# DEPARTMENT OF ELECTRICAL ENGINEERING

# GOVT POLYTECHNIC KORAPUT

**SUBJECT- BASIC ELECTRICAL/ELECTRONICS ENGINEERING**

**SEMESTER- $1^{st}$ & $2^{nd}$ SEMESTER ELECTRICAL ENGINEERING**

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**(LECT. IN ELECTRICAL ENGINEERING)**

# (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.

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 $I = \frac{dq}{dt}$ (Charges) / (seconds) (ampere)

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

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'

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

$W = Vq$

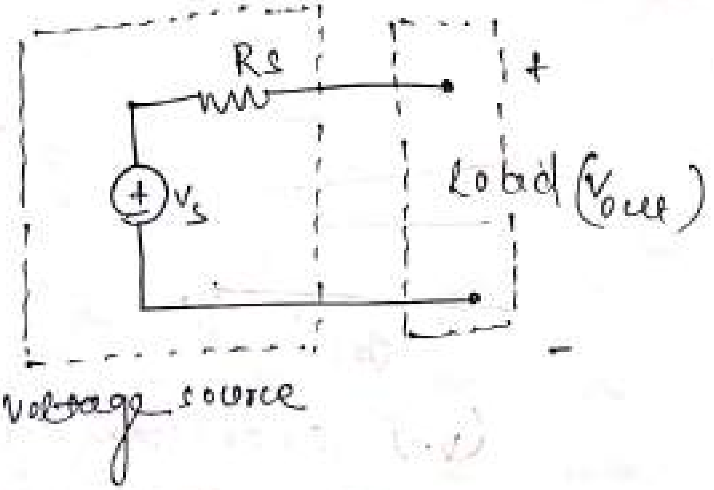
$1e^- = 1.6 \times 10^{-19}$ coulomb

1 coulomb = $0.625 \times 10^{19}$ $e^-$

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

1.2

## Source and load




**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 component of a circuit that consumes electric power or electrical energy.

→ lamp, TV, Heater

## 1.3 State ohm's law and concept of resistance

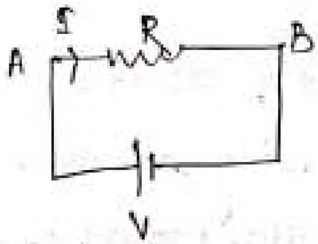
### Ohm's law

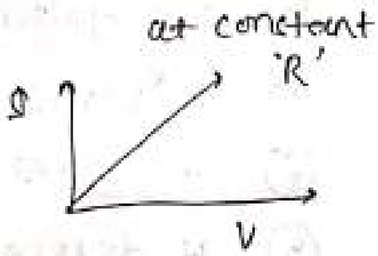
Ohm's law state that the current flowing in a conductor is directly proportional to the potential difference between two ends of a conductor at constant temperature.

$I \propto V$

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

$\Rightarrow \boxed{V = IR}$




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

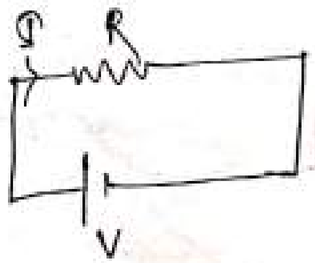
I = current

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.




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

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## Resistance (R)

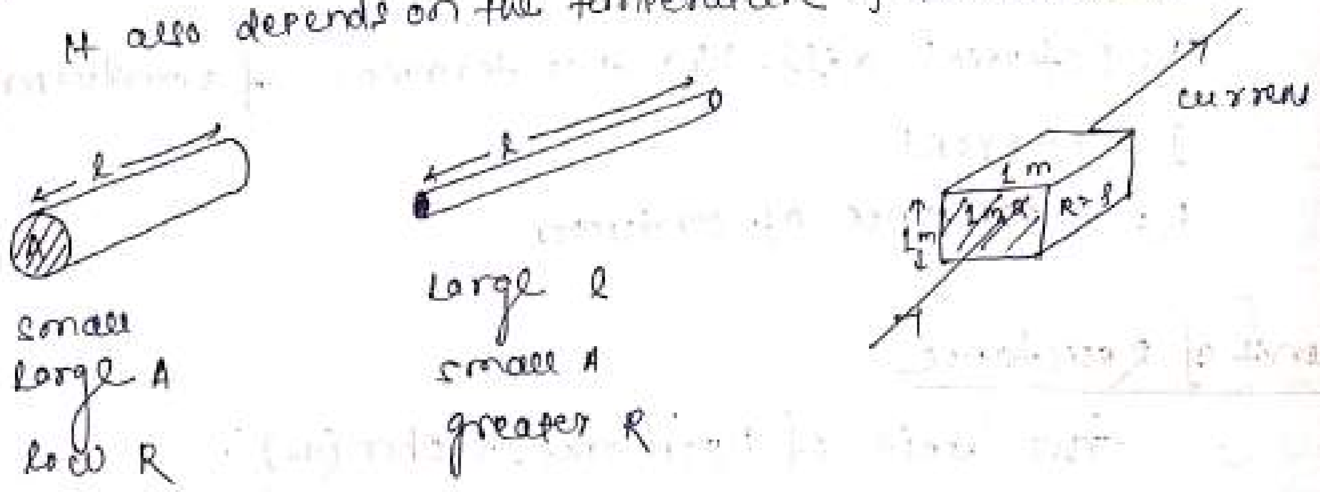
It is defined as the property of a material due to which it opposes the flow of current through it. It is denoted by 'R'

unit = $\Omega$ (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.




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

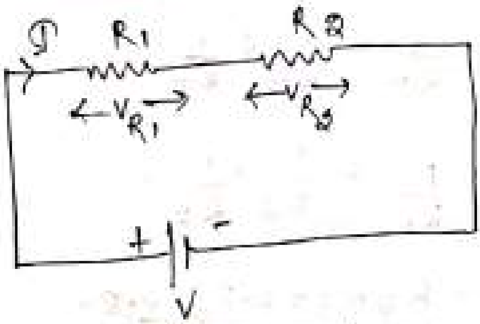
$\Rightarrow$ $\boxed{R = \rho \frac{L}{A}}$

$\rho$ = specific Resistance / Resistivity

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

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

## 1.4 Relation of V, I & R in series circuit




(series connection of pure resistance in DC circuit)

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

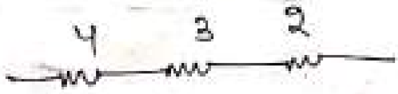
$V_{R_1}$, $V_{R_2}$ = voltage drop against individual resistance.

$IR_{eq} = IR_1 + IR_2$

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

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**

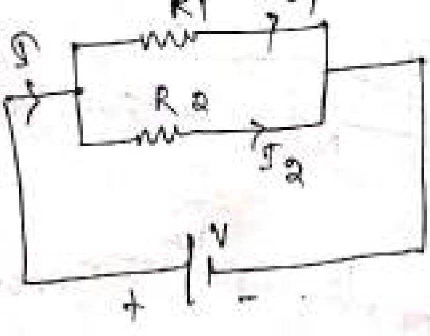



$R_{eq} = 4 + 3 + 2 = 9\Omega$

**Q.2**


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

## 1.5 Relation of V, I & R in Parallel circuit



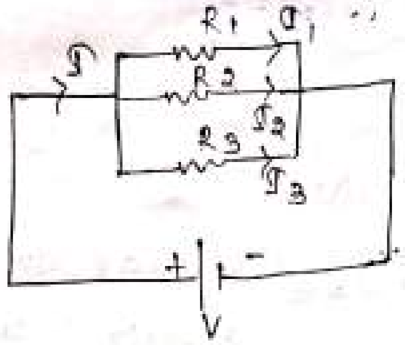

$I = I_1 + I_2$

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

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

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

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




$I = I_1 + I_2 + I_3$

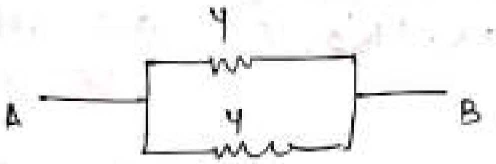
$\Rightarrow \frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

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

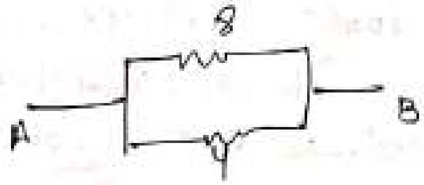
$\Rightarrow \frac{1}{R_{eq}} = \frac{R_2R_3 + R_1R_3 + R_1R_2}{R_1R_2R_3}$

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

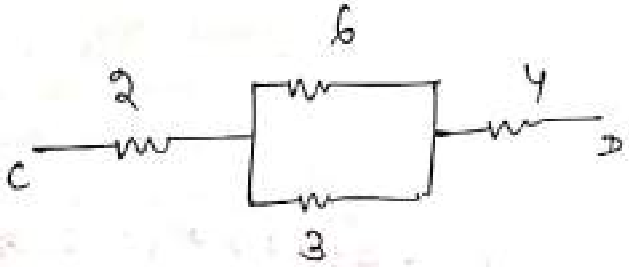
**Q.1**



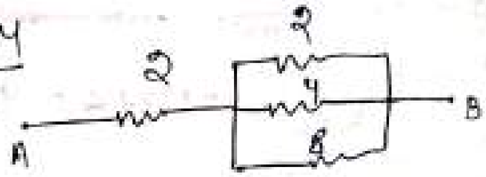

**Q.2**



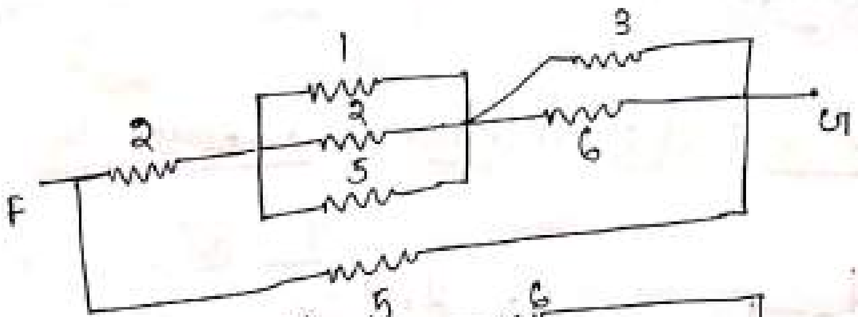

**Q.3**



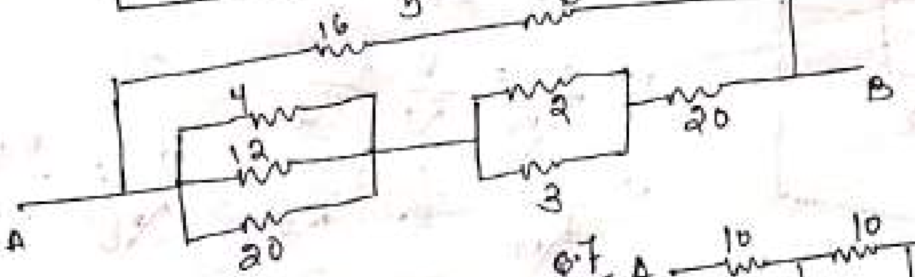

**Q.4**



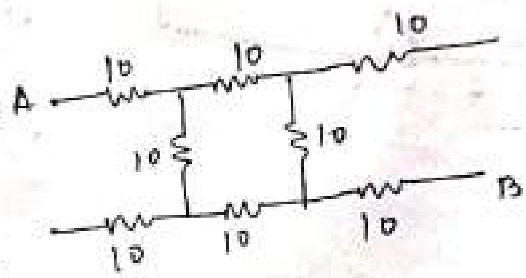

**Q.4**




**Q.5**

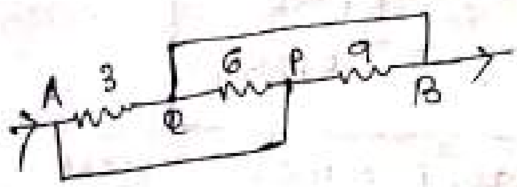



**Q.7**

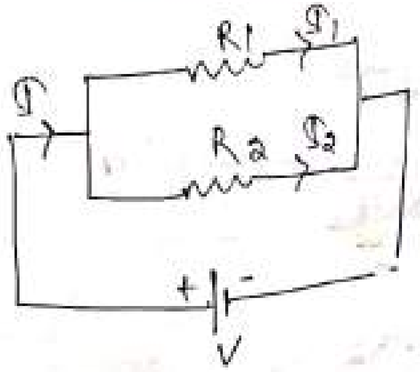



Ans = 30 Ω

**Q.6**



## 1.6 Division of current in parallel circuit




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

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

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

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

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

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

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

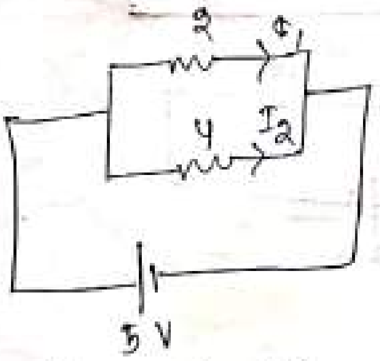
$I_2 = \frac{V}{R_2}$

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

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

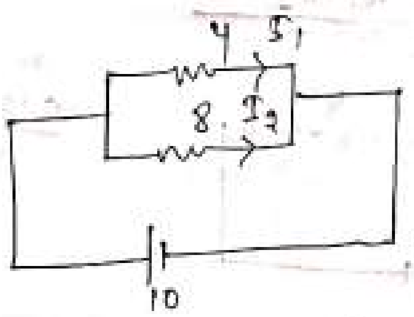
$\Rightarrow \boxed{I_2 = I\left(\frac{R_1}{R_1 + R_2}\right)}$

Q.1



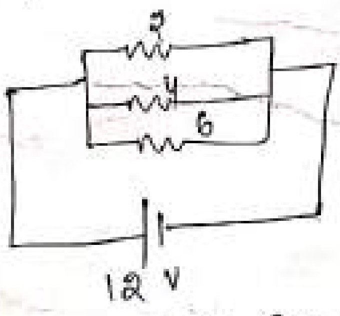

Find $I$, $I_1$ & $I_2$

Q.2



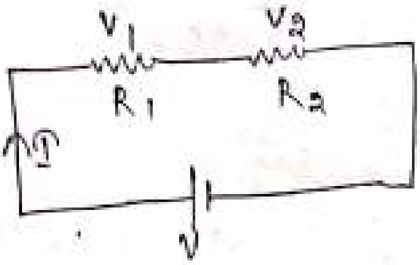

Find $I$, $I_1$ & $I_2$.

Q.3




Find $I$, $I_1$, $I_2$ & $I_3$

# Division of voltage in series circuit




$R_{eq} = R_1 + R_2$

$I = \frac{V}{R_{eq}} = \frac{V}{R_1+R_2} \longrightarrow eq^n (1)$

$V_1 = I \cdot R_1$

$\Rightarrow I = \frac{V_1}{R_1} \longrightarrow eq^n (2)$

$V_2 = I \cdot R_2$

$\Rightarrow I = \frac{V_2}{R_2} \longrightarrow eq^n (3)$

from $eq^n$ (1) & (2), we get

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

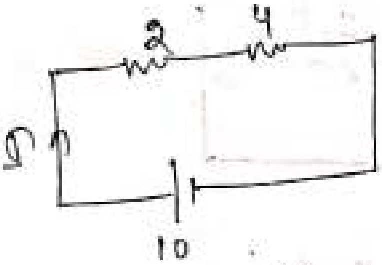
$\Rightarrow \boxed{V_1 = V\left(\frac{R_1}{R_1+R_2}\right)}$

from $eq^n$ (1) & (3), we get

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

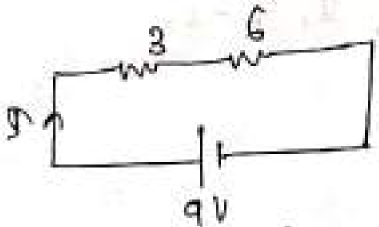
$\Rightarrow \boxed{V_2 = V\left(\frac{R_2}{R_1+R_2}\right)}$

Q.1




Q.2


Q.3

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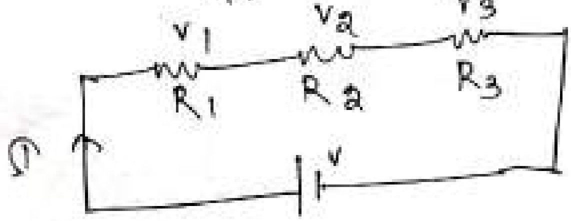



I, $V_1 = V\left(\frac{R_1}{R_1+R_2+R_3}\right)$

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

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

## 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.

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

* 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.

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

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

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

or

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

or

$$(P) = Vi = i.R.i = i^2R$$

or

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

## Energy :-

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

$$\text{Electrical energy} = \text{Electrical power} \times t$$
$$= P \times t$$
$$E = Vit = I^2Rt = \frac{V^2}{R}t$$

So electrical energy is measured in kwh.

## 1.8 Kirchhoff's law

particularly useful

(i) In determining the equivalent resistance of a complicated network of conductor.

(ii) For calculating the current flowing in the various conductor.

It has 2 Laws

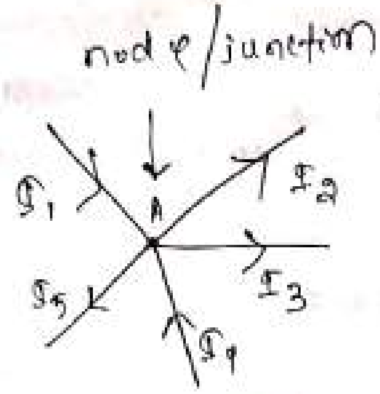
### (1) Kirchhoff's current law (KCL)

" 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)

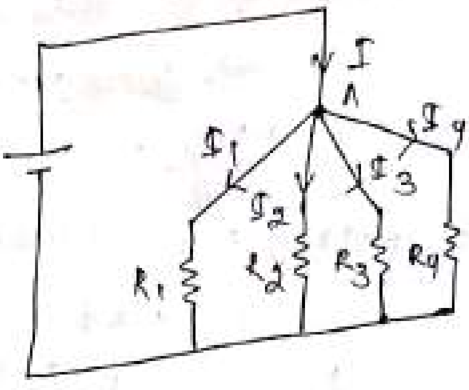



Fig-2)

For Fig 1

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

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

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

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

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

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

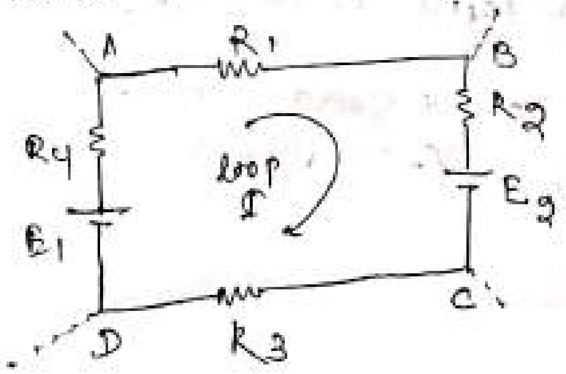
$\boxed{\Sigma I = 0}$

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.

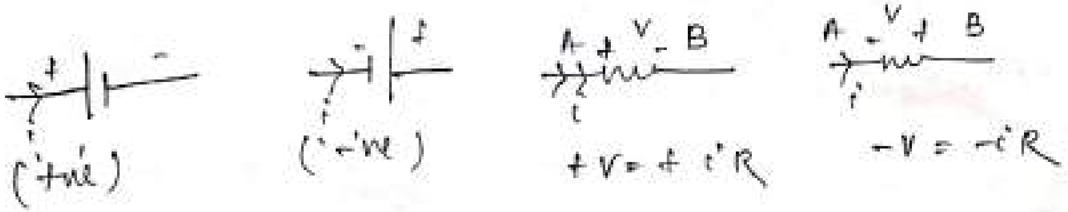


$IR_1 + IR_2 + E_2 - IR_3 - E_1 + IR_4 = 0$

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

imp *

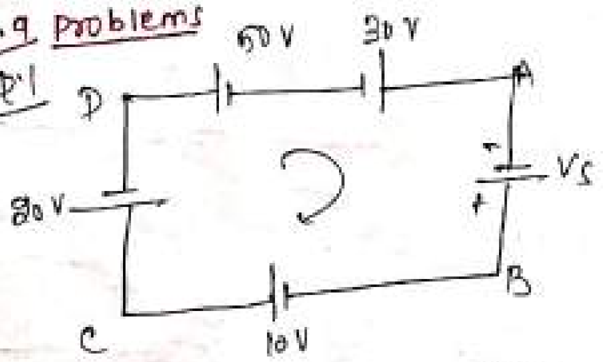
It is important to note that the sign of the battery emf is independent of the direction of the current through that branch.




* 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



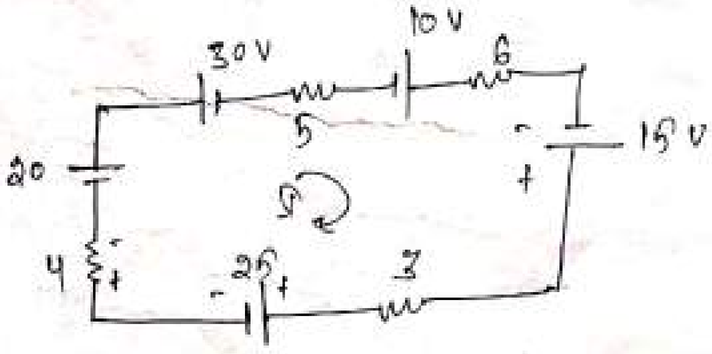

$-V_s - 10 + 20 + 60 - 30 = 0$

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

$\Rightarrow -V_s + 30 = 0$

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

Q.2




Find 'I'

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

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

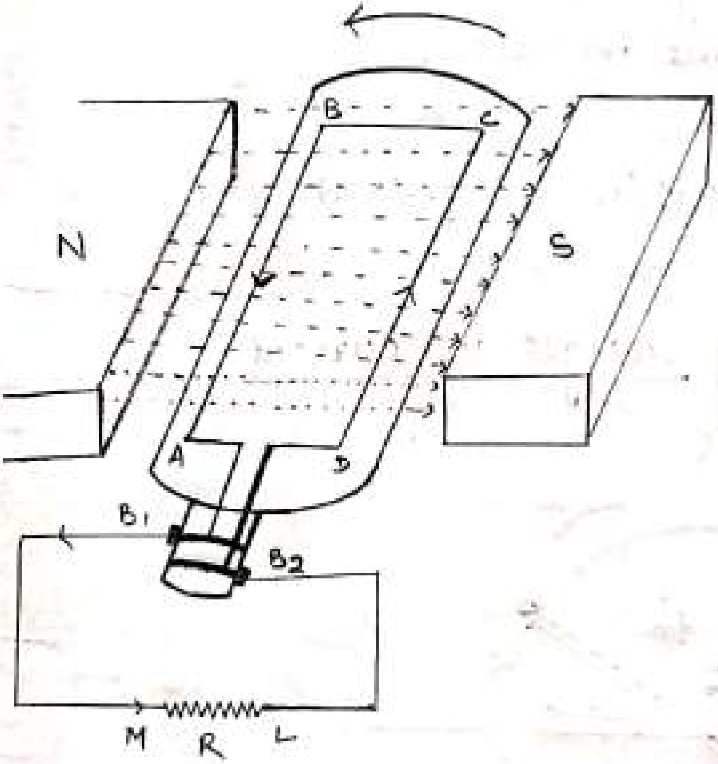
$\Rightarrow 18I + 10 = 0$

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

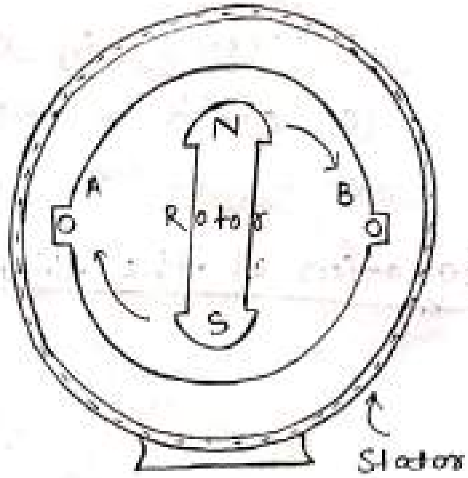
# chapter-2 A.C Theory

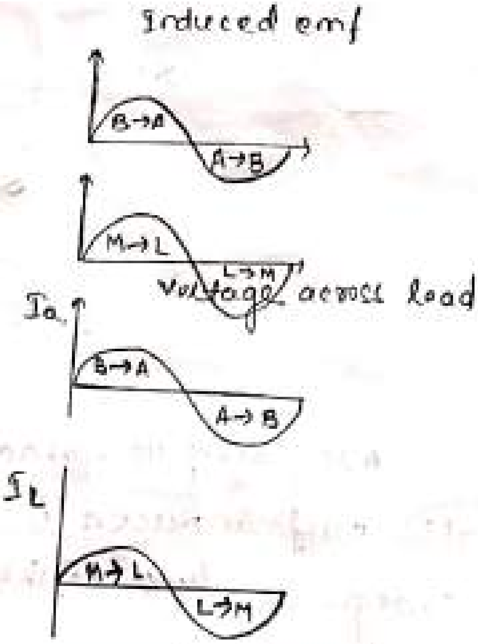
## 2.1 Generation of alternating emf

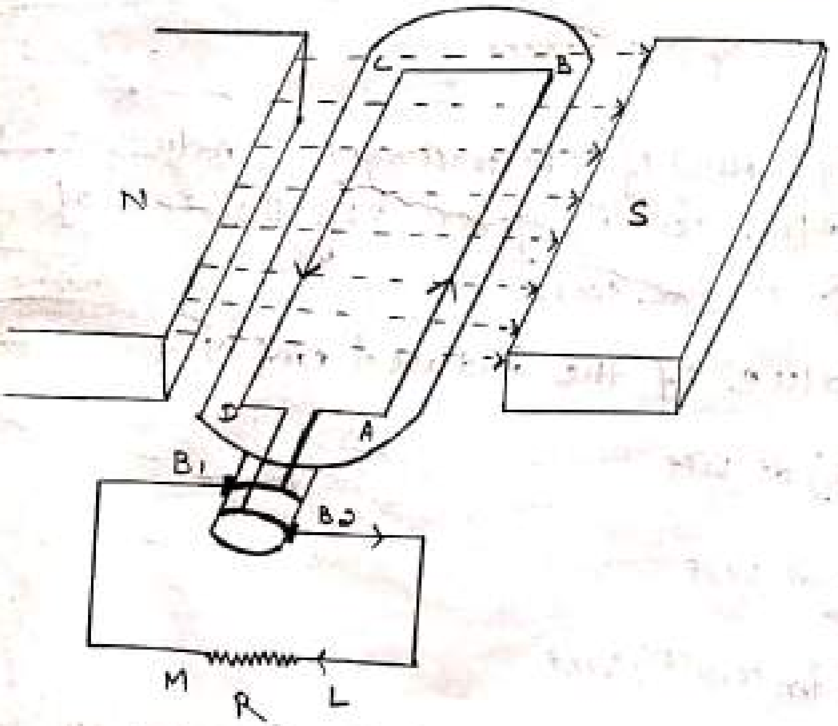
(Generation of alternating voltage and current)




(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.

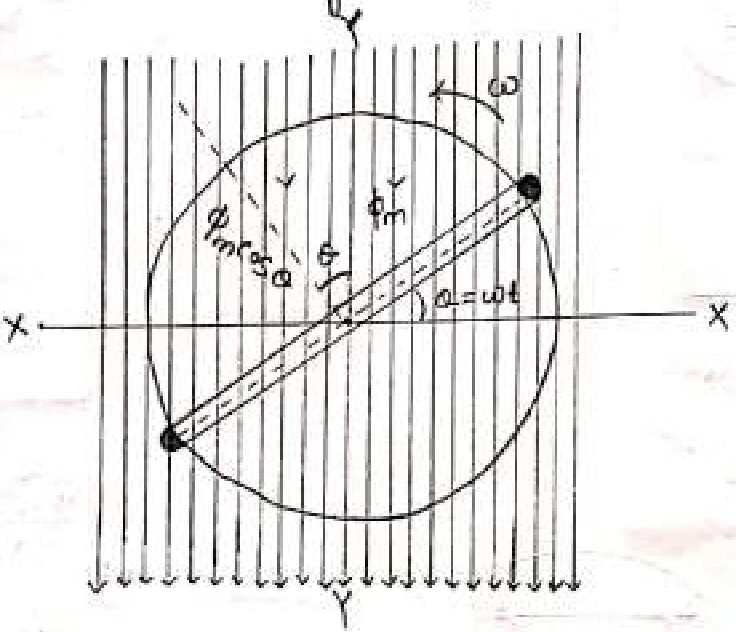
The value of the voltage generated depends upon

(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

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

when $\theta = 90°$, $\sin\theta = 1$

'e' has maximum value say 'Em'

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

$\Rightarrow$ $E_m = N\phi_m \omega$

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

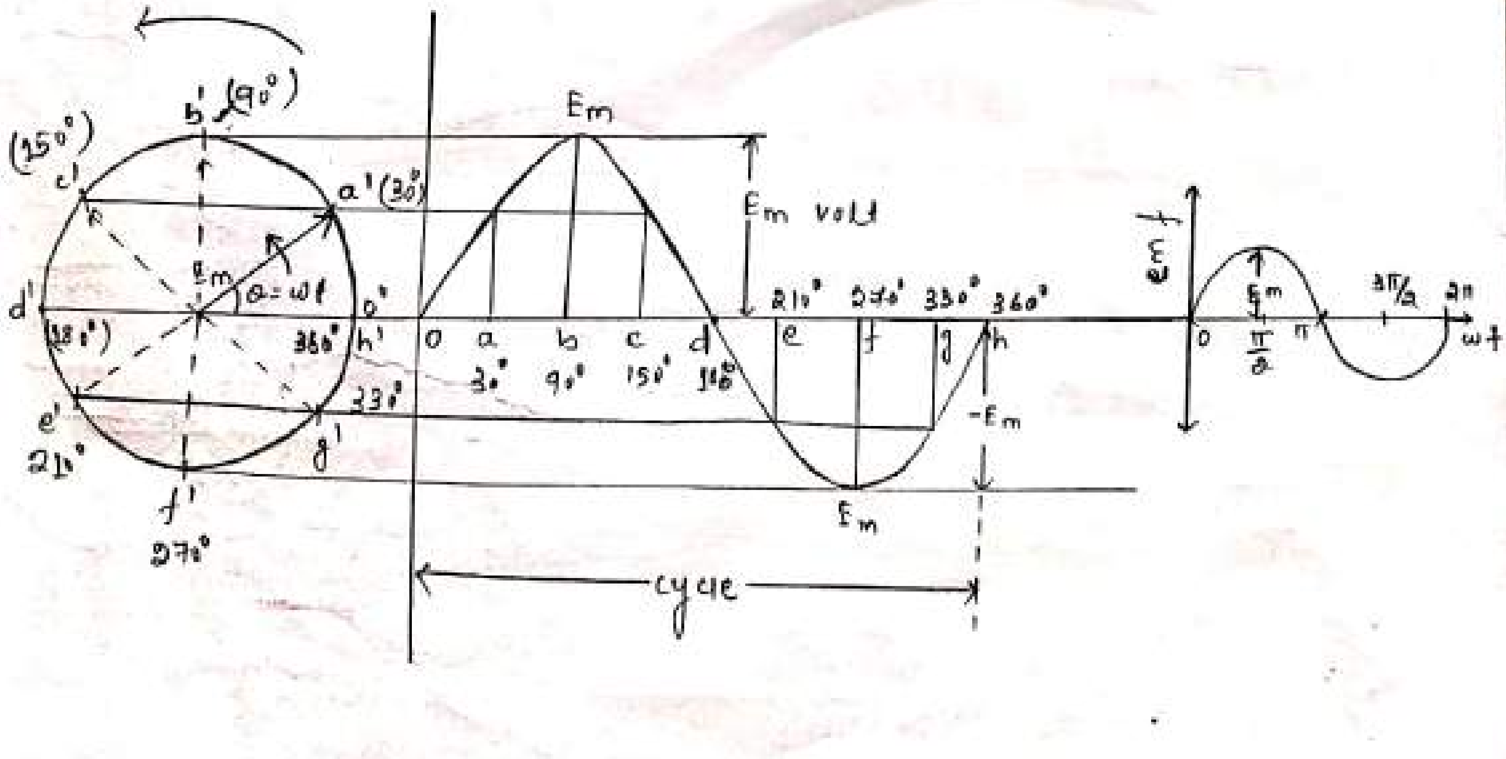
so $e = E_m \sin\theta$ $\quad$ $e = E_m \sin\omega t$ $\quad$ $e = E_m \sin 2\pi f t$

$I = I_m \sin\theta$ $\quad$ $i = I_m \sin\omega t$ $\quad$ $i = I_m \sin 2\pi f t$

$\omega$ = angular velocity

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

$\omega t = \theta$

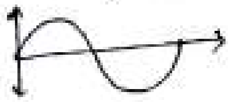


## 2.2 Difference between D.C & A.C

| 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)

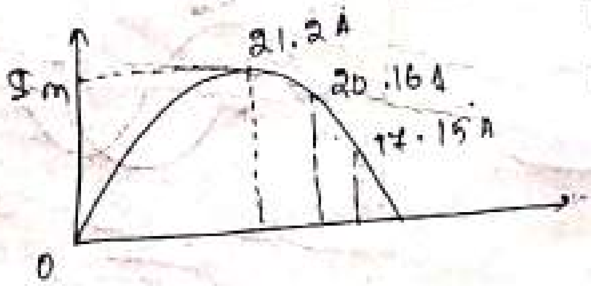
**Time period (T):→** The time taken by an alternating quantity to complete one cycle is called it's time period.

