GOVERMENT POLYTECHNIC,SAMBALPUR

ELECTRICAL ENGINEERING DEPARTMENT

Subject: BEE (TH4 A&B)

Prepared by: **Mr. AKASH RAJAK**

Th.4(a). BASIC ELECTRICAL ENGINEERING
(1st sem Common)

Theory: 2 Periods per Week — I.A : 10 Marks
Total Periods: 30 Periods — End Sem Exam : 40 Marks
Examination: 1.5 Hours — TOTAL MARKS : 50 Marks

Topic wise Distribution of Periods and Marks

Sl.No.	Topics	Periods
1	Fundamentals	04
2	A C Theory	07
3	Generation of Elect. Power	03
4	Conversion of Electrical Energy	05
5	Wiring and Power Billing	04
6	Measuring Instrument	03
7	Conservation of Electrical Energy	04
	Total	**30**

Objective
1. To be familiar with A.C Fundamental and circuits
2. To be familiar with basic principle and application of energy conversion devices
3. To be familiar with generation of Electrical power
4. To be familiar with wiring and protective device
5. To be familiar with calculation and commercial Billing of electrical power & energy
6. To have basic knowledge of various electrical measuring instruments & conservation of electrical energy

1. FUNDAMENTALS

1.1 Concept of current flow.
1.2 Concept of source and load.
1.3 State Ohm's law and concept of resistance.
1.4 Relation of V, I & R in series circuit.
1.5 Relation of V, I & R in parallel circuit.
1.6 Division of current in parallel circuit.
1.7 Effect of power in series & parallel circuit.
1.8 Kirchhoff's Law.
1.9 Simple problems on Kirchhoff's law.

2. A.C. THEORY

2.1 Generation of alternating emf.
2.2 Difference between D.C. & A.C.
2.3 Define Amplitude, instantaneous value, cycle, Time period, frequency, phase angle, phase difference.
2.4 State & Explain RMS value, Average value, Amplitude factor & Form factor with Simple problems.
2.5 Represent AC values in phasor diagrams.
2.6 AC through pure resistance, inductance & capacitance
2.7 AC though RL, RC, RLC series circuits.
2.8 Simple problems on RL, RC & RLC series circuits.
2.9 Concept of Power and Power factor
2.10 Impedance triangle and power triangle.

3. GENERATION OF ELECTRICAL POWER

3.1 Give elementary idea on generation of electricity from thermal , hydro & nuclear power station with block diagram

4. CONVERSION OF ELECTRICAL ENERGY

4.1 Introduction of DC machines.
4.2 Main parts of DC machines.
4.3 Principle of operation of DC generator
4.4 EMF equation of generator and simple problem.
4.5 Classification of DC generator
4.6 Principle of operation of DC motor.
4.7 Classification of DC motor.
4.8 Uses of different types of DC generators & motors.
4.9 Types and uses of single phase induction motors.
4.10 Types and uses of 3-phase induction motors.
4.11 Concept of transformer & its applications

5. WIRING AND POWER BILLING

5.1 Types of wiring for domestic installations.
5.2 Layout of household electrical wiring (single line diagram showing all the important component in the system).
5.3 List out the basic protective devices used in house hold wiring.
5.4 Calculate energy consumed in a small electrical installation

6. MEASURING INSTRUMENTS

6.1 Introduction to measuring instruments.
6.2 Torques in instruments.
6.3 Different uses of PMMC type of instruments (Ammeter & Voltmeter).
6.4 Different uses of MI type of instruments (Ammeter & Voltmeter).
6.5 Draw the connection diagram of A.C/ D.C Ammeter, voltmeter, energy meter and wattmeter. (Single phase only).

7. CONSERVATION OF ELECTRICAL ENERGY

7.1 Concept of Lumen
7.2 Different types of Lamps (Filament, fluorescent, Mercury Vapour, Sodium Vapour, Neon, LED bulb) its Construction and Principle.
7.3 Star rating of home appliances (Terminology, Energy efficiency, Star rating Concept)

Syllabus Coverage upto I.A

Chapter 1,2,3

BOOKS RECOMENDED:

1. Concept of Basic Electrical Enginnering ,P.K Das and A.K. Mallick by B.M Publications
2. ABC of Electrical Enginnering by Jain & Jain (Dhanpat Rai Publication)
3. Fundamentals of Electrical Engg and Electronics by B.L Thereja
4. Fundamentals of Electrical Engg by Asfaq Hussain
5. Fundamentals of Electrical Engg by JB Gupta
6. Basic Electrical Engg. By Chakraborti (Mcgraw Hill)

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① Fundamentals

1.1 Electric currents :-

The electric current is defined as the rate of flow of electric charge or electrons w. r. to time.

$$\text{current} = \frac{\text{charge flowing across any cross-section}}{\text{Time taken for crossing the section}}$$

The current is the rate of flow of charges with respect to time (t)

so $I = \frac{dq}{dt}$ — I (ampere), dq (charges), dt (seconds)

$$\boxed{i = \frac{q}{t}}$$

i = electric current (amp)
q = charges (coulombs)
t = time (seconds)

Voltage voltage b/w two points is defined as the energy required to move one coulomb of charge from one point to another, and it is denoted by 'v'.

→ It is expressed in terms energy (w) per unit charge 'q'

$$V = \frac{W}{q}$$

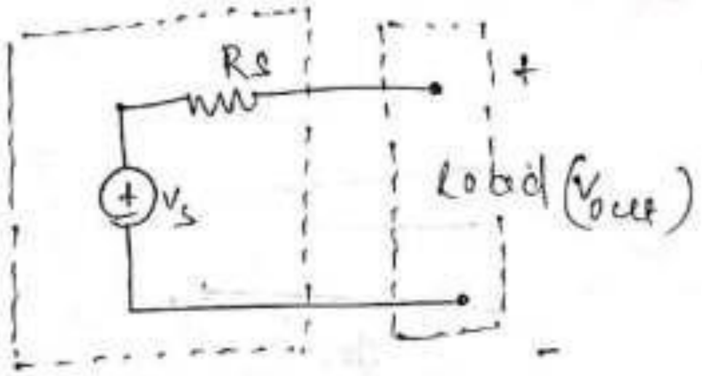
$$W = Vq$$

$1e^- = 1.6 \times 10^{-19}$ coulomb

1 coulomb = 0.625×10^{19} e^-

1 coulomb = $\frac{1}{1.6 \times 10^{-19}}$ e^-

1.2 Source and load



voltage source

Source :→ An electrical source is an electrical device of a circuit that delivers a net amount of energy to the outside / to it's terminals / load.

types of source :→
2 types of source

1. voltage source → Battery, generator
2. current source → semiconductor device like transistor, photo electric cell.

Load (passive element)

An electrical load is an electrical components of a circuit that consumes electric power or electrical energy.

→ lamp, TV, Heater

1.3 State ohm's law and concept of resistance

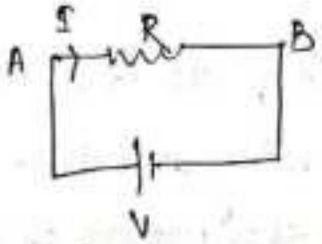
Ohm's law

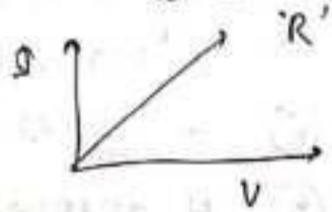
Ohm's law state that the current flowing in a conductor is directly proportional to the potential difference between two ends of a conductor at constant temperature.

$I \propto V$

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

$\Rightarrow \boxed{V = IR}$





V = potential diff. b/w two terminal of a conductor

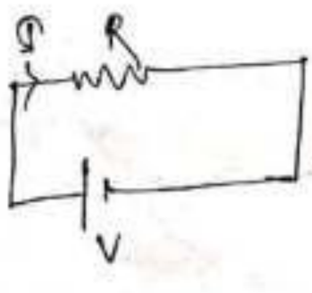
I = current

R = Resistance of conductor

unit of Resistance

The unit of Resistance is ohm (Ω)

A conductor is said to have a resistance of one ohm if it permit's one ampere current to flow through it when one volt is impressed across it's terminals.



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

Resistance (R)

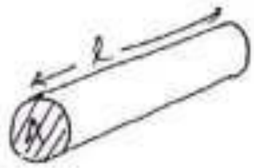
It is defined as the property of a material due to which it opposes the flow of current through it. It is denoted by 'R'

unit = Ω (Ohm)

Law of Resistance

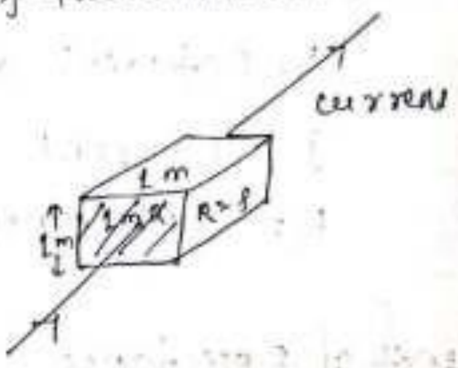
The resistance 'R' offered by a conductor depends on the following factors

1. It varies directly as it's length (L)
2. It varies inversely as the cross-section 'A' of the conductor
3. It depends on the nature of the material
4. It also depends on the temperature of the conductor.



small
Large A
Low R

Large l
small A
greater R



$$R \propto \frac{L}{A}$$

$$\Rightarrow \boxed{R = \rho \frac{L}{A}}$$

ρ = specific Resistance / Resistivity

when $L = 1\,m$, $A = 1\,m^2$ then $\boxed{R = \rho}$

$$\rho = \frac{RA}{l} = \frac{ohm \cdot m^2}{m} = ohm \cdot m.$$

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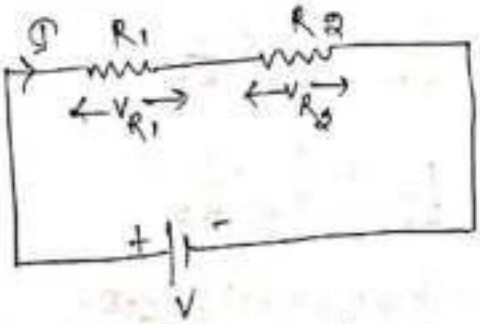
1.4 Relation of V, I & R in series circuit



(series connection of pure resistance in DC circuit)

$V = V_{R_1} + V_{R_2}$

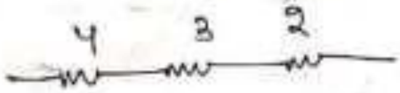
V_{R_1}, V_{R_2} : voltage drop against individual resistance.

$IR_{eq} = IR_1 + IR_2$

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

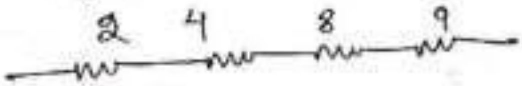
In series circuit, current 'I' is same in each branch and total resistance $R_{eq} = R_1 + R_2$, and also voltage is divided in each branch.

Q.1



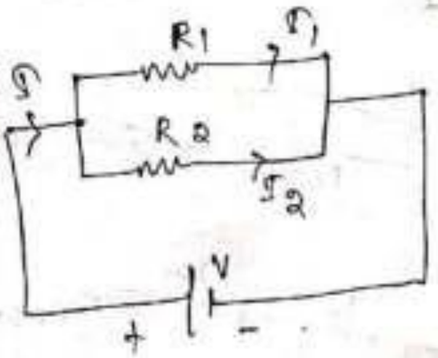
$R_{eq} = 4 + 3 + 2 = 9\Omega$

Q.2



$R_{eq} = 2 + 4 + 8 + 9 = 23\Omega$

1.5 Relation of V, I & R in Parallel circuit



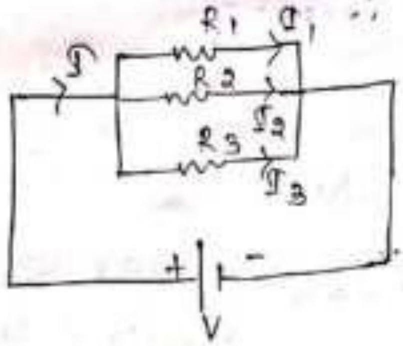
$I = I_1 + I_2$

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

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

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

In parallel circuit, voltage is same, current is divided in each branch and $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$



$$I = I_1 + I_2 + I_3$$

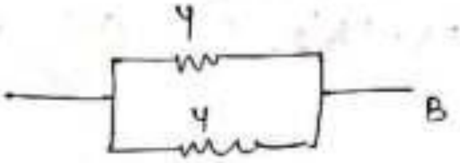
$$\Rightarrow \frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\Rightarrow \frac{1}{R_{eq}} = \frac{R_2R_3 + R_1R_3 + R_1R_2}{R_1R_2R_3}$$

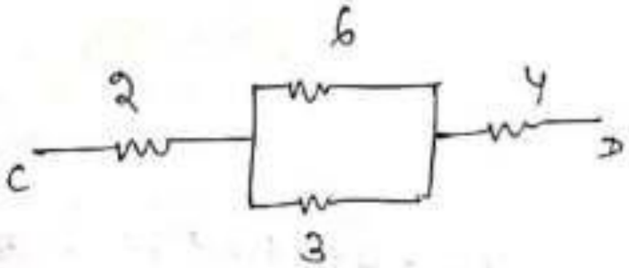
$$\Rightarrow \boxed{R_{eq} = \frac{R_1R_2R_3}{R_1R_2 + R_2R_3 + R_3R_1}}$$

Q.1

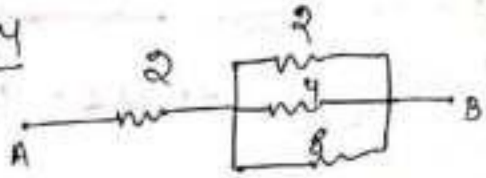


Q.2

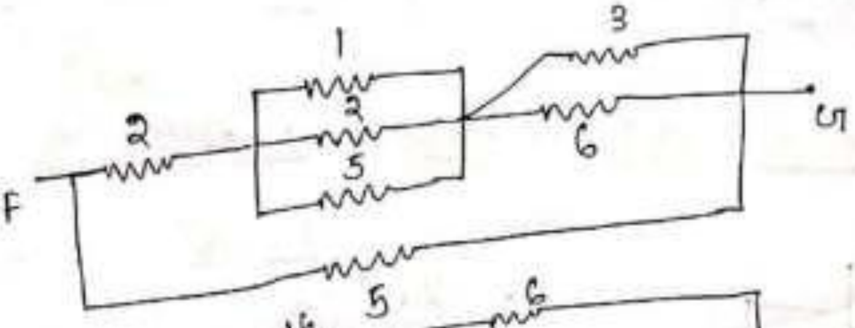
Q.3



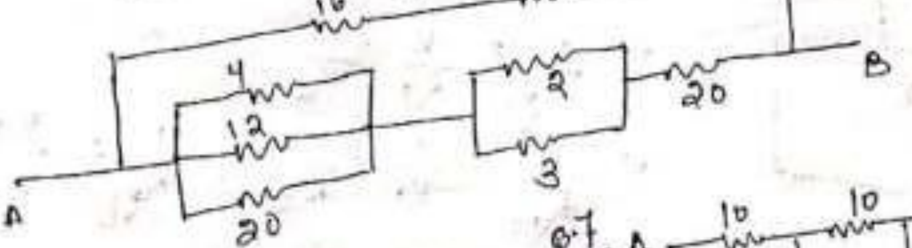
Q.4



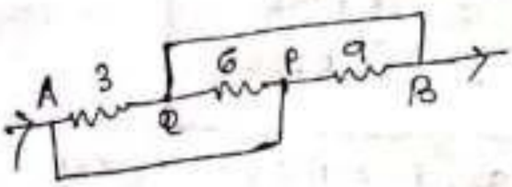
Q.4



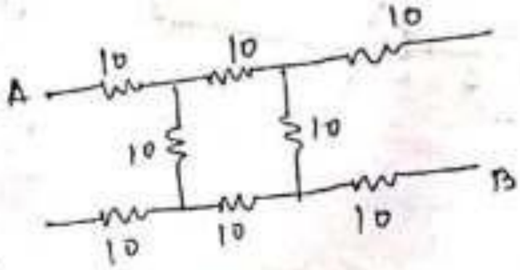
Q.5



Q.6

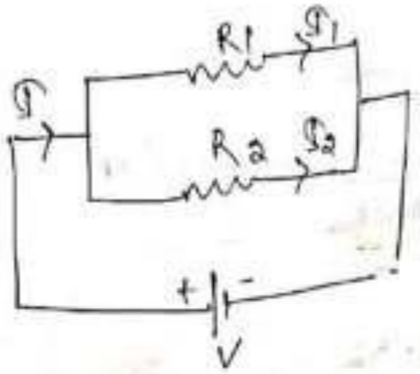


Q.7



Ans = 30

1.6 Division of current in parallel circuit



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

$$I = \frac{V}{R_{eq}}$$

$$\Rightarrow \boxed{V = I \cdot R_{eq}} \rightarrow eq^n (1)$$

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

$$\Rightarrow I_1 = \frac{I \cdot R_{eq}}{R_1}$$

$$\Rightarrow I_1 = \frac{I}{R_1}\left(\frac{R_1 R_2}{R_1 + R_2}\right)$$

$$\Rightarrow \boxed{I_1 = I\left(\frac{R_2}{R_1 + R_2}\right)}$$

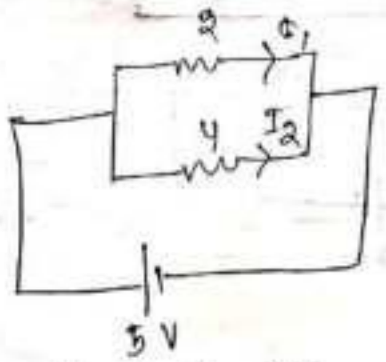
$$I_2 = \frac{V}{R_2}$$

$$\Rightarrow I_2 = \frac{I \cdot R_{eq}}{R_2}$$

$$\Rightarrow I_2 = \frac{I}{R_2}\left(\frac{R_1 R_2}{R_1 + R_2}\right)$$

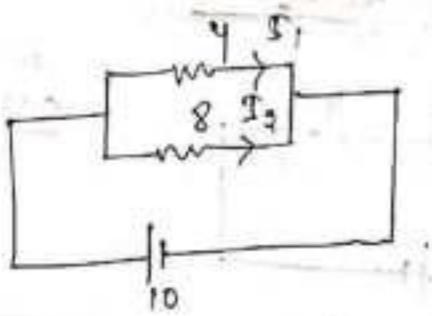
$$\Rightarrow \boxed{I_2 = I\left(\frac{R_1}{R_1 + R_2}\right)}$$

Q.1



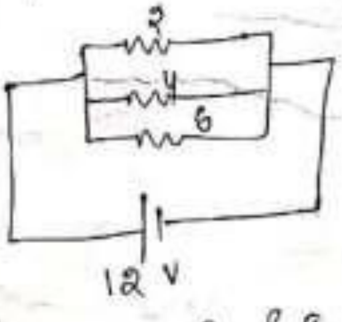
Find I, I_1 & I_2

Q.2



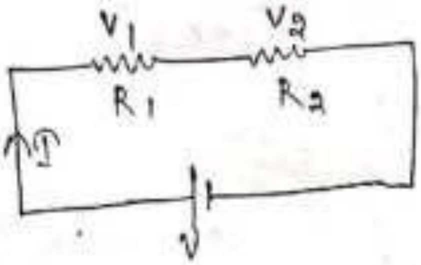
Find I, I_1 & I_2

Q.3



Find I, I_1, I_2 & I_3

Division of voltage in series circuit



$R_{eq} = R_1 + R_2$

$I = \frac{V}{R_{eq}} = \frac{V}{R_1 + R_2}$ → eqⁿ (1)

$V_1 = I \cdot R_1$

$\Rightarrow I = \frac{V_1}{R_1}$ → eqⁿ (2)

from eqⁿ (1) & (2), we get

$\frac{V}{R_1 + R_2} = \frac{V_1}{R_1}$

$\Rightarrow \boxed{V_1 = V\left(\frac{R_1}{R_1 + R_2}\right)}$

$V_2 = I \cdot R_2$

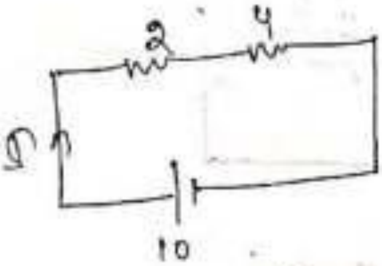
$\Rightarrow I = \frac{V_2}{R_2}$ → eqⁿ (3)

from eqⁿ (1) & (3), we get

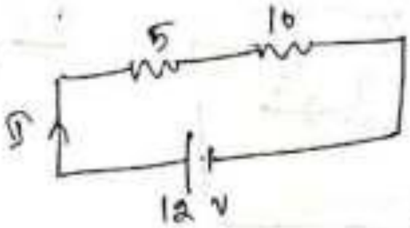
$\frac{V}{R_1 + R_2} = \frac{V_2}{R_2}$

$\Rightarrow \boxed{V_2 = V\left(\frac{R_2}{R_1 + R_2}\right)}$

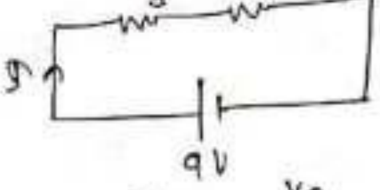
Q.1



Q.2



Q.3



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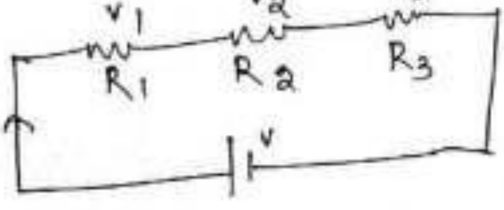

I, $V_1 = V\left(\frac{R_1}{R_1 + R_2 + R_3}\right)$

$V_2 = V\left(\frac{R_2}{R_1 + R_2 + R_3}\right)$

$V_3 = V\left(\frac{R_3}{R_1 + R_2 + R_3}\right)$

1.7 Effect of Power in series and Parallel circuit

Power :→ The rate at which work is done in an electric circuit is called electric power.

electric power = $\frac{\text{workdone in an electric circuit}}{\text{time}}$

* when 'voltage' 'v' is applied to a circuit, it causes current to flow through it, clearly work is being done by moving the electrons in the circuit.

* This workdone is moving the electrons in a unit time is called the electric power.

V = P.D across 'AB' in volt

I = current in Amp

R = Resistance of AB in ohms

t = time in seconds for which current flows.

$i = \frac{q}{t}$

$V = \frac{work}{Q}$

$\Rightarrow V = \frac{W}{Q} \Rightarrow \boxed{W = Vq = VIt}$

power (P) = $\frac{W}{t} = \frac{Vit}{t} = Vi$ Joule/second or watt

or

(P) = $Vi = i \cdot R \cdot i = i^2R$

or

(P) = $Vi = V \cdot \frac{V}{R} = \frac{V^2}{R}$

or

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Energy:-

Energy is defined as the ability of doing work. In electricity, the total workdone is an electric circuit is called electrical energy.

Electrical energy = Electrical power × t

$= P \times t$

$E = Vit = I^2Rt = \frac{V^2}{R}t$

So electrical energy is measured in kwh.

1.8 Kirchhoff's law

particularly useful

1. In determining the equivalent resistance of a complicated network of conductor.
2. For calculating the current flowing in the various conductor.

