B.E.E

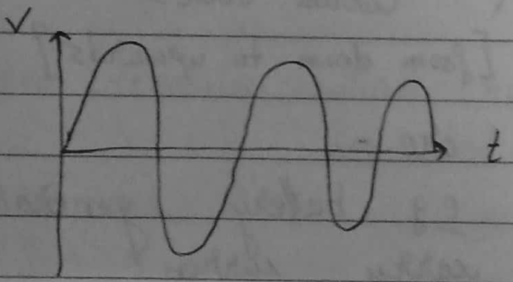
Basics of Electrical Engineering

DC → Electronics [devices, appliances]
AC → Electrics [work]

Introduction to DC Circuits -

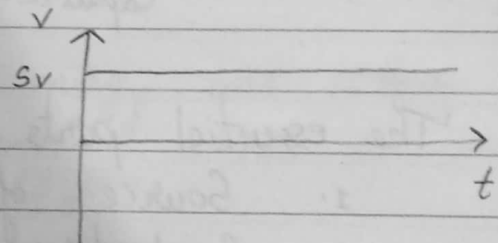
AC [to stabelise the fluctuation, so we need stabalizers]

⇒ AC



220 - 270 V

DC [Mobile Battery]



Constant

DC Voltage

Constant voltage value

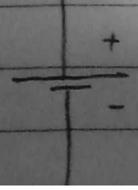
DC Circuits

3 types of components
Closed path supplies current is called Circuit

- Source
- Conductors
- Output

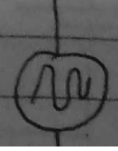
DC Source

Positive & -ve terminal

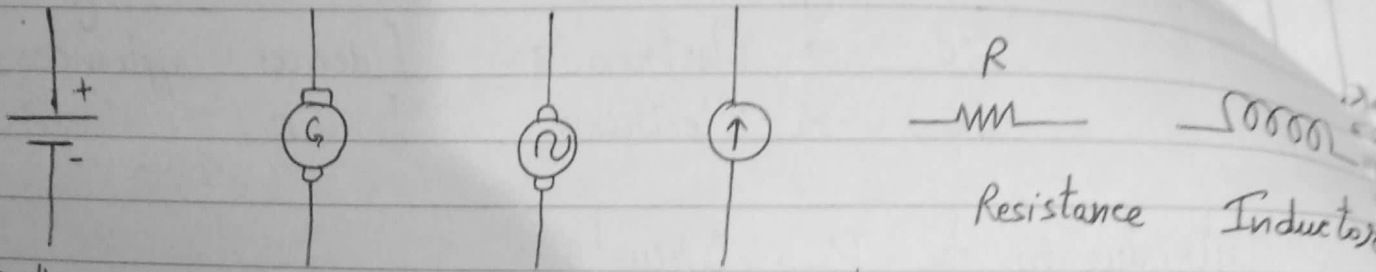


AC Source

Sine Wave

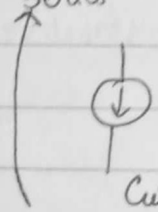


DC Terminology - [Components]



DC Battery — DC Generator — AC Generator — Current Source series — Resistance — Inductor

Capacitor



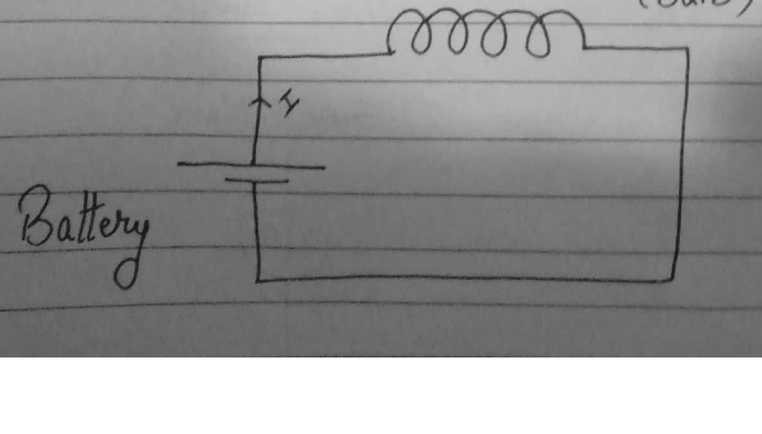
Current Series
[from down to upwards]

The essential parts of DC circuits are -

1. Source of Power — e.g battery, generator
2. Conductors — used to carry current
3. Load — e.g bulb, resistance

⇒ The Source supplies electrical energy to the load which converts it into heat or other form of energy. does conversion of electrical energy into another form of energy is possible only with the help of circuits.

⇒ The closed path followed by direct current is called DC Circuits.



In a DC circuit, load may be connected in series, parallel and their combination.

DC circuit can be classified as series crct, parrallel crct and series, parrallel

* Terminology of DC Circuit are Active and Passive:

Active Elements which supplies electrical energy to the circuit V_1 and V_2 are examples.

Passive Elements which receives electrical energy and either converted into heat energy or stores in $\vec{E}$ and $\vec{B}$. e.g R_1, R_2, R_3

* **Parameters** - Various elements of electric ckt.

Node : is a junction where two or more elements connecting together. e.g A, B, C, D

Junction : is a point where three or more elements connecting only B and D

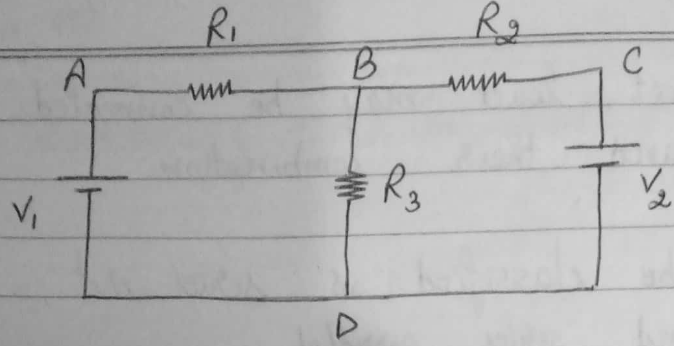
Branch : that part of a circuit which lies b/w two junction point or ~~node~~.

BCD, BD, ABD

Loop : any closed path of circuit.

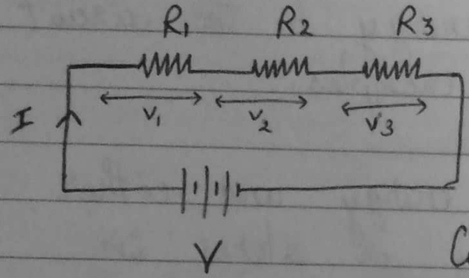
Mesh : Elementary form of loop and can not be further divided but loop in a loop is not a mesh.

Junction |→ Major Node



DC Circuit & its Terminology :

DC Circuits Types →



① Series Circuit - The circuit in which resistances are connected end to end so that there is only one path for current to flow is called a series circuit.

Consider three resistance R_1, R_2, R_3 connect in series across a battery of V volts and there is only one path for current (I) is same throughout the circuit.

By using Ohm's Law, the voltage drops across R_1 is V_1, across R_2 is V_2 and across R_3 is V_3.

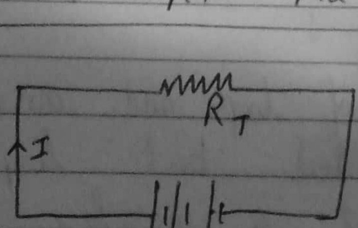
So

$$V_1 = IR_1$$
$$V_2 = IR_2$$
$$V_3 = IR_3$$

For a Series Circuit, Sum of voltage drop is equals to applied voltage

$$V = V_1 + V_2 + V_3$$
$$V = IR_1 + IR_2 + IR_3$$
$$V = I(R_1 + R_2 + R_3)$$
$$\frac{V}{I} = R_1 + R_2 + R_3$$

$$\therefore \boxed{R_T = R_1 + R_2 + R_3}$$



Hence when no. of resistances are connected in series then total R is the sum of individual resistances.

Following Points : • Current flowing through each ~~a~~ resistance is same.

• The applied voltage is equals to sum of the voltage drop differently.

• The total path consumed in the circuit is equal to sum of path consumed by individual resistances.

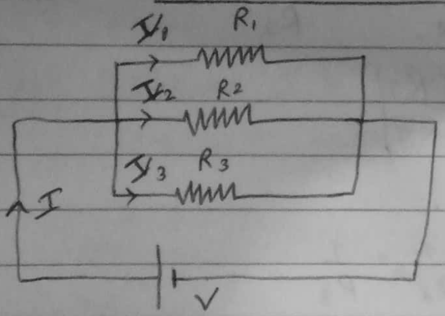
• Each resistance has its own ~~resist~~ voltage drop.

Voltage Divide Rule →

$$I = \frac{V}{R_T} \quad \text{[Total one]}$$

$$V_1 = IR_1 = \frac{VR_1}{R_T} \qquad V_2 = \frac{VR_2}{R_T} \qquad V_3 = \frac{VR_3}{R_T}$$

② Parallel Circuit - The circuit in which one end of each resistance is joined to a common point and other end of each resistance is joined to another common point so there are as many paths for current flow as no. of resistances is called parallel circuit.



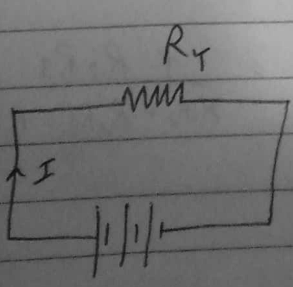
The current flowing through R_1 is I_1, across R_2 is I_2 . . . .

So $I_1 = \frac{V}{R_1}$ $\qquad I_2 = \frac{V}{R_2}$ $\qquad I_3 = \frac{V}{R_3}$

For a parallel circuit sum of branch current is equal to total current.

$$I = I_1 + I_2 + I_3$$

$$= \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$



$$= V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

$$\frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

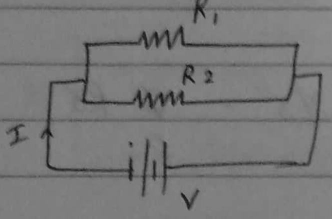
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Imp

Following Points :

- Voltage is same across the circuit.
- Total Current is equals to the sum of the individual currents.
- The total path consumed in the circuit is equal to the sum of path consumed by individual resistances.
- Each resistance has its own current.

Current Divide Rule -



$$V = IR_T \quad [\text{for total}]$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

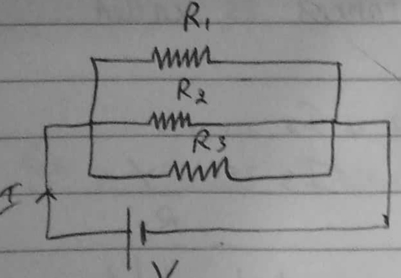
$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

$$I_1 = \frac{V}{R_1} = \frac{IR_T}{R_1} \qquad I_2 = \frac{V}{R_2} = \frac{IR_T}{R_2}$$

Put value of R_T to solve

$$\cancel{I_3 = \frac{V}{R_3} = \frac{IR_T}{R_3}}$$

Current Divide Rule for three resistances.



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{R_2R_3 + R_1R_3 + R_1R_2}{R_1R_2R_3}$$

$$V = IR_T$$

$$R_T = \frac{R_1R_2R_3}{R_2R_3 + R_1R_3 + R_1R_2}$$

$$I_1 = \frac{V}{R_1} = \frac{IR_T}{R_1} = \frac{I}{R_1}\left[\frac{R_1R_2R_3}{R_2R_3 + R_1R_3 + R_1R_2}\right] = \frac{I R_2R_3}{R_1R_2 + R_2R_3 + R_1R_3}$$

$$I_2 = \frac{V}{R_2} = \frac{IR_T}{R_2} = \frac{I R_1R_3}{R_1R_2 + R_2R_3 + R_1R_3}$$

$$I_3 = \frac{V}{R_3} = \frac{IR_T}{R_3} = \frac{I R_1R_2}{R_1R_2 + R_2R_3 + R_1R_3}$$

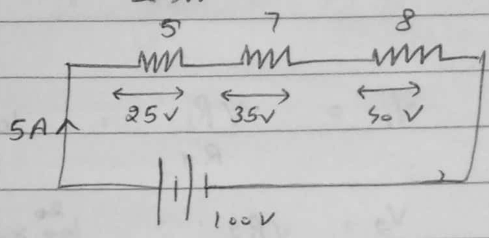
Numericals :

Que : Determine current through and voltage in each resistance load 5, 7, 8 Ω are connected in Series across a 100 V Source.

$R_T = 5 + 7 + 8 = 20\ \Omega$

$V = I R_T$

$I = \dfrac{V}{R_T} = \dfrac{100}{20} = 5\ A$

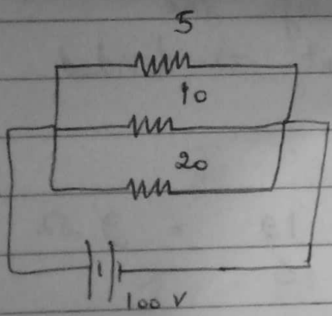


$V_1 = \dfrac{\cancel{I}\, V R_1}{R_T} = \dfrac{100 \times \cancel{5}}{20\ 4} = 25\ V$

$V_2 = \dfrac{V R_2}{R_T} = \dfrac{100 \times 7}{20} = 35\ V$

$V_3 = \dfrac{V R_3}{R_T} = \dfrac{100 \times 8}{20} = 40\ V$

Que : Determine I & voltage through 3 resistance of 5, 10, 20 Ω in Parallel across 100 V battery also find the current drawn and Power from source ?



$\dfrac{1}{R_T} = \dfrac{1}{5} + \dfrac{1}{10} + \dfrac{1}{20} = \dfrac{4+2+1}{20} = \dfrac{7}{20}$

$R_T = \dfrac{20}{7}\ \Omega$

$V = I R_T$

$100 = I \times \dfrac{20}{7}$

$I = \dfrac{100 \times 7}{20} = 35\ A$

$I_1 = \dfrac{35 \times 200}{50 + 200 + 100} = \dfrac{7000}{350} = 20\ A$

$I_2 = \dfrac{35 \times 100}{350} = 10\ A$

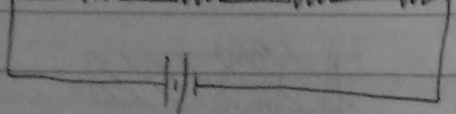
$I_3 = \dfrac{35 \times 50}{350} = 5\ A$

$P = VI$

$= 100 \times 35$

$= 3500\ W$

Que : 4 resistances of ohmic value 5Ω, 10, 15, 20 are in series across 100 V source. How voltage is divided & also find the Power ?



$R_T = 5 + 10 + 15 + 20$

$= 50\,\Omega$

$V = IR_T$

$\therefore \quad I = \frac{100}{50} = 2A$

$V_1 = \frac{VR_1}{R_T} = \frac{100 \times 5}{50} = 10\,V$

$V_2 = \frac{VR_2}{R_T} = \frac{100 \times 10}{50} = 20\,V$

$V_3 = \frac{VR_3}{R_T} = \frac{100 \times 15}{50} = 30\,V$

$V_4 = 100 - 60 = 40\,V$

$P = VI$

$= 100 \times 2$

$= 200\,W$

Que : 3 resistance 4, 12, 6 are connected in Parallel if the total current is 12 A. How is current ~~is~~ divided into the loads ?

48
12
24
144

2 | 4, 12, 6
2 | 2, 6, 3
3 | 1, 3, 1

$R_T = \frac{1}{4} + \frac{1}{12} + \frac{1}{6} = \frac{3+1+2}{12} = \frac{12}{6} = 2\,\Omega$

$V = IR_T = 12 \times 2 = 24\,V$

$\therefore \quad I_1 = \frac{IR_2R_3}{R_1R_2 + R_2R_3 + R_3R_1} = \frac{12 \times 12 \times 6}{144} = 6A$

$I_2 = \frac{12 \times 4 \times 6}{144} = 2A$

$I_3 = \frac{12 \times 4 \times 12}{144} = 4A$

Que 3 resistors of 4, 12, 6 Ω with voltage of 24 V. Find Current across each ?

$$\frac{1}{R_T} = \frac{1}{4} + \frac{1}{12} + \frac{1}{6} = \frac{3+1+2}{12}$$

$$R_T = 2\,\Omega \qquad V = 24\,V$$

$$V = I R_T \qquad I = \frac{V}{R_T} = \frac{24}{2} = 12\,A$$

$$I_1 = \frac{V}{R_1} = \frac{24}{4} = 6\,A$$

$$I_2 = \frac{V}{R_2} = \frac{24}{12} = 2\,A$$

$$I_3 = \frac{V}{R_3} = \frac{24}{6} = 4\,A$$

Que 2 resistors R_1, R_2 connected in Parallel to a certain supply the current taken from supply $I = 5A$. Calculate the value of R_1 if $R_2 = 6\,\Omega$ and current through R_1 is 2A. Also find the total ~~path~~ Power absorbed by the Circuit ?

$$I_T = 5A \qquad I_1 = 2A \qquad I_2 = 3A$$

$$I_1 = \frac{V}{R_1} \qquad \therefore$$

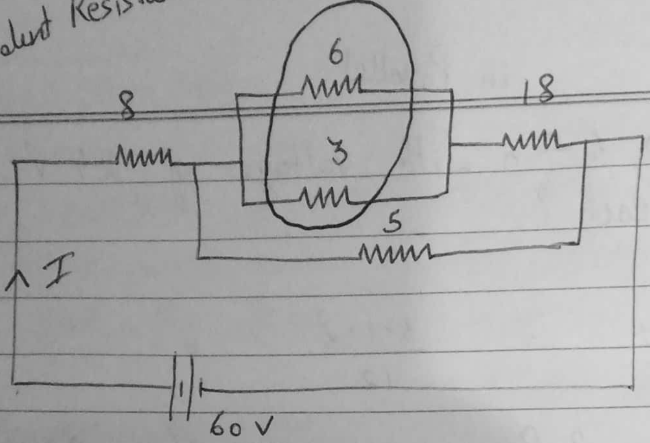
$$I_2 = \frac{V}{R_2} \qquad V = I_2 R_2 = 3(6) = 18\,V$$

$$\therefore \quad R_1 = \frac{V}{I_1} = \frac{18}{2} = 9\,\Omega$$

$$\text{Power} = VI = 5 \times 18 = 90\,W$$

Find equivalent Resistance ?

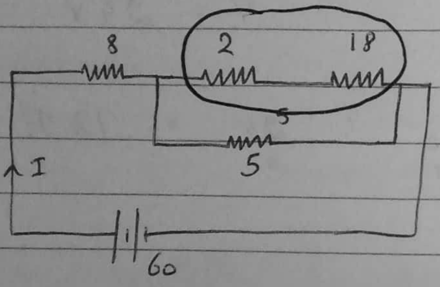
Que



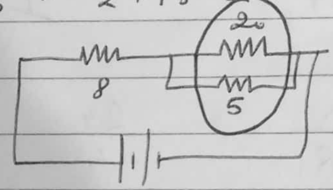
$$\frac{1}{R_p} = \frac{1}{6} + \frac{1}{3}$$

$$= \frac{1+2}{6}$$

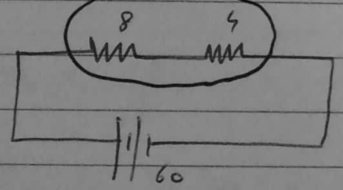
$$R_p = 6/3 = 2$$



$$R_s = 2 + 18 = 20$$



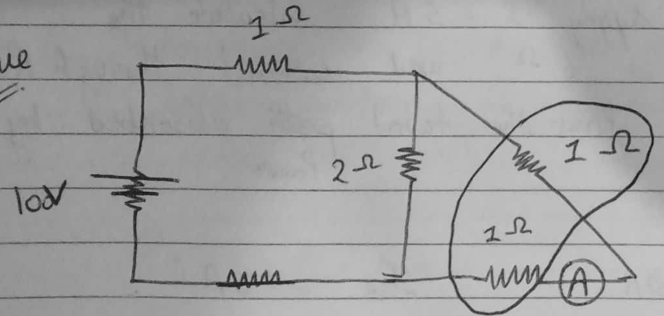
$$R_p = \frac{1}{20} + \frac{1}{5} = \frac{1+4}{20} = \frac{20}{5} = 4$$



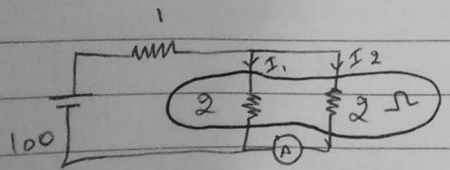
$$R_T = 8 + 4 = 12\,\Omega$$

$$I_T = \frac{V}{R} = \frac{60}{12} = 5A$$

Que



Find current through ampere ?



$$R_s = 1 + 1 = 2\,\Omega$$

$$R_p = \frac{1}{2} + \frac{1}{2} = 1\,\Omega$$

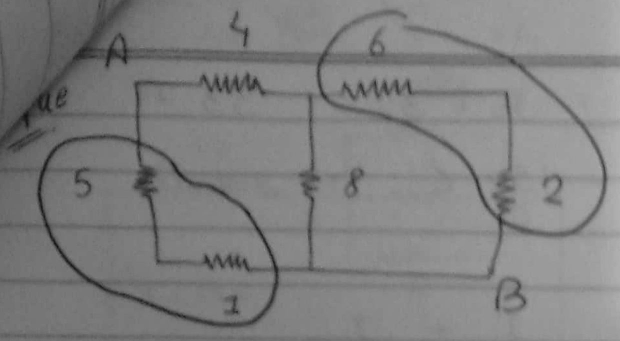
$$R_T = 1 + 1 = 2\,\Omega$$

$$I = \frac{V}{R_T} = \frac{100}{2} = 50A$$

$$I_2 = \frac{I R_1}{R_T} = \frac{50 \times 2}{2}$$

$$I_2 = 50\,A$$

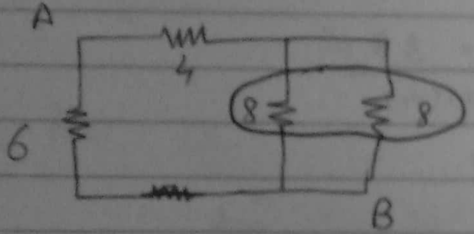
Que

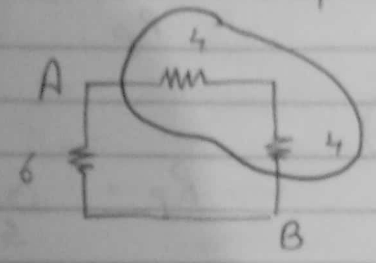


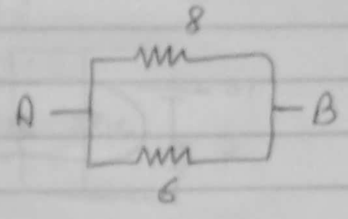
$R_s = 6 + 2 = 8\,\Omega$

$\frac{1}{R_p} = \frac{1}{8} + \frac{1}{8} = \frac{2}{8}$

$R_p = 4\,\Omega$



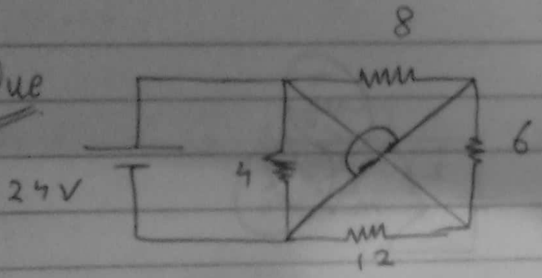




$\frac{1}{R_p} = \frac{1}{8} + \frac{1}{6} = \frac{6+8}{48} = \frac{48}{14}$

$R_p = 3.42\,\Omega$

Que



- ~~Due yo~~
- Due to the diagonal wire, the all four become parallel combination

$\therefore \frac{1}{R_p} = \frac{1}{8} + \frac{1}{6} + \frac{1}{4} + \frac{1}{12}$

$= \frac{3+4+6+2}{24} = \frac{20}{24}$

$= \frac{20}{24}$

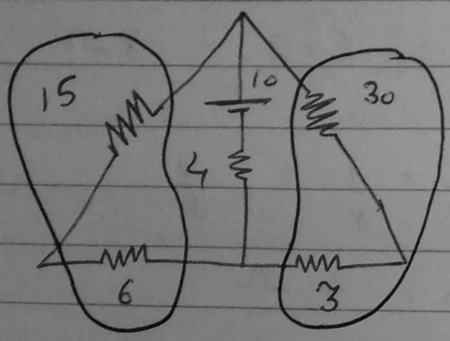
$R_p = \frac{24}{20}$

$= 1.6\,\Omega$

$V = IR_p \qquad I = \frac{V}{R_p}$

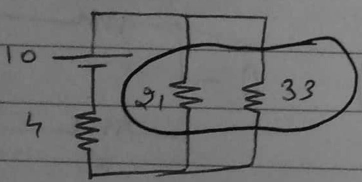
$I_T = \frac{24 \times 20}{24} = 20\,A$

Que Find the equivalent resistance of the given circuit?



$$R_p = 30 + 3 = 33\ \Omega$$

$$R_p = 15 + 6 = 21\ \Omega$$



$$\frac{1}{R_p} = \frac{1}{33} + \frac{1}{21}$$

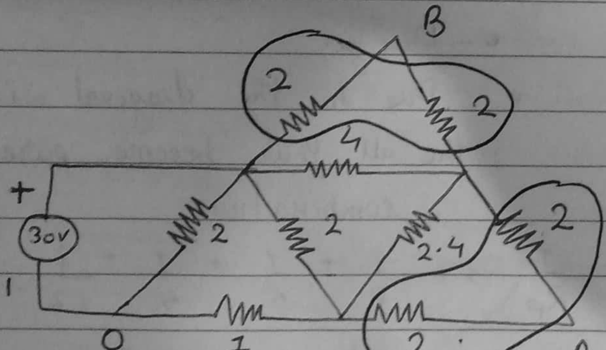
$$= \frac{21 + 33}{(33)(21)}$$

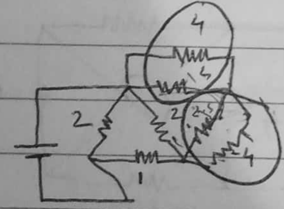
$$R_p = \frac{(33)(21)}{54}$$

$$(R_s)\ R_T = \frac{(33)(21) + 4(54)}{54} = 16.8\ \Omega$$

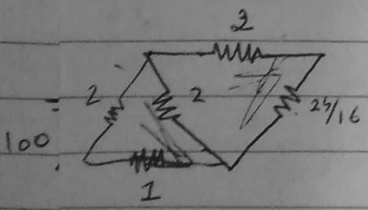
$$I = \frac{10}{16.8} = .59\ A$$

Que





$$\frac{1}{R_p} = \frac{1}{4} + \frac{1}{4} = \frac{2}{4} = 2$$

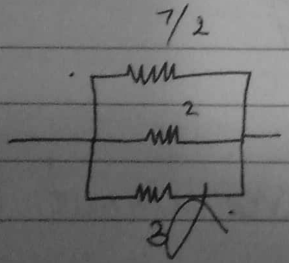


$$R_s = \frac{24}{16} + 2 = \frac{3+4}{2} = \frac{7}{2}$$

$$\frac{1}{4} + \frac{10}{24} = \frac{6+10}{24} = \frac{24}{16}$$

$$R_s = 2 + 1 = 3$$

$$R_s = 2 + \frac{24}{16} = \frac{32+24}{16} = \frac{56}{16} = \frac{7}{2}$$



$$\frac{1}{R_T} = \frac{1}{2} + \frac{1}{3} + \frac{7}{2} = \frac{3+2+21}{6}$$

$$R_T = \frac{6}{26}\ \times$$

$20 = V_1 + V_2$

$V_1 = IR_1$ $\quad V_2 = IR_2$

$= 1.5(10)$ $\quad 20 - 15 =$

$= 15$ $\quad 5 = IR_2$

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PAGE

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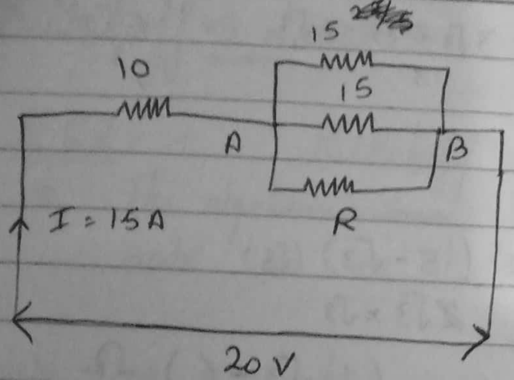


$I = 1.5\,A$

$$\frac{1}{R_T} = \frac{1}{15} + \frac{1}{15} + \frac{1}{R}$$

$$\frac{1}{R_T} = \frac{R + R + 15}{15R}$$

$$R_T = \frac{15R}{2R+15}$$

$$R_{net} = \frac{V}{I} = \frac{\cancel{200}^{40}}{\cancel{15}_{3}} = \frac{40}{3}$$

$$R_{net} = 10 + \frac{15R}{2R+15}$$

$$10 + \frac{15R}{2R+15} = \frac{40}{3}$$

$$\frac{\cancel{15}^{3} R}{2R+15} = \frac{40-30}{3} = \frac{\cancel{10}^{2}}{3}$$

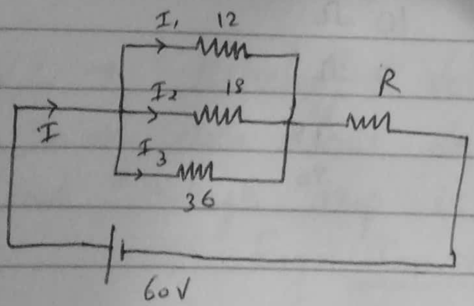
$4R + 30 = 9R$

$30 = 5R$

$\boxed{R = 6\,\Omega}$

$I_1 = \frac{V}{R_1} = \frac{\cancel{20}^{4}}{\cancel{15}_{3}}$ $\quad I_2 = \frac{\cancel{20}^{4}}{\cancel{15}_{3}}$ $\quad I_3 = \frac{\cancel{20}^{10}}{\cancel{6}_{3}}$

Que



Power Consumed through $12\,\Omega$ = 36 W

$P = I_1^2 R$

$36 = I_1^2 (12)$

$I_1^2 = 3$

$I_1 = \sqrt{3}$

In Parallel

$V = I_1 R_1$

$= \sqrt{3}\,(12)$

$= 12\sqrt{3}$

In Series

$V = V_1 + V_2$

$60 = 12\sqrt{3} + V_2$

$V_2 = 60 - 12\sqrt{3}$

$$I_2 = V/R = \frac{\cancel{12}^{2}\sqrt{3}}{\cancel{18}_{3}} = \frac{2\sqrt{3}}{3}$$

$$R = \frac{V_2}{I} = \frac{60 - 12\sqrt{3}}{\sqrt{3} + \frac{2\sqrt{3}}{3} + \frac{\sqrt{3}}{3}}$$

$$I_3 = V/R = \frac{12\sqrt{3}}{36_{3}} = \frac{\sqrt{3}}{3}$$

$$\text{Total } I = \sqrt{3} + \frac{\sqrt{3}}{3} + \frac{2\sqrt{3}}{3} = \frac{3\sqrt{3} + \sqrt{3} + 2\sqrt{3}}{3} = \frac{6\sqrt{3}}{3}$$

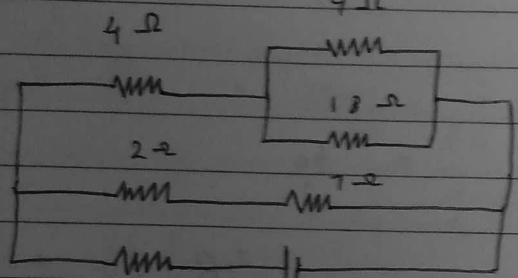
$$= 2\sqrt{3}$$

$$\therefore \quad R = \frac{60 - 12\sqrt{3}}{2\sqrt{3}} = \frac{\overset{6}{\cancel{12}}\,(5-\sqrt{3})(\sqrt{3})}{\cancel{2}\sqrt{3}\times\sqrt{3}}$$

$$= \frac{\overset{2}{\cancel{6}}\,[5\sqrt{3} - 3]}{\cancel{3}} = (10\sqrt{3} - 6)\ \Omega$$

$$= \underline{11}$$

Que



Find
(i) Current in 15
(ii) Voltage across 18
(iii) Power dissipated in 7 Ω ?

$$\frac{1}{R_p} = \frac{1}{9} + \frac{1}{18} = \frac{2+1}{18} \qquad R_p = \frac{18}{3} = 6\ \Omega$$

$$R_{S_1} = 4 + 6 = 10\ \Omega$$

$$R_{S_2} = 2 + 7 = 9\ \Omega$$

$$\frac{1}{R_p} = \frac{1}{10} + \frac{1}{9} = \frac{9+10}{90} = \frac{19}{90}$$

$$\begin{array}{r}15\\ \times 19\\ \hline 135\\ 15\end{array}$$

$$R_p = \frac{90}{19}\ \Omega$$

$$R_T = 15 + \frac{90}{19} = \frac{15(19) + 90}{19}$$

$$= \frac{285 + 90}{19} = \frac{375}{19}$$

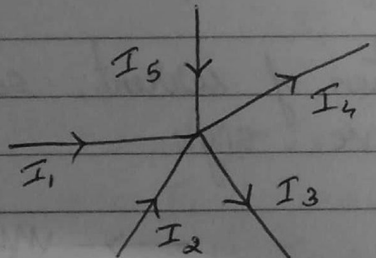
$$I = \frac{V}{R} = \frac{\overset{\overset{5}{\cancel{25}}}{\cancel{125}} \times 19}{\underset{\underset{3}{\cancel{15}}}{\cancel{\cancel{375}}_{75}}} = 6.3\ A$$

Kirchoff's Law :

* **KCL** → Kirchoff's Circuital Law [Current]

⇒ The algebric sum of current meeting at a junction or node in an electric Circuit is zero.

Consider five conductors carrying current meeting at a node A and algebric sum is 1 in which the sign of quantity is taken into account if we take sign of current towards the node is positive and when we take sign of current flowing away from node A is negative, Thus apply KCL and we get.



$$I_1 + I_2 - I_3 - I_4 + I_5 = 0$$

⇒ Sum of currents flowing towards any junction in an electric Circuit is equal to sum of currents flowing away from that junction.

* **KVL** → Kirchoff's Voltage Law

In any close circuit or mesh, the algebric sum of the electromotive force and voltage drop is equal to zero

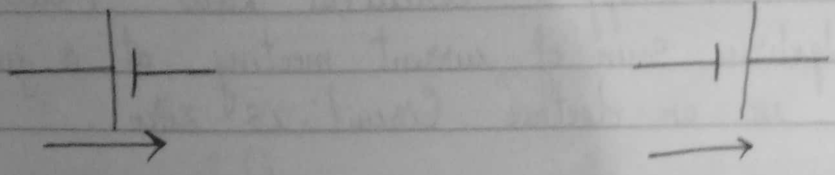
Sign Convention → Positive terminal → Rising Potential
Negative terminal → Falling Potential

- While applying KVL to a close circuit, the algebric sum are Consider therefore it is very inportant to assign proper sign to the emf and voltage drop to the circuit.

Rise in Potential is positive & fall in potential is negative

1. If we go from ~~pot~~ +ve terminal to -ve terminal of battery and there is fall in potential, so we get -ve sign.

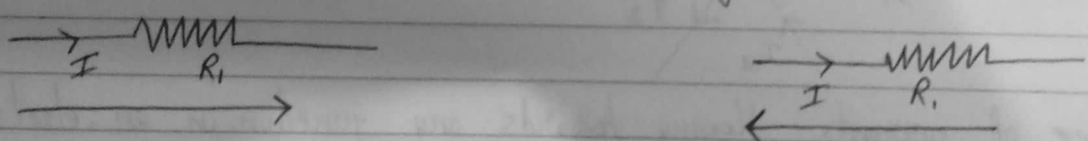
2. If we go from -ve terminal to +ve terminal of battery there is rise in potential and sign of emf is positive



Emf is -ve Emf is +ve

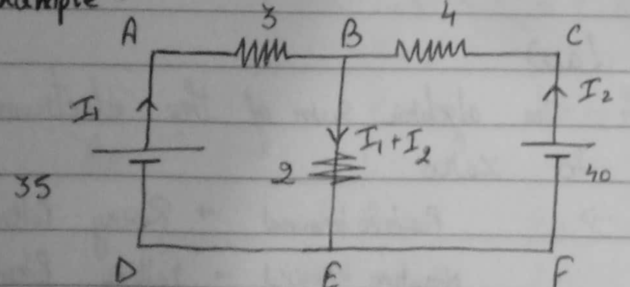
- When a current flow through resistor there is a voltage drop across it, if we go through the resistance in the same direction as the current, so there is fall in potential, the sign is negative.

If we go opposite to the direction of current, so here is rise in potential with positive sign.



Emf is $-IR_1$ Emf is $+IR_1$

Example -



Apply KVL in ABEDA

$$-3I_1 - 2(I_1+I_2) + 35 = 0$$

$$-3I_1 - 2I_1 - 2I_2 + 35 = 0$$

$$-2I_2 - 5I_1 + 35 = 0 \quad \text{—} \; 1$$

Apply KVL in CFEBC

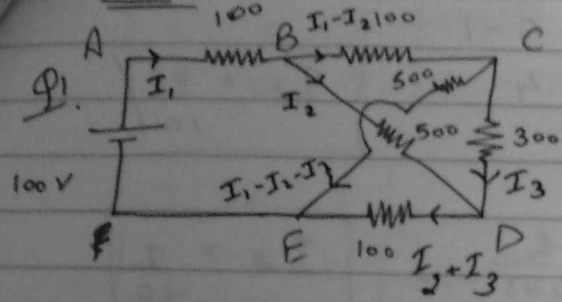
$$-40 + 2(I_1+I_2) + 4I_2 = 0$$

$$-40 + 2I_1 + 2I_2 + 4I_2 = 0$$

$$2I_1 + 6I_2 - 40 = 0 \quad \text{—} \; 2$$

Numericals :

Q1. Find current accross each branch ?



Loop ABCDEA

$$-100 I_1 - 100(I_1 - I_2) - 300 I_3 - 100(I_2 + I_3) + 100 = 0$$

$$-100 I_1 - 100 I_1 + \cancel{100 I_2} - 300 I_3 - \cancel{100 I_2} - 100 I_3 + 100 = 0$$

$$-200 I_1 - 400 I_3 = -100$$

$$2I_1 + 4I_3 = 1 \quad — ①$$

$$I_1 = \frac{1 - 4I_3}{2}$$

Loop BCDB

$$-100(I_1 - I_2) - I_3 300 + 500 I_2 = 0$$

$$-100 I_1 + 100 I_2 - 300 I_3 + 500 I_2 = 0$$

$$-100 I_1 + 600 I_2 - 300 I_3 = 0$$

$$I_1 + 3I_3 = 6 I_2 \quad — ②$$

Loop CEDC

$$-500(I_1 - I_2 - I_3) + 100(I_2 + I_3) + 300 I_3 = 0$$

$$-500 I_1 + 500 I_2 + 500 I_3 + 100 I_2 + 100 I_3 + 300 I_3 = 0$$

$$-500 I_1 + 600 I_2 + 900 I_3 = 0$$

$$6I_2 + 9I_3 = 5I_1 \quad — ③$$

Put I_1 in ②

$$\frac{1 - 4I_3}{2} + 3I_3 = 6 I_2$$

$$1 - 4I_3 + 6I_3 = 12 I_2$$

$$1 + 2I_3 = 12 I_2$$

$$\frac{1 + 2I_3}{12} = I_2$$

Put in ③

$$\frac{1 + 2I_3}{2} + 9 I_3 = \frac{5 - 20 I_3}{2}$$

$$1 + 2I_3 + 18I_3 = 5 - 20I_3$$
$$20I_3 + 20I_3 = 5 - 1$$
$$40I_3 = 4 \qquad \boxed{I_3 = \frac{1}{10}}$$

$$I_2 = \frac{1 + \frac{1}{5}}{12} = \frac{\frac{6}{5}}{\frac{12}{1}} = \frac{6}{\frac{12 \times 5}{2}} = \boxed{I_2 = \frac{1}{10}}$$

$$I_1 = \frac{1 - \frac{4}{10}}{2} = \frac{\frac{10-4}{10}}{\frac{2}{1}} = \frac{\overset{3}{\cancel{6}} \times 1}{\cancel{2} \times 10} \qquad \boxed{I_3 = \frac{3}{10}}$$

*** Apply Cramer' Rule to find value of current [Short Cut]

- Make matrix of coefficient of variables

$$\begin{vmatrix} 2 & 0 & 4 \\ 1 & -6 & 3 \\ -5 & 6 & 9 \end{vmatrix} \begin{vmatrix} I_1 \\ I_2 \\ I_3 \end{vmatrix} = \begin{vmatrix} 1 \\ 0 \\ 0 \end{vmatrix}$$

- Find determinant as Δ

$$\Delta = 2[-54 - 18] + 4[6 - 30]$$
$$= -2[72] + 4[-24]$$
$$= -240$$

- Find Δ_1 using first column interchange with the equivalent Column

$$\begin{vmatrix} 1 & 0 & 4 \\ 0 & -6 & 3 \\ 0 & 6 & 9 \end{vmatrix} \qquad \Delta_1 = -54 - 18 = -72$$

Exams, Apply Cramer's Rule for more than 3 equations...

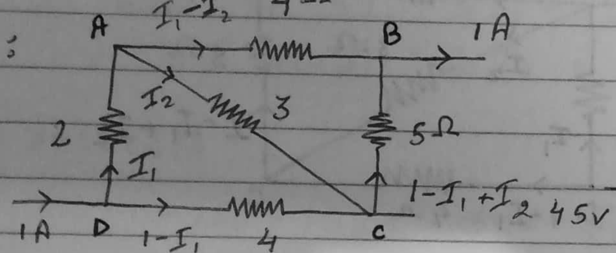
$$\begin{vmatrix} 2 & 1 & 4 \\ 1 & 0 & 3 \\ -5 & 0 & 9 \end{vmatrix} \qquad \Delta_2 = 1(9+15) = 24$$

$$\begin{vmatrix} 2 & 0 & 1 \\ 1 & -6 & 0 \\ -5 & -6 & 0 \end{vmatrix} \qquad \Delta_3 = -24 = 6-30$$

→ Then find values by $I_1 = \frac{\Delta_1}{\Delta}$ $\quad I_2 = \frac{\Delta_2}{\Delta}$ $\quad I_3 = \frac{\Delta_3}{\Delta}$

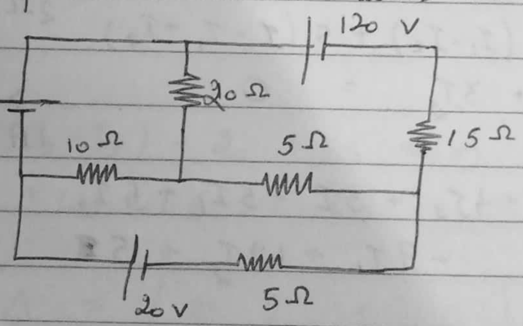
Assignment :

Q1 :

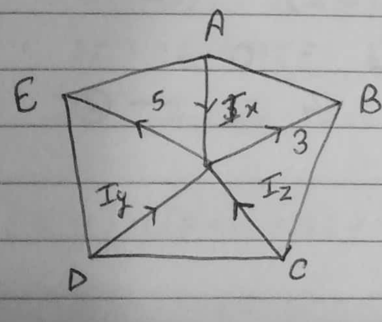


Find current in each branch ?

Q2 Find Current across 20 Ω ?



Q3.



(i) $I_x = ?$ if $I_y = 2A$ $I_3 = 0.A$

(ii) $I_z = ?$ if $I_x = 2$ $I_y = I_z$

(iii) $I_y = ?$ if $I_x = I_y$ $I_z = I_y$

Using KCL

Algebric Sum of incoming = Algebric Sum of outgoing

$$I_y + I_z + I_x = 5 + 3$$

$$I_x + I_y + I_z = 8$$

(i) $I_x + I_y + I_x = 8$

$I_x + 2 + 0 = 8$ $\qquad I_x = 6A$

(ii) $I_x + I_y + I_x = 8$

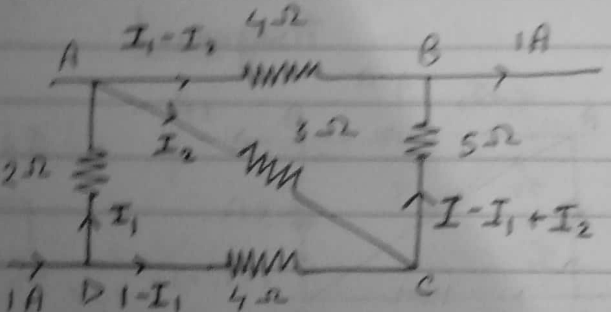
$2 + 2I_x = 8$

$2I_x = 8 - 2$ $\qquad I_x = 3A$

(iii) $I_x + I_y + I_x = 8$

$3I_y = 8$ $\qquad I_y = 8/3\ A$

Que! Loop ABCA



$-4(I_1 - I_2) + 5(I - I_1 + I_2) + 3I_2 = 0$

$-4I_1 + 4I_2 + 5I - 5I_1 + 5I_2 + 3I_2 = 0$

$-9I_1 + 12I_2 + 5I = 0$ — (1)

Loop ADCA $\qquad 2I_1 - 4(I - I_1) + 3I_2 = 0$

$2I_1 - 4 + 4I_1 + 3I_2 = 0$

$6I_1 + 3I_2 = 4$ — (2)

$\Delta = \begin{vmatrix} 9 & -12 \\ 6 & 3 \end{vmatrix} = 27 + 72 = 99$

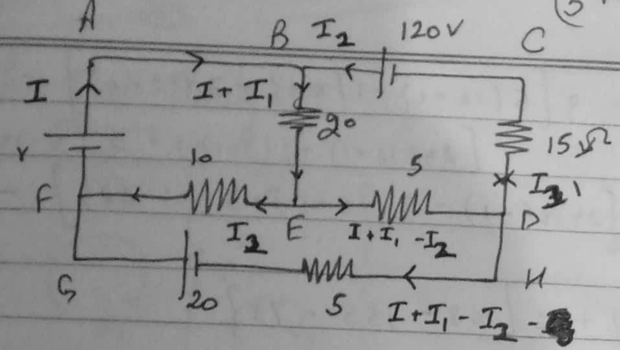
$\Delta_1 = \begin{vmatrix} 5 & -12 \\ 4 & 3 \end{vmatrix} = 15 + 48 = 63$

$\Delta_2 = \begin{vmatrix} 9 & 5 \\ 6 & 4 \end{vmatrix} = 36 - 30 = 6$

$I_1 = \frac{63}{99} = \frac{21}{33} = \frac{7}{11}$ $\qquad I_2 = \frac{6}{99} = \frac{2}{33}$

(3 Variables)

Que 2



Loop ABEFA

$$-20(I+I_1) - 10I_2 + 45 = 0$$
$$45 = 20I + 20I_1 + 10I_2 \quad — ①$$

Loop BCDEB

$$-120 + 15I_3 + 5(I+I_1-I_2) + 20(I+I_1) = 0$$
$$15I_3 + 5I + 5I_1 - 5I_2 + 20I_1 + 20I = 120$$
$$25I + 25I_1 - 5I_2 + 15I_3 = 120 \quad — ②$$

Loop FDHGF $\quad +10I_2 - 5(I+I_1-I_2) - 5(I+I_1-I_2-I_3) + 20 = 0$

$$10I_2 - 5I - 5I_1 + 5I_2 - 5I - 5I_1 + 5I_2 + 5I_3 + 20 = 0$$
$$-10I - 10I_1 + 20I_2 + 5I_3 = -20 \quad — ③$$

Loop ABCDHGFA

$$-120 + 15I_3 - 5(I+I_1-I_2-I_3) + 20 + 45 = 0$$
$$15I_3 - 5I - 5I_1 + 5I_2 + 5I_3 = 120 - 65 = 55 \quad — ⑤$$

Eq

$$9 = 2I + 2I_1 + 2I_2$$
$$24 = 5I + 5I_1 - I_2 + 3I_3$$
$$4 = 2I + 2I_1 - 4I_2 - I_3$$
$$11 = 4I_3 - I - I_1 + I_2$$

$$\Delta = \begin{vmatrix} 2 & 2 & 1 & 0 \\ 5 & 5 & -1 & 3 \\ 2 & 2 & -4 & -1 \\ -1 & -1 & 1 & 4 \end{vmatrix}$$

$$2\,|5(-16+1) + 1(8-1) + 3(2-4)| - 2\,|5(8-1) + 1(8-1) + 3(2-4)| + 1\,|5(20+3) - 5(8-1) + 3(-2+2)| + 0$$

$$\Rightarrow 2[-75 + 7 - 6] - 2[35 + 7 - 6] + [115 - 35]$$

$$2[-74] - 2[36] + [80] = -148 - 72 + 80$$
$$= -140$$

$$\Delta_1 = \begin{vmatrix} 9 & 2 & 1 & 0 \\ 24 & 5 & -1 & 3 \\ 4 & 2 & 4 & -1 \\ 11 & -1 & 1 & 4 \end{vmatrix}$$

$9[5(16+1)+1[8-1]+3(2+4)] - 2[24(16+1)+1(16+11)+3(4-44)] + [24(8-1)-5(16+11)+3(-4-22)] - 0$

$9[85+7+18] - 2[408+27-120] + 1[168-135-78]$

$990 - 630 - 45 = 315$

$$\Delta_2 = \begin{vmatrix} 2 & 9 & 1 & 0 \\ 5 & 24 & -1 & 3 \\ 2 & 4 & 4 & -1 \\ -1 & 11 & 1 & 4 \end{vmatrix}$$

$2[24(16+1)+1(16+11)+3(4-44)] - 9[$

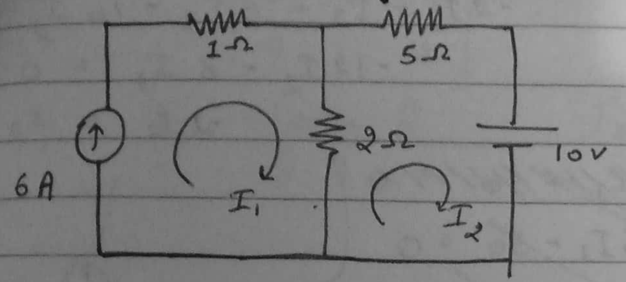
Q2.

Most Imp

① Identify Mesh

② Assign current in clockwise direc

Mesh And Analysis :



If first branch has current source then it is equal to First Current.

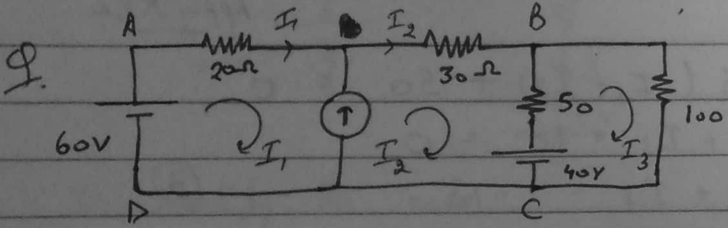
$\therefore \; I_1 = 6\,A$

Apply KVL to 2^{nd} Loop

Mesh Current ↓ Loop

$$5I_2 - 10 - 2(I_1 - I_2) = 0$$
$$5I_2 - 10 - 2I_1 + 2I_2 = 0$$
$$7I_2 = 22 \qquad I_2 = \frac{22}{7} = 3.1\,A$$

Q.



If here is current source then first solve current source.

Form a ~~mesh~~ Super mesh which proves that the current Source in in 2^{nd}.

Super Mesh : ABCDA

$$-20I_1 - 30I_2 - 50(I_2 - I_3) - 40 + 60 = 0 \qquad — ②$$
$$20I_1 + 80I_2 - 50I_3 = -20$$

Current source eq $I_2 - I_1 = 1$ — ① (Simple Mesh)

Loop 3.
$$-100I_3 + 40 - 50(I_3 + I_3) = 0$$
$$40 = 150I_3 + 50I_2 \qquad — ③$$

$I_2 = 1 + I_1$

$$40 = 150I_3 + 50 + 50I_1$$

$(150I_3 + 50I_1 = -10) \times 2$

$-50I_3 + 100I_1 = -100$

$$20I_1 + 80 + 80I_1 - 50I_3 = -20$$

$300I_3 + 100I_1 = -20$

$-50I_3 + 100I_1 = -100$

$350I_3 = 80$

$$I_3 = \frac{8}{35}\,A$$

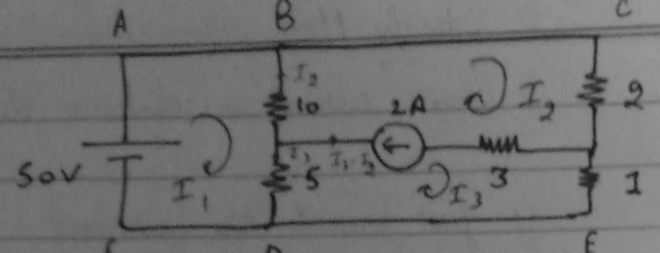
$$150\left(\frac{8}{35}\right) + 20 = -50I_1$$

$$\frac{240 + 140}{7} = \frac{380}{7 \times 50} = -I_1$$

$$I_1 = -\frac{38}{35}\,A$$

$$I_2 = -\frac{3}{35}\,A$$

Q



Super Mesh BCE

$-2I_2 - I_3 - 5I_3 - 10I_2$

$-12I_2 - 6I_3 = 0$

$-2I_2 = I_3$

~~Mesh ABDEA~~

~~Mesh ABDEA $\quad +10I_2 + 5I_3 + 50 = 0$~~

~~$10I_2 + 5I_3 = -50$~~

~~$10I_2 + 5(-2I_2) = -50$~~

~~$10I_2 - 10I_2 = -50$~~

(1)

~~Mesh $\quad +3(I_3 - I_2) - I_3 - 5I_3 = 0$~~

~~$3I_3 - 3I_2$~~

Apply KVL

Mesh ABDFA $\quad 10(I_1 + I_2) + 5(I_1 + I_3) + 50 = 0$

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

$3I_1 + 2I_2 + I_3 = -10 \quad$ — (3)

Eq^n of Current Source $\quad I_2 - I_3 = 2 \quad$ — (2)

$-2I_2 - 3I_3 - 5(I_3 + I_1)$

$$\Delta = \begin{vmatrix} 0 & -2 & -1 \\ 3 & 2 & 1 \\ 0 & 1 & -1 \end{vmatrix} \qquad 3[2+1] = 3 \times 3 = 9$$

$$\Delta_1 = \begin{vmatrix} 0 & -2 & -1 \\ -10 & 2 & 1 \\ 2 & 1 & -1 \end{vmatrix} \qquad 2[10-2] - 1[-10-4] = 16 + 14 = 30$$

$$\Delta_2 = \begin{vmatrix} 0 & 0 & -1 \\ 3 & -10 & 1 \\ 0 & 2 & -1 \end{vmatrix} \qquad 3[2] = 6$$

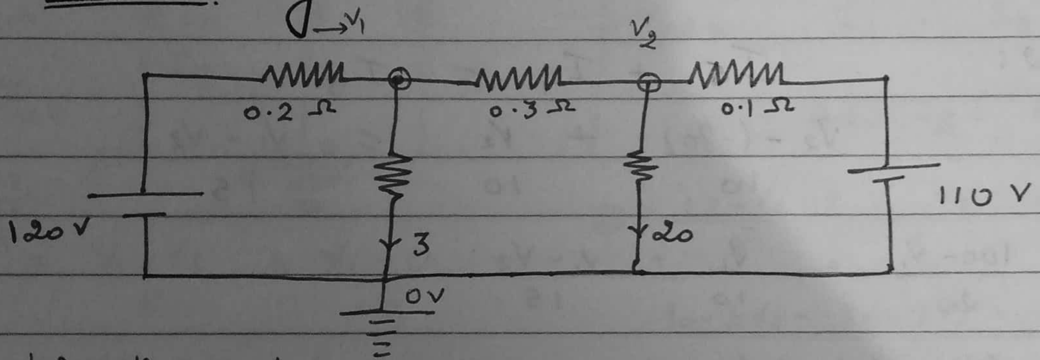
Mesh → KVL

Nodal → KCL

$$\Delta_3 = \begin{vmatrix} 0 & -2 & 0 \\ 3 & 2 & -10 \\ 0 & 1 & 2 \end{vmatrix} \quad -3\,[-4] = 12$$

$\therefore \quad I_1 = \frac{103}{38} A \qquad I_2 = \frac{2}{3} A \qquad I_3 = \frac{4}{3} A$

Imp. Nodal Analysis :

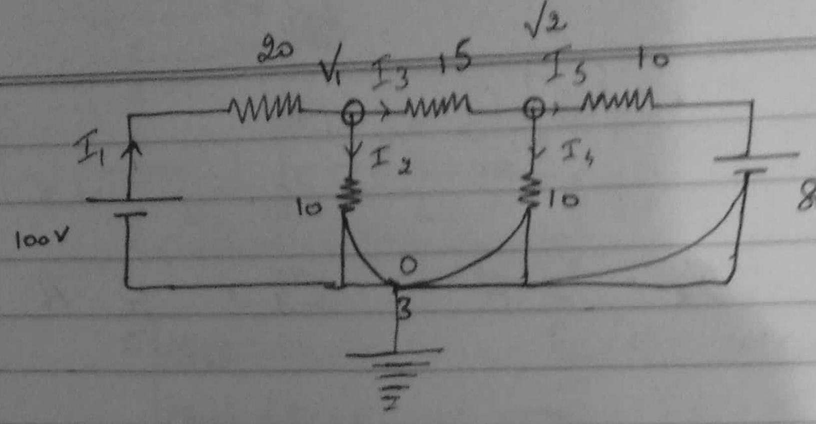


1. Identify the node.
2. Apply KCL in each and every node.
3. Select node as Reference node and give it as 0 V attached with ground potential.
4. Apply KCL
5. Voltage at node, we have to find.

STEPS : • Mark all the nodes. • Select one of the node as Reference Node. • Assign the unknown potential (find) of all the nodes with respect to the reference node.

- At each node, assume the unknown current and mark the direction. Apply KCL at each node and the equation in terms of node voltage by solving the equation determining the node voltage.

$I_1 = I_2 + 3$



$I = V/R$

2 Poten

At Node 1 :

$$I_1 = I_2 + I_3$$

$$\frac{100 - V_1}{20} = \frac{(V_1 - 0)}{10} + \frac{V_1 - V_2}{15}$$

At Node 2 :

$$I_5 + I_4 = I_3$$

$$\frac{V_2 - (-80)}{10} + \frac{V_2}{10} = \frac{V_1 - V_2}{15}$$

Now Solve :

$$\frac{100 - V_1}{20} = \frac{V_1}{10} + \frac{V_1 - V_2}{15}$$

$$\frac{300 - 3V_1 = 6V_1 + 4V_1 - 4V_2}{\cancel{60}}$$

$$13V_1 - 4V_2 = 300 \quad - (1)$$

$$\frac{V_2 + 80}{10} + \frac{V_2}{10} = \frac{V_1 - V_2}{15}$$

$$\frac{3V_2 + 240 + 3V_2 = 2V_1 - 2V_2}{\cancel{30}}$$

$$2V_1 - 8V_2 = 240 \quad - (2)$$

$$\frac{-300 + 13V_1}{4} = V_2$$

Put in (2)

$$2V_1 - \overset{2}{\cancel{8}}\left[\frac{13V_1 - 300}{\cancel{4}}\right] = 240$$

$$2V_1 - 26V_1 + 600 = 240$$

$$-24V_1 = -600 + 240$$

$$V_1 = \frac{360}{24}$$

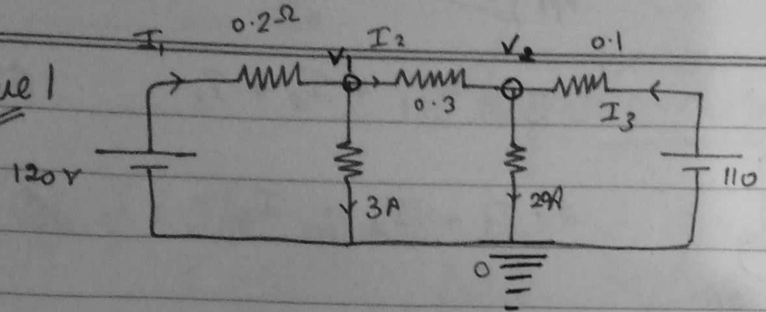
$$V_1 = 15\ V$$

$$\frac{-300 + 13(15)}{4} = V_2$$

$$\frac{-300 + 195}{4} = -\frac{105}{4}\ V_2$$

$$V_2 = \frac{105}{4}\ V$$

Que 1



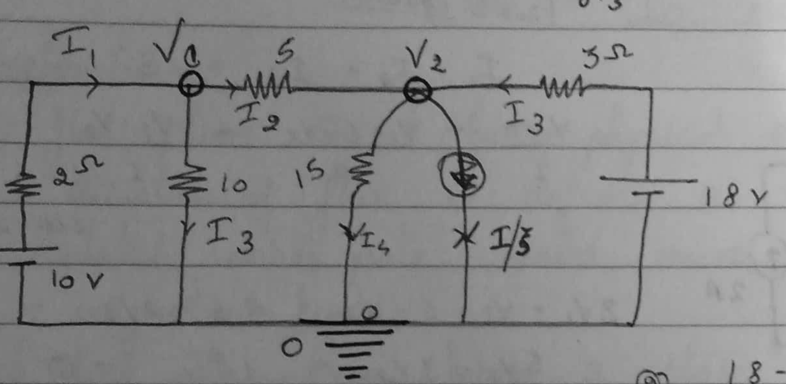
$$I_1 = I_2 + 3$$

$$\frac{120 - V_1}{0.2} = \frac{V_1 - 0}{0.3} + 3$$

$$I_2 + I_3 = 20$$

$$\frac{V_1 - V_2}{0.3} + \frac{110 - V_2}{0.1} = 20$$

Q2



$$I_1 = I_2 + I_3$$

$$I_3 + I_2 = I_4 + \frac{1}{3}$$

①

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

$$\frac{50 - 5V_1 = 2V_1 - 2V_2 + V_1}{\cancel{10}}$$

$$8V_1 - 2V_2 = 50$$

$$4V_1 - V_2 = 25 \quad — ①$$

$$4V_1 - 25 = V_2 \longrightarrow$$

②

$$\frac{18 - V_2}{3} + \frac{V_1 - V_2}{5} = \frac{V_2 - 0}{15} + \frac{1}{3}$$

$$\frac{90 - 5V_2 + 3V_1 - 3V_2}{\cancel{15}} = V_2 + 5$$

$$85 = 2V_1 + 4V_2$$

$$2V_1 + 4V_2 = 85 \quad — ②$$

$$2V_1 + 4[4V_1 - 25] = 85$$

$$2V_1 + 16V_1 - 100 = 85$$

$$18V_1 = 185$$

$$\boxed{V_1 = \frac{185}{18}}$$

$$V_2 = \cancel{4}\left(\frac{185}{18}\right) - 25$$

$$= \frac{740 - 450}{18} = \frac{290}{18}$$

$$\boxed{V_2 = \frac{290}{18}}$$

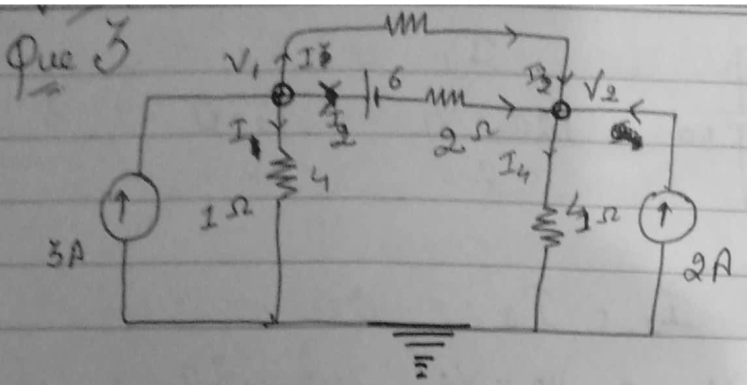
$$I_1 = \frac{10 - V_1}{2} = \frac{180 - 185}{36} = \frac{-5}{36}$$

$$I_2 = \frac{21}{18}$$

$$I_3 = \frac{V_1}{10} = \frac{185}{180}$$

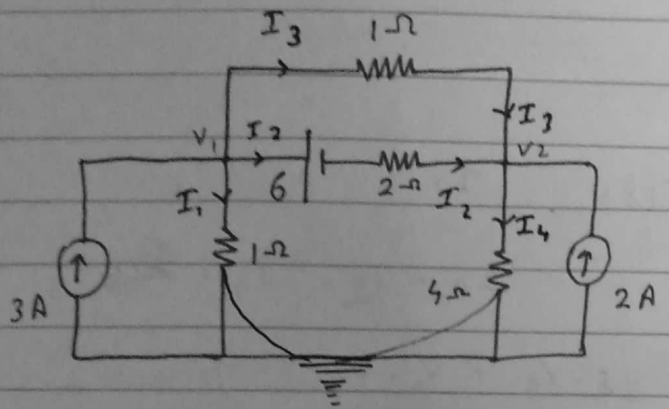
$$I_4 = \frac{V_2}{15} = \frac{\cancel{290}^{145}}{15 \times \cancel{18}^{9}} = \frac{\cancel{145}^{29}}{\cancel{135}^{27}} = \frac{29}{27}$$

Que 3



$$3 = I_1 + I_2 + I_3 \quad (1)$$

$$2 + I_3 + I_2 = I_4 \quad (2)$$



From (1) equation.

$$I_1 + I_2 + I_3 = 3$$

$$\frac{V_1 - 0}{1} + \frac{V_1 - 6 - V_2}{2} + \frac{V_1 - V_2}{1} = 3$$

LCM = 2

$$2V_1 + V_1 - 6 - V_2 + 2V_1 - 2V_2 = 6$$

$$5V_1 - 3V_2 = 12 \quad - (1)$$

From (2)

$$2 + I_3 + I_2 = I_4$$

$$2 + \frac{V_2 - V_1}{1} + \frac{V_1 - 6 - V_2}{2} = \frac{V_2 - 0}{4}$$

$$8 + 4V_2 - 4V_1 + 2V_1 - 12 - 2V_2 = V_2$$

$$-4 = 2V_1 - V_2 \quad - (2)$$

$$2V_1 + 4 = V_2$$

$$5V_1 - 3(2V_1 + 4) = 12$$

$$5V_1 - 6V_1 - 12 = 12$$

$$-V_1 = 24$$

$$\boxed{V_1 = -24}$$

$$V_2 = -48 + 4$$

$$\boxed{V_2 = -44}$$

$$I_1 = V_1 = -24 \text{ A}$$

$$I_2 = \frac{V_1 - 6 - V_2}{2} = \frac{-24 - 6 + 44}{2} = \frac{44 - 30}{2} = \frac{14}{2} = 7 \text{ A}$$

$$I_3 = V_1 - V_2 = -24 + 44 = 20 \text{ A}$$

$$I_4 = \frac{V_2}{4} = -11 \text{ A}$$

Magnetic Circuits

Flux ϕ : The magnetic lines of force produced by magnet is Called Magnetic Flux.

Its unit is Weber. or Wb

$$1\ Wb = 10^8 \text{ Magnetic Lines}$$

Characteristic -

- Magnetic flux lines do not have physical existance [With Diagram]
- The direction of flux is defined as the direction in which an isolated north pole would move if it were placed in a magnetic field.
- Each line of flux form a close loop by itself.
- The flux lines never intersect
- The line of flux closer to each other and having same direction repel each other.
- The line of flux closer to each other and having opposite direction attract each other.

Defination of Magnetic Quantity :

Flux Density → It is denoted by B and it is flux per unit area. at a right angle to the flux.

It's units are Wb/m^2 or Tesla

Magneto Motive Force → MMF is the cause for producing flux in a magnetic Circuit.

It is obtain as the product of current flowing through a coil of n-turns, its units is A.

$$MMF = NI = Amp$$

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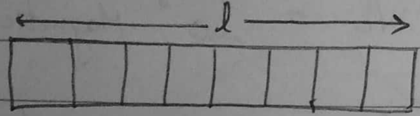
Magnetic Field Intensity → [Magnetising Force]
It is donated by H
It is defined as MMF per unit length of magnetic flux Power. It is a major of the ability of magnetising object to produce magnetic induction in another magnetic substance.



$$H = \frac{MMF}{l} = \boxed{\frac{NI}{L} = H}$$ Its Units A/m

Permeability → It is the property of magnetic medium. Flux Density $\propto$ Magnetising force which produces its

$$B \propto H$$
$$B = \mu H \qquad \mu = B/H$$

μ is Constant of Proportionality called permeability

Relative Permeability → It is defined as the ratio of flux density produced in that medium to the flux density produced in vaccum.

$$\mu_r = \frac{\mu}{\mu_0} \qquad \mu_0 = 4\pi \times 10^{-7}$$

Reluctance → It is ~~def~~ denoted by S
It is defined as ratio of MMF to the flux

$$S = \frac{MMF}{\phi} = \frac{NI}{\phi} \text{ or } S = \frac{l}{\mu_0 \mu_r a}$$ Units - A/Wb

Permience → It is the reciprocal of reluctance.

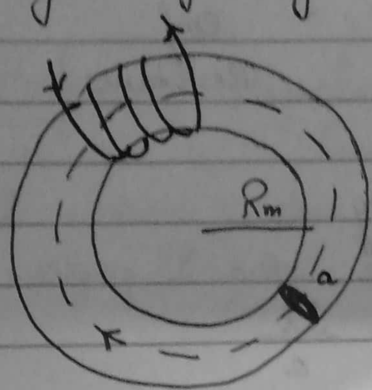
Units Wb/A

It is readiness with which magnetic flux is developed.

Magnetic Circuits

↙ Simple ↘ Composite

Analysis of Magnetic Circuit



$$MMF = NI$$

$$H = \frac{NI}{l} = \frac{NI}{2\pi R_m}$$

$$B = \mu_0 \mu_r H = \mu_0 \mu_r \frac{NI}{l}$$

We know that $B = \phi/a$

$$\phi = Ba$$

$$\phi = \mu_0 \mu_r \frac{NI}{l} a$$

Note $S = \frac{l}{\mu_0 \mu_r a}$

OR.

$$\phi = \frac{\frac{NI}{l}}{\mu_0 \mu_r a} = \frac{NI}{S}$$

$$\boxed{\phi = \frac{NI}{S}}$$

$$\text{Flux} = \frac{MMF}{\text{Reluctance}} \qquad \text{lly} \qquad \text{Current} = \frac{emf}{\text{Reluctance}}$$

$B = \frac{\phi}{a}$ $\quad H = \frac{B}{\mu_0 \mu_r}$ $\quad MMF = NI$ $\quad H = \frac{NI}{l}$

$$H = \frac{Nl - NI}{\text{Reluctance}}$$

Magnetic Circuit

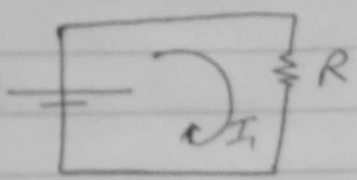
- 

- The closed path followed by magnetic flux is known as magnetic circuit
  - Flux = $\frac{MMF}{\text{Reluctance}}$
- MMF
- Reluctivity
- Reluctance

$$S = \frac{l}{\mu_0 \mu_r a}$$

- Permience = $\frac{1}{\text{Reluctance}}$
- Flux Density $B = \frac{\phi}{a}$ Wb/m^2
- Magnetising force $H = \frac{NI}{l}$ A/m
- Mag flux does not actually flow in magnetic circuit
- The reluctance of mag circuit is not constant
- In a mag circuit, the energy is req to create flux but to maintain it
- In a mag ckt, there is no insulations

Electric Circuit

- 

emf

- The closed path followed by alternating current is known as electric circuit
  - Current = $\frac{emf}{\text{Resistance}}$
- emf
- Resistivity
- Resistance

$$R = \frac{\rho l}{a}$$

- Conductance = $\frac{1}{\text{Resistance}}$
- Current density $J = \frac{I}{a}$ A/m^2
- Electric field intensity = $\frac{V}{d}$ Volt/m ($d \rightarrow$ distance)
- Electric current actually flows in electric circuit
- The resistance of electric circuit is Const
- In an electric ckt, the energy is required as long as the current flowing through the circuit
- These are many insulators.

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Magnetic Circuit The closed path followed by magnetic flux.

Magnetic flux follows the complete loop or a circuit coming back to its starting point.

They are classified into 2 types
① Simple ② Composite

Simple which is made up of single magnetic materials.

Composite have 2 different specimen offering different magnetic properties. Both of them may be magnetic or one of them is non-magnetic.

Analysis of Magnetic Circuit - circular
Consider a ~~solid~~ circular solenoid having a magnetic path of l-meters, area of cross section $A\ m^2$ and coils of current carrying I current with N loops.

(Done notes in previous page)

[Assignment Tutorial 2 Q 8, 9] are v.v.v.v. Imp

Electromagnetic Induction : The link between electricity and magnetism was discovered by Orested in 1824. Later in 1831, Faraday discovered that magnetic field can create an electric current in a conductor. When the magnetic flux linking a conductor changes and emf is induced in a conductor. This phenomenon is known as Electromagnetic Induction.

Magnetic effect of electric Current: When electric current flows through a conductor, magnetic field is set up along conductors length, The magnetic lines of forces are in the form of concentric circles, around the conductor. The direction of of lines of forces depends upon direction of current. It can be determined by using 2 rules.

Rule 1 Right Hand Gripping Rule

Hold the conductor in the right hand with outstreched thumb pointing in the direction of I. Then the other finger point in the direction of magnetic field around the conductor.

Rule 2 Right Hand Cork screw Rule

The direction of magnetic field is in the direction of rotation of a rotation of right hand cork screw turned as to advance along the wire in the current direction.

⇒ The following facts can be noted about the magnetic effect of electric currents:

1. Greater the current through the conductor, stronger the magnetic field.
2. Magnetic field is stronger near the conductor and becomes weaker when we now away from the conductor.
3. The shape of conductor determine pattern of magnetic field
4. When two conductors carrying the same amount of current in opposition directions are kept side by side then there is no magnetic effect.
5. When two conductors carrying same I in same direction are kept side by side then the magnetic effect product is twice the effect caused due to one such conductor.

Current Carrying Conductors in magnetic field

Consider a current carrying conductor or placed at right angle to the magnetic field.

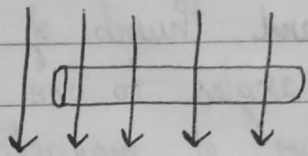


Fig 1

Let I be current through the conductor in Amperes. and it is the effective length of the conductor in meters. B is the flux density of magnetic field (wb/m).

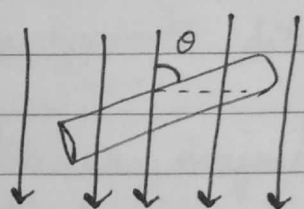


Fig 2

By the law of interaction, the conductor experiences the force which is ⊥ to both field and current.
The force, F acting on the conductor is BlI

$$F = BlI \quad \text{— ①}$$

This relation is true only when the conductor and the magnetic field are at right angles to each other. If the conductor is inclined at an angle θ to the magnetic field (Fig 2), then length of conductor will be

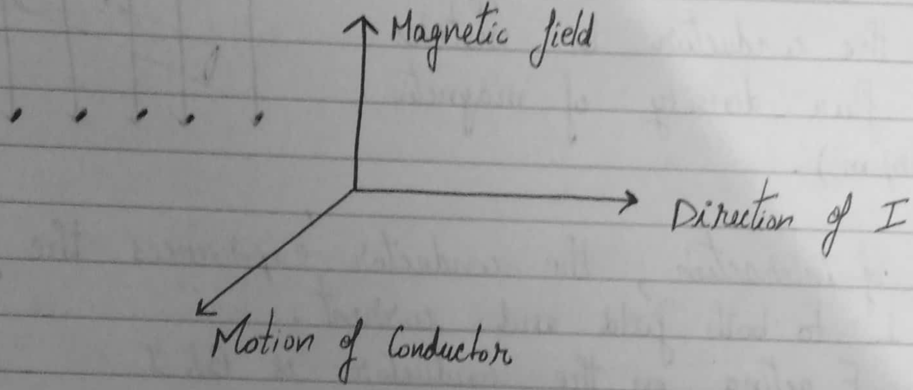
$$l = l \sin\theta \quad \text{— ②}$$

$$F = BIl \sin\theta \quad \text{— ③}$$

The direction of force can be calculated by applying flemings left hand Rule...

Flemings Left Hand Rule :

Stretch out the forefinger, middle finger and thumb of the left hand so that they are at right angles to one another. If the forefinger points in the direction of magnetic field (N → S) and the middle finger points towards the direction of current, then thumb will point in the direction of motion of conductor.

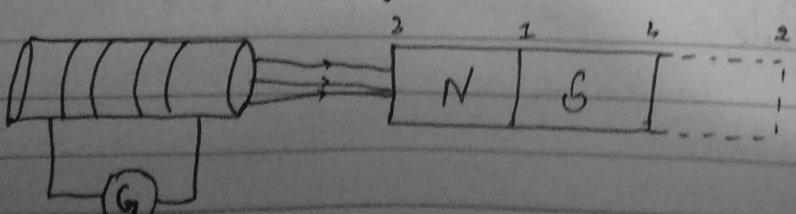


Laws of Electromagnetic Induction :

* Faraday's Law → Whenever the magnetic flux linking a circuit changes and emf is always induced in it. The magnitude of such an emf is proportional to the rate of change of flux linkages.

* Lenz Law → This law states that any induced emf will circulate a current in such a direction so as to oppose the cause producing it.

Illustration of Lenz Law :



Case 1 → When bar magnet is stationary (1, 2)
[The flux is linking] No deflection

Case 2 → When bar magnet is near coil, flux increased (3,4)
deflection takes place

Case 3 → bar marget is moved away, flux decreases and
deflection in galvanometer but in opposite direction.

It can be noted that amt. of deflection in galvanometer i.e. magnitude of induced emf depends upon the quickness of bar magnet or coils movement.
Hence, we can conclude that whenever the magnetic flux linking a conductor changes an emf is always induced in it.
And its magnitude depends on the rate of change of the flux linking with coil.

Mathematical Explanation :

N → number of turns
ϕ_1 → flux linked ~~in~~ coil Initially
ϕ_2 → Final flux linked with coil
t → time taken for creating change in flux

Initial Flux linkage = $N\phi_1$
Final Flux linkage = $N\phi_2$

Magnitude of avg (average) induced emf $E = \frac{N\phi_2 - N\phi_1}{t}$ V

$$= \frac{N(\phi_2 - \phi_1)}{t} \quad \text{—— (1)}$$

Case 1 → When bar magnet is stationary (1, 2)
[The flux is linking] No deflection

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deflection takes place

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Final Flux linkage = $N\phi_2$

Magnitude of avg (average) induced emf $E = \dfrac{N\phi_2 - N\phi_1}{t}$ V

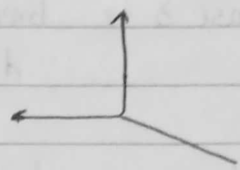
$$= \frac{N(\phi_2 - \phi_1)}{t} \quad \text{— (1)}$$

Calculating differential form of eq ① we get induced emf at any instant

$$E = \frac{N\phi_2 - N\phi_1}{t} = \frac{N(\phi_2 - \phi_1)}{t} \text{ volts}$$

Using lenz law, eq ② can be written as

$$\boxed{E = \frac{N\,d\phi}{dt} \text{ volts}}$$



Flemings Right hand Rule :

The direction of induced emf can be calculated by using flemings right hand Rule

⇒ Hold the thumb, forefinger and middle finger of the right hand at right angles to one another. If the thumb points to the direction of motion and the forefinger to the direction of magnetic field then the middle finger points towards the direction of induced emf.

Induced Emf :

Two types of emf
① Dynamically induced emf
② Statically induced emf
- Self induced emf
- mutually induced emf

* An emf is induced in a coil or conductor whenever there is change in flux linkages. It can be categorised into two ways.

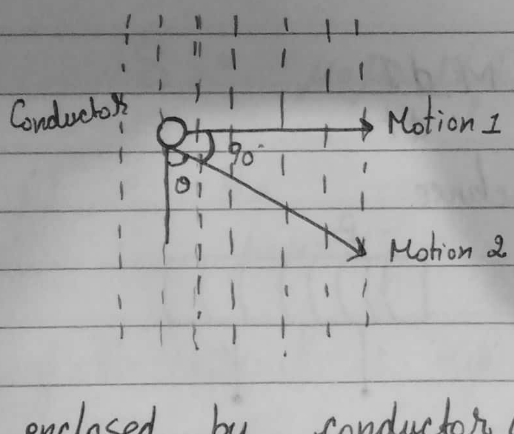
Dynamically induced emf - The Conductor is moved in stationary magnetic field such that there is a mag change in flux linkages. This kind of emf is called dynamilly induced emf.

e.g generators.

Statiscally induced emf The conductor is stationary and magnetic field is moving, this kind of induced emf is known as statiscally induced emf.
e.g transformer

Dynamically induced emf [Derivation]

Consider a stationary mag. field of flux density (B). Let the direction of mag. field is as shown in fig. In this field, a conductor is circular cross section is placed.
Let l be the effective length of the conductor. Let the conductor is moving at right angles to the field.
In time dt seconds, the distance moved is dx m



The area ~~sw~~ enclosed by conductor $a = l\,dx$ — ① and flux linked by conductor $\phi = Ba = Bl\,dx$ — ②
Acc to Faraday's law
induced emf $= E = \phi/dt = Bl\dfrac{dx}{dt}$

$\left[\dfrac{dx}{dt} = v\right]$ ∴ $\boxed{E = Blv}$ volts

Let the conductor ~~b~~ be moved with same velocity in an inclined direction making an angle θ to the direction of field then induced emf $\boxed{E = Blv\sin\theta}$

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Statistically induced emf

- Self Induced emf : The emf induced in a circuit when the mag flux linking it changes the flux produced by current in same circuit.

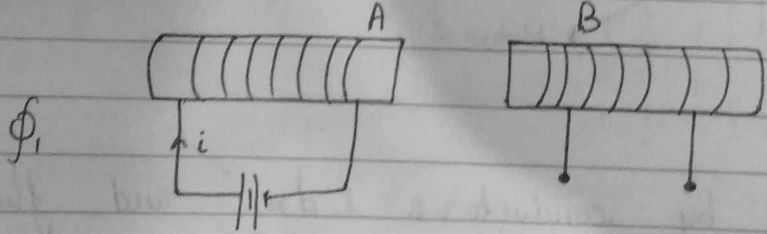
$$E = N\frac{d\phi}{dt} \quad \text{or} \quad E = L\frac{dI}{dt}$$

where L is coefficient of self inductance

- Mutually Induced emf The emf induced in one circuit due to change of flux linking it, the flux being produced by current in another circuit.

$$E_m = M\frac{dI}{dt}$$

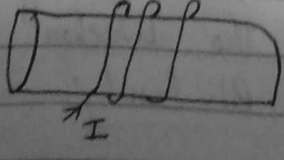
where M is mutual inductance



✯ Self Inductance:

Self inductance of a circuit is the flux linkages per unit current.

Denoted by $L = \frac{N\phi}{I}$ Henry



Equation for Self Inductance :

Consider a circuit with no. of turns in magnetising winding
I is magnetising Current , $l \rightarrow$ length of magnetic Ckt.
a is area of cross section
μr is the relative Permeability

Magnetising force (H) = $\frac{\text{Magnetomotive Force}}{\text{length}} = \frac{NI}{l}$ — ①

MMF → The magnetic pressure which setUp magnetic flux in a magnetic circuit.

Magnetic Flux Density (B) = $\mu_o \mu_r H$ — ② ∴ $\boxed{B \propto H \quad \mu = \mu_o \mu_r}$

Use eq ① in eq. ②

$$B = \mu_o \mu_r \frac{NI}{l} \text{ Tesla}$$

Magnetic flux (ϕ) = Ba $\boxed{B = \phi/a}$

$= \mu_o \mu_r \frac{NI}{l} a$ Weber

Flux linkage of the circuit is $N\phi = \mu_o \mu_r \frac{N^2 I a}{l}$

Self Inductance = $\frac{N\phi}{I} = \mu_o \mu_r N^2 \frac{a}{l}$

$$L = \frac{N^2}{S}$$

$\boxed{S = \frac{l}{\mu_o \mu_r a}}$

where
S is Reluctance → The opposition offered to magnetic flux by a magnetic circuit

★ Relationship Self Inductance & Self Induced emf :

We know that induced emf is $-N\frac{d\phi}{dt}$

and we know that self inductance is $\frac{N\phi}{I}$

$$LI = N\phi$$

For a small increament of current dI, let the increment flux is $d\phi$

$$L\,dI = N\,d\phi$$

$$L = N\frac{d\phi}{dI}$$

$$\frac{L\,dI}{dt} = \frac{N\,d\phi}{dt}$$

$$-L\frac{dI}{dt} = -N\frac{d\phi}{dt} \quad \text{—— (4)}$$

$$\therefore \boxed{e = -N\frac{d\phi}{dt}}$$

where $L = \frac{N^2}{S}$

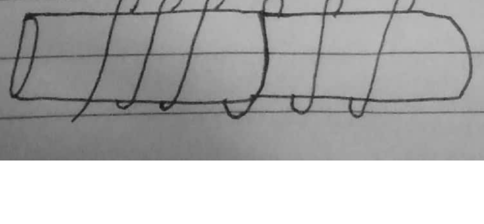
The self induced emf in a circuit is directly proportional to the rate of change of current in the same circuit.

★ Mutual Inductance :

Denoted by M

Mutual Inductance b/w 2 circuits is defined as the flux linkages in 1 ckt per unit current in the other circuit.

Units are Henry



$$M = \frac{N_2 \phi_1}{I_1} \quad \& \quad M = \frac{N_1 \phi_2}{I_2}$$

N_1 is no. of turns in Coil 1
N_2 is no. of turns in Coil 2
l is length of circuit
μ_r is relative Permeability
a : area of cross Section
I_1 : Magnetising current in Coil 1
ϕ_1 : Mag flux produced by Current

Reluctance of the magnetic circuit (S) is $\frac{l}{a\mu_0\mu_r}$

$$\phi_1 \text{ is } \frac{MMF}{S} = \frac{N_1 I_1}{S}$$

Assume that all the flux (ϕ_1) links the entire coil 2.
So flux linkage of circuit 2 $\psi_{21} = \frac{N_2 N_1 I}{S}$

$$\psi_{21} = N_2 \phi_1 \qquad \boxed{M I_1 = N_2 \phi_1}$$

$$\psi_{21} = M I_1$$

$$\boxed{M = \frac{\phi_{21}}{I_1}}$$

Relationship b/w Mutual Inductanced

Mutually induced emf in Coil 2 is $EM_2 = \frac{\phi_{21}}{t} = \frac{N_2 \phi_1}{t}$

At any instance $EM_2 = -N_2 \frac{d\phi_1}{dt}$ — ①

Mutual inductance b/w 2 circuits can be $\cancel{N_1\phi_2}$ $\frac{N_2 \phi_1}{I_1}$

$$M I_1 = N_2 \phi_1$$

$$N_2 \frac{d\phi_1}{dt} = M \frac{dI_1}{dt}$$

$$-N_2 \frac{d\phi}{dt} = -M \frac{dI_1}{dt} \quad — ②$$

From ① & ②

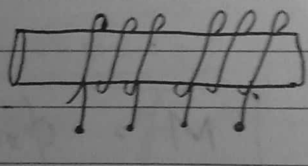
$$\boxed{EM_2 = -M \frac{dI_1}{dt}}$$

||ly

$$\boxed{EM_1 = -M \frac{dI_2}{dt}}$$

Thus the mutually induced emf in a circuit is directly proportional to the rate of change of current in another circuit.

⇒ Coupling Coefficient b/w two Magnetically circuits



I_2 → magnetising Current in I_2

ϕ_2 is flux caused by current I_2

THere will be mutual flux linkages when both the coils are energised simultaneously.

Let a fraction of flux ϕ_1 is linked in coil 2 is $K_1 \phi_1$

Flux linkages of Coil 2 $\quad \psi_{21} = N_2 K_1 \phi_1$ $\quad \boxed{\psi_{21} = N_2 \phi_1}$

~~Mutl~~ Mutual Inductance $\quad M = \frac{\psi_{21}}{I_1} = \frac{N_2 K_1 \phi_1}{I_1}$

$$= \frac{N_2 K_1}{I_1}\left(\frac{N_1 I_1}{S}\right) \qquad \phi = \frac{NI}{S}$$

$$= \frac{N_1 N_2 K_1}{S} \quad — ①$$

Let a fraction of flux ϕ_2 is $K_2 \phi_2$

flux linkage of $\psi_{12} = N_1 K_2 \phi_2$

$$M = \frac{\psi_{12}}{I_2} = \frac{N_1 K_2 \phi_2}{I_2}$$

$$= \frac{N_1 K_2}{I_2}\left(\frac{N_2 I_2}{S}\right)$$

$$= \frac{N_1 N_2 K_2}{S} \quad - ②$$

From eq ① & ②

$$M^2 \Rightarrow \boxed{(M_1 M_2) = \frac{N_1^2 N_2^2 K_1 K_2}{S^2}}$$

$$M^2 = K^2 \frac{N_1^2}{S} \cdot \frac{N_2^2}{S} \qquad | K_1 = K_2 = K$$

$$M^2 = K^2 L_1 L_2$$

$$\therefore \boxed{M = K\sqrt{L_1 L_2}}$$

where L_1 & L_2 are self inductance of coil 1 and 2.

So

$$K^2 = \frac{M^2}{L_1 L_2}$$

$$\boxed{K = \frac{M}{\sqrt{L_1 L_2}}}$$

* AC Fundamentals :

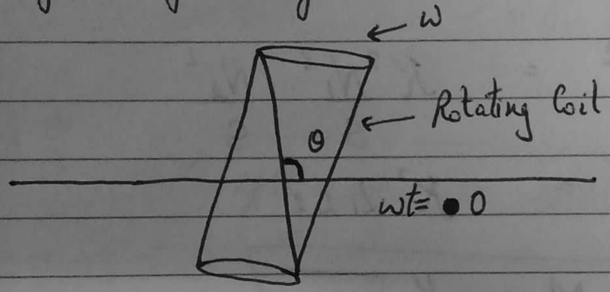
Alternating quantity is one which is having ~~===~~ varying magnitude and angle with respect to x - axis.
Since it is time varying in nature. So, we will represent it in three ways:

1. By its effective value
2. By its average value
3. By its peak value

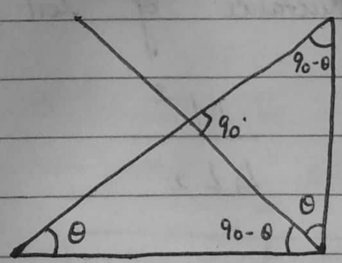
Generation of alternating emf :

Consider a coil having n turns placed in a magnetic field of ~~===~~ maximum value 'ϕ'$_m$

(a)



(b)



The coil is initially along reference axis. Here field is ϕ

When the coil is along reference axis at $wt = 0$, it is called zero emf position
Let at any instant (t) sec, the coil takes the position as shown in fig (b). Here coil makes an angle

$\theta = \omega t$ with the reference axis.

In this position, the normal component of mag flux wrt plane of coil is $\phi = \phi_m \cos\theta$

$$\theta = \omega t$$

$$\therefore \phi = \phi_m \cos\omega t$$

Flux linkage at this instant $= N\phi = N\phi_m \cos\omega t$.

The emf induced in the coil at this instant $e = -\dfrac{d\psi}{dt}$

$$e = -\frac{(N\phi_m \cos\omega t)}{dt}$$

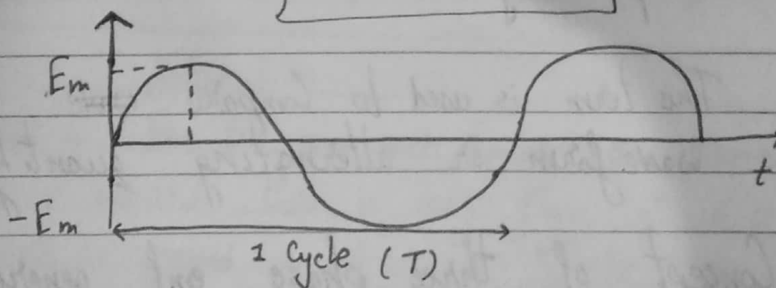
$$e = -\frac{d}{dt}(N\phi_m \cos\omega t) = \boxed{e = \omega N \phi_m \sin\omega t} \quad - (1)$$

With eq(1) we can ~~calc~~ calculation emf at any instant differently

- at $\omega t = 0$ or 180 — $e = 0$
- at $\omega t = 90$ — $e = \omega N \phi_m$ (Max)
- at $\omega t = 270$ — $e = -\omega N \phi_m$

Let $N\phi_m$ denotes the maximum value of induced emf. so we can write it as $\boxed{e = E_m \sin\omega t}$

At



Important Terms :

- Waveform → It is a graph in which instantaneous value of any quantity is plotted against time

- Alternating Waveform It reverses its direction at regularly recuring intervals.

- Periodic Waveform It repeats itself after definite time interval.

- Cycle One Complete Set of positive and negative half combine to form a cycle

- Amplitude The maximum +ve or -ve value of an alternating quantity is known as amplitude

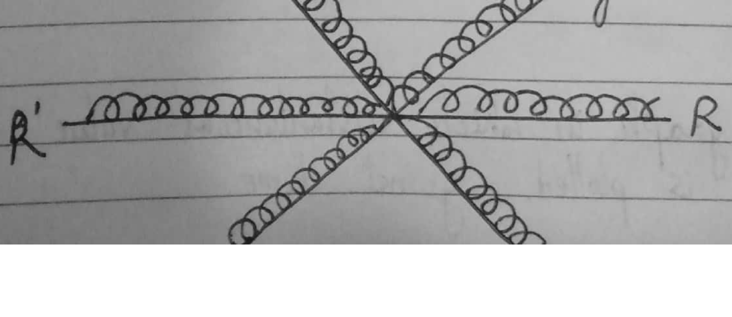
- Frequency The no. of cycles per second of an alternating quantity is known as frequency.

- Period Time period of an alternating quantity is the time taken to Complete one Cycle.

- Phase It is the time that has elapsed since the quantity has last past through 0 opoint of reference and passed positively.

- Phase Difference This term is used to Compare ~~wate~~ the phase of two wave form or alternating quantity.

⇒ Concept of <u>three phase</u> emf generation

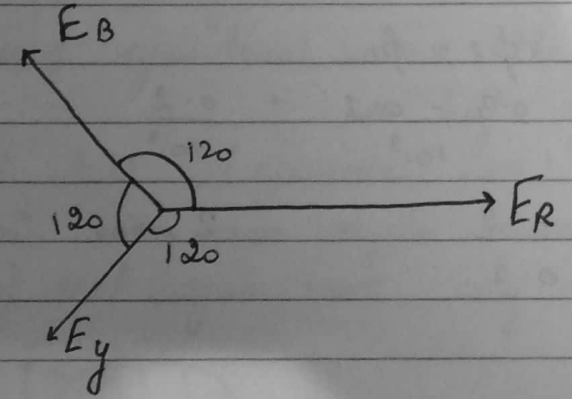


120° seperation with anticlockwise

Consider three Coils YY', RR', BB' placed in mag field of max value ϕ_m. The Coils are displaced by an angle of 120° in space b/w any two. Let all the coils rotate in anticlockwise direction with angular velocity ω

$$e_R = E_m \sin \omega t$$
$$e_y = E_m \sin(\omega t - 120^\circ)$$
$$e_B = E_m \sin(\omega t - 240^\circ)$$

Phasor Diagram



The RYB indicates that R reaches at its maximum value first Y phase follows R and B follows Y reaching R.
(RYB)
Hence, this sequence describes positive phase sequence.

Que The field coil of 4 ~~Volts~~ Poles DC gene each having 500 turns are Connec in Series. When field is excited, there is mag flux of 0.02 Wb/P if the field Circuit is opened in 0.02 s & residual magnetism is 0.002 Wb/Pole, Calculate the avg voltage which is induced across the field terminals. In which direction, is voltage directed in the dir of current.

Que 2 A

A Coil of resistance 150 Ω placed in magnetic flux of 0.1 Wb. The Coil has 500 turns and a galvanometer 450 Ω is Conn in Series with it. The Coil is moved (dt) 0.1 s from the given field to another field (ϕ_2) of 0.3 milli Wb. Find the avg induced emf & avg Current through the Coil?

R = 150 $\quad \phi_1 = 0.1 \quad N = 500$

$$emf = \frac{N\,d\phi}{dt}$$

$$d\phi = \phi_2 - \phi_1 = \frac{0.3 - 0.1}{10^3} = \frac{0.2}{10^3}$$

$$e = 500 \times \frac{0.2}{0.1} = 2 \times 500 = \frac{1000\ V}{10^3}$$

$$\boxed{e = 1V}$$

e = (1V)

$$i = \frac{V}{R} = \frac{1V}{150 + 450} = \frac{1}{600} = 0.0017A$$

* Values of alternating quantity of Current :

Peak Value - The max value attained by an alt. quantity during one cycle is called peak value or max. value or crest or amplitude.

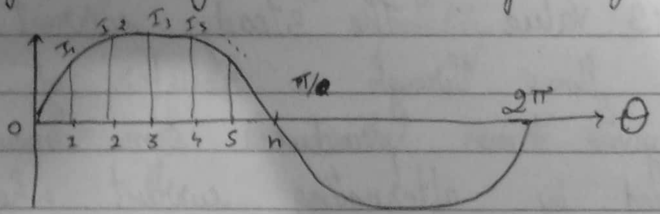
at 90° Max Value is E_m

Avg Value or Mean Value - The arithematic average of all the instantaneous value considered of an alternating quantity (i or v) over a cycle.

eg in case of symmetrical waves, the +ve half is equal to -ve half cycle.

· So net = 0 (sinosodal wave) $\int_0^{\pi}$ (1 cycle).

Therefore, avg value over one cycle is zero. So, to determine avg value of such symm wave, only half cycle is considered



Divide +ve half into n ~~terms~~ times

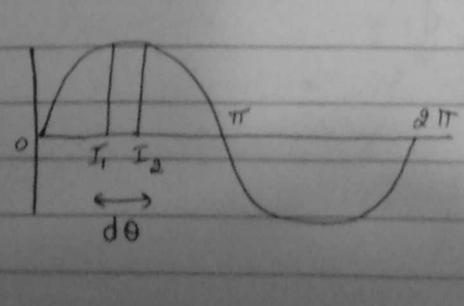
Mid Coordinates are i_1, i_2 ....

Formula

I_{av} = Mean value of ~~ind~~ mid ordinates

$$I_{av} = \frac{I_1 + I_2 + I_3 + I_5 \ldots\ldots I_n}{n}$$

$$= \frac{\text{area of alternation}}{\text{Base}}$$



$I_m \sin\theta = I$

Consider elementary strip of thickness $d\theta$ in the +ve half cycle where i is the mid ordinate then area of strip = $i\,d\theta$

Area of strip $= I\,d\theta$

Area of half cycle $= \int_0^{\pi} I\,d\theta$

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

$= -I_m \cos\theta \Big]_0^{\pi}$

$= -I_m \left[\cos\pi - \cos 0\right]$

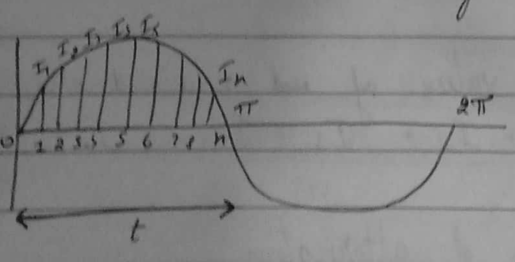
$= -I_m \left[-1 - 1\right]$

$= 2 I_m$

Base $= \pi$

Avg Value of Current $= \dfrac{2 I_m}{\pi} = 0.637\, I_m$

Effective or RMS Value : The steady current which when flows through a resistor of known resistance for given time produces same amount of heat as produced by alternating current when flows through the same current for the same time.



Let i be the alternating current flowing through resistor

$t \rightarrow$ time taken

$I_{eff} \rightarrow$ by dc

Each interval is having t/n (s) duration

Mid ordinates are $\dot{I}_1, \dot{I}_2, \dot{I}_3 \ldots\ldots I_n$

Then the heat produced $H = i^2 R t$

in 1st interval $= i_1^2 R t/n$

2nd interval $= i_2^2 R t/n$

n^{th} $= i_n^2 R t/n$

$$\text{Total heat produced} = i_1^2 R \frac{t}{n} + i_2^2 R \frac{t}{n} + \dots\dots \frac{i_n^2 R t}{n}$$

Since, Total heat produced is equal to heat produced by DC

$$\therefore \quad I_{eff}^2 R t = \text{Total heat produced}$$

Comparing both Equations

$$I_{eff}^2 = \frac{i_1^2 + i_2^2 + i_3^2 + i_5^2 \dots\dots i_n^2}{n}$$

So, I_{eff} is equal to square root of mean of squares of instantaneous values.

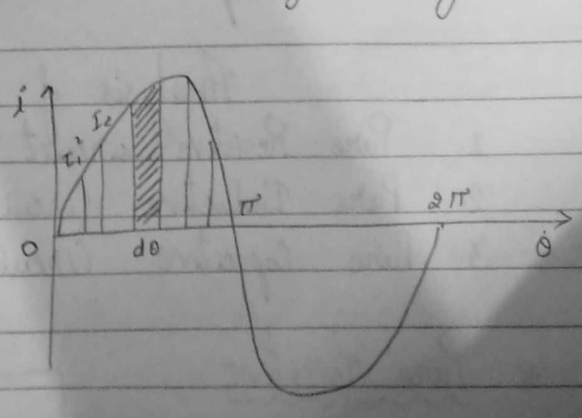
or also called Root mean square value

Note. RMS is the actual value of alternating quantity which tells the energy transfer capability of alternating ~~current~~ source

RMS value of Sinosodal wave :

To determine the RMS value, the squared wave of alternating current is drawn in which elementary strip of thickness $d\theta$ in first half cycle (i^2) is the mid ordinate

$I = I_m \sin\theta$



Area of strip $= I^2 d\theta$

$$\text{Area of +ve cycle} = \int_0^{\pi} I^2 d\theta$$

$$= \int_0^{\pi} I_m^2 \sin^2\theta \, d\theta$$

$$= I_m^2 \int_0^{\pi} \frac{1-\cos 2\theta}{2} d\theta$$

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

$$= \frac{I_m^2}{2}\left[\pi\right] = \frac{\pi I_m^2}{2}$$

Base $= \pi$

Area of First half $= \frac{\pi}{2} I_m^2$

$$I_{rms} = \sqrt{\frac{\text{Area of } 1^{st} \text{ half of sq}}{\text{Base}}} = \frac{I_m}{\sqrt{2}}$$

$$\boxed{I_{rms} = 0.707\, I_m}$$

- Form Factor - It is the ratio of RMS value to ~~actual~~ avg value of an intantaneous quantity
- Peak Factor - It is the ratio of peak value to the rms value of alternating voltage or current.

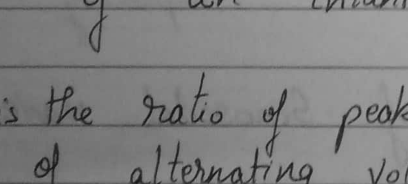
* Phasor Representation of Alternating Quantities :

Analysis of AC Circuits →

1. Pure Resistive circuit
2. Pure Inductive Circuit
3. Pure Capacitive Circuit

* Pure Resistive

i R



$V = V_m \sin \omega t$

We know that $V = V_m \sin\omega t$ — ①

& $V = iR$

$$i = \frac{V}{R} = \frac{V_m \sin\omega t}{R}$$

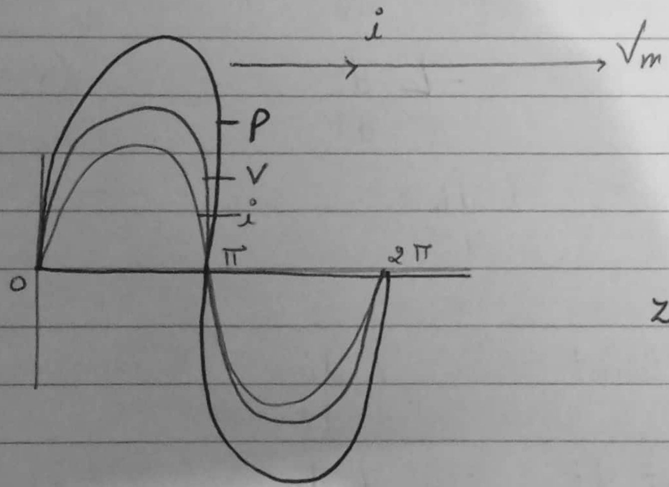
So $i = i_m \sin\omega t$ — ②

From ① & ② we find that applied voltage and resulting current are in same phase with each other.

Phasor Representation Voltage and Current are in same phase

Wave form

i v



Impedence

$$Z = \frac{\text{Total voltage}}{\text{Total Current}}$$

$$Z = \frac{V}{i} = \frac{V_m \sin\omega t}{I_m \sin\omega t}$$

$$= \frac{V_m}{I_m} = \frac{V_m}{\frac{V_m}{R}}$$

$$\boxed{Z = R}$$

Avg Power

$$P = VI$$

$$P = V_m \sin\omega t \; I_m \sin\omega t$$

$$= V_m I_m \sin^2\omega t \qquad (\omega t = \theta)$$

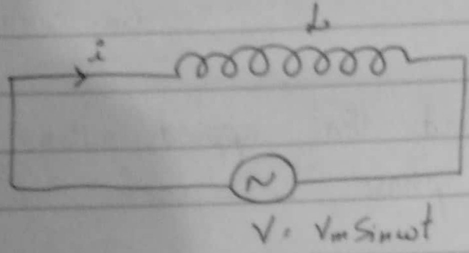
$$\text{Avg } P = \int_0^{\pi} V_m I_m \sin^2\omega t = V_m I_m \int_0^{\pi} \frac{1 - \cos 2\theta}{2}\, d\theta$$

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

Power Factor: It is the Cosine of the phase angle b/w voltage and current.

$$\cos\phi = \cos 0 = 1.$$

* Pure Inductive



We know that $V = V_m \sin\omega t$ — ①

and Self induced emf always opposes the applied voltage

$$e = -L\frac{di}{dt} \qquad (V = -e)$$

$$\therefore V = L\frac{di}{dt} \quad — ②$$

Use ① in ②

$$V_m \sin\omega t = L\frac{di}{dt}$$

$$V_m \sin\omega t \, dt = L\, di$$

$$\int di = \int \frac{V_m \sin\omega t \, dt}{L}$$

$$i = \frac{V_m}{L}\int \sin\omega t \, dt$$

$$i = \frac{V_m}{\omega L}\left[-\cos\omega t\right]$$

$X_L = \omega L$

$\therefore i_m = \frac{V_m}{X_L}$

$$i = \cancel{V_m}\; i_m \sin\left(\omega t - \frac{\pi}{2}\right) \quad — ③$$

$$Z = \frac{V_m}{I_m} = \frac{V_m}{\frac{V_m}{\omega L}} \qquad \underline{Z = \omega L}$$

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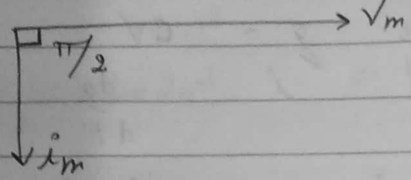
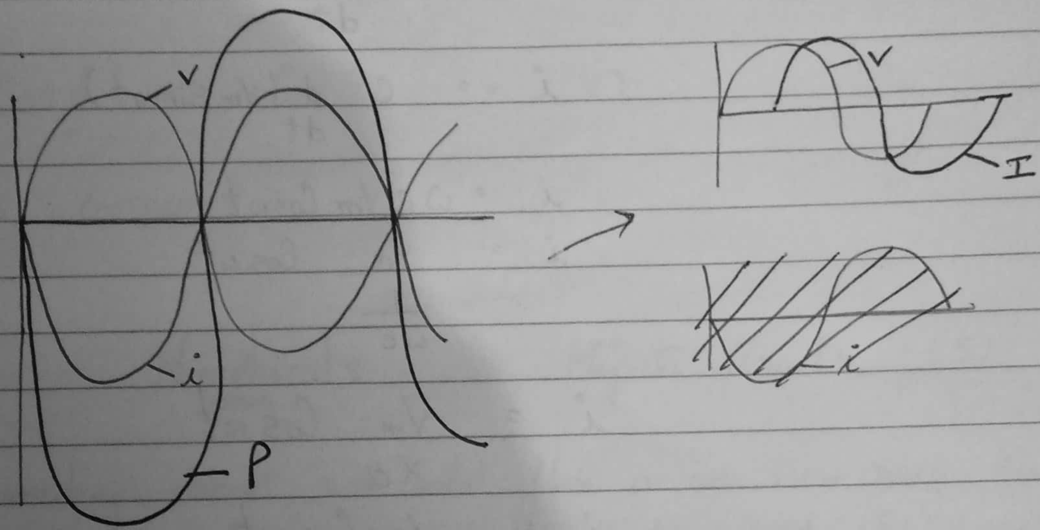
From ① & ② ③ The current through inductance lags behind the applied voltage by an angle of 90°

Phasor :



Waveform



Avg Power

$$P = VI$$

$$P = -V_m \sin\omega t \; I_m \cos\omega t$$

$$P = -\frac{V_m I_m}{2} \left(2 \sin\omega t \cos\omega t \right)$$

$$\text{Avg } P = \int_0^{\pi} -\frac{V_m I_m}{2} \, \sin 2\omega t \, dt = -\frac{V_m I_m}{2} \int_0^{\pi} \sin 2\omega t \, dt$$

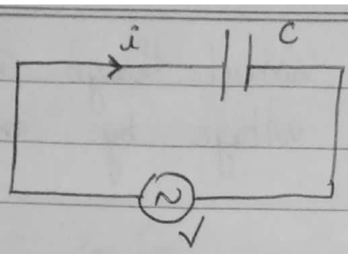
$$= -\frac{V_m I_m}{2} \left[-\frac{\cos 2\omega t}{2\omega} \right]_0^{\pi}$$

$$= -\frac{V_m I_m}{2} \left[-\cos\pi + \cos 0 \right] = 0$$

Power Factor

$$\cos\phi = \cos 90 = 0$$

* Pure Capacitive



$$V = V_m \sin\omega t \quad -(1)$$

We know

charge on Capacitor $q = CV$

Current through circuit $i = \frac{dq}{dt}$

$$\therefore \quad i = \frac{d}{dt}(CV)$$

$$i = C\frac{d}{dt}(V_m \sin\omega t)$$

$$i = \omega C V_m \cos\omega t$$

$$i = \frac{V_m}{\frac{1}{\omega C}} \cos\omega t$$

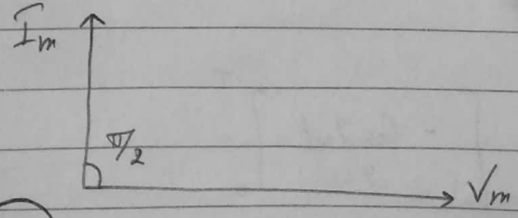
$$i = \frac{V_m}{X_C} \cos\omega t$$

$$i = i_m \cos\omega t$$

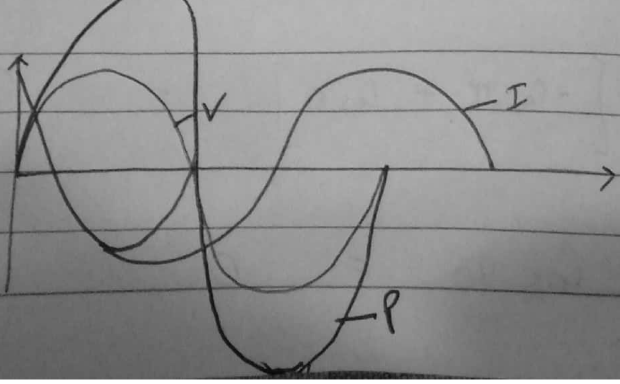
$$i = i_m \sin\left(\omega t + \frac{\pi}{2}\right) \quad -(2)$$

From (1) & (2) In a pure Capacitive circuit, ~~capacitor leads~~ current leads the applied voltage by an angle of 90°

Phasor



Waveform



Avg Power

$P = VI$

$P = V_m \sin\omega t \; I_m \sin(\omega t + \frac{\pi}{2})$

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

Avg P $= \int_0^{\pi} \frac{V_m I_m}{2} \sin 2\omega t = 0$

Power Factor

$\cos\phi = \cos 90 = 0$

No power is consumed....

Numericals : Magnetic Circuits (5)

Q1: Find the exciting current and total flux in an iron ring 10 cm in mean Diameter 10 cm² in cross Section and wound 150 turns of wire. The flux Density (B) is 0.1 Wb/m² and permeability (μ_r) is 800.

(2.083×10^3 A)

$\phi = BA = 0.1 \times (10 \times 10^{-4})^2$

$= \frac{1}{10} \times 100 \times 10^{-8} = 10^{-5}$

Total Flux $= 0.1$ mWb

$\frac{\phi L}{A \mu_0 \mu_r} = NI$ (Reluctance)

$L = \pi D$

$L = 3.14 \times 10 \times 10^{-2}$

$= 3.14 \times 10^{-1}$

$\frac{0.1 \times 3.14 \times 10^{-1}}{4\pi \times 10^{-7} \; 10 \times 10^{-4} \times 800 \times 150} = I$

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Q 2 An air core solenoid has length (l) 30 cm and D of 1.5 cm. Calculate its reluctance (S) if it has 900 (N) turns. (1350.959×10^3 A/wb)

$$S = \frac{l}{a \mu_0 \mu_r}$$

$a = \frac{\pi D^2}{4}$

$\mu_r = 1$ (Default)

$$S = \frac{30 \times 10^{-2} \times 4 \times 4\pi \times 10^{7}}{\pi \times (1.5 \times 10^{-3})^2 \times 1} = 213.33$$

×

Que 3 A Conductor 10 cm (l) long carrying current of 60 A (I) lies ⊥ to a field of strength 1000 (H). Calculate ① Force acting on the Conductor ② Mechanical Power to move this Conductor against this force against speed of 1 m/s (v) ③ Emf induced in the conductor.

$$\text{Force} = BIl = \mu_0 H I l = 4\pi \times 10^{-7} \times 1000 \times 60 \times \frac{10}{100}$$

$$= 24\pi \times 10^{-4}$$

(7.5×10^{-3} N)

$$\text{Power} = F \times v$$
$$= 7.5 \times 10^{-3} \times 1 = 7.5 \times 10^{-3} \text{ W}$$

$$\text{Emf} = Blv = \mu_0 H l v = 4\pi \times 10^{-7} \times 1000 \times \frac{1}{10} \times 1$$

$$= 4\pi \times 10^{-5} \text{ V}$$

Que 4 The no. of turns in two coupled coils are 600 (N_1) & 1700 (N_2). when a Current of 6A flow in second coil. The total mag flux produced in Coil is 0.8 mWb (ϕ_2) and the flux linked with the first Coil is 0.5 (ϕ_1). Calculate L_1, L_2 and K, M

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(0.028) $\qquad$ (0.226)

$l_1 = \frac{N_1 \phi_1}{I_1}$ $\qquad$ $l_2 = \frac{N_2 \phi_2}{I_2}$

$M = K\sqrt{l_1 l_2}$ $\qquad$ $M = \frac{N_1 N_2 K_1}{S}$

(0.05) $\quad \downarrow$

(0.625) $\qquad K = \frac{\phi_{21}}{\phi_2}$

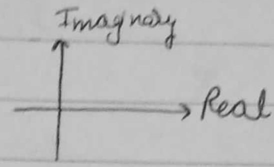
Q5 A Conductor of length 1m moves at right to a uniform Mag field of density 1.5 wbm with a velocity of 50 m/s Calculate the emf used in it. also find the value of induced emf when Conductor moves at 30° to the direction of field ?

emf = Blv
$= 1.5 \times 1 \times 50$
$= 75$

ind emf = $Blv \sin\theta$
$= 75 \sin 30$
$= \frac{75}{2} = 37.5$

Single Phase AC Circuits :

Phasors :



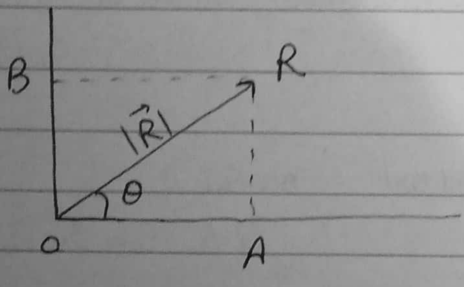
- Magnitude
- Angle

$a \pm ib$

$$\text{Mag} = \sqrt{a^2 + b^2}$$
$$\text{Angle} = \theta = \tan^{-1}\left(\frac{\pm b}{a}\right)$$

The phasor of alternating quantities can be represented as
(a) Rectangular form
(b) Polar form

Fig1



1. **Rectangular** In ΔOAR $\quad \cos\theta = \frac{OA}{OR}$

$$OA = OR\cos\theta = R\cos\theta \quad - (1)$$

IIly $\quad \sin\theta = \frac{AR}{OR}$

$$RA = OR\sin\theta = R\sin\theta \quad - (2)$$

X Component $\Rightarrow R\cos\theta$ $\qquad$ Y Component $\Rightarrow R\sin\theta$

$$\left.\begin{aligned} \therefore \vec{R} &= R\cos\theta + iR\sin\theta \\ R &= a + ib \end{aligned}\right\}$$

2. **Polar** In fig(1) if vector $|\vec{R}|$ represent magnitude of the vector then θ will represent angle.
then expression R will be -

$$R = \sqrt{a^2 + b^2}$$

and $\theta = \tan^{-1}\left(\frac{b}{a}\right)$

$\boxed{|R| \text{ angle } \pm \theta}$ or $\boxed{Re^{\pm i\theta}}$

e.g Q Express the Complex no. in polar form $7-5j$

$|\vec{R}| = \sqrt{(7)^2 + (5)^2} = \sqrt{49+25} = \sqrt{74}$

$= 8.602$

$\theta = \tan^{-1}\left(\frac{-5}{-7}\right) = -0.62$.

$= -35.54^\circ$

as. $8.602 < -35.54$

① $-9 + 6j$
② $-8 - 8j$
] Practise

Que Solve the expression in polar form $10 \angle 60^\circ + 8 \angle -45^\circ$

$\Rightarrow 10e^{60} + 8e^{-45}$

$\Rightarrow 10\left[\cos 60 + i \sin 60\right] + 8\left[\cos(-45) + i \sin(-45)\right]$

$\Rightarrow 10 \cos 60 + 10 i \sin 60 + 8 \cos(-45) + 8 i \sin(-45)$

$= 10 \times \frac{1}{2} + i\, 10 \times \frac{\sqrt{3}}{2} + 8 \left(\frac{1}{\sqrt{2}}\right) + \left(-8 i \frac{1}{\sqrt{2}}\right)$

$= 5 + i5\sqrt{3} + \frac{8}{\sqrt{2}} - \frac{8i}{\sqrt{2}}$ $\Rightarrow 10.656 + i\,3.01$

$= 5 + 5.656 + i\,(8.66 - 5.656)$

$11.07 < 15.72^\circ$

$= 10.656 + i\,3.01$

$$\text{Magnitude} = \sqrt{(10.66)^2 + (3.01)^2}$$
$$= \sqrt{113.63 + 9.06}$$
$$= \sqrt{122.69} = 10.61$$

$$\text{Angle} = \tan^{-1}\left(\frac{3.01}{10.66}\right)$$
$$= \tan^{-1}(0.282)$$
$$= \cancel{0.2714} \quad 15.74^\circ$$

① $(-2-5j) \div (5+7j)$
② $(5+4j) \times (-4-6j)$ } Practise $46.15 < -83.03^\circ$

$5.39 < -111.8^\circ$

$8.6 < 54.46^\circ$

NOTE

Multiplication of two complex

$$A\angle\theta \times B\angle\phi = AB \angle \theta + \phi$$

Division of two Complex

$$A\angle\theta \div B\angle\phi = \frac{A}{B} \angle \theta - \phi$$

Practise

Q1. Express in polar @ $-9 + 6j$

$$\text{Mag} = \sqrt{81 + 36} = \sqrt{117} = 10.82$$

$$\theta = \tan^{-1}\left(\frac{6}{-9}\right) = \tan^{-1}\left(\frac{-2}{3}\right) = -33.69$$

$$10.82 \angle -33.69^\circ$$

b. $-8 - 8j$

$$|\vec{R}| = \sqrt{64 + 64} = \sqrt{128}$$

$$= \underline{11 \cdot 31}$$

$$\theta = \tan^{-1}\left(\frac{-8}{8}\right) = \tan^{-1}(-1) = -45^\circ$$

$$\therefore \quad \underline{11 \cdot 31} \angle -45^\circ \qquad \underline{11} \cdot 31\, e^{-45}$$

Q Express in polar form (a) $(-2 - 5j) \div (5 + 7j)$

=

(i) $-2 - 5j$

$$\text{Mag} = \sqrt{4 + 25} = \sqrt{29} = 5 \cdot 38$$

$$\theta = \tan^{-1}\left(\frac{5}{2}\right) = \tan^{-1}\left(\frac{5}{2}\right) = 68 \cdot 19^\circ$$

$$5 \cdot 38 \angle 68 \cdot 19^\circ$$

(ii) $5 + 7j$

$$\text{Mag} = \sqrt{25 + 49} = \sqrt{74} = 8 \cdot 6$$

$$\theta = \tan^{-1}\left(\frac{7}{5}\right) = 54 \cdot 46^\circ$$

$$8 \cdot 6 \angle 54 \cdot 46^\circ$$

Resultant: $5 \cdot 38 \angle 68 \cdot 19 \div 8 \cdot 6 \angle 54 \cdot 46$

$$\Rightarrow \frac{5 \cdot 38}{8 \cdot 6} \angle 68 \cdot 19 - 54 \cdot 46$$

$$\Rightarrow 0 \cdot 625 \angle 13 \cdot 73^\circ$$

(b) $(5+4j) \times (-4-6j)$

(i) $5+4j$

$$\text{Mag} = \sqrt{25+16} = \sqrt{41}$$

$$= 6.40$$

$$\theta = \tan^{-1}\left(\frac{4}{5}\right) = 38.65$$

$\therefore$ $6.40 \angle 38.65^\circ$

(ii) $-4-6j$

$$\text{Mag} = \sqrt{16+36} = \sqrt{52}$$

$$= 7.21$$

$$\theta = \tan^{-1}\left(\frac{6}{4}\right) = 56.30$$

$\therefore$ $7.21 \angle 56.30^\circ$

Hence Resultant

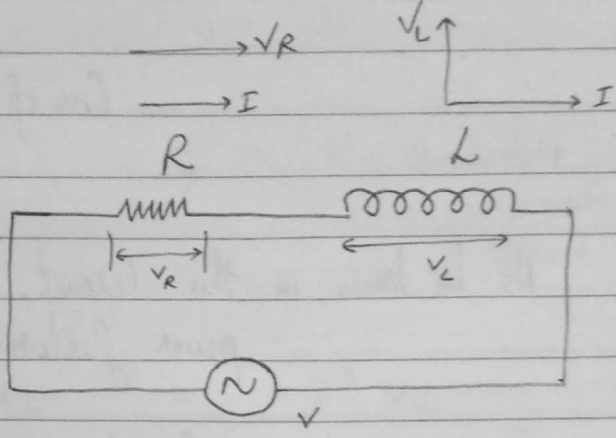
$$6.40 \angle 38.65^\circ \times 7.21 \angle 56.30^\circ$$

$$= (6.40)(7.21) \angle 38.65 + 56.30$$

$$= 46.144 \angle 94.95^\circ$$

* RL , LC , RC Series Circuit And Power Calculations :

RL Circuit :



In Case of purely resistive circuit,
V & I in same phase

$R = \vec{V_R} = I_R$

$L = \vec{V_L} = I_{XL}$

Applied Voltage $\quad V = V_R + V_L \quad$ — ①

$$V = IR + jIX_L \quad - ② = I[R + jX_L]$$

$$\frac{V}{I} = R + jX_L$$

Impedence $\quad Z = R + jX_L$

So $\quad V = \sqrt{(V_R)^2 + (V_L)^2} = \sqrt{(IR)^2 + (IX_L)^2}$

$$V = I\sqrt{R^2 + X_L^2} \quad — ③$$

$$I = V/\sqrt{R^2 + X_L^2} \qquad \frac{V}{I} = \sqrt{R^2 + X_L^2}$$

$$|\vec{Z}| = \sqrt{R^2 + X_L^2} \quad — ④$$

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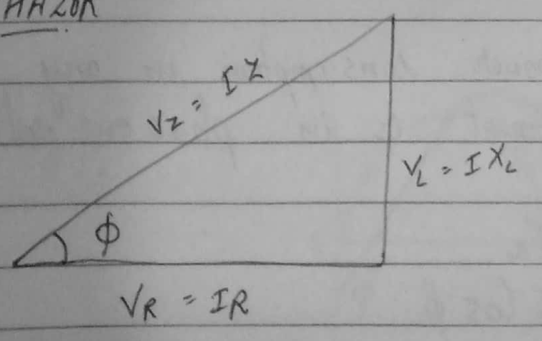


From the triangle ABC

$$\tan\phi = \frac{X_L}{R} = \frac{\omega L}{R}$$

$$\phi = \tan^{-1}\left(\frac{X_L}{R}\right) \quad — ⑤$$

ϕ is called the phase angle and it is the ~~voltage~~ angle b/w voltage and angle.

Power Factor $\quad \cos\phi$ = Power Factor

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

As we know in this Circuit, the current lags the voltage so the power factor is lagging.

$$\cos\phi = \cos\left[\tan^{-1}\left(\frac{X_L}{R}\right)\right] \quad \text{--- (5)}$$

Power Calculation

The Principle Current I can be written in two forms of current Component i.e. I_a and I_r

First one is a component I_a in phase with voltage this is called active or real or Watt full Component.

$$\therefore I_a = I\cos\phi$$

Second, the component I_R at right angle to voltage this component is called Reactive or Quadrative or Watties Component

$$\therefore I = \sqrt{I_a^2 + I_r^2}$$

We will Calculate three types of power, (1) Actual Power, (2) Reactive Power (3) Complex Power.

Actual Power (P) (True) - There is a real power consumption in any circuit when a current component is in phase voltage It is measured in Watt

$$P = VI_a$$

$$P = VI\cos\phi$$

$$P = VI\frac{R}{Z} = \frac{V}{Z} \cdot IR$$

$$P = I^2R$$

It can be seen that the actual power Consumption is dependent on power factor Circuit.

Reactive / Quadrature Power (Q)

Q = $V \times$ Quadrature Component of Current

When 90° phase apart

$$Q = VI_r$$
$$Q = VI \sin\phi$$
$$Q = VI \frac{X_L}{Z} = I^2 X_L$$

Units of reactive Power is VAR (Reactive Volt Ampere)

Complex or Apparent Power (S)

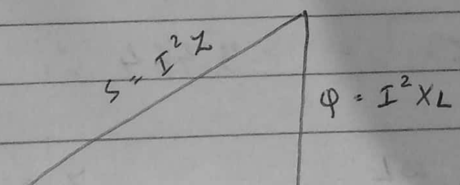
It is Calculated as the product of voltage and Current and measured in Volt Ampere

↓

Resultant Power

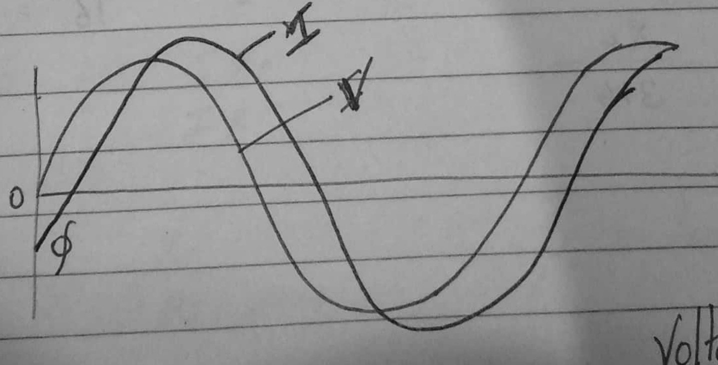
$$S = VI \longrightarrow \text{Total Current (Resultant)}$$
$$S = I^2 Z \qquad S = \frac{V^2}{Z}$$

These three powers can be represented as



Power Triangle

Waveform



Voltage leads Current

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Q In a series circuit, containing pure resistive & inductive, the current and voltage are expressed as $i(t) = 5 \sin\left[314 + \frac{2\pi}{3}\right]$

$$v(t) = 20 \sin\left[314 + \frac{5\pi}{6}\right]$$

Find (i) impedence
(ii) resistance, inductance and power factor

Phase Angle of V $= \frac{2\pi}{3} \times \frac{180}{\pi} = 120^\circ$

Phase Angle of I $= \frac{5\pi}{6} \times \frac{180}{\pi} = 150^\circ$

Voltage leads by 30°

Power Factor $= \cos\phi = \cos 30 = \frac{\sqrt{3}}{2} = 0.8$

Impedence $= Z = \frac{20}{5} = 4$

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

$= 0.866 \times Z = 3.464$

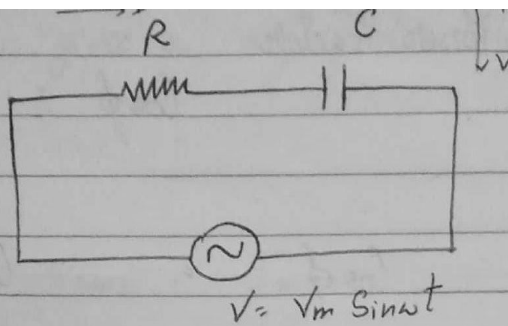
Inductance $= X_L = \omega L$ $\qquad Z = \sqrt{R^2 + X_L^2}$

$X_L = 314 \times L$ $\qquad Z^2 = R^2 + X_L^2$

$\qquad 16 = (3.4)^2 + X_L^2$

$L = \frac{X_L}{314}$

RC Series Circuit -



In case of purely Resistive Ckt
V & I in same phase

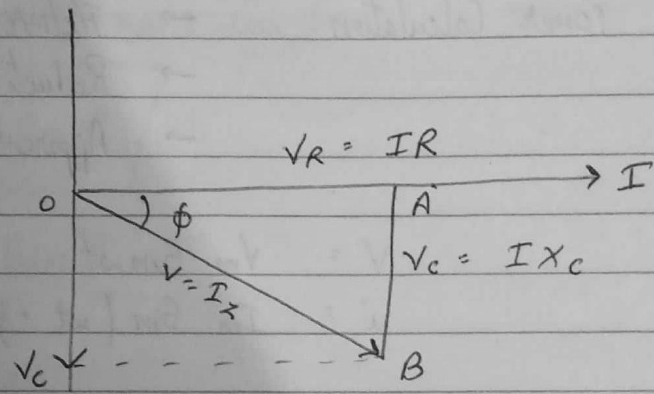
$R \Rightarrow V_R = IR$

$C \Rightarrow V_C = I X_C$

Magnitude

In $\triangle AOB$

$$V = \sqrt{(V_R)^2 + (V_C)^2}$$



$$V = \sqrt{(IR)^2 + (IX_C)^2}$$

$$V = I\sqrt{R^2 + X_C^2} \quad - ①$$

$$I = \frac{V}{\sqrt{R^2 + X_C^2}}$$

$$I = \frac{V}{Z}$$ where z is impedence

$$\therefore \quad |\vec{Z}| = \sqrt{(R)^2 + (X_C)^2} \quad - ②$$

Phase Angle

From phasor diagram $\quad \tan\phi = \dfrac{V_C}{V_R} \quad - ③$

$$\therefore \quad \tan\phi = \frac{I X_C}{I R}$$

$$\tan\phi = \frac{X_C}{R} \qquad \phi = \tan^{-1}\left(\frac{X_C}{R}\right) \quad - ④$$

Power Factor

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

$$\cos\phi = \cos\left(\tan^{-1}\left(\frac{X_C}{R}\right)\right) \quad \text{— ③}$$

Power Calculation → Active Power
→ Reductive Power
→ Apparent Power

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

Instantaneous power $= p = Vi$

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

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

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

- Avg Power consumed in the circuit over a complete cycle.

$$P = \text{avg}\ \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}}\cos\phi - \text{avg}\ \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}}\cos(2\omega t + \phi)$$

As the quantity $\frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos(2\omega t + \phi)$ gives a negligible value

So we can ignore this term.

As $V_{rms} = \frac{V_m}{\sqrt{2}}$ & $I_{rms} = \frac{I_m}{\sqrt{2}}$

Hence.

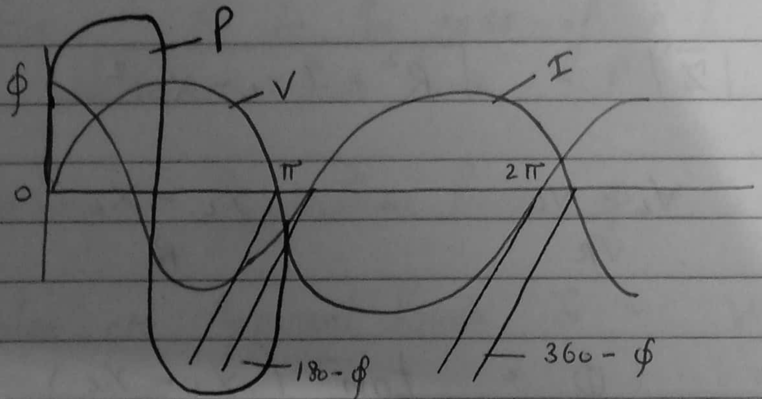
$$P = V_{rms} I_{rms} \cos\phi$$

$$\boxed{P = VI \cos\phi}$$

$$Q = VI \sin\phi$$

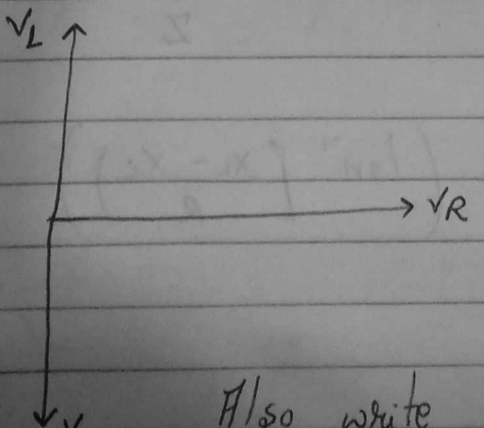
$$S = VI$$

Waveform -



***** M. Imp.

RLC Series Circuit :



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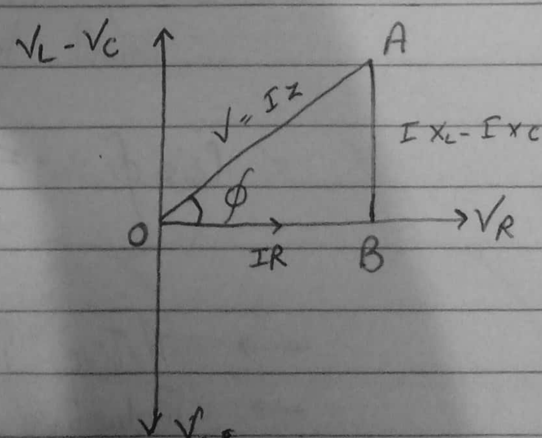


Also write the theory of introduction

Magnitude

$$V = \sqrt{(V_R)^2 + (V_L - V_C)^2}$$

$$V = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$

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

$$V/I = \sqrt{R^2 + (X_L - X_C)^2}$$

$$I = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}} \quad — ①$$

$$\therefore \quad I = \frac{V}{Z} \quad — ②$$

So.

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

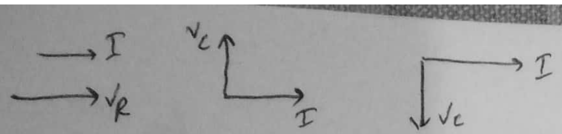
$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$$

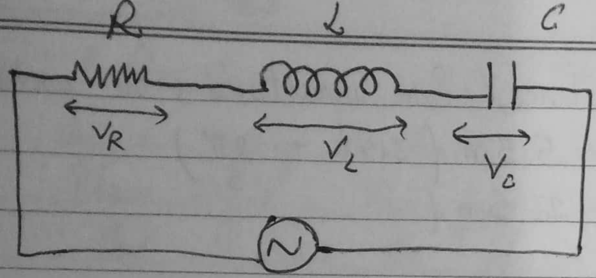
$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

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

$$\cos\phi = \cos\left(\tan^{-1}\left[\frac{X_L - X_C}{R}\right)\right)$$

→ Active Power
→ Reductive Power
→ Apparent Power





Voltage across R = $V_R = RI$

Voltage across L = V_L

= $I X_L$

Voltage across C = V_C

= $I X_C$

If $X_L > X_C$, circuit behave like R-L circuit

If $X_C > X_L$, circuit behave like R-C circuit

If $X_L = X_C$, circuit behave like pure resistive circuit

↳ Resonance

Power Calculation: As in the case of R-L circuit

Actual or Real Power $P = VI\cos\phi$ W

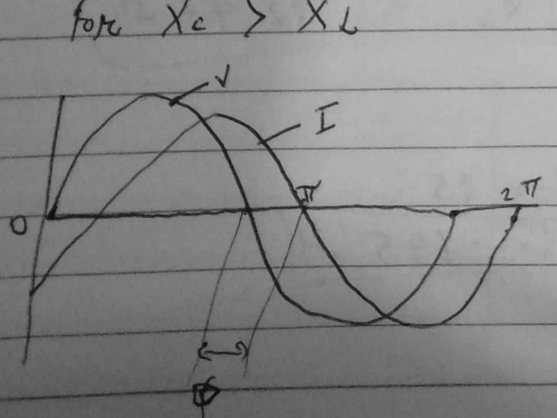
Reactive or Quadrative Power $\varphi = VI\sin\phi$ VAR

Complex or Apparent Power $S = VI$ Volt Ampere

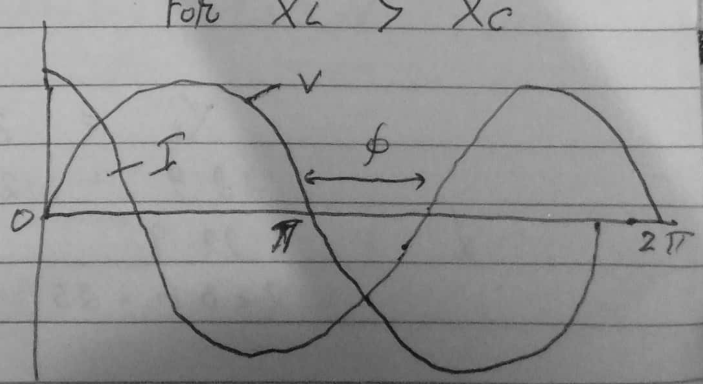
$$S = \sqrt{P^2 + \varphi^2}$$

Power Factor p.f. = $\cos\phi = \dfrac{\text{Real Power}}{\text{Apparent Power}}$

For $X_C > X_L$



For $X_L > X_C$



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Q In a Series Circuit containing Pure Resistance, Pure Inductance, the current in pure resistive is

$i(t) = 5 \sin\left(314t + \frac{2\pi}{5}\right)$

$v(t) = 20 \sin($

Que An inductive Coil take 10 A & dissipates 1000 W when connected to a supply at 250 Volts, 25 Hz. Calculate impedence, reactance, effective Resistance, Inductance & Power Factor.

$$P = VI \cos\phi$$

$$1000 = 250 \times 10 \times \cos\phi$$

$$\frac{\cancel{1000}^{2}}{\cancel{250} \times \cancel{10}_{5}} = \cos\phi$$

$$\boxed{\cos\phi = \frac{2}{5}}$$

$$P = I^2 R$$

$$1000 = 10 \times 10\ R \qquad \boxed{R = 10\ \Omega}$$

$$Z = \frac{V}{R} = \frac{250}{10}$$

$$\boxed{Z = 25}$$

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

$$(25)^2 = (10)^2 + (X_L)^2$$

$$X_L = \sqrt{625 - 100}$$

$$X_L = \sqrt{525}$$

$$\boxed{X_L = 22.91\ \Omega}$$

$$X_L = 2\pi L \omega$$

$$22.9 = 2 \times 3.14 \times L \times 25$$

$$L = \frac{22.9}{2 \times 3.14 \times 25} = \boxed{L = .145\ H}$$

Que A Resistance of 100 Ω is Connected in Series with 50 micro F capacitor to a supply at 200 V, 50 Hz. Find Impedence, Current, Phase Angle. Also find voltage across Resistance and Capacitor. And draw the phasor Diagram.

$$X_c = \frac{1}{2\pi f c} = \frac{1}{2\pi \omega C} = \frac{1}{2\times 3.14 \times 50 \times 50 \times 10^{-6}}$$

$$= \frac{10^6}{2\times 3.14 \times 2500} = \frac{10^6}{15700} = 63.69$$

$$Z = \sqrt{R^2 + (X_c)^2} = \sqrt{(100)^2 + (63.69)^2} = \sqrt{14056.4161}$$

$$= 118.56\ \Omega$$

$$i = \frac{V}{Z} = \frac{200}{118.56} = 1.69\ A$$

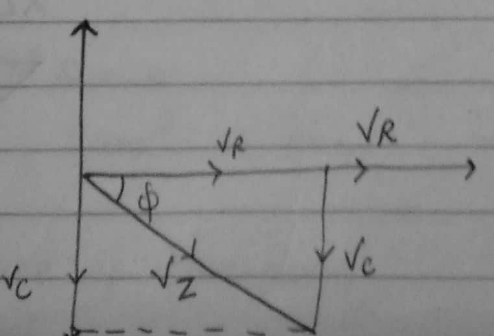
Power $\cos\phi = \frac{R}{Z} = \frac{100}{118.56} = \cancel{0.008}$

$$= 0.843$$

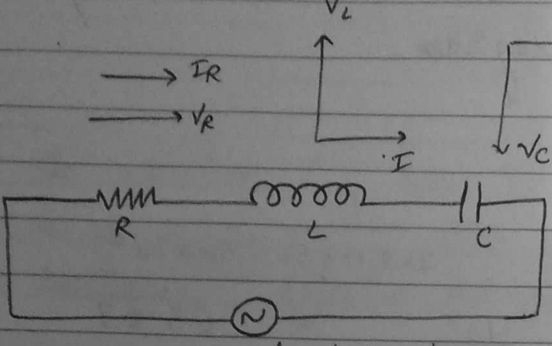
$$\phi = \cos^{-1}(0.843) = 32.486^\circ$$

$$V_R = IR = 1.69 \times 100 = 169\ V$$

$$V_c = IX_c = 1.69 \times 63.69 = 107.63\ V$$

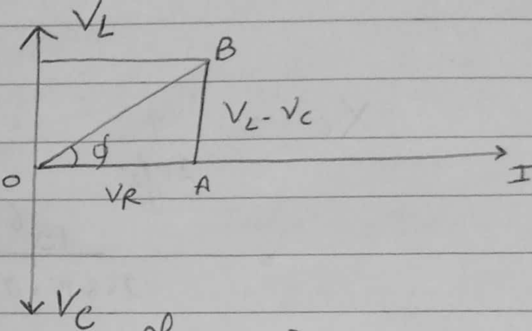


Continued RLC Circuit



$V = V_m \sin\omega t$

Circuit Diagram



Phasor Diagram

if $\quad i = i_m \sin\omega t \qquad v = V_m \sin\omega t$

then circuit current can be considered in three Cases in RLC

Case 1 : $\quad X_L > X_C$ Then the circuit is R-L Circuit

Current lags behind voltage at angle of 90°

$$i = i_m \sin(\omega t - \phi)$$

Case 2 : $\quad X_L < X_C$ Then the circuit is RC Circuit

Current leads the voltage by 90°

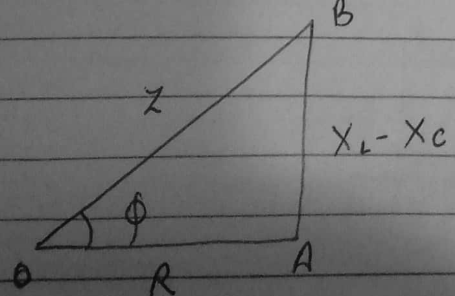
$$i = i_m \sin(\omega t + \phi)$$

Case 3 : $\quad X_L = X_C$ Then the circuit is purely R

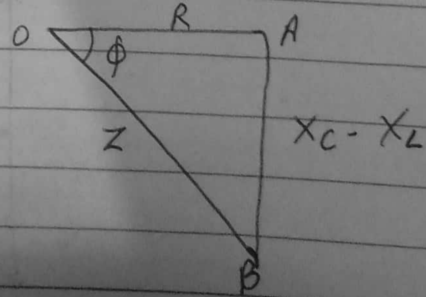
$$Z = R$$

$$i = i_m \sin\omega t$$

$X_L > X_C$



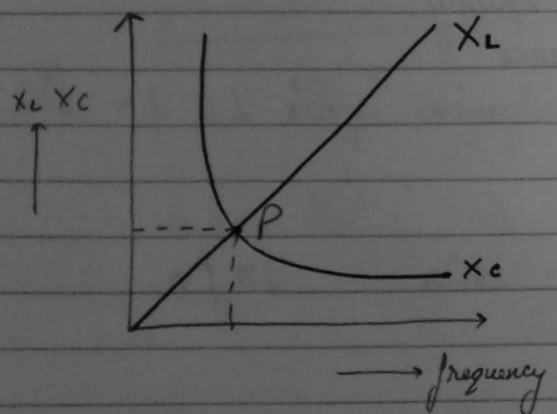
$X_L < X_C$



* **Resonance :**

When the circuit current is in phase with the applied voltage, the circuit is said to be in Resonance.

This condition can be achieved in RLC circuit



X_L leads X_C

We know that, at resonance

$$X_L = X_C$$

$$X_L - X_C = 0 \quad — ①$$

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

Use eq ①

we get $\quad Z_r = R$

We know that $\quad I_r = \frac{V}{Z_r} = \frac{V}{R} \quad \therefore \boxed{I_r = \frac{V}{R}}$

1. Current is Maximum, Resonance I
2. Power Factor = $\cos\phi = \cos 0 = 1$

when $\cos\phi = 1$ → In Pure Resistive circuit
→ In RLC circuit

3. $V_R = I_R$ in phase $\xrightarrow[V_R\ I_R]{}$

4. Impedence is Minimum

So Current is Max ⟶ Power is also Max

as $P = I^2 R$

5. Power at Resonce is Maximum

So. This circuit is called Acceptor Circuit

Resonance Circuit and

Resonance Frequency Frequency at which resonance occurs is known as resonance frequency.

$X_L = X_C$ at resonance

$\omega_r L = \frac{1}{\omega_r C}$ $\Rightarrow$ $\omega_r^2 LC = 1$

$\omega_r = \frac{1}{\sqrt{LC}}$ $\omega_r = 2\pi f_r$

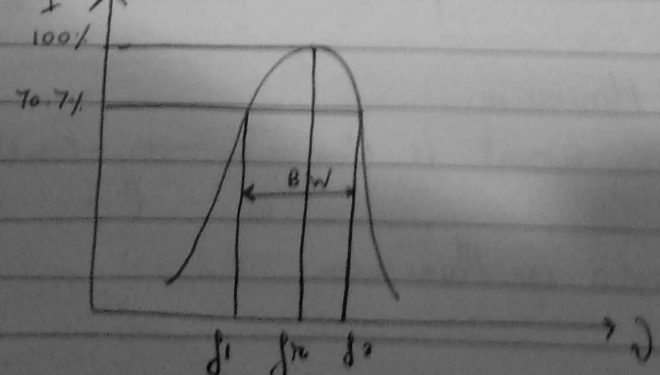
$\therefore$ $2\pi f_r = \frac{1}{\sqrt{LC}}$

$\therefore$ $\boxed{f_r = \frac{1}{2\pi\sqrt{LC}}}$

Bandwidth The range of frequency at which circuit offers low impedence is called bandwidth circuit.

OR

The range of frequency at which current or voltage is equal to 70.7% of maximum value of is called bandwidth



Quality Factor The factor at which potential difference across L or C rises to that of the applied voltage is called Quality factor.

$$\boxed{Q = \frac{\text{Voltage across L or C}}{\text{Applied Voltage}}}$$

OR Q is voltage magnification at resonance.

We know that $V_L = I_0 X_L$ — ①

$V_C = I_0 X_C$ — ②

$\therefore V = I_0 Z$ or $I_0 R$ — ③

Voltage Magnification $= \frac{V_L}{V}$ or $\frac{V_C}{V}$

So $Q = \frac{I_0 X_L}{I_0 R}$ or $\frac{I_0 X_C}{I_0 R}$

$$Q = \frac{X_L}{R} = \frac{\omega_0 L}{R} \quad \text{For } L$$

OR

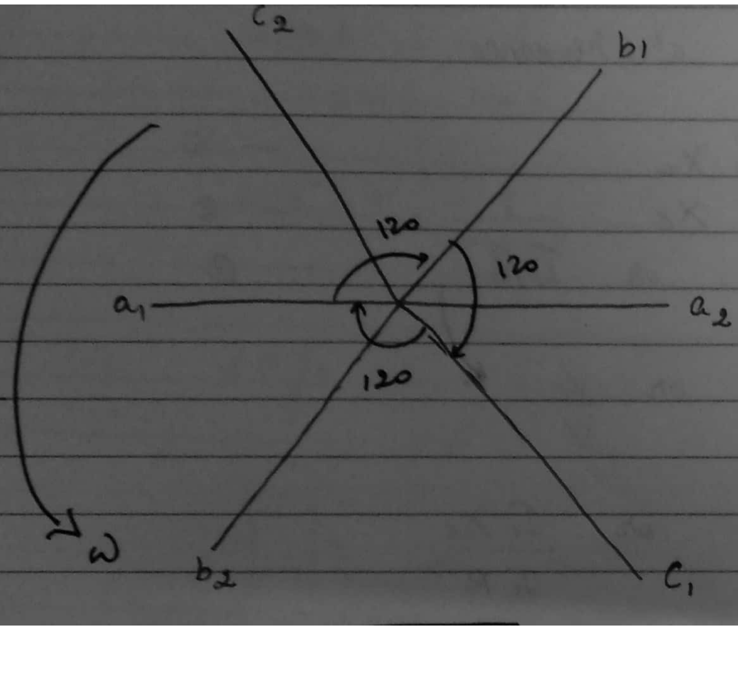
$$Q = \frac{X_C}{R} = \frac{1}{\omega_0 C R} \quad \text{For } C$$

Use anyone of

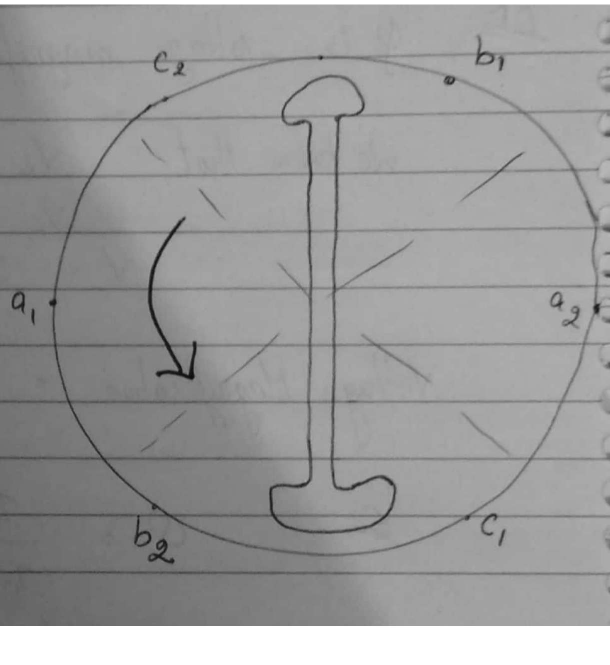
$$Q = \frac{2\pi f_0 L}{R} = \frac{2\pi}{R} \frac{1}{2\pi\sqrt{LC}} L$$

$$= \frac{L}{R\sqrt{LC}}$$

$$\boxed{Q = \frac{1}{R}\sqrt{\frac{L}{C}}}$$



c_2
b_1
120
120
a_1
a_2
120
ω
b_2
c_1



c_2
b_1
a_1
a_2
b_2
c_1

To connect coil with load, we need 2 wires and to connect 3 windings & 3 load, we need 6 wires.

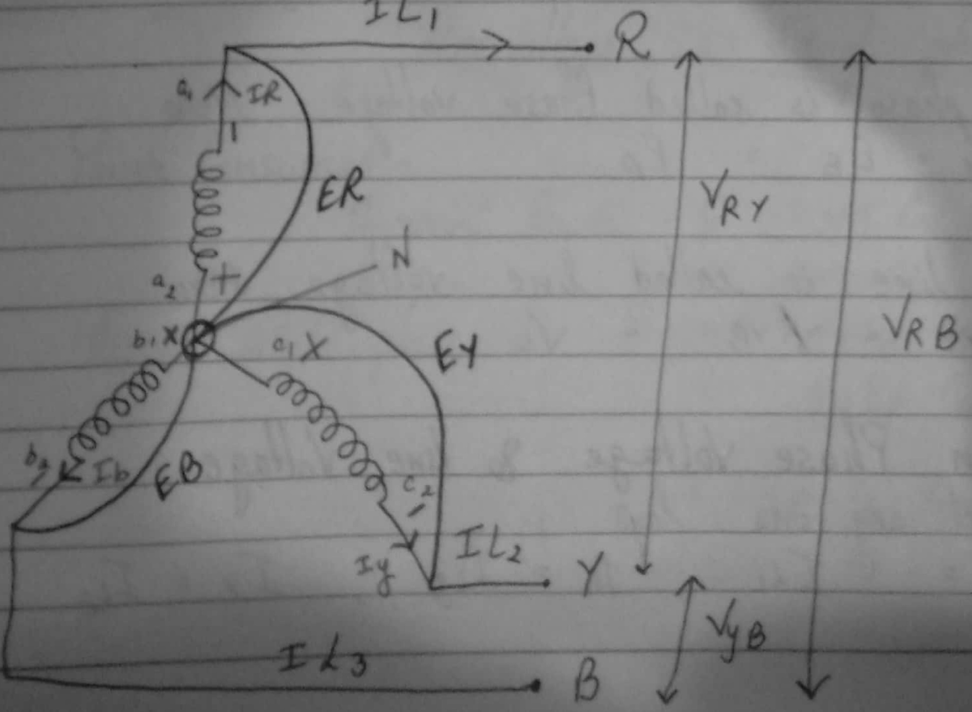
To decrease the complexitity of circuit, or (no. of ~~nos~~ wires) we use 3 phases

→ Star Connection | Y

→ Delta Connection or Mesh

STAR Connection :

The point at which we connect similar point is called neutral.



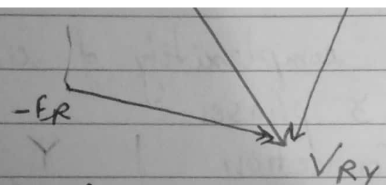
3 Phase 3 Wires

or

3 Phase 4 Wire

↓

4th is the wire from neutral point



Similar ends either start or finish of windings are connected at a common point called Common or neutral points.

The current in each line is called line current. Here

$I_{L1} = I_{L2} = I_{L3} = I_L$ [Line Current]

Incoming = Outgoing $\quad I_P = I_L$ — ①

Hence, Phase Current = Line Current

Using KVL, select anyone loop

$$E_R + V_{RY} - E_Y = 0$$

$$V_{RY} = E_Y - E_R \quad - ②$$ → This helps us in making phasor

*** Draw Directions carefully for phasor

Using law of parallelogram

$$|\vec{a} - \vec{b}| = \sqrt{|a|^2 + |b|^2 + 2|a||b|\cos\theta} \quad - ③$$

Using ② in ③

$$V_{RY} = \sqrt{(E_R)^2 + (E_y)^2 + 2E_R E_y \cos\theta}$$

$$V_L = \sqrt{3}\, E_p \quad — ④$$

Similarly $\quad V_{BY} = V_{RB} = V_L = \sqrt{3}\, E_p$

So.

$$\boxed{\text{line voltage is } \sqrt{3} \text{ of phase voltage}}$$

Power Consumed -

Apparent Power $\quad P = VI\cos\phi$

Across 1 single phase $\quad P = I_R E_R \cos\phi$

$$= I_p E_p \cos\phi$$

$$= I_p \frac{V_L}{\sqrt{3}} \cos\phi$$

$$\boxed{P = \frac{I_L V_L}{\sqrt{3}} \cos\phi}$$

Total Apparent Power in 3 phase $= 3 \cdot \frac{V_L I_L}{\sqrt{3}} \cos\phi$

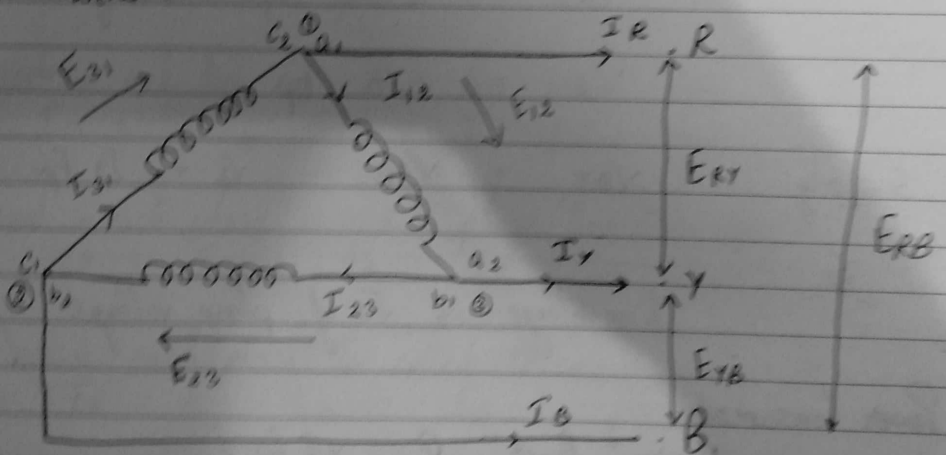
$= \sqrt{3}\, V_L I_L \cos\phi$ watt

Reactive Power $= P_R = E_p I_p \sin\phi$

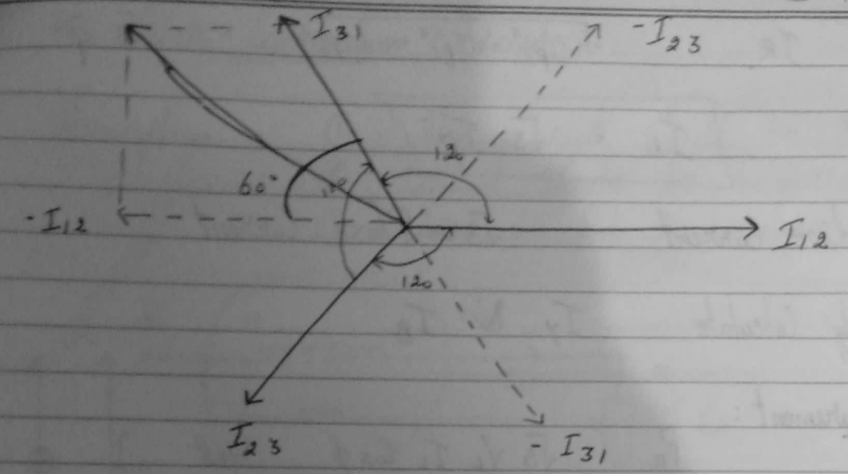
$$\boxed{P_R = \sqrt{3}\, V_L I_L \sin\phi} \quad \text{VAR}$$

Delta Connection :

Dissimilar ends of 3 phase coil are connected together to form a mesh. It means finish of one winding to the start terminal of the other wind.



$E_{RY} = E_{YB} = E_{RB} = E_L$ [Line Voltage]
$I_{12} = I_{23} = I_{31} = I_p$ [Phase Current]
$I_R = I_Y = I_B = I_L$ [Line Current]
$E_{12} = E_{23} = E_{31} = E_p$ [Phase Voltage]



Voltage across Terminal 1, 2 is same as across RY

$$E_{12} = E_{RY} \quad , \quad E_{23} = E_{YB} \quad , \quad E_{31} = E_{BR}$$

$\therefore$ $\boxed{E_P = E_L}$ ① Hence, $\boxed{\text{Line Voltage} = \text{Phase Voltage}}$

Relation b/w Phase Current And Line Current -

Since, the system is balanced.
So, I_{12}, I_{23}, I_{31} are equal in magnitude but displaced from one another by $120°$

$$I_{12} = I_{23} = I_{31} = I_P \quad — ②$$

Current is divided at every junction 1, 2 and 3
So, using KCL in junction 1.

$$I_{31} = I_R + I_{12}$$

$$I_R = I_{31} - I_{12}$$

$$\therefore \quad I_R = \sqrt{(I_{31})^2 + (I_{12})^2 + 2(I_{31})(I_{12})\cos 60}$$

$$I_R = \sqrt{(I_P)^2 + (I_P)^2 + (I_P)^2} = \sqrt{3}\, I_P$$

$$\boxed{I_L = \sqrt{3}\, I_P}$$

Hence, Line Current = $\sqrt{3}$ x Phase Current

Similarly Calculate I_Y & I_B

Power Measurement:

$$\left.\begin{aligned} P_a &= \sqrt{3}\, V_L I_L \cos\phi \quad \text{Watt} \\ P_r &= \sqrt{3}\, V_L I_L \sin\phi \quad \text{VAR} \end{aligned}\right\} \quad (4)$$

Hence. Total Power consumed is same in star and delta Connection.

Measurement of Power in 3-Phase Circuits

OR. Explain the wattmeter method for Power?

Power consumed in 3-Phase can be calculated by using 2 wattmeters.

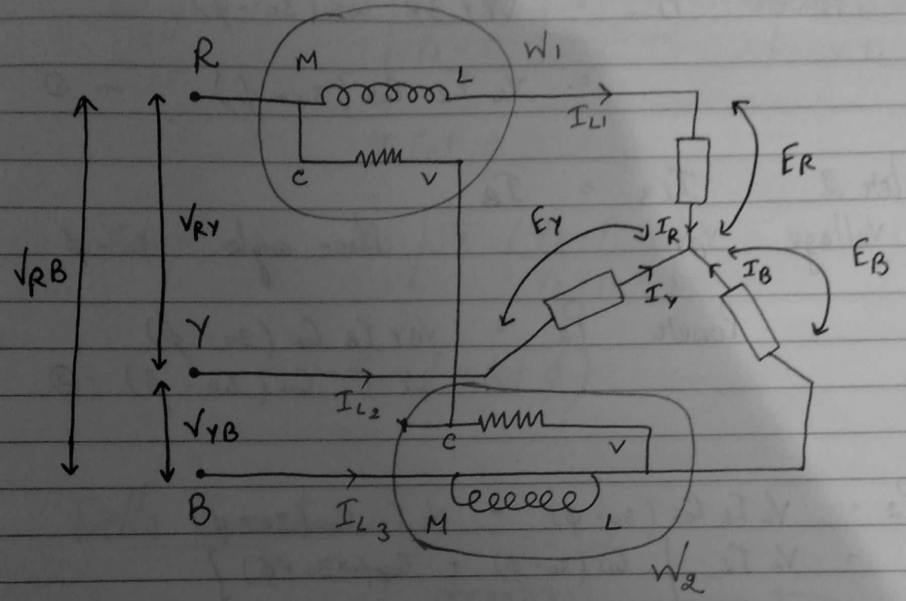
Wattmeter is an indicating instrument which will show deflection in the form of Power.

Two coils are used, one as current coil and other as voltage or pressure coil. The current coil is connected in series with the load and the pressure coil is connected across the load.

Deflection torque is produced with which is proportional to the power being measured.

* Star Connection Load :

Assumption -
1. The circuit should be RYB.
2. Circuit should be balanced.
3. Load is RL in nature.

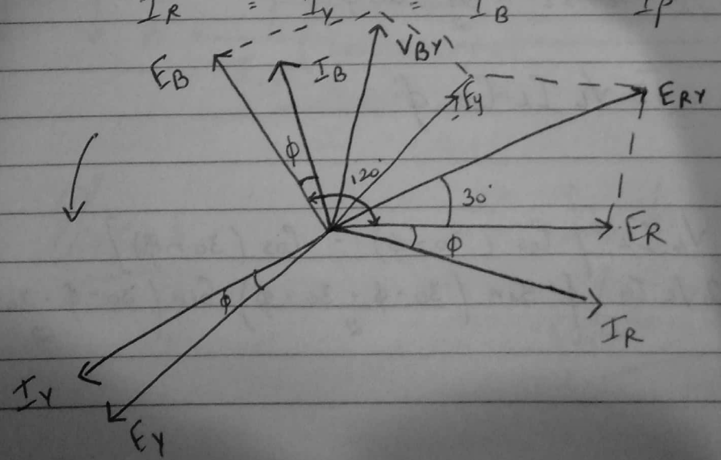


$I_{L1} = I_{L2} = I_{L3} = I_L$ [Line Current]

$E_R = E_Y = E_B = E_P$ [Phase Voltage]

$V_{RY} = V_{YB} = V_{RB} = V_L$ [Line Voltage]

$I_R = I_Y = I_B = I_P$ [Phase Current]



For Wattmeter 1 $\quad I_{L1} = I_R$

Voltage V_{RY}

Phase angle $= 30 + \phi$

Power $P_1 = V_{RY} I_R \cos(30+\phi)$

$= V_L I_L \cos(30+\phi) \quad —①$

For Wattmeter 2 $\quad I_{L3} = I_B$

Voltage V_{BY} $\quad$ Phase angle $= 30 - \phi$

Power $P_2 = V_{BY} I_B \cos(30-\phi)$

$= V_L I_L \cos(30-\phi) \quad -②$

Add.

$$P_1 + P_2 = V_L I_L \cos(30-\phi) + V_L I_L \cos(30+\phi)$$
$$= V_L I_L \left[\cos(30-\phi) + \cos(30+\phi)\right]$$
$$= 2 V_L I_L \left[\cos\left(\frac{30-\phi+30+\phi}{2}\right) \cos\left(\frac{30-\phi-30-\phi}{2}\right)\right]$$
$$= 2 V_L I_L \cos 30 \cos\phi$$
$$= 2 \times V_L I_L \times \frac{\sqrt{3}}{2} \cos\phi$$
$$= \sqrt{3} V_L I_L \cos\phi$$

Sub.

$$P_2 - P_1 = V_L I_L \left[\cos(30-\phi) - \cos(30+\phi)\right]$$
$$= -2 V_L I_L \left[\sin\left(\frac{30-\phi+30+\phi}{2}\right) \sin\left(\frac{30-\phi-30-\phi}{2}\right)\right]$$

$$= 2V_L I_L \sin 30 \sin\phi$$

$$= V_L I_L \sin\phi$$

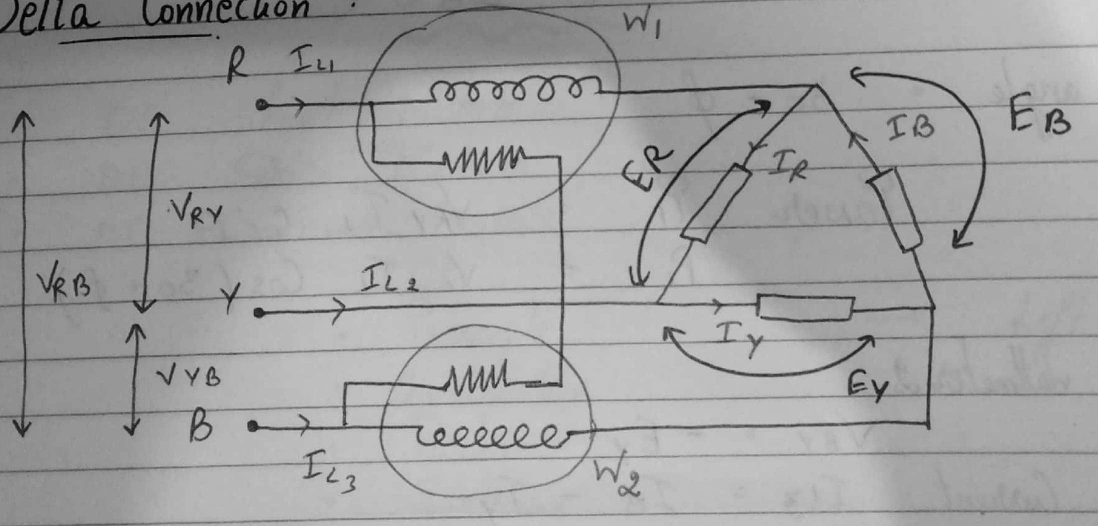
$$\tan\phi = \sqrt{3}\left[\frac{P_2 - P_1}{P_2 + P_1}\right] = \sqrt{3}\left[\frac{\sqrt{3}V_L I_L \cos\phi}{V_L I_L \sin\phi}\right]$$

$$= 3\cot\phi$$

$$\cos\phi = \cos\left[\sqrt{3}\left(\frac{P_2 - P_1}{P_2 + P_1}\right)\right] = \cos\left[\sqrt{3}\left(\sqrt{3}\cot\phi\right)\right]$$

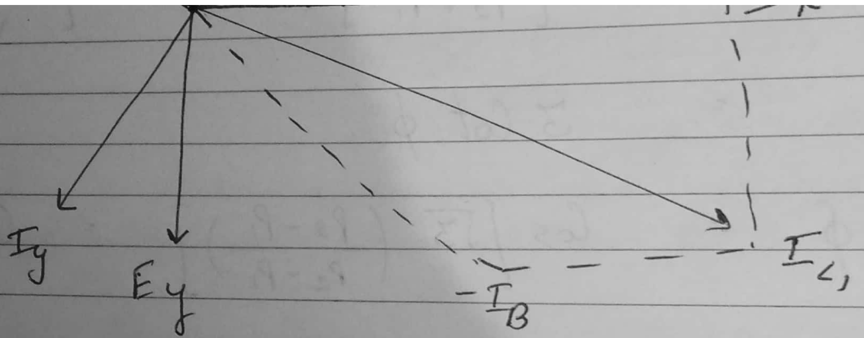
$$= \cos\left(3\cot\phi\right)$$

<u>Delta Connection</u> :



<u>Phasor</u>

Similar to the Star Connection



Across wattmeter 1

$$\tan\phi = \sqrt{3}\left[\frac{P_2 - P_1}{P_2 + P_1}\right]$$

Power Factor

$$\cos\phi = \cos\left[\tan^{-1}\sqrt{3}\left(\frac{P_2 - P_1}{P_2 + P_1}\right)\right]$$

DC Motor

1. DC Shunt Motor
2. DC Series Motor
3. DC Composed Motor

- Principle → Left Hand Rule
- Construction
- Parts
- Working
- Definition
- Diagram

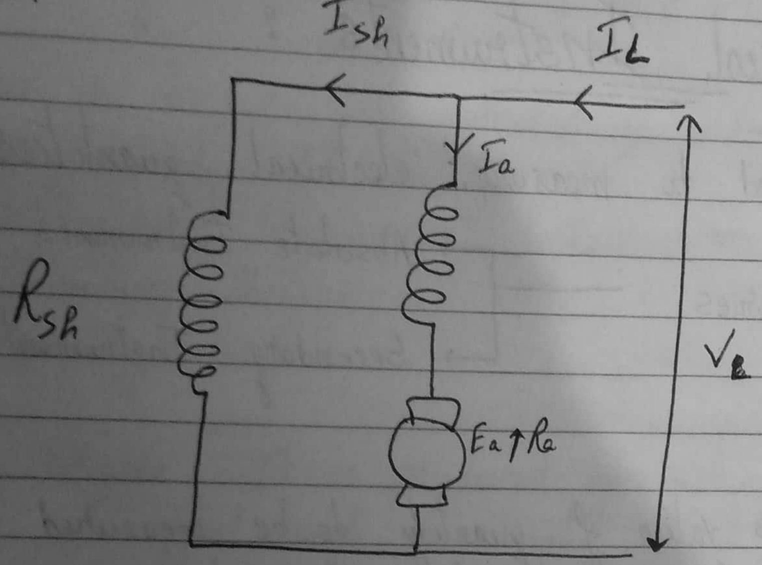
$$\boxed{\underset{\text{Back emf}}{E_b} = V - \underset{\text{Armature}}{I_a} R_a}$$ → Resistance

$$I_{sh} = \frac{V}{R_{sh}}$$

$$I_a = I_L - I_{sh}$$

$$E_b = V - I_a R_a - 2V_b$$

Compound :



$$I_{sh} = \frac{V}{R_{sh}}$$

$$I_a = I_L - I_{sh}$$

$$I_{se} = I_a$$

$$\therefore \quad E_b = V - V_a (R_a + R_{se}) - 2V_b$$

★ Electrical Instruments :

These are used to measure electrical quantities.

2 Broad Categories → Absolute Instruments
→ Secondary Instruments

Absolute : Give value of quantity to be measured in form of Constant of instrument.
They donot require any prior Calibration.
↓
changes in Reading to get correct Readings

e.g galvanometer

Secondary : Give value of quantity to be measured in the form of deflection.
It is further divided into 3 categories

Indicating
- Indicate magnitude of electrical quantity being measured
- Pointer moves over the scale to indicate magnitude.

e.g ammeter, voltmeter etc.

Integrating
- These are those which adds up electrical energy and measure the total energy in given time period.

e.g energymeter.

Recording
- Gives continous record of variation of electrical quantity being measured.

Essentials of Indicating Instruments :

- The force or torque required for operation of indicating instruments are basically of 3 types :
  1. Deflection Torque (T_d)
  2. Controlling Torque (T_c)
  3. Damping Torque

Deflecting Torque It is produced by making of one of the effect such as magnetic effect, Dynamic effect, electromagnetic effect.

It is required to move the moving system from zero position.

Controlling Torque It opposes the T_d and increases with deflection of moving system. The pointer is broad to rest at a position where T_c and T_d are equal.

Damping Torque When T_d is applied to moving system, it deflects the pointer whereas T_c controls the deflection and tries to stop the pointer at its final position ($T_c = T_d$) But due to initia problem, pointer oscilates before Coming to rest position. These oscillations are undesirable, so move the pointer quickly to rest position we apply damping Torque.

Transducers :

Which converts non-electrical quantity into electrical ~~sgsl~~ signals

→ Active

→ Passive

Active Which generally produce own power for operation

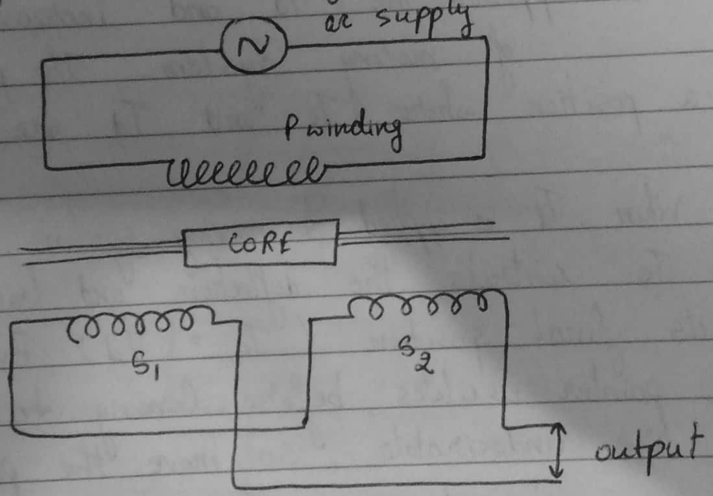
Passive which Require enternal power for their operation.

LVDT :

Linear Variable Differential Transducer

→ It consist of 1 primary winding to which ac source is connected and consist of two secondary windings S_1 and S_2 which are placed on either side of primary winding. Secondary having equal no. of turns but are connected in series opposition, so that emf induced in coils opposes each other.

The position of core determines flux linkage b/w primary and each of the secondary windings.



1 Case 1 Core is in between
Both are having equal emf... ∴ $\boxed{e_{S_1} = e_{S_2}}$

Case 2 Core is at Left side
induced emf linking with S_1 is more than S_2

$$\boxed{e_{S_1} > e_{S_2}}$$

Voltage is in phase with S_1

Case 3 Core is shifted towards right side

$\therefore$ $e_{s_2} > e_{s_1}$

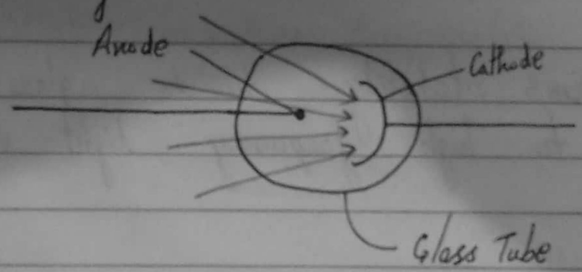
Hence

Induced emf is varying linearly $\therefore$
Output voltage of LVDT is Linear function of core Displacement.

Photo Electric Transducers :

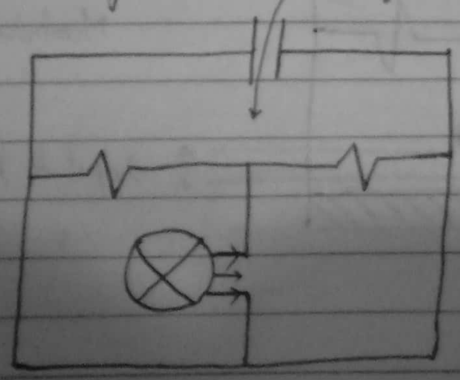
This transducer may use of photoelectric cells or phototudes's properties.

Incident light changes into voltage, induced emf $\therefore$
Phototude is a device and its electron emission is controlled by amount of incident light.

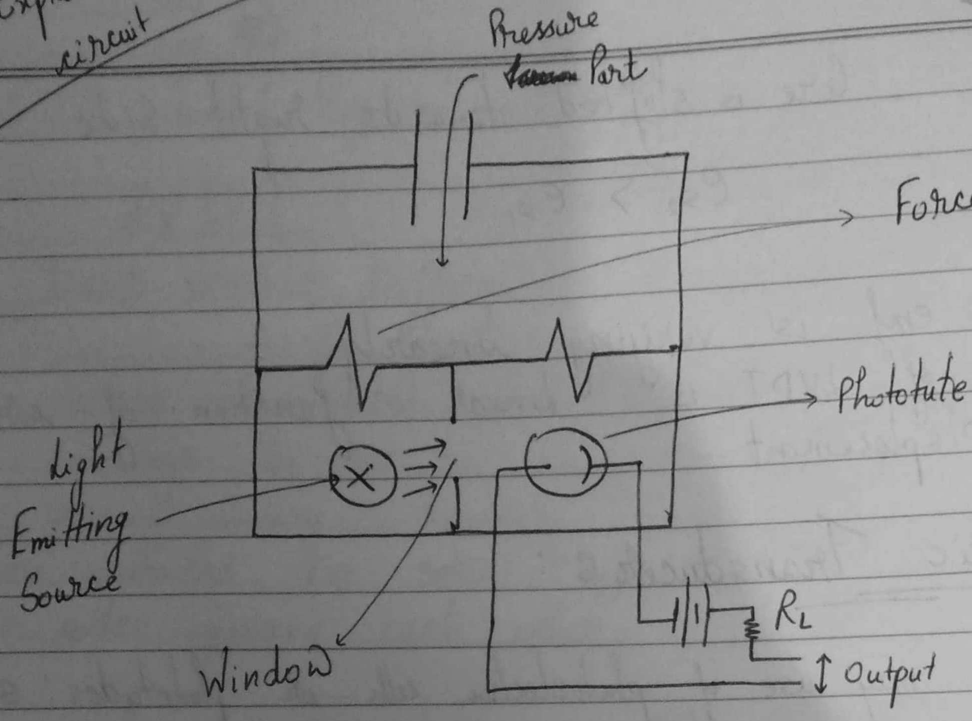


Principle:

The current produced is directly proportional to the amount of incident light.



Explain this circuit



[Micro ampere]
↓
Values

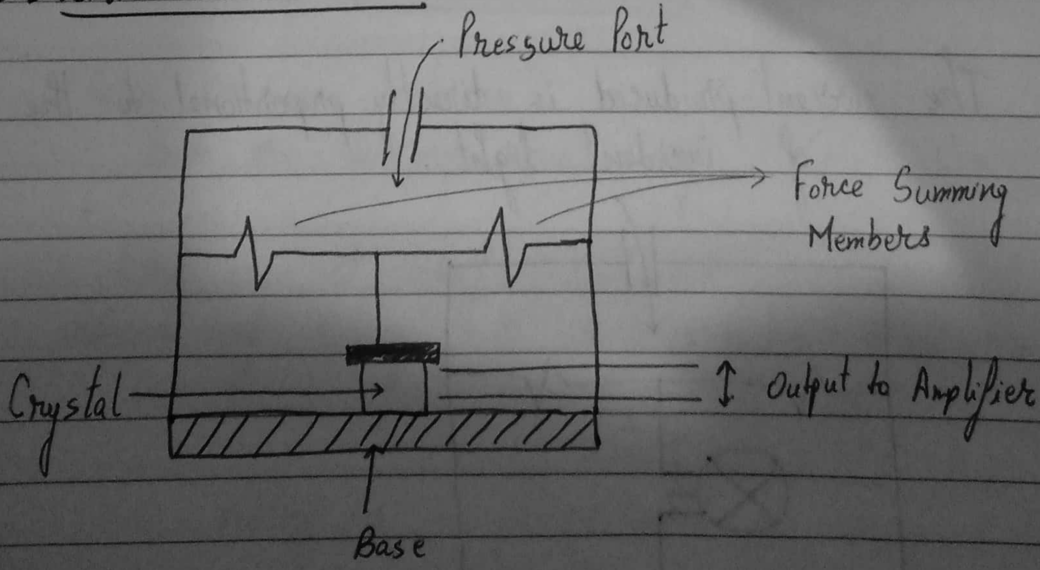
ADVANTAGE

- High efficiency
- It can measure static & Dynamic phenomena

DISADVANTAGE

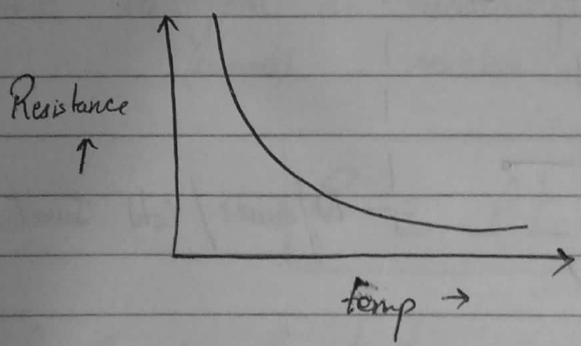
- Poor Long Terms Stability due to glass tube
- Poor Response to high frequency light variations.

Piezo Electric Transducers :



Thermist : → Thermal + Resistor

Two terminal semi- Conductor device.
It is having negative temperature Coefficient of Resistance
(It is inversely proportional to resistance)

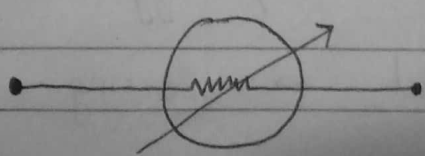


Normal Range of Thermister

$-100^\circ C$ to $300^\circ C$

Resistance Range of thermister
$0.5\ \Omega$ to $75\ M\Omega$

Symbol.



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exponential

Equation $$R_{T_1} = R_{T_0} \exp\left[\beta\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]$$

R_{T_1} ↓ absolute temp

Application :

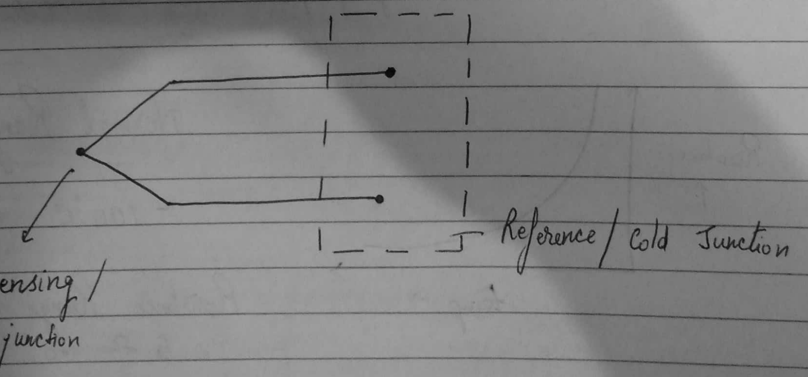
It is used to measure thermal conductivity, power at high temp.

It is used to provide time Delay in Circuit operation.

* It is composed of nickel, uranium and cobalt.

Thermo Couple :

It is consist of two metal [dissimiler] wires which is joined together at one end and terminated at another end.



Emf is induced when there is temp difference by two junction.

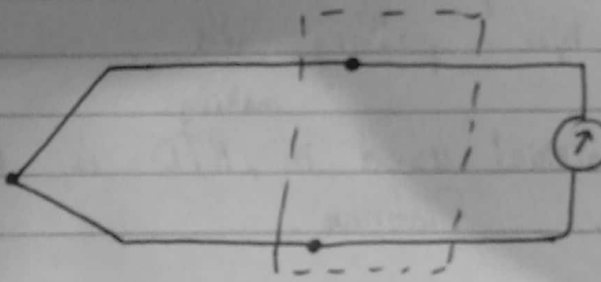
Joined together Terminal → Sensing

When a temp diff. exist b/w sensing and reference, junction, an emf is induced that causes flow of current in the circuit.

* Thermo electric effect caused by contact potential at a junction is called Seeback effect

So Thermocouple produces an emf when a temp difference exist between hot and cold junction.
Magnitude of produced emf is directly proportional to difference in temp b/w hot and cold junction

#



To Measure the temp by using thermocouple, A simple method is used to join a recording instrument or
(connect) sensitive milliampere.

$$\boxed{e = At + \frac{1}{2}Bt^2 + \frac{1}{3}Ct^3}$$

A, B, C are Constant
& t is the temperature difference.

Resistor of a conductor changes when its temp changes. This property is used in RTD for temperature measurement.

$$R_1 = R_{refference} \left[1 + \alpha \Delta T \right]$$

R_1 = resistance of conductor at $t°c$
R_{ref} resistance at Reference temp
α is the temp coefficient of resistance
ΔT Diff b/w operating and

The most Common material used in making RTD is Nickel, Copper, Platinum.

The Properties of Conductor Material in RTD :

1. High temp Coeff of Resistance (α).
2. High Resistivity to Permit Construction of small sensor
3. Melting temperature should be high.

The Resistance temp Relationship of Platinum is

$$T = 100 \frac{[R_T - R_0]}{R_{100} - R_0} + \alpha \left(\frac{T}{100} - 1 \right) \frac{T}{100}$$

Here.

T : temp
R_T : Resistance at temp T
R_0 : Resistance at $0^\circ C$ temp
R_{100} : Resistance at $100^\circ C$
α : Callender's Constant

Resistance Thermometer are generally of probe type for immertion in medium whose temp is to be measured. While measuring temp, the change in Resistance [ΔR] is measured using Wheat stone Bridge.