Example $f = 50$ HZ

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

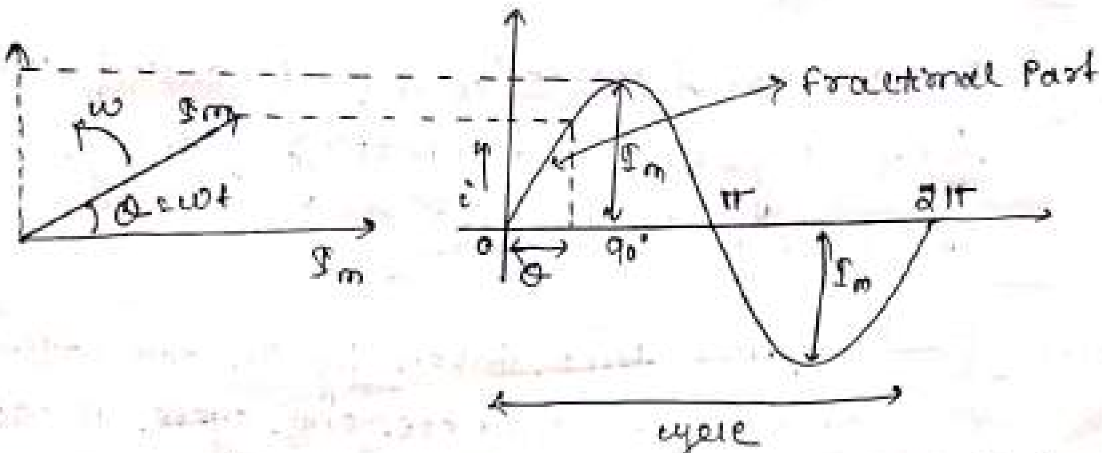



$e = E_m \sin \omega t$ $\quad i = I_m \sin \omega t$

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

## Phase angle ($\theta$)

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.



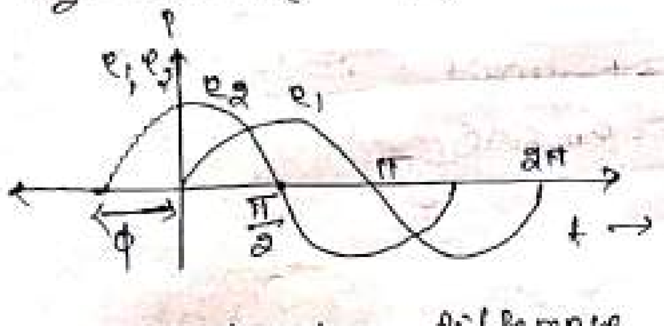

(The phase of the rotating coil at the instant is 'ωt' which is called it's phase angle θ.)

## Phase difference ($\phi$)

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.

$e_1 = E_m \sin \omega t$

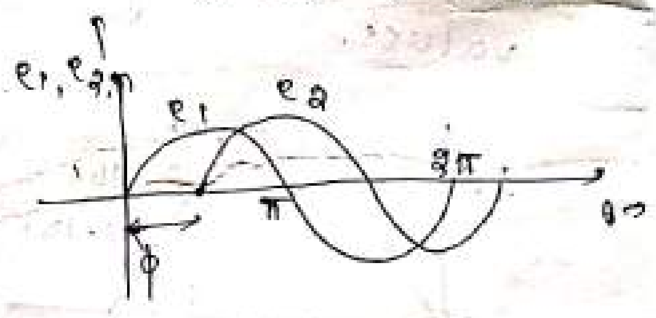
$e_2 = E_m \sin(\omega t + \phi)$




$\phi$ = phase difference

$e_1 = E_m \sin \omega t$

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



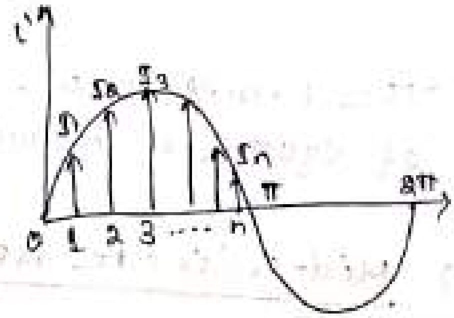
2.4

## 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

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

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

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

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

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

$= 120 \sin 60^\circ$

$= 103.9$ Amp

(b) $96 = 120 \sin\omega t$

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

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

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

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

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

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

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

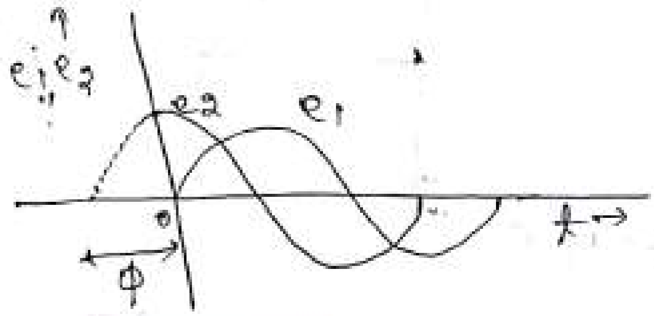
## Represent AC values in phasor diagrams

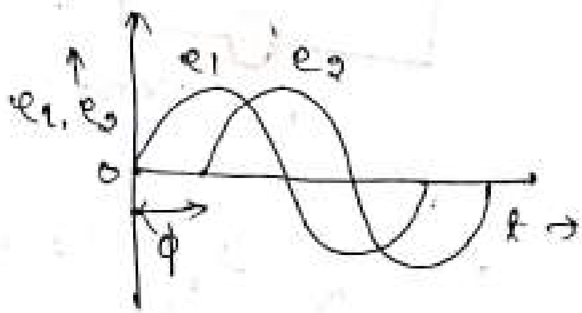
$e_1 = E_m \sin\omega t$

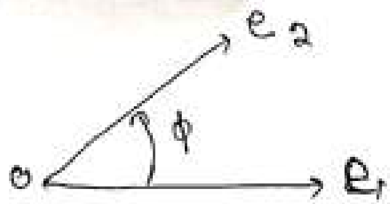
$e_2 = E_m \sin(\omega t + \phi)$

$e_1 = E_m \sin\omega t$

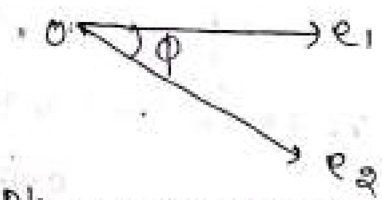
$e_2 = E_m \sin(\omega t - \phi)$




Phasor presentation

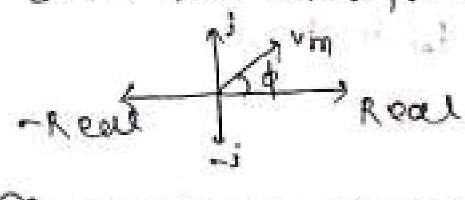



Phasor representation

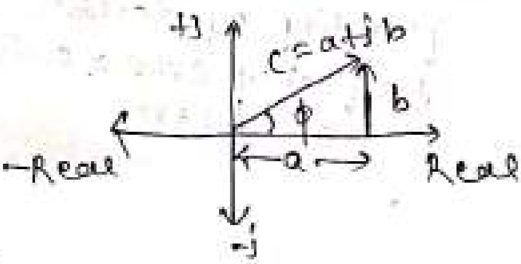
### Phasor Representation

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 $a+jb$.

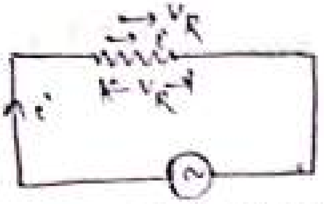



$c = \sqrt{a^2+b^2}$

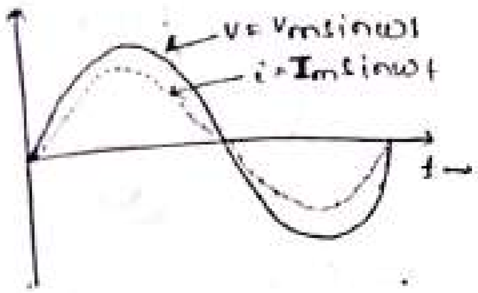
$\phi = \tan^{-1}\left(\frac{b}{a}\right)$

## 2.6 AC through pure resistance, inductance & capacitance

### AC through pure resistance :→




$V = V_m \sin \omega t$




$V = i \cdot R$

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


$P = VI \cos\phi$

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

$\Rightarrow P = V \cdot I$

(OR)

$P = V \cdot I$

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

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

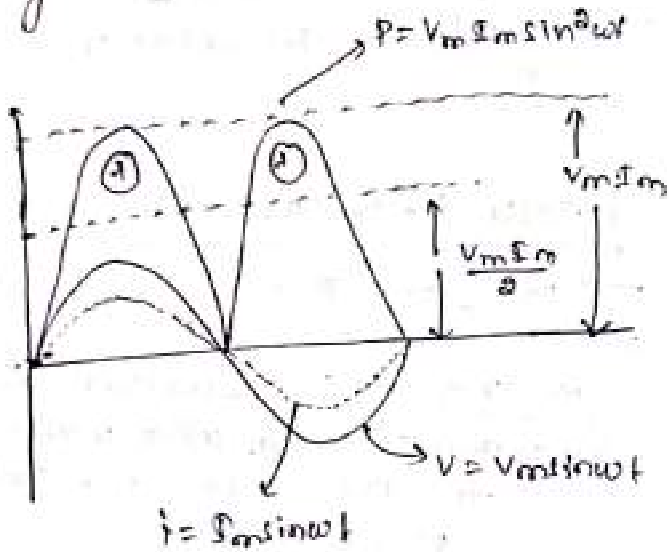
$\Rightarrow P = \frac{V_m^2}{R} \left( \frac{1 - \cos 2\omega t}{2} \right)$

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

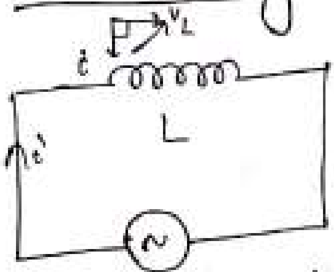
$\Rightarrow P = \frac{V_m^2}{2R} = \frac{V_m}{2} \cdot \frac{V_m}{R} = \frac{V_m}{2} \cdot I_m$

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

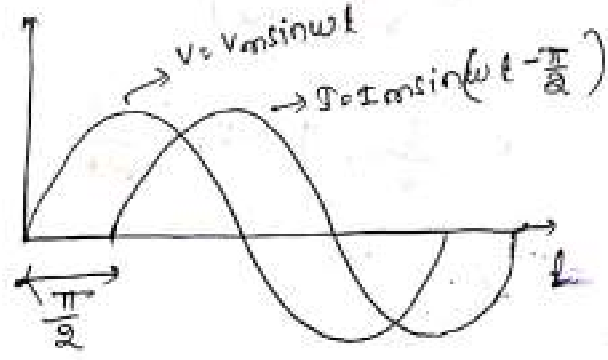
$\Rightarrow \boxed{P = V_{rms} \cdot I_{rms}}$



## AC through pure inductor :→




$V = V_m \sin\omega t$




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

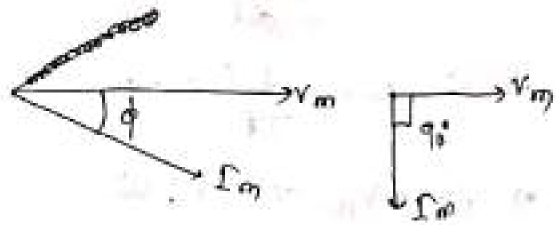
$$\Rightarrow di = \frac{V}{L}dt$$

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

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

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

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




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

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

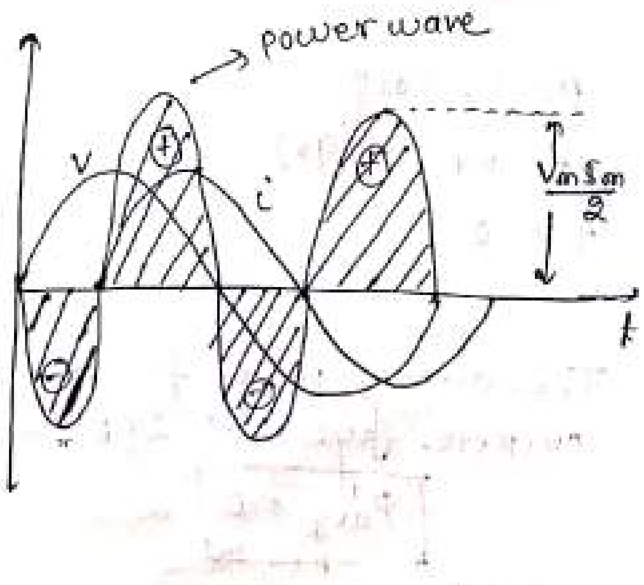
$$\Rightarrow i = I_m\left\{\sin\left(\omega t - \frac{\pi}{2}\right)\right\}$$

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

$P = VI \cos\phi$

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

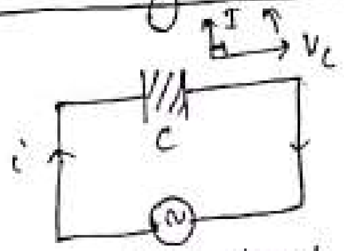
$\Rightarrow P = 0$



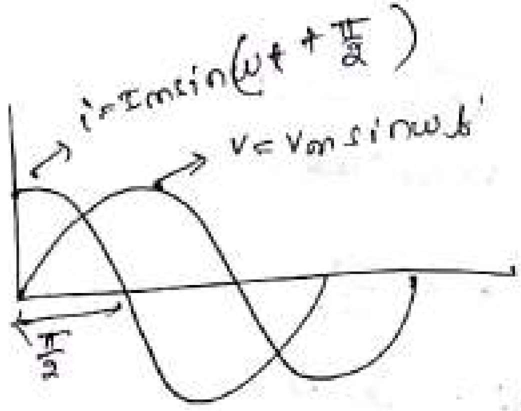

The average power for a complete cycle is zero.

$$P_{avg} = 0$$

# AC through pure capacitor :→




$v = V_m \sin\omega t$




$C = \frac{q}{V}$ , $q = CV$ , $i = \frac{dq}{dt}$

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

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

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

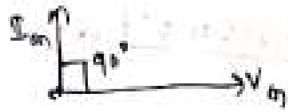
$\Rightarrow i = CV_m \cos\omega t \cdot \omega$

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

$\Rightarrow i = \omega C V_m \sin(\omega t + 90°)$

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

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

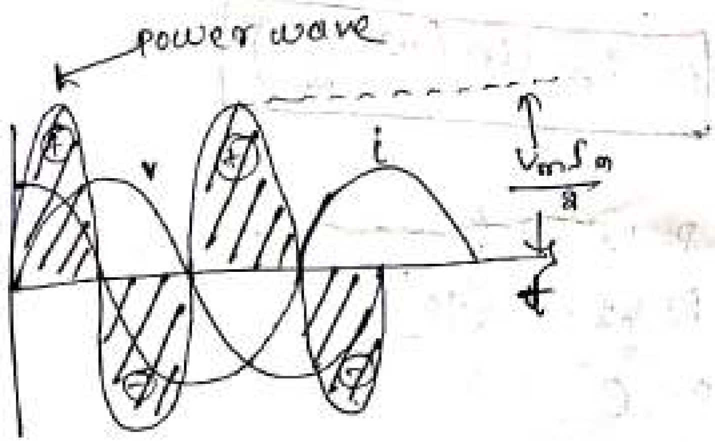



$$\boxed{I = \frac{V_m}{(1/\omega C)} = \frac{V_m}{X_C}}$$

$P = VI\cos\phi$

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

$\Rightarrow P = 0$

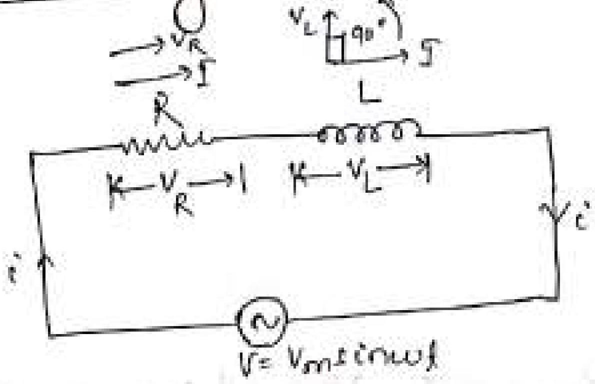



The average power for a complete cycle is zero

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

## 2.7 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.

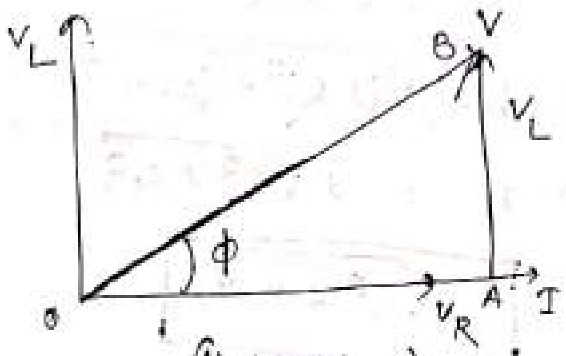
→ voltage '$V_R$' across resistor is inphase with current and voltage '$V_L$' across inductor leads the current by 90°.

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

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

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

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




(Voltage triangle)

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

$$\Rightarrow \tan\phi = \frac{I X_L}{I R}$$

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

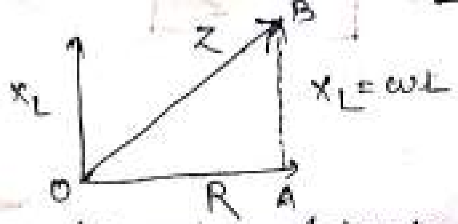
$$\boxed{I = \frac{V}{Z}}$$

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

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

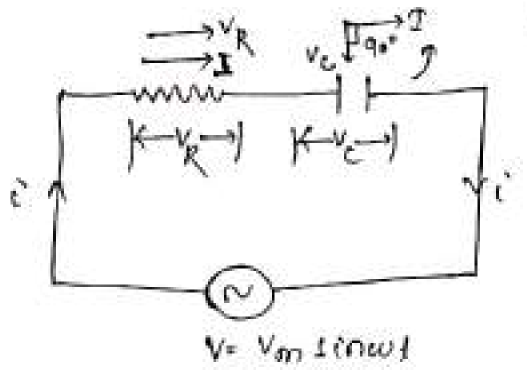
$$\Rightarrow \cos\phi = \frac{I.R}{I.Z} = \frac{R}{Z}$$

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




(Impedance triangle)

## AC through series RC circuit




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

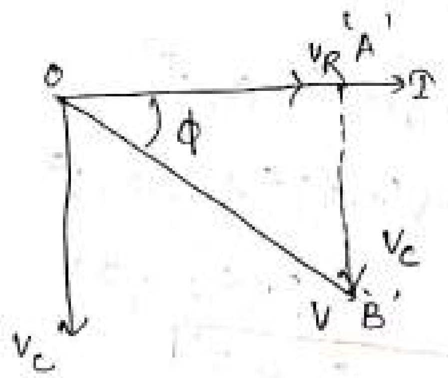
→ The voltage '$V_R$' across resistor is in-phase with current and voltage '$V_C$' across capacitor lags the current by 90°.

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

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

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

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




(voltage triangle)

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

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

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

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

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

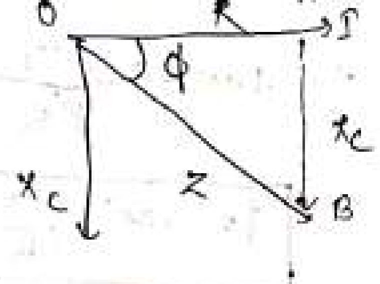
$\boxed{P = VI\cos\phi}$

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

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

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

$\Rightarrow$




(Impedance triangle)

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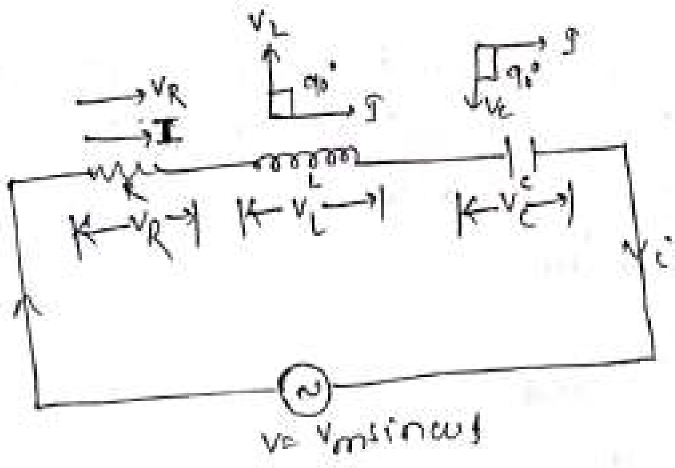
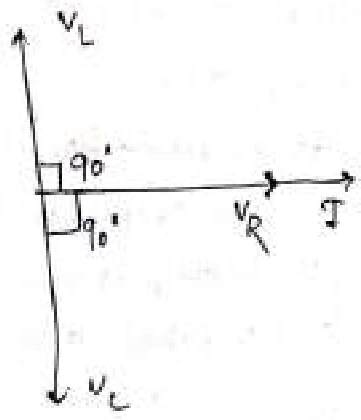
# AC through series R-L-C circuit



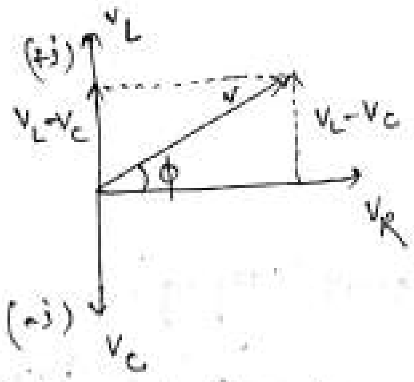



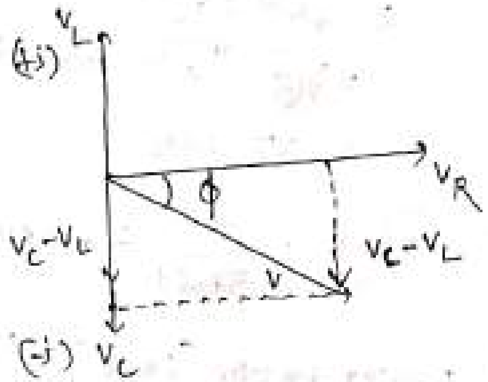

(i) $V_L > V_C$

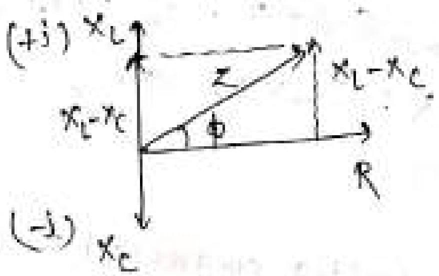
$X_L > X_C$

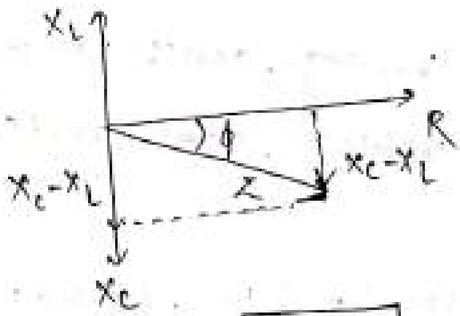
(ii) $V_C > V_L$

$X_C > X_L$




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

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

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

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

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

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

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

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

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

## 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, 50Hz 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).

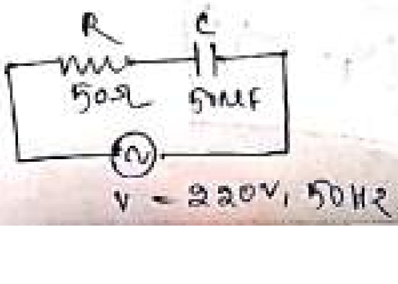
(iii) voltage across Reactor $(V_L) = I X_L = 6.2 \times 31.416 = 194.8\,V$

(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 connected of 50μF 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 $(V_R) = I.R = 2.7\times 50 = 135\,V$

(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 capacitance 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

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

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' = $V_R = I.R = 10.3 \times 12 = 123.6V$

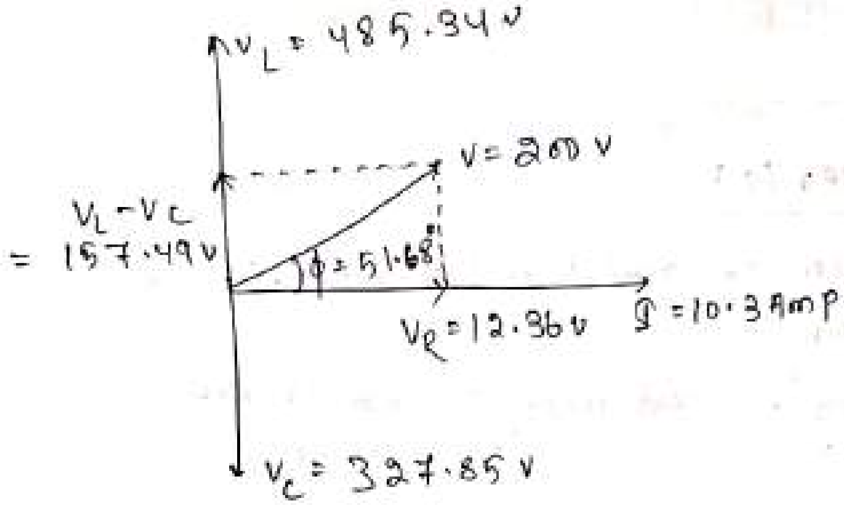
voltage drop across 'L' = $V_L = I.X_L = 10.3 \times 47.12 = 485.34V$

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

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

$= 200\,V$

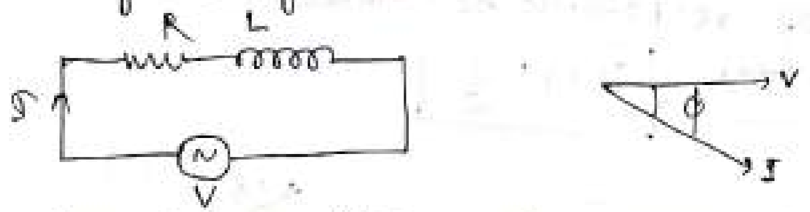
$\phi = \cos^{-1}(0.62) = 51.68°$




## 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)

$Q = I X_L = VI \sin\phi$

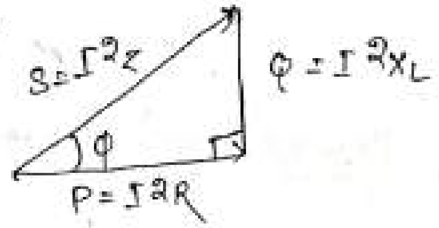
### ③ Apparent power (S)

→ 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).