It has 2 Laws

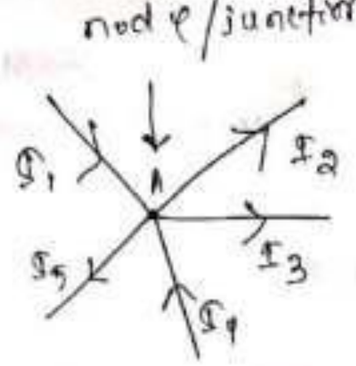
1. Kirchhoff's current law (KCL)

" In any electrical network, the algebraic sum of the current meeting at a point or junction is zero."

or

The sum of incoming current is equal to the sum of outgoing current at a point or junction.

incoming current = out-going current
(+ve sign) (-ve sign)



(Fig-1)

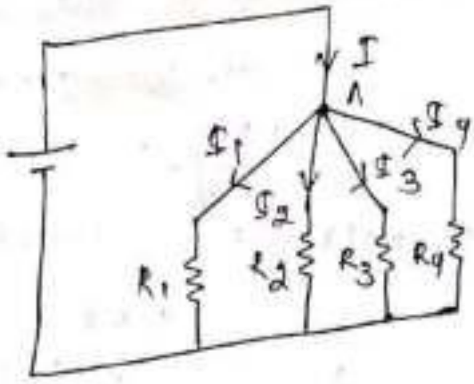


Fig-2)

For Fig-1

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

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

$\Rightarrow \boxed{I_1 + I_4 = I_2 + I_3 + I_5}$

$I + (-I_1) + (-I_2) + (-I_3) + (-I_4) = 0$

$\Rightarrow I - I_1 - I_2 - I_3 - I_4 = 0$

$\Rightarrow \boxed{I = I_1 + I_2 + I_3 + I_4}$

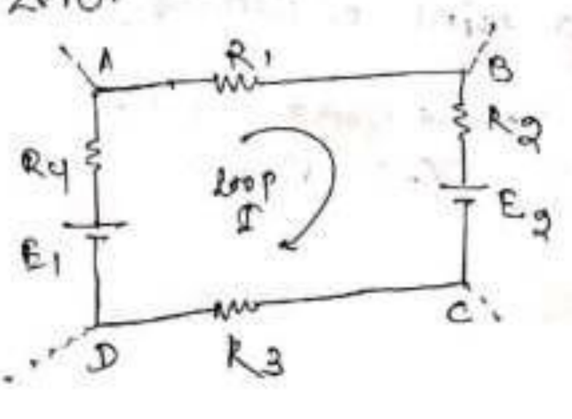
$\boxed{\sum I = 0}$

② Kirchhoff's voltage law (KVL)

* The algebraic sum of the product of current and resistance in each of the conductors in any closed path in a network plus the algebraic sum of the emfs in that path is zero.

(or)

* The algebraic sum of the product of I & R in each conductor plus the algebraic sum of the emf in a closed path is zero.

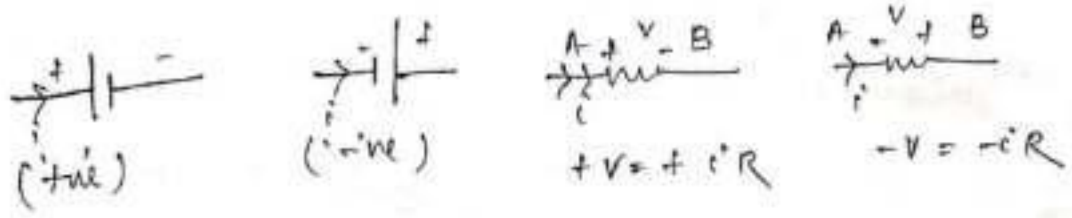


$IR_1 + IR_2 + E_2 - IR_3 - E_1 + IR_4 = 0$

$\Rightarrow \boxed{IR_1 + IR_2 + IR_3 + IR_4 = E_1 - E_2}$

imp *

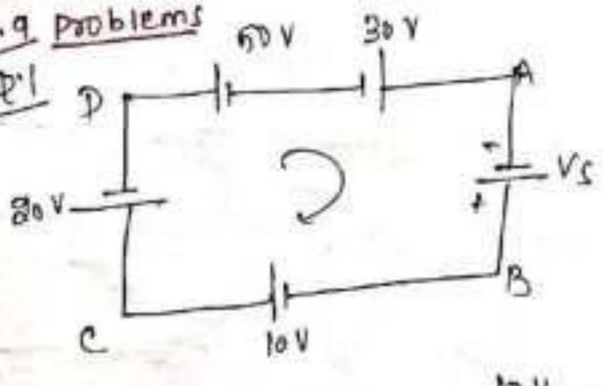
It is important to note that the sign of the battery emf is independent of the direction of the current through that branch.



* it is clear that the sign of voltage drop across a resistor depends on the direction of current through that resistor but is independent of the polarity of any other source of emf in the ckt under consideration.

1.9 Problems

Q.1



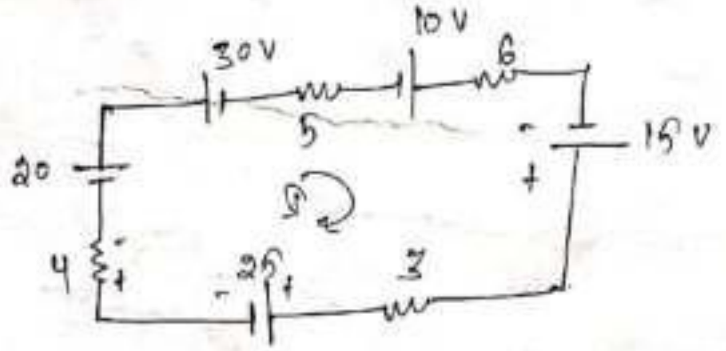
$-V_s - 10 + 20 + 50 - 30 = 0$

$\Rightarrow -V_s - 40 + 70 = 0$

$\Rightarrow -V_s + 30 = 0$

$\Rightarrow \boxed{V_s = 30 \text{ volt}}$

Q.2



Find 'I'

$-15 + 3I + 25 + 4I - 20 + 30 + 5I - 10 + 6I = 0$

$\Rightarrow 18I - 45 + 55 = 0$

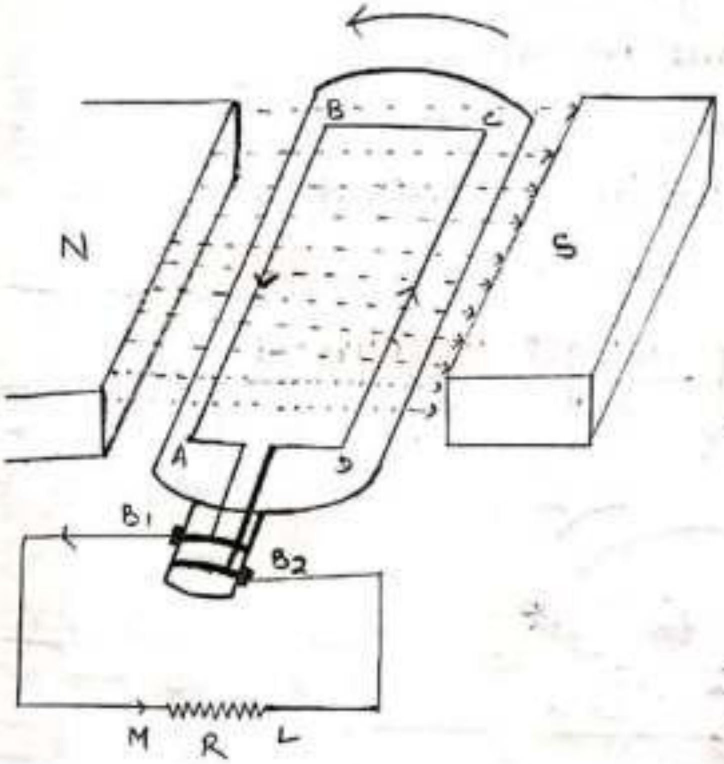
$\Rightarrow 18I + 10 = 0$

$\Rightarrow I = \frac{-10}{18} = -0.55 \text{ Amp}$

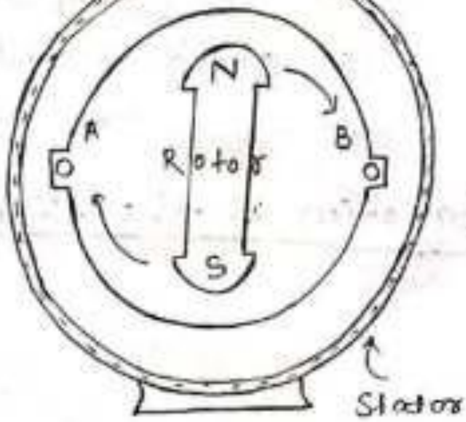
Chapter-2 A.C Theory

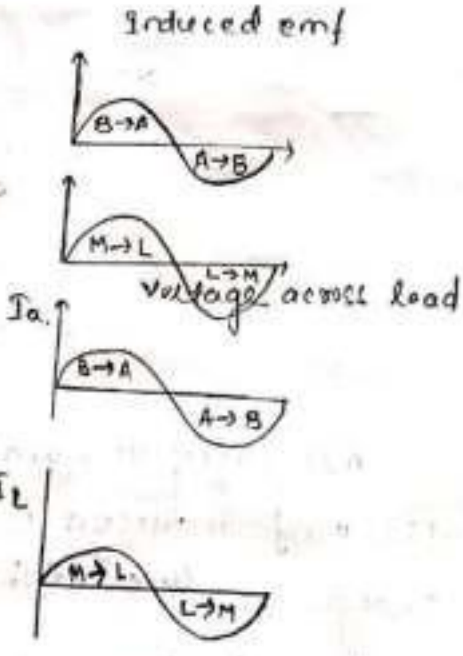
2.1 Generation of alternating emf

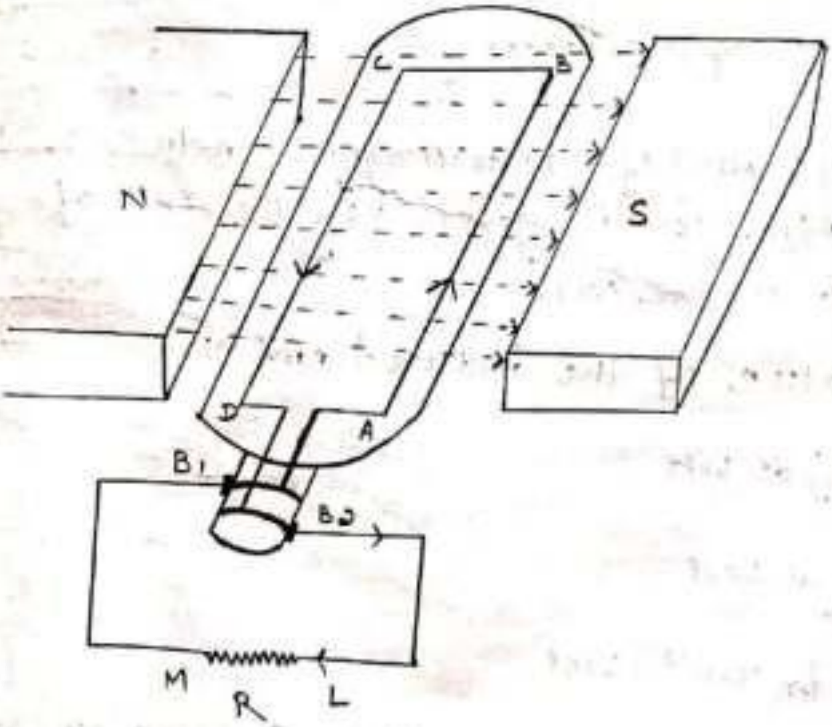
(Generation of alternating voltage and current)



(Fig-1)







(Fig-2)

Alternating voltage may be generated by rotating a coil in a magnetic field or by rotating a magnetic field with in a stationary coil.

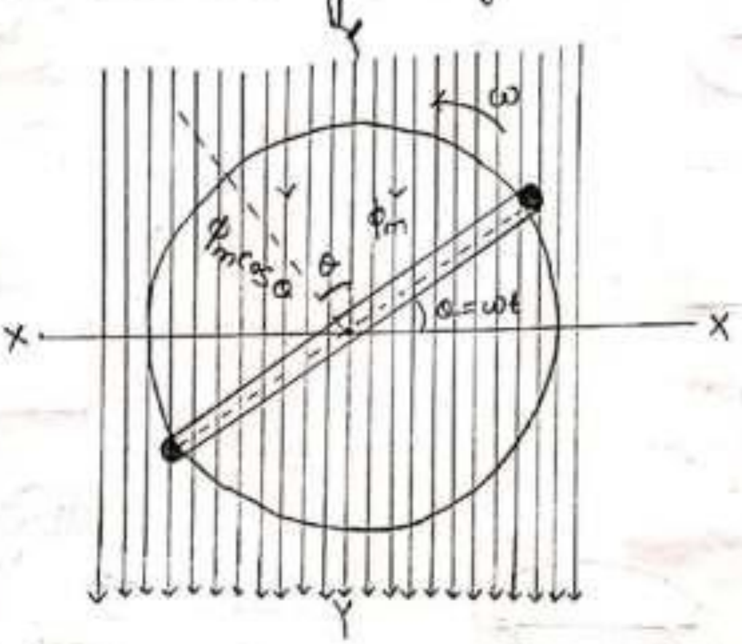
The value of the voltage generated depends upon

(a) The number of turns in the coil

(b) strength of the field

(c) Speed at which the coil / magnetic field

Equation of the Alternating voltages and current



According to faraday's law of electromagnetic induction, the emf induced in the coil is given by the rate of change of flux-linkage in the coil.

Instantaneous value of the induced emf is

$$e = -\frac{d}{dt}(N\phi)\, dt \text{ volt}$$

$$\Rightarrow e = -N\frac{d\phi}{dt} \cdot dt \text{ volt}$$

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

$$\Rightarrow e = -N\phi_m \frac{d}{dt}(\cos\omega t) \text{ volt} = -N\phi_m(-\sin\omega t)\cdot\omega \text{ volt}$$

$\Rightarrow e = N\phi_m \omega \sin \omega t$ volt

$\Rightarrow$ $\boxed{e = N\phi_m \omega \sin\theta}$ volt

when $\theta = 90°$, $\sin\theta = 1$

'e' has maximum value, say 'E_m'

so $E_m = N\phi_m \omega \cdot 1$

$\Rightarrow$ $\boxed{E_m = N\phi_m \omega}$

$\Rightarrow$ $\boxed{E_m = \omega N B_m A = 2\pi f N B_m A}$

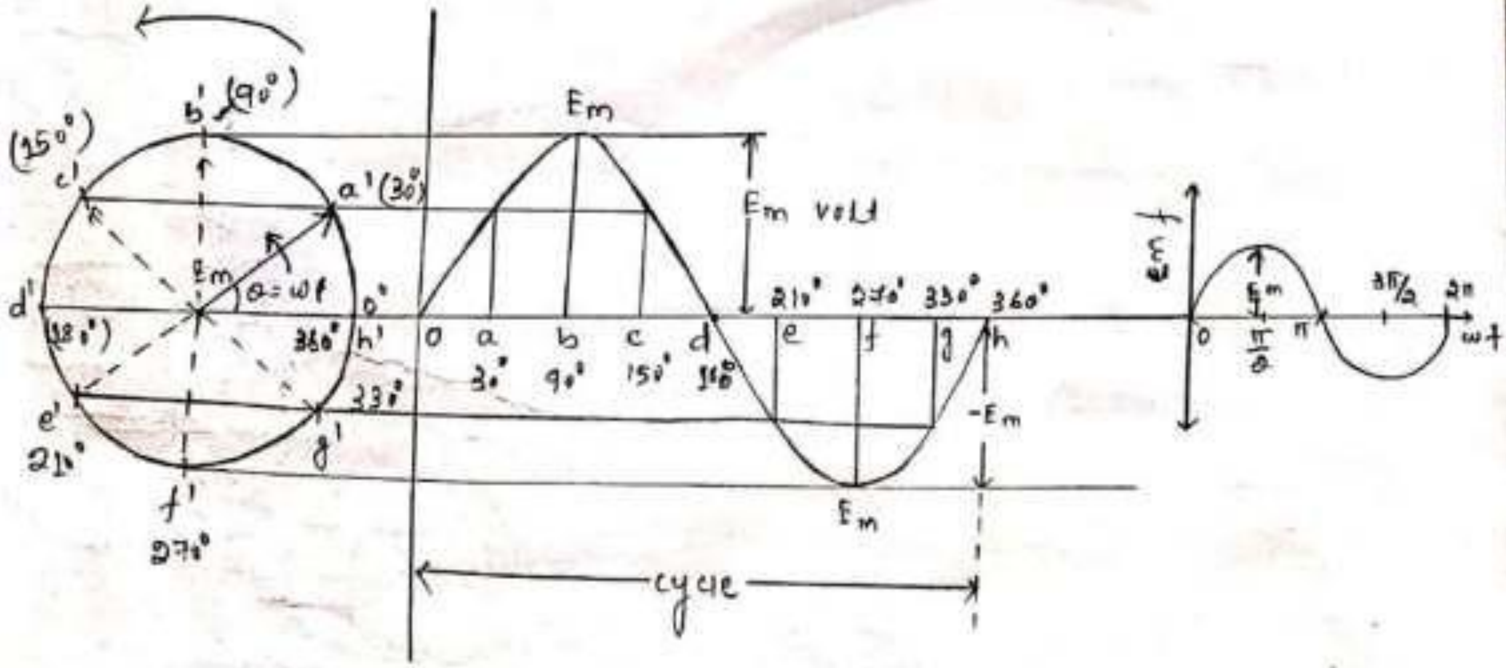
so $\boxed{e = E_m \sin\theta}$ $\boxed{e = E_m \sin\omega t}$ $\boxed{e = E_m \sin 2\pi f t}$

$\boxed{I = I_m \sin\theta}$ $\boxed{i = I_m \sin\omega t}$ $\boxed{i = I_m \sin 2\pi f t}$

ω = angular velocity

$\omega = 2\pi f$ radian/second

$\omega t = \theta$

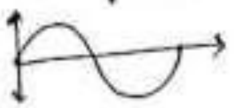


2.2 Difference between D.C & A.C

Basic	Alternating current (A.C)	Direct current (D.C)
① Defination	→ The direction of current reverse periodically	→ The direction of the current remain same
② frequency	→ 50 HZ or 60 HZ	→ zero
③ power factor	→ Lies between '0' & '1'	→ always 1
④ Types of loads	→ Their loads are resistive, inductive & capacitive	→ Their load is usually resistive in nature
⑤ source	→ Alternator	→ Generator, battery, solar cell
⑥ passive parameter	→ impedance	→ Resistance

2.3 **cycle:→**

one complete set of positive and negative values of alternating quantity is known as cycle.



frequency (f):→ The no. of cycle/second is called the frequency of the alternating quantity.

it's unit is hertz (Hz)

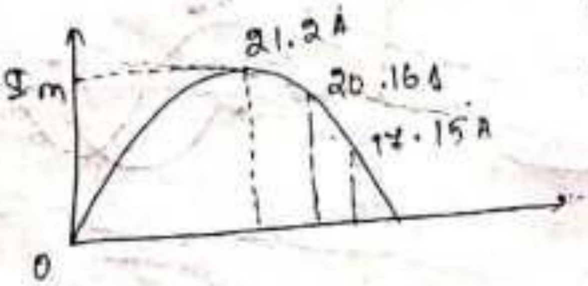
Time Period (T):→ The time taken by an alternating quantity to complete one cycle is called it's time period.

Example $f = 50$ Hz

$$T = \frac{1}{f} = \frac{1}{50} = 0.02 \text{ sec.}$$

Amplitude:→ The maximum value, positive or negative of an alternating quantity is known as it's amplitude

Instantaneous value:→ The value of voltage or current obtained at any instant of time is called instantaneous values.

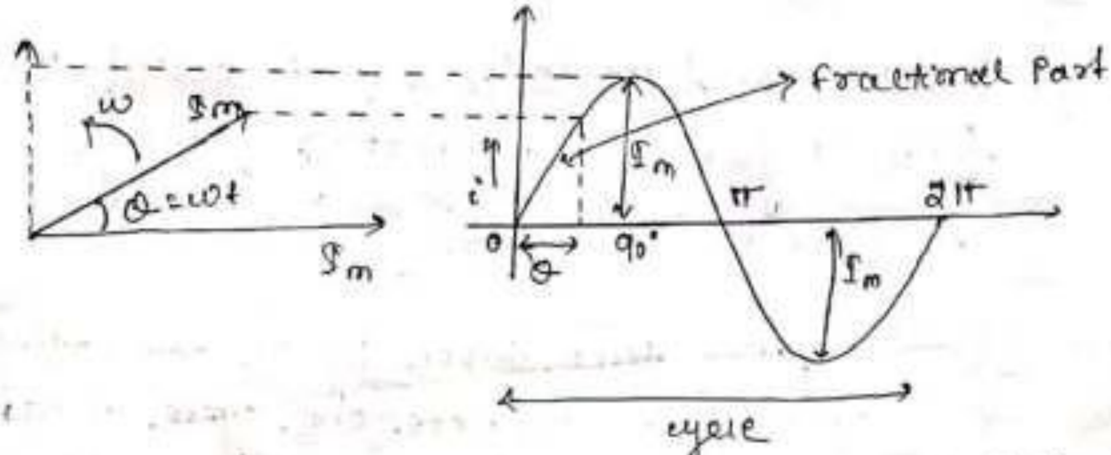


$e = E_m \sin \omega t$ $\quad$ $i = I_m \sin \omega t$

$e = e_m \sin \theta$ $\quad$ $i = I_m \sin \theta$

Phase angle (θ)

The phase angle of an alternating quantity is defined as the fractional part of a cycle through which the quantity moves forward from a selected origin.



(The phase of the rotating coil at the instant is 'ωt' which is called it's phase angle θ.)

Phase difference (ϕ)

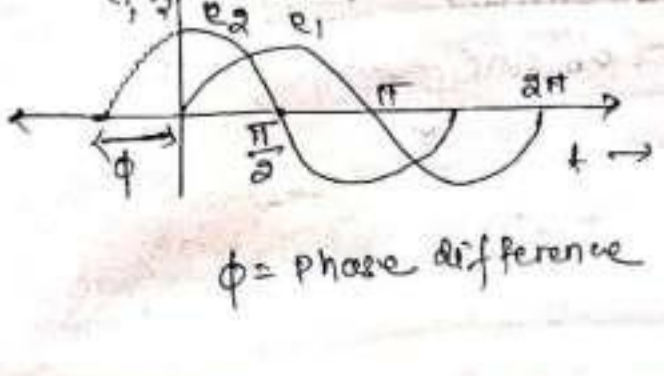
The phase difference between the two electrical quantities is defined as the angular phase difference between the maximum possible value of the two alternating quantities having the same frequency.

