\circ$$

$$314 = 2\pi f = \omega$$
$$f = \frac{314}{2\pi}$$
$$\boxed{f = 50\,Hz}$$

$$\therefore\ X_c = \frac{1}{2\pi f C}$$
$$C = \frac{1}{2\pi \times 50 \times 7.07}$$
$$\boxed{C = 446\,\mu F}$$

~~Q10. A metal filament lamp rated at 750W, 100V & has p.f = 0.707 leading.~~

Q10. A metal filament lamp rated at 750W, 100V is to be connected in series with a capacitor across a 230V, 60Hz supply. Calculate a) The capacitance required. b) The phase angle between current & supply voltage.



$$P = V \times I$$
$$I = \frac{P}{V} = \frac{750}{100}$$
$$\boxed{I = 7.5A}$$

(iv) $P.f = \frac{R}{Z} = \frac{32}{71.43} = 0.447$

$\therefore \boxed{\cos\theta = 0.447}$

(v) $P = VI\cos\phi$
$= 240 \times 3.35 \times 0.447$
$= 359.388$ Watts.

(vi) $P_{coil} = V_{coil} \times I \times \cos\phi$
Here $\cos\phi = \frac{R}{Z} = \frac{12}{\sqrt{R^2 + X_L^2}} = \frac{12}{\sqrt{(144)^2 + (15.70)^2}}$
$= 0.607$

$\therefore P_{coil} = 66.2 \times 3.35 \times 0.607$
$= 135.45$ Watts.

Q8:- A voltage of 250V is applied to an inductive circuit of impedance $(5+j10)\Omega$. Calculate current, power factor, apparent & reactive power.

$Z = 5 + j10$
$V = 250V$
$Z = \sqrt{25+100} = \sqrt{125} = 11.18\,\Omega$
$Z = \frac{V}{I} \Rightarrow I = \frac{V}{Z} = \frac{250}{11.18} = 22.36$

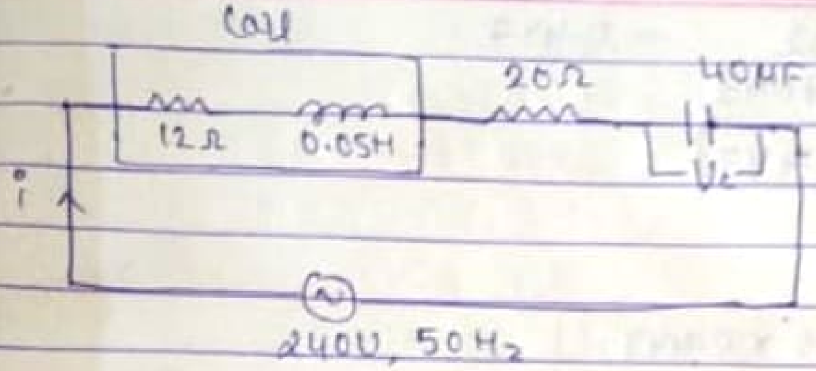
$\boxed{I = 22.36A}$

$\tan\theta = \frac{X_L}{R} = \frac{10}{\cancel{2}5} = 2$

$\theta = \tan^{-1}(2)$
$\boxed{\theta = 63.4349}$

$\therefore$ Power factor; $\cos\theta = 0.4472$

Apparent Power, $= \cancel{\theta}\ V \times I$
$= 250 \times 22.36$
$= 5590\,VA$



$X_L = 2\pi f L = 2\times\pi\times50\times0.05$

$X_L = 15.70\,\Omega$

$X_C = \frac{1}{2\pi\times50\times40\times10^{-6}}$ $X_C = \frac{1}{2\pi f C}$

$X_C = 79.57\,\Omega$

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{(32)^2 + (15.7079 - 79.5774)^2}$

$= 71.4374$

$I = \frac{240}{71.4374} = 3.35A$ —(i)

(ii) $V_{coil} = \cancel{Z}\ I \times Z_{coil}$

$= 3.35 \times \sqrt{R^2 + X_L^2}$

$= 3.35 + \sqrt{(12)^2 + (2\times\pi\times0.05\times50)^2}$

$= 3.35 \times \sqrt{144 + 246.49}$

$= 3.35 \times 19.7608$

$= 66.19$

$\boxed{V_{coil} = 66.2\ V}$.

(iii) $V_c = I X_c$

$= 3.35 \times 79.57$

$= 266.5595\,V$

$\boxed{V_c = 267V}$

(b) $I = 96A$

$\therefore \ 96 = 120 \sin(2\pi f t)$

$\sin^{-1}(0.8) = 2\pi f t$

$53.130 = 2 \times \pi \times 60 \times t$

$t = \dfrac{53.13}{2 \times \pi \times 60}$

$\boxed{t = 0.141}$

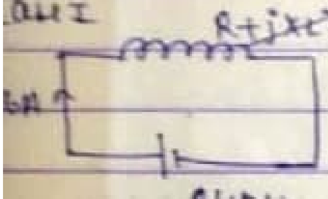
Q6:- When a certain inductive coil is connected to a dc supply at 240V, the current in the coil is 16A. When the same coil is connected to an ac ~~circuit~~ supply at 240V, 50Hz, the current is 12.27A. Calculate i) resistance (ii) Impedance (iii) reactance & (iv) the inductance of the coil. If the supply were to be altered to 60Hz at 240V, then what happens to the current.

Frequency of DC supply is always '0'.

$\because X_L$ has frequency component to it

$\therefore \ X_L = 2\pi f L = 0$

Case I

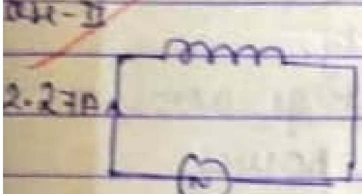


$\therefore R = \dfrac{V}{I} = \dfrac{240}{16} = 15\,\Omega$

$\boxed{R = 15\,\Omega}$ Resistance

Now, for AC supply.

Case-II



Now, $Z = \dfrac{V}{I} = \dfrac{240}{12.27} = 19.55\,\Omega$

Impendance $\boxed{Z = 19.55\,\Omega}$

Now, $Z = \sqrt{R^2 + X_L^2}$

$$Z^2 = R^2 + X_L^2$$

$$X_L^2 = Z^2 - R^2$$

$$X_L = \sqrt{Z^2 - R^2}$$

$$= \sqrt{(19.55)^2 - (15)^2}$$

$$\boxed{X_L = 12.53\,\Omega} \longrightarrow \text{Reactance}$$

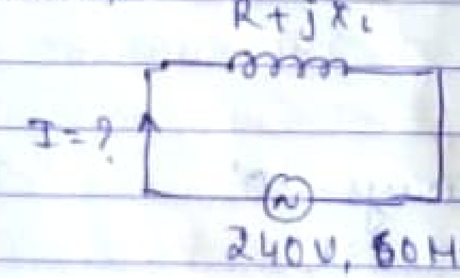
Now, $X_L = 2\pi f L$

$$L = \frac{X_L}{2\pi f} = \frac{12.53}{2 \times 3.14 \times 50}$$

$$L = \frac{12.53}{314} = 0.0399$$

$$\boxed{L = 0.0399\,H} \rightarrow \text{Inductance}$$

Now,



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

$$= \sqrt{(15)^2 + (2 \times \pi \times 60 \times 0.0399)^2}$$

$$\boxed{Z \simeq 21.26\,\Omega}$$

$$I = \frac{V}{Z} = \frac{240}{21.26} = 11.28\,A$$

Q7:- A coil of resistance $12\,\Omega$ & inductance $0.05H$, a non-inductive resistor of $20\,\Omega$ resistance & a loss-free $40\mu F$ capacitor are connected in series across a 240V, 50Hz sinusoidal supply. Calculate a) the current b) the voltage across the coil and the capacitor, c) the power consumed in the circuit, d) the power consumed by the coil and e) the power factor of the circuit.

- Active Power is the power dissipated in the circuit ~~resistance~~ resistance given by $VI\cos\phi$. Its unit is Watts.

- Reactive Power is the power developed in the reactance of the circuit given by $VI\sin\phi$. Its unit is VAr.

- Apparant Power is the product of Voltage & current. Its unit is VA.

Q5. An Alternating current of $f = 50\,Hz$ has a maximum value of 120A. Write down the equation for its instantaneous value. Reckoning time from the instant the current is zero and is becoming positive, find
(a) instantaneous value after 1/360 sec.
(b) the time taken to reach 96A for the first time.

$f = 60\,Hz$

$I_M = 120A$

$I = I_m \sin\omega t$

$I = 120 \sin(2\pi f t)$

(a) $t = \frac{1}{360}$ sec

$$I = 120 \sin\left(2\pi \times 60 \times \frac{1}{360}\right)$$

$$= 120 \sin(\pi/3)$$

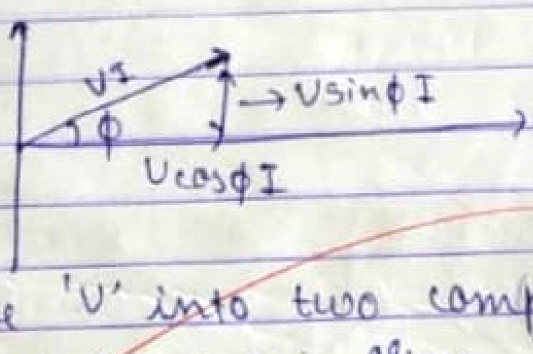
$$\boxed{I = 103.92A}$$

Importance Of Power factor -

- If the value of power factor is in b/w 0.8 to 1 then it is ideal case.
- The value of power factor should be kept as high as possible in the circuit so that the angle b/w current & voltage is less and they became as nearer as possible.
- Low Powerfactor causes high ~~voltage~~ loss ~~in~~ power loss in the line, & thus decreasing the line efficiency.
- Power factor of 1 is preferred by electric board also. If it is less than that then they have to supply more current for a given power use & thus more power loss.

Q4. Define active and reactive power in a A.C. circuits.

Let 'I' be the ~~refor~~ reference quantity.



Resolve 'V' into two components along x-axis as well as y-axis. Since, 'I' is the reference quantity Hence we multiply every side by I.

$\therefore$ $VI\cos\phi$ → Active Power

$VI\sin\phi$ → Reactive Power

VI → Apparant Power

$$P = \frac{V_m I_m}{2}\left[\cos(\omega t - \omega t + \phi) - \cos(\omega t - \omega t + \phi)\right]$$

$$= \frac{V_m I_m}{2}\left[\cos\phi - \cos(2\omega t - \phi)\right]$$

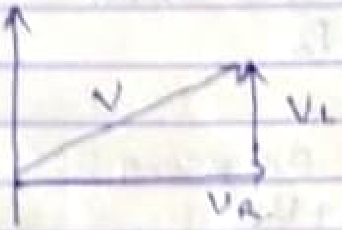
$\because$ It varies from 0 to 2π & avg. value of one complete cycle is 0. $\therefore$ It will not contribute anything to the power

$$P = \frac{V_m I_m \cos\phi}{2}$$

$\because V_{rms} = \frac{V_m}{\sqrt{2}}$; $I_{rms} = \frac{I_m}{\sqrt{2}}$

$\therefore$ $\boxed{P = V_{rms} I_{rms} \cos\phi}$

Phasor Diagram:



$V = V_R + V_L$

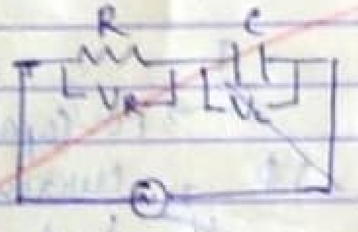
$V = IR + IX_L$

$V = I(R + X_L)$

$V/I = R + X_L \Rightarrow \boxed{Z = R + X_L}$

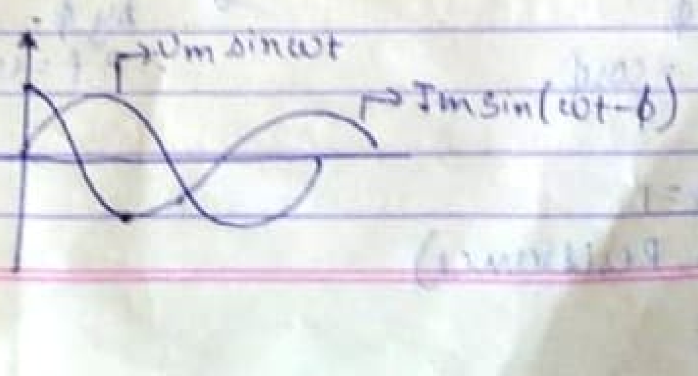
* RC- Circuit

Let us consider a circuit with rms voltage as 'V'. There is a resistance 'R' & capacitor 'C'. Since, both are connected in series hence current through both will be same. Let voltage drop across the resistance be 'V_R' & capacitor be 'V_C'.



$V_R = IR$

$V_C = IX_C$



$P = VI$

$= V_m \sin\omega t \; I_m (\sin(\omega t + \phi))$

$= V_m I_m \sin\omega t \sin(\omega t + \phi)$

$= \frac{V_m I_m}{2} [\cos\phi]$

$$\boxed{P = V_{rms} I_{rms} \cos\phi}$$

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

$\frac{I_m}{\sqrt{2}} = I_{rms}$

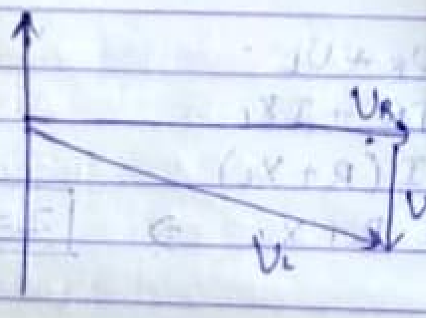
- Phasor diagram:

$V = V_R + V_C$

$V = IR - IX_C$

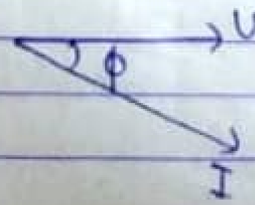
$V/I = R - jX_C$

$Z = (R - jX_C)$



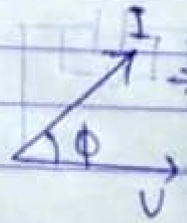
Q3. Define power factor and explain the importance of power factor.

- Power factor of an alternating circuit is defined as the cosine of angle b/w the current and the voltage.
- It is also defined as the ratio of resistor to the impedance.



→ For inductance current lacks by ϕ

$\therefore$ P.f = $\cos\phi$



→ For capacitan[ce] current l[eads] by ϕ.

$\therefore$ P. f = $\cos\phi$

$\cos\phi = 1$

(For Resistance)