→ $S = VI$

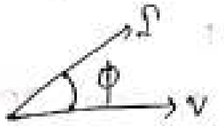
$S = \sqrt{P^2 + Q^2}$




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

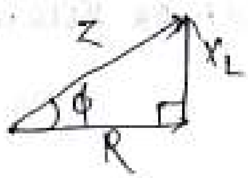




## 2.10 Impedance triangle and power triangle

### Impedance triangle

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



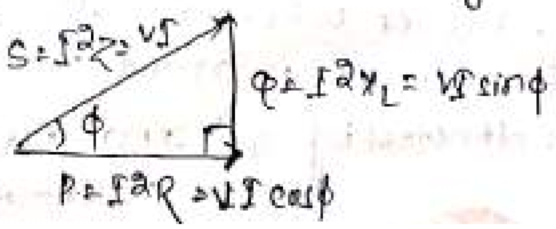

'φ' = Phase angle between 'R' and 'Z'

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

### Power triangle

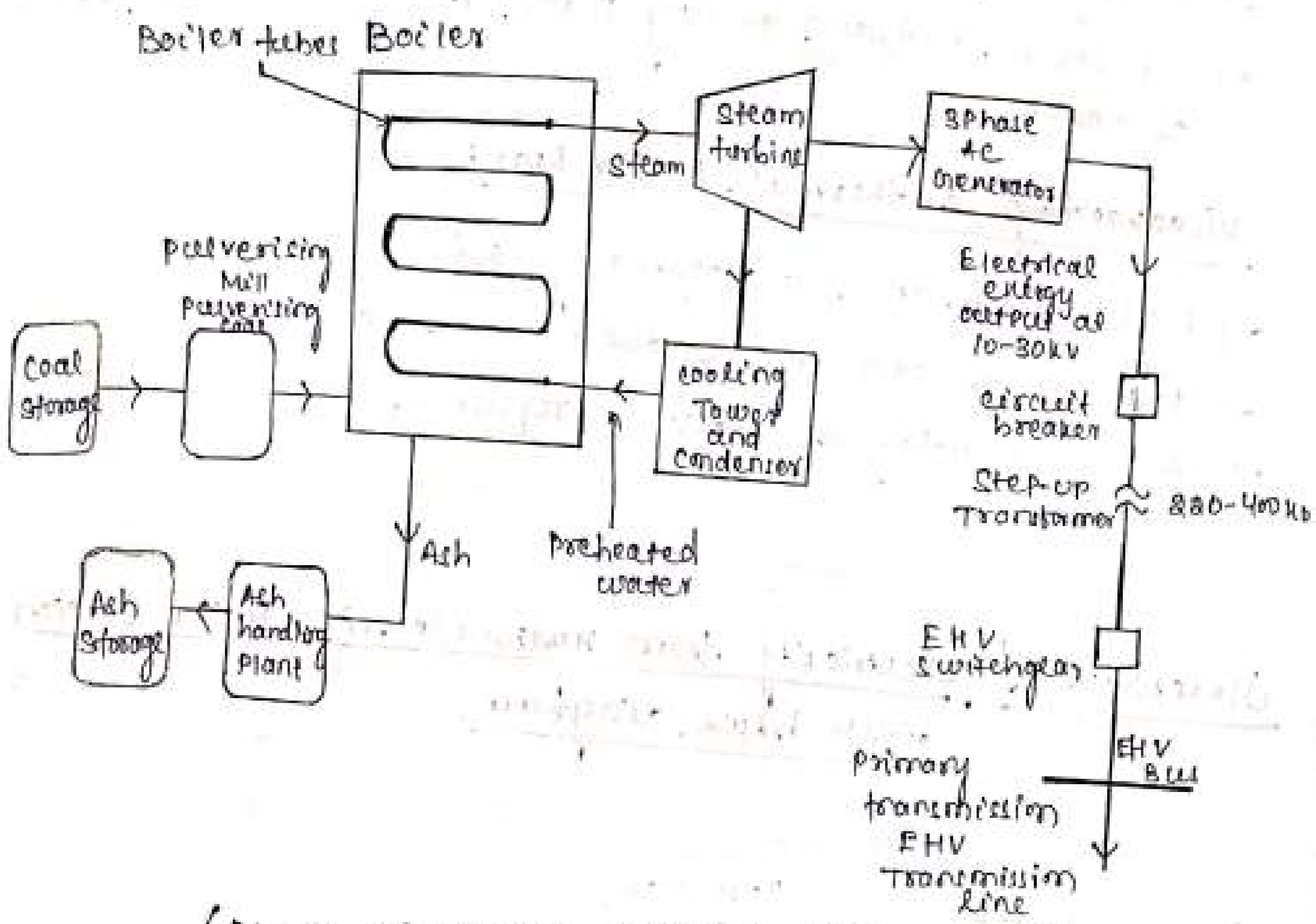
→ The graphical representation of active, reactive and apparent power in a right angle triangle with an phase angle 'φ' is called power triangle.

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



# 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.

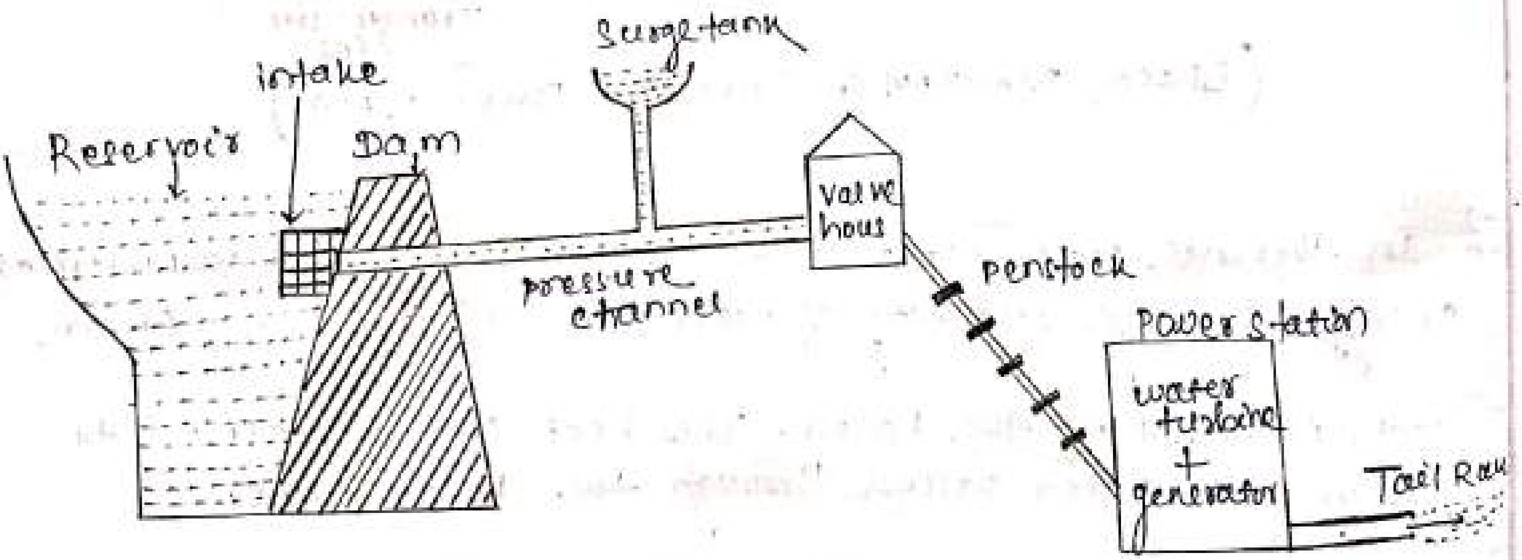
## Disadvantages of thermal power plant

→ 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.

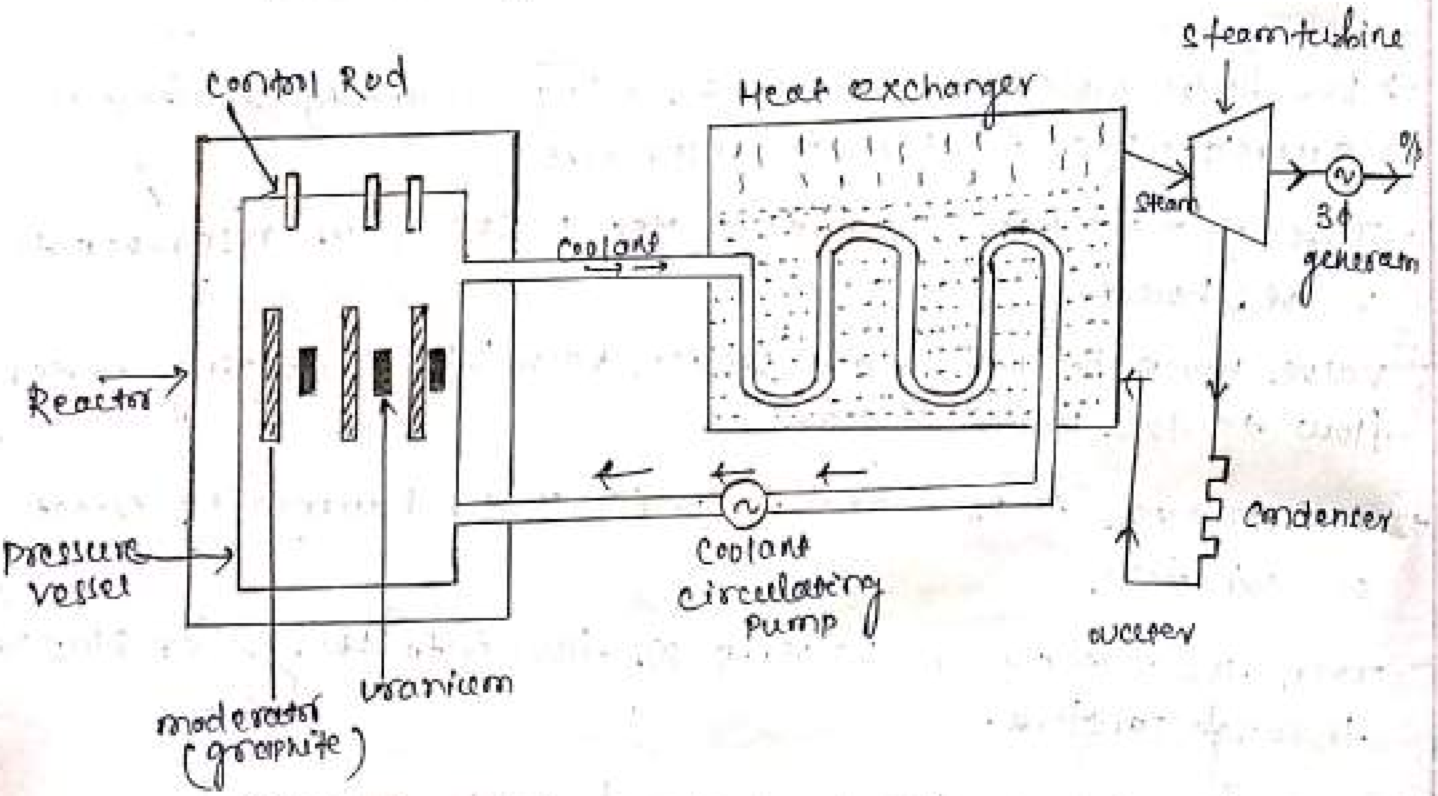
## Disadvantages

→ 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.

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~~ stare 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

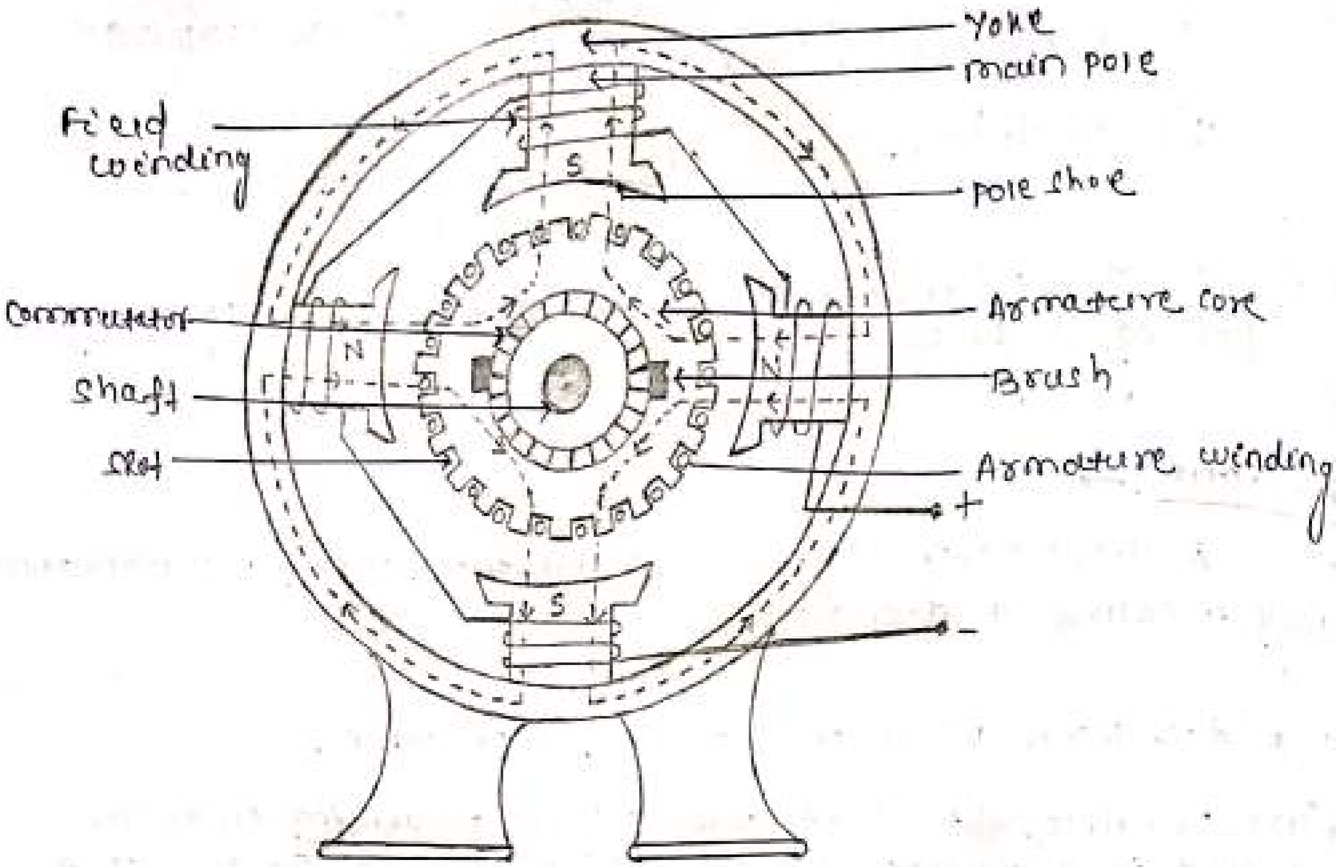
⑥ commutator

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 ($B = 0.8\ wb/m^2$)

2) cast steel → for large M/c ($B = 1.5\ wb/m^2$)

$\left(\uparrow B = \frac{\phi}{A \downarrow}\right)$

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

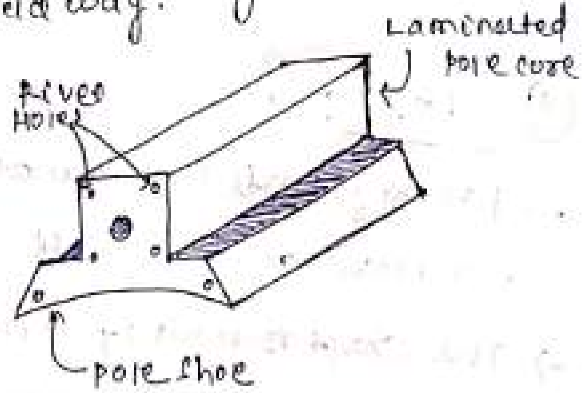
③ Field winding / Field coil! →

→ 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 wether 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:** →

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

→ These are used to reduce armature reaction.

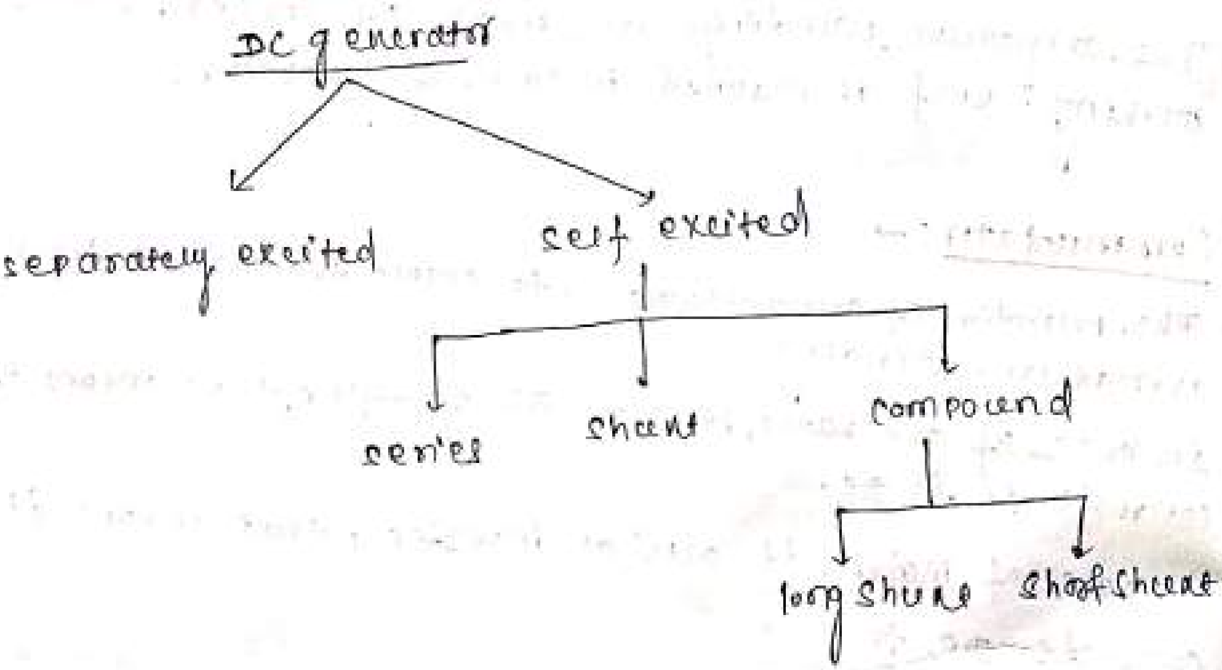
(9) **Shaft:** →

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

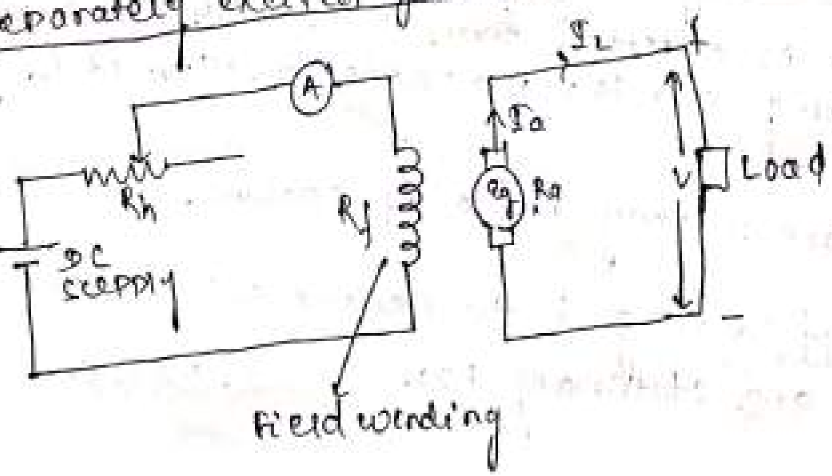
→ The shaft is made of mild steel

→ 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 DC generator, an external DC voltage source is used to excite the field.

$I_a = I_L$

$I_a$ = armature current

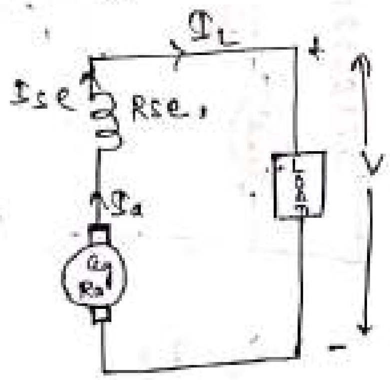
$I_L$ = Line current

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

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




$I_a = I_{se} = I_L$

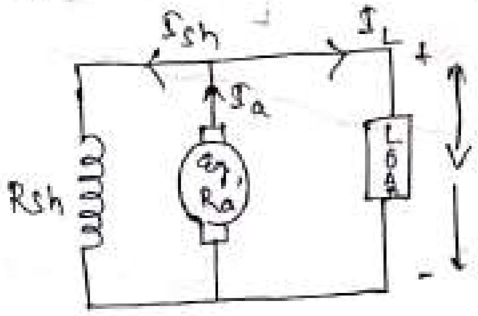
$V = E_g - I_a R_a - I_a R_{se}$

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

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

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

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

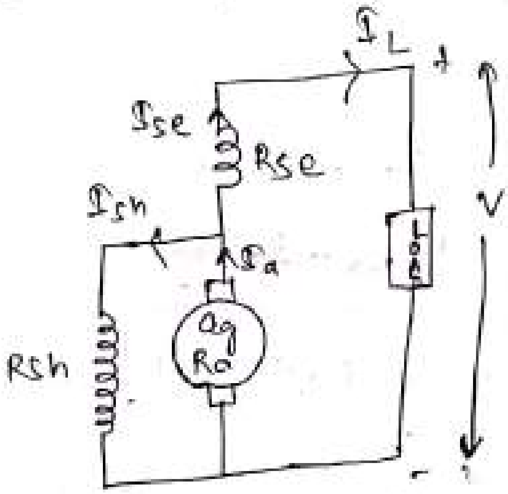
## (c) compound generator

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

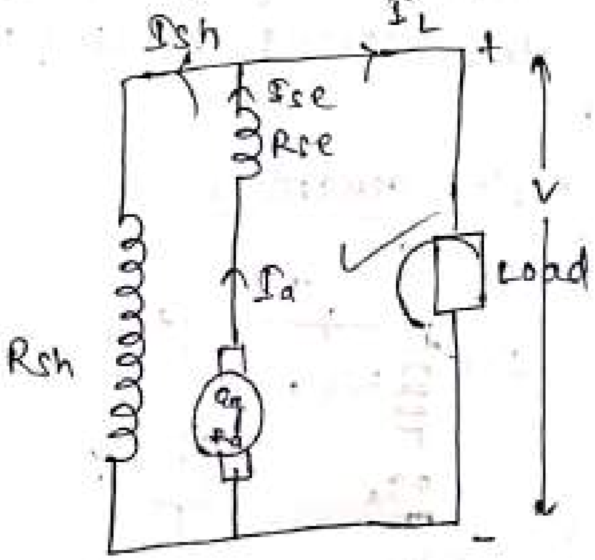
→ According to connection their are 2 types of compound generator

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

**short-shunt**




**long-shunt**




Short-shunt:

$I_{se} = I_L$

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

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

$\Rightarrow e_g - I_aR_a = V + I_{se}R_{se}$

$$\Rightarrow \boxed{V = e_g - I_aR_a - I_{se}R_{se}}$$

Long-shunt:

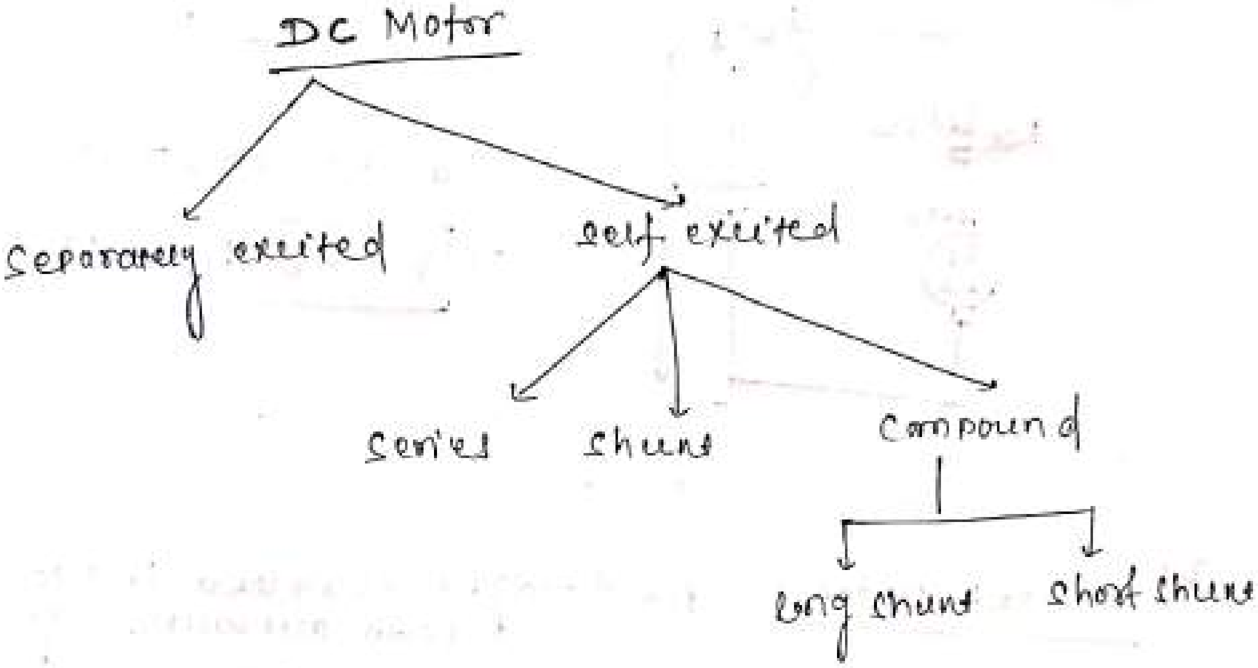
$I_a = I_{se}$

$I_a = I_{sh} + I_L$

$$\boxed{V = e_g - I_aR_a - I_{se}R_{se} = I_{sh}R_{sh}}$$

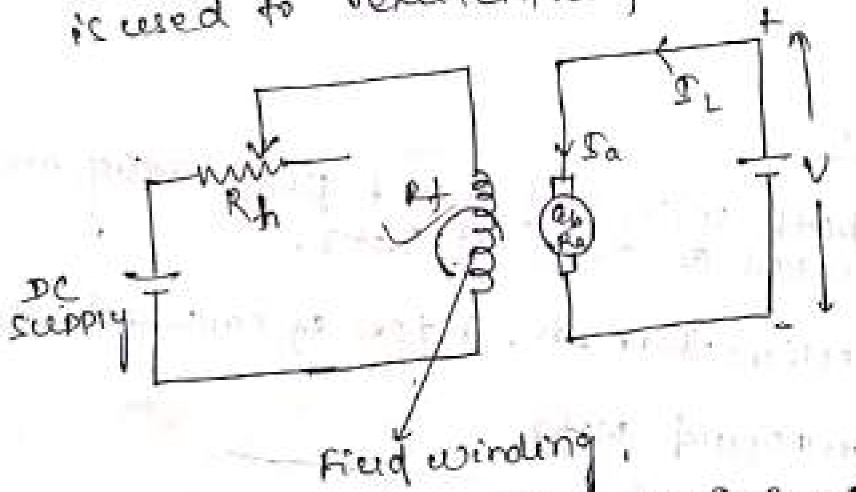
$$\boxed{I_{sh} = \frac{V}{R_{sh}}}$$

## 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.

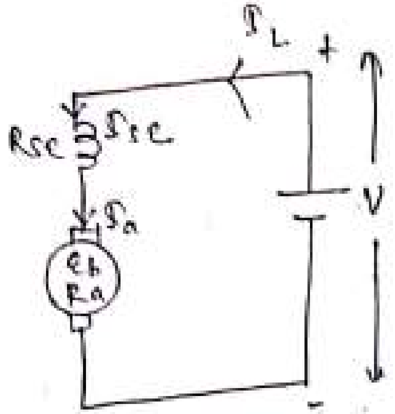



$I_a = I_L$ , $e_b = V - I_aR_a$ ⇒ $V = e_b + I_aR_a$

### (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.

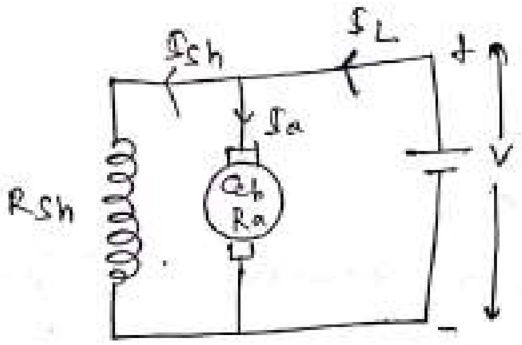



$I_L = I_{se} = I_a$

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

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

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




$I_L = I_{sh} + I_a$

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

$V = e_b + I_aR_a$

$e_b = V - I_aR_a$

(c) Compound Motor

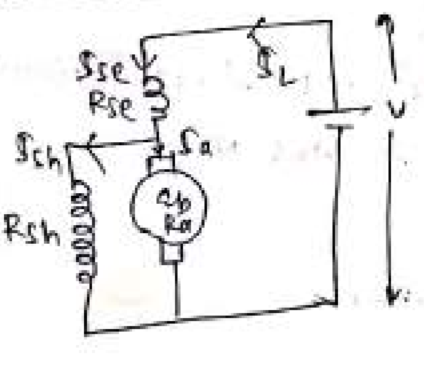
→ In a motor, if both series and shunt field windings are present, then it is called as compound motor.