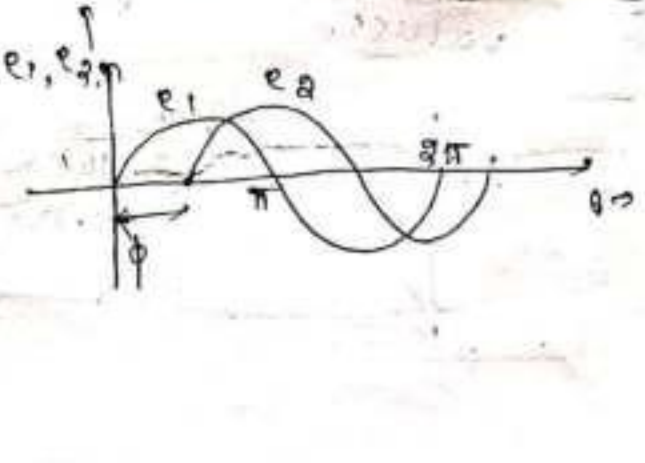
$e_1 = E_m \sin \omega t$

$e_2 = E_m \sin(\omega t + \phi)$

$e_1 = E_m \sin \omega t$

$e_2 = E_m \sin(\omega t - \phi)$





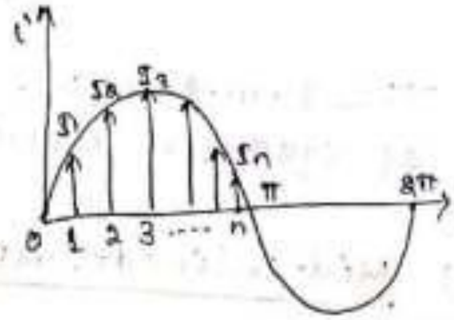
ϕ = phase difference

Average value

→ The average of all the instantaneous values of an alternating voltage or current over one complete cycle is called average value

(i) Mid-ordinate Method

$$I_{av} = \frac{I_1 + I_2 + I_3 + \cdots - I_n}{n}$$



→ The average value over a complete cycle is zero (sinusoidal & non-sinusoidal)

→ Hence the average value is obtained by adding or integrating the instantaneous values of voltage or current over one half-cycle only.

→ But in the case of an unsymmetrical alternating current (i.e. half-wave rectified current) the average value must always be taken over the whole cycle.

(ii) Analytical Method

$$I_{av} = \int_0^{\pi} \frac{i\,d\theta}{(\pi - 0)} = \int_0^{\pi} \frac{I_m \sin\theta\, d\theta}{\pi} = \frac{I_m}{\pi} \int_0^{\pi} \sin\theta\, d\theta$$

$$= \frac{I_m}{\pi}\left[-\cos\theta\right]_0^{\pi} = \frac{I_m}{\pi} - [\cos\pi - \cos 0]$$

$$= \frac{I_m}{\pi} - (-1-1) = \frac{2 I_m}{\pi} = \frac{I_m}{(\pi/2)} = 0.637\, I_m$$

Rms value (Root-mean-square value)

The Rms value of an alternating current is given by that steady (D.C) current which when flowing through a given circuit for a given time produces the same heat as produced by the alternating current when flowing through the same circuit for the same time.

(OR)

The steady current which, when flows through a resistor of known resistance for a given period of time than as a result, the same quantity of heat is produced by the alternating current when flow through the same resistor for the same period of time is called R.m.s or effective value of the alternating current.

(OR)

The r.m.s value is defined as the square root of means of square of instantaneous values over one cycle.

(i) <u>Mid-ordinate Method</u>

$$I_{rms} = I_{eff} = \sqrt{\left(\frac{I_1^2 + I_2^2 + I_3^2 + \cdots\cdots + I_n^2}{n}\right)}$$

$$I_{eff} = \sqrt{\text{mean of square of instantaneous values}}$$

$$V_{rms} = V_{eff} = \sqrt{\left(\frac{v_1^2 + v_2^2 + v_3^2 + \cdots\cdots + v_n^2}{n}\right)}$$

(ii) <u>Analytical Method</u>

$$I_{rms} = \sqrt{\int_0^{2\pi} \frac{i^2 d\theta}{(2\pi - 0)}}$$

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

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

$$= \sqrt{\frac{I_m^2}{4\pi} \int_0^{2\pi} (1 - \cos 2\theta)\, d\theta}$$

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

$$\Rightarrow I_{rms} = \sqrt{\frac{I_m^2}{4\pi} \left\{[\theta]_0^{2\pi} - 0\right\}}$$

$$= \sqrt{\frac{I_m^2}{4\pi} [\theta]_0^{2\pi}}$$

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

$$= \sqrt{\frac{I_m^2}{4\pi} \cdot 2\pi}$$

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

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

Amplitude factor (crest or peak factor)

It is defined as the ratio between maximum value and R.m.s value.

$$K_a = \frac{\text{maximum value}}{\text{R.m.s value}} = \frac{I_m}{I_m/\sqrt{2}} = \sqrt{2} = 1.414$$

(OR)

(It is defined as the ratio of maximum value to R.m.s value)

Form factor

The ratio of R.m.s value to average value is known as form factor.

$$\text{Form factor}(K_f) = \frac{\text{R.m.s value}}{\text{Average value}} = \frac{\frac{I_m}{\sqrt{2}}}{\frac{2I_m}{\pi}} = \frac{0.707 I_m}{0.637 I_m} = 1.11$$

Q.1

A sine wave is represented by the equation $e = 144\sin(314t - \frac{\pi}{3})$. Calculate the average value, rms value and frequency.

① $V_{av} = \frac{2V_m}{\pi} = \frac{2 \times 144}{\pi} = 91.71$ volt

② $V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{144}{\sqrt{2}} = 101.82$ volt.

③ $\omega = 2\pi f$

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

Q.2 An alternating current, frequency 60 Hz has a maximum value of 120 Amp. write down the equation for its instantaneous value.

Find (a) The instantaneous value after 1/360 second.

(b) The time taken to reach 96 Amp for the first time.

$I = I_m \sin\omega t$

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

$= 120\sin(2\pi \cdot 60 \cdot t)$

$= 120\sin(120\pi t)$

(a)

$$i = 120 \sin(120\pi t)$$

$$= 120 \sin\left(120 \times 180 \times \frac{1}{360}\right)$$

$$= 120 \sin 60^\circ$$

$$= 103.9 \text{ Amp}$$

(b)

$$96 = 120 \sin \omega t$$

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

$$\Rightarrow 96 = 120 \sin(2 \times 180 \times 60 \times t)$$

$$\Rightarrow 96 = 120 \sin(21600 t)$$

$$\Rightarrow \sin(21600 t) = \frac{96}{120} = 0.8$$

$$\Rightarrow 21600 t = \sin^{-1}(0.8) = 53.13$$

$$\Rightarrow t = \frac{53.13}{21600}$$

$$\Rightarrow t = 2.45 \times 10^{-3} \text{ sec.}$$

25 ~~Aswathnarayan~~

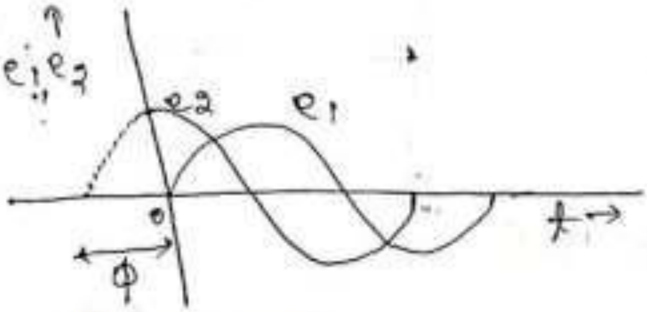
Represent AC values in phasor diagrams

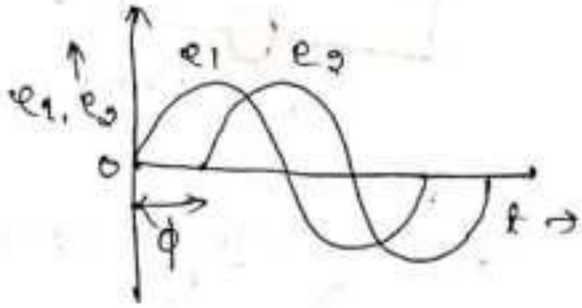
$e_1 = E_m \sin \omega t$

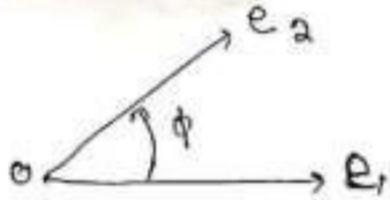
$e_2 = E_m \sin(\omega t + \phi)$

$e_1 = E_m \sin \omega t$

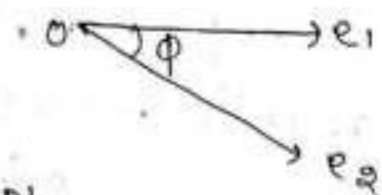
$e_2 = E_m \sin(\omega t - \phi)$







Phasor presentation

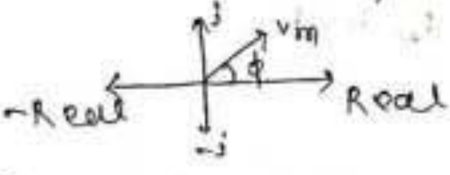


Phasor representation

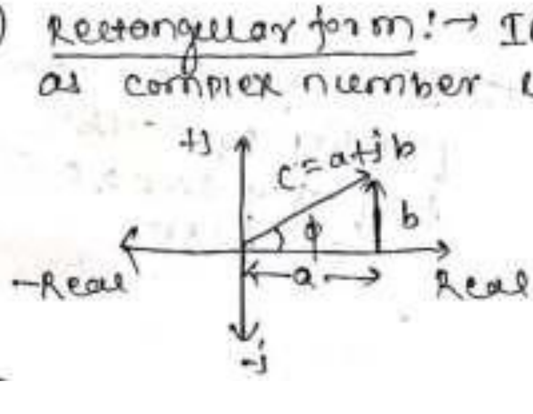
Phasor Representation

There are 3 way of phasor representation in mathematical form.

① polar form :→ suppose we have a phasor which has an amplitude of V_m and makes an angle with the horizontal axis. so in the polar form, we can represent it as V_m.



② Rectangular form :→ In this form we can represent any phasor as complex number like a+jb.

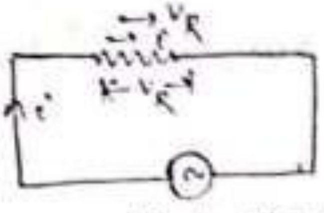


$c = \sqrt{a^2 + b^2}$

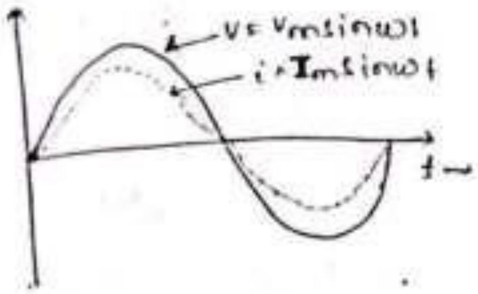
$\phi = \tan^{-1}\left(\frac{b}{a}\right)$

2.6 AC through pure resistance, inductance & capacitance

AC through pure resistance :→

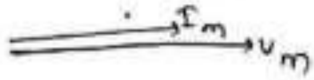


$V = V_m \sin\omega t$



$V = i \cdot R$

$\Rightarrow i = \frac{V}{R} = \frac{V_m \sin\omega t}{R} = i_m \sin\omega t \rightarrow eq^n (1)$



$P = VI\cos\phi$

$\Rightarrow P = VI\cos(0) \longrightarrow$ angle b/w voltage and current

$\Rightarrow P = V \cdot I$

(OR)

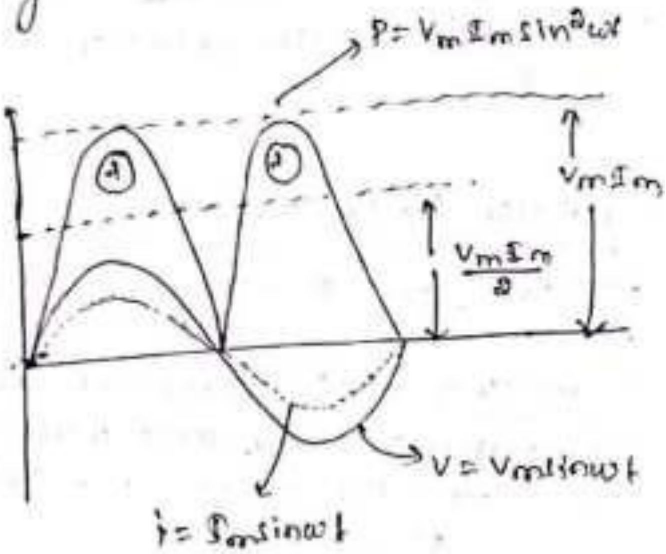
$P = V \cdot I$

$\Rightarrow P = V_m \sin\omega t \times \frac{V_m \sin\omega t}{R}$

$\Rightarrow P = \frac{V_m^2}{R} \sin^2\omega t$

$\Rightarrow P = \frac{V_m^2}{R}\left(\frac{1 - \cos 2\omega t}{2}\right)$

$\Rightarrow P = \frac{V_m^2}{2R} - \frac{V_m^2}{2R}(\cos 2\omega t) \rightarrow 0$ → The average of a sinusoidal quantity of double frequency over a complete cycle is zero.

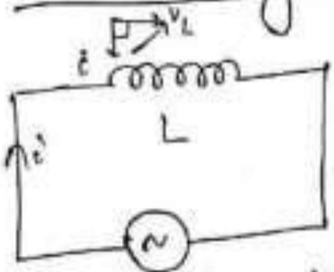


$\Rightarrow P = \frac{V_m^2}{2R} = \frac{V_m}{2} \cdot \frac{V_m}{R} = \frac{V_m}{2} \cdot I_m$

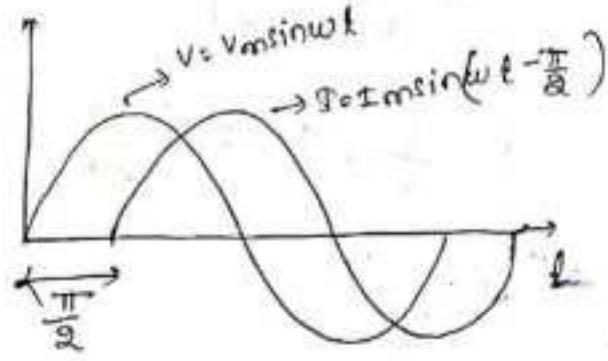
$\Rightarrow P = \frac{V_m I_m}{\sqrt{2} \cdot \sqrt{2}} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} = V_{rms} \cdot I_{rms}$

$\Rightarrow \boxed{P = V_{rms} \cdot I_{rms}}$

AC through pure inductor :-



$V = V_m \sin\omega t$



$$V = L\frac{di}{dt}$$

$$\Rightarrow di = \frac{V}{L}dt$$

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

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

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

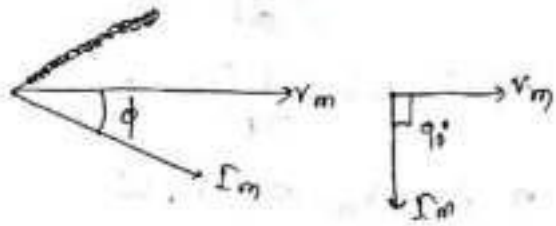
$$\Rightarrow i = \frac{V_m}{L}\left[\frac{-\cos\omega t}{\omega}\right] = \frac{V_m}{\omega L}\left[-\cos\omega t\right]$$

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

$$I_m = \frac{V_m}{\omega L} = \frac{V_m}{X_L}$$

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

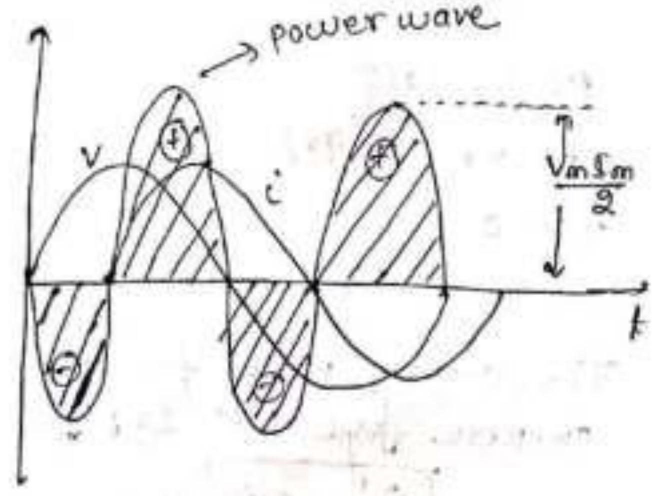
$$\Rightarrow \boxed{i = I_m\sin\left(\omega t - \frac{\pi}{2}\right)}$$



$$P = VI\cos\phi$$

$$\Rightarrow P = VI\cdot\cos(90)$$

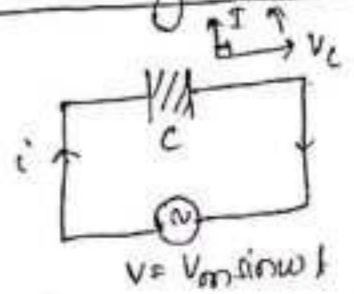
$$\Rightarrow P = 0$$

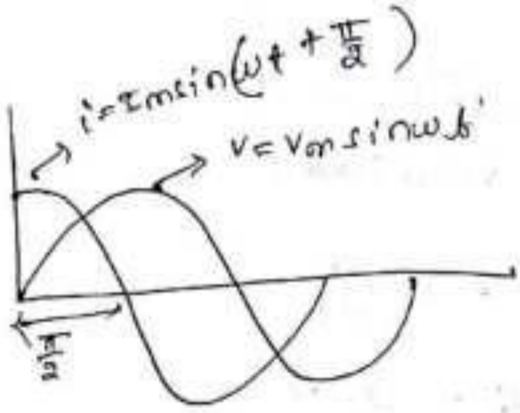


The average power for a complete cycle is zero.

$$\boxed{P_{avg} = 0}$$

AC through pure capacitor :→





$c = \frac{q}{V}$, $q = cV$, $i = \frac{dq}{dt}$

$\Rightarrow i = \frac{d}{dt}(cV)$

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

$\Rightarrow i = cV_m \frac{d}{dt}(\sin\omega t)$

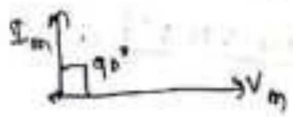
$\Rightarrow i = cV_m \cos\omega t \cdot \omega$

$\Rightarrow i = \omega c V_m \cos\omega t$

$\Rightarrow i = \omega c V_m \sin(\omega t + 90^\circ)$

$\Rightarrow \boxed{i = \omega c V_m \sin(\omega t + \frac{\pi}{2})}$

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

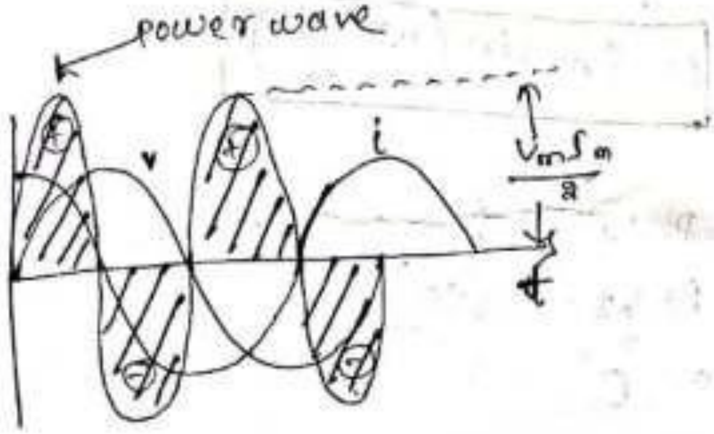


$$\boxed{I = \frac{V_m}{(1/\omega c)} = \frac{V_m}{X_c}}$$

$p = VI\cos\phi$

$\Rightarrow p = VI\cos(90)$

$\Rightarrow p = 0$

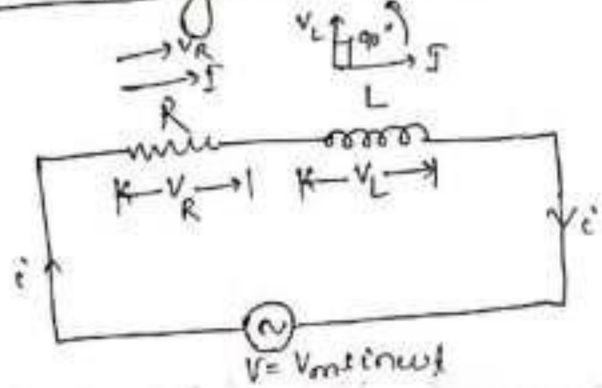


The average power for a complete cycle is zero

$$\boxed{P_{avg} = 0}$$

9.7 AC through RL, RC, RLC series circuits

AC through series RL circuit



→ consider a series R-L ckt where applied voltage and current are V & I respectively.

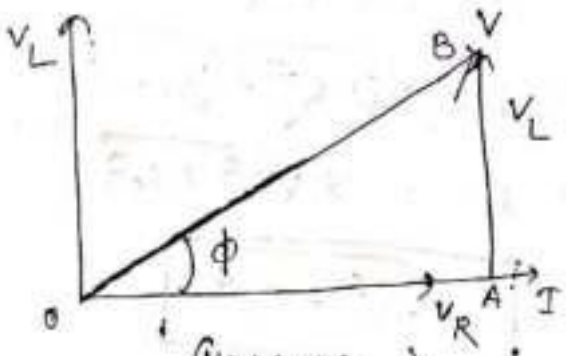
→ voltage 'V_R' across resistor is inphase with current and voltage 'V_L' across inductor leads the current by 90°.

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

$$\Rightarrow IZ = \sqrt{(I.R)^2 + (I.X_L)^2}$$

$$\Rightarrow \not{I} Z = \not{I}\sqrt{(R^2 + X_L^2)}$$

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



(Voltage triangle)

$$\tan\phi = \frac{p}{b} = \frac{V_L}{V_R}$$

$$\Rightarrow \tan\phi = \frac{\not{I}X_L}{\not{I}R}$$

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

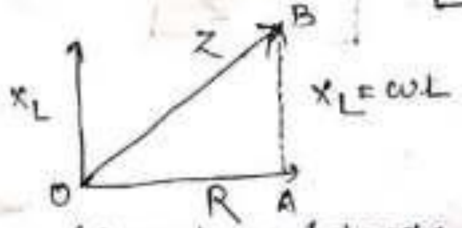
$$\boxed{I = \frac{V}{Z}}$$

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

$$\cos\phi = \frac{b}{h} = \frac{V_R}{V}$$

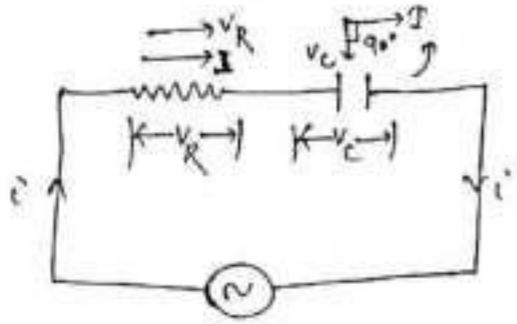
$$\Rightarrow \cos\phi = \frac{\not{I}.R}{\not{I}.Z} = \frac{R}{Z}$$

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



(Impedance triangle)

A.C. through series RC circuit



$V = V_m \sin \omega t$

→ Consider a series RC circuit, where applied voltage and current are 'V' & 'I' respectively.

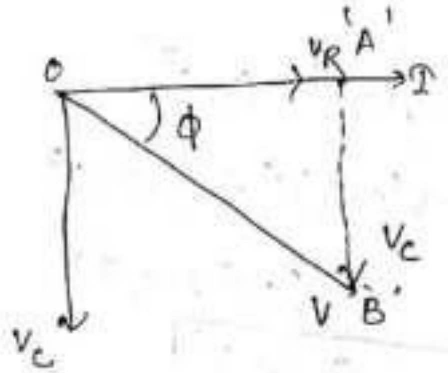
→ The voltage 'V_R' across resistor is in-phase with current and voltage 'V_C' across capacitor lags the current by 90°.

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

$$\Rightarrow I \cdot Z = \sqrt{(I R)^2 + (I \cdot X_C)^2}$$

$$\Rightarrow I \cdot Z = I \sqrt{R^2 + X_C^2}$$

$$\Rightarrow \boxed{Z = \sqrt{R^2 + X_C^2}}$$



(Voltage triangle)

$$\tan\phi = \frac{p}{b} = \frac{V_C}{V_R}$$

$$\Rightarrow \tan\phi = \frac{I \cdot X_C}{I \cdot R}$$

$$\Rightarrow \tan\phi = \frac{X_C}{R}$$

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

$$\boxed{I = \frac{V}{Z}}$$

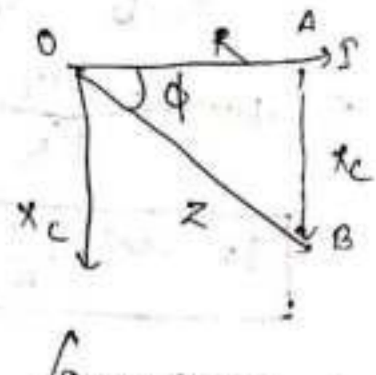
$$\boxed{P = V I \cos\phi}$$

$$\cos\phi = \frac{p}{h} = \frac{V_R}{V}$$

$$\Rightarrow \cos\phi = \frac{I \cdot R}{I \cdot Z}$$

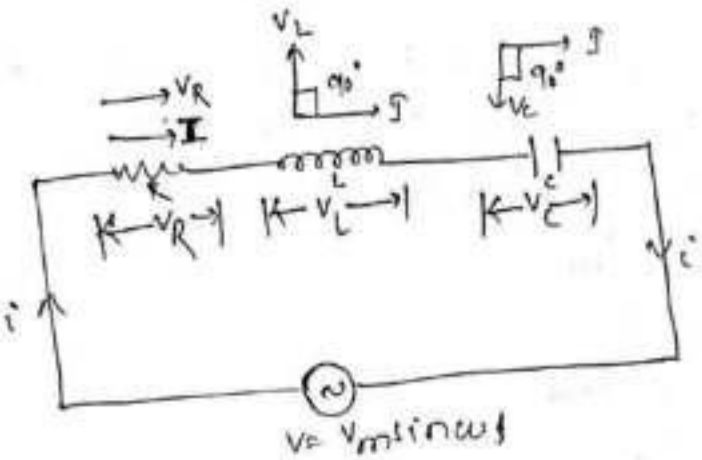
$$\Rightarrow \boxed{\cos\phi = \frac{R}{Z}}$$

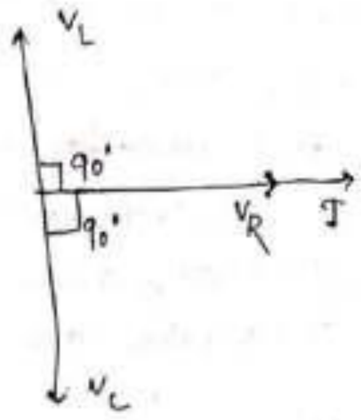
→



(Impedance triangle)

AC through series R-L-C Circuit



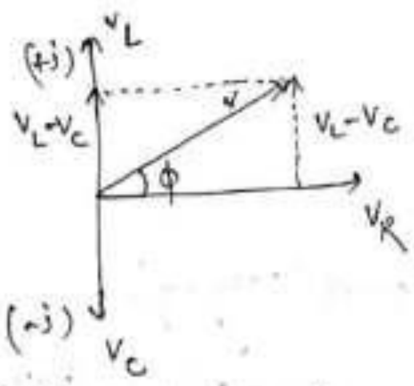


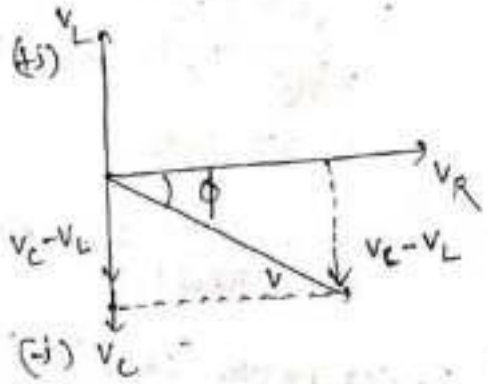
(i) $V_L > V_C$

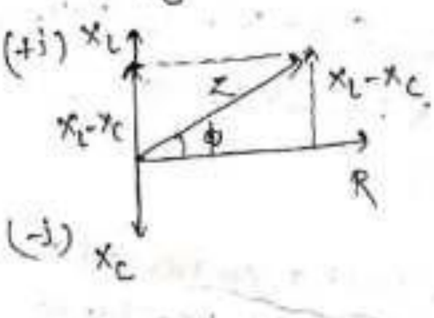
$X_L > X_C$

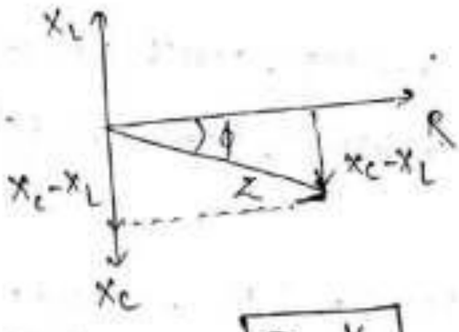
(ii) $V_C > V_L$

$X_C > X_L$









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

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

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

$$\boxed{I = \frac{V}{Z}}$$

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

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

$$\tan\phi = \frac{p}{b} = \frac{V_L - V_C}{V_R}$$

$$= \frac{I(X_L - X_C)}{I \cdot R}$$

$$\Rightarrow \tan\phi = \frac{X_L - X_C}{R}$$

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2.8 Simple problems on RL, RC & RLC series circuit

Q.1 In a circuit an inductor of 0.1 H is connected in series with a resistor of 20Ω. The circuit is connected across a 230V, 50 Hz single phase supply. Find the

(i) current flowing in the circuit
(ii) Power factor of the circuit
(iii) voltage across the reactor, and
(iv) voltage across the resistor.

given

$L = 0.1H$

$X_L = 2\pi f L = 2 \times 3.14 \times 50 \times 0.1 = 31.416\Omega$

(inductive reactance)

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

$= \sqrt{(20)^2 + (31.416)^2}$

$= 37.24\Omega$

(i) $I = \frac{V}{Z} = \frac{230}{37.24} = 6.2\,Amp$

(ii) power Factor $(\cos\phi) = \frac{R}{Z} = \frac{20}{37.24} = 0.54$ (lagging).

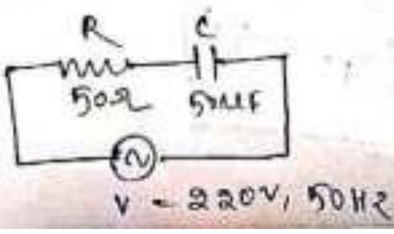
(iii) voltage across Reactor $(V_L) = I X_L = 6.2 \times 31.416 = 194.8\,V$

(iv) voltage across resistor $(V_R) = I.R = 6.2 \times 20 = 124\,V$

Q.2 A resistor of 50Ω is connected in series with a capacitive reactance of 50 connected to a supply at 220V, 50HZ. Find (i) capacitive reactance (ii) Impedance (iii) current (iv) power factor of the circuit (v) phase angle (vi) voltage across resistor (vii) voltage across capacitor and (viii) power consumed.

given $R = 50\Omega$

$C = 50\,\mu F$



(i) capacitive reactance $X_C = \frac{1}{2\pi f C} = \frac{1}{2 \times 3.14 \times 50 \times 50 \times 10^{-6}} = 63.66\,\Omega$

(ii) impedance $Z = \sqrt{R^2 + X_C^2}$

$= \sqrt{(50)^2 + (63.66)^2} = 80.95\,\Omega$

(iii) circuit current $I = \frac{V}{Z} = \frac{220V}{80.95} = 2.7$ Amp

(iv) power factor; $\cos\phi = \frac{R}{Z} = \frac{50}{80.95} = 0.617$ (leading)

(v) phase angle $(\phi) = \cos^{-1}\left(\frac{R}{Z}\right) = \cos^{-1}(0.617) = 51.9^\circ$ (leading)

(vi) voltage across resistor $(V_R) = I.R = 27 \times 50 = 155\,V$

(vii) voltage across capacitor $(V_C) = I.X_C = 2.7 \times 63.66 = 172$ volt

(viii) power consumed $(P) = VI\cos\phi = 220 \times 2.7 \times 0.617 = 366.5$ watt

Q.3

A coil of resistance 'R' and inductance 'L' is connected across 100V, 50 Hz supply. The current through the coil is found to be 2 Amp and the power dissipated is 100 watt. Find R and L.

impedance, $Z = \frac{V}{I} = \frac{100}{2} = 50\,\Omega$

power dissipated, $I^2R = (2)^2 . R = 100$ watt

$\Rightarrow 4R = 100$

$\Rightarrow R = \frac{100}{4} = 25\,\Omega$

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

$\Rightarrow (50)^2 = (25)^2 + X_L^2$

$\Rightarrow X_L = \sqrt{(50)^2 - (25)^2} = 43.3\,\Omega$

$X_L = 2\pi f L$

$\Rightarrow L = \frac{X_L}{2\pi f} = \frac{43.3}{2 \times 3.14 \times 50} = 0.1378\,H$

Q.4 A resistance of 12Ω, an inductance of 0.15H and a capacitor of 100μF are connected in series across 200V, 50Hz supply. Calculate (a) current (b) power factor of the circuit (c) voltage drops across resistance, inductance and capacitance (d) draw the complete phasor diagram of the circuit.

given

$R = 12\Omega$, $L = 0.15\,H$ $C = 100\,\mu F$

inductive reactance, $X_L = 2\pi f L$

$= 2 \times 3.14 \times 50 \times 0.15 = 47.12\,\Omega$

capacitive reactance, $X_C = \frac{1}{2\pi f C}$

$= \frac{1}{2 \times 3.14 \times 50 \times 100 \times 10^{-6}}$

$= 31.83\Omega$

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

$= \sqrt{(12)^2 + (47.12 - 31.83)^2}$

$= 19.44\,\Omega$

(a) current $(I) = \frac{V}{Z} = \frac{200}{19.44} = 10.3$ Amp

(b) power factor $(\cos\phi) = \frac{R}{Z} = \frac{12}{19.44} = 0.62$ (lagging)

(c) voltage drop across 'R' = $V_R = I.R = 10.3 \times 12 = 123.6\,V$

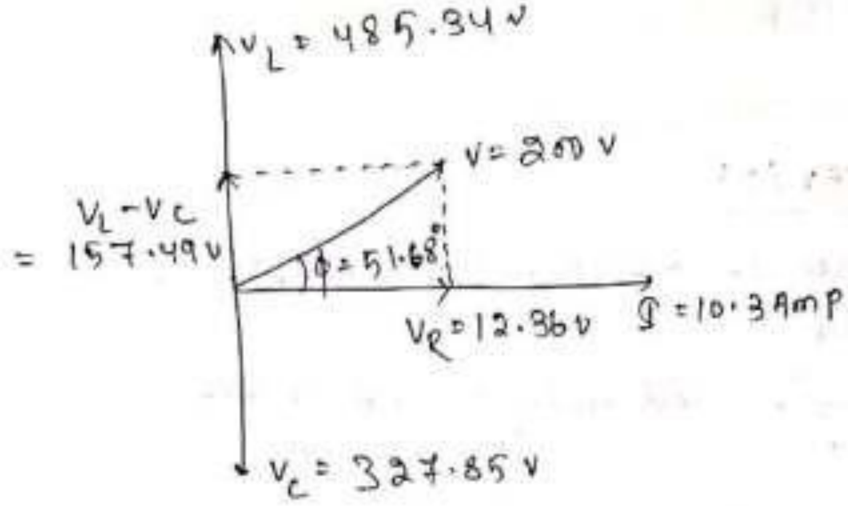
voltage drop across 'L' = $V_L = I.X_L = 10.3 \times 47.12 = 485.34\,V$

voltage drop across 'C' = $V_C = I.X_C = 10.3 \times 31.83 = 327.85\,V$

$V = \sqrt{(123.6)^2 + (157.49)^2}$

$= 200\,V$

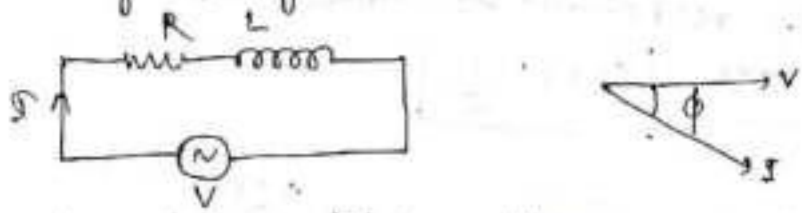
$\phi = \cos^{-1}(0.62) = 51.68^\circ$



2.9 Concept of power and power-factor

Power (Active, Reactive and apparent power)

Let a series R-L circuit draw a current of 'I' when an alternating voltage 'V' is applied to it.



Suppose that current 'I' lags the voltage by an angle 'ϕ'. Then '3' power drawn by the circuit are as under.

① Active / Real / True power (P)

→ The power which is actually consumed in a resistor of circuit is called active power.

→ It is denoted by 'P' and unit is watt or kilo-watt.

$$P = I^2 R = VI\cos\phi$$

② Reactive power (Q)

→ The power which is developed in the inductive reactance of the circuit is called reactive power.

→ It is denoted by 'Q' and unit is VAR or KVAR (Volt-Ampere-Reactive)

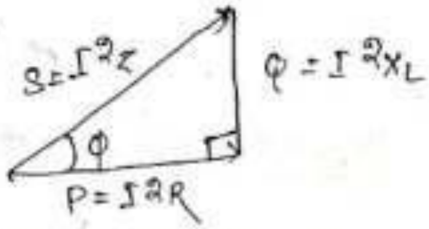
③ Apparent power (S)

→ The vector sum of active and reactive power is called apparent power.

→ It is denoted by 'S' and unit is VA or KVA (Volt-Ampere).

→ $S = VI$

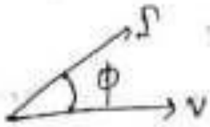
$S = \sqrt{P^2 + Q^2}$

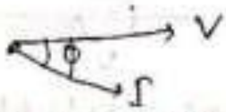


Power factor

→ The cosine angle between voltage and current is called power factor ($\cos\phi$).

→ The ratio of resistance to impedance is also called power factor. $\boxed{\cos\phi = \frac{R}{Z}}$

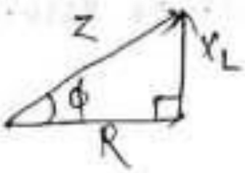




2.10 Impedance triangle and power triangle

Impedance triangle

→ The representation of resistance, reactance, and impedance in a right angle triangle with an phase angle 'ϕ' is called impedance triangle.



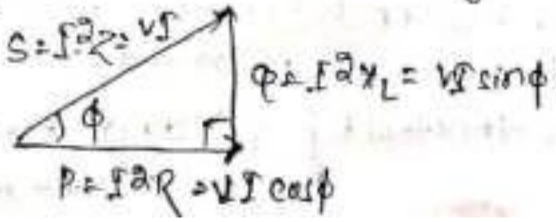
'ϕ' = Phase angle between 'R' and 'Z'

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

Power triangle

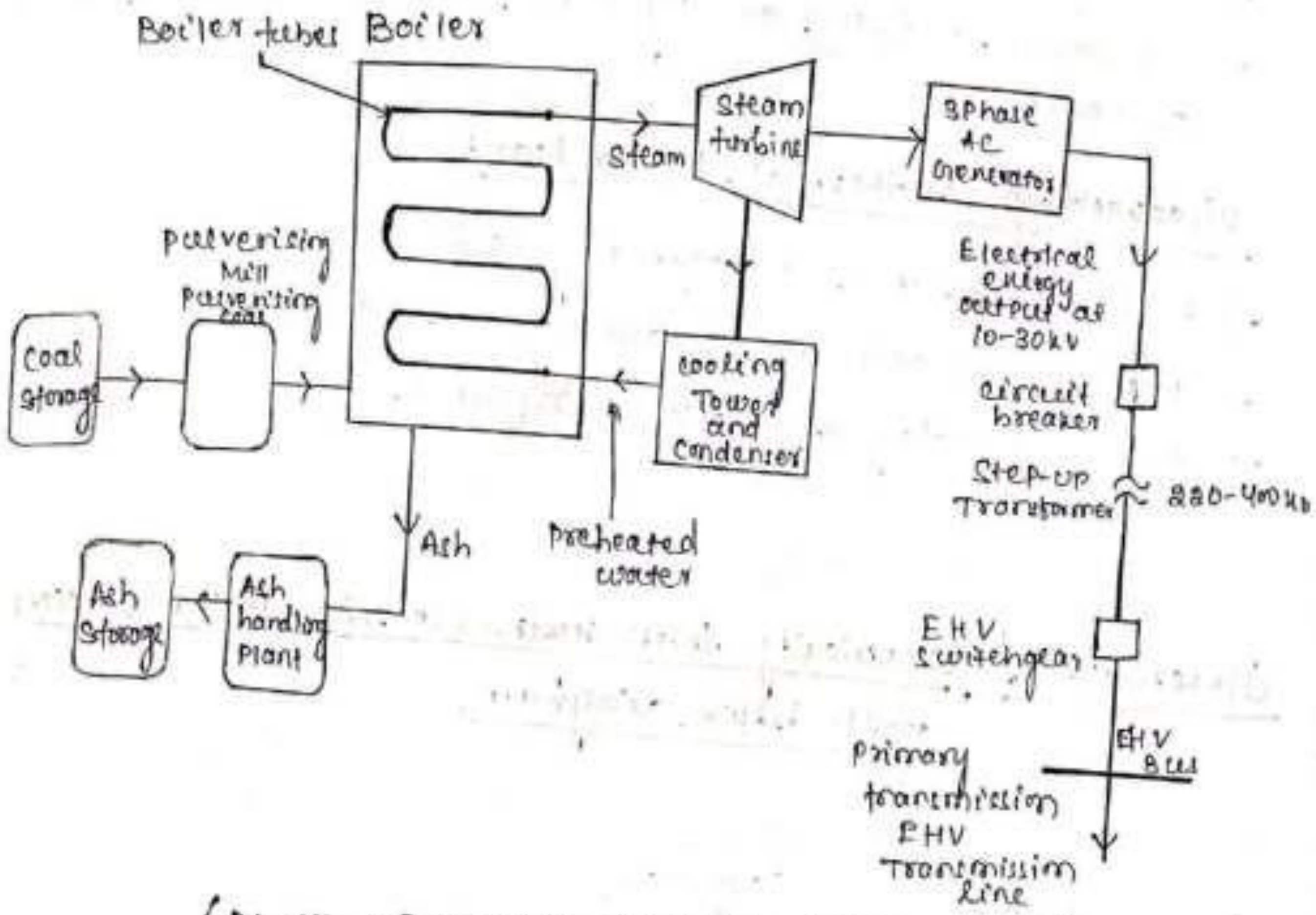
→ The graphical representation of active, reactive and apparent power in a right angle triangle with an phase angle 'ϕ' is called power triangle.

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



Chapter-3 Generation of Electrical Power

3.1 Generation of electricity from thermal power station with block diagram.



(BLOCK DIAGRAM OF THERMAL POWER PLANT)

→ In thermal power plant heat energy is converted into Electrical energy. A large quantity of water is used for making steam.

→ coal is burnt in the boiler. This heat converts water into steam when water passes through the boiler tube.

→ Here steam turbine is coupled with generators.

→ Then steam from boiler passes into steam turbine and rotates the turbine. For that coupled generator rotates and produce electrical energy.

→ The steam from steam turbine passes into condenser where steam converts into water and this water passes into boiler for re-use.

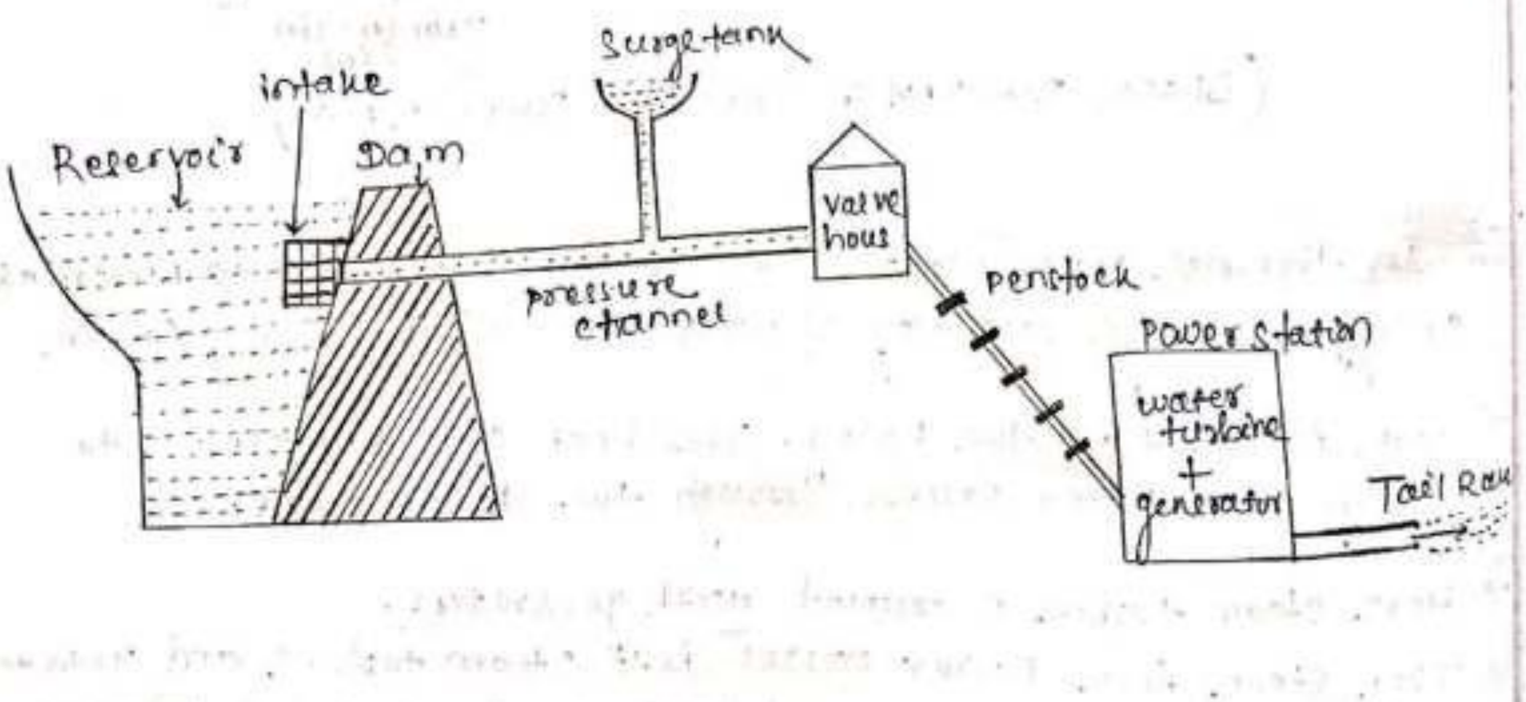
Advantages of thermal power plant

→ The fuel (coal) is cheaper.
→ Less initial cost as compared to other generating plants.
→ It required less space.
→ It can be installed at any place irrespective of the existance of coal.

Disadvantages of thermal power plant

→ High maintenance and operating cost.
→ pollution of atmosphere due to fuel (coal)
→ A huge quantity of water is required.

Generation of electricity from Hydro-electric power station with block diagram.



Elements of hydro-Electric power plant:→

(1) Storage reservoir:→ It's purpose is to store water.

(2) Dam:→ The dam used to raise the water surface of stream to increase an artificial head.

(3) penstock:→ A penstock is the long pipe that carries the water flowing from the reservoir towards the power generation unit.

(4) Intake:→ These are the gates built on the inside of the dam to controlled the water flow from reservoir.

(5) surgetank:→ Surge-tank is used to avoid water hammering effect and to save penstock.

→ For hydro-electric power plant, a huge quantity of water is required which is store in reservoir.

→ Through a pressure channel water passes from reservoir to valve house.

→ valve house contain main 'sluice valve' for controlling water flow to the power station.

→ A surgetank is provided to avoid water hammering effect on penstock

→ Then the water from valve house flow into the power station through penstock.

→ In power station turbine coupled with generator.

→ In power station, water from penstock fall on blade of turbine, where kinetic energy of water is converted into rotational motion of the blade.

→ Due to rotational motion of blade, the coupled generator also rotates and produces electrical energy.

Advantages

→ They donot pollute atmosphere.

→ The lake's water can be used for irrigation purpose.

→ Hydro-power project control flood.

→ Cheapest in operation and maintenance.

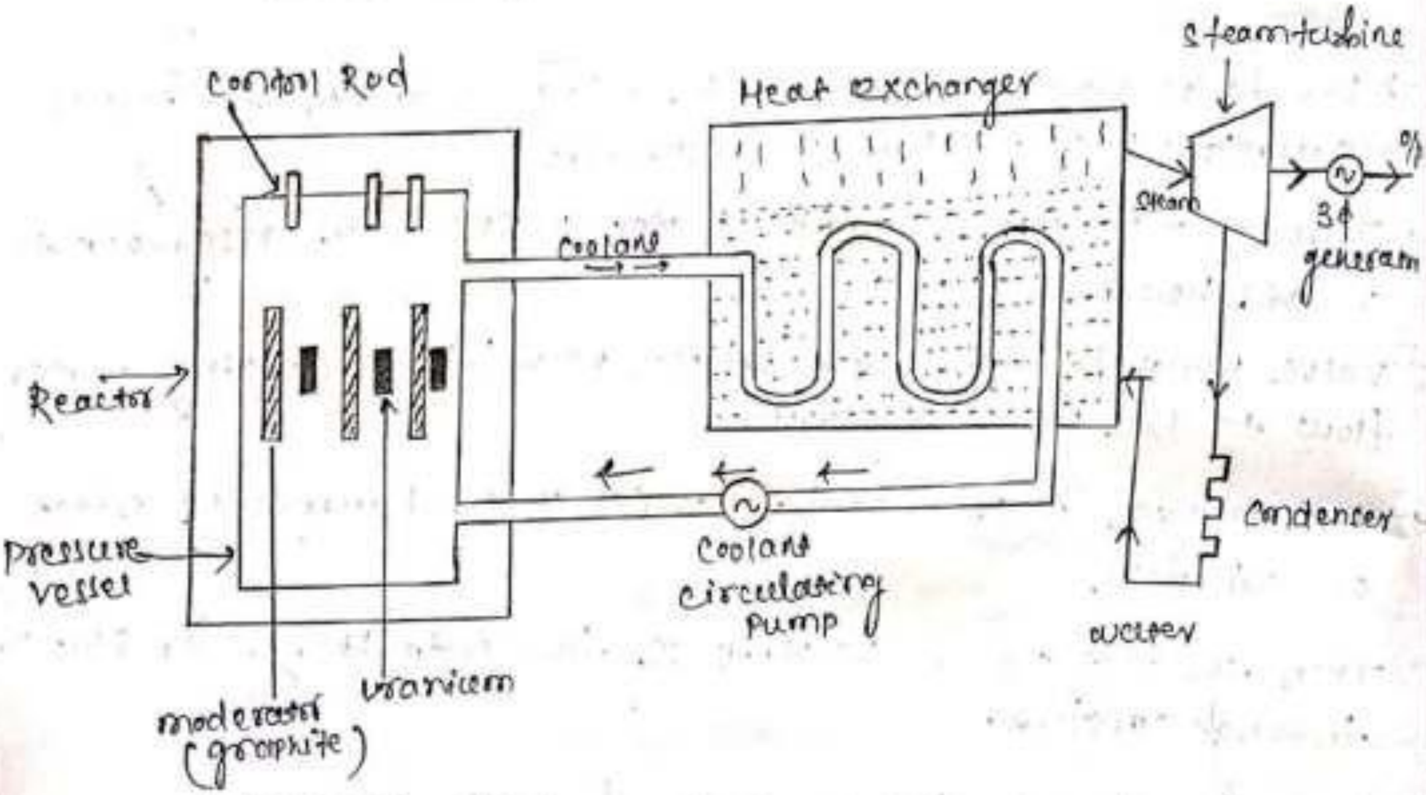
Disadvantages

→ Dams are extremely expensive to build.

→ It depends on rain

→ It requires large area

Generation of electricity from Nuclear power station with block diagram.



The whole arrangement of nuclear power plant can be divided into :—

① Nuclear Reactor
② Heat exchanger
③ Steam turbine
④ Condenser
⑤ Alternator

① Nuclear Reactor

→ Inside the nuclear reactor a huge amount of heat energy is produced when uranium 235 (U235) is bombarded with moving neutron.

→ The moderator made of graphite rods which slowdown the speed of neutrons.

→ The control rods made of cadmium which is a strong neutron absorber and thus regulates the supply of neutron for fission.

→ The heat produced in reactor is removed by the coolant which consist of liquid sodium.

→ The coolant carries the heat to the heat exchanger.

② Heat exchanger

→ The coolant gives up heat to the heat exchanger which is utilised in raising the steam.

③ Steam Turbine

→ The steam drive the steam turbine. After doing a useful work in the turbine, the steam is exhausted to condenser.

④ Condenser

→ In condenser, the steam is converted into water and fed to the heat-exchanger for re-use.

⑤ Alternator

→ The steam turbine drives the alternator which converts mechanical energy into electrical energy.

Advantages

→ The amount of fuel required is quite small.
→ It require less space as compare to other power plant.

Disadvantages

→ Fuel is expensive and not abundantly available everywhere.
→ It has high capital cost.
→ maintenance charge is high.

Chapter-4 Conversion of Electrical Energy

4.1 Introduction of DC Machine

Classification of Electrical Machine

- Static device (Transformer)
- Rotating device
  - DC Machine ($V, f = 0$)
    - DC Motor
    - D.C Generator
  - AC Machine (V, f)
    - Synchronous Machine ($N_r = N_s$)
      - Synchronous Motor
      - Synchronous generator (Alternator)
    - Asynchronous Machine (Induction Machine) ($N_r \neq N_s$)
      - Induction Motor
        - 3 Phase Motor
        - 1 Phase Motor
      - Induction generator

D.C Machine

① **DC generator:** →

→ A machine that converts mechanical energy into electrical energy is called a D.C. Generator.

→ DC generator works on the principle of Faraday's law ~~law~~ of electro-magnetic induction.

→ The law state that, whenever a conductor cuts the magnetic field flux, emf is induced and this emf causes the flow of current in a closed circuit.

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The basic essential parts of a electrical generator are

① A magnetic field

② conductor → which cuts the magnetic field.

→ The direction of induced emf can be determined by using fleming's right hand rule.

② DC Motor :→

→ A d.c Machine that converts electrical energy into mechanical energy is called a d.c Motor.

→ A d.c Motor works on ~~the~~ Lorenz's principle.

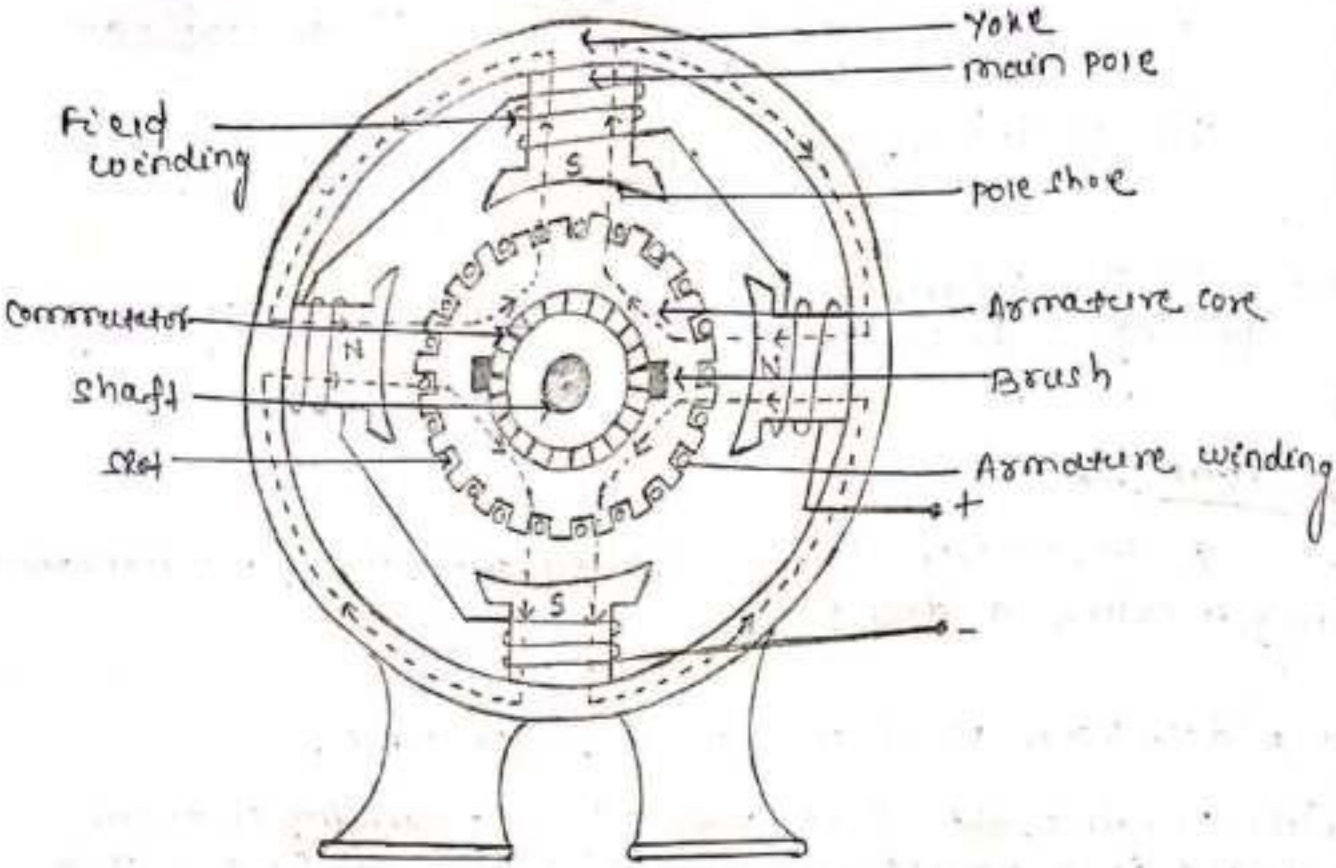
→ The principle ~~state~~ states that, when a current carrying conductor placed in a magnetic field, a mechanical force acts on the conductor.

→ The direction of Mechanical force can be determined by fleming's left hand rule.

4.2 Main parts of DC Machine

A d.c. Machine essentially consist of the following parts

1. Magnetic frame or Yoke
2. pole cores and pole shoes
3. Field coil / Field windings
4. Armature core
5. Armature windings
6. commutator
7. Brushes & Bearing
8. interpole
9. shaft
10. Base



(Cross-section view of a D.C Machine)

① **Yoke** :→ The outer section of the machine is called yoke or magnetic frame.

It serves two purposes

① It provides mechanical protection to the whole machine
② It carries the magnetic flux produced by poles.

Material used

1) cast iron → for small M/c $(B = 0.8\ wb/m^2)$ $\left(B = \frac{\phi}{A}\right)$
2) cast steel → for large M/c $(B = 1.5\ wb/m^2)$

② **Pole cores & Pole shoes**

→ The field magnets consists of pole core and pole shoe.
→ The rectangular form is called pole core over which field windings are provided.
→ The bottom part of pole core is called pole shoe. and it is curved in nature inorder to get uniform flux distribution

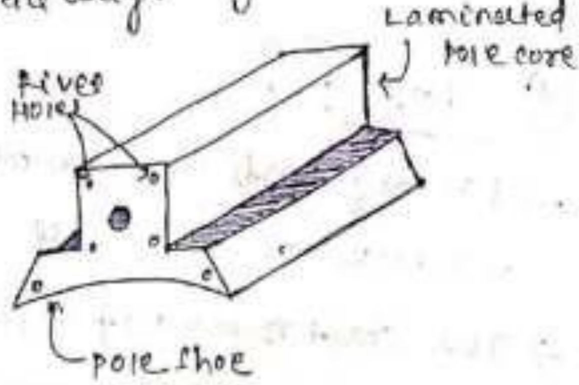
(3) Field winding / Field coil! →

→ Field windings are used to form electro-magnet & that produce the flux when current passes through these coils.

① series field wdg ② shunt field wdg.

(4) Armature core! →

→ It is the rotating part of a D.C Machine and is connected to the shaft.



(5) Armature windings! →

→ The conductors which are placed over the armature slot in a suitable manner is known as armature winding.

→ The armature windings are made of copper, in which "working": emf is induced in case of generator.

(6) Commutator! →

→ The function of commutator is to collect the current from the armature winding.

→ In case of generator, it acts as rectifier, that means it converts AC to DC.

→ In case of Motor, it acts as inverter, that means it converts DC to AC.

(7) Brush and Bearing! →

→ The current is collected from or supply through the brushes depending upon the machine whether it is generator or motor.

→ The brushes are usually made of carbon.

→ The function of bearing is to reduce friction between the rotating and stationary part of the Machine.

(8) Interpole! →

→ There are small poles placed in between the main poles.

→ These are used to reduce armature reaction.

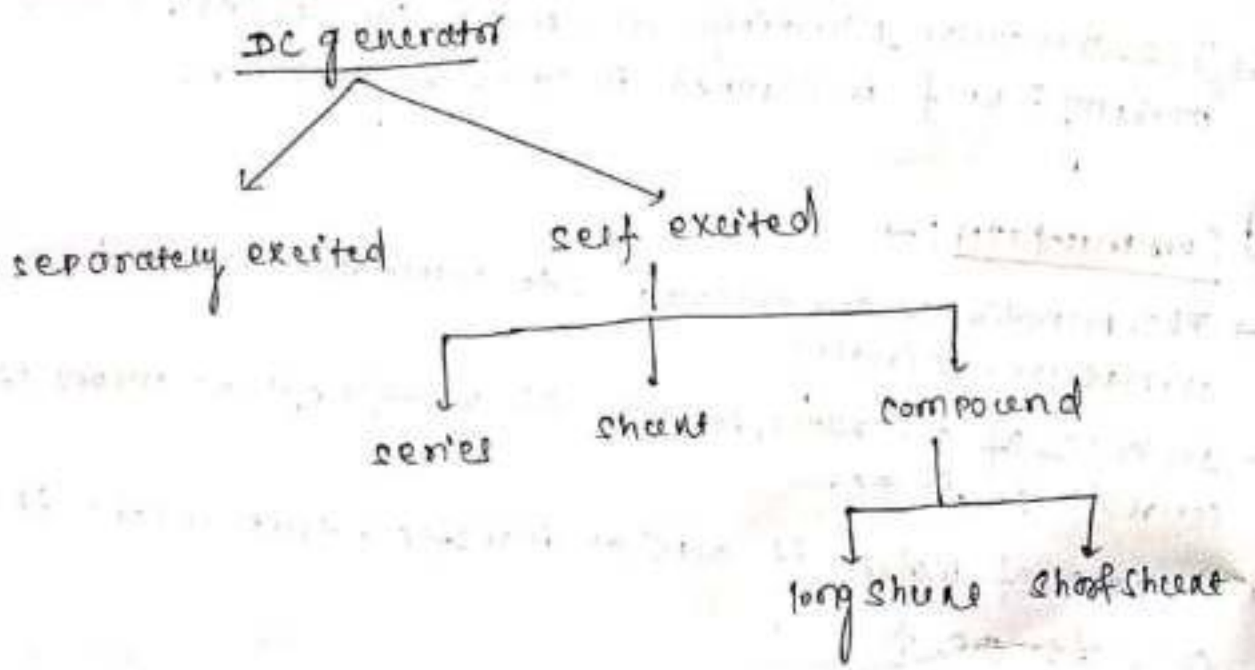
(9) Shaft! →

→ Rotating parts like armature core, commutator, cooling fan's are mounted on the shaft.

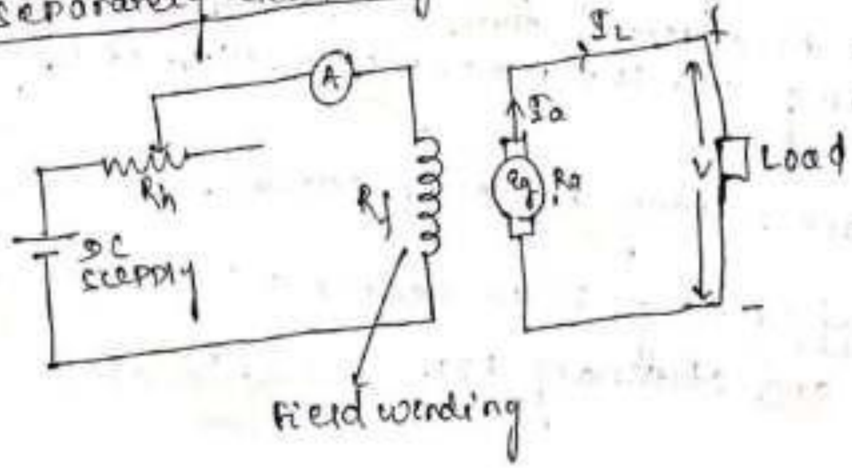
→ The shaft is made of mild steel

→ It is used to transfer mechanical energy from primemover to the armature (in generator) & from armature to load (in motor)

4.3 Classification of DC generator



(1) separately excited generator



→ In separately excited D.C. generator, an external DC voltage source is used to excite the field.

$I_a = I_L$

I_a = armature current

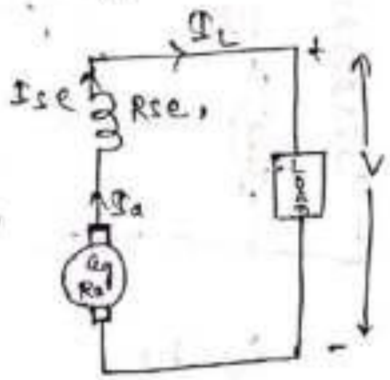
I_L = Line current

$$\boxed{V = E_g - I_a R_a}$$

② self excited generator

→ In self excited D.C generator, the field winding is excited by the current produced by the generator it'self.

ⓐ series generator



$I_a = I_{se} = I_L$

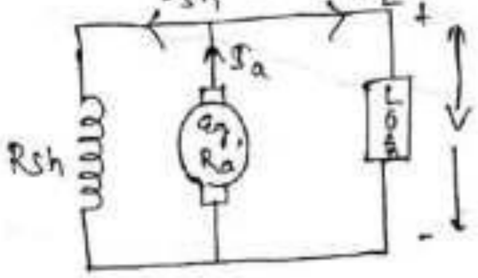
$V = E_g - I_a R_a - I_a R_{se}$

$$\boxed{V = E_g - I_a (R_a + R_{se})}$$

Here the field winding is connected in series with the armature winding.

ⓑ shunt generator

Here the field winding is connected in parallel with the armature winding.



$I_a = I_{sh} + I_L$

I_{sh} = shaft current

$V = I_{sh} \times R_{sh}$

$$\boxed{V = E_g - I_a R_a}$$

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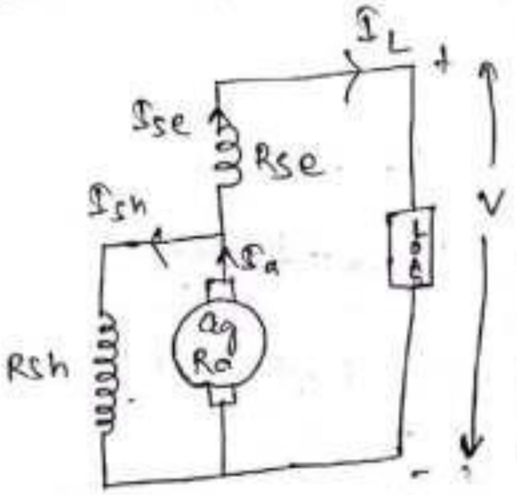
(c) compound generator

→ In a generator if both series and shunt field windings are present then it is called as compound generator.

→ According to connection their are 2 types of compound generator

1. short shunt compound generator
2. long shunt compound generator

Short-shunt



$I_{se} = I_L$

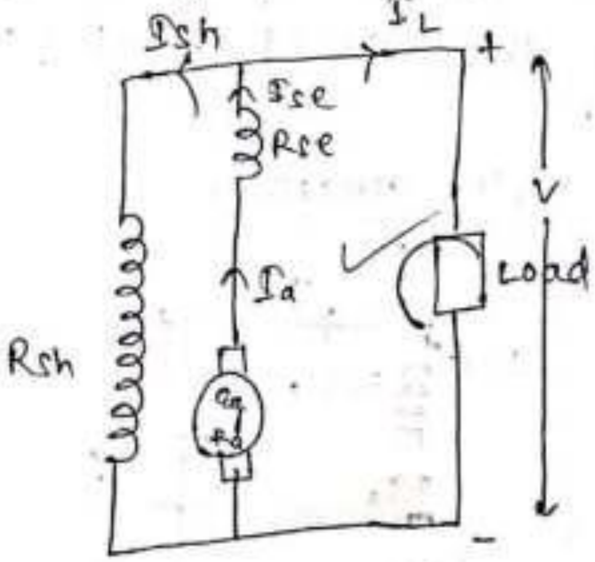
$I_{sh}R_{sh} = E_g - I_aR_a = V + I_{se}R_{se}$

⇒ $$I_{sh} = \frac{V + I_{se}R_{se}}{R_{sh}}$$

⇒ $E_g - I_aR_a = V + I_{se}R_{se}$

⇒ $$V = E_g - I_aR_a - I_{se}R_{se}$$

Long-shunt



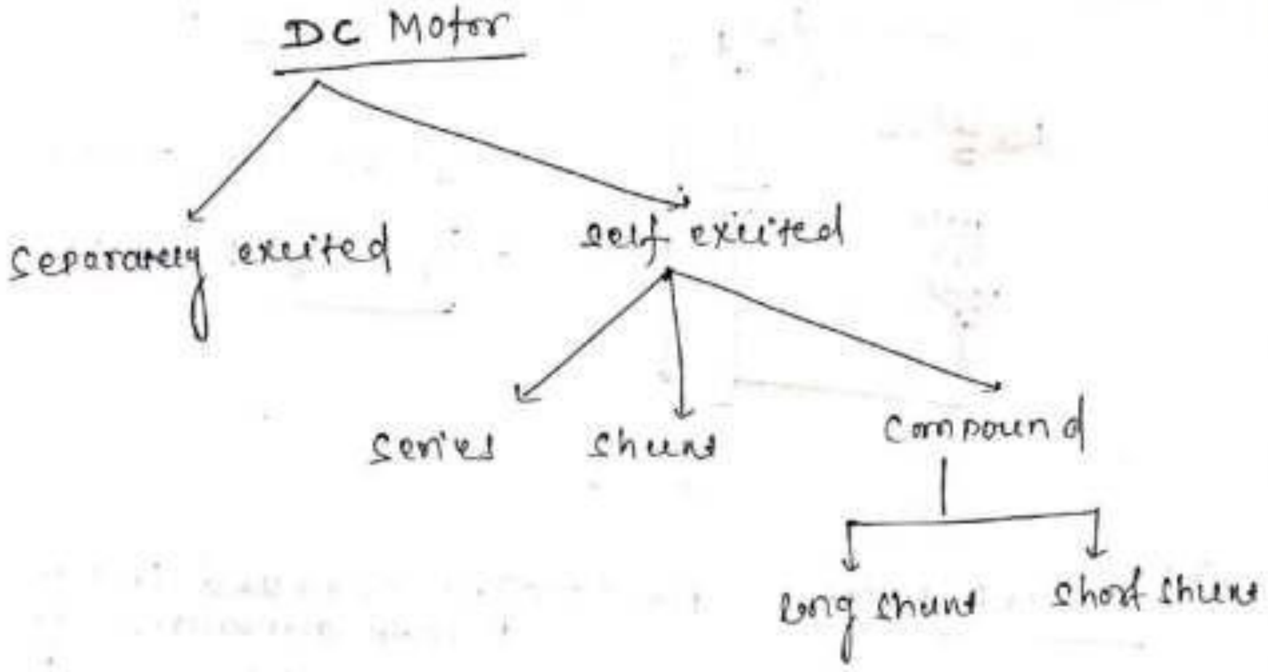
$I_a = I_{se}$

$I_a = I_{sh} + I_L$

$$V = E_g - I_aR_a - I_{se}R_{se} = I_{sh}R_{sh}$$

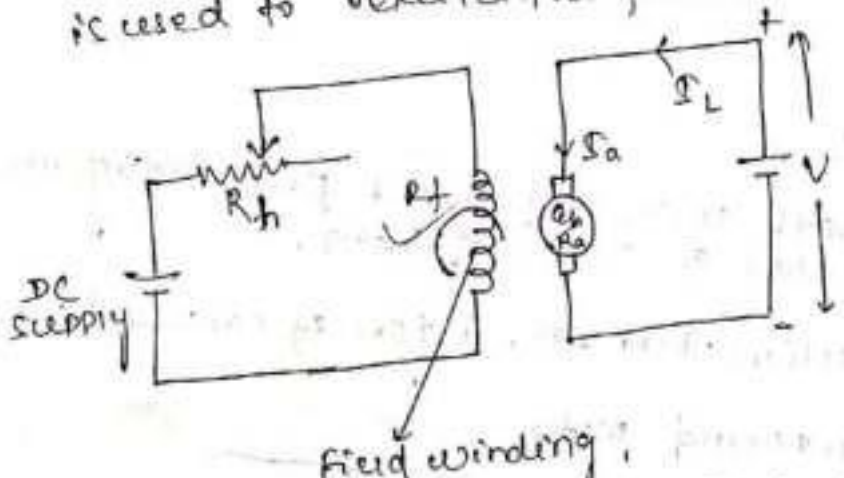
$$I_{sh} = \frac{V}{R_{sh}}$$

4.4 Classification of DC Motor



(1) Separately excited DC Motor

→ In separately excited Motor, an external voltage source is used to excite the field.

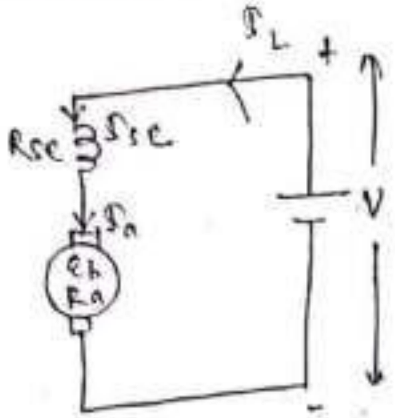


$I_a = I_L$, $E_b = V - I_a R_a \Rightarrow \boxed{V = E_b + I_a R_a}$

(2) Self excited DC Motor.

→ In self excited DC Motor, the field windings is excited by the current supply to the Motor.

(a) **Series Motor** Field wdg. is connected in series with armature wdg.

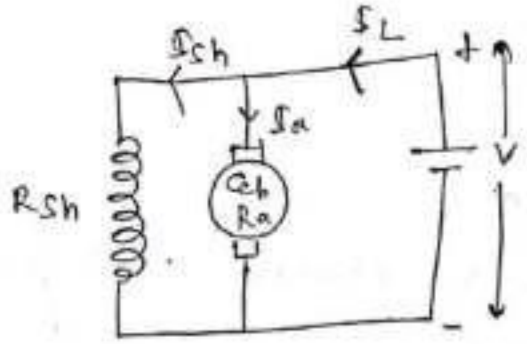


$I_L = I_{se} = I_a$

$e_b = V - I_{se}R_{se} - I_aR_a$

$\Rightarrow$ $\boxed{V = e_b + I_{se}R_{se} + I_aR_a}$

(b) **Shunt Motor** Field wdg. is connected in parallel with armature wdg.



$I_L = I_{sh} + I_a$

$\boxed{V = I_{sh}R_{sh}}$

$\boxed{V = e_b + I_aR_a}$

$\boxed{e_b = V - I_aR_a}$

(c) **Compound Motor**

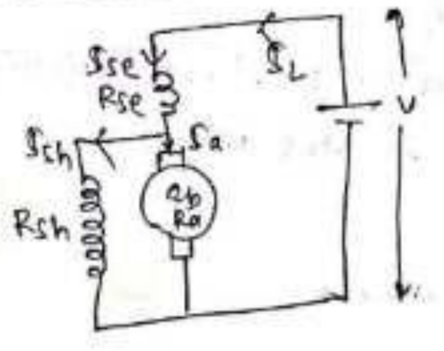
→ In a motor, if both series and shunt field windings are present, then it is called as compound motor.

→ According to connection their are 2 types of compound motor

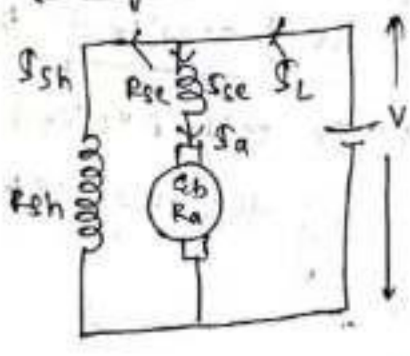
① Short shunt compound motor

② Long shunt compound motor

Short-shunt



Long-shunt



$I_L = I_{se}$, $I_{se} = I_a + I_{sh}$

$I_{sh} R_{sh} = E_b + I_a R_a = V - I_{se} R_{se}$

$\Rightarrow$ $V = E_b + I_a R_a + I_{se} R_{se}$

$\Rightarrow$ $E_b = V - I_a R_a - I_{se} R_{se}$

$I_L = I_{sh} + I_{se}$, $I_{se} = I_a$

$V = I_{sh} R_{sh} = E_b + I_a R_a + I_{se} R_{se}$

$\Rightarrow$ $V = E_b + I_a R_a + I_{se} R_{se}$

$\Rightarrow$ $V = E_b + I_a (R_a + R_{se})$

$\Rightarrow$ $E_b = V - I_a (R_a + R_{se})$

Application of DC Motors

Types of Motor	Characteristics	Application
(1) DC Shunt Motor (Constant speed)	→ It is used where the speed is required to remain constant from No-load to full-load → medium starting torque	→ Lathes → Drills → Blowers & fans → Boring mills → centrifugal pumps
(2) DC Series Motor (High starting torque)	→ It is used where high starting torque is required for accelerating a heavy mass. → variable speed	→ Electric traction → cranes → Elevator → conveyors → hoists → air compressor → vacuum cleaner
(3) compound motor (a) cumulative type → constant speed → High starting torque	→ constant speed is required with irregular loads or suddenly applied heavy load. → High starting torque	→ Elevator → conveyors → Rolling mills → ice machines → printing press

Application of DC generator

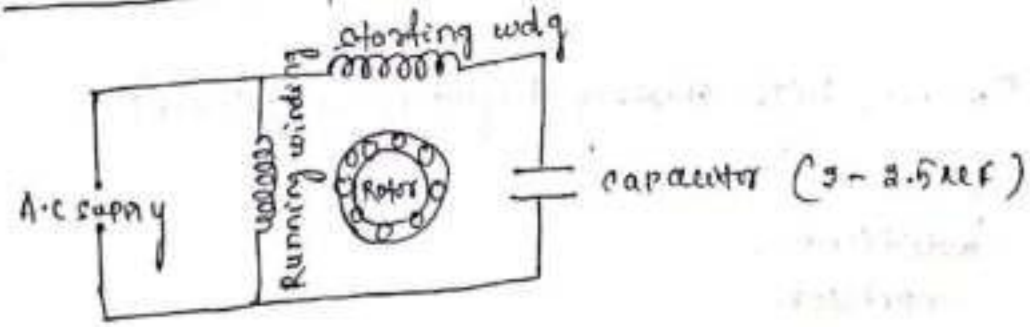
Types of generator	Characteristics	Applications
(1) Shunt generator	→ constant terminal voltage	→ Batteries charging
(2) series generator	→ Rising voltage characteristics	→ Booster (In certain type of distribution system, particularly in railway service.
(3) compound generator (a) cummulative type	→ over compounding compensate voltage drop in the distribution line and voltage at consumer terminal remain more	→ DC generator, (Lighting, power service)
(b) Differential	→ constant current generator	→ Arc welding.

4.6 Types and uses of single phase Induction Motors

Classification of A.C single phase Motor

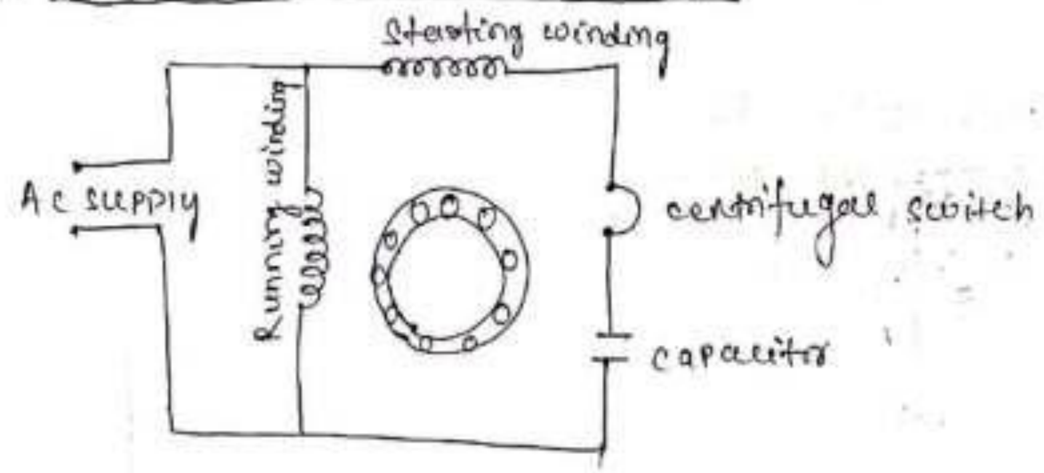
- Induction type
  - split phase type Motor
    - capacitor start Motor
    - permanent capacitor Motor
    - capacitor start capacitor run Motor
    - shaded pole Motor
- commutator type
  - universal Motor
  - Repulsion motor

① permanent capacitor Motor



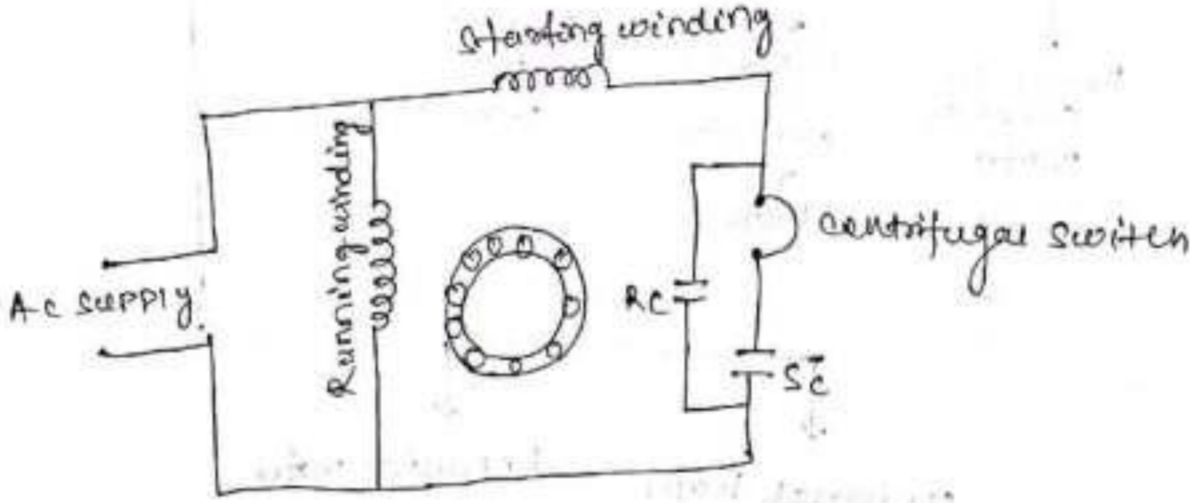
uses :→ ceiling fan, ~~[illegible]~~ Table Fan,

(2) capacitor start induction Motor



uses :→ Lathe machine,
Drill Machine
grinders

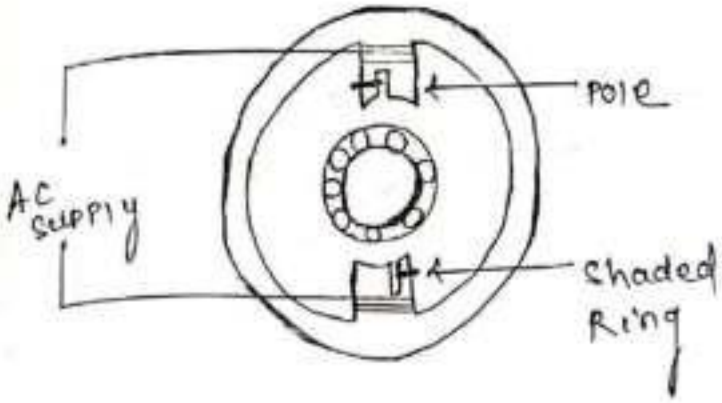
(3) capacitor start capacitor run induction motor



RC = Running capacitor
S.C. = Starting capacitor

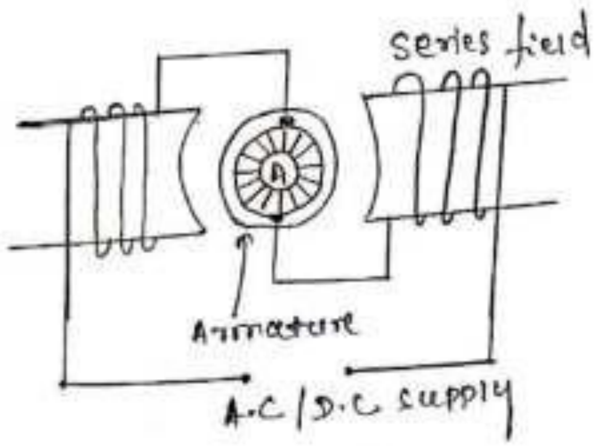
uses :→ (where high starting torque is required)
Refrigerators,
air conditioner,
air compressors
blowers

④ Shaded pole Motor



uses :- cooler pumps
small fans
hair dryer
electric wall clock

⑤ universal Motor → This motor works on A.C and D.C both supply.



uses :- portable drill machine
sewing machine
vacuum cleaner

4.7 Concept of Lumen

① **Luminous flux :→**

The total quantity of light emitted by a source of light per second is called luminous flux.

② **Lumen :→**

It is the unit of luminous flux.

Example

Crompton

Luminous flux

18 watt ⟶ 1600 Lumen

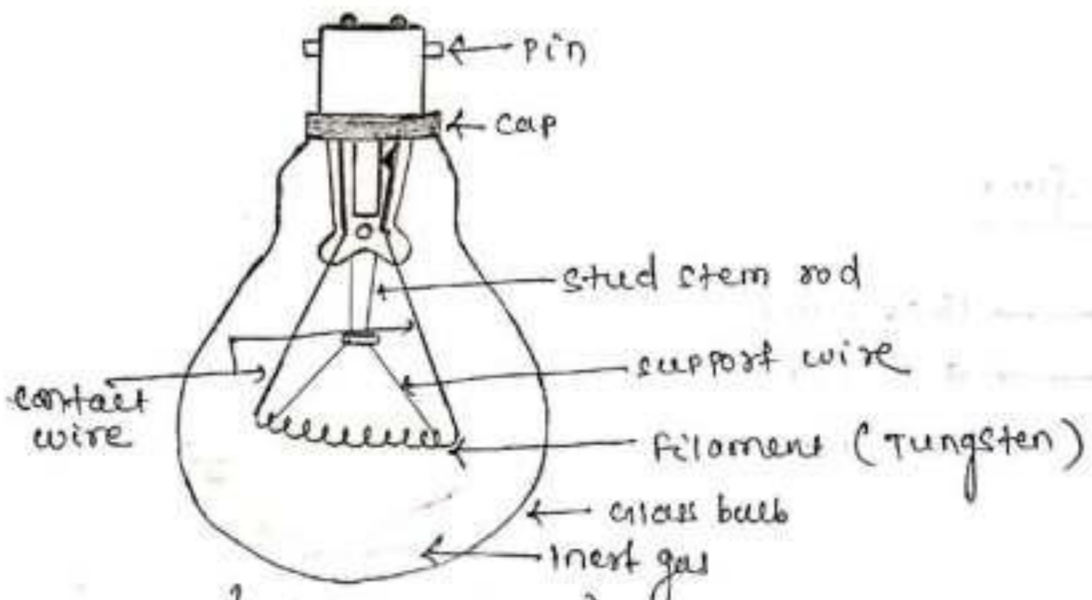
36 watt ⟶ 2450 Lumen

20 watt ⟶ 2000 lumen

4.8 Different types of lamps (Filament, Fluorescent, LED bulb) its construction and principle

The electric lamp is a source which convert electric energy into heat energy and then lighting energy.

① Filament type :→
(Incandescent lamp)



(Filament lamp)

→ It consist of a glass bulb containing carbon or tungsten filament.

→ The production of light due to heating effect of filament caused by electric current flow through it.

→ The working temperature of carbon filament is about 1600°c to 1800°c, as at higher temperature it starts evaporating and thus, blackens the inner surface of glass bulb due to this carbon filament is rarely used for making the bulb.

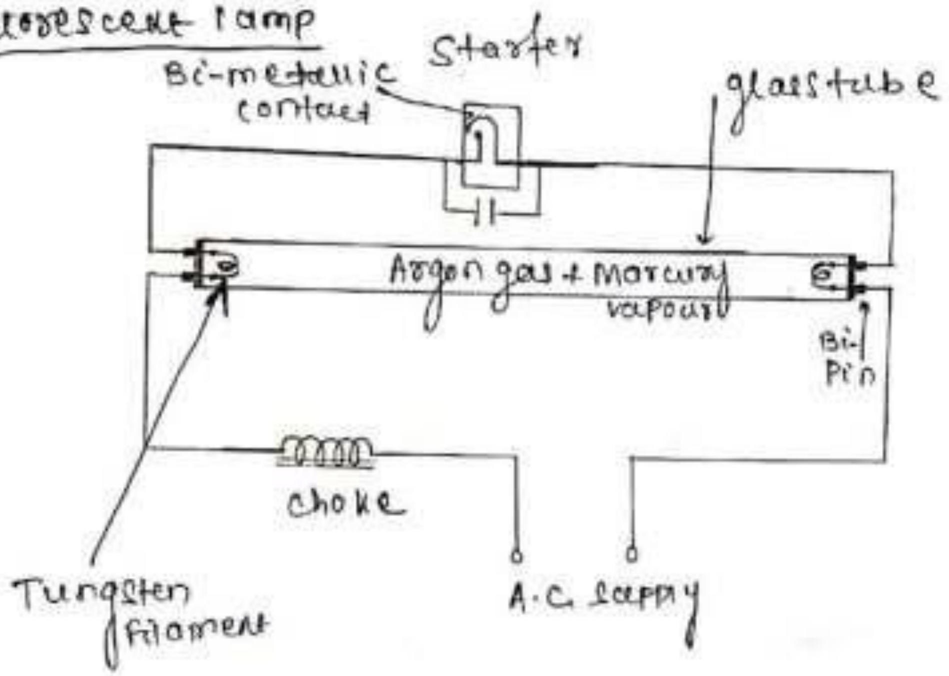
→ The tungsten filaments are of two types
① coiled filament (ᗰ)

② coiled coil filament.

→ Lamps upto 40 watts are vacuum type where as lamps above 40 watts are gas filled.

→ Normally argon with small percentage of nitrogen gas is used which prevents the blackening of inside of the lamp due to evaporation of tungsten filament operating at high temperature.

② Fluorescent lamp



→ Tube is made of glass with fluorescent powder coating to it's inner surface.

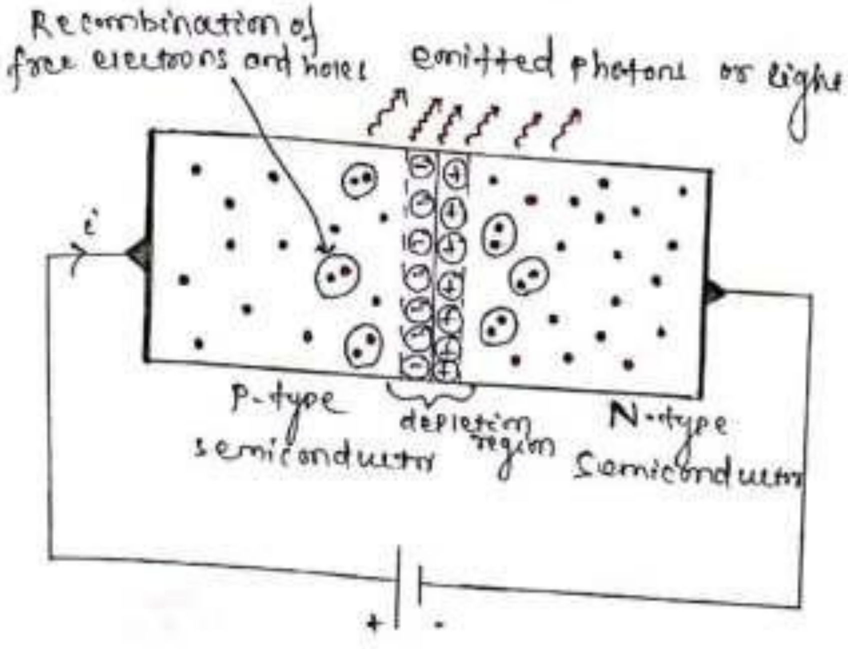
→ Tungsten filament is used.

→ The mercury vapour with small quantity of argon gas at low pressure is filled up in the tube.

→ when fluorescent tube is connected to supply through choke and starter, about 1000 volt is induced.

→ Due to this, filament discharges the gas on heating and provides path for the flow of electrons, as gas after discharge acts as a conductor. Mercury vapour are vaporized and give full light.

(3) LED bulb (Light emitting diode)



→ The light emitting diode is a P-N junction diode. It is made up of a special type of semiconductor.

→ under the forward biased condition, when a suitable voltage is applied across the diode, electrons and holes are moving fast across the junction.

→ Then electrons are able to recombine with holes within the device and releasing energy in the form of photons or light.

Advantages of LED

1. smaller size
2. Physical Robustness
3. longer life
4. lower energy consumption
5. faster switching

Application of LED

→ Bulb in homes and industries
→ traffic signal
→ used in motor cycles and cars
→ Display

4.9 Star Rating of home appliances

Energy efficiency :→

→ energy efficiency means using less energy to provide the same service.

→ energy efficiency can be defined as a reduction in the energy used for given service (heating, lighting etc)

Example :→

CFL is more efficient than incandescent bulb as it uses much less electrical energy to produce the same amount of light.

Star Rating :→ More number of stars meant a higher efficiency appliances which consumes less electricity

Chapter-5 Wiring and power Billing

5.1 Types of wiring for domestic installations

Followings are the type of internal wiring usually employed in industries and house wiring.

1. cleat wiring
2. casing and capping wiring
3. Batten wiring
4. conduit wiring → surface wiring
   → underground / concealed type wiring

1. Cleat wiring

→ In this type of internal wiring the cables used are either VIR or PVC types.

→ The cables are held by porcelain cleats above the wall or ceiling.

→ The cleats are made in two halves, one base and the other cap.

Advantages

→ It's the cheapest system of internal wiring

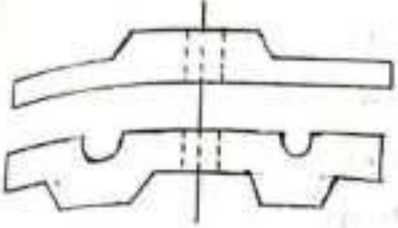
→ Inspection, alternation and addition can be easily made.

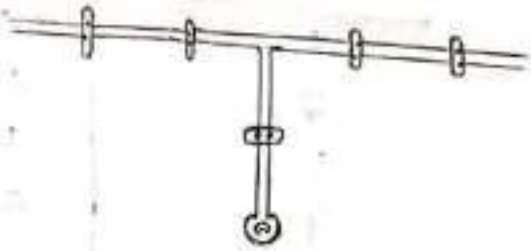
→ Skill required is little.

Disadvantages

→ It's not good looking.

→ It is quite temporary and destroy quickly.





② casing and capping wiring

→ In this type of wiring PVC casing and capping are being used.

→ This type of wiring is achieved by using hollow channel made of PVC plastic.

Advantages

→ Easily inspect by opening the capping.

→ Easy to install and rewire.

Disadvantages

→ This type of wiring can be used only on surface and cannot be concealed in plaster.

→ since it requires better workmanship, the labour cost is higher.

③ Batten wiring

→ In this type of wiring, cables are run on perfectly straight and well varnished teak wood batten.

→ The width of batten depends upon the number and size of cable to be carried by it.

Advantages

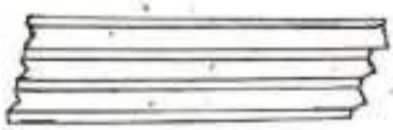
→ It's installation is easy and quick

→ It's life is sufficiently long.

Disadvantages

→ Good workmanship is required.

→ This type of wiring cannot be recommended for use in situation open to sun and rain.



(4) Conduit wiring (PVC)

(1) Concealed conduit wiring

→ The conduits are fixed along the wall or ceiling in plaster at the time of construction.

(2) Surface conduit wiring

→ In this type of wiring, the conduits are placed on the surface of the wall and hold with the help of conduit saddle.

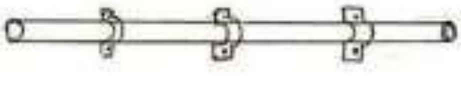
→ This type of wiring is applied in the industrial wiring.

Advantages

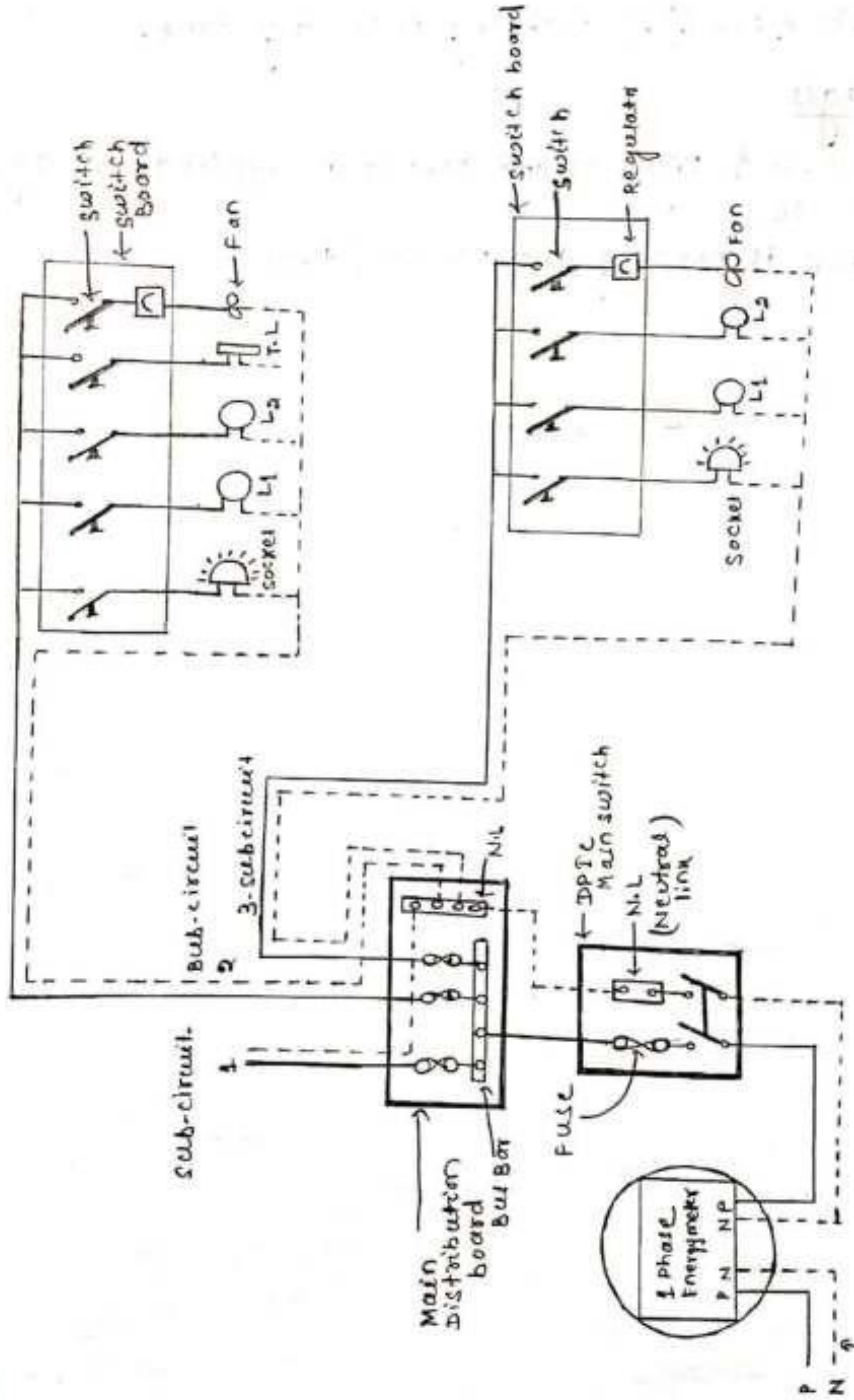
→ It provide protection against mechanical damage.
→ The whole system is waterproof.
→ It's life is long.
→ It is shock proof, if earthing is properly done.

Disadvantages

→ Experience and highly skilled labour is required for carrying out the job.
→ It's erection is not easy and required time.



5.2 Layout of household electrical wiring (single line diagram showing all the important component in the system



5.3 List out the basic protective devices used in house hold wiring.

① Fuse :→

→ Fuse is a current interrupting device which breaks the circuit under short circuit or overload condition.

→ The action of fuse is based upon the heating effect of the electronic current.

→ The material commonly used for fuse elements are tin, lead, silver, copper, zinc, aluminium and alloy of lead and tin.

→ The materials used for fuse elements must be of low melting point and high conducting in nature.

Advantages

→ It is a simplest and cheapest protective device.

→ It require no maintenance.

→ It's operation is completely automatic which can break heavy short-circuit current without noise or smoke.

Disadvantages

→ considerable time is lost in rewiring or replacing a fuse after operation.

② MCB (Miniature circuit Breaker)

→ It is a protective device which make a circuit under normal condition and break a circuit under fault condition.

→ It operated manually under normal condition and automatically under fault condition.

③ Earthing

Connection of non-current carrying parts of electrical apparatus, such as metallic frame, earth terminal of socket etc to the general mass of earth in such a manner that at all times an immediate discharge of electrical energy takes place without danger.

Generally 2 types of earthing are there

① pipe earthing
② plate earthing

pipe earthing :→

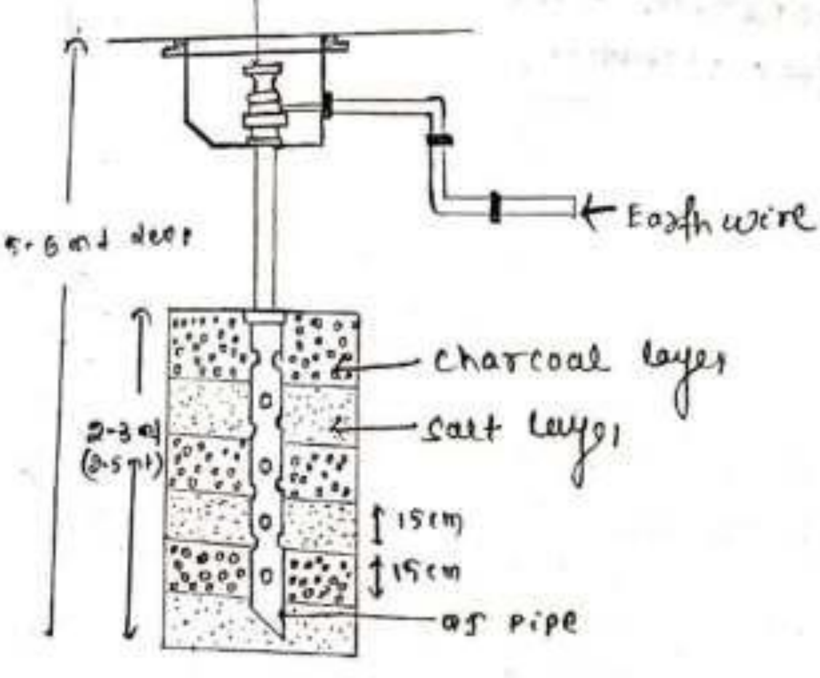
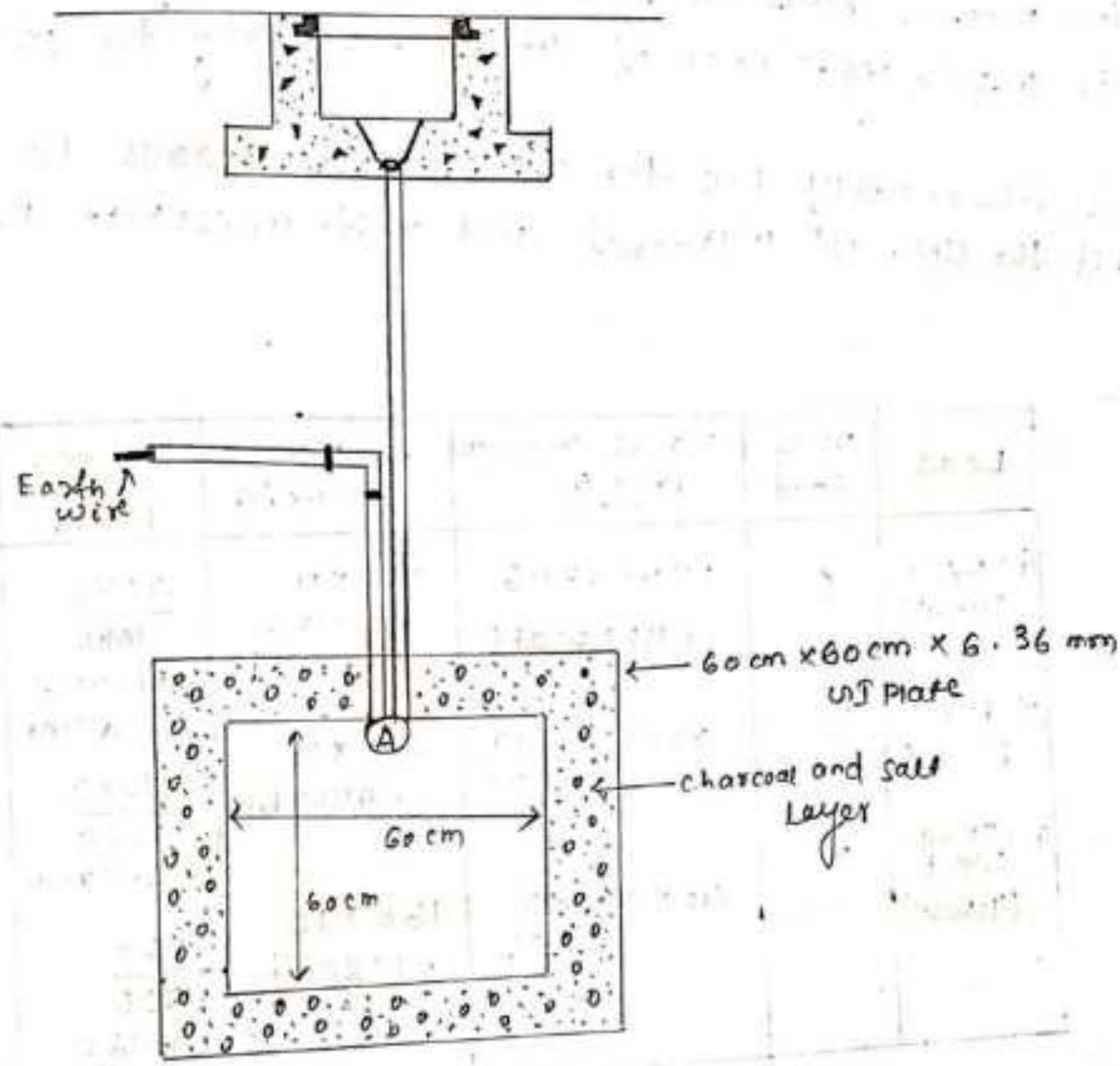


plate earthing :→



5.4 Calculate energy concerned in a small electrical installation

Q.1

A building has the following appliances.

(i) A 1.5 HP motor running for 4 hrs in a day.

(ii) 5 no. of Fans each of 80 watt running for 10 hrs in a day.

(iii) 4 tube light each of 40 watt running for 12 hrs in a day.

Find the monthly bill for a month of 30 days if the cost of first 100 unit is 1.40/unit and rest units at RS 4.10/unit.

Ans

Load	No. of load	Total connected load in watt	E = Pt watt hr	unit in kWhr
(i) Motor (1.5 HP)	1	1×1.5×746 = 1119 watt	1119×4 = 4476 watt hr	$\frac{4476}{1000}$ = 4.476 kWhr
(ii) Fan 80 watt	3	80×3 = 240 watt	240×10 = 2400 Whr	$\frac{2400}{1000}$ = 2.4 kWh
(iii) Tube light (40 watt)	4	40×4 = 160 watt	160×12 = 1920 Whr	$\frac{1920}{1000}$ = 1.920 kWhr

Total unit concerned in one day

= (4.476 + 2.4 + 1.92) kWhr

= 8.796 kWhr

Total unit concerned for 30 days

= 8.796 × 30

= 263.88 unit

cost of 1st, 100 unit is Rs. 1.40

= 100 × 1.40 = 140/-

cost of remaining 163.88 unit = 163.88 × 4.10 = 671.90

Total cost for 30 days = 140 + 672 = 812/-

Q.2 A building has the following electrical appliances

(i) A heater 1000 watt running for 5 hrs a day.

(ii) 4 fans each 60 watt running for 10 hrs a day.

(iii) 4 tube light each of 40 watt running 8 hrs a day.

Find monthly energy consumed for the month of october and bill if unit cost is Rs. 4/-

Ans.

Load	No. of load	Total connected load in watt	E = P t watt.hr	unit in kwhr
(i) Heater (1000W)	1	1000×1 = 1000W	1000×5 = 5000wh	$\frac{5000}{1000}$ = 5 kwh
(ii) Fan 60W	4	60×4 = 240 W	240×10 = 2400 wh	$\frac{2400}{1000}$ = 2.4 kwh
(iii) tube light 40W	4	40×4 = 160W	160×8 = 1280wh	$\frac{1280}{1000}$ = 1.280 kwh

Total energy consumed in one day

$= (5 + 2.4 + 1.28)$ kwhr

$= 8.68$ kwh

Total energy consumed for the month of october

$= 8.68 \times 31$

$= 269.08$ kwh

cost of electrical energy $= 269.08 \times 4$

$= 1076.32/-$

$= 1076/-$

Chapter- 6 Measuring Instruments

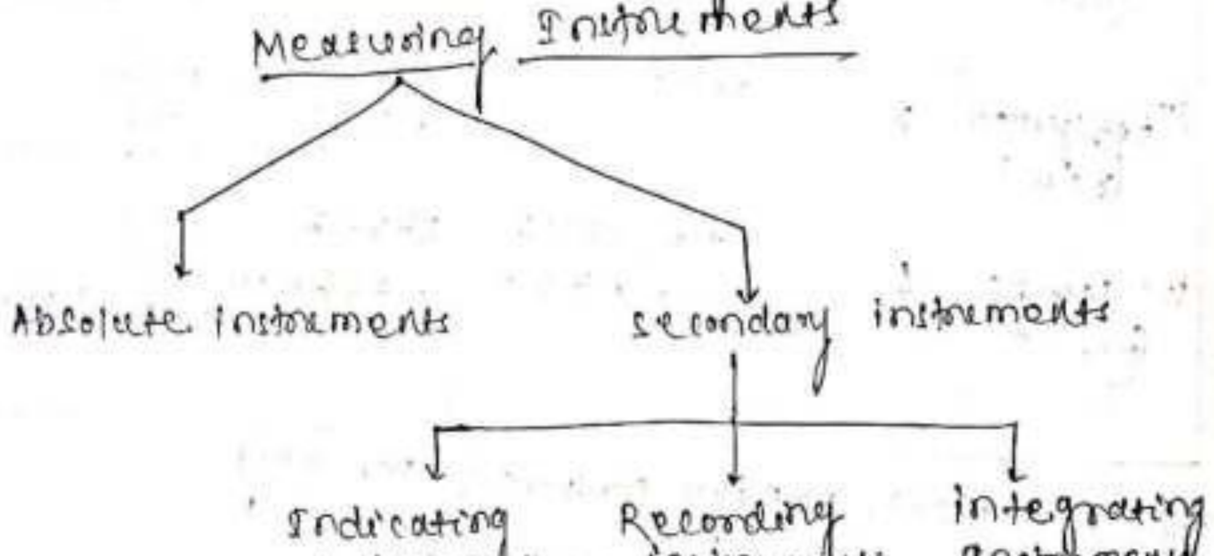
6.1 Introduction to Measuring Instruments

Measuring Instruments

The instruments which are used to measure electrical quantities i.e. voltage, current, power, energy, resistance, frequency etc. are called electrical instruments.

current → Ammeter
voltage → voltmeter
power → wattmeter
energy → energymeter
resistance → ohmmeter
frequency → frequency meter

Classification of electrical measuring Instruments



Absolute Instrument

→ These instrument does not give direct reading, but it gives interms of instrumental physical constant.

→ It is a time consuming process, But gives all most 100% correct value. Hence these are used only in research laboratory.

EX! → Tangent galvanometer

Secondary Instrument

→ This instruments which indicate the electrical quantity to be measured directly interms of deflection are known as secondary instrument.

→ It gives direct reading and generally 3 types

(a) Indicating Instrument

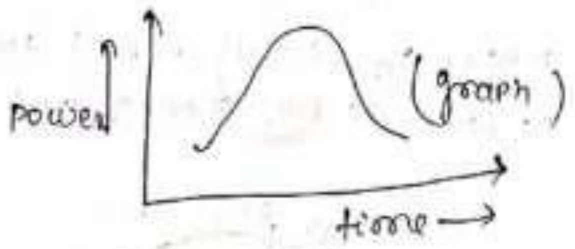
→ These instrument gives the instantaneous value of electrical quantity at the time of measurement.

Ex:→ ordinary Ammeter, Voltmeter, wattmeter

(b) Recording Instrument

→ The value to be measured is continuously recorded over a graph paper by using a light weight pen.

Ex:→ Recording ammeter, voltmeter, wattmeter, storage oscilloscope



(c) Integrating Instrument

→ This instruments adds the measure value to the existing value.

Ex:→ energy meter

6.2 Torques in Instruments

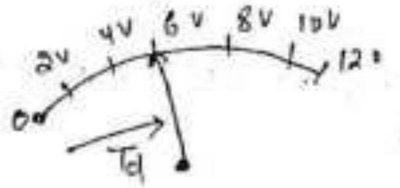
For satisfactory working of indicating instruments the following '3' torques are needed.

1. Deflecting Torque (T_D)
2. controlling Torque (T_C)
3. Damping Torque

① Deflecting Torque (T_D)

→ The deflecting torque causes the moving system of the instrument to move from it's initial zero position.

→ T_d always acts clockwise direction.



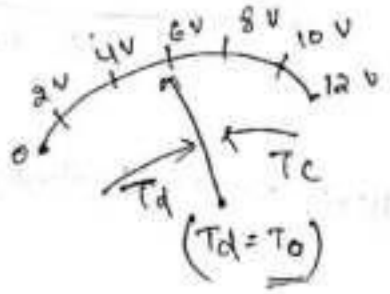
* T_d causes the motion of pointer from '0' position to required value.

② Controlling Torque (T_c)

→ To get the pointer at required final value controlling torque (T_c) is required.

→ The controlling Torque acts in opposite direction to deflecting torque.

→ when T_c exactly equal and opposite to T_d ($T_c = T_d$), then pointer to be stoped and gives the reading.



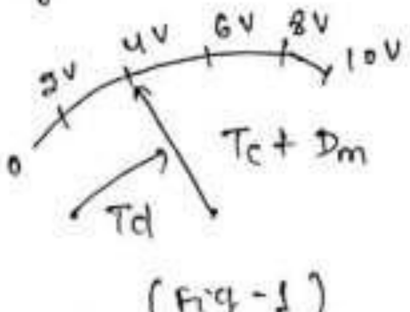
③ Damping Torque

→ A damping torque is necessary in order to bring the pointer to rest position quickly.

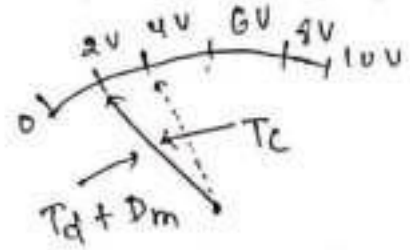
→ The damping torque always acts opposite to the pointer. (Both clockwise and anticlockwise direction)

→ * If damping torque is not present, then the meter pointer start like a motor with high speed. Then T_c comes quickly because spring tighten suddenly. Then pointer makes the oscillation w.r.t. to final value, and takes more time to give the reading.

→ To reduce the oscillation, pointer speed has to be reduced. For this damping torque is required to reduce speed of pointer only.



(Fig-1)



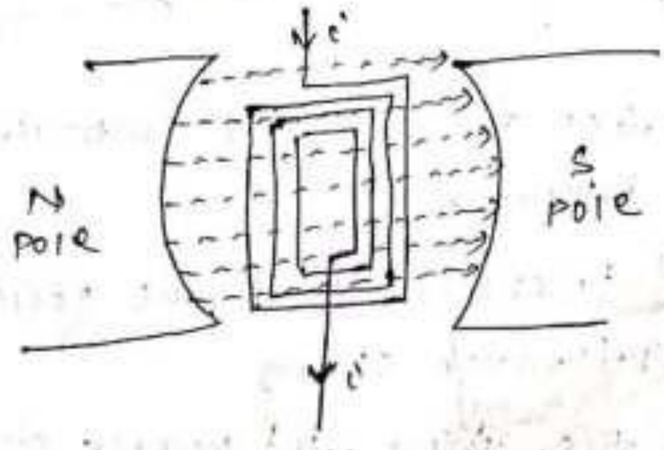
(Fig-2)

Deflecting Torque

According to the Lorenz's principle, when a current carrying conductor placed in a magnetic field, experience a mechanical force i.e. $F = B I l \sin\theta$

B → magnetic field, I → current, l → length

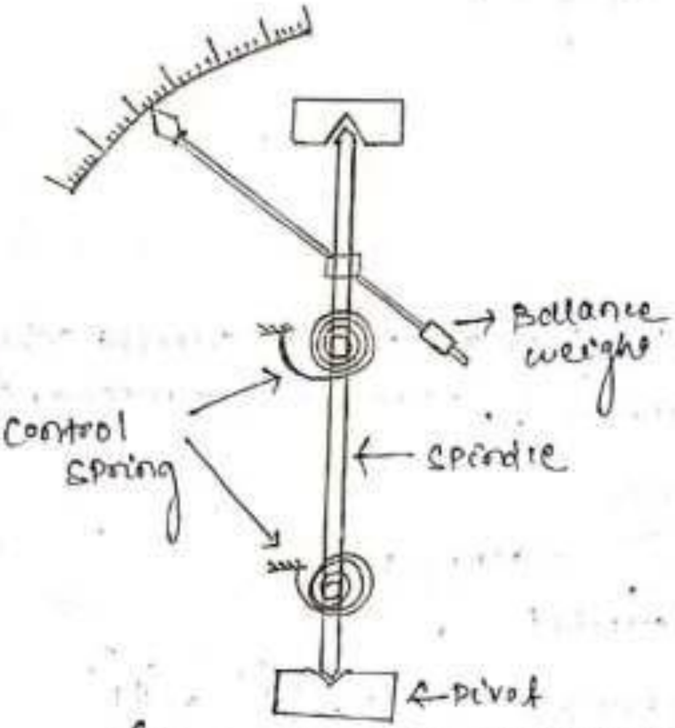
θ = angle between 'B' & 'Il'



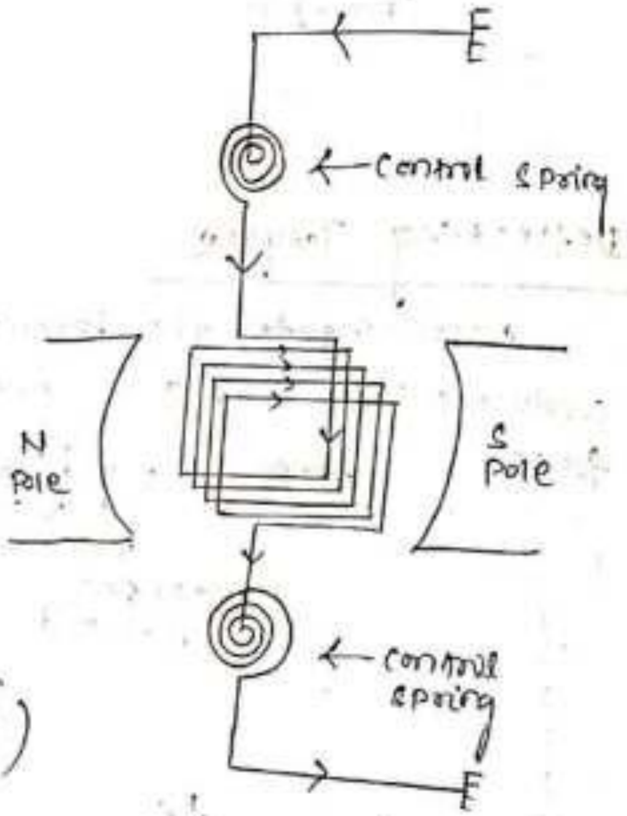
Controlling Torque

The controlling torque in indicating instrument can be obtained either by a spring or by gravity control.

ⓐ Spring control (commonly used in modern instruments).



(Spring control arrangement)



→ Here two spiral hair springs are used for controlling purpose which are made of Phosphor bronze.

→ The springs are connected in series with the coils so current passes to the coil through spring.

→ when current enter into the spring, the pointer deflects and the spring is twisted in the opposite direction.

→ This twist in the spring produces a restoring torque which is directly proportional to the angle of deflection of the moving system.

→ The pointer comes to the position of rest when $T_c = T_d$

$T_d \propto I$ since deflection 'θ' is directly proportional to the current I, the spring controlled instrument have a uniform scale.

$T_C \propto \theta$

at $T_d = T_C$

$\boxed{\theta \propto I}$

since $\theta \propto I$ it gives uniform scale.

Advantages of spring control

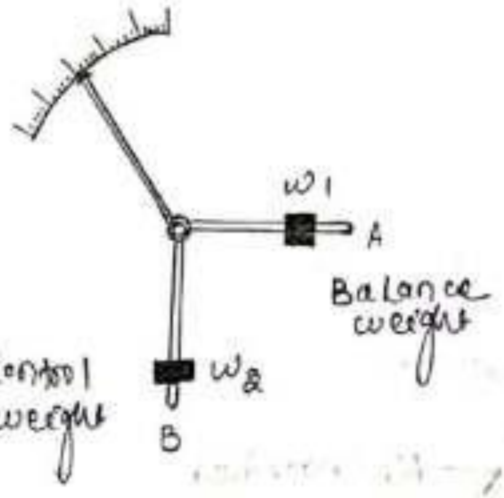
→ It can be placed in horizontal or vertical position.

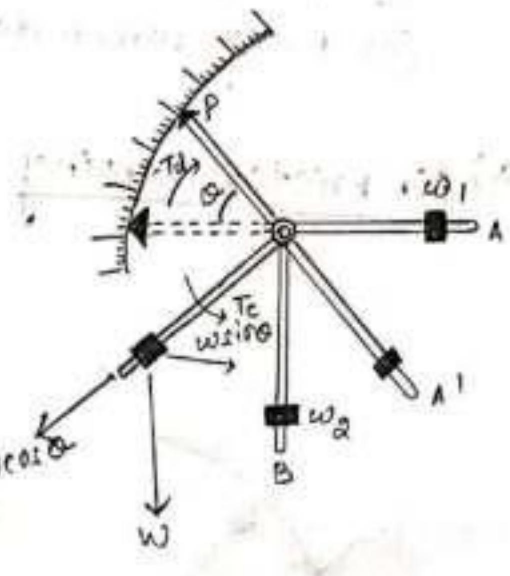
→ It gives linear scale. T_c ↗ θ ($T_c \propto \theta$)

→ scale length is more possible (up to 360°)

→ All indicating instruments are provided with spring control to produce controlling torque.

b) Gravity control (Not much used in modern instruments)





→ mass 'A' and 'B' are attached to the spindle 'S' of the moving system. The basic functions of 'A' is to balance the weight of the pointer 'P'. B provides the controlling torque. For zero position of the pointer, the mass 'B' is vertical.

→ When current flows through the instrument, the pointer is deflected through an angle, mass 'B' also deflected from its original position by an angle 'θ'. The controlling torque is proportional the sine of the angular deflection.

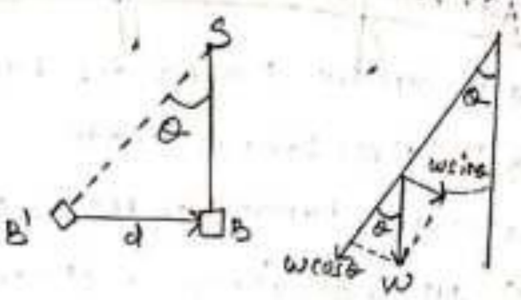
$$(T_c \propto \sin\alpha)$$

Disadvantages

→ Gravity controlled used instrument must be placed in vertical position only.

→ Scale length is possible upto 90° only.

→ It gives non-linear scale.



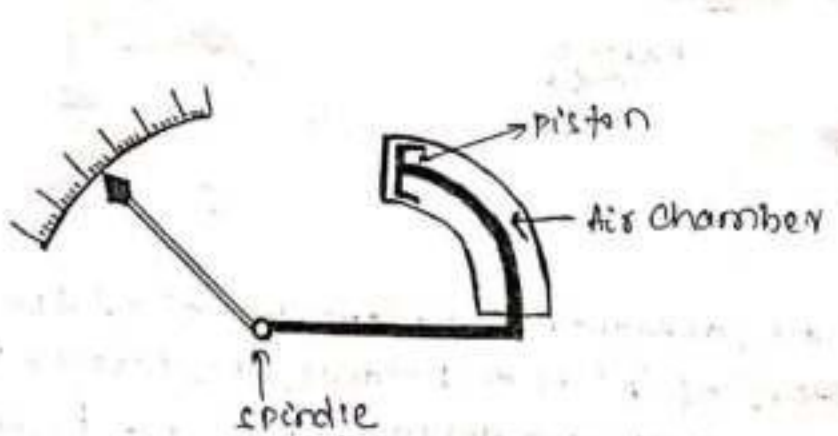
Damping Torque

→ A damping force is necessary in order to bring the pointer to rest in its deflection (deflected) position quickly.

→ There are 3 system of damping is generally use.

(a) Air friction damping
(b) Fluid friction damping
(c) Eddy current damping

(a) Air friction damping



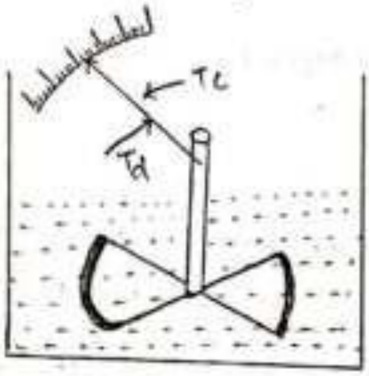
→ In this arrangement, a small aluminium piston is attached to the spindle of the moving system. The piston itself moves in a circular or rectangular chamber with one side open to air.

→ Damping of the moving system is brought about by compression and suction of the air in the chamber.

→ when the piston moves into the chamber, the air inside it gets compressed. Thus, the pressure created due to compressed air opposes the motion of the piston.

→ similarly, when the piston moves out of the chamber, the motion is again opposed due to the pressure being greater on the open side than on the closed side of the chamber.

(b) Fluid friction damping



→ A highly viscous fluid is used to reduce the speed of pointer.

→ Here Motion of spindle occurs due to friction between disc and fluid.

Disadvantages

→ It is not a portable instrument.

→ Always vertically mounted instrument

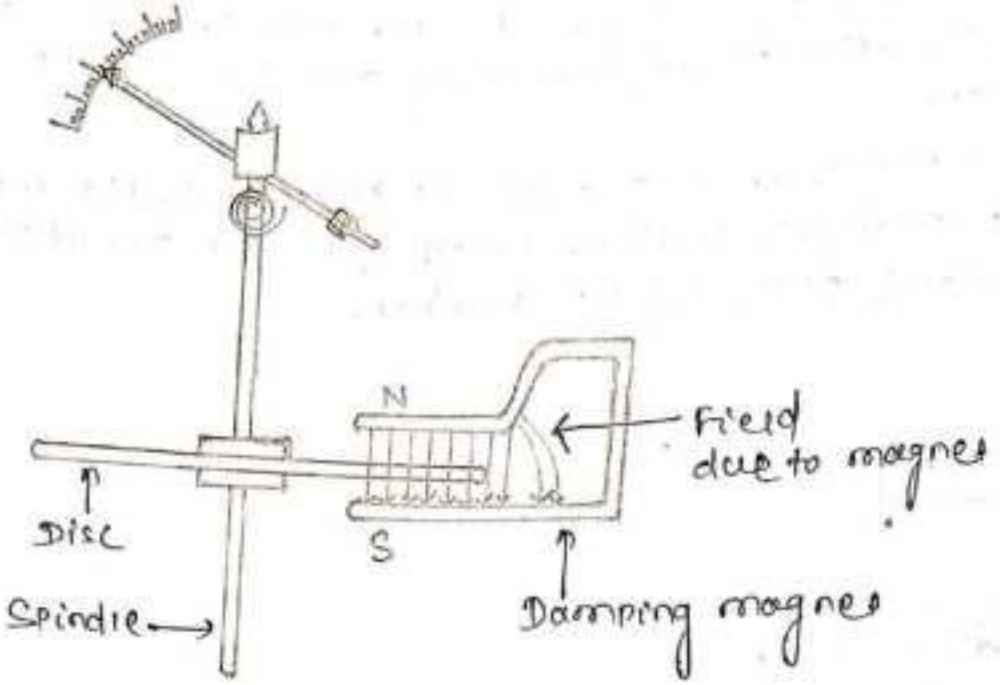
(C) Eddy current damping

→ Eddy current damping is the most efficient method of damping.

→ A thin aluminium or copper (non-magnetic) disc is mounted on a spindle of the moving system.

→ The edge of the disc is so adjusted that it moves between poles of a permanent magnet.

→ Thus, when the disc rotates, it cuts the magnetic flux lines and an emf is induced, which causes current, called eddy current, to circulate in the disc.



→ By applying Lenz's law, it can be seen that the direction of the eddy currents is such that they exert a force which opposes the direction of rotation of the disc.

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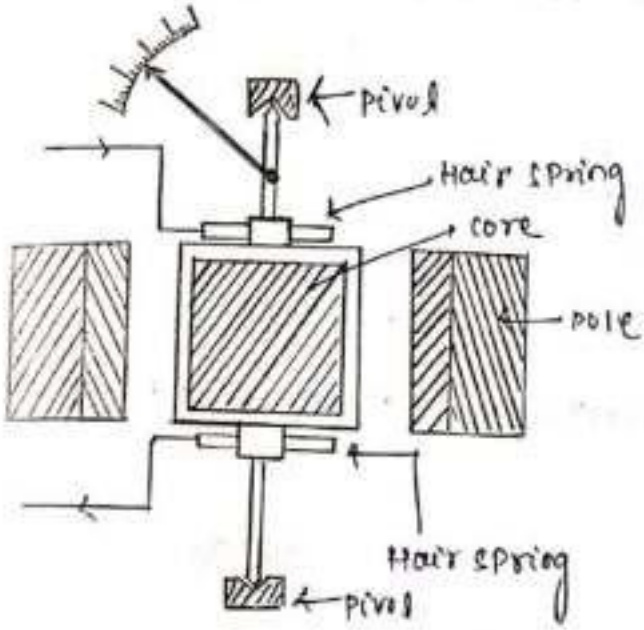
6.3 Different uses of PMMC type of instruments (Ammeter & voltmeter)

PMMC type Instrument (permanent magnet moving coil)



Construction

→ Here a rectangular coil mounted on a Aluminium frame, which is pivoted on Jewelled bearing.

→ A moving coil is placed in magnetic field of permanent magnet and this permanent magnet is made of ALNICO

→ Deflecting torque (T_D) is developed due to motion of this coil

→ Here spring control is given for developing controlling torque (T_C). This spring is connected in series with moving coil Through this spring current enter into the moving coil.

→ A pointer is attached with the pivot and bearing.

→ The damping torque is provided by eddy current method in the aluminium frame.

Working principle :→

According to Lorentz's principle, when this current carrying moving coil present in a magnetic field, a torque is produced. This torque is called deflecting torque (T_d) because of this T_d, pointer moves in forward direction and gives reading.

$$F = BIL$$

B = Flux density

I = current in coil

L = length of coil

T_d = Force × perpendicular displacement

$= F \times b$

$= BI(L \times b)$

$\Rightarrow \boxed{T_d = BIA}$

$\Rightarrow \boxed{T_d = NBIA}$ N = No. of turns of coil

when $T_c = T_d$

$\Rightarrow K_c \theta = NBIA$

$\Rightarrow \boxed{\theta = \frac{NBIA}{K_c}}$ θ = angle of deflection

Advantages → very accurate and reliable. → No hysteresis loss

→ They have low power consumption. → It can be used as ammeter and voltmeter

→ The scales are uniform

→ It's range can be changed by using a shunt and series resistance.

Disadvantages

→ It can be used only by DC supply

→ It is costly as compared to moving iron instrument.

→ some errors are caused due to ageing of control springs and the permanent magnet.

6.4 Different uses of MI type of instruments (Ammeter & Voltmeter)

Moving Iron Instrument

Moving iron Instruments are of 2 types

(a) Attraction type (single piece iron)

(b) Repulsion type (double piece iron)

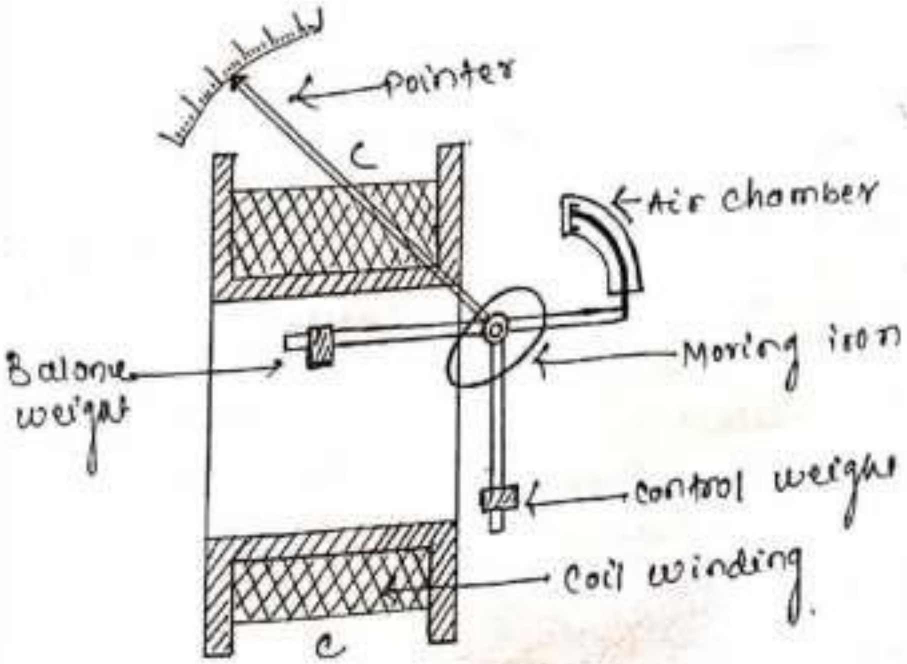
(a) Attraction type

Construction :→

→ Here a non-magnetised soft iron piece is used for moving purpose, which is attached with spindle. Here deflecting torque (T_d) is developed due to rotation of iron piece.

→ Controlling Torque (T_c) is developed by using gravity control

→ Damping torque is developed by using air damping method



Working

- When current passes through the coil, it will behaves as a magnet and produced magnetic field, i.e electrical energy converted into magnetic energy.
- Because of this magnetic energy, iron piece is attracted by magnetic field, for this motion of iron piece, pointer moves and gives reading.

Advantages

- It is cheaper
- It can be used for both AC and DC supply
- It is simple in construction.

Disadvantages

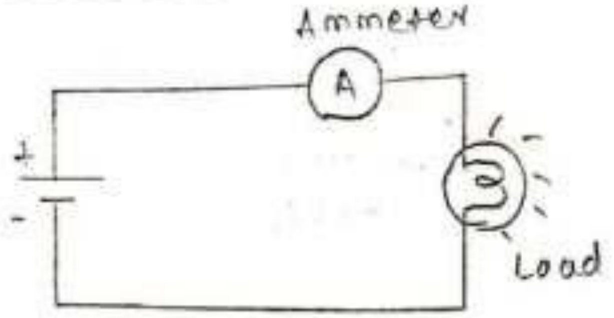
- It's scale is not-uniform ($T_d \propto I^2$)
- It consume more power
- Stray losses affect it's reading.

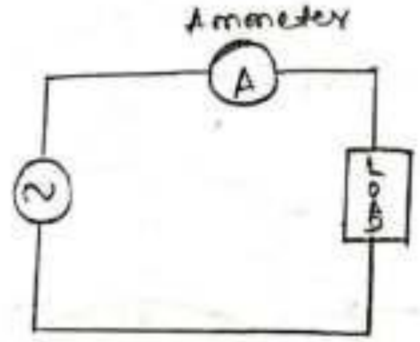
$$T_d \propto \phi \propto I$$

$$\Rightarrow \boxed{T_d \propto I^2}$$

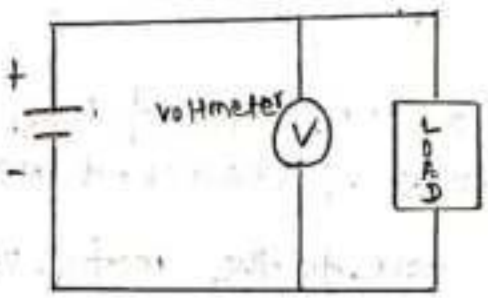
6.5 Draw the connection diagram of A.C/D.C Ammeter voltmeter, energy meter and watt meter (single phase only)

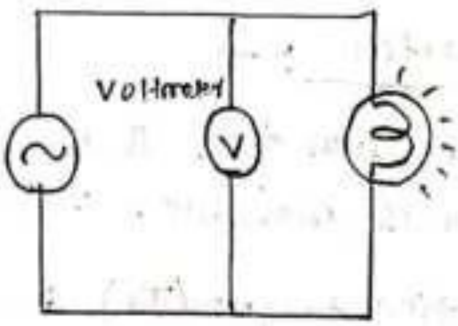
Ammeter (A.C/D.C) connection



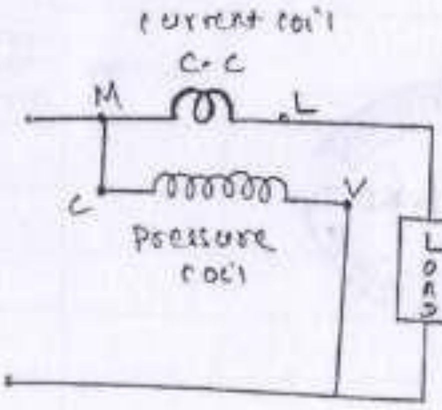


Voltmeter connection (A.C/D.C)





wattmeter connection



Energymeter connection