Basic Electrical Engineering

Unit - 1 DC & AC Circuits

DC Circuits :- Electrical Circuit Elements [R, L, C], Ohm's laws and it's limitations. KCL & KVL, Series-Parallel Circuits, Super Position theorem, Sample Prblms

AC Circuits :- AC Fundamentals : Equation of AC Voltage & Current, Waveform, time period, frequency, Amplitude, phase, phase difference, Average value, RMS value, form factor, Peakfactor, Voltage & current Relationship with phasor diagrams in R, L, C ckt concepts of Impedance, Active power, Reactive Power and apparent Power. Concept of Power-factor (Numerical problems)

Unit - II Machines and Measuring Instruments

Machines :- Construction, Principle and Operation of
1. DC Motor 2. DC Generator 3. Single phase T/F
4. Three phase Induction Motor 5. Alternator

- Applications of Electrical Machines.

Measuring Instruments :- Construction and Working Principle of
* Permanent Magnet Moving Coil (PMMC)
* Moving Iron (MI) Instruments
* Wheat Stone Bridge

UNIT-I

DC & AC Circuits

* **Voltage** :— It is define as the amount of work to be done to move a unit positive test charge from one place to another

$$\therefore \boxed{V = \frac{W}{Q}} \quad \text{Volts}$$

* **Current** :— It is defined as the time rate change of charge passing through a cross-sectional area of conductor.

$$\therefore \boxed{I = \frac{Q}{T}} \quad \text{Amps}$$

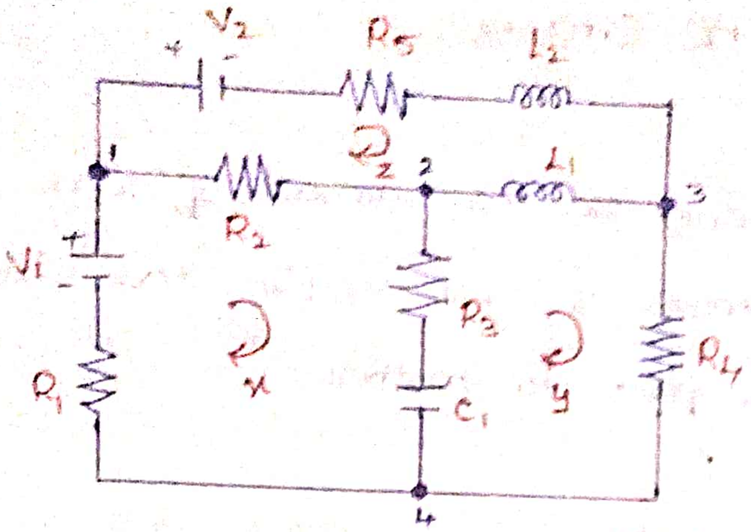
* **Power** :— The rate at which electric energy is converted to other forms of energy, equal to the product of current and voltage drop

$$P = \frac{W}{t} = VI \quad \text{watts} \qquad P = \frac{\text{Energy}}{\text{time}}$$

* **Energy** :— It is defined as the capacity to do work.

The Energy may exist in many forms such as electrical, Mechanical, Chemical, thermal etc., units is Joule

* Branch, Node, Loop :-



* **Branch :-** A direct path Joining two nodes of a network or graph is Called branch.
  A Branch may have one or more elements Connected in Series.

  Ex :- 12, 23, 24 etc.

* **Node :-** It is a Junction Point Where various electrical Elements are Connected together.

  Ex :- 1, 2, 3, 4 are nodes.

* **Loop :-** A loop is a Closed Path in the Circuit Where one returns to the Starting node without Crossing any intermediate node twice.

  Ex :- x, y, z are loops.

* **Active Network :-** These are the types of network which Contains one or more than one Eng Source in it.

* **Passive network :-** These are the types of network which does not Contain any Eng Source in it.

Network Elements

- Active Elements
  - Current Source
  - Voltage Source
- Passive Elements
  - Resistance
  - Inductance
  - Capacitance

* **Active Element :-** They are voltage and current source.

Example :- Generator, transistors etc.

* **Passive Elements :-** The components which stores or maintain energy in the form of voltage or current is known as Passive components.

Example :- Resistor, Inductor, Capacitor

* **Resistance (R) :-** The property of a material to resist the flow of electrons is called resistance.

Symbols :- The resistance of the conductor is $\propto$ to the length of the conductor and inversely proportional to the area of cross section.

R

Units :- ohm's (Ω)

$\therefore$ $R = \frac{\rho l}{a}$ Ω

* **Inductance :- (L)** It is the property of a circuit element by which it opposes the change in flux or current.

The inductance of a coil is defined as the ratio of flux linkage to the current flowing through the coil.

L

Units :- Henry

$L = \frac{N\phi}{I}$

* **Capacitor :-** Capacitor is a device that stores electrical charge.

It is defined as the ratio of charge transferred from one plate to an other of the capacitor to be the potential difference produce b/w the plate

Unit :- farad

$\therefore C = \frac{Q}{V}$

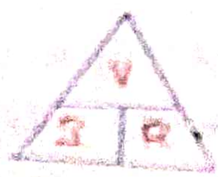
* **Ohm's Law :-**

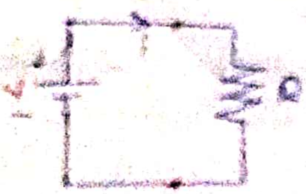
It state that at constant temperature in an electrical circuit the current flowing through a conductor from one terminal point on the conductor to another terminal point on the conductor is directly proportional to the potential difference (i.e., voltage drop or voltage) across the two terminal points

(or)

The potential difference applied across the circuit is directly proportional to the current flowing through the circuit provided the temperature remain constant

$V \propto I \Rightarrow V = IR$





$\therefore V = IR$ volts

$I = \frac{V}{R}$ Amp

$R = \frac{V}{I}$ Ω

* **Limitations of ohm's law :—**

1. It is applicable only for metallic conductors such as copper, silver etc.
2. It is not applicable for all electronic circuits such as vacuum tubes, semiconductor devices etc.

Problems

1. Calculate the Resistance of a conductor when there is a current 4.5 Amps passing through it and the voltage 60V in the ckt?

Sol

Given data

Voltage $V = 60V$

Current $I = 4.5$ Amps

$R = ?$

According to ohm's law

$$R = \frac{V}{I} = \frac{60}{4.5} = 13.33\Omega$$

2. A battery of a negligible resistance is connected to a 20Ω. What must be the battery voltage in order to that current of 0.75 Amps?

Sol Given data

Resistance $R = 20\Omega$

Current $I = 0.75$ Amps

$\therefore V = I \times R = 20 \times 0.75$

$\boxed{V = 15}$ volts.

3. Determine the resistance of 100mts length of a wire having a uniform Cross sectional area of 0.1×10^{-6} m^2 if the wire is made of some resistivity 50×10^{-8} Ω-m

Sol Given data:-

length $l = 100$ mts

Cross sectional area $= 0.1 \times 10^{-6} m^2$

Resistivity $\rho = 50 \times 10^{-8}$ Ω-m

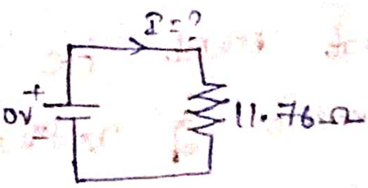
$$\therefore R = \rho \frac{l}{a} \ \Omega$$

$$= 50 \times 10^{-8} \times \frac{100}{0.1 \times 10^{-6}}$$

$$\therefore \boxed{R = 500\,\Omega}$$

* Home work:-

1. A 110V at the Resistance 11.76 are Connected to a Ckt what will be the Current and Power in the Given Ckt



2. The Resistance of a solid Conductor of diameter 0.5×10^{-2} mts and length is 3mts and the resistance is 0.00945Ω Calculate the Resistivity of an hallow Conductor? of [illegible]

Area $= \frac{\pi d^2}{4}$

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

$$\therefore \rho = \frac{R \times a}{l} \ \Omega\text{-mts}$$

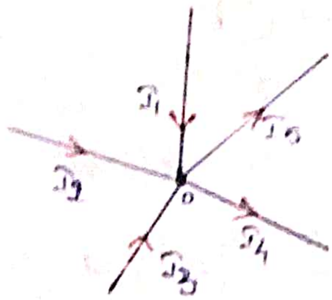
* Kirchoff's Laws :-

*** Kirchoff's Current Law :-** This law is also Called Kirchoff's Junction rule. It states that the algebraic sum of the Currents meeting at a node or Junction is Equal to zero.

(or)

The sum of the Currents Entering at a node is Equal to the sum of the Current leaving that node.

$$\Sigma I = 0$$



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

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

*** Kirchoff's Voltage Law :-** This law is also Called Kirchoff's loop rule. "The algebraic sum of the Potential differences around a Circuit must be zero"

(or)

In a closed Path, the algebraic sum of the Product of the Conductor plus Current and Resistance in Each of the Conductor plus the algebraic sum of the Emf in that Path is Equal to zero.

$$\Sigma IR + \Sigma EMF = 0$$

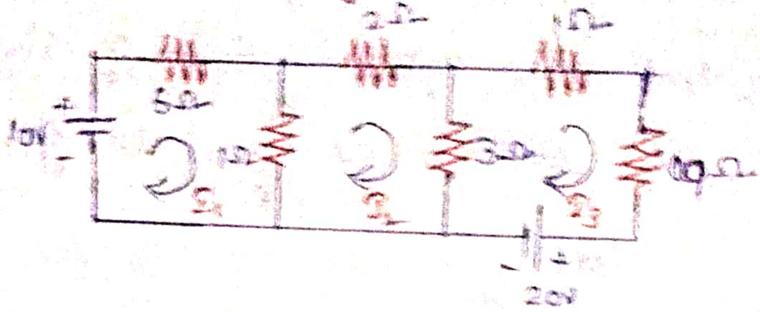
$\therefore V = IR$

$$\therefore \Sigma V + \Sigma Emf = 0$$

* Problems :—

Mesh Analysis

Find the current through the 2Ω resistor of the network.



Sol — Apply KVL to loop 1

$$-10 + 6I_1 + 1(I_1 - I_2) = 0$$

$$-10 + 6I_1 + I_1 - I_2 = 0$$

$$\boxed{7I_1 - I_2 = 10} \longrightarrow (1)$$

— Apply KVL to loop 2

$$1(I_2 - I_1) + 2I_2 + 3(I_2 - I_3) = 0$$

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

$$\boxed{-I_1 + 6I_2 - 3I_3 = 0} \longrightarrow (2)$$

Apply KVL to loop 3

$$3(I_3 - I_2) + 1I_3 + 9I_3 = -20$$

$$3I_3 - 3I_2 + 10I_3 = -20$$

$$\boxed{-3I_2 + 13I_3 = -20} \longrightarrow (3)$$

Solving eq 1 & 2 & 3

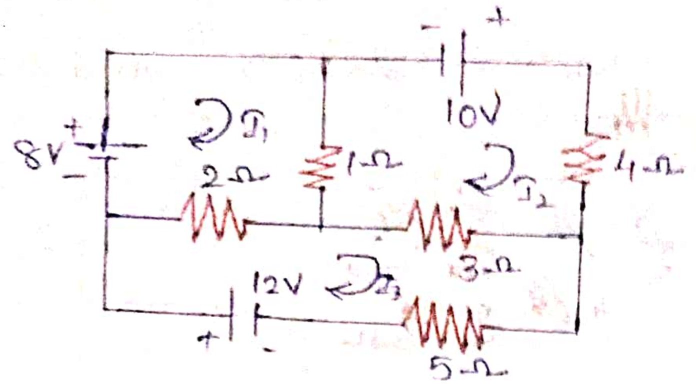
$I_1 = 1.34$ Amps

$I_2 = -0.62$ Amps

$I_3 = -1.68$ Amps

$I_{2Ω} = I_2 = -0.62$ Amps

2. Determine the current through the 5Ω resistor of the network shown



Sol — Apply KVL to loop '1'

$$-8 + 1(I_1 - I_2) + 2(I_1 - I_3) = 0$$

$$I_1 - I_2 + 2I_1 - 2I_3 = 8$$

$$3I_1 - I_2 - 2I_3 = 8 \longrightarrow (1)$$

— Apply KVL to loop '2'

$$-10 + 4I_2 + 3(I_2 - I_3) + 1(I_2 - I_1) = 0$$

$$4I_2 + 3I_2 - 3I_3 + I_2 - I_1 = 10$$

$$-I_1 + 8I_2 - 3I_3 = 10 \longrightarrow (2)$$

— Apply KVL to loop '3'

$$-12 + 2(I_3 - I_1) + 3(I_3 - I_2) + 5I_3 = 0$$

$$2I_3 - 2I_1 + 3I_3 - 3I_2 + 5I_3 = 12$$

$$-2I_1 - 3I_2 + 10I_3 = 12 \longrightarrow (3)$$

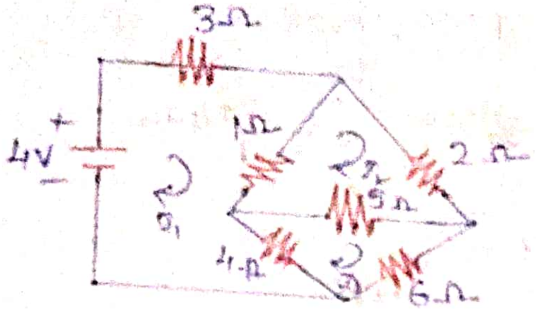
$I_1 = 6.012$ Amps

$I_2 = 3.27$ Amps

$I_3 = 3.383$

∴ The current at 5Ω resistor is $I_3 = 3.383$ Amps

3. Find the current supplied by the battery of the network shown in fig:



Sol - Apply KVL to loop I

$$-4 + 3I_1 + 1(I_1 - I_2) + 4(I_1 - I_3) = 0$$

$$3I_1 + I_1 - I_2 + 4I_1 - 4I_3 = 4$$

$$8I_1 - I_2 - 4I_3 = 4 \longrightarrow (1)$$

Apply KVL to loop 2.

$$0 = 2I_2 + 5(I_2 - I_3) + 1(I_2 - I_1)$$

$$2I_2 + 5I_2 - 5I_3 + I_2 - I_1 = 0$$

$$-I_1 + 8I_2 - 5I_3 = 0 \longrightarrow (2)$$

Apply KVL to loop 3

$$0 = 6I_3 + 4(I_3 - I_1) + 5(I_3 - I_2)$$

$$6I_3 + 4I_3 - 4I_1 + 5I_3 - 5I_2 = 0$$

$$-4I_1 - 5I_2 + 15I_3 = 0 \longrightarrow (3)$$

Solving 1, 2 & 3 we get

$I_1 = 0.658$ Amps

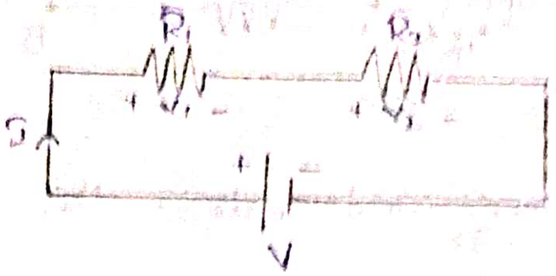
$I_2 = 0.242$ Amps

$I_3 = 0.256$ Amps

Current supplied by the battery $= I_1 = 0.658$ Amps

* Resistances in Series :—

In Series Connection the Same Current will flow through all the Elements which are Connected in Series



— From Circuit diagram

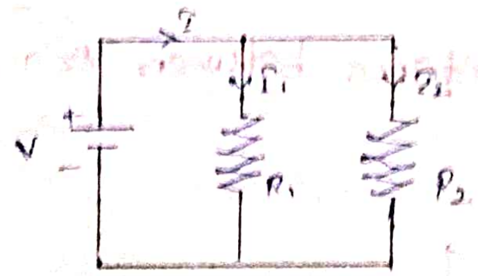
$$V = V_1 + V_2$$

$$IR = IR_1 + IR_2$$

$$\boxed{R_{eq} = R_1 + R_2}$$

* Resistance in Parallel :—

In Parallel circuit the voltage across Each branch is same which are connected in Parallel



$$\therefore I = I_1 + I_2$$

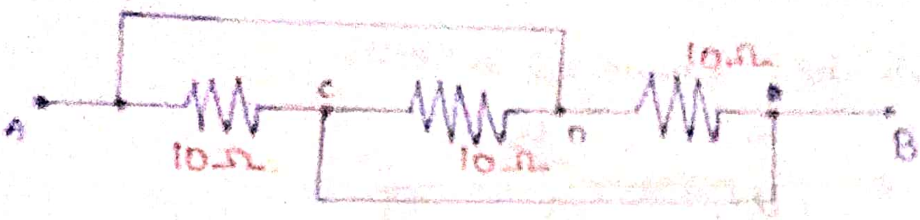
$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

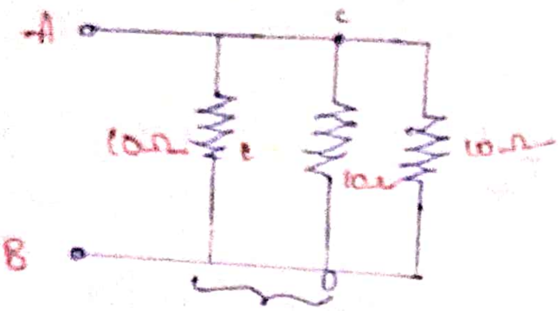
$$\therefore \boxed{R_1 \| R_2 = \frac{R_1 \times R_2}{R_1 + R_2}}$$

1. Find an Equivalent resistance between A and B in the network?

Sol

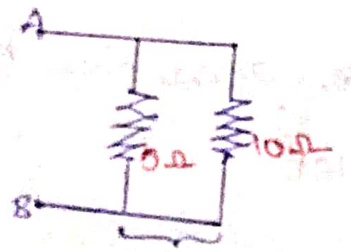


Sol Marking all the Junctions and redraw the network.



⇒ $R_1 \| R_2 = \frac{R_1 \times R_2}{R_1 + R_2}$

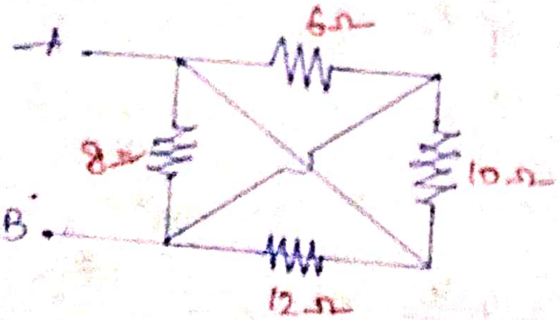
$= \frac{10 \times 10}{10+10} = 5\Omega$

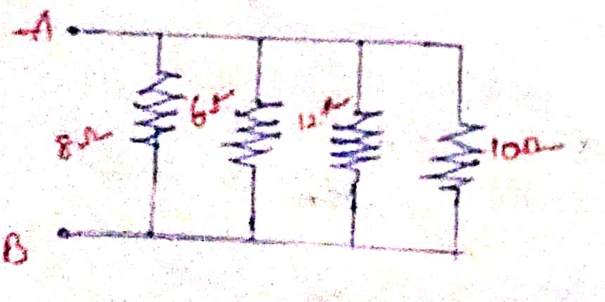


⇒ $\frac{5 \times 10}{5+10} = 3.33\Omega$

2. Find an Equivalent resistance between A and B in the network?

Sol

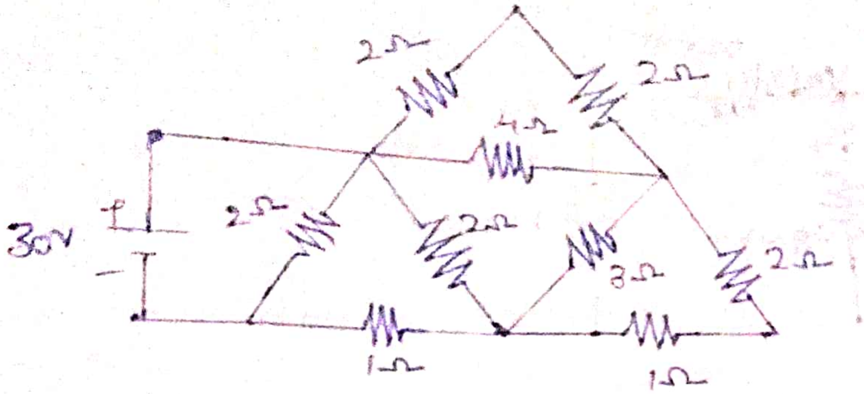


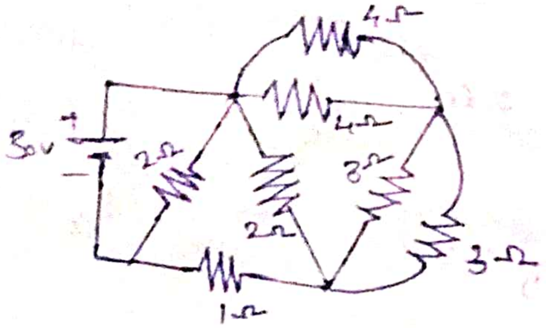


⇒ 2.11Ω

3. Determine the current delivered by the source in the network.

Sol

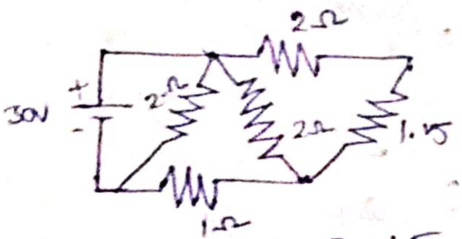




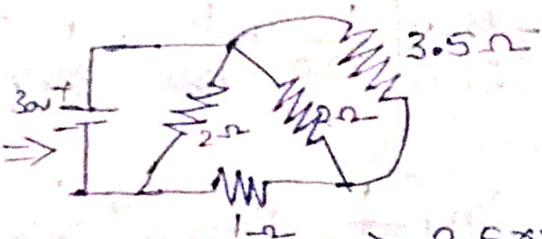
$= 2+2 = 4\Omega$

$= 2+1 = 3\Omega$

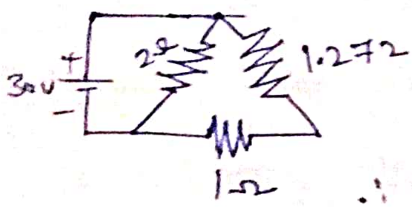
$\Rightarrow \frac{4\times4}{4+4} = 2\Omega, \quad \frac{3\times3}{3+3} = 1.5\Omega$

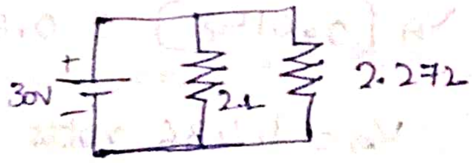


$\Rightarrow 2+1.5 = 3.5$



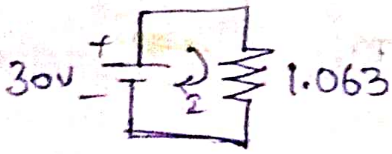
$\Rightarrow \frac{3.5\times2}{3.5+2} = 1.272\Omega$





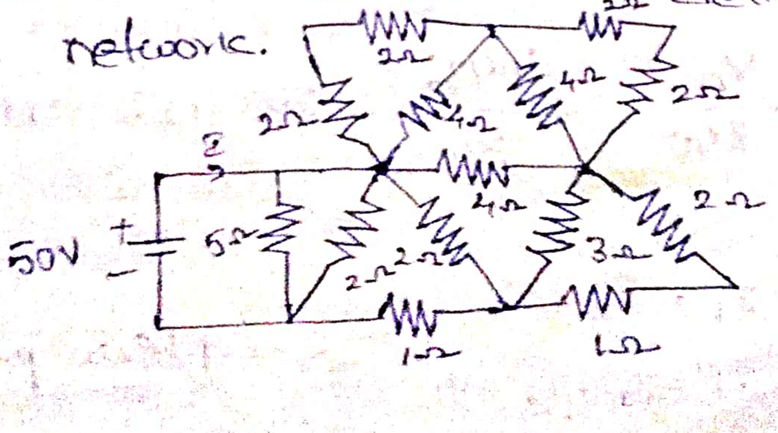
$\therefore 1.272+1 = 2.272\Omega$

$\Rightarrow \frac{2\times2.272}{2+2.272} = 1.063\Omega$



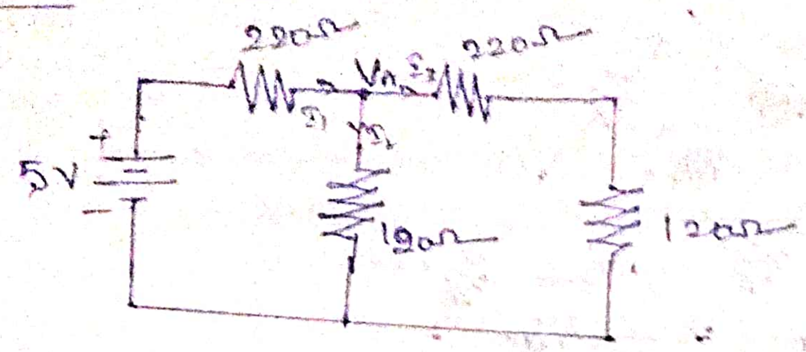
$\Rightarrow I = \frac{V}{R} = \frac{30}{1.063} = 28.2$ Amps

Home work: Find the current delivered by the source in the network.



Ans:- 56.82 ≈ 57 Amp

* Node Analysis :—



Sol

$$\frac{V_A - 5}{220} + \frac{V_A}{120} + \frac{V_A}{340} = 0$$

$$\frac{V_A}{220} - \frac{5}{220} + \frac{V_A}{120} + \frac{V_A}{340} = 0$$

$$-\frac{5}{220} + V_A\left[\frac{1}{220} + \frac{1}{120} + \frac{1}{340}\right] = 0$$

$$V_A\left(\frac{1}{220} + \frac{1}{120} + \frac{1}{340}\right) = \frac{5}{220}$$

$$V_A\,[0.0158] = 0.0227$$

$$V_A = 1.436 \text{ volts}$$

$$\therefore I_1 = \frac{5 - 1.436}{220} = 0.0162 \text{ Amps}$$

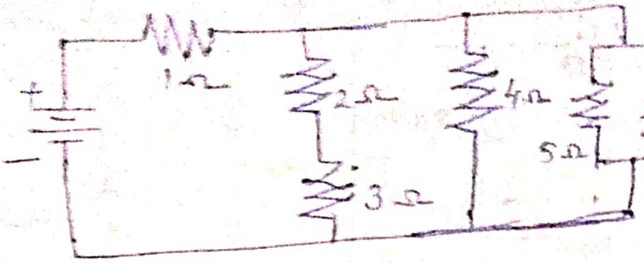
$$I_2 = \frac{V_A}{120} = \frac{1.436}{120} = 0.0119 \text{ Amp}$$

$$I_3 = \frac{V_A}{340} = \frac{1.436}{340} = 0.00422 \text{ Amps}$$

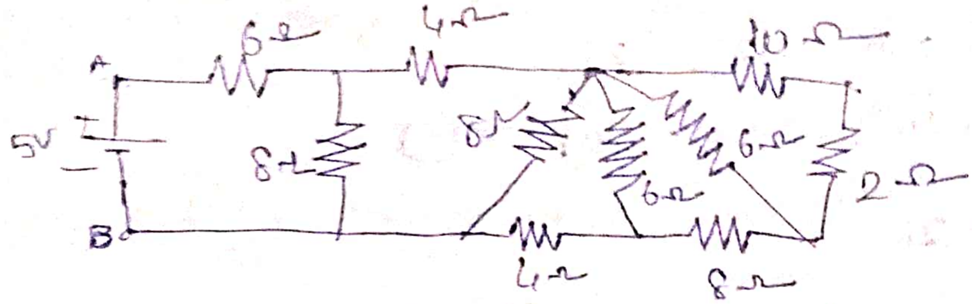
$$\therefore I_1 = I_2 + I_3$$

$$I_1 - I_2 - I_3 = 0 \Rightarrow \text{Hence proved}$$

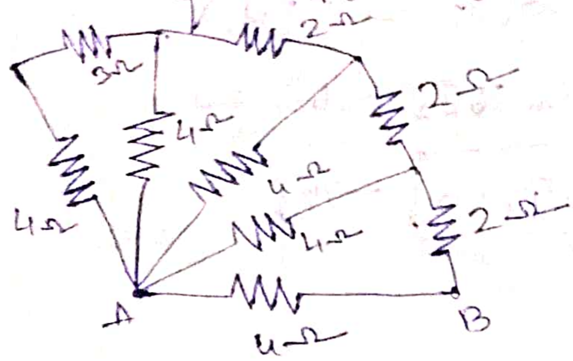
* Find the current in a given circuit.



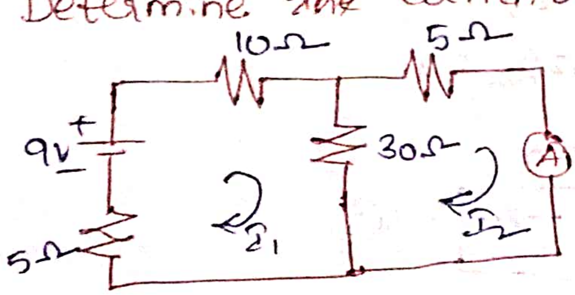
* Find the Equalent resistance & current in between A & B



* Find the Equivalent Resistance between A & B



1. Determine the current drawn by the ammeter



Sol According to KVL for loop I_1

$$-9 + 5I_1 + 10I_1 + 30(I_1 - I_2) = 0$$

$$5I_1 + 10I_1 + 30I_1 - 30I_2 = 9$$

$$\boxed{45I_1 - 30I_2 = 9V} \rightarrow (1)$$

Apply KVL to loop I_2

$$5I_2 + 30(I_2 - I_1) = 0$$

$$5I_2 + 30I_2 - 30I_1 = 0 \Rightarrow 35I_2 - 30I_1 = 0$$

$$-30I_1 + 35I_2 = 0 \rightarrow (2)$$

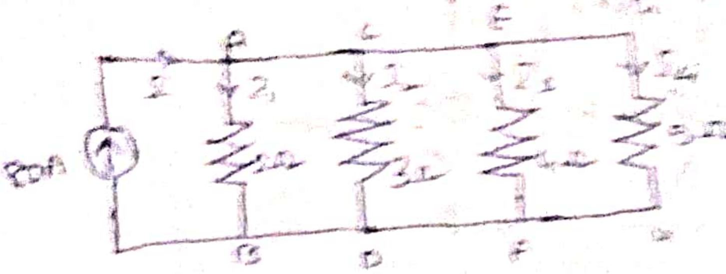
$I_1 = 0.466$

$\boxed{I_2 = 0.4}$

Hence proved

* By applying KCL calculate the current flowing through all the branches in the circuit as shown in fig.

Sol



$$I_1 = \frac{V_{AB}}{2},\ I_2 = \frac{V_{CD}}{3},\ I_3 = \frac{V_{EF}}{4},\ I_4 = \frac{V_{GH}}{5}.$$

$\because V_{AB} = V_{CD} = V_{EF} = V_{GH} = V$

$\therefore$ By applying KCL we get

$$I = I_1 + I_2 + I_3 + I_4$$

$$80 = \frac{V}{2} + \frac{V}{3} + \frac{V}{4} + \frac{V}{5}$$

$$80 = V\left[\frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{5}\right]$$

$$80 = V[1.283]$$

$$\therefore V = \frac{80}{1.283} = 62.35016$$

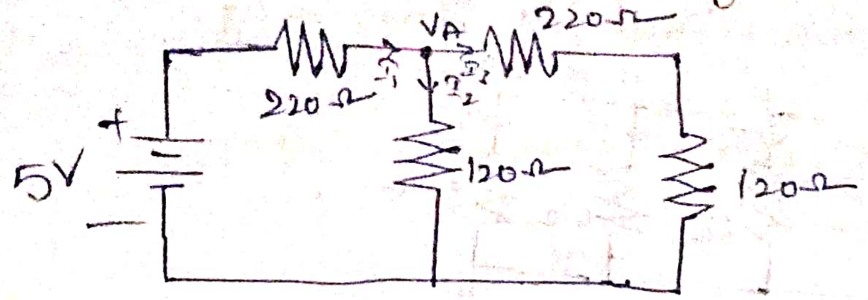
$$\therefore I_1 = \frac{62.35}{2} = 31.17\ Amp$$

$$I_2 = \frac{62.35}{3} = 20.77\ A$$

$$I_3 = \frac{62.35}{4} = 15.58\ A$$

$$I_4 = \frac{62.35}{5} = 12.47\ A$$

2 - Apply & Prove the KCL in given network



Sol

$$\frac{5-V_A}{220} + \frac{V_A}{120} + \frac{V_A}{340} = 0$$

$$\frac{V_A}{220} - \frac{5}{220} + \frac{V_A}{120} + \frac{V_A}{340} = 0$$

$$\frac{-5}{220} \quad V_A\left[\frac{1}{220} + \frac{1}{120} + \frac{1}{340}\right] = 0$$

$$V_A[0.0158] = \frac{5}{220} \Rightarrow 0.0227$$

$$\therefore V_A = \frac{0.0227}{0.0158} = 1.43 \text{ volts}$$

$$\therefore I_1 = \frac{5-1.43}{220} = 0.0162\,A$$

$$I_2 = \frac{1.43}{120} = 0.0119\,A$$

$$I_3 = \frac{1.43}{340} = 4.2058 \times 10^{-3}$$

$$= 0.0042058\,\text{Amp}$$

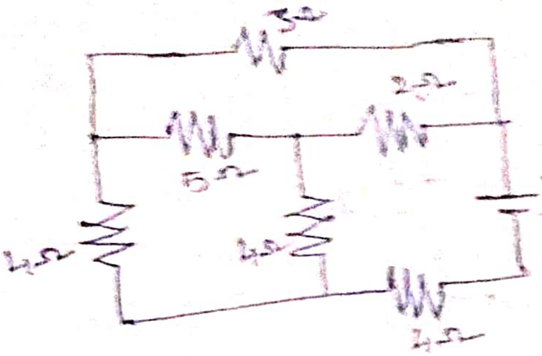
$$\therefore I_1 - I_2 - I_3 = 0.$$

$$\therefore \boxed{0.016 - 0.0119 - 0.0042058 = 0}$$

Hence Proved

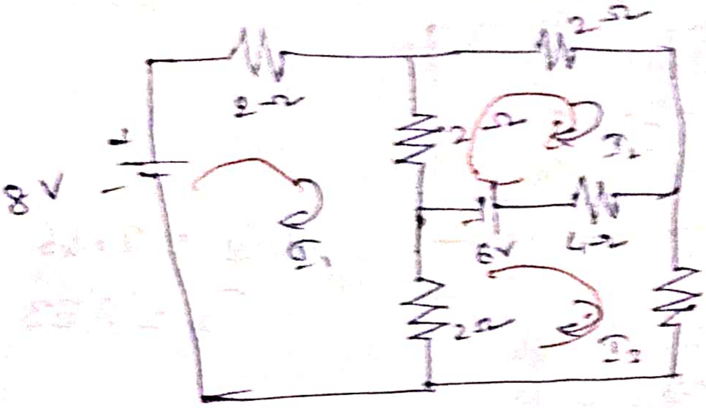
1. State and Explain the Kirchhoff's Current & voltage laws?

2. Find the Current delivered by the 12V battery?



1.66 A
0.93 A
0.83 A

3. Find the Current through 4Ω resistor in the network



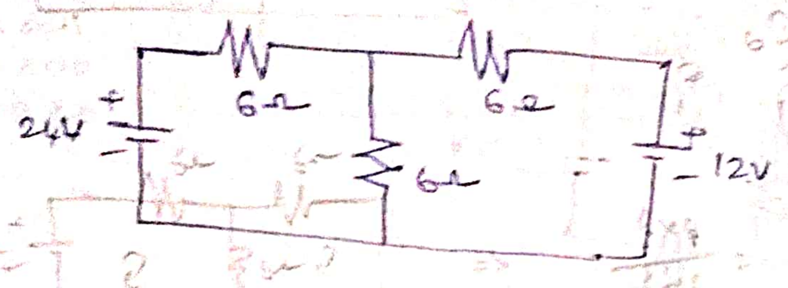
$I_1 = 2A$
$I_2 = 0.5A$
$I_3 = 1.5A$
$I_{4Ω} = I_3 - I_2 = 1Amp$

* Super Position theorem :—

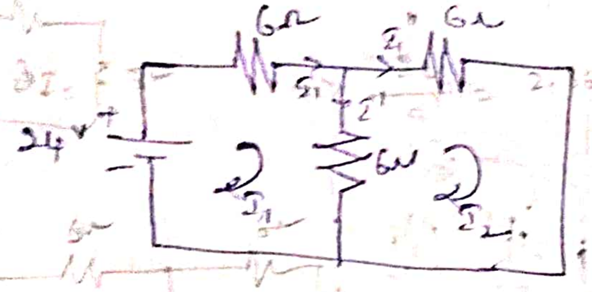
The Super Position theorem States that in a linear network Containing more than one Source, the Current flowing in any branch is the algebraic sum of Currents that would have been produced by Each Source taken Separately, with all the other Sources replaced by their respectively internal resistances. In Case the internal resistence of a Source is not provided, the Voltage Sources will be Short Circuited and Current Sources will be open Circuited.

1) Using the superposition theorem find the value of Current I_{BD} in the Circuit Shown in fig!

Sol



Sol Case (i) :- V_1 acting alone, V_2 short circuited

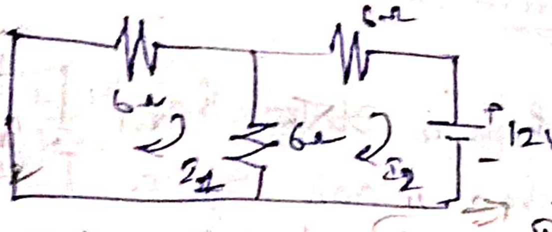


$12I_1 - 6I_2 = 24$
$-6I_1 + 12I_2 = 0$

$I_1 = 2.66$
$I_2 = 1.33$

$I' = 1.33$

Case (ii) :- V_2 acting alone, V_1 short circuited

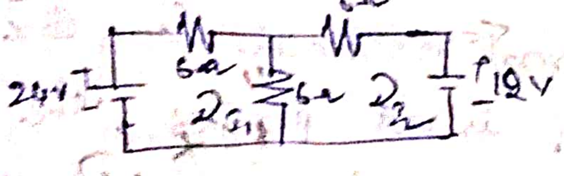


$12I_1 - 6I_2 = 0$
$-6I_1 + 12I_2 = -12$

$I_1 = -0.66$
$I_2 = -1.33$

$I'' = 0.67$

Case (iii) :-



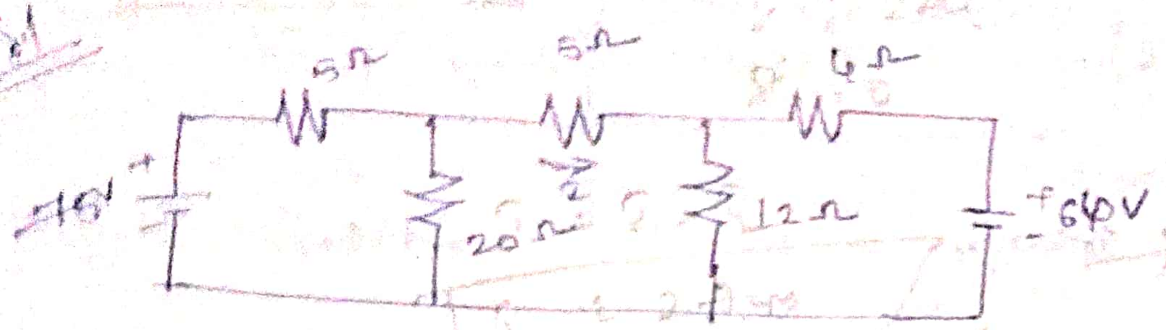
$12I_1 - 6I_2 = 24$
$-6I_1 + 12I_2 = -12$

$I_1 = 2$
$I_2 = 0$

$I = I' + I''$
$= 1.33 + 0.67$
$= 2$ Amps.

1) For the circuit, Calculate the current I using the Superposition theorem?

Sol



Sol

Case(i):-

$25I_1 - 20I_2 = 75$ $\quad I_1 = 8$ $\quad I_1' = 2$

$-20I_1 + 37I_2 - 12I_3 = 0$ $\quad I_2 = 5$

$-12I_2 + 16I_3 = 0$ $\quad I_3 = 3.75$

Case(ii):-

$25I_1 - 20I_2 = 0$ $\quad I_1 = -3.2$

$-20I_1 + 37I_2 - 12I_3 = 0$ $\quad I_2 = -4$ $\quad I_1'' = 3$

$-12I_2 + 16I_3 = -64$ $\quad I_3 = -7$

Case(iii):-

$25I_1 - 20I_2 = 75$ $\quad I_1 = 3.8$

$-20I_1 + 37I_2 - 12I_3 = 0$

$-12I_2 + 16I_3 = -64$ $\quad I_2 = 1$

$I_3 = -\frac{13}{4} = 3.25$

$I = I_1' + I_1''$

$= -2 + 3 = 1$ Amp

Hence proved

$i_1 = 0.256$ | 0.154 | ±0.266

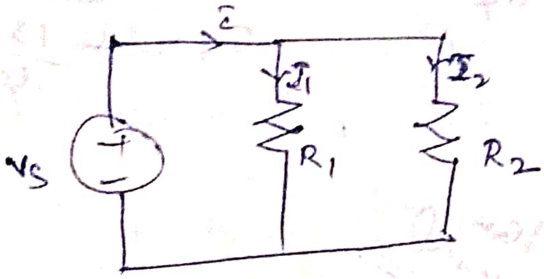
$i_2 : 0.075$ | −0.0607 | ±0.252

$i_3 : -0.169$ | −0.54 | wrong

---

* Current Division Rule :-

Current Has to be divided among the resistors in Parallel uses current division Rule

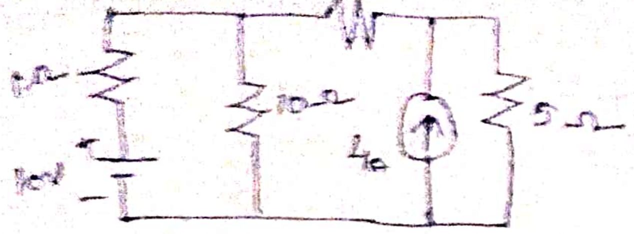


$$\therefore I_1 = I \times \frac{R_2}{R_1 + R_2}$$

$$\therefore I_2 = I_0 \times \frac{R_1}{R_1 + R_2}$$

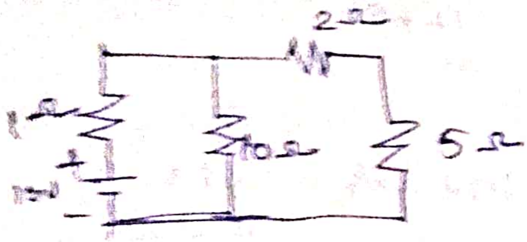
$\therefore I_3$ " " so on

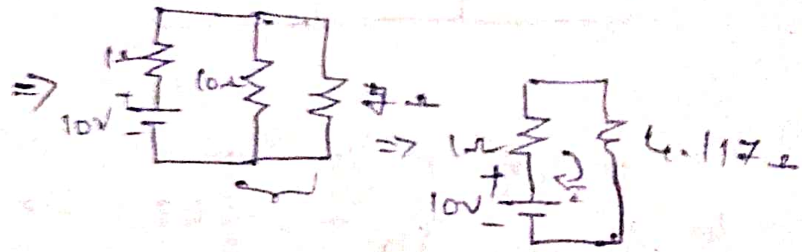
1) Find the current in the 10Ω Resistor in fig



Sol:

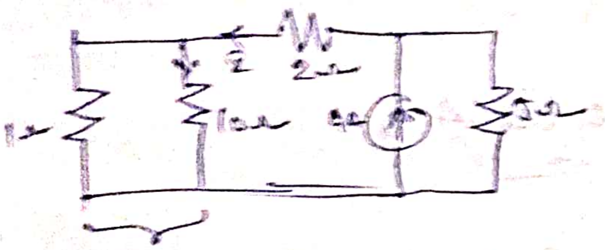
4A is open circuited

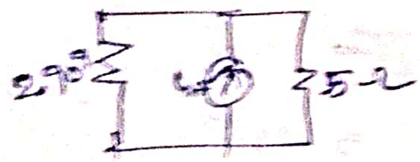




$$\Rightarrow I = \frac{10}{5.117} = 1.95 \text{ Amps}$$

$$I_1' = I \times \frac{7}{10+7} = 0.802 \text{ Amp}$$





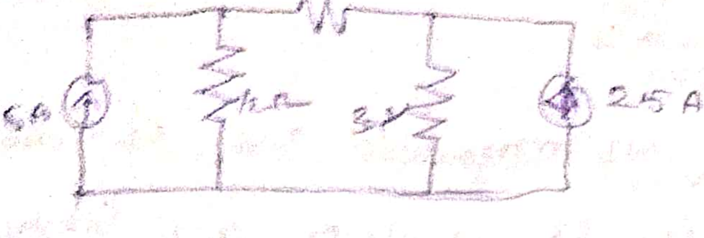
$$\Rightarrow I = 2.528 \text{ Amps}$$

$$I_1'' = 2.528 \times \frac{1}{1+10} = 0.229 \text{ Amps}$$

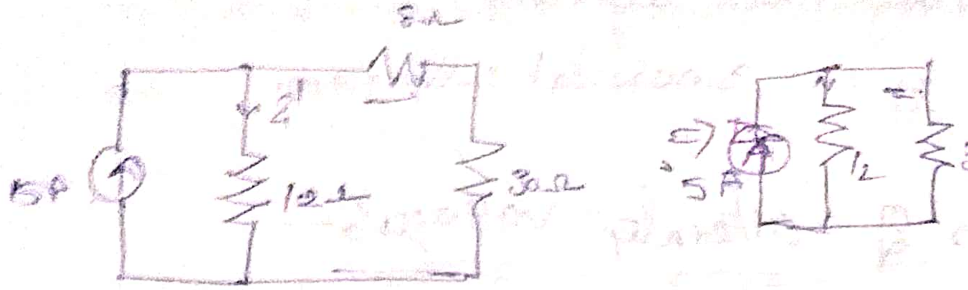
$$I = I' + I'' = 0.802 + 0.229$$

$$\boxed{I = 1.03 \text{ Amps}}$$

find the 8Ω current through 8Ω resistor?



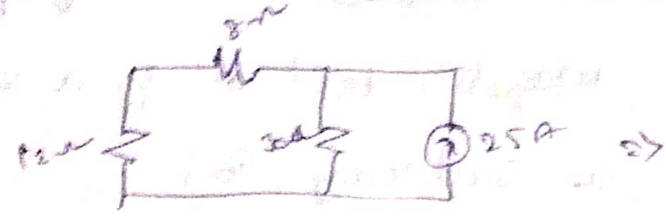
Sol



$\Rightarrow I_1' = 5 \times \frac{12}{12+38}$

$= 1.2$ Amp

Step 2:-



$\Rightarrow I_1'' = 25 \times \frac{30}{20+30} = 15$ Amp

$\therefore I = I' + I'' = 1.25 + 15 = 16.2$ Amp

...t through the

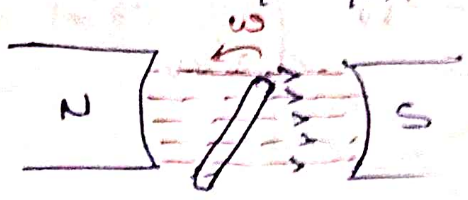
AC Quantities

An alternating waveform changes its magnitude and direction periodically. Many times alternating voltages and currents are represented by a sinusoidal waveform.

* Generation of alternating voltages

- An alternating voltage can be generated either by rotating a coil in a stationary magnetic field or by a rotating a magnetic field within a stationary coil.
In both the cases the magnetic field is cut by the conductor or coil and an Emf is induced in the coil according to Faraday's law of Electromagnetic Induction.

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



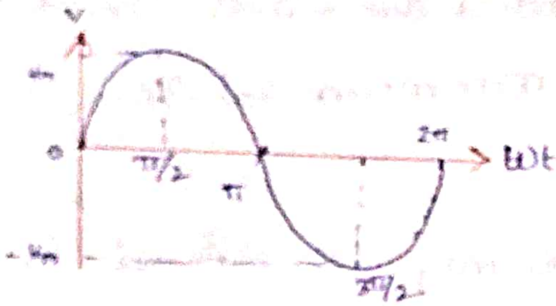
$$e = -N\frac{d\phi}{dt} = E_m \sin\omega t$$

*

AC Quantities on Circuits

* **Waveform;**— A waveform is a graph in which the instantaneous value of any Quantity is plotted against time.

∴ Alternating waveform



* **Cycle:**— one complete set of Positive and negative values of an alternating Quantity is termed a cycle

* **Frequency:**— The number of cycles per second of an alternating Quantity is known as its frequency. It is denoted by 'f' and is measured in Hertz (Hz)

* **Time period:**— The time taken by an alternating Quantity to complete one cycle, is called its time period. It is denoted by T and is measured in seconds.

$$T = \frac{1}{f} \text{ sec}$$

* **Amplitude:**— The maximum positive or negative value of an alternating Quantity is called the amplitude

* **phase:**— The phase of an alternating Quantity is the time that has elapsed since the Quantity has last passed through zero point of reference

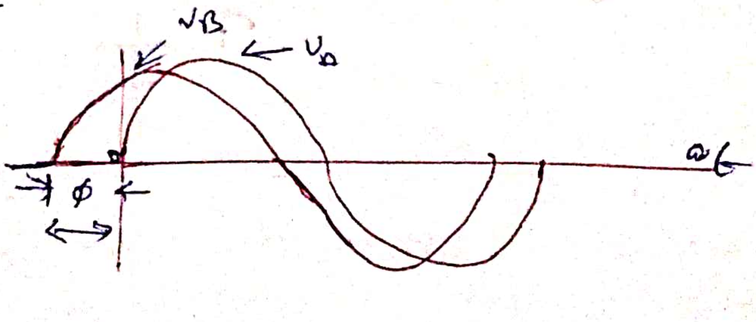
* **phase differences**— This term is used to compare the phases of two alternating Quantities.

Two alternating Quantities are said to be in phase when they reach their maximum and zero values at the same time.

Their maximum value may be different in magnitude

A leading alternating Quantity is one which reaches its maximum or zero value Earlier compared to the other Quantity

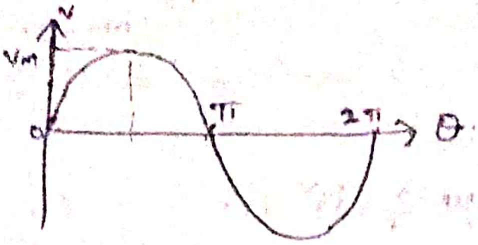
A lagging alternating Quantity is one which attains its maximum or zero value later than the other Quantity. A plus (+) sign when used in connection with the phase difference denotes 'lead' where as a minus (−) sign denotes 'lag'.



$V_A = V_m \sin \omega t$

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

* Root Mean Square (rms) or



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

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} v^2(\theta)\, d\theta}$$

∴ Substitute $v = V_m \sin\theta = V_m^2 \sin^2\theta$

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

∴ $\left[\sin^2\theta = \frac{1-\cos 2\theta}{2}\right]$

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

∴ $\int \cos 2\theta = \frac{\sin 2\theta}{2}$

$\int 1 = \theta$

$$= \sqrt{\frac{V_m^2}{4\pi}\left[1 - \frac{\sin 2\theta}{2}\right]_0^{2\pi}}$$

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

∴ $[\sin 4\pi = 0]$

$$= \sqrt{\frac{V_m^2}{4\pi}[2\pi]}$$

$$= \sqrt{\frac{V_m^2}{2}}$$

$$= \sqrt{\frac{1}{2}} \cdot \sqrt{V_m^2}$$

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

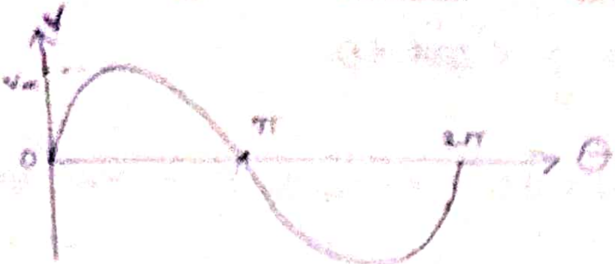
$$I_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + i_3^2 + \dots + i_n^2}{n}}$$

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

$$= \sqrt{\text{mean value of } (i)^2}$$

— Hence rms value of the alternating current is given by.

* Average value of Sinusoidal wave-form :—



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

— The average value of an alternating Quantity is defined as the arithmetic mean of all the values over one Complete cycle.

$$V_{avg} = \frac{1}{\pi} \int_0^{\pi} v(\theta)\, d\theta$$

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

$$= \frac{V_m}{\pi} \int_0^{\pi} \sin\theta \, d\theta \qquad \therefore \int \sin\theta = -\cos\theta$$

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

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

$$= \frac{V_m}{\pi} \left[-(-1) - (-1)\right] \qquad \therefore \cos\pi = -1, \ \cos 0 = 1$$

$$= \frac{V_m}{\pi} (1 + 1)$$

$$\boxed{V_{avg} = \frac{2V_m}{\pi}} \Rightarrow 0.637\, V_m$$

$$I_{avg} = \frac{i_1 + i_2 + \cdots + i_m}{m}$$

The average value of the Current is given by.

* **Form factor:-** It is defined as the ratio of rms value to the average value of the given Quantity

$$\text{Form factor} = \frac{\text{Rms value}}{\text{Average value}}$$

$$= \frac{0.707\, V_m}{0.637\, V_m}$$

$$\boxed{\text{form factor} = 1.11}$$

* **Peak factor :-** Crest factor

It is defined as the ratio of maximum value to Rms value of the given Quantity is known as Peak factor

$$\text{Peak factor} = \frac{\text{Maximum value}}{\text{Rms value}} = 1.414$$

Find the RMS and average value of an AC represented by

$i = 6.28 \sin 3140t$

Sol Given $i = 6.28 \sin 3140t$

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

$I_m = 6.28$, $\omega = 3140$

$\therefore I_{rms} = \frac{I_m}{\sqrt{2}} = 0.707 \times 6.28$

$= 4.439 \approx 4.44$ Amp

$\therefore I_{avg} = 0.636 \times I_m = 0.636 \times 6.28$

$= 3.99$ Amps

2. An alternating current is given by $i = 141.4 \sin 314t$

find (i) maximum value of current

(ii) frequency

(iii) Instantaneous value when $t = 0.001$ sec

Sol

$i = 141.4 \sin 314t$

$i = I_m \sin \omega t$

(i) maximum value of current $I_m = 141.4$ Amp

(ii) $\omega = 2\pi f$

$314 = 2\pi f$

$\therefore f = \frac{314}{2\pi} \Rightarrow 49.9 \approx 50$ Hz

(iii) $i = 141.4 \sin[2\pi f t] \Rightarrow i = 141.4 \sin(2\pi \times 50 \times 0.001)$

$i = 141.4 \sin\left(\frac{\pi}{10}\right) \Rightarrow i = 141.4 \sin(18°) = 43.695$ Amp

$= 43.695$ Amp

3) An alternating voltage has an amplitude of 100V find its (i) RMS value (ii) Average value

Sol) $E_m = 100V$

∴ RMS value $V_{rms} = 0.707 \times 100$

$= 70.7V$

∴ Average value $V_{avg} = 0.636 \times 100$

$= 63.6V$

4. An alternating current is represented by $i = 220 \sin(157t + \frac{\pi}{2})$ ($I_m \sin \omega t + \phi$). Calculate the following. (i) frequency (ii) Time (iii) Peak value (iv) Mean value or Average value (v) Rms value

Sol)

(i) frequency =

$\omega = 2\pi \times f$

$157 = 2\pi \times f \Rightarrow f = \frac{157}{2\pi} = 25Hz$

(ii) Time $T = \frac{1}{f} = \frac{1}{25} = 0.04$ sec

(iii) $I_m = 220$ Amps

(iv) Average value $I_{avg} = 0.636 \times I_m$

$= 0.636 \times 220$

$= 139.92$ Amps $= 140$ Amps

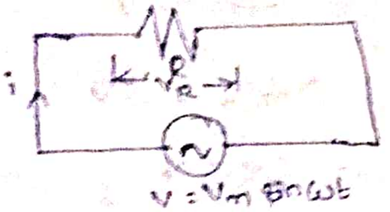
(v) Rms value $I_{rms} = 0.707 \times 220$

$= 155.6 \approx 156$ Amps

* Behaviour of a Pure Resistor in An AC Circuit

Consider a Pure Resistor R Connected across an alternating Voltage Source V as shown in fig

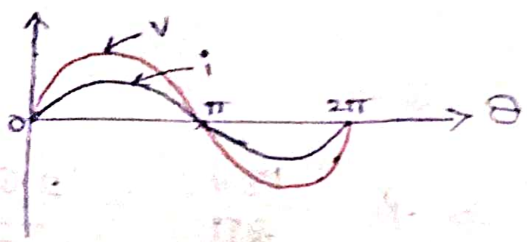
Let alternating Voltage $V = V_m \sin\omega t$



* Current :- The alternating Current i is given by

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

* Waveform :- Shows the voltage & current waveform



* phasor diagram :- Shows the phasor diagram

* Impedance :- It is the resistance offered to the flow of current in an ac circuit. In a Purely resistive circuit

$$Z = \frac{V}{I} = \frac{V_m}{I_m} = \frac{V_m}{\frac{V_m}{R}} = R$$

$$\therefore \boxed{Z = R}$$

* phase difference: Since the voltage & current are in phase with each other, the phase difference is zero

$\boxed{\phi = 0}$

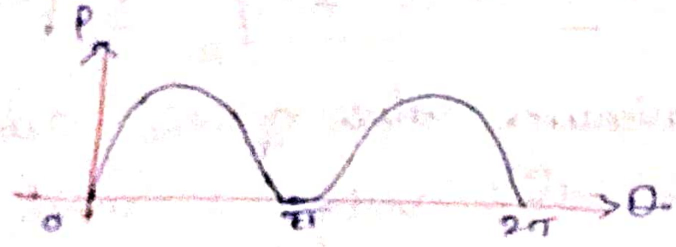
* Power factor :- It is defined as the cosine of the angle b/w the voltage & current phasors.

$$P.f = \cos\phi = \cos 0° = 1$$

unity P.f.

* Power :- Instantenous Power

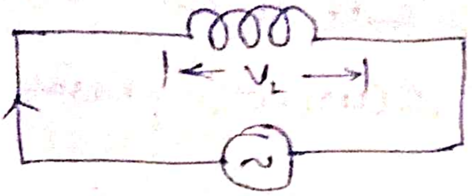
$\boxed{P = VI}$ $\therefore P = VI\cos\phi$



Power Waveform

* Behaviour of a Pure Inductor in an AC Circuit

Consider a Pure Inductor L Connected across an alternating voltage V as shown in fig



$V = V_m \sin\omega t$

* **Voltage :-** The ac Generating voltage

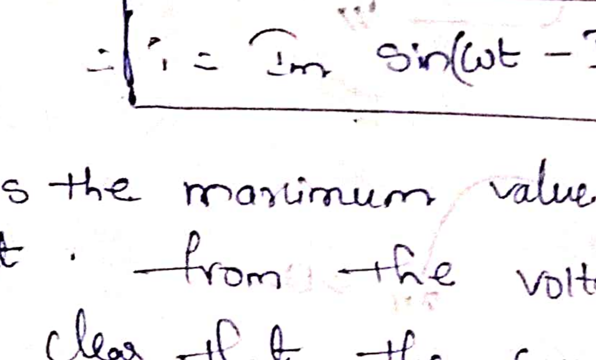
$$V = V_m \sin\omega t \quad \text{volts}$$

* **Current :-** The ac i is given by

$$\therefore i = I_m \sin\left(\omega t - \frac{\pi}{2}\right) \qquad \therefore I_m = \frac{V_m}{\omega L}$$

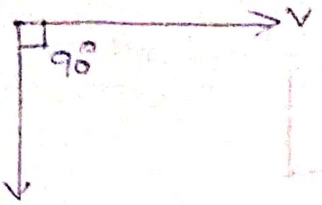
$\therefore I_m$ is the maximum value of the alternating current. from the voltage & current Equation it is clear that the current lags behind the voltage by 90° in a Purely Inductive Circuit

* **Waveform :-** Shows the voltage & current waveform



Waveform

* **phasor diagram :-** Shows the phasor diagram



* **Impedance :-** In a pure Inductive Circuit

$$Z = \frac{V}{I} = \frac{V_m}{I_m} = \frac{V_m}{\frac{V_m}{\omega L}} = \omega L$$

$\therefore$ $\boxed{Z = \omega L}$ $\quad \because \boxed{\omega = 2\pi f}$ //

The ωL is called Inductive Reactance, it is denoted by X_L and is measured ohm (Ω)

* **phase difference :-**

It is the angle between the voltage & current phasor

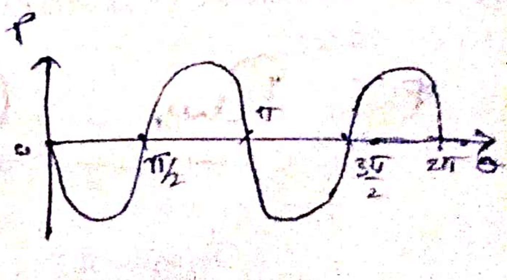
$\boxed{\phi = 90^\circ}$ //

* **Power factor :-** It is defined as the cosine of the angle between the voltage & current phasor

$$P.f = \cos\phi = \cos 90^\circ = 0$$

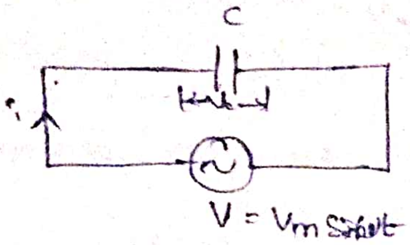
* **Power :-** Instantaneous power $\boxed{P = VI\cos\phi}$

$\boxed{P = VI}$ watts //



$\therefore$ $\boxed{P = -\frac{V_m I_m}{2} \sin 2\omega t}$ //

* Pure Capacitor in an AC Circuit :-



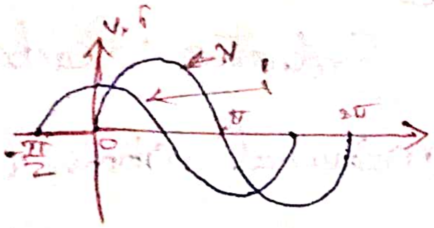
* Voltage :-

$$V = V_m \sin \omega t \quad \text{volts}$$

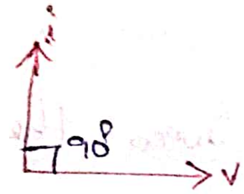
* I current :- $i = I_m \sin(\omega t + \frac{\pi}{2})$ Amps

$\therefore$ $\boxed{I_m = \omega C V_m}$

* Waveform :-



* phasor diagram :-



* Impedance :-

$$Z = \frac{V}{I} = \frac{V_m}{\omega C V_m} = \frac{1}{\omega C}$$

$$\therefore \boxed{Z = \frac{1}{\omega C}} \ \Omega$$

* phase difference :- $\phi = 90°$

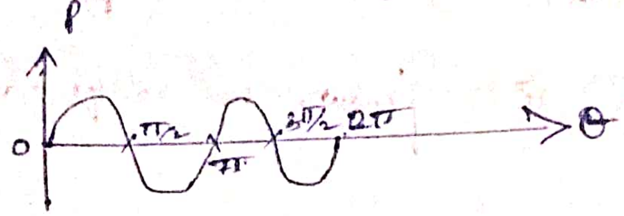
* Power factor :-

$$p.f = \cos\phi = \cos 90° = 0$$

∴ Power :-

$P = vi$

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



* Problems :-

1. An ac circuit consist of a ~~Power~~ pure resistance of 10 ohms and is connected across an ac supply of 230V, 50Hz. Calculate (i) current (ii) Power consumed (iii) P.f (iv) write down the Equations of voltage & current

Sol (i) Current :- $I = \frac{V}{R} = \frac{230}{10} = 23$ Amps

(ii) Power $P = VI = 230 \times 23$

$= 5290$ watts

(iii) Power factor $= \cos\phi = \cos 0° = 1$

unity P.f

(iv)

$v = V_m \sin\omega t$

$i = I_m \sin\omega t$

∴ $V = \frac{1}{\sqrt{2}} V_m$

∴ $V_m = \sqrt{2} \times V \Rightarrow \sqrt{2} \times 230 = 325.26$ V

$I_m = \sqrt{2} \times i = \sqrt{2} \times 23 = 32.52$ Amps

⇒ $\omega = 2\pi \times f$

$= 2\pi \times 50 = 314.15$

$v = 325.26 \sin 314.15t$ volts

$i = 32.526 \sin 314.15t$ Amps

2. An inductive coil having negligible resistance and 0.1 henry inductance is connected across a 200V, 50Hz supply. Find (a) Inductive Reactance (b) Rms value of current (c) Power (d) p.f. (e) Equations for voltage & current

Sol

(i) $X_L = 2\pi f L$

$= 2\pi \times 50 \times 0.1$

$X_L = 31.41\,\Omega$

(ii) $I_{rms} = \frac{V}{X_L} = \frac{200}{31.41} = 6.367$ Amps

(iii) Power $= V \times I \times \cos\phi$

(iv) $\because \cos\phi = \cos(90) = 0$

$\therefore$ Power $\boxed{P = 0}$ //

(V)

$V = V_m \sin\omega t$

$i = I_m \sin(\omega t - \frac{\pi}{2})$

$\therefore V_m = 1.414 \times 200$

$= 282.8$ volts

$I_m = 1.414 \times 6.367$

$= 9$ Amps

$\therefore V = 282.8 \sin 314.16 t$

$i = 9 \sin(314.16t - \frac{\pi}{2})$

3. A Capacitor has a Capacitance of 30 μ farads which is Connected across a 230V, 50 Hz supply. Find (a) Capacitive reactance (b) rms value of current (c) Power (d) P.f (e) Equation of for Voltage & current.

Sol

(i) $X_c = \frac{1}{2\pi f \times C} = \frac{1}{2 \times \pi \times 50 \times 30 \times 10^{-6}} = 106.103\ \Omega$

(ii) $I = \frac{V_m}{X_c} = \frac{230}{106.103} = 2.167\ Amps$

(iii) $Power = V I \cos\phi$

(iv) $\therefore \cos\phi = \cos 90° = 0$

$\therefore$ Power $\boxed{P = 0}$

(v) $v = V_m \sin\omega t$

$i = I_m \sin(\omega t + \frac{\pi}{2})$

$\therefore$

$V_m = \sqrt{2} \times V$

$= 325.26$ volts

$I_m = \sqrt{2} \times 2.16 = 3.05$ Amps

$\therefore v = 325.26 \sin 314.15 t$

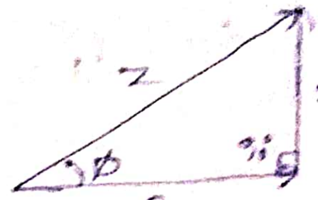
$i = 3.05 \sin(314.15 t + \frac{\pi}{2})$

* **Impedance :—** The Impedance is defined as the ratio of sinusoidal Voltage to the sinusoidal Current

$\therefore Z = \frac{V}{I}\ \Omega \quad , \quad Z = R + jX\ \Omega$

∴ The real part of the Impedance is resistance, and the Imaginary Part is reactance

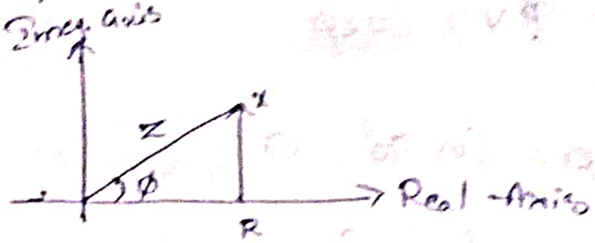
$\therefore Z = R + j(X_L - X_C)\ \Omega$



Impedance triangle :-

Z

$j^2 = -1$



* **Admittance :—** The inverse of Impedance is admittance
It is defined as the ratio of sinusoidal Current to voltage.

$\therefore$ Admittance $Y = \frac{1}{Z}\ \mho$

$\therefore$ Conductance $G = \frac{1}{R}\ \mho$

$\therefore$ Susceptance $B = \frac{1}{X}\ \mho$

* **Power :—** Power is the rate at which work is done.

$\therefore$ Power $\boxed{P = V \times I}$ watts in DC Source

$\therefore$ Power $\boxed{P = VI\cos\phi}$ watts in AC Source

$\therefore \boxed{P = VI}\ \because \cos\phi = 1$

* Active Power :—

Active power in an ac circuit is given by the product of voltage, current and cosine of the phase angle ϕ

$$\therefore \boxed{P = VI\cos\phi} \text{ watts}$$

* Reactive Power :—

Reactive power in an ac circuit is given by the product of voltage, current and sine of the phase angle ϕ

$$\therefore \boxed{Q = VI\sin\phi} \text{ VAR}$$

volt Ampere Reactive

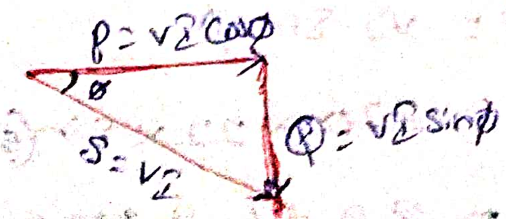
* Apparent Power :—

The product of rms value of voltage & current is called Apparent power

$$\boxed{S = VI} \text{ KVA}$$

* Power triangle :—

The equations associated with the average, reactive, apparent power can be developed geometrically on a right angle triangle called the power triangle



* Power Factor :-

The ratio of active power to the apparent power is known as power factor.

$$\therefore \text{Power factor} = \frac{\text{Active power}}{\text{Apparent power}} = \frac{P}{S}$$

* Find the power delivered from a sinusoidal voltage source with $V = 220$ volts to an impedance $Z = 6+j8\ \Omega$, also calculate the power factor, active power, reactive power, apparent power.

Sol:

$V = 220$ volts

$Z = R + jX \Rightarrow 6+j8\ \Omega \Rightarrow$

$$\therefore I = \frac{V}{Z} = \frac{220}{10\angle 53.13}$$

$$\boxed{I = 22\angle -53.13}\ \text{Amps}$$

Active Power $P = VI\cos\phi$

$= 220 \times 22 \times \cos(53.13^\circ) = 2904$ watts

$Pf = \cos\phi = \cos(53.13) = 0.6$

* The (voltage & current) absorbed from load.

Reactive power $Q = VI\sin\phi$

$= 220 \times 22 \times \sin(53.13^\circ)$

$= 3871.9$ VAR

Apparent power $S = VI = 220 \times 22$

$= 4840$ VA

UNIT- II

Machines & Measuring Instruments

* **DC Generator :—** A DC Generator is a machine which converts mechanical Energy into Electrical Energy.

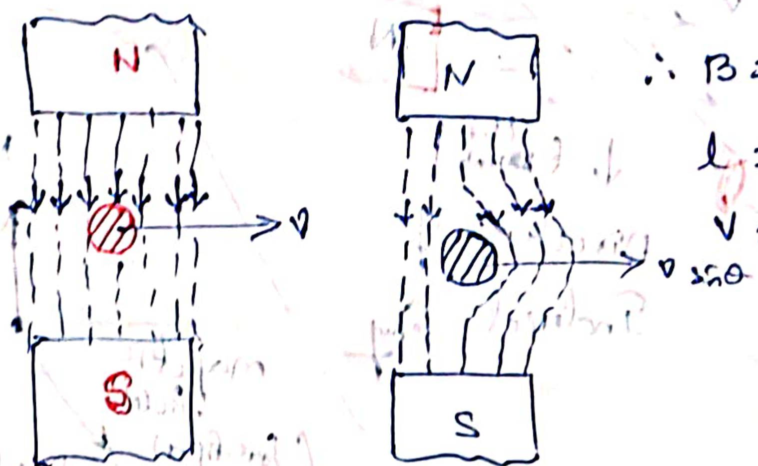
The Energy Conversion is based on the principle of "dynamically induced Emf"

* **Statement :-** Whenever a ~~Constant~~ Conductor cuts magnetic flux lines causes a dynamically induced Emf Produced in that Conductor.

It works on the Principle of "Faraday's Laws of Electro magnetic Induction"

* **Dynamically Induced Emf :—**

An Emf induced in a Conductor due to its motion on uniform magnetic field is called dynamically Induced Emf.



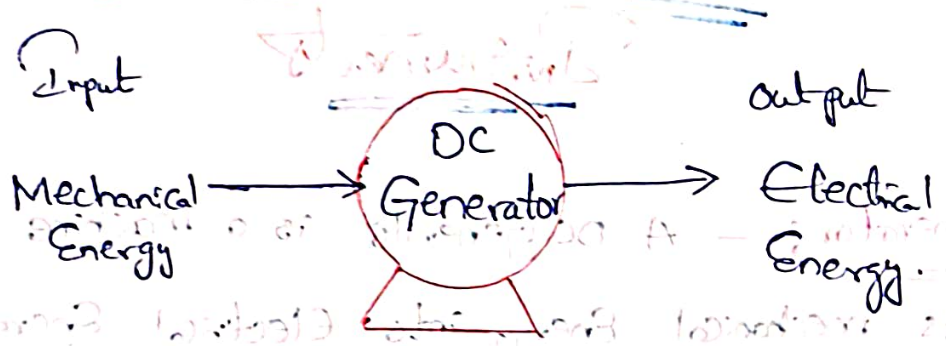
∴ B = flux density

l = length mts

v = velocity mts/sec

$e = Blv$ volts $e = Blv\sin\theta$

* **Diagram:—**



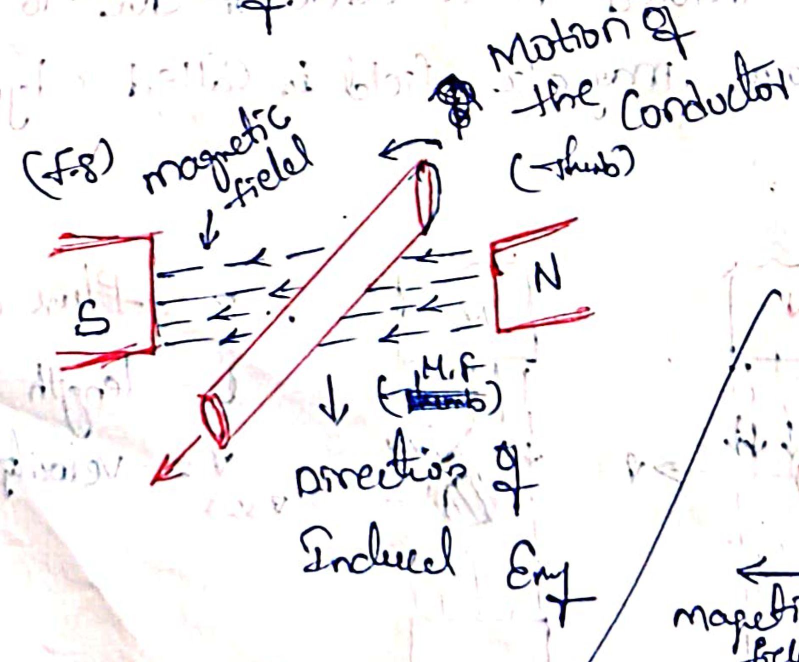
* **Fleming's Right Hand Rule:—**

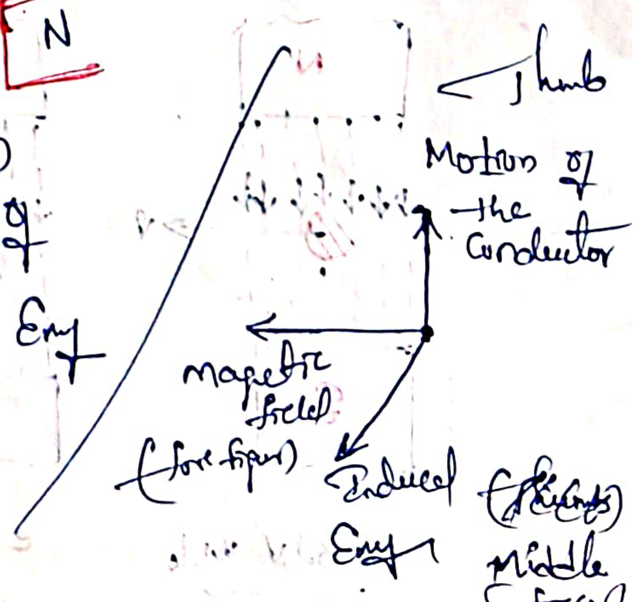
— This rule is mainly used to find the "Direction of induced Emf in a Conductor" placed in magnetic field

— Fore finger indicate the direction of magnetic field

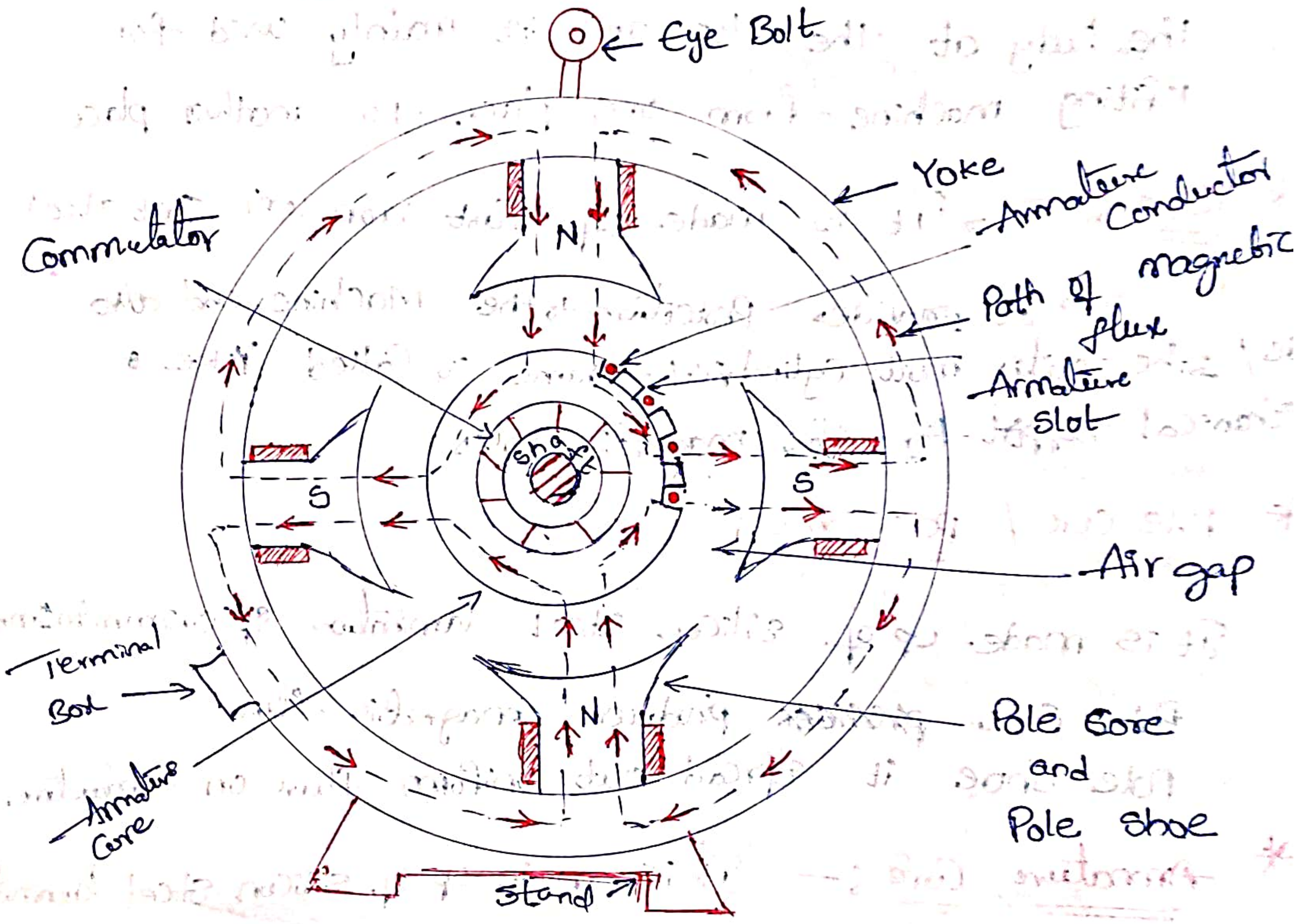
— Thumb Indicate the direction of Motion of the Conductor.

Middle finger indicate the direction of the induced Emf.





* Construction & working of DC Generator :



* Parts of DC Generator :—

1. Eye Bolt
2. Yoke
3. Pole Core & Pole shoe
4. Armature Core
5. Commutator
6. Brushes
7. Shaft
8. Terminal Box
9. Stand (or) Base plate
10. Enter Poles.

* **Eye Bolt :—** It is made of Cast iron. It is provided the body at the top and is mainly used for lifting machine from one place to another place

* **Yoke :—** → It is made of Cast iron (or) Cast steel

→ It provides Protection to the Machine and also provide / → The outer most cylindrical frame is called Yoke. Mechanical Support for the magnetic poles.

* **Pole core / pole shoe :—**

It is made up of silicon steel laminations of 0.2mm to 1mm

Pole Core ~~provides~~ produces magnetic flux

Pole Shoe it spread out uniform flux on Conductor.

* **Armature Core :—** It is made up of silicon steel laminat 0.3mm to 0.5mm.

It Houses the Conductors to produce dynamically Induced Emf.

* **Armature winding :—** It is made up of Copper.

In Armature winding the Emf will be induced.

* **Commutator :—**

It is made up of Hard drawn Copper.

It Converts AC to D.C

* **Brushes :—** It is made up of Carbon (or) Graphite (or) Copper

It Collects the current from Commutator Segments.

* Shaft :— It is made up of steel. It Beary the whole machine.
* Terminal Box :- It is made up of Cast iron. All termi are brought at to this place.
* Base plate :— It is made up of Cast iron (or) Cast Ste It provide Support to the machine to have the facility of foundation.
* Enter Poles :— It is made up of Silicon steel laminat It reduces the Cross magnetizating Effect.

* Emf Equation of DC Generator :—

Generated Emf $E_g = \frac{\phi Z N}{60} \times \frac{P}{A}$ volts

∴ E_g = Generating voltage in volts

ϕ = flux per pole wb

Z = no. of Conductors

N = Speed in rpm

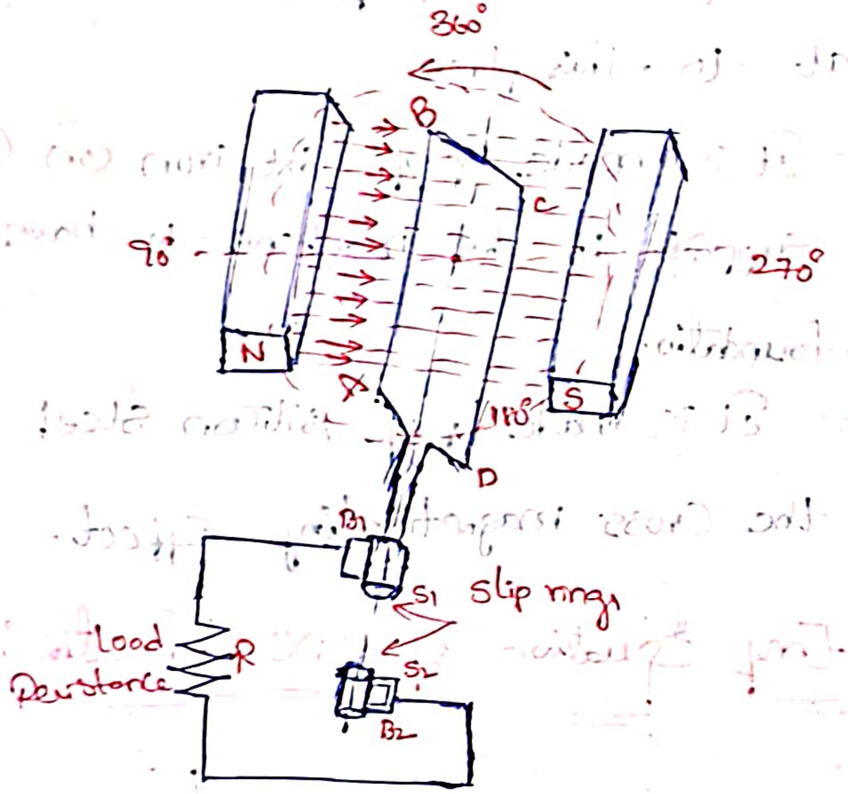
P = no. of Poles

A = no. of Parallel Paths

∴ for lap winding $A = P$

for wave winding $A = 2$

* Simple Loop Generator :-



Consider a single turn coil ABCD rotating in the uniform magnetic field.

The two ends of coil are joined to two slip rings S_1, S_2 which are insulated from each other and from the shaft and these slip rings S_1, S_2 which are insulated from each other and from the shaft and these slip rings rotate along with the coil.

*At zero degree (Position '1') :-

In this position the induced emf is zero because the coil sides AB and CD are cutting no flux but are moving parallel to it.

* 0° to 90° [Position 2]:—

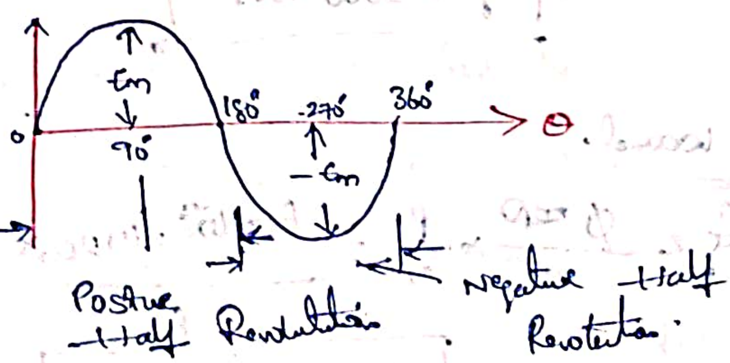
The coil rotates 0° to 90° therefore the rate of cutting flux linkages is maximum. Hence at this instant the Emf induced is maximum. but flux linked with the coil is minimum.

* 90° to 180° [Position 3]:—

The flux linked with the coil gradually increases but the rate of change of flux linkage decreases.
Hence Emf induced in this position is decreased to zero.

* 180° - 360° (Position 4) :- The variations in the magnitude of Emf are similar to those in the first half revolution.

It value is maximum when coil is in position 4 and ~~[illegible]~~ minimum when in position 1.



* Applications of DC Generator:—

* The various applications of DC Generators are as listed below:

1. used for General lighting.
2. used for to charge battery because they can be made to give constant output voltage.
3. Used in Series arc lighting
4. Used for supplying field Excitation current in DC locomotives for Regenerative braking.

1. A 4-Pole, DC Generator having wave wound & lap wound armature winding has 51 slots each slot containing 20 conductors. Find the generated voltage in the machine when speed is 1500 rpm and flux per pole is 60 mwb?

Sol Given data

$P = 4$

$A = 2$, wave wound

$A = P = 4$, lap wound

$Z = 51 \times 20 = 1020$

$N = 1500$ rpm

$\phi = 60$ mwb $= 60 \times 10^{-3}$

for wave wound:

$$\therefore E_g = \frac{\phi Z N}{60} \times \frac{P}{A} = \frac{60 \times 10^{-3} \times 1020 \times 1500}{60} \times \frac{4}{2}$$

$$E_g = 3060 \text{ volts}$$

For lap wound.

$$\therefore E_g = \frac{\phi Z N}{60} \times \frac{P}{A} = \frac{60 \times 10^{-3} \times 1020 \times 1500}{60} \times \frac{2}{2}$$

$$E_g = 1530 \text{ volts}$$

* An 8-pole DC Generator has 960 armature conductors and a flux per pole of 20 m-wb. Calculate the Emf Generated when running at 500 rpm if the armature is (i) lap (ii) wave connected.

Sol for lap = 160 volts, for wave = 640 volts

* Block diagram of DC Motor :-

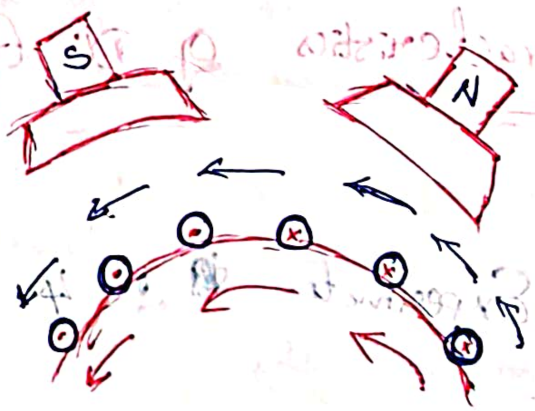
D.C Motor is a rotating Machine which Converts Electrical Energy into Mechanical Energy.

Electrical Energy → D.C Motor → Mechanical Energy

The Construction of DC Motor is similar to DC Generator.

* Working of DC Motor :-

The D.C Motor works on the Principle that "when a Current Carrying Conductor is placed in a magnetic field, it Experience a mechanical force" tending it to drive from Position of higher flux linkage to the Position of lower flux linkage and the direction of this force is obtained by Fleming's Left hand rule.

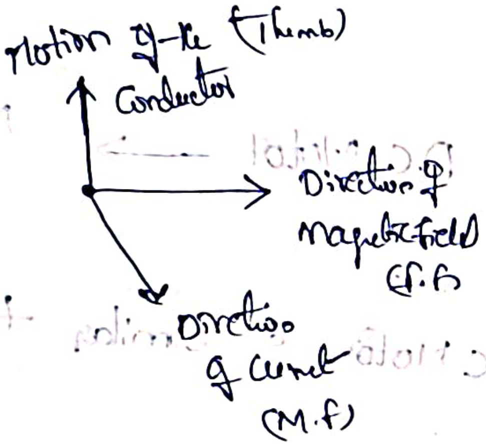


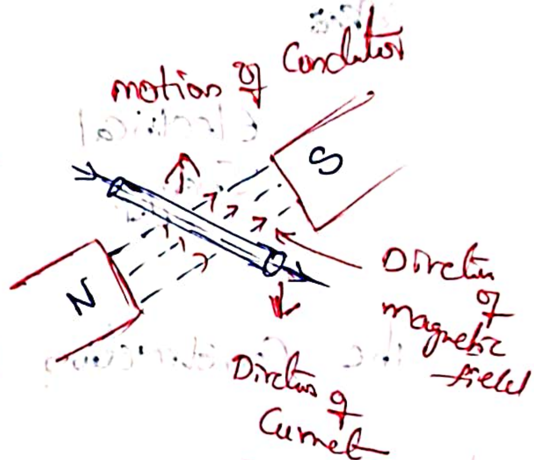
* fig shows a part of Multipole DC Motor.
* The Magnetic field is set up by the field winding.
* Supply is given to armature Conductor, the current will flow through the Conductor a mechanical force Experience hence it tends to rotate

* Each Conductor Experiences a force and it tends to rotate the armature in anticlockwise direction as shown in fig
* The force on all Conductors Collectively produce a driving torque which ...

* Flemings Left hand Rule :—

This rule is mainly used to find the "Direction of force on the Conductor" placed in a magnetic field.





* Back Emf :— [E_b]

According to faradays law of Electromagnetic Induction Principle an Emf is induced in the conductor, whose direction is opposition to the applied voltage Because of its opposing direction it is known as Back Emf.

$$\therefore E_b = \frac{\phi Z N}{60} \times \frac{P}{A} \text{ volts}$$

* Magnetization Characteristics of DC Generator :—

In BEE Lab Experiment no. 4.

* Applications :—

1. Domestic
2. Agricultural
3. Industrial etc

* Single - phase Transformer:

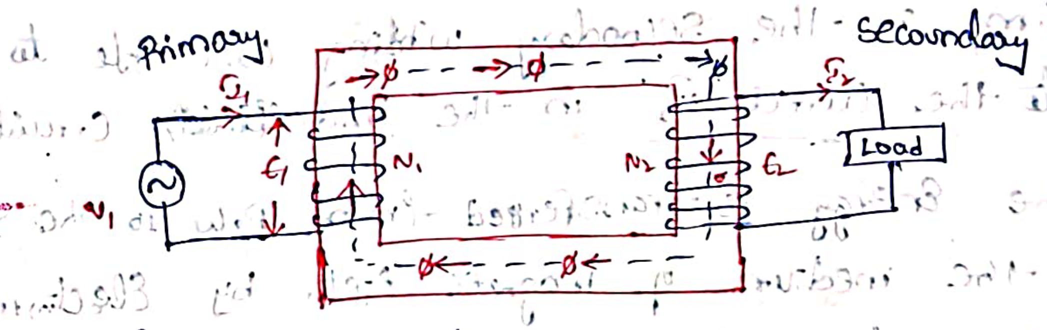
Define:- A Transformer is a static device, which transfers Electrical Power from one voltage level to another voltage level without changing the frequency.

Principle of working of a transformer:

The transformer works on the principle of Faraday's law of Electromagnetic Induction "When ever a conductor links the changing flux, an Emf is induced in that conductor"

induced Emf ∝ rate of change of flux linkages & no. of turns.

* Construction:



* Transformer essentially consists of two windings. Primary & secoundary which are wound on a common laminated magne core.
* The core is made up of silicon steel lamination (or) soft iron to provide a path of Low relucatance for magnetic flux.
* The winding which is connected to supply main is known as Primary winding
* The winding which is connected to the Load circuit is known as Secoundary winding

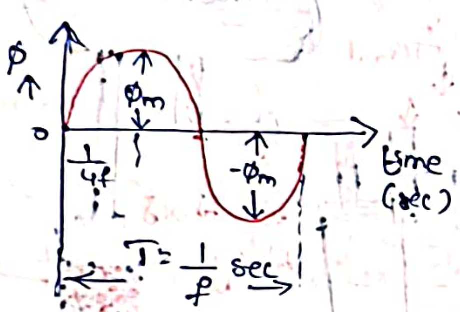
* There is no Electrical (or mechanical) Connection b/w the two windings. but there is a magnetic linkage b/w the them.

Working :—

* The Primary winding is Connected to an a.c supply source of voltage V_1, ~~and~~ current I_1 and freq f will flow through it.
* This Current produces an alternating flux 'ϕ' in the Core which varies with time
* This flux first links with p.w hence produces self Induced Emf E_1 in p.w which opposes the applied voltage
* ~~The Emf~~ The flux 'ϕ' Passes through the magnetic Core, and links with secondary winding also. so induces an Emf called mutual Induced Emf E_2 in the secondary winding
* The Emf in the secondary winding will able to Circulate the current I_2 in the load ~~circuit~~ circuit.
* Thus the Energy is transferred from p.w to the s.w through the medium of magnetic field by Electromagnetic Induction principle without any change in freq.

$$\therefore \frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = \frac{V_1}{V_2} = K$$

* Emf Equation of Transformer :-



Average rate of change of flux, $\frac{d\phi}{dt} = \frac{\phi_m}{1/4f}$

$= 4 \times \phi_m \times f$ volts

∴ form factor = 1.11

∴ RMS Emf/turn $= 1.11 \times 4 \times f \times \phi_m$

$$E = 4.44 f \phi_m \text{ volts}$$

∴ Emf induced in P.W. & S.W

$$E_1 = 4.44 \times f \times \phi_m \times N_1 \text{ volts}$$

$$E_2 = 4.44 \times f \times \phi_m \times N_2 \text{ volts}$$

* 1-ϕ T/F has 400 turns on P.W. & 1000 turns on S.W. If it is operating at 50Hz supply. the maximum flux 0.045 wb find (i) P.W & S.W. Emf (ii) Ef induced / turn

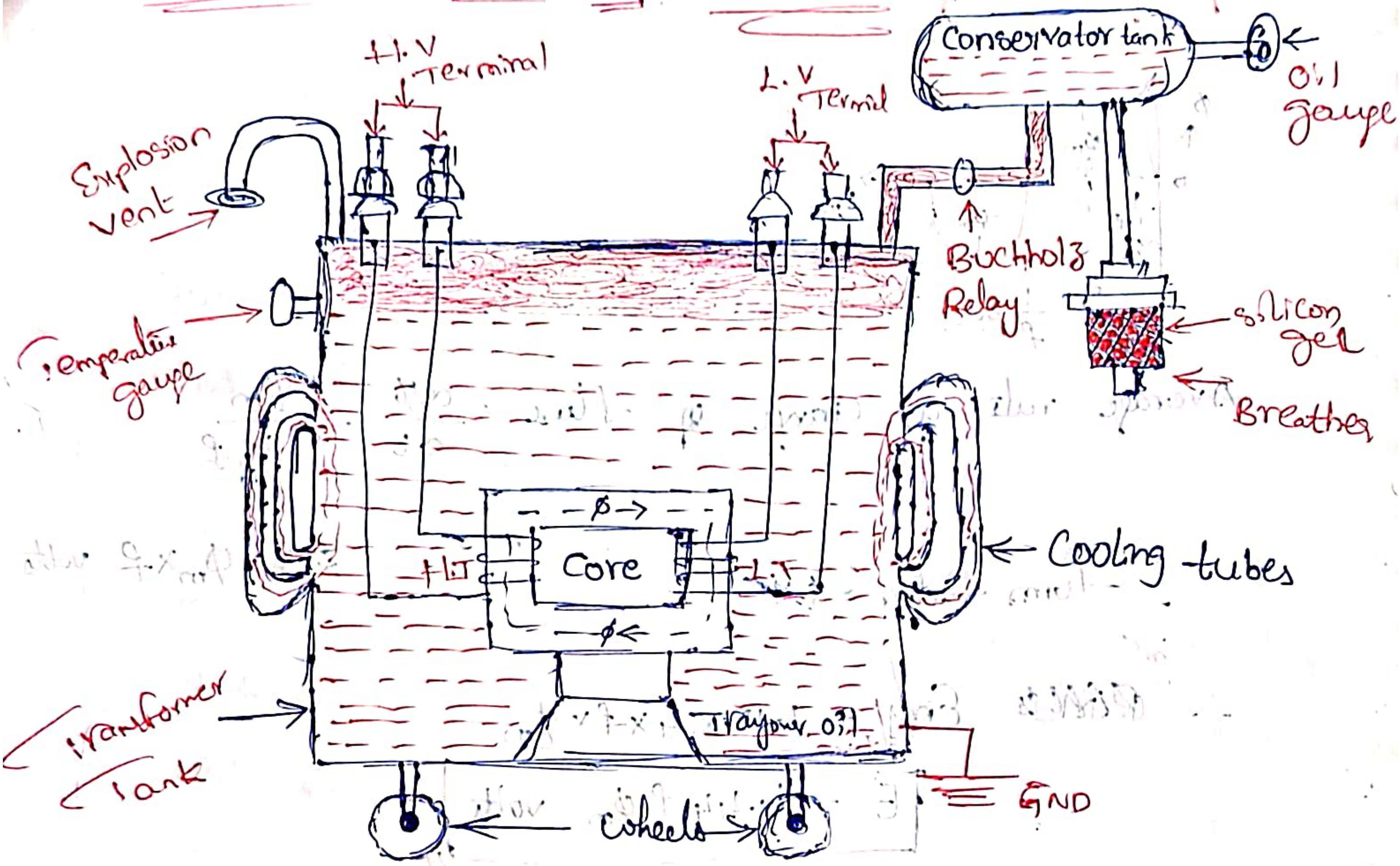
Sol) P.W

$E_1 = 4.44 \times \phi_m \times f \times N_1 = 3996$ V

$E_2 = 4.44 \times \phi_m \times f \times N_2 = 9990$ V

$\therefore E = 4.44 \times \phi_m \times f = 10$ V.

* Constructional Details of Transformer :-



* **Core :-** * The purpose of core is to provide a path of low reluctance for the magnetic flux.
  * It is made with silicon steel lamination.

* **Windings :-** The windings are made with copper conductors and are placed on the core. The winding connected to supply is known as P.W., The winding connected to load is known as S.W.

* **Transformer tank :-**

T/f's are generally housed in a tightly - fitted sheet-metal tanks filled with special insulating oil.

The core & windings are completely dipped in the oil inside the tank.

* **Transformer oil :—**

→ The Insulating oil which is Used in the tank of a transformer is Called Transformer oil.

→ It acts as insulating medium b/w windings & tank.

→ It provides better Cooling by Circulating through the Cooling tubes

* **Conservator tank :—**

→ It is a Small oil tank mounted above the transformer and Connected to the main tank by a pipe.

→ The oil level of a transformer will Changes depends on Load on T/f.

→ Therefore the volume of oil [illegible] increase in tank which flows into Conservator tank.

→ It Stores the Expansion oil in transformer tank.

* **Terminals & Bushings :—**

→ The winding are Connected to the HV & LV line through insulator bushings mounted on the top of the transformer tank

→ The connections to the winding are Copper rods or bars insulated from the tank

* **Exhaust pipe :—**

→ T/f provided with Exhausted pipe made of steel

→ It is Connected to tank and has a Small bend at End

* It protects the tank from the large Expansion of the accidental gas formation and windings are short circuited etc.,

* **Breather:** When the oil Expands the air is flow out and cool air is drawn inside under contraction of oil, this process is known as Breathing.

* **Oil Gauge:**

Oil gauge indicates the level of oil in the tank. The oil gauge provided with an alarm which gives an alarm when the oil level has dropped below certain level due to oil leak.

* **Temperature gauge:**

The temperature gauge indicate the temperature of the oil.

* **Cooling System:**

The current is flowing through the windings heat is produced. Hence cooling is necessary for T/F which can be provided by different methods ① natural air cooling ② oil Immersed forced air, ③ water & oil cooling & air-blast cooling.

(2M)

* Core type T/F	Shell type T/F
1. In this type core is surronded by the winding	1. In this type winding is surrounded by the core
2. Cylindrical type winding is used	2. Sandwiched type winding is used
3. Magnetic flux only magnetic path	3. Magnetic flux has two magnetic paths
4. Used for HV & High power level	4. Used for LV & Low power load

* Three-phase Induction Motor :— [AC Supply]

An Electric Motor Converts Electrical Energy into a Mechanical Energy, which is then supplied to different types of loads.

* Construction :-

3-ϕ Induction motor mainly classified into two types

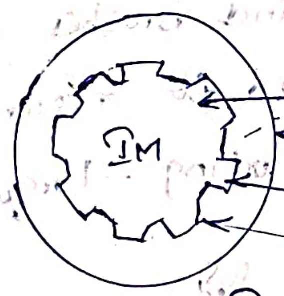
1. Stator 2. Rotor

* Stator :—

The Stator is the Stationary Part. It is an outer stationary hollow Cylindrical Structure, made up of High-grade steel lamination alloy to reduce Eddy Current losses.

The 3-ϕ Supply is given to the Stator winding, a rotating magnetic field of Constant magnitude is produced.

This Rotating magnetic flux induces an Emf in the rotor by mutual Induction principle.



Stator of 3-ϕ Induction Motor

* Rotor :—

The rotor is the rotating Part of the motor, mounted on a shaft is a hallow laminated Core having slots on its outer frame. Based on winding the rotor classified into two types

1. Squirrel Cage rotor 2. Wound (or) Slip ring rotor

* Squirrel Cage rotor :-

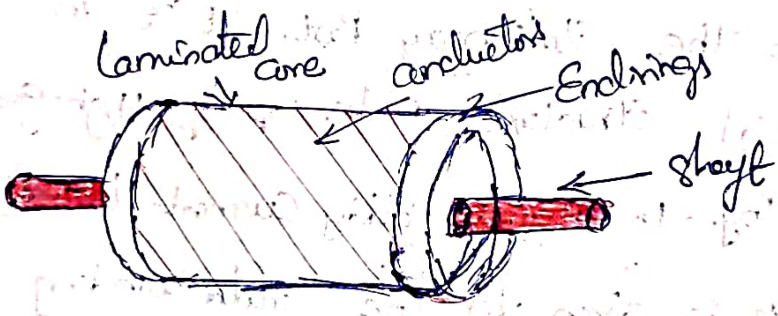
→ Rotor consists of bars which are shorted at the Ends with the help of End rings.

→ External resistance cannot be added in the rotor ckt.

Speed control is possible from stator side

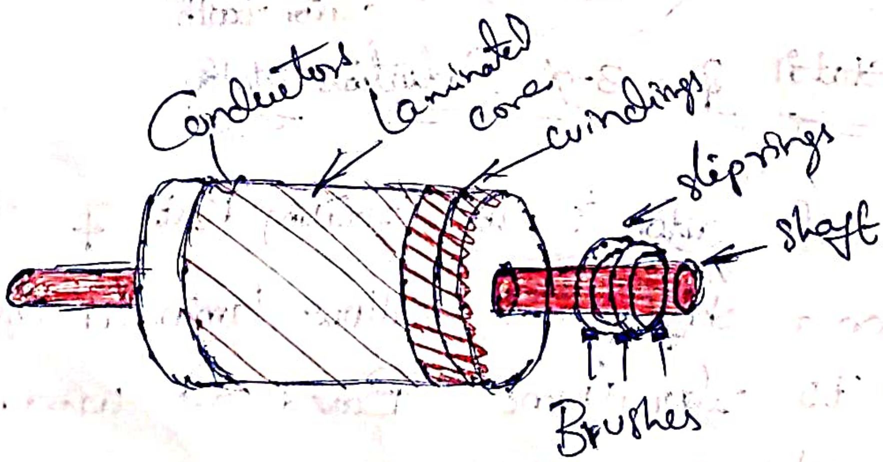
Slipring and brushes are not present & simple in construction

starting torque can be obtained moderate it used in fans, lathe machines, Grinders etc.

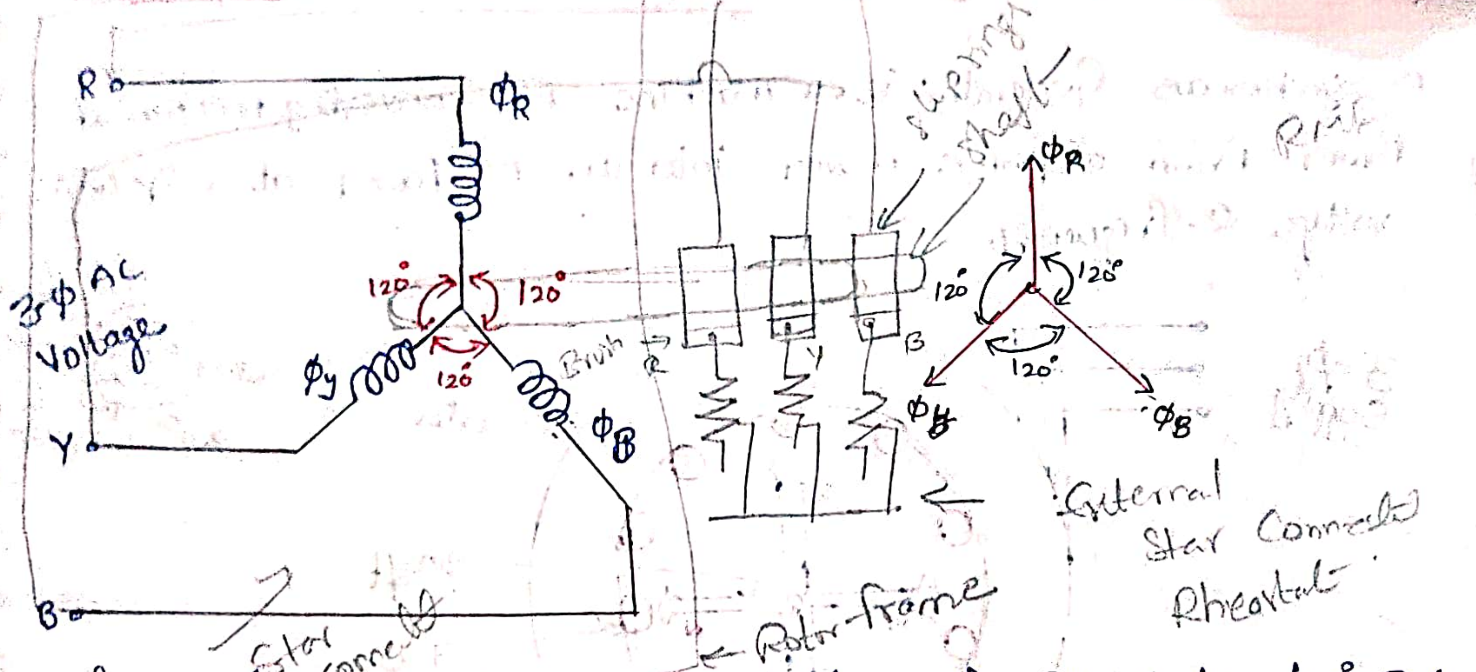


* Wound or slip ring rotor :-

Rotor consists of 3φ winding similar to stator. the External resistance can be added in the rotor ckt speed control is possible. the slipring and brushes are present the construction is complicated it requires regular maintance. It obtained high starting torque It used in Lifts, Elevators etc.



* Working :-



Three phase windings are displaced in spaced by 120° Each are supplied by 3-φ Currents, displaced in time by 120° a magnetic flux is produced which rotates in space

The 3φ balanced voltages are applied to the Stator winding they Circulated three currents I_R, I_Y & I_B in respective winding are displaced from Each other by 120° Electrical.

Each alternating current phase produces three flux ϕ_R, ϕ_Y, ϕ_B which are displaced from Each other by 120°. the Instantaneous values of the 3 fluxes

$$\therefore \phi_R = \phi_m \sin \omega t$$

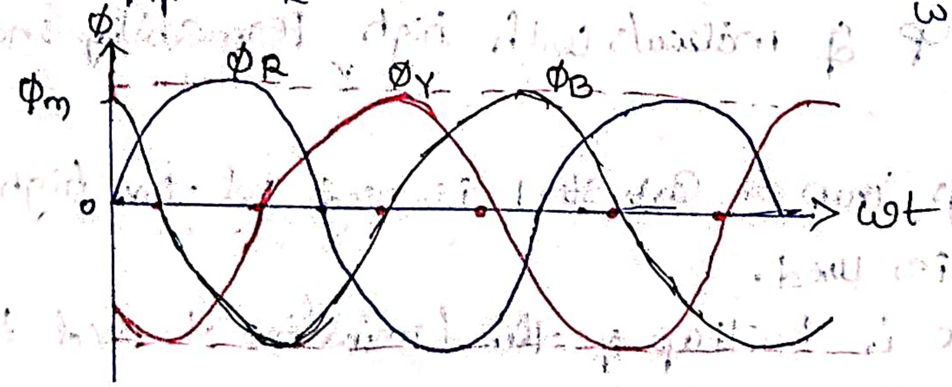
$$\phi_Y = \phi_m \sin(\omega t - 120^\circ)$$

$$\phi_B = \phi_m \sin(\omega t + 240^\circ)$$

when

$\omega t = 0^\circ$, $\omega t = 60^\circ$, $\omega t = 120^\circ$, $\omega t = 180^\circ$ — Total flux $\phi_T = 1.5\phi_m$

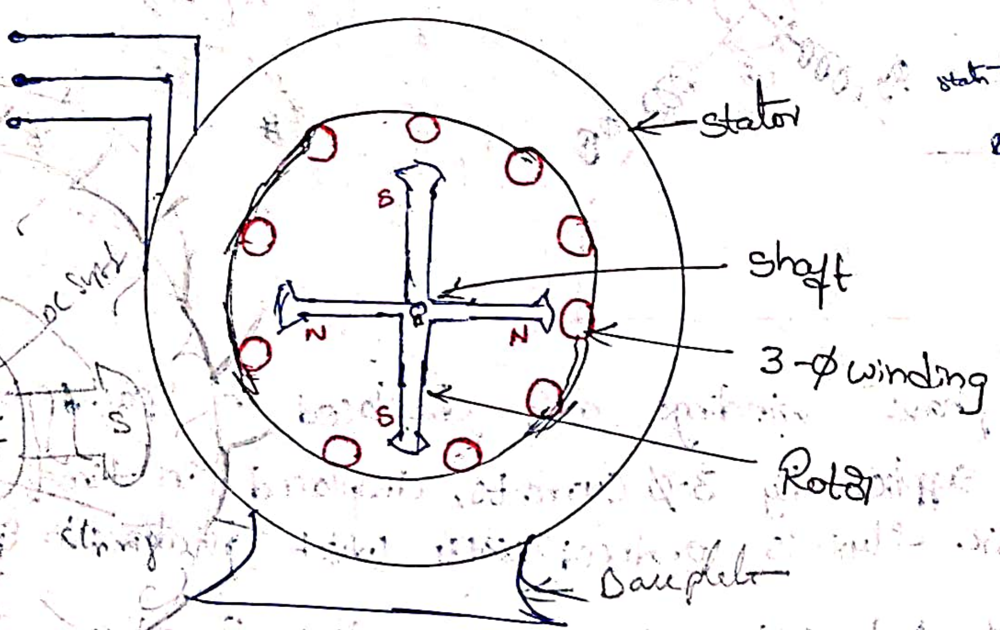
$$\Rightarrow \phi_T = \phi_R + \phi_Y + \phi_B$$

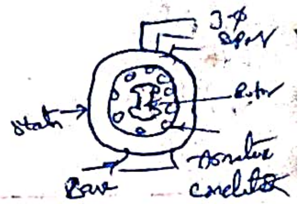


% slip $s = \frac{N_s - N}{N_s}$

* Alternator (or) Synchronous Generator (or) AC Generator :-

A Synchronous Generator is a machine for converting mechanical Power from a prime mover into an AC Power at a specific voltage & frequency.





The two main Parts of a synchronous machine are stator and rotor. The stator is the stationary Part of the machine and it Carries the armature winding in which the voltage is Generated. The output of the machine is taken from the Stator. The rotor is the rotating Part of the machine it Produces the main field flux.

* Construction :-

Stator is a hollow cylindrical structure forming the outer Cover of a Synchronous machine.

- It is made up of materials with high permeability and low hysteresis loss.
- For low ratings iron or Cast steel is used and for high rating silicon steel is used.
- The stator core is build up of thin lamination it used to reduce the Eddy current loss.

Rotor are classified into two types 1. Salient pole type 2. non-Salient Pole rotor

The Salient pole rotor consists of four (or) more poles, projected out from the surface of the rotor core as shown in fig. Since the rotor is subjected to changing magnetic field it is made up of thin steel lamination to reduce eddy current losses. Separate damper winding is required. It has non-uniform air gap. The non-sinusoidal flux distribution due to non-uniform air gap.

Working :-

An alternator is an electrical machine which converts M.Energy into alternating electrical energy.

It works on Principle of "faraday's law of Electromagnetic Induction."

Whenever a conductor cuts the magnetic flux an Emf induced in it, there is a relative motion b/w that conductor and magnetic field.

The rotor is rotated in the anti-clockwise direction by a Prime mover, the stator or armature conductor are cut by the magnetic flux of rotor poles. Consequently an Emf is alternating induced in armature conductors due to Electromag Induction. The direction of Induced Emf can be found by fleming right hand rules. The magnitude of the voltage induced in each phase depends upon the rotor flux, the number and Position of the conductor.

The synchronous speed $N_s = \frac{120 \times f}{P}$ rpm

$\therefore f = \frac{N_s \times P}{120}$ Hz

* Applications :

* DC Generator :—

1. DC Generator can provide wide range of voltage output and usually used for testing purpose in the laboratories.
2. Used for general lighting
3. Used for giving the excitation to the alternators.
4. Used for supplying field excitation current in DC locomotives for regenerative breaking.
5. Used in series arc lighting.
6. Used for driving a motor

* DC Motor :—

1. Higher rating DC motor are used in machine tools, printing presses, conveyors, fans, pumps, cranes, papermills textile mills etc.,
2. Used as traction motors in electric locomotives.

* Transformer :—

1. The generated voltage at 11 kV is converted into higher voltages of 132 kV, 220 kV, 440 kV & 765 kV with the help of transformer.
2. In radio, television circuit transformer is used as a coupling device in the form of input T/F, inter-stage T/F & output T/F.
3. Instrument T/F are used to measure voltage & currents
4. T/F used in telephone ckts, instrumentation ckts, control ckts

* 3-ϕ Induction Motor :—

1. Squirrel-Cage motors with low rotor resistance are used for fans, centrifugal pumps, wood-working tools etc.
2. for High resistance are used for Compressors, punching machines, Elevators etc.,
3. slip-ring Induction motors are suitable for High starting torque & speed Control.

Examples: Lifts, Pumps, Cranes, winding machines, mills etc.,

* Alternator :—

Brushless Alternator :— Mainly used in the production of bulk AC power for Commercial purpose. for Example, in various power plants such as thermal, hydro & nuclear.

Diesel electric locomotive alternators - used in diesel electric multiple units

Automotive alternators - used in modern automobiles.

Radio alternators - used for low brand radio-fz transmission

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* Comparison of wound rotor & Squirrel Cage rotor I. Motor :?
* Difference b/w Salient pole &. cylindrical type rotor ?

Measuring Instruments

Measurement is Essentially a Process in which the magnitude of a quantity is determined in Comparision with another Similar quantity.

The measurement of Electrical quantities requires a wide variety of techniques and instruments to perform a required measurement.

1.	current	Amps(A)	Ammeter
2.	voltage	volt	voltmeter
3.	Power	watts	wattmeter
4.	Energy	kwh	Energy meter
5	Resistence	Ω	ohm-meter or megger
6.	frequency	Hz	frequency meter/Counter

* Analog & Digital Instruments :-

*Analog Instrument :— Measurement :-

The device that is used for measurement of certain physical quantity is called

An Analog Instrument indicates the magnitude of the quantity in the form of the pointer movement.

* Digital Instrument :-

Digital Instruments indicate the value of the quantity in digital format i.e, in number which can be read easily

Based on the Properties the Instruments can be classified into two types:—
1. Absolute Instruments
2. Secoundary Instruments
- → Indicating Instruments
- → Recording Instruments
- → Integrating Instruments

*** Absolute Instrument :—**

There Instruments give the value of quantity to be measured in terms of deflection and instrument constant

Ex:— Tangent Galvanometer

*** Secoundary Instrument :—**

There Instruments give the value of quantity to be measured in terms of deflection only.

Ex:— Ameter, Voltmeter, wattmeter, watt-hour meter etc.

*** Indicating Instruments :—**

The instruments which indicate the value of quantity to be measured directly on the calibrated scale are known as the Indicating Instruments

Examples:— Ameter, Voltmeter, wattmeter Etc.

*** Recording Instrument :—**

The Instruments which give a Continuous record of the variation of the quantity to be measured in a given time are called Recording Instruments.

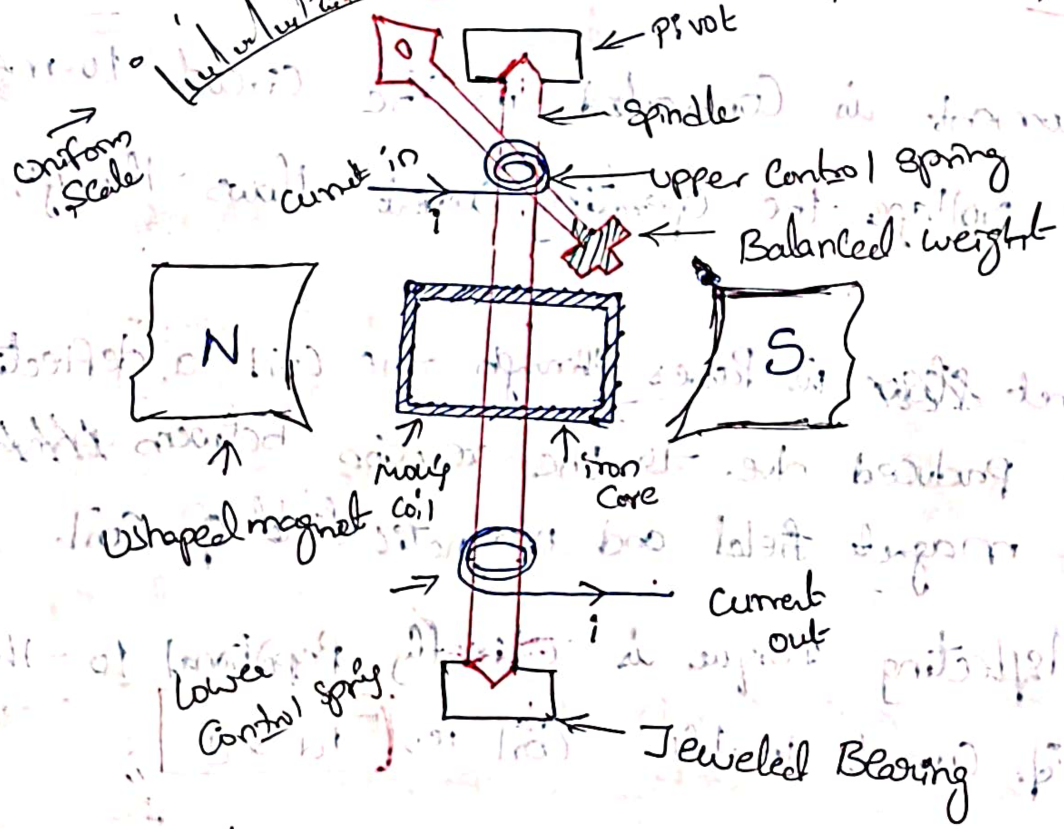
Examples:— Hospitals, substations etc.,

*** Integrating Instrument :—** The instruments which measure the total quantity of Electricity or Electrical Energy in a given time are called Integrating Instrument. Examples:— watt-hour meter etc.

* Moving Coil [M.C] Instruments :-

In this type of Instruments the iron core is stationary but the current carrying coil rotates, hence the name moving coil Instruments.

* Permanent Magnet Moving coil (PMMC) Instrument :-



* Construction :-

1. It mainly Consists of a Permanent magnet and a rectangular Moving coil.
2. The Permanent magnet has 'U- shaped' soft iron poles (N & S) between which a cylindrical iron core is mounted.
3. A light rectangular Coil of many turns of fine wire is wound on an aluminium inside which is an iron Core as shown in fig.
4. The Coil is fixed on a spindle which is pivoted upon bearings in such a way that it rotates freely b/w the Poles pieces.
5. Two hair Spiral springs of phosphor bronze are mounted one above & the other below the Coil.

The Springs serves two purposes. it leads the current into and out of the coil and also provides the controlling torque. A light pointer is attached to the spindle which moves over a calibrated scale. The clamping torque is provided by Eddy currents induced in the aluminium former.

Working :—

* The Instrument is connected in the circuit to measure current (or) voltage, the operating current flows through the coil.

* The current is passes through the coil a deflecting torque is produced due to the reaction between Permanent magnet field and magnetic field of coil.

* This deflecting torque is directly proportional to the value of current in the coil ie., $T_d \propto I$

* Due to this torque the coil moves and the pointer deflects over the calibrated scale.

* The coil moves the springs are twisted (or) Re-wound, thus the spring offer a controlling torque to the moving system.

* The controlling torque due to spring is directly proportional to the deflection of the moving part $T_c \propto \theta$.

* The deflecting & controlling torque are Equal $T_d = T_c$ the Pointer comes to rest position

* hence $\theta \propto I$, since the deflection 'θ' is directly proportional to the current 'I' these Instruments have Uniform scale

* Advantages :—

1. Uniform Scale
2. The Power Consumption is very low, hence the Efficiency is high
3. High torque/ weight ratio
4. No hysteresis loss
5. Very accurate & reliable
6. High sensitivity

*- Disadvantage :-

1. They Cannot be Used for A.C measurement (Used only for DC Measurements)
2. These are more Costlier than moving Iron Instrument

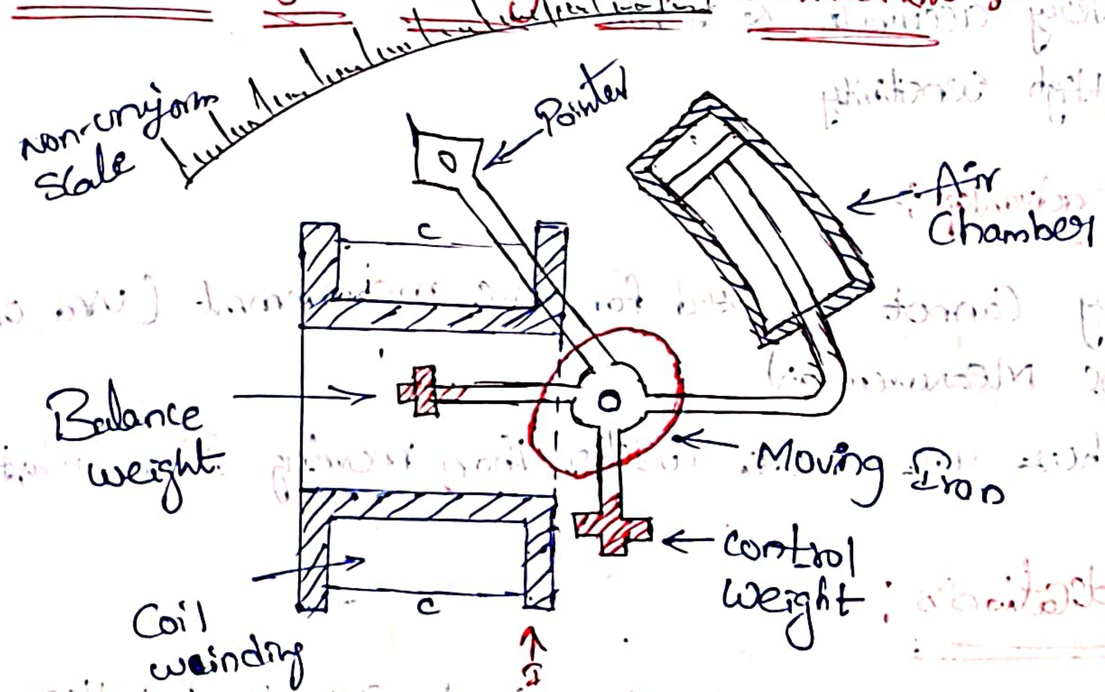
* Applications :—

1. In the measurement of direct currents & voltages
2. In D.C galvanometer to detect Small Currents
3. In Conjunction with rectifiers or thermo-junctions for A.C measurements over a wide range of frequencies

* Moving Iron Instrument :—

In this type of Instruments the current carrying coil is stationary but the Iron Core rotates hence it is called Moving Iron Instruments.

* Attractive type Moving Iron Instrument :—



* The construction details of attraction type moving Iron Instrument
* It consists of a fixed coil through which the current is passed.
* A oval-shaped soft iron is attached to the spindle in such a way that it can move in and out of the coil
* A pointer is attached to the spindle so that it may deflect along with the moving Iron over a calibrated scale.
* The spindle to provide controlling force.
* An aluminium vane is attached to the spindle which moves in a closed air chamber to provide damping torque.

Working :-

1. The Instrument is Connected in the Circuit to measure Current (or) voltage the operating current flows through the Coil.
2. Current flows through the Coil the Electromagnetic field is setup along its axis.
3. The Coil behaves like a magnet and therefore it attracts the soft iron piece towards it.
4. Thus providing the deflection torque. (T_d)
5. The deflection torque Cause the Pointer attached to the moving system moves from zero position over a calibrated scale.
6. The deflecting torque depends upon the value of magnetic flux or in other words the current flowing through the Coil.
7. The spiral spring offers the Controlling torque T_c which depends upon the angle of twist, the deflection torque is Equal to the Controlling torque (T_c). $\therefore$ $\boxed{T_d = T_c}$, the Pointer will Comes to rest position.

$\therefore$ $T_d \propto$ square of the current (I^2)

$\therefore$ $T_c = \theta$

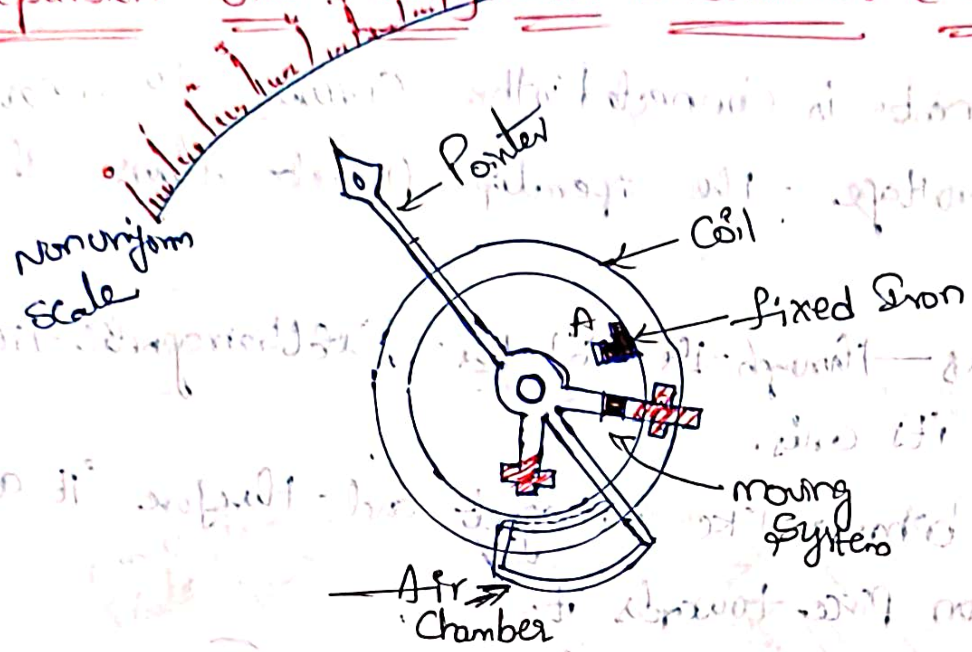
$\therefore$ At a steady Position $T_d = T_c$

$\therefore$ $\theta \propto I^2$ — for DC

$\therefore$ $\theta \propto I_{rms}^2$ — for AC meaurement

$\therefore$ Hence the Scale is not uniform

* Repulsion type Moving Iron Instrument [M.I.] :-



* **Construction :-**

* The construction of the repulsion type Moving Iron Instrument
* It Consist of a fixed Cylindrical hollow Coil, Inside which there are two Soft iron pieces. A & B.
* The Iron A is fixed and Iron B is movable which Carries a Pointer that moves over a Calibrated scale.
* The damping is provided by air friction due to the motion of the piston in an air Chamber.

* **Working :-**

* The Instrument is Connected in the Circuit to measure current or voltage the operating current flow through the Coil.
* The Current is passed through the coil of the instrument the magnetic field is produced.
* As the both Soft-iron pieces are in the same magnetic field this magnetic field magnetizes the two Iron pieces in the Same direction i.e, Similar Polarities are developed on the both Iron pieces

* Because of same polarity the two iron pieces are repel each other.

* The movable iron moves which causes the pointer to move from its zero position over a calibrated scale.

* Thus providing the deflecting torque T_d the pointer will come to rest at a position when deflection torque is equal to the controlling torque T_c $\therefore T_d = T_c$

* The controlling torque is provided by one spiral sp. at the top of the instrument.

$\therefore$ The deflecting torque $T_d \propto I^2$

Controlling torque $T_c \propto \theta$

$\therefore T_d = T_c$

$\therefore \theta \propto I^2$ — for DC

$\theta \propto I_{rms}^2$ — for AC

Hence the scale is not uniform.

* Advantages :—

1. These instruments can be used for both AC & DC measurement
2. These are cheap, robust & simple construction.
3. These instrument have high operating torque
4. These are reasonably accurate
5. Can be used in any position.

6. The coil is fixed, hence there is less possibility of faults

* **Disadvantages:**

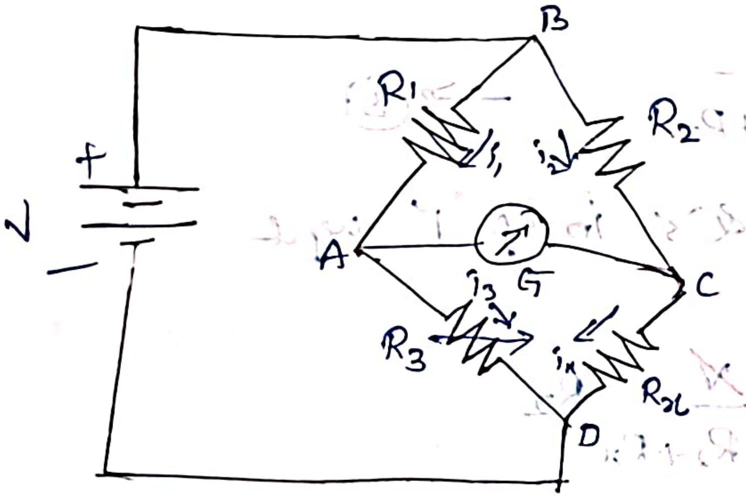
1. The scale is not uniform
2. Power consumption is higher for low voltage range
3. Errors are developed due to change in frequency in case of A.C measurement.

* Comparision between MC & MI Instrument:

MC	MI
1. Iron core is stationary but the current carrying coil rotates	1. Current carrying coil is stationary but the Iron core rotates
2. Complex in construction	2. Simple in construction
3. Expensive in cost	3. Cheaper in cost
4. Eddy current damping is provided	4. Air friction damping is provided
5. Uniform scale	5. Non-uniform scale
6. More accurate & reliable	6. Less accurate & reliable
7. Used for DC measurement only	7. Used for both AC & DC measurements

Wheat Stone Bridge :—

Wheat Stone Bridge is a type of DC bridge that is used for the measurement of unknown Resistance.
This device is particularly useful for accurately measuring resistance values, and it has been used in various Applications, including Strain gauge measurement, temperature sensors, and resistance measurements in Scientific & Engineering Experiments.



* Wheat Stone Bridge is based on the principle of null deflection,
* The wheat stone bridge consist of a circuit of four resistance R_1, R_2, R_3, R_x arranged in the arms AB, BC, AD, CD in a quadrilateral ABCD as shown in fig.
* R_3 is variable resistance, R_x is unknown resistance
* The points B & D linked to battery V & A & C linked to Galvanometer G.
* The resistance are chosen in such a way that the galvanometer shows zero deflection

Bridge at Balance Condition

In order to determine the bridge balance Equation

$$i_1 R_1 = i_2 R_2 \quad \rightarrow (1)$$

In order to have null current through the galvanometer

$$i_1 = i_3 = \frac{V}{R_1 + R_3} \quad \rightarrow (2)$$

$$i_2 = i_x = \frac{V}{R_2 + R_x} \quad \rightarrow (3)$$

Substitute Eq '2' & '3' in Eq '1' we get

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

$$\frac{R_1}{R_1 + R_3} \times \frac{R_2}{R_2 + R_x}$$

$$R_1 (R_2 + R_x) = R_2 (R_1 + R_3)$$

$$\cancel{R_1 R_2} + R_1 R_x = \cancel{R_2 R_1} + R_2 R_3$$

$$R_1 R_x = R_2 R_3$$

$$\boxed{R_x = \frac{R_2 R_3}{R_1}}$$

Hence by we determined the value of unknown resistance in balanced condition using known resistance.