→ According to connection their are 2 types of compound motor

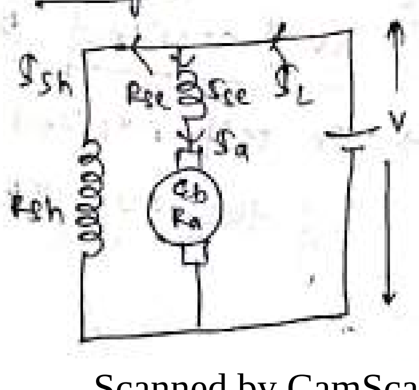
① Short shunt compound motor

② Long shunt compound motor

Short-shunt




Long-shunt



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

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

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

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

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

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

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

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

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

## 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<br>→ medium starting torque | → Lathes<br>→ Drills<br>→ Blowers & fans<br>→ Boring mills<br>→ centrifugal pumps |
| (2) DC Series Motor (High starting torque) | → It is used where high starting torque is required for accelerating a heavy mass.<br>→ variable speed | → Electric traction<br>→ cranes<br>→ Elevator<br>→ conveyors<br>→ hoists<br>→ air compressor<br>→ vacuum cleaner |
| (3) compound motor<br>(a) cumulative type<br>→ constant speed<br>→ High starting torque | → constant speed is required with irregular loads or suddenly applied heavy load.<br>→ High starting torque | → Elevator<br>→ conveyors<br>→ Rolling mills<br>→ ice machines<br>→ printing press |

## Application of DC generator

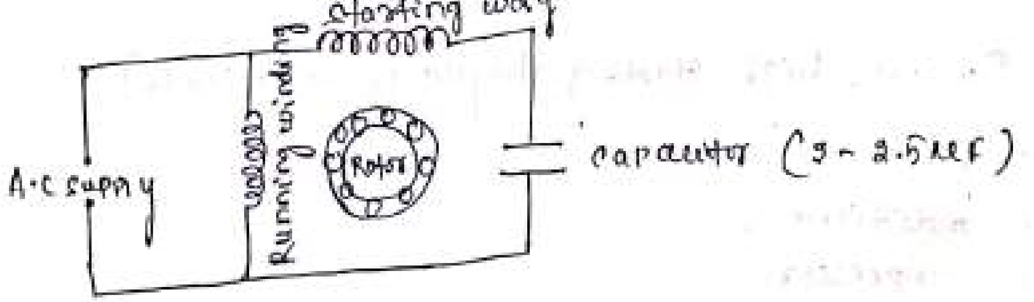
| Types of generator | Characteristics | Applications |
| --- | --- | --- |
| ① Shunt generator | → constant terminal voltage | → Batteries charging |
| ② series generator | → Rising voltage characteristics | → Booster (In certain type of distribution system, particularly in railway service. |
| ③ compound generator (a) cumulative 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

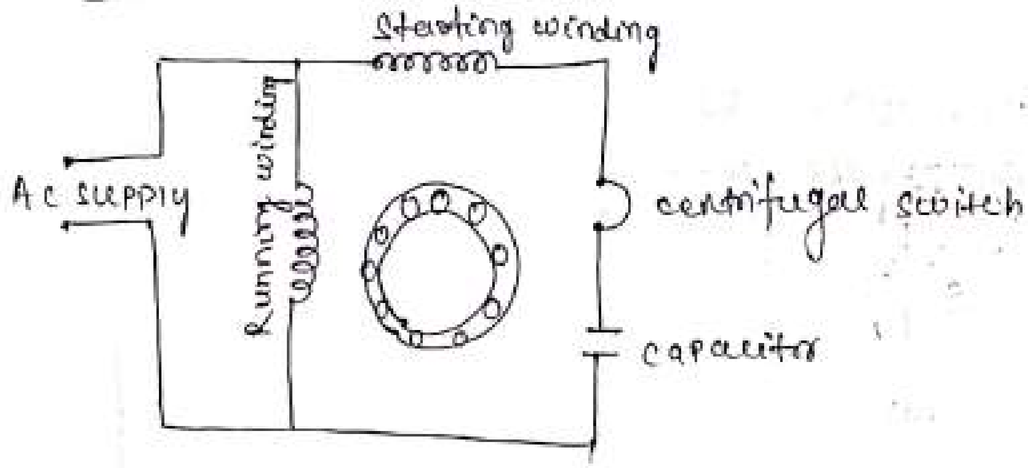
- Induction type
  - Split phase type Motor
    - capacitor start Motor
    - permanent capacitor Motor
    - capacitor start capacitor run Motor
    - shaded pole Motor
- commutator type
  - universal Motor
  - Repulsion motor

## (1) permanent capacitor Motor



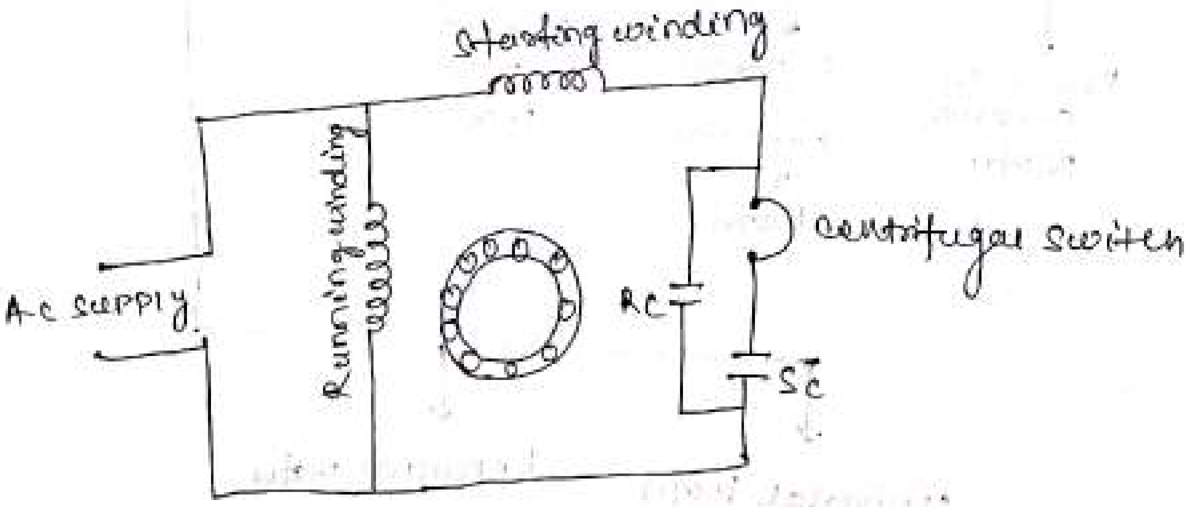

uses :→ ceiling fan, ~~[illegible]~~ Table Fan,

## (2) capacitor start induction Motor




uses! → Lathe machine,
Drill Machine
grinders

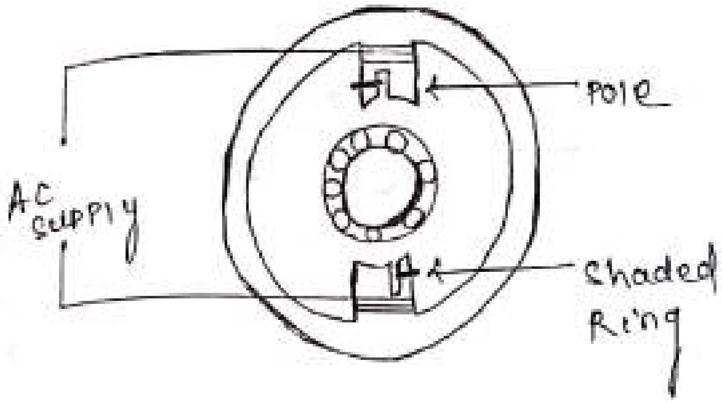
## (3) capacitor start capacitor run Induction motor




RC = Running capacitor
S.C. = Starting capacitor

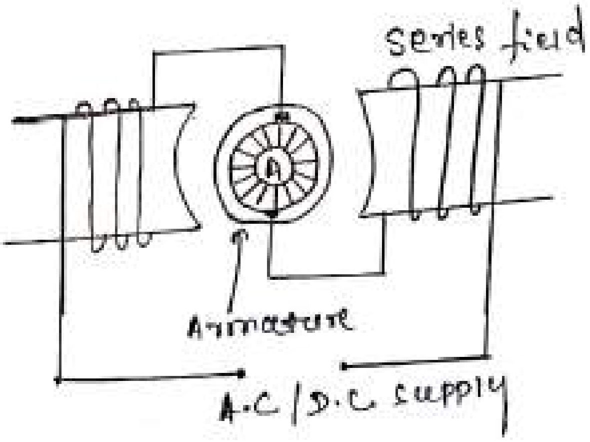
uses! → (where high starting torque is required)
Refrigerators,
air conditioner,
air compressors
blowers

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

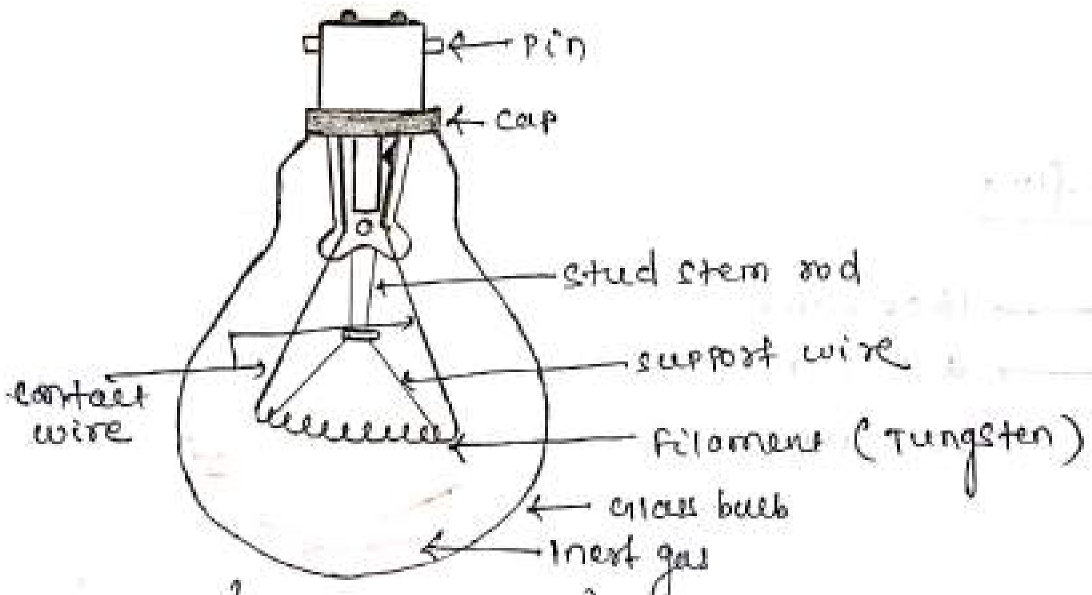
20 watt ⟶ 2000 lumen

Scanned by CamScanner

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.

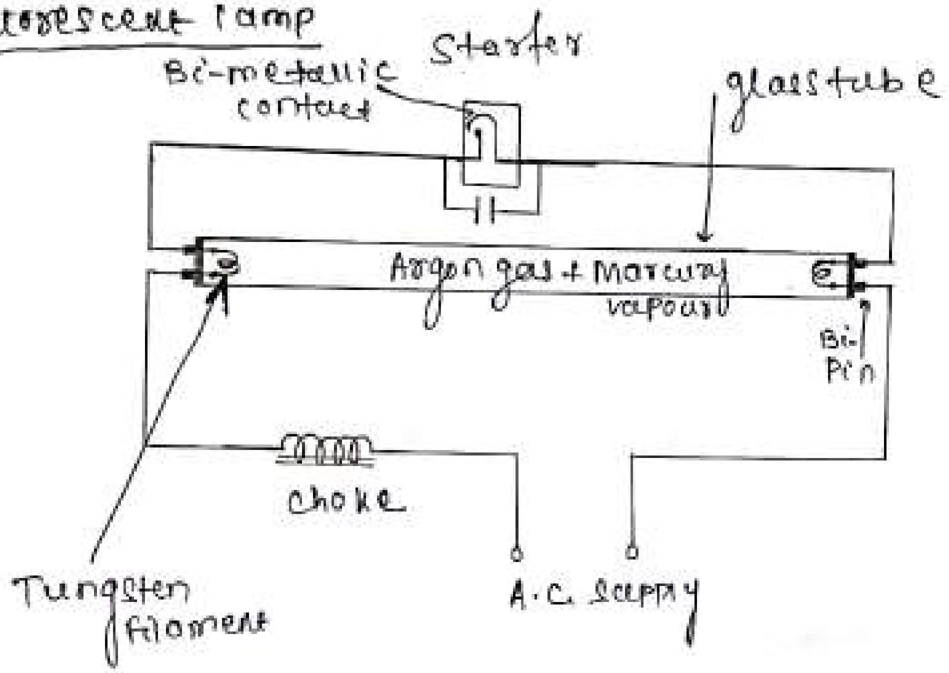
→ The tungsten filaments are of two types
① coiled filament

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

㉒ Fluorescent lamp




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

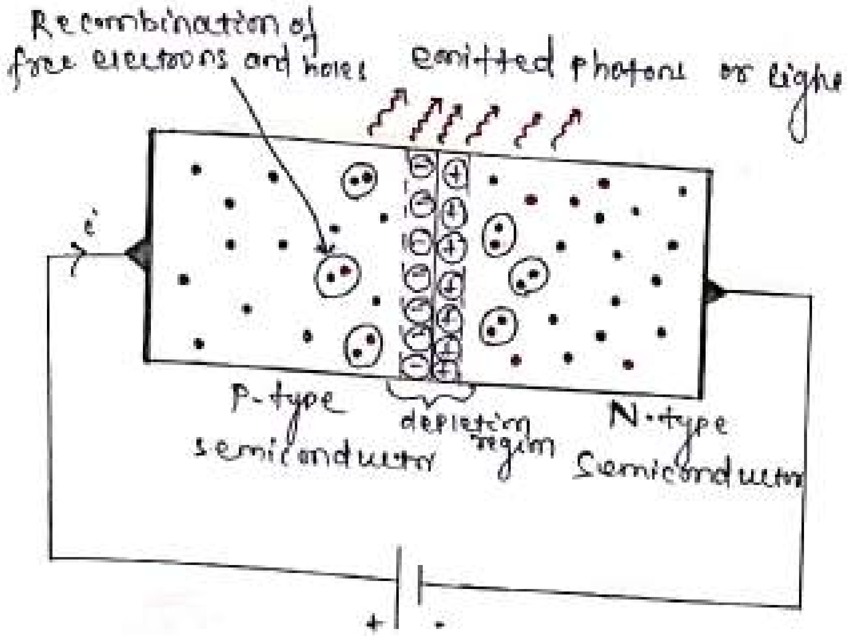
→ Tungsten filament is used.

→ 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

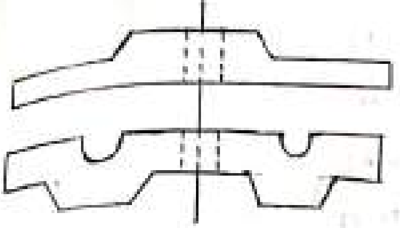
→ Inspection, alternation and addition can be easily made

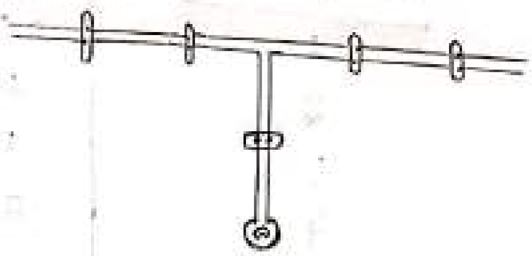
→ Skill required is little.

**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

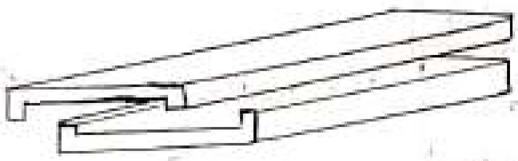
→ Easyly inspect by opening the capping.

→ 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

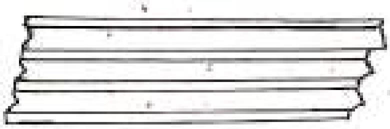
→ It's installation is easy and quick

→ 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 the conduit saddle.

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

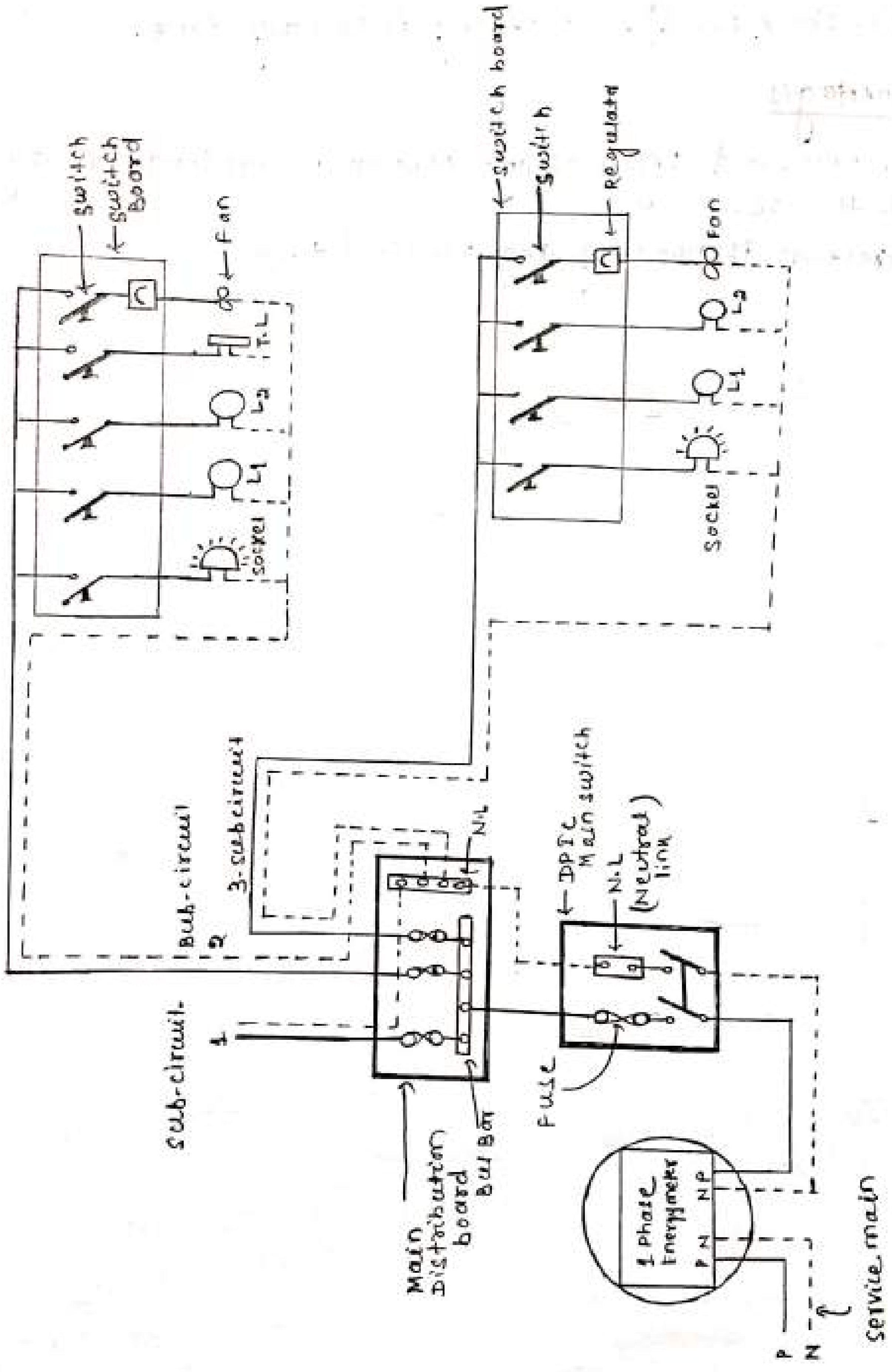
## Advantages

- 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 electric 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 earthings are there

① pipe earthing
② plate earthing

**pipe earthing:→**

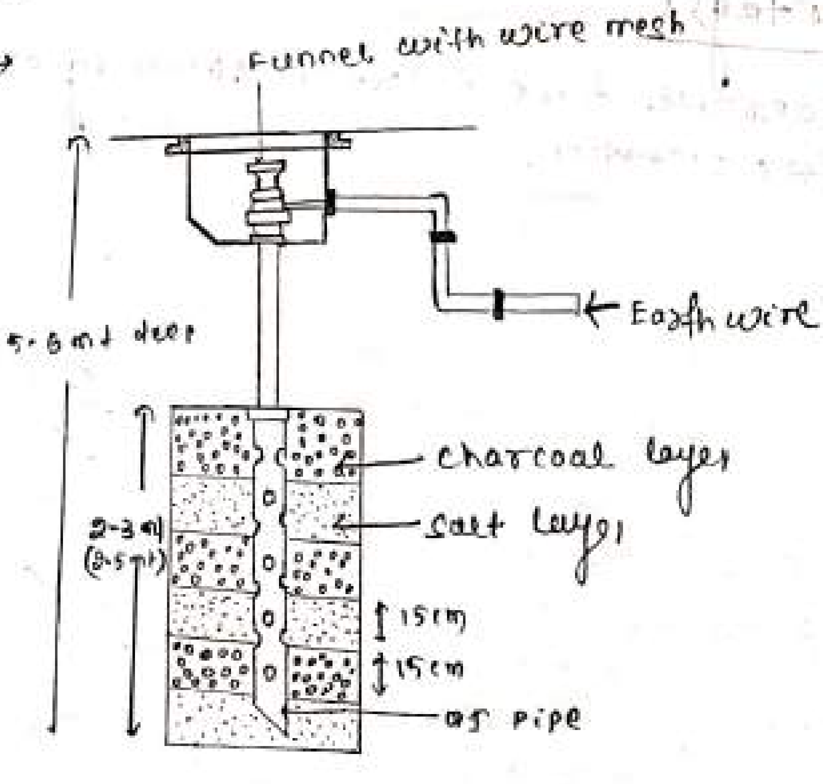
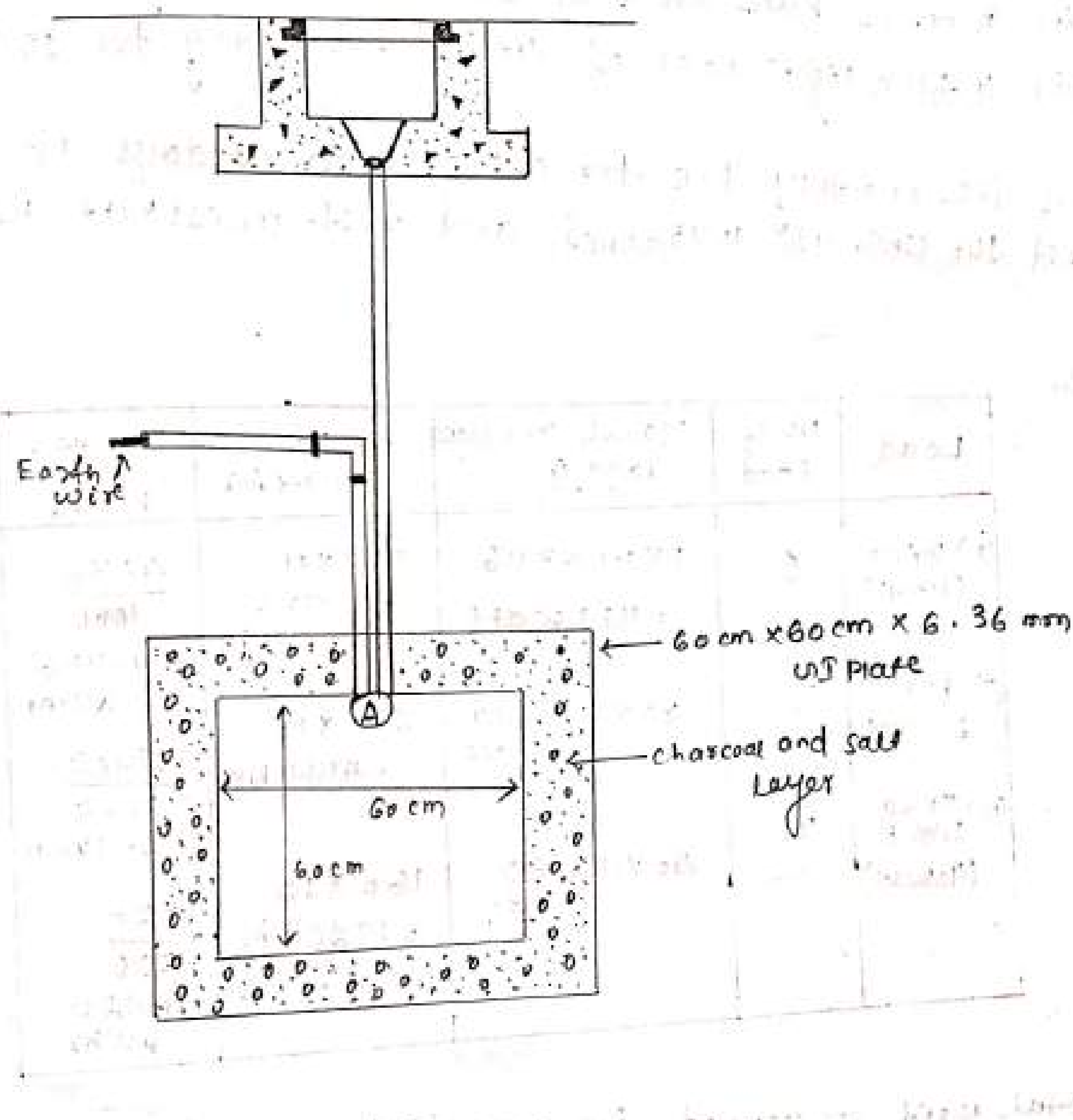


plate earthing :→



## 5.4 Calculate energy consumed 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) 3 no. of Fans each of 80 watt running for 10 hrs in a day.
(iii) 4 tube lights 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 | 4476/1000 = 4.476 kWhr |
| (ii) Fan 80 watt | 3 | 80×3 = 240 watt | 240×10 = 2400 Whr | 2400/1000 = 2.4 kWh |
| (iii) Tube light (40 watt) | 4 | 40×4 = 160 watt | 160×12 = 1920 Whr | 1920/1000 = 1.920 kWhr |

Total unit consumed in one day

= (4.476 + 2.4 + 1.92) kWhr

= 8.796 kWhr

Total unit consumed 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 x 1 = 1000w | 1000 x 5 = 5000wh | $\frac{5000}{1000}$ = 5 kwh |
| (ii) Fan (60w) | 4 | 60 x 4 = 240 w | 240 x 10 = 2400 wh | $\frac{2400}{1000}$ = 2.4 kwh |
| (iii) tube light 40w | 4 | 40 x 4 = 160w | 160 x 8 = 1280 wh | $\frac{1280}{1000}$ = 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 x 31

= 269.08 kwh

cost of electrical energy = 269.08 x 4

= 1076.32/-

= 1076/-

# Chapter- 6 Measuring Instruments

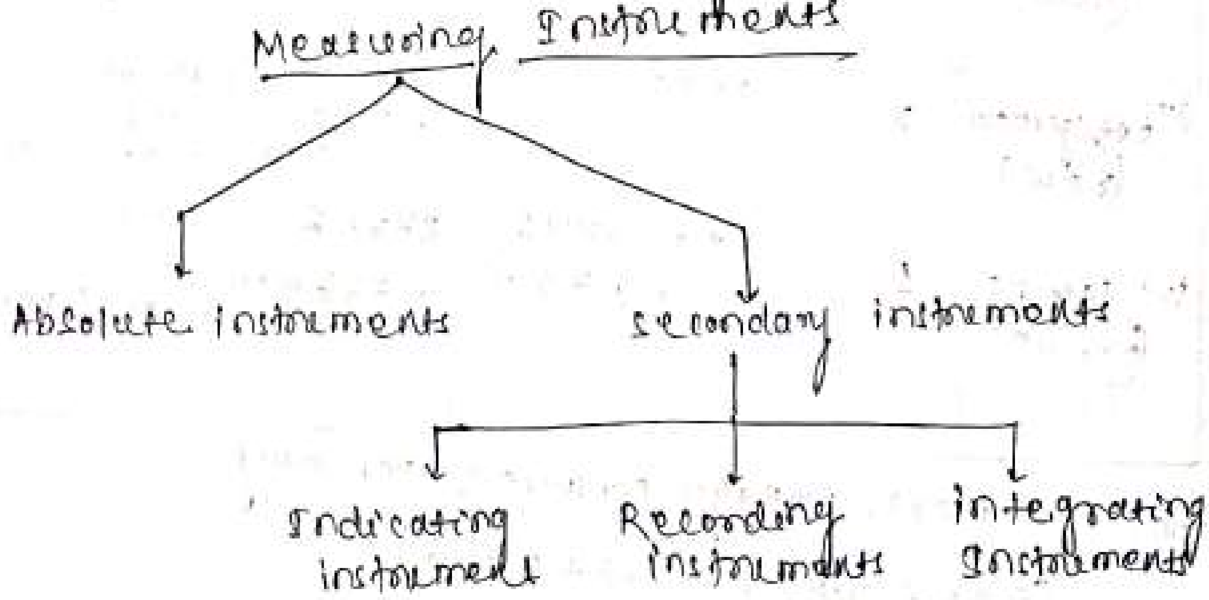
## 6.1 Introduction to measuring Instruments

### 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 almost 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**

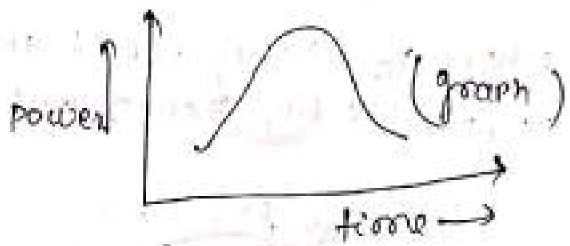
→ These instrument gives the instantaneous value of electrical quantity at the time of measurement.

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

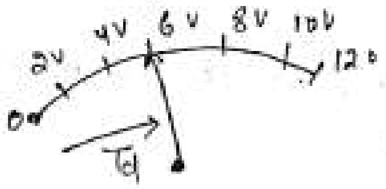
For satisfactory working of indicating instruments the following 3 torques are needed.

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.



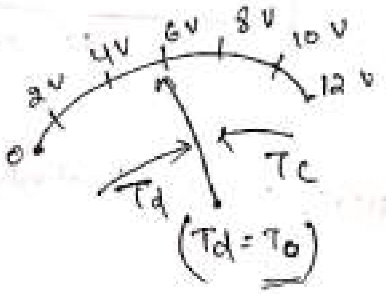

* $T_d$ causes the motion of pointer from '0' position to required value.

## 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.



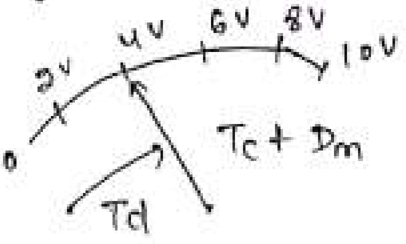

## ③ Damping Torque

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

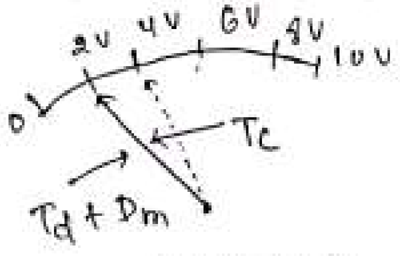
→ The damping torque always acts opposite to the pointer. (Both clockwise and anticlockwise direction)

→ * 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)

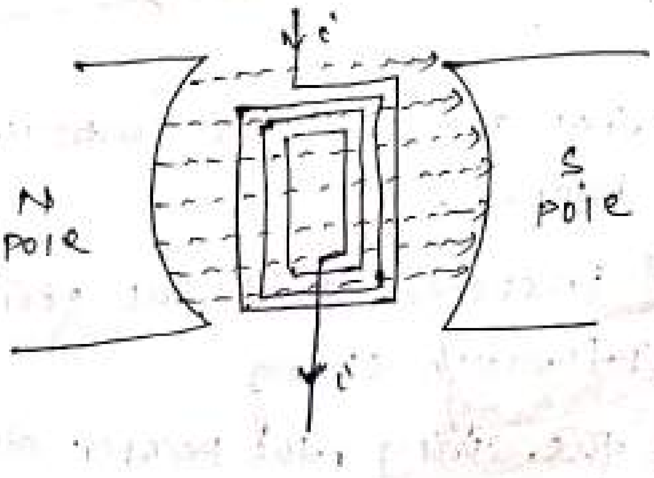
## Deflecting Torque

According to the Lorenz's principle, when a current carrying conductor placed in a magnetic field, experience a mechanical force

i.e $F = BIl\sin\theta$

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

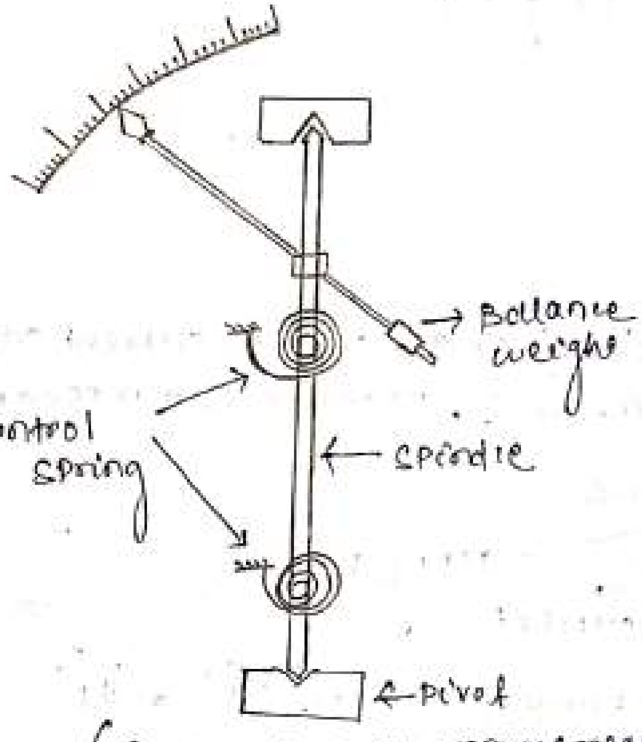
$\theta$ = angle between 'B' & 'IL'



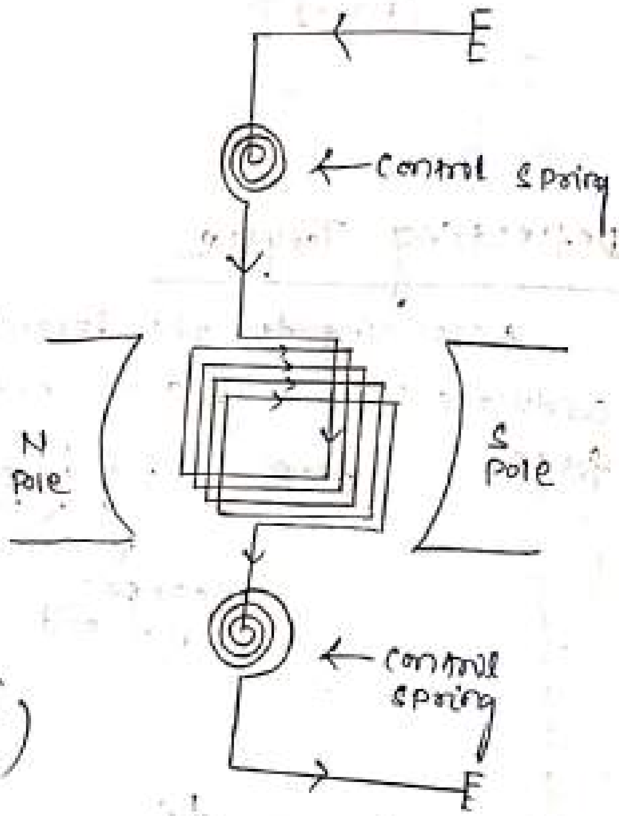
## Controlling Torque

. 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 $T_c = T_d$

$T_d \propto I$

$T_C \propto \theta$

at $T_d = T_C$

$\boxed{\theta \propto I}$

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

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

## Advantages of spring control

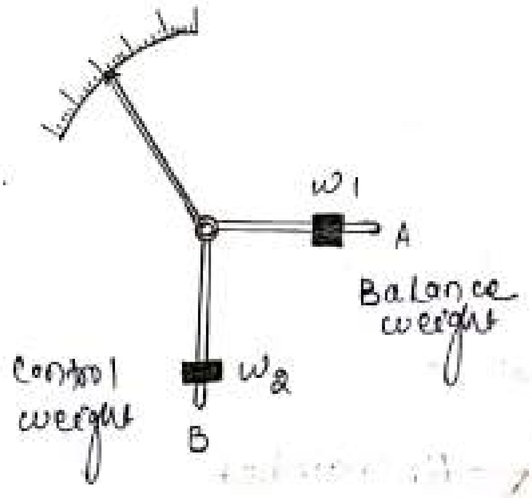
→ It can be placed in horizontal or vertical position.

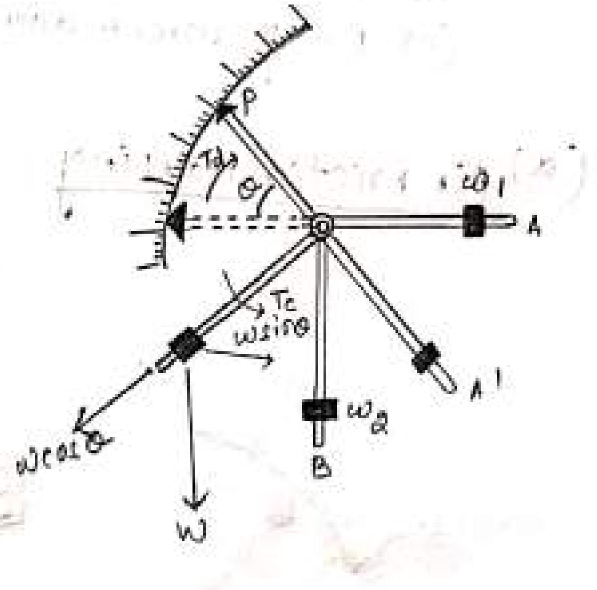
→ It gives linear scale. $T_c$ ↗ $\theta$ ($T_c \propto \theta$)

→ 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 function 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.

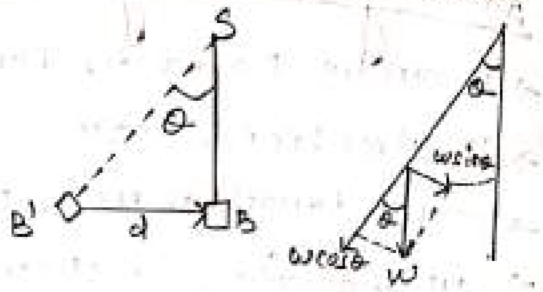
$(T_c \propto \sin\theta)$

## Disadvantages

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

→ scale length is possible upto 90° only.

→ It gives non-linear scale.



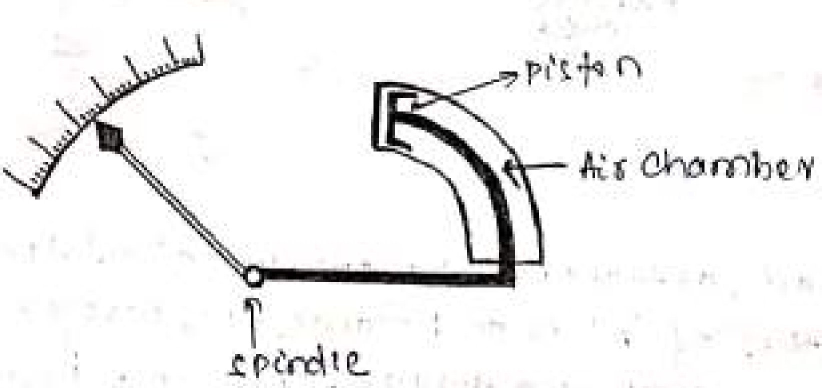

## Damping Torque

→ 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



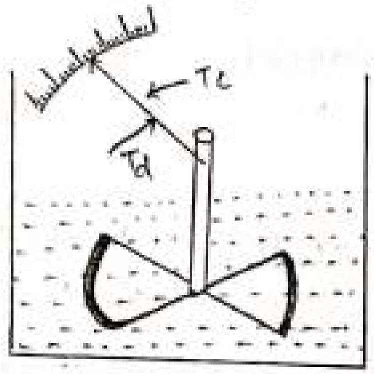

→ In this arrangement, a small aluminium piston is attached to the spindle of the moving system. The piston itself moves in a circular or rectangular chamber with one side open to air.

→ 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.

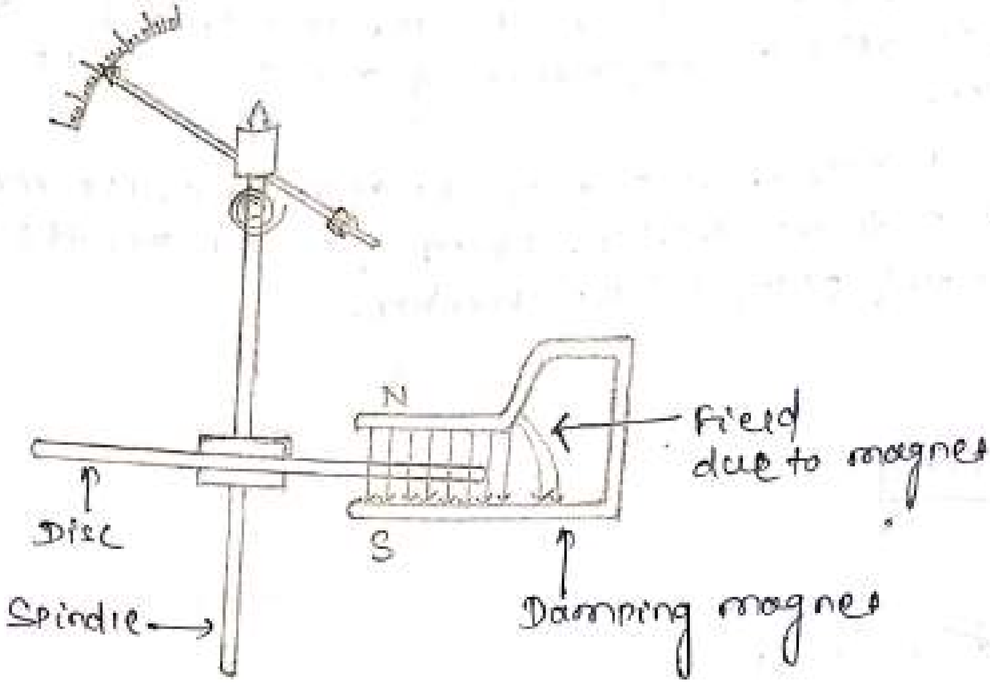
## (c) Eddy current damping

→ 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.

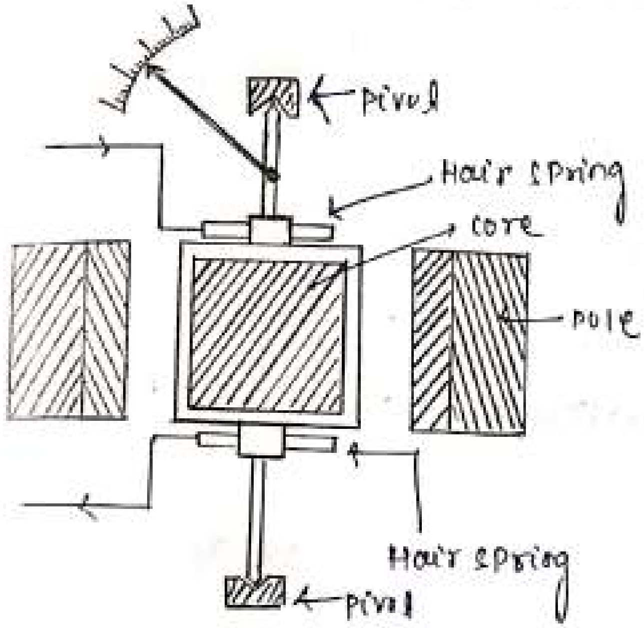
→ Thus, when the disc rotates, it cuts the magnetic flux lines and an emf is induced, which causes current, called eddy current, to circulate in the disc.




→ 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.

## 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 of 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 $(T_d)$ and 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)

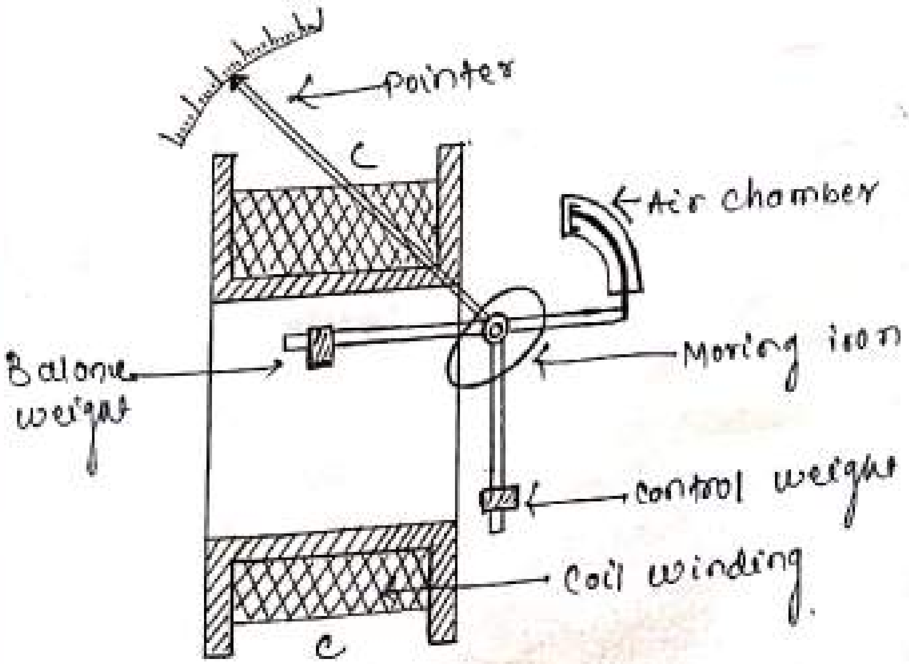
### (a) Attraction type

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

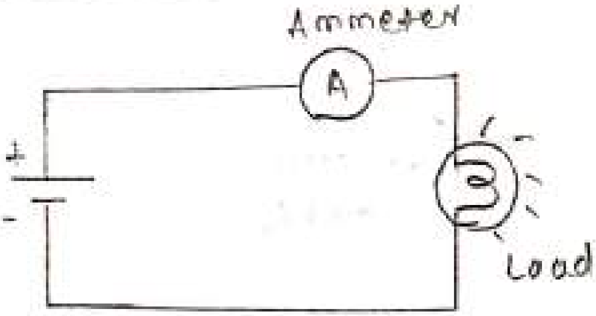
→ It's scale is not - uniform ($T_d \propto I^2$)
→ It consume more power
→ stray losses affect it's reading.

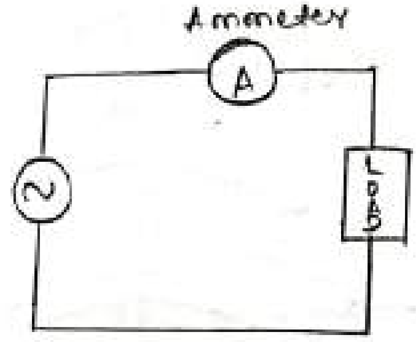
$T_d \propto \phi I$

→ $\boxed{T_d \propto I^2}$

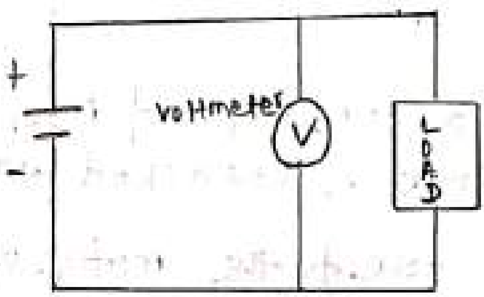
6.5 Draw the connection diagram of A.C/D.C Ammeter, voltmeter, energy meter and watt meter (single phase only)

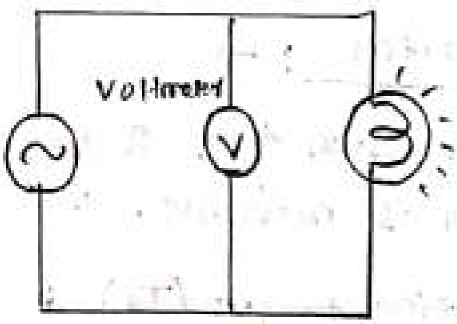
Ammeter (A.C/D.C) connection



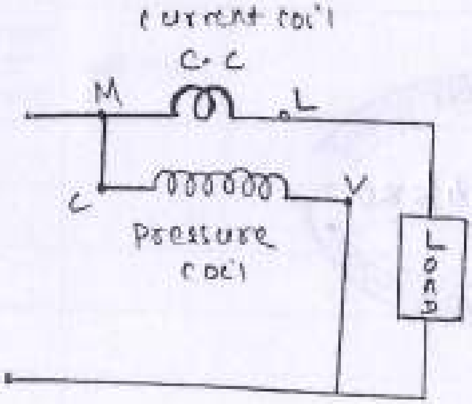




Voltmeter connection (A.C/D.C)

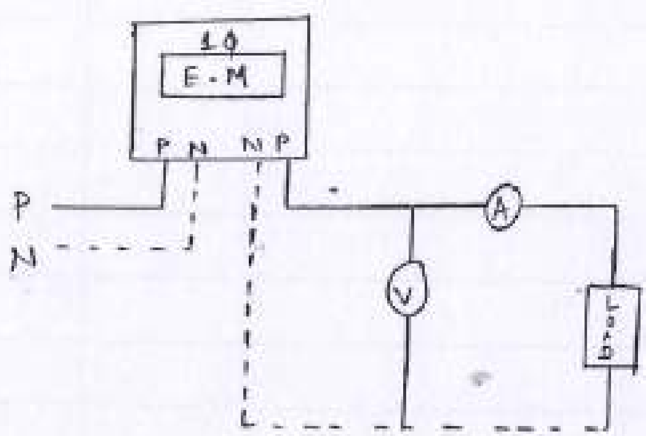


Wattmeter Connection




Energymeter connection



# Chapter -1- Electronic Devices

## 1.1 Basic concept of Electronics and its applications

Electronics is the branch of science and engineering which deals with the flow of electrons through vaccum or gas or semiconductor.

Electronics is derived from the word electron, which is present inside the atom of all materials.

As such electronics is the branch of engineering which essentially deals with electronic devices and their utilization.

### Applications of Electronics

Electronics plays important role in allmost all spheres of life. Some of the important applications are –

a) Communication & Entertainment:

Electronics plays a very vast role in the field of communication. Starting from telephone, telegraph to wireless, sattellite communications, world wide communication in real time, in audio, video form over a short range of time

~~is~~ are the contribution of Electronics.

In the field of entertainment - voice & music recording and playing, visual display systems and almost all aspects of entertainment are flourished with electronics.

b) <u>Industrial Application</u>:

Industrial tasks like conveyance, transportation, extraction, lighting, process control, cutting, bending, melting, smelting, packaging etc are being performed electronically.

c) <u>Defence applications</u>

RADARS, SONARS, AWACS etc are electronic systems used in military applications. Missile launching, Aeroplane/war plane landing etc are enabled by electronics principles.

d) <u>Medical applications</u>

. Medical diagnosis and treatment processes like x-ray, Endoscopy, Electrocardiography are performed by electronics systems. Oscilloscopes, various electronic measuring instruments are used in the field of medical science.

e) Automobile field:

In automobile field, ignition systems, breaking systems, control of fuel flow, speed measurement and monitoring, control of engine performance, fault tracing and automatic control systems are performed with the help of electronics.

f) Digital Electronics: measurement and recording instruments, display units are operated with digital electronics. Almost all measuring and controll instruments are now a days converting from its analog mode to digital electronics mode.

g) Instrumentation: operations like calibration, sophistication, accuracy, maintenance etc. are coming under instrumentation which is mostly electronically performed.

## 1.2. Basic concept of Electron emission and its types

Electron emission: The liberation of electrons from the surface of a substance (usualy metals) is known as electron emission.

In some materials (usualy metals) the valence electrons in the outermost orbit are very loosely held by the nucleus.

These electrons are called free electrons. The force by which a metal surface prevents the free electrons from escaping is called surface barrier of that metal.

If sufficient amount of external energy is applied to the metal, the kinetic energy of the free electrons will be increased over the surface barrier and they will be liberated from the surface.

The amount of energy required by an electron to overcome the surface barrier of a metal to escape from its surface is called work function of that metal.

* work function has the unit of (energy) eV (electron volt)

Types of electron emission:

Electrons are emitted from the surface of a metal if sufficient energy (equal to work function of the metal) is supplied externally. This external energy may come from heat, electric field, light or by bombardment of charged particles on the metal surface. Accordingly there are 4 methods of electronic emission.

a) **Thermionic emission**: The metallic surface is heated to very high temperature (about 2500°c) so as to enable the free electrons to leave the surface. This type of electron emission is called thermionic emission. (2)

Thus thermionic emission is the process of electron emission from a metal surface by supplying thermal energy (heat) to it. The emitter is required to have small (low) work function.

**Richardson - Dushman equation:** The amount of thermionic emission increases rapidly with rise in emitter temperature, which increases the emission current. The emission current density is given by Richardson-Dushman eqn -

$$\boxed{J_s = AT^2 e^{-b/T}} \quad amp/m^2$$

where $J_s$ = emission current density = current per square meter of emitter surface (amp/m²)

T = absolute temp. of emitter (°K)

A = constant depending upon the type of emitter. ( amp/m²/K²)

b = a constant for the emitter

and $\boxed{b = \frac{\phi e}{K}}$ where $\phi$ = work function of emitter

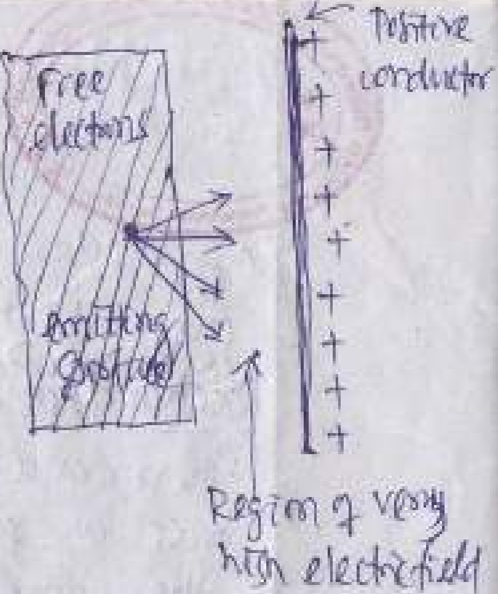
e = charge of electron ($1.602 \times 10^{-19}$ coul)

K = boltzman constant = $1.38 \times 10^{-23}$ J/K

$$\therefore b = \frac{\phi \times 1.602 \times 10^{-19}}{1.38 \times 10^{-23}} = 11600\phi \, K.$$

(b) **Field emission:** The process of electron emission from the surface of a material by applying very strong electric field (+ve field) at the surface is known as field emission.

A very high voltage (+vely charged) conductor is placed close to the metal surface. The very high +ve field attracts electrons from the metalic surface. because the force of attraction exceeds the ~~potent~~ surface barrier.

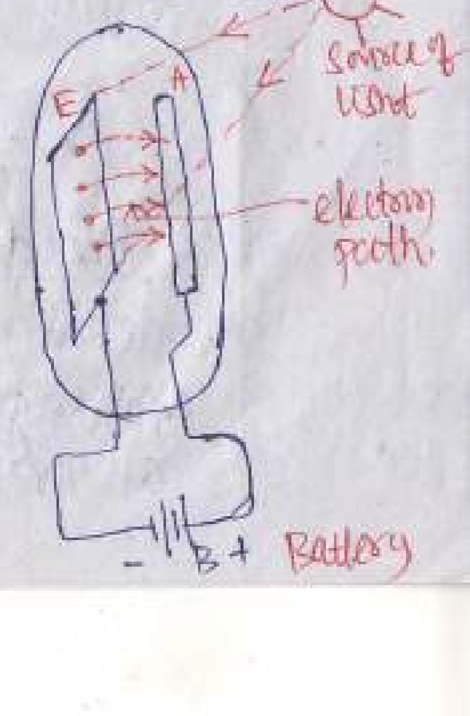



Electric field of the order of million volts per centimeter distance between the emitting surface and the +ve conductor is required to cause field emission. The temperature at the time of field emission may be equal to room temperature (very low as compared to thermionic emission) Hence field emission is also sometimes called as <u>cold cathode emission</u> or <u>auto-electronic emission</u>.

c) <u>photoelectric emission</u>:

Electron emission from a metalic surface by the application of light is called photoelectric emission.

When rays of light of proper intensity strikes the surface of certain metals (photo emissive metals like pottasium, sodium, cesium), the



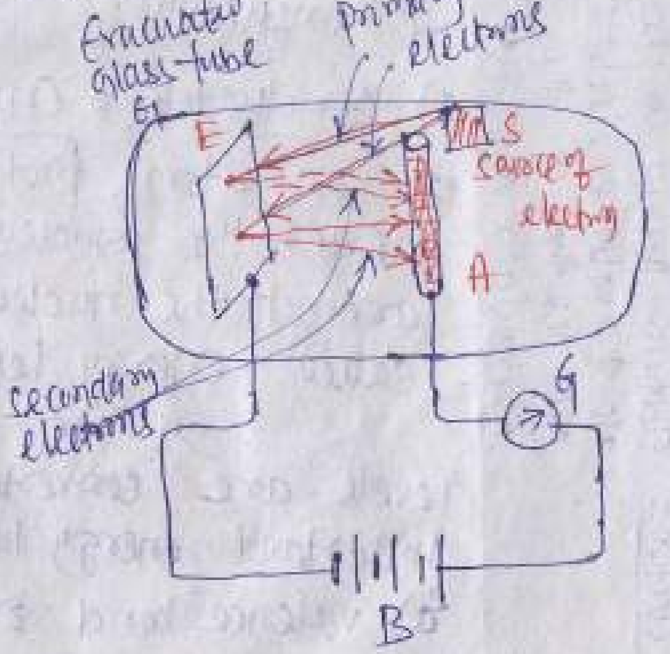
energy of photons of light is transferred to the free electrons. If the energy of the striking photons is greater than the work function of the metal (called emitter or cathode) then electrons are liberated from the metal surface.

Such electrons are called photoelectrons and are collected by a +vely charged anode. A potential difference is maintained between the anode and cathode. The whole arrangement is called a phototube.

The amount of photoelectric emission depends upon the intensity of light falling on the metal surface and the frequency of radiation.

(d) Secondary emission:

Electron emission from a metallic surface by the bombardment of high speed electrons or other particles is known as secondary emission.




As shown in the figure, when very high velocity electrons (primary electrons) strikes a metal surface, they give part or full of their kinetic energy to the free electrons in the metal, thus enabling them to overcome the workfunction of the metal and get liberated (called secondary electrons).

These secondary electrons collected by the anode, produces emission current. Intensity of emission current depends upon the emitter material and mass and energy of the bombarding particles.

## 1.3 Classification of material according to electrical conductivity.

According to electrical conductivity, ~~any~~ materials can be classified into 3 categories a) conductor b) semiconductor c) non conductor or insulator.

~~a) conductor~~ • Energy Band Structure

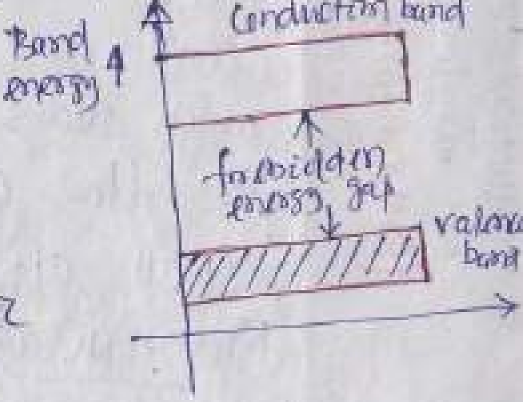
In an atom, proton and neutron are positioned inside the nucleus, where as electrons revolve around the nucleus in different orbits called energy levels.

In an isolated atom, the energy levels are converted into energy bands. Important energy bands in an atom are i) valence band ii) conduction band. There is an energy difference or gap between these two bands called forbidden energy gap.

Valence electron: Electrons present in the outermost orbit of an atom are called valence electrons. No. of valence electrons can be maximum upto 8. If the no. of valence electrons are less than 4, then the material is a conductor, more than 4, it is non conductor or insulator and equal to 4 is a semiconductor.

i) <u>valence band</u>: The electrons in the outermost orbit of an atom are called ~~free~~ valence electrons. These electrons posses highest energy and the energy band that contains valence electrons, is called valence band. This band may be completely or partly filled.

ii) <u>conduction band</u>:




when the valence electrons will get some external energy they will be liberated from the surface (free from atomic bond) and will move to a next higher energy band.
These electrons are called free electrons and are responsible for conduction of electrical current in the material. The band consisting these free (conduction) electrons is called conduction band.

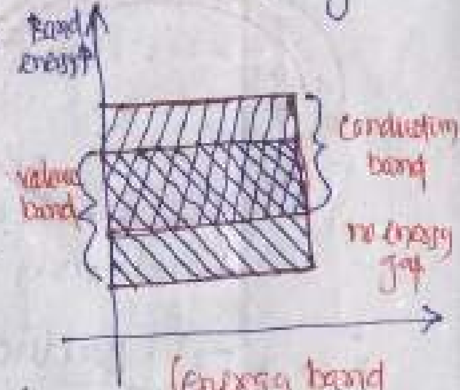
iii) <u>Forebidden energy gap</u>:
The energy gap between valence band and conduction band is called forebidden energy gap. No electron can remain in forebidden energy gap.

a) <u>conductors</u>: The materials (usualy metals) which allows the passage of electric current through it without any obstruction or resistance are called ~~and~~ conductors.

considering the energyband structure of conductors — they have filled valence

Conductors have very high conductivity and very low (zero) resistivity.
(Ex of conductors - copper, Aluminium, silver, etc)

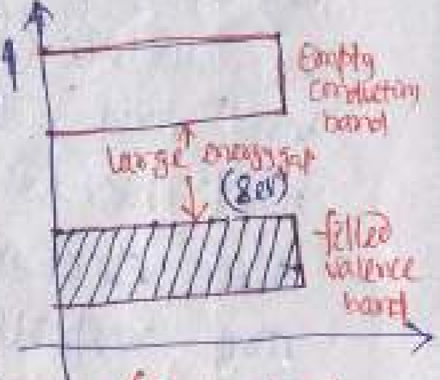
bands and filled conduction bands. Actually these two bands are partly overlaping with each other and there is no forbidden energy gap. So large no. of free electrons are present in conduction band which allows large current to flow across it, with small applied potential difference.



(energy band structure of conductor)

b) Insulators:

Insulators (non conductors) are materials through which electric current cannot pass through. Insulators have very less (zero) conductivity and very high resistivity.

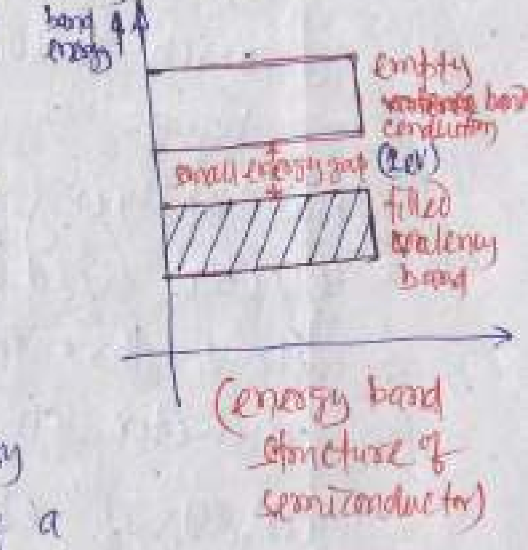


(Energy band structure of insulators)

(Ex. of insulators; wood, glass, mica etc)

In terms of energy band structure - insulators have completely filled valence band and completely empty conduction band with a very wide forbidden energy gap in between. As no free electrons are available in the conduction band, electric current can not flow through it.

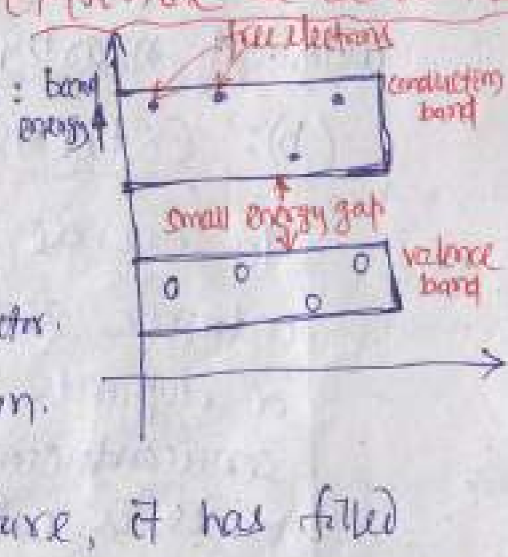
c) Semi conductors. Semiconductors are materials (ex: carbon, germanium, silicon) whose electrical conductivity lies between those of conductor and insulators.




under ordinary condition, semiconductors have filled valence band and empty conduction band but with a small forbidden energy gap (1eV). So applying a small electric field, valence electrons will jump to conduction band and the material will conduct electric current. Now increasing temperature, more no. of valence electrons will jump to conduction band, thus increasing the conductivity of the semiconductor.

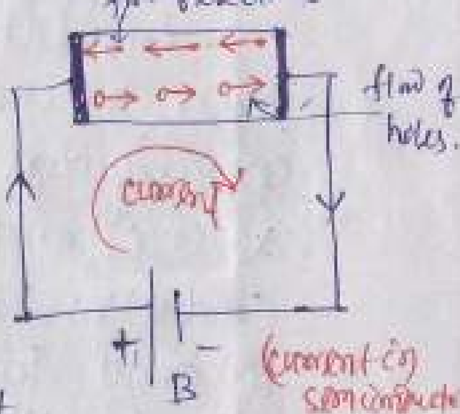
## 1.4: Intrinsic and Extrinsic Semiconductors

a): Intrinsic semiconductor:

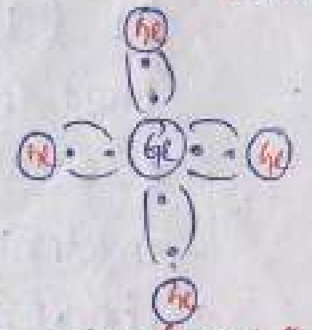



A semiconductor in its extremely pure form is called intrinsic semiconductor.
Ex: pure germanium, silicon.

At absolute zero temperature, it has filled valence band and empty conduction band. But with slight increase in temperature (say upto room temperature), some valence electrons will move to conduction band and move there freely. The absence of electron (-ve charge) in valence band produces a hole (+ve charge) which also can move freely in valence band.




Now applying an external electric field, current flows through the semiconductor. This current consists of electron current (opposite in direction) and hole current (in direction).




(bond structure of pure semiconductor)

If we will consider bond structure of intrinsic semiconductor (Ge or Si) it has valency = 4, so 4, outer electrons makes covalent bond with 4 nearby germanium atoms as shown in fig.

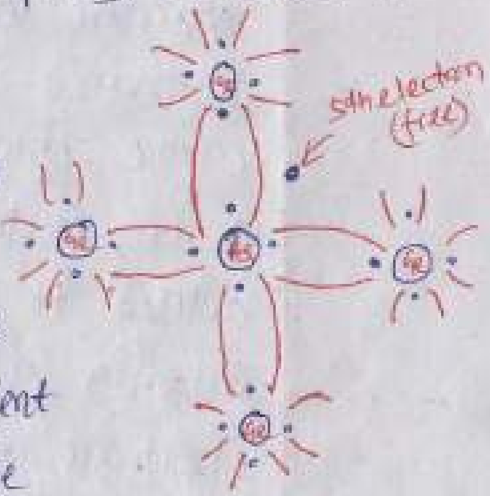
(b): Extrinsic Semiconductor.

To increase the conduction ability, pure or intrinsic semiconductors are added with impurities or dopants, forming an impure or extrinsic semiconductors. The dopants are added (this process is called doping) in atomic level and the proportion is $1 : 10^8$ (impurity atom to base atoms). The dopant atom will have valency $4 \pm 1 = 5$ or 3. where 4 is the valency of Ge & Si. According there are two types of extrinsic semiconductors.

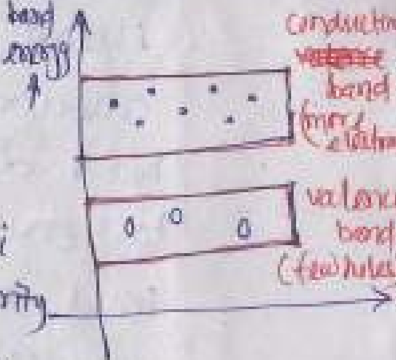
## i) n-type extrinsic semiconductors:



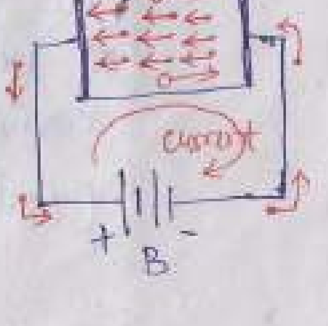
n- type (or negative type) extrinsic semiconductors are produced when pure Ge or Si is added with some pentavalent impurity atoms (Ex- Arsenic, Antimony etc).




considering the atomic structure, when pentavalent arsenic (As) is added, it has 5 valence electrons out of which 4 makes covalent bonds with 4 nearby Ge atoms and the 5th electron remains free and moves to the conduction band. With the application of little heat or electricity no. of free electrons in conduction band becomes much more than the no. of holes in valence band.

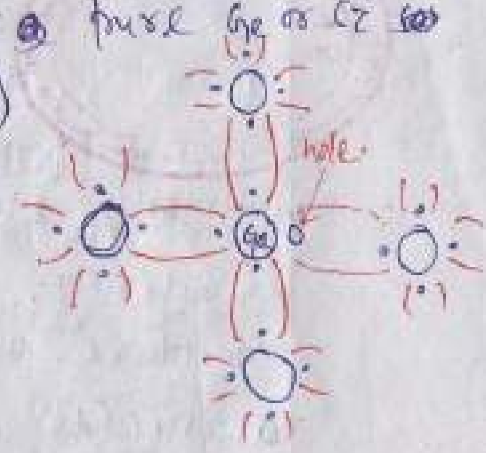



So in n-type extrinsic semi conductors, electrons are majority carriers and holes are minority carrier and total circuit current is mostly due to electrons. This can be practically verified by applying an external electric field as shown in the figure.

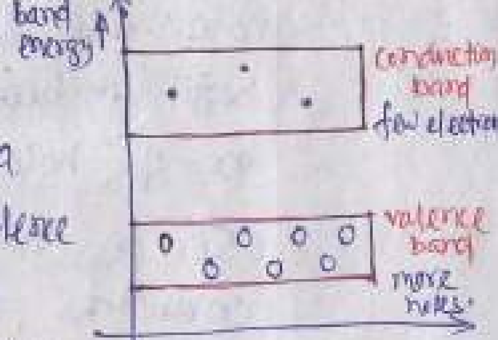


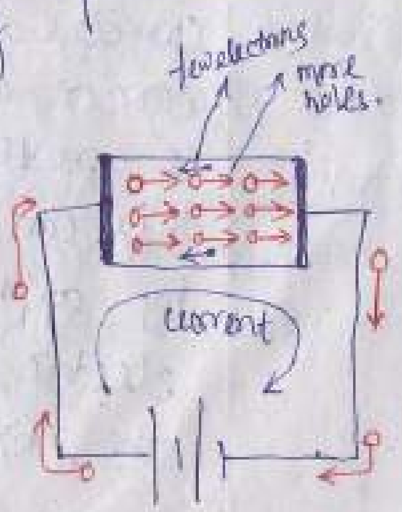
## (ii) p-type extrinsic semiconductor:

When trivalent impurities like Boron, gallium, indium are added to pure Ge or Si the p-type (+ve type) extrinsic semiconductor is formed. As shown in the figure, when a Ga impurity atom is added to Ge, Ga has valency 3. So the 3 valence (outermost) electrons make covalent bonds with 3 neighbouring Ge atoms and one more electron of Ga atom is required to make bond with the 4th surrounding Ge atom. This absence of electron is called a hole.




Considering the energy band diagram, there are a large number of holes in valence band and few electrons in conduction band. By applying an external electric field the circuit current consists of mostly holes (majority carriers) and few electrons (called minority carriers)



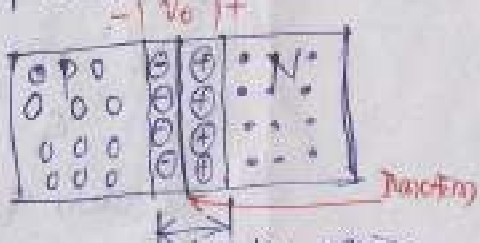
## 1.5 Difference between vaccum tube & semiconductor devices.

Both vaccumtube devices and semiconductor (solid state) devices serves the same purpose. The initialy invented electronic devices were vaccum tubes (or gas filled tubes) in the form of diode, triode, tetrode, pentode --etc. Because of certain disadvantages like glass envelope structure, large volume etc, they are being replaced by solid state devices made of off semiconductor materials like Ge & Si

- In solid state devices junctions formed which is not there in vaccum tubes. The solid state devices are named as P-N junction diodes, transistors, FETs, IGBTs, MOSFETs etc.

1.6. a) PN junction diode.

When a p type semiconductor comes in close contact of an n-type semiconductor a p-n junction is formed. Actually the junction is fabricated by special techniques like growing, alloying and diffusion methods.




At the instance of junction formation, holes from p-side and electrons from n-side diffuse to the opposite side and combine with each other and depleted away (make a void) width of the junction increases till their energy is just sufficient to cross the junction, then the width of the junction remain fixed. The junction region on either side have no charge carriers and only ions (+ve ions on N side and -ve ions on P side). This region is called depletion region or space charge region.


A potential difference exists between the two ends (across) the junction. This potential is called junction potential or barrier potential. Barrier potential of a junction depends upon factors like semiconductor material, amount of doping and temperature.

For silicon, $V_0 = 0.7V$

for Germanium $V_0 = 0.3V$.

## PN Junction as a diode

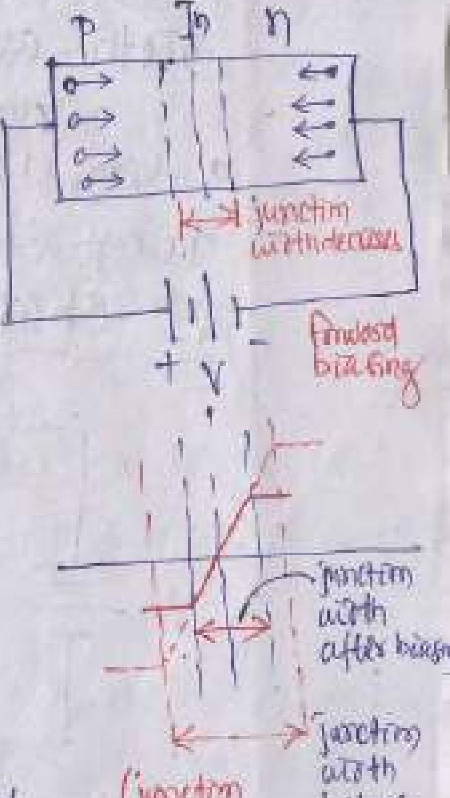


A P-N junction is also called a pn junction diode or simply diode. The terminal connected to p side is the anode(A) and terminal at n side is the cathode(K)


Symbol.

Working principle: A diode works only when it is properly biased. Biasing is applying an electric field (voltage) across the terminals. Biasing is of two types a) forword biasing and (b) reverse biasing.

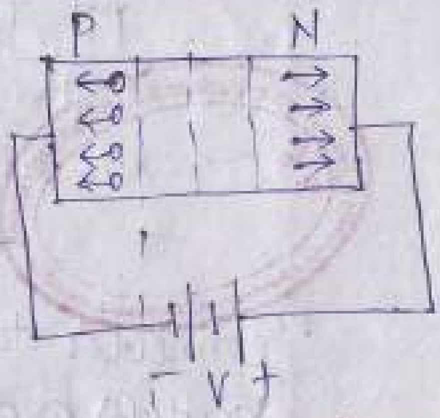
a) Forword biasing:



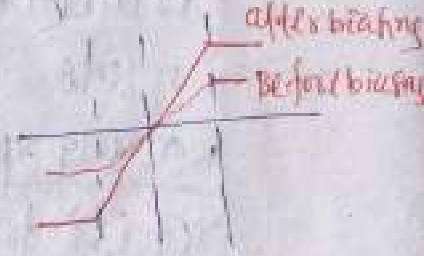

When +ve plate of the battery connected to p side and -ve plate to n side of a P-N junction, it is said to be forword biased. By forword biasing holes & electrons from p & N sides moves towords the junction and so junction width decreses and in turn the barier potential also reduces.

The junction offers very low resistance to the flow of current through it.

b) Reverse biasing:

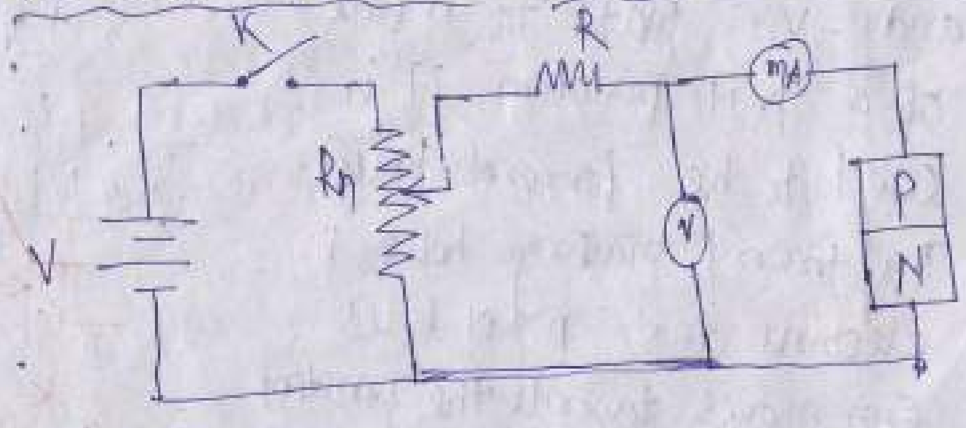



when -ve plate of the battery is connected to p side and +ve plate to N side of a PN junction it is said to be reverse biased. Holes from P side and electrons from n side got attracted by the reverse bias and moves away from the junction, increasing the junction width as well as barrier potential.



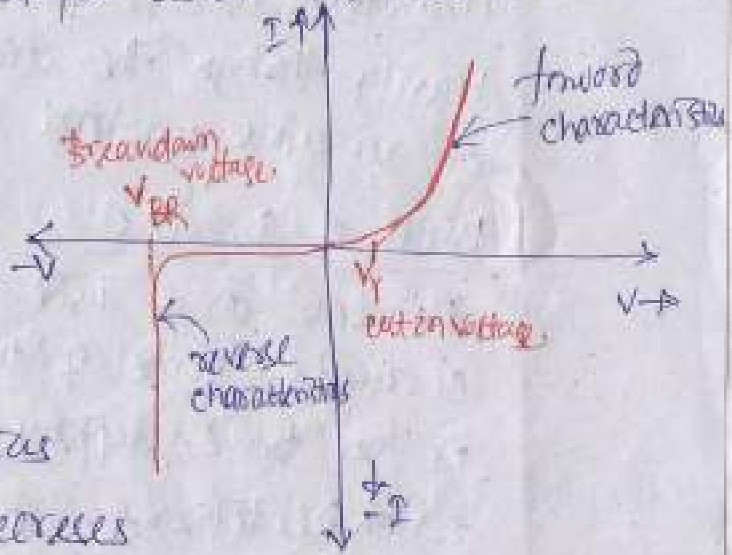

During reverse bias the junction offers a very high resistance to the current flowing through it.

VI characteristics of PN junction diode




To draw the VI characteristic of a PN junction diode. the circuit connection as shown in figure is made. The diode is biased by the external voltage V.

The voltage developed across the diode and current flowing through the diode can be changed by varying the rheostat.




a) Forward bias:

During forward bias the junction width decreases and it offers a low resistance. So forward current can flow through the diode. For '0' voltage, current is zero when forward voltage increased in small increments up to certain voltage, there will be no current this is due to the fact that the forward voltage has to overcome the junction potential barrier, then only current can flow. So, the amount of forward voltage at which forward current can flow through a PN diode is called cut in or threshold voltage ($V_\gamma$). After threshold, increasing voltage, current increases.

b) reverse bias: During reverse bias, junction width increases and it offers a very high resistance to current flow. Increasing the reverse voltage, a point will be reached when the diode will breakdown (lost its property of P & N semiconductors). This voltage at which breakdown occurs is called breakdown voltage. After breakdown current flow heavily through the diode and voltage across it remains constant at ($V_{BR}$), breakdown voltage.

## Uses of Diodes.

Diodes are used in almost all electronic circuits. Some of the applications are—

i) In powersupply applications.

ii) In Rectifiers.

iii) In inverters and convertors.

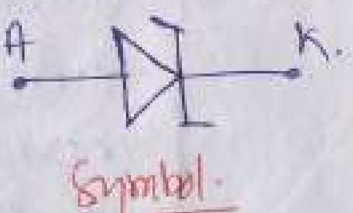
iv) For freewheeling operation.

v) For stabilization purposes.

## b) Zener diode:

An ordinary diode when reverse biased and the bias voltage increases at certain value the diode will breakdown. After breakdown current increases sharply very heavily and voltage remains constant at breakdown value. The sharpness of the breakdown curve depends upon the doping concentration.

A properly doped crystal diode which has a sharp breakdown voltage is called a Zener diode.




Symbol.

- A Zener diode is an ordinary P-N junction diode except the fact that it is properly doped to produce sharp breakdown voltage.
- It is always connected in reversebiased condition.

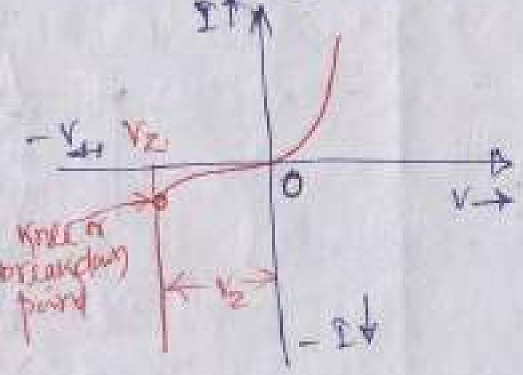
- zenor diode has a sharp breakdown voltage called zenor voltage ($V_Z$).



- If it is forward biased, it behaves like an ordinary diode.

VI characteristics:

VI characteristics of a zenor diode is similar to that of an ordinary PN junction diode. only fact is that the diode is operated in reverse biased condition and in break down region.

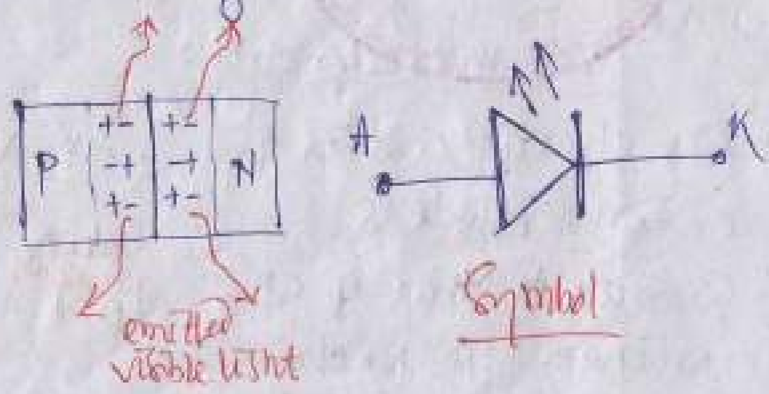



uses of zenor diode

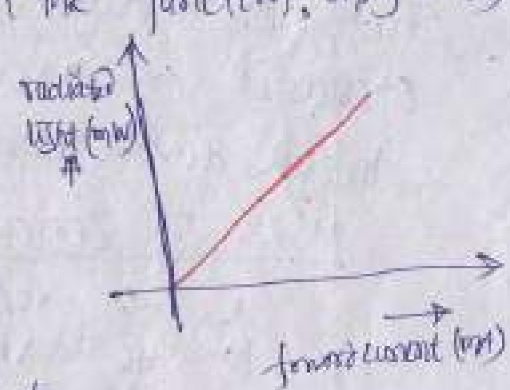
1. in voltage stabilization circuits.
2. As a voltage regulator.
3. As a -ve voltage source.

c) Light emitting diodes (LEDs)

- Light emitting diodes are producing visible light of different colours (wavelength) basing upon the principle, that - when holes and electrons from p side and n side respectively recombine with eachother they gives out some energy, in the form of heat and light. in ordinary diodes this energy is lost in the form of heat, but in some special purpose diodes, using Galium arsenide (GaAs) Galium phosphide (GaP) etc as the PN type materials, during junction formation, visible intense coloured light can come out due to hole-electron recombination. These diodes are called light emitting diodes (LEDs).

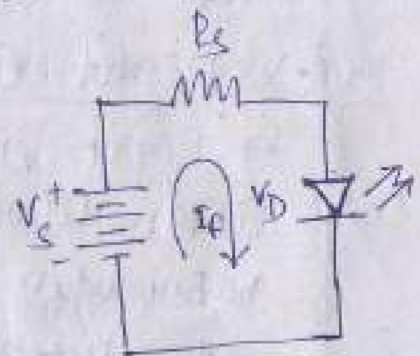



Light is emitted from the junction, only when the diode is forward biased. When forward biased, forward current flows. Increasing forward bias, forward current increases and intensity of emitted light also increases.




LED voltage & current:

In the fig. is shown an LED connected to a voltage source $V_S$ through a resistance $R_S$. If $V_D$ is the voltage across the LED, then voltage across $R_S$ is $V_S - V_D$. Then the forward current flowing in the circuit




$$I_F = \frac{V_S - V_D}{R_S}$$

## 1.7. Integrated circuits.

In a big electronics circuit (of computer, TV etc) thousands of discrete components like resistors, diodes, capacitors, transistors etc are used and interconnected. If all of them are to be separately placed and connected, they will require a large space. To overcome this difficulties a large no. of components (resistors, capacitors, diodes, transistors) are fabricated inside a small chip of semiconductor material. This chip is called integrated circuit (IC) or IC chip.

An integrated circuit (IC chip) is one in which circuit components like transistors diodes, resistors etc are fabricated in such a way that they automatically become the integral part of the same chip and their interconnections also established.

- An IC is very small in size, typical size of an IC is 0.2mm x 0.2mm x 0.001mm.
- no component can be taken out separately as it is fabricated well inside the chip.
- no component or any part their of can be projected out of the chip.

## Advantages of ICs

1. Incresed reliability due to lesser no. of components.

2. Extremely small size as all components and interconnections are fabricated inside the chip.
3. Less weight and occupies less space.
4. Low power requirements.
5. Greater ability to operate at extreme values of temperature.
6. Low cost because of simultaneous production of hundreds of alike circuits on a small semiconductor wafer.
7. The circuit layout is greatly simplified because integrated circuits are constrained to use minimum number of external connections.

**Disadvantages:**

1. If any one component goes out of order, the whole IC is to be replaced.
2. Capacitors of value exceeding 30 pF can not be fabricated in IC form.
3. Inductors and transformers can not be fabricated in IC form.
4. It is not possible to produce high power ICs (greater than 10W)
5. There is lack of flexibility i.e., parameters of the various components inside the IC can not be altered.

— x —

Assignment Questions



Ch-1. Electronic Devices

Q.1. Define electronics? [2]

Q.2. Mention some important applications of electronics? [5]

Q.3. Explain electron emission? [2]

Q.4 What are the different types of electronic emission? Explain each type briefly? [5]+[5]

Q.5 Explain how valence electrons determine the electrical behaviour of a material? [5]

Q.6. Explain how materials can be classified depending upon their electrical conductivity characteristics? [5]

Q.7. What is energy band structure of an atom? Define valence band, conduction band and forbidden energy gap? [2+5]

Q.8. Draw energy band diagrams of conductor, semiconductor and non conductor? [5]

Q.9. Explain how semiconductor can be classified? What are the different types? [5]

Q.10. Differentiate between intrinsic and extrinsic semiconductor? [5]

Q.11. Explain how p type & n type extrinsic semiconductors are produced from pure (intrinsic) semiconductor? [5]

Q.12. Differentiate between vaccum tube and semiconductor devices ? [5]

Q.13. Explain how P-N Junction acts as a diode ? [2]

Q.14. what is biasing of a P-N Junction? How a P-N Junction behaves during forward bias and reverse bias ? [2+5]

Q.15. Draw the circuit diagram for obtaining the V-I characteristics of a P-N Junction diode? and draw the VI characteristic ? [5+2.5]

Q.16. Explain i) cut in voltage/knee voltage/threshold voltage and ii) Breakdown voltage of a diode from the V-I characteristics ? [5]

Q.17 what are the different uses of diode ? [5]

Q.18 what is a Zener diode ? what are its uses ? [5]

Q.19 what is an LED ? [5].

Q.20 what is integrated circuit ? [5]

Q.21. what are the advantages and disadvantages of an IC ? [5].

Q.22. Define the terms a) surface barrier b) work function ? [2]

Q.23. what general conditions must be satisfied before an electron can escape from the surface of a material ? [5].

## Multiple choice questions

1. The outermost orbit of an atom can have a maximum of ______ electrons.

a) 2 b) 4 c) 8 d) 16.

2. When the outermost orbit of an atom has less than 4 electrons, the material is generally a ______.

a) conductor b) insulator.

c) semiconductor d) non of the above.

3. The valence electron have ______.

a) very small energy b) least energy

c) maximum energy d) non of the above

4. A large no. of free electrons exist in ______

a) semiconductors b) conductors.

c) insulators d) none of the above.

5. When the outermost orbit of an atom have exactly 4 electrons, the material is generally ______

a) metal b) non metal

c) semiconductor d) ~~all the~~ none of the above

6. When the outermost orbit of an atom have more than 4 electrons, the material is generally a ______

a) metal b) non metal

c) semiconductor d) none of the above.

Q.7. workfunction of metals is generally measured in the unit of - - - - .

a) Joules b) Erg c) watt d) electron volt

Q.8. The electrons emitted by a thermionic emitter are called - - - -

a) free electrons b) loose electrons

c) thermionic electrons d) bound electrons.

Q.9. Field emission is utilised in - - - -

a) vaccum tubes b) TV picture tubes.

c) gas filled tubes d) mercury pool devices

Q.10. Thermionic emitters are required to have - - - - workfunction.

a) low b) High c) medium d) very high.

Q.11 The electrons in the 3rd orbit of an atom have - - - energy than the electrons in the 2nd orbit.

a) more b) less c) same d) non of the above

Q.12. when an electron jumps from higher orbit to a lower orbit, it - - - - energy.

a) absorbs b) emits c) some time absorbs some time emits d) none of the above.

Q.13 A semiconductor has - - - - band.

a) almost empty valence b) almost empty conduction

c) almost full conduction d) non of the above.

# Ch-2 Electronic Circuits ①

## 2.1 Rectifiers and its uses:

Rectifier is an electronic circuit (or device) which converts ac signal into dc signal. The ac electrical signal available for our domestic use is of 220-240V peak to peak sinusoidal voltage signal of frequency 50 Hz. It runs our fans, acs, motors etc. But most of the electronic devices like phones, TVs etc needs dc voltage. So rectifiers are used to convert ac signal into dc signal.

**Uses**
1) Rectifiers are used in power supplies
ii) in the dc power supply unit of almost all electronic devices.

## 2.2 Types of rectifiers.

Rectifiers can be of two types —
- a) Half wave rectifier (HWR)
- b) Full wave rectifier (FWR)

Full wave rectifier can again be divided into two types —
- i) centre tap full wave rectifier
- ii) Bridge full wave rectifier.

### a) Half wave rectifier:

In the figure1(a) is shown the basic circuit of a half wave rectifier. It consists of a single diode (D) and the load resistance $R_L$. The ac input voltage is applied with the help of a transformer. i.e., the HWR is connected to the secondary of the transformer. Fig 2(a) shows the input voltage waveform. Fig 2(b) and (c) respectively shows output voltage waveform and output current waveform. output voltage is the voltage across $R_L$ and output current is the current flowing through $R_L$.

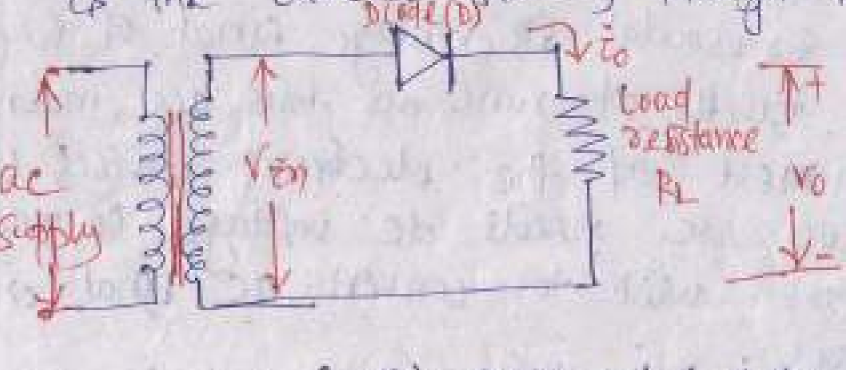



fig 1(a) Basic ckt of HWR.

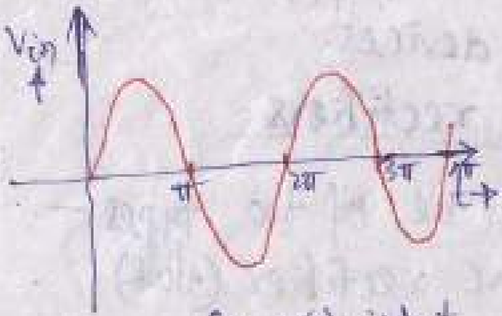



fig 2(a) input voltage.

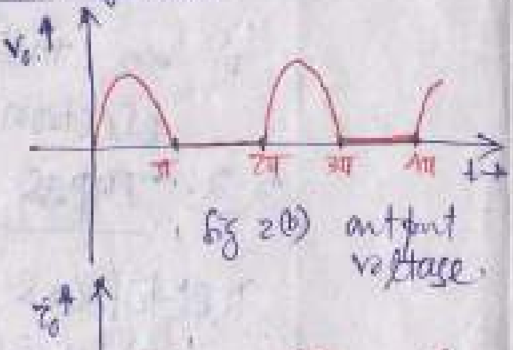



fig 2(b) output voltage.

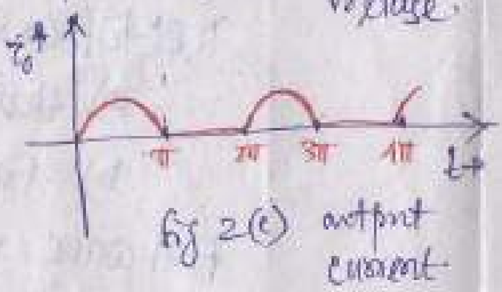
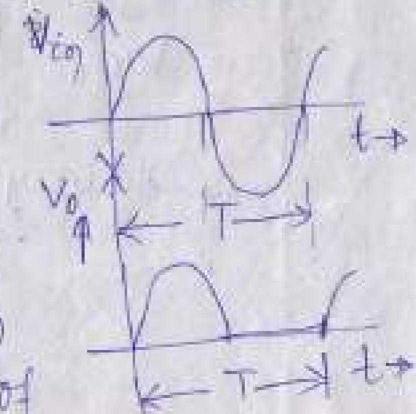



fig 2(c) output current

## Circuit operation:

The ac input voltage is applied to the rectifier through a transformer. During +ve half cycle of the ac input, the diode is forward biased (The cutin or threshold voltage is assumed to be zero volt) and conducts during the entire +ve half cycle. Assuming forward resistance ($R_f$) of the diode to be negligibly small, the current in the circuit (load current) $i_0 = \frac{V_{in}}{R_L}$ and output voltage $V_0 = i_0 \cdot R_L = V_{in}$ so during +ve half cycle of the input, the output equals to the input.

During -ve half cycle of the input, the diode is reverse biased. The reverse resistance of the diode ($R_R$) is very very large ($\simeq \infty$), so it acts as an open circuit and so load current $i_0 = 0$ and $V_0 = i_0 \cdot R_L = 0$ also. The output voltage and current waveforms are as shown in fig 2(b) & 2(c).




## output frequency of HWR

output frequency of a HWR is same as input signal frequency (50 Hz). as shown in the figure, the duration of one complete cycle (time period) is same for both input as well as output signal. So their frequencies are also same.

## Efficiency of HWR

Efficiency of the HWR is defined as the ratio of dc power output to ac power input.

$$\text{efficiency } \eta = \frac{\text{output dc power}}{\text{input ac power}}$$

## dc output power ($P_{dc}$)

dc power output = $(\text{dc output current})^2 \times R_L$

or $P_{dc} = I_{dc}^2 \times R_L$

$$I_{dc} = \frac{1}{2\pi}\int_0^{\pi} i_0 \cdot d\theta = \frac{1}{2\pi}\int_0^{\pi} \frac{V_m \sin\theta}{r_f + R_L} \cdot d\theta$$

As $i_0$ is available between 0 to $\pi$ only, the limits of integration are from 0 to $\pi$

$\because V_0 = V_m \sin\theta$ and $i_0 = \frac{V_0}{r_f + R_L}$

where $r_f \rightarrow$ forward resistance of the diode

$$= \frac{V_m}{2\pi(r_f+R_L)} \int_0^{\pi} \sin\theta \cdot d\theta = \frac{V_m}{2\pi(r_f+R_L)} \cdot \left[-\cos\theta\right]_0^{\pi}$$

$$= \frac{V_m}{2\pi(r_f+R_L)} \times 2 = \frac{V_m}{(r_f+R_L)} \cdot \frac{1}{\pi} = \frac{I_m}{\pi}.$$

$$\therefore P_{dc} = I_{dc}^2 \times R_L = \left(\frac{I_m}{\pi}\right)^2 \times R_L$$

ac input power ($P_{ac}$)

$$P_{ac} = I_{rms}^2 (r_f + R_L)$$

for a halfwave rectified wave $I_{rms} = \frac{I_m}{2}$

$$\therefore P_{ac} = \left(\frac{I_m}{2}\right)^2 (r_f + R_L)$$

now efficiency $\eta = \frac{P_{dc}}{P_{ac}} = \frac{(I_m/\pi)^2 \times R_L}{\left(\frac{I_m}{2}\right)^2 \times (r_f+R_L)}$

or $\eta = \frac{0.406 \cdot R_L}{r_f + R_L} = \frac{0.406}{1 + r_f/R_L}$

as $r_f <<< R_L$, $r_f/R_L <<< 1$

so $\boxed{\eta = 0.406 = 40.6\%}$

Advantages & Disadvantages of HWR.

Advantages 1) The circuit is simple and contains few components.

2) The circuit is less costly.

Disadvantage 1. efficiency is less.

2. The output power is less.

3. The −ve half cycle of the input is not at all utilised.

b) Full wave Rectifier

It is the rectifier, which utilises the full waveform of the ac input (both halves) to produce the dc output.

FWR can be of two types-

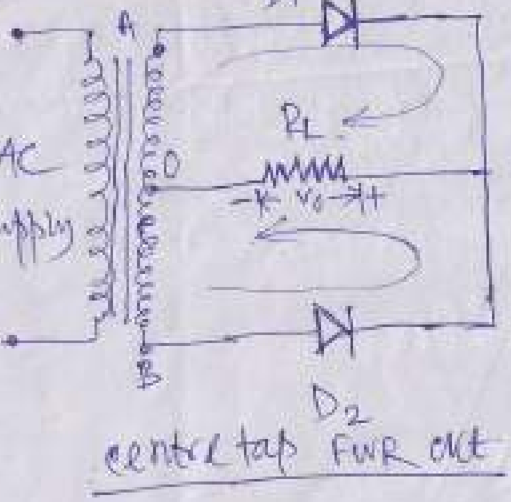
(a) centre-tap fullwave rectifier
(b) bridge full wave rectifier.



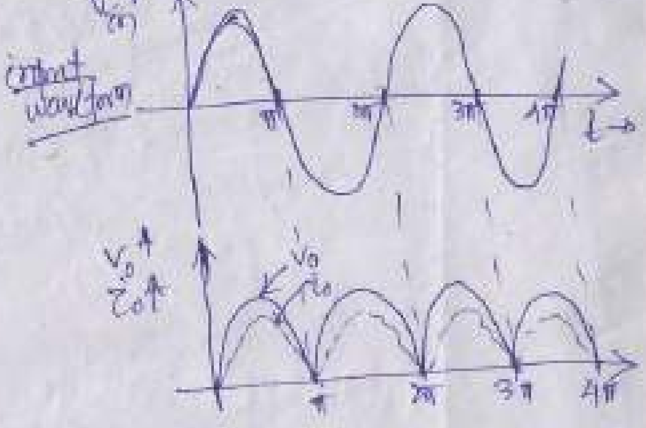


i) centre tap fullwave rectifier:

Two diodes are connected to the secondary winding of a transformer and the load is connected between centre point (tap) of the transformer and junction of the two diodes cathodes. The circuit is as shown in figure.




centre tap FWR ckt




(output voltage and current waveforms)

operation: During +ve half cycle of the ac input, point A is at higher (+ve) potential and point B is at -ve potential. So current flows through diode $D_1$ only (as it is forward biased) and load $R_L$ to produce $V_0$ as shown in the figure.

During -ve half cycle point B is at +ve potential and A is -ve, so $D_1$ is off and $D_2$ conducts. current flows through $D_2$ and load $R_L$. so the current through $R_L$ is in the same direction as it was before (not reversed)

So at the output we are getting dc voltage.

Peak inverse voltage: It is the maximum reverse voltage that a diode can withstand without damage.

During +ve half cycle of ac input, diode $D_2$ is not conducting (reverse biased) and a voltage of maximum value of $2V_m$ appears across it. Similarly in -ve half cycle, max. voltage across the reverse biased diode $D_1$ is also $2V_m$.

So $\boxed{PIV = 2V_m}$ in centre tap FWR.

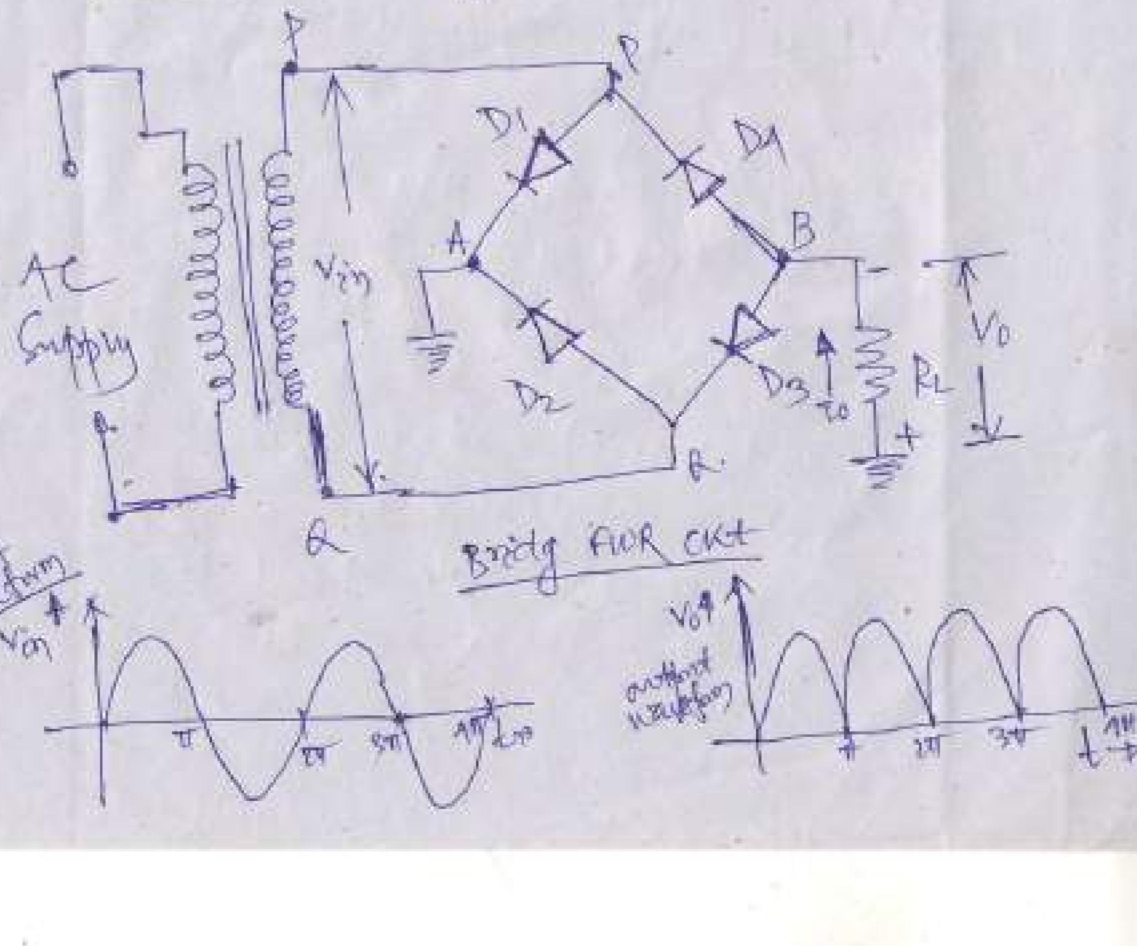
Disadvantages of FWR (centre tap)

i) It is difficult to locate the centre tap on the secondary winding.

ii) The dc output is small as each diode utilizes only one half of the secondary winding voltage.

iii) The diodes used must have high PIV.

Fullwave Bridge Rectifier.



In the fig. is shown a fullwave bridge (3)



rectifier ckt. It uses 4 diodes in the 4 arms of the bridge. The load resistance is connected between two corner points A & B and ac input voltage is applied between the two other corner points P & Q.

Operation: During +ve half cycle of the ac input voltage (0 to π), point P is at higher potential (+ve) and point Q is at lower potential (-ve) so current flows through the sequence P - $D_1$ - A - load $R_L$ - $D_3$ - Q. Diodes $D_1$ & $D_3$ are forward biased (ON) and $D_2$ $D_4$ are reverse biased (OFF). So during this period (0 to π), the output $V_0$ is equal to input $V_i$.

During -ve half cycle of the input signal (π to 2π) point Q is at higher potential and P is at lower potential. So Diodes $D_2$ & $D_4$ are forward biased and $D_1$ & $D_3$ are reverse biased. So current flows from Q - $D_2$ - A - Load $R_L$ - B - $D_4$ - P. So we get another +ve half cycle for ~~In both the cas~~ at the output for the -ve half cycle of the input $V_i$.

In both the cases current flows in the same direction through load resistance $R_L$ i.e, A to B. So the output current is unidirectional (dc) and output voltage $V_0$ (= $i_0 \times R_L$) is also dc. This is shown in the output waveform.

Peak inverse voltage: As it is the maximum reverse voltage developed across a diode when it is reverse biased —

1. During +ve half cycle of ac input (0 to π)

diodes $D_2$ & $D_4$ are reverse biased ($D_1$ & $D_3$ are ON so offers short ckt) — the maximum voltage developed across each diode is equal to $V_m$.

ii) During -ve halfcycle of ac input (from $\pi$ to $2\pi$) $D_1$ & $D_3$ are reverse biased ($D_2$ & $D_4$ are short), so maximum reverse voltage across $D_1$ & $D_3$ is $V_m$.

So in a FWR, PIV of the diodes, $\boxed{PIV = V_m}$

Advantages i) No need of a centre tapped transformer

2) output is twice of that of a centre tapped rectifier

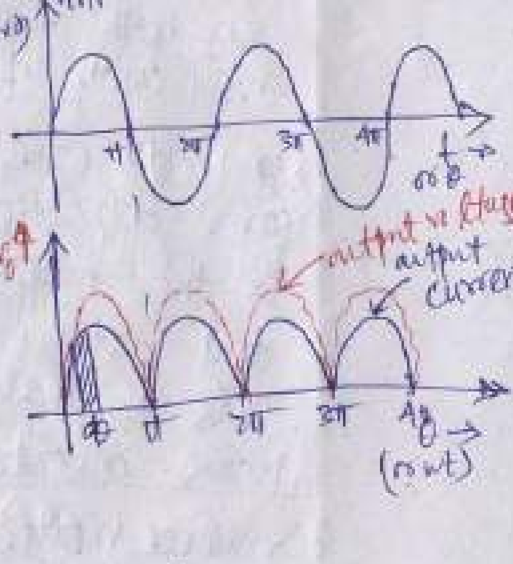
3) PIV is half of that of the centre tapped rectifier

Disadvantages i) It required four diodes.

ii) As two diodes conducts during one halfcycle of the input signal, their internal resistances (though very small) comes in series which produces a measurable resistance, which is not desired, as it will affect the efficiency.

Efficiency of FWR

Consider the FWR circuit, its input voltage and output voltage and current waveforms are as shown




Let $r_f$ and $R_L$ be the forward resistance of diode and load resistance respectively instantaneous current in the ckt, $i = \frac{v}{r_f + R_L} = \frac{V_m \sin\theta}{r_f + R_L}$

$= I_m \sin\theta$ where $I_m = \frac{V_m}{r_f + R_L}$

dc output power

we know for a fullwave rectified wave $I_{dc} = \frac{2I_m}{\pi}$

$\therefore$ dc output power $= P_{dc} = I_{dc}^2 \cdot R_L = \left(\frac{2I_m}{\pi}\right)^2 \cdot R_L$

ac input power

ac input power is $P_{ac} = I_{rms}^2 (r_f + R_L)$

for a fullwave rectified wave $I_{rms} = \frac{I_m}{\sqrt{2}}$

$$\therefore P_{ac} = \left(\frac{I_m}{\sqrt{2}}\right)^2 \cdot (r_f + R_L)$$

$\therefore$ fullwave rectification efficiency -

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{(2I_m/\pi)^2 \cdot R_L}{(I_m/\sqrt{2})^2 (r_f + R_L)}$$

$$= \frac{8}{\pi^2} \cdot \frac{R_L}{r_f + R_L} = 0.812 \frac{R_L}{r_f + R_L} = \frac{0.812}{1 + \frac{r_f}{R_L}}$$

The efficiency will be maximum, if $r_f << R_L$ then $r_f/R_L$ is very very less incomparision to 1 and $\boxed{\eta = 0.812 = 81.2\%}$

nature of rectifier output & ripple factor

The output of a rectifier is not pure dc but actualy pulsating dc in nature so it contains dc component along with ac component. This ac component is also called as ripple.

The ratio of rms value of ac component to the dc component in the rectifier output is known as ripple factor.

ripple factor = $\frac{\text{rms value of ac component}}{\text{value of dc component}} = \frac{I_{ac}}{I_{dc}}$

## Mathematical analysis

As the output current of a rectifier contains ac component as well as dc component, its rms value is $I_{rms} = \sqrt{I_{dc}^2 + I_{ac}^2}$

$$\text{or, } I_{rms}^2 = I_{dc}^2 + I_{ac}^2$$

$$\text{or, } I_{ac}^2 = I_{rms}^2 - I_{dc}^2$$

$$\text{or } I_{ac} = \sqrt{I_{rms}^2 - I_{dc}^2}$$

dividing both sides by $I_{dc}$ –

$$\frac{I_{ac}}{I_{dc}} = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}}$$

$$\therefore \text{ripple factor} = \frac{I_{ac}}{I_{dc}} = \frac{1}{I_{dc}}\sqrt{I_{rms}^2 - I_{dc}^2} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

i) for half wave rectifier:–

$I_{rms} = I_m/2$, $I_{dc} = I_m/\pi$

$$\therefore \text{ripple factor} = \sqrt{\left(\frac{I_m/2}{I_m/\pi}\right)^2 - 1} = 1.21$$

ii) for fullwave rectifier:–

$I_{rms} = I_m/\sqrt{2}$, $I_{dc} = \frac{2I_m}{\pi}$

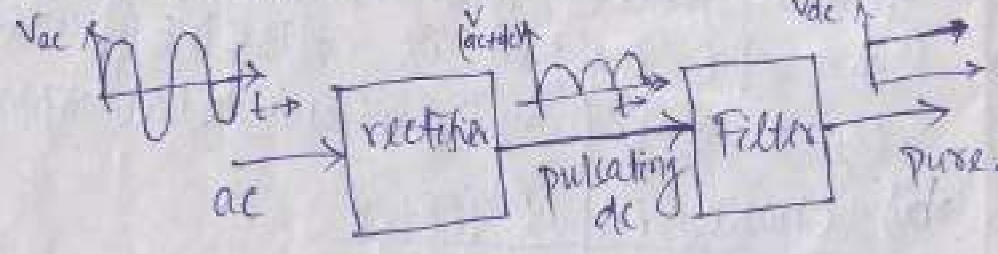
$$\therefore \text{ripplefactor} = \sqrt{\left(\frac{I_m/\sqrt{2}}{2I_m/\pi}\right)^2 - 1} = 0.48$$

It is seen that pulsating component is very less in FWR output than that in HWR output.

# 2.3 Filters : classification and function. (1)



Filter is an electronic circuit which filters out the pulsating ac components present in the rectifier output and produces pure dc output.




Basically there are 3 types of filters-

a) capacitor filter b) choke input filter

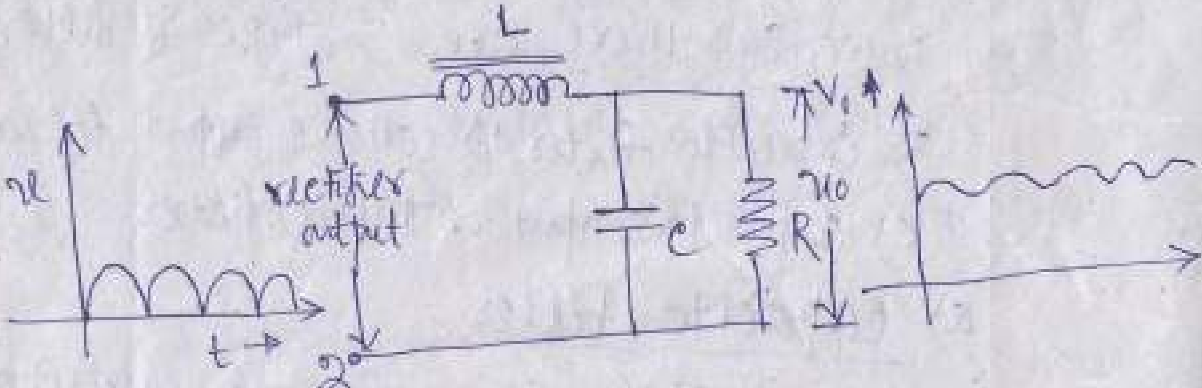
c) capacitor input or π (pie) filter.

a) Capacitor Filter

In the below figure is shown a capacitor filter which contains a single capacitor to which the load resistance $R_L$ is connected in parallel and input is the pulsating dc output of a rectifier.

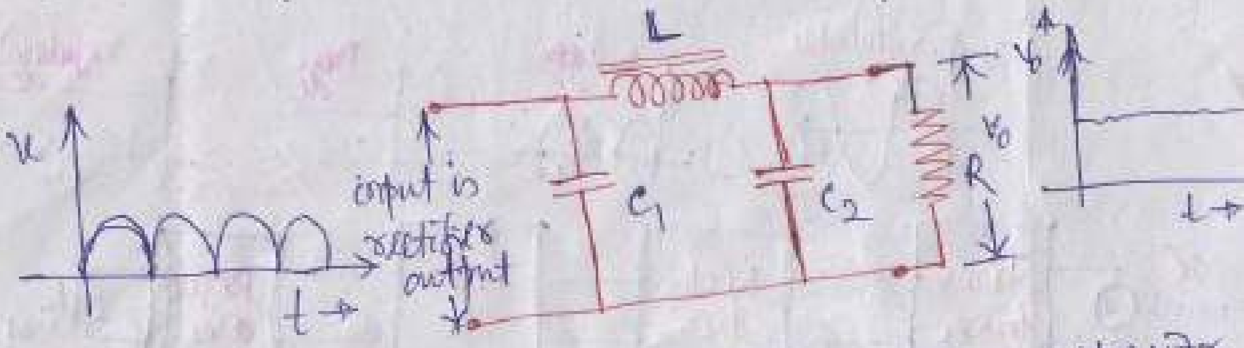

when rectifier output increses it charges the capacitor and at peak value of input the capacitor is fully charged to $V_m$ (point A in the output). Then when input decreases from $V_m$ to 0, the capacitor discharges through R to a value as represented by point B. Again in the next input cycle charging (B to C) and discharging (C to D) of capacitor takes place. This process continues and the output is ABCDEF, which is a waveform containing less ripples.

b) Choke input filter




In the fig. is shown a choke (inductor) input filter which contains an inductor in series with a capacitor filter C and a resistance R. The pulsating output of the rectifier output is applied to the filter ckt. at input terminals 1 & 2. A choke offers very high resistance (opposes) to ac components and passes only dc components to further pass through R & C combination. So the final output is a dc contains very less pulsating components.

c) capacitor input (or π) filter:



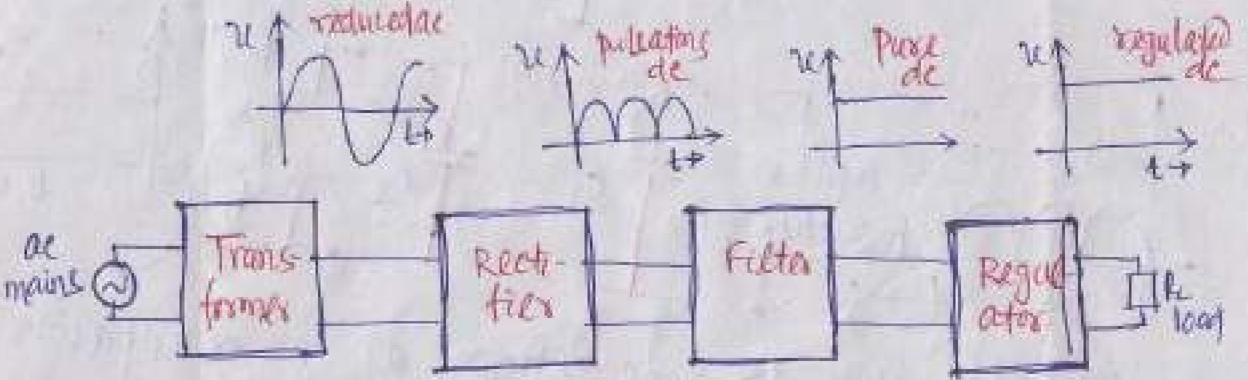

In the fig is shown a π or capacitor input filter which contains two capacitors in parallel path and an inductor (choke) in series path. The operation can be explained as -

a) capacitor $C_1$: It offers low reactance to ac and high reactance to dc: as it is in the parallel path, dc component goes forward to the next component that is inductor and bypasses the ac component.

b) inductor L: It is in series path and offers high reactance to ac component and so opposes it and passes the dc component unopposed through it. So ac components are further filtered out.

c) capacitor $C_2$: It is in parallel path and offers high reactance to dc components (passes it) and low reactance to ac component (opposes). So the remaining amount of ac component is filtered out and almost pure dc goes to the load to produce output.

## 2.4 working of DC power supply (Block diagram)




In the figure is shown the basic block diagram of a regulated dc power supply. If the regulator is there then it is called unregulated power supply.

The regulated dc power supply consists of following blocks —

a) Transformer: Usualy a stepdown transformer is used which reduces the amplitude of the ac mains supply and provides it to the rectifier.

b) rectifier: the rectifier convers ac input to pulsating dc at its output.

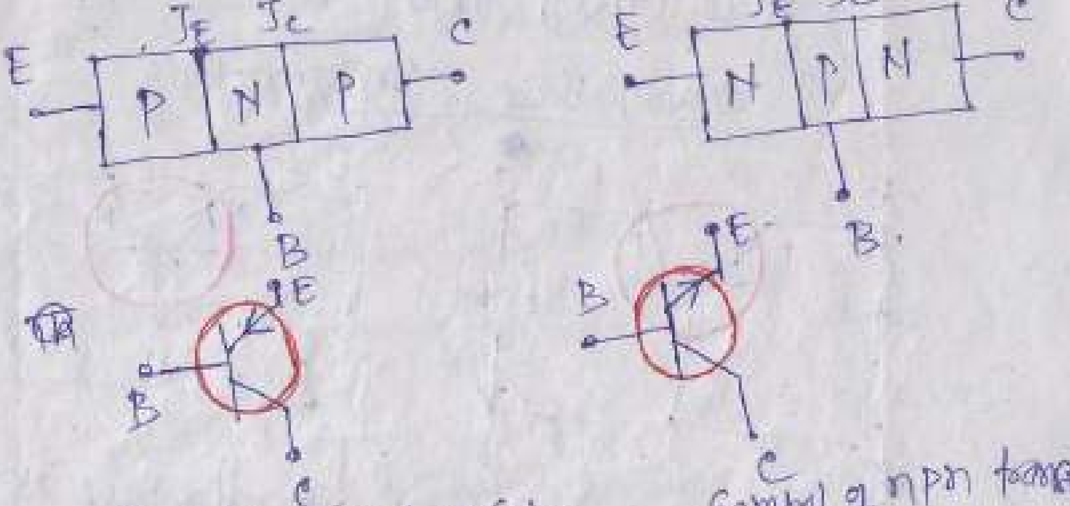
c) Filter: Filter out, filters out the pulsating (ac) components and provides pure dc at its output.

d) Regulator: Regulator is used in only regulated power supply, to regulate the output (load) voltage and current.

## 2·5 (a) Transistor and its types. ⑤



Transistor is a 3 terminal, 2-junction, alternate P-N, semiconductor device. A p or n type semiconductor is sandwitched between a pair of opposite type. Accordingly there are two types of transistors. PNP and NPN as shown below.



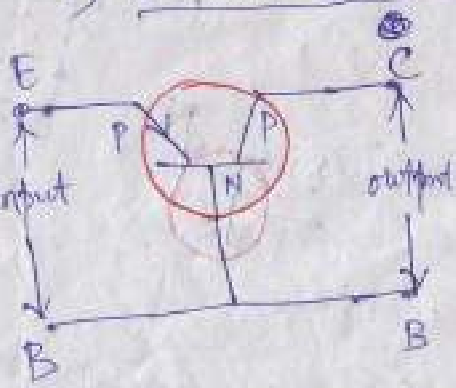

Symbol of PNP transistor     Symbol of npn transistor

- The terminals connected to the extreme ends are one is emitter (E) & other is collector (C)
- The middle one is base(B).
- The emitter is wider than base and heavily doped, the base is the thinest piece and lightly doped and collector is moderately doped and the thickest (most wide).
- The junction between emitter & base is called emitter-base junction or emitter-junction or emitter diode
- The junction between collector & base is called collector base junction, or collector junction or collector diode.

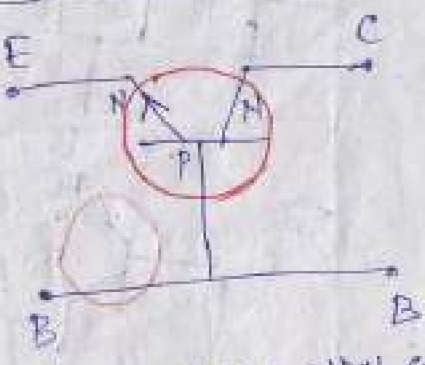
(b) Transistor configurations

Transistor is a 3-terminal device but in its operation it is connected as a two port or four terminal device, by converting any one terminal into two, or in otherwords it can be said as one terminal (B, E or C) is made common to both input and output. Accordingly there are 3 configurations—

i) common base configuration:

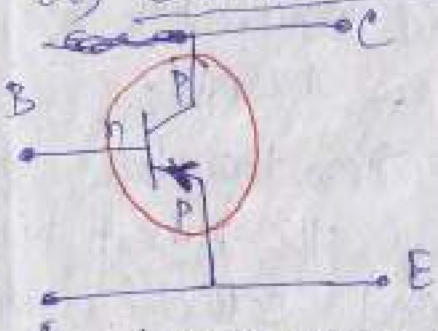



(common base PNP config.)

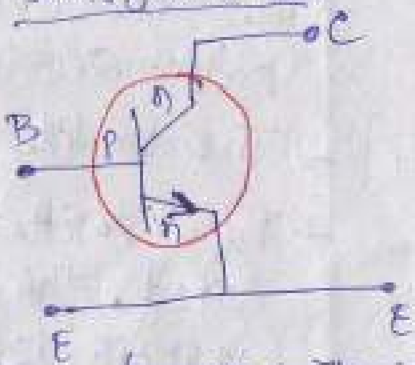



(common base NPN config.)

ii) common emitter configuration:

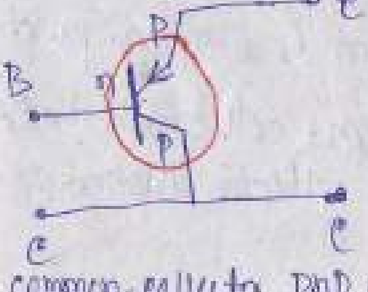



(common emitter PNP config.)




(common emitter npn config.)

iii) common collector configuration:



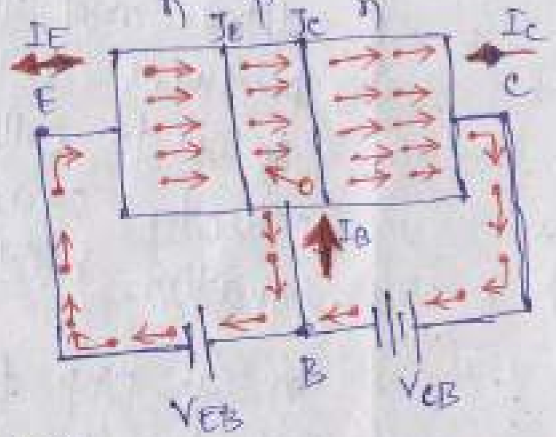

common-collector PNP config.


common collector npn config.

In npn transistor, the current is mainly due to electrons.

## (c) Operation of a transistor (npn type)

In the fig. is shown an npn transistor in common base configuration. Emitter junction is forward biased by $V_{EB}$ and collector junction is reverse biased by $V_{CB}$.

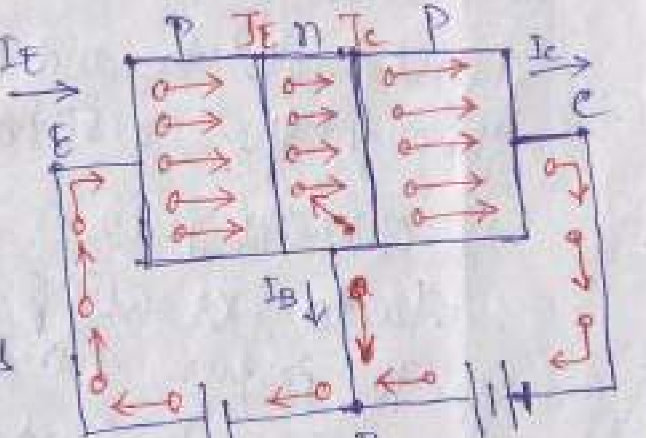



Forward bias pushes electrons towards the junction, this constitute the emitter current $I_E$. As the base region (P type) is thin and lightly doped, only few electrons (about 5%) coming from emitter side combines with the holes in base region and constitute the base current $I_B$. The remaining electrons passes to collector region (n-type) and produces collector current ($I_C$).

So the total emitter current $I_E = I_B + I_C$

## Operation of pnp transistor

Emitter junction is forward biased and collector junction is reverse biased.



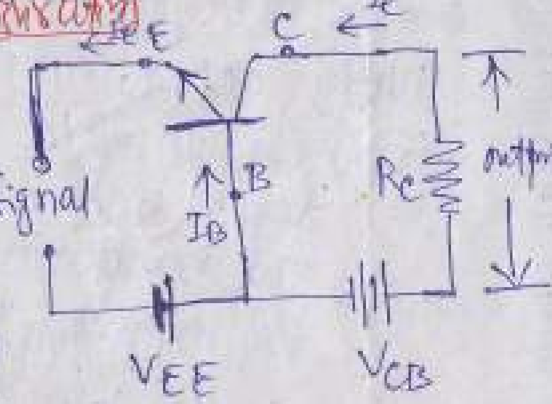

The forward bias, pushes the holes in emitter region (P type) towards base which produces emitter current $I_E$. Few holes (about 5%)

combine with the few electrons present in lightly doped and thin (n type) base region and produces base current ($I_B$). Remaining holes passes to collector region and constitute collector current ($I_C$). Here also the same equation holds good $\boxed{I_E = I_B + I_C}$

In a pnp transistor, the current is mostly due to flow of holes.

## Expression of current gain

### i) common base configuration




In the fig. is shown an npn transistor in CB configuration. The signal to be amplified is applied between emitter and base terminals (input port) and output is taken across collector and base terminals (output port) through the resistance Rc.

Current gain or current amplification factor is always the ratio of output current to input current (in case of dc operation). In CB config., input current is $I_E$ and output current is $I_C$. The signal to be amplified is an ac signal. In this case the current gain or current amplification factor (α) is defined as the ~~cha~~ ratio of change in collector current to change in ~~bas~~ emitter current at constant collector to base voltage ($V_{CB}$). 



$$\alpha = \frac{\Delta I_C}{\Delta I_E}\Big|_{\text{at const } V_{CB}}$$

It can be assumed that total collector current $I_C$ consists of two parts — i) amplified emitter current ($=\alpha I_E$) and leakage current which can be represented as $I_{CBO}$ (that is the collector to base current when emitter is open.

$$\therefore\ I_C = \alpha I_E + I_{CBO} \quad \text{—— (1)}$$

we know $I_E = I_C + I_B$

putting in (1) $I_C = \alpha(I_C + I_B) + I_{CBO}$ —(2)

or, $I_C - \alpha I_C = \alpha I_B + I_{CBO}$

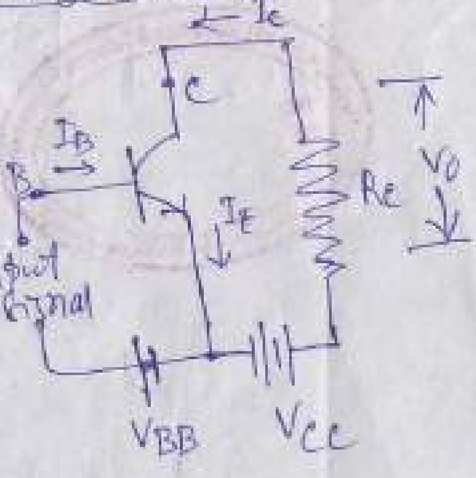
or, $I_C(1-\alpha) = \alpha I_B + I_{CBO}$

or, $$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}.$$

from eqn (2), $I_C - I_{CBO} = \alpha(I_C + I_B)$

or $$\alpha = \frac{I_C - I_{CBO}}{I_C + I_B}.$$

iii) common emitter configuration:




current amplification factor or current gain of CE configuration ($\beta$) is defined as the ratio of change in collector current to change in base current at constant $V_{ce}$.

$$\boxed{\beta = \frac{\Delta I_c}{\Delta I_B}\Big|_{\text{at constant } V_{ce}}}$$

relation ship between $\alpha$ & $\beta$

$$\alpha = \frac{\Delta I_c}{\Delta I_E} \quad \text{and} \quad \beta = \frac{\Delta I_c}{\Delta I_B}$$

for a transistor $I_E = I_B + I_c$

or, $\Delta I_E = \Delta I_B + \Delta I_c$

or, $\Delta I_B = \Delta I_E - \Delta I_c$

putting in the eqn for $\beta$, $\beta = \dfrac{\Delta I_c}{\Delta I_E - \Delta I_c}$

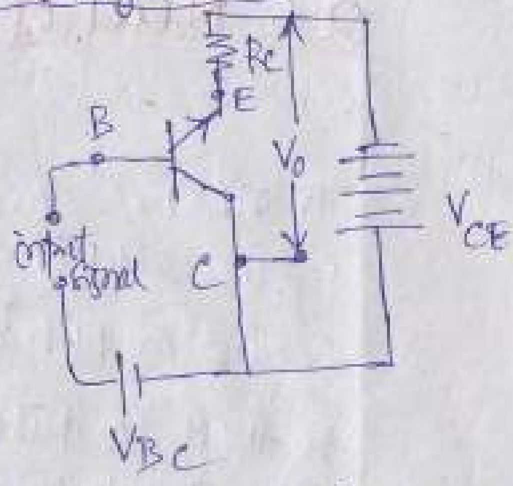
dividing $N^r$ & $D^r$ by $\Delta I_E$, $\beta = \dfrac{\Delta I_c / \Delta I_E}{1 - \frac{\Delta I_c}{\Delta I_E}} = \dfrac{\alpha}{1-\alpha}$

$$\therefore \boxed{\beta = \frac{\alpha}{1-\alpha}}$$

Similarly $\beta(1-\alpha) = \alpha$ or, $\beta = \alpha + \alpha\beta = \alpha(1+\beta)$

or $\boxed{\alpha = \dfrac{\beta}{1+\beta}}$

iii) <u>common collector configuration</u>




current amplification factor or current gain of a transistor in common collector configuration ($\gamma$) is given as the ratio of change in emitter current to that in base current.

$$\boxed{\gamma = \frac{\Delta I_E}{\Delta I_B}\Big|_{\text{const } V_{CE}}}$$

<u>relationship with $\alpha$</u>

now $\alpha = \frac{\Delta I_C}{\Delta I_E}$, $\gamma = \frac{\Delta I_E}{\Delta I_B}$

we know, $I_E = I_B + I_C$ or, $\Delta I_E = \Delta I_B + \Delta I_C$

or, $\Delta I_B = \Delta I_E - \Delta I_C$

now $\gamma = \frac{\Delta I_E}{\Delta I_B} = \frac{\Delta I_E}{\Delta I_E - \Delta I_C}$

dividing $N^r$ & $D^r$ by $\Delta I_C$ —

$$\gamma = \frac{\Delta I_E / \Delta I_C}{\frac{\Delta I_E}{\Delta I_C} - 1} = \frac{1/\alpha}{1/\alpha - 1} = \frac{1}{1-\alpha}$$

$\therefore$ [illegible]

$$\boxed{\gamma = \frac{1}{1-\alpha}}$$

[illegible] or, $\alpha(\gamma - 1) = \gamma$ [illegible]

or, $\boxed{\alpha = \frac{\gamma}{\gamma - 1}}$

So we have $\boxed{\alpha = \frac{\beta}{\beta+1} = \frac{\gamma-1}{\gamma}}$

# 2.6 Need of Biasing and different types of biasing

Transistors are used for two purposes -
1. for switching (as an - ON-OFF switch)
2. for amplification (enhancing strength of weak signal)

Faithful amplification is the process of raising the strength of a weak signal without any change in its general shape.

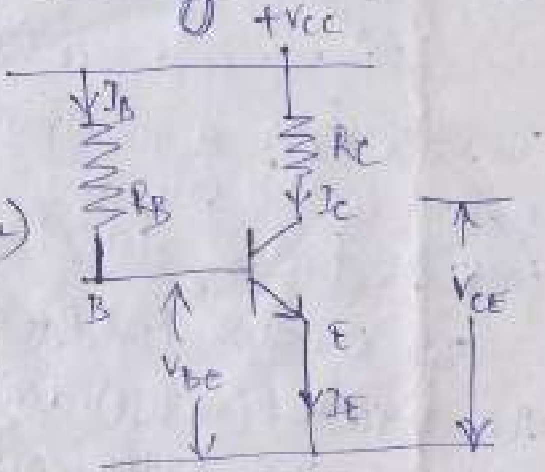
For faithfull amplification, the transistor must full fill the 3 basic conditions -
1. Flow of proper zero signal collector current
2. maintaining minimum proper base emitter voltage ($V_{BE}$) at any instant [$V_{BE} \geq$ 0.3V for Ge, 0.7V for Si]
3. maintaining minimum proper collector-emitter voltage ($V_{CE}$) at any instant [$V_{CE} \geq$ 0.5V for Ge, 1V for Si]

Above 3 conditions are fullfilled when the transistor is operated in the active region of operation (of its output characteristics) i.e, base-emitter junction is forward biased and base collector junction is reverse biased.

Transistor biasing: Transistor biasing is the method by which we can ensure flow of proper zero signal collector current and maintain proper base-emitter voltage and collector-emitter voltage at any instant.

Types of Biasing 1) Base resistor method 2) Emitter bias method 3) Biasing with collector-feed back resistor 4) voltage divider bias

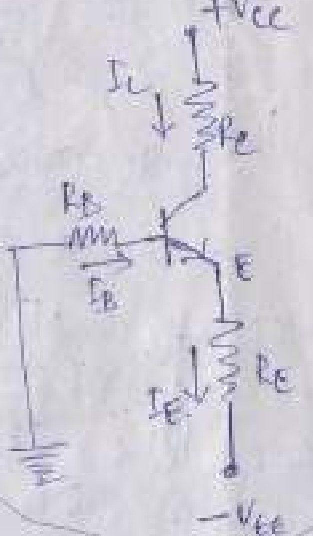
## i) Base resistor method of biasing




In this method of biasing a very high resistance (several hundred kΩ) is connected between the base and +ve terminal of supply for npn transistor (base & -ve terminal of supply for PNP transistor).

The required zero signal base current $I_B$ flows through $R_B$ by the supply $V_{CC}$. The value of $I_B$ (and hence $I_C = \beta I_B$) can be varied by varying the values of $R_B$.

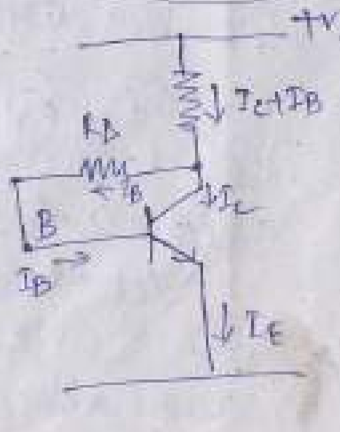
## ii) Emitter bias method




In emitter bias method two voltage supplies are used. (usually both are equal & opposite) along with an emitter resistance $R_E$.

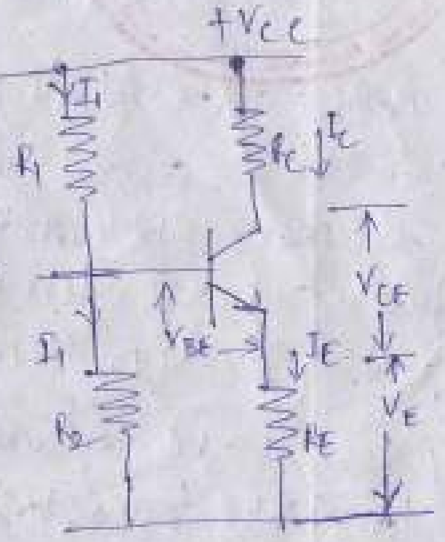
This bias provides better performance of amplification.

## iii) collector feedback bias




In this method the base resistor $R_B$ is connected to collector to provide a feedback circuit there the zero signal base current $I_B$ (and hence $I_C = \beta \cdot I_B$) is not controlled by Vcc but controlled by $V_{CB}$.

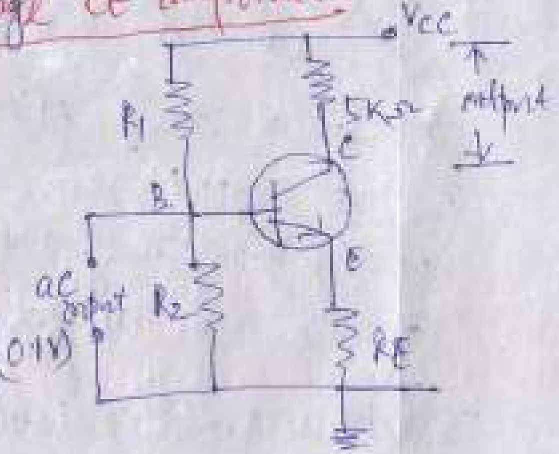
iv) voltage divider bias:




This is the most widely used method of biasing which provides proper stabilization.

Two resistors $R_1$ & $R_2$ provide the potential (voltage) divider network. The voltage drop across $R_2$ $\left(= V_{CC} \cdot \frac{R_2}{R_1+R_2}\right)$ forward biases the base emitter junction and zero signal base current (so $I_C = \beta I_B$) flows in the transistor.

## 2.7. Amplifiers (concept), working principle of single stage CE amplifier.




Basic concept:

To analyze the basic concept of amplification by a transistor, let consider the CE, npn transistor with potential divider bias as shown in fig.

The signal to be amplified is applied at the base terminal, and the output is taken from the collector (output) terminal.

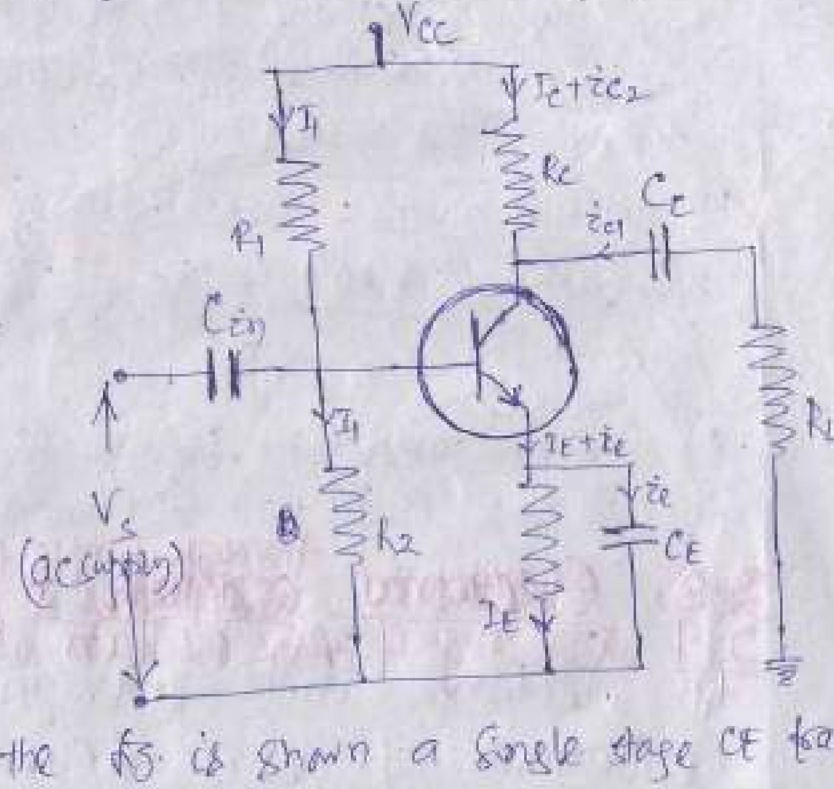
Let the input signal is weak and can produce only a voltage change of about 0.1V. Let this small voltage change produces a small base current which is then amplified by the transistor ($\beta$ times) and produces a larger collector current ($I_C = \beta I_B$). This current passing through the high collector resistance (nearly 1 to 10 kΩ) produces a large output voltage.

For ex: Let the 0.1 V change in base ckt, produces a current change of 2mA in collector ckt ($I_C$) and let $R_C = 5\,k\Omega$, then output voltage $V_0 = 2mA \times 5k\Omega$
$= 10\,V$.

input voltage was $= 0.1\,V$.

$\therefore$ voltage amplification factor or voltage gain $= \frac{10}{0.1} = 100$

## Single Stage Common Emitter Amplifier:




In the fig. is shown a single stage CE transistor amplifier. Different components and circuitry can be described as follows.

i) Biasing circuit: The resistances $R_1$, $R_2$ & $R_E$ from the biasing and stabilization circuit. By proper biasing the operating point is made proper and stable.

ii) Input capacitor Cin: Input capacitor $C_{in}$

couples the input ac signal to the base of transistor. It only allows ac signal to flow into the transistor & blocks any dc signal.

iii) Emitter bypass capacitor $C_E$: Emitter bypass capacitor $C_E$ allows the amplified ac signal to by pass the emitter resistance $R_E$.

ix) output coupling capacitor $C_C$: It couples the amplified output to next stage or to the load.

Various current components in the circuit can be designated as follows —

a) Base current: without applying ac signal, the base current (dc) due to biasing is $I_B$ and that due to ac signal it is $i_b$. Therefore total base current $\boxed{i_B = I_B + i_b}$

b) collector current: dc part is $I_C$ and ac part (applying signal) is $i_c$, so total collector current $\boxed{i_C = I_C + i_c}$

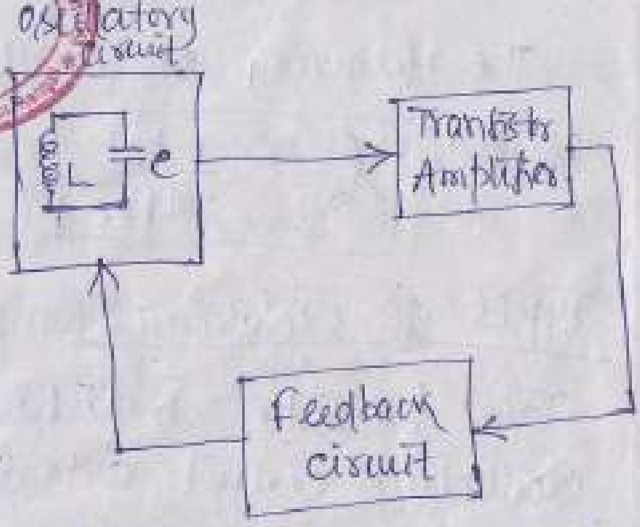
c) Emitter current: $I_E$ is dc current and $i_e$ is ac current and total current $\boxed{i_E = I_E + i_e}$

~~Q-4, Electronic oscillators & its classification~~

2.9 working of Basic oscillator with diff elements through simple block diagram

An electronic device that generates sinusoidal oscillations of desired frequency is called sinusoidal oscillator.

An oscillator contains 3 basic components, one is the oscillatory circuit or tank circuit, 2nd unit is a transistor amplifier and 3rd unit is a feed back circuit. The interconnection as shown in the figure as can produce Sinusoidal oscillations




working principle of the oscillator

The tank circuit consists of a capacitor and an inductor in parallel with each other. The capacitor is initially charged. when the connection is made it starts discharging, so the inductor starts charging. The electrical energy stored in the capacitor converts to magnetic energy in the inductor. when the capacitor is fully discharged, the inductor becomes fully charged. Now inductor discharges and capacitor starts charging but this time in opposite direction.

This process of charging and discharging between L & C (conversion of energy from electrical to magnetic and vice-versa) continues. If there will be no losses in L or C, then this oscillation will continue indefinitely. This oscillation signal is amplified by the transistor amplifier. To compensate any loss in L or C or in the process of energy conversion, a part of the output is truly feedback to the input (tank circuit) by the feedback circuit.

The frequency of oscillation is given as-

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

Types of electronic (transistor) oscillators -

The transistor amplifier along with the oscillatory circuit and feedback network can produce continuous undamped oscillations of any desired frequency.

Different types of oscillators differs from each other in the way of feedback employed to compensate the losses in the oscillatory circuit. Different oscillators are-
1. Tuned collector oscillator 2. Hartley oscillator
3. Wien bridge oscillator 4. phase shift oscillator.
5. Colpitt's oscillator 6. Crystal oscillator.

## 2.8 Electronic oscillation and its classification

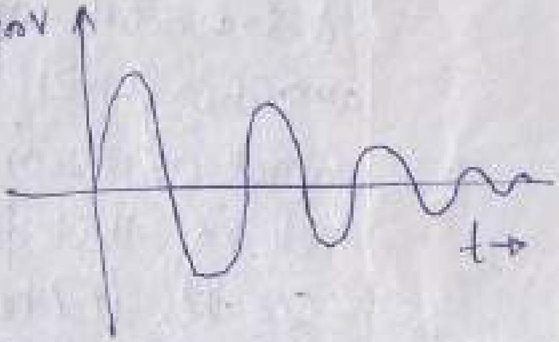
- An electronic device that generates sinusoidal oscillations of desired frequency is known as sinusoidal oscillator.

An oscillator actualy does not generate frequency or energy, it only acts as an energy converter. It takes dc energy in and converts it into ac energy (signals) of desired frequency.

Types of Sinusoidal oscillations

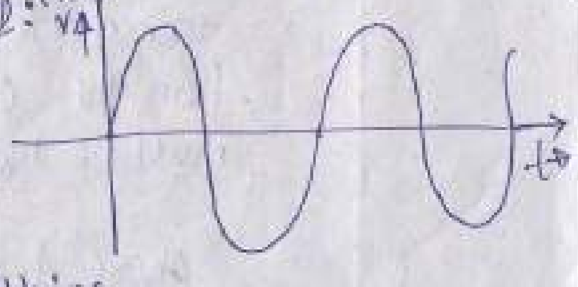
Sinusoidal oscillations are of two types —
a) Damped oscillation b) Undamped oscillations

Damped oscillation:



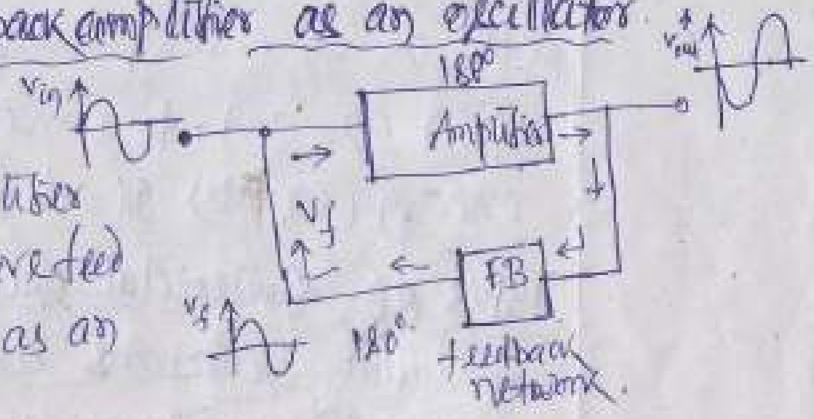

The oscillation in which the amplitude of the signal decreases from cycle to cycle, is called damped oscillation. It is due to the fact that in every cycle of operation, some amount of energy is lost. This loss goes on increasing cumulatively from cycle to cycle, so the amplitude goes on decreasing

Undamped oscillation:




If the amount of energy lost during the cycle can be compensated by supplying it externally, then the amplitude of signal will remain constant in every cycle, this type of oscillation is called undamped oscillation.

# A +ve feedback amplifier as an oscillator




A transistor amplifier with proper positive feed back can act as an oscillator.

A sinusoidal input signal is amplified by the amplifier which produces 180° phase shift. This signal is again passed through a feedback network that produces another 180° phase shift so the feedback signal is in phase with the input signal. Now the input signal is taken out and the feedback signal is amplified. The above facts can be summerised as—

1. A transistor amplifier with proper positive feedback will work as an oscillator.
2. The circuit needs only a quick trigger to start the oscillation. once oscillation started, no external signal source is needed.
3. In order to get continuous undamped output from the circuit, the following condition must be met — $\boxed{m_v \cdot A_v = 1}$

where $A_v$ = voltage gain of amplifier without feedback

$m_v$ = feedback fraction.

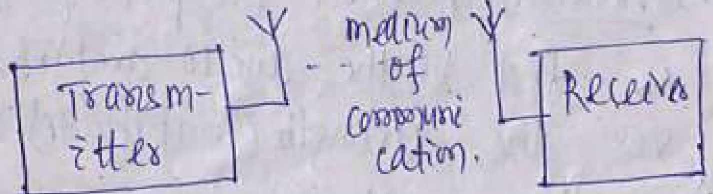
This relation is called Barkhausen criterion.

— x —

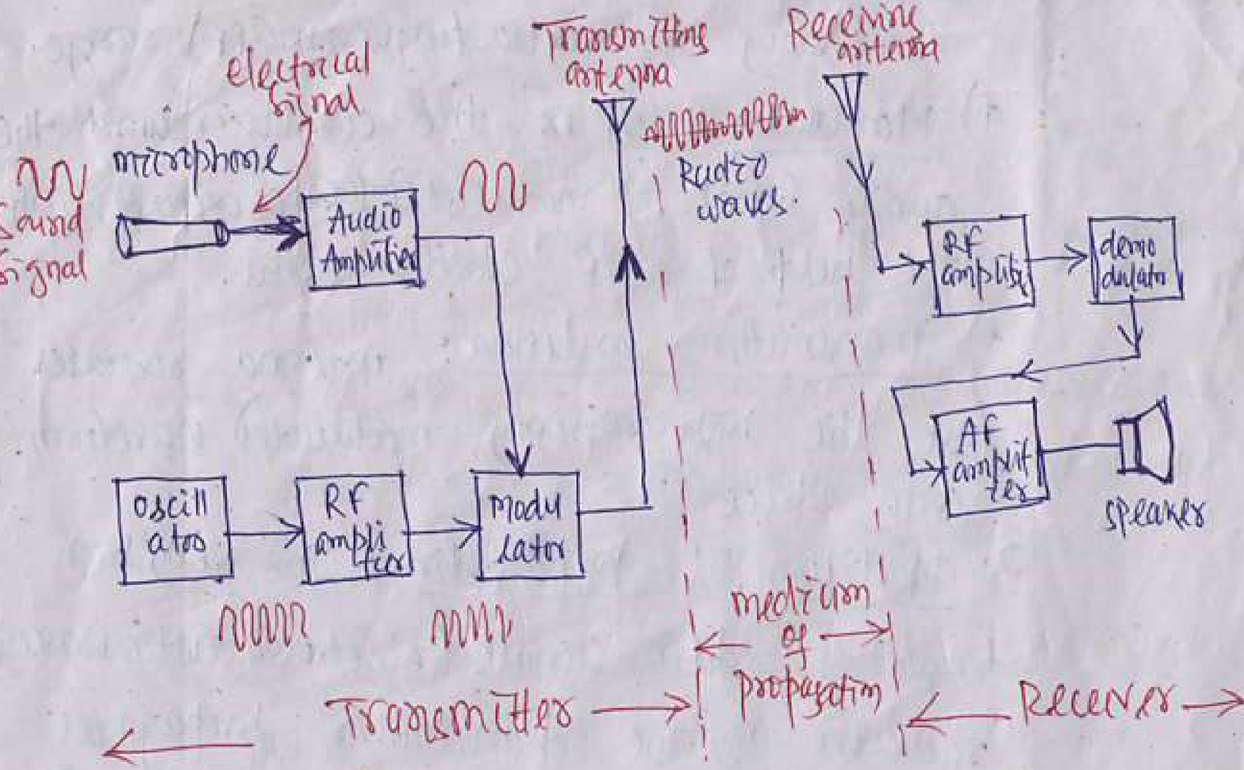
# Ch:3 Communication System

## 3.1 Basic communication system:

Communication is the process of connecting or transporting information from the transmitter (sender) to the receiver (may be at a distant place), through a medium. The entire system consists of 3 parts.




The above block diagram can be extended as-



① Transmitter converts the audio signal into electrical signal, modulates it with high frequency RF carrier and transmits to air (space) which is the medium. Different components in transmitter are-

a) Microphone: microphone converts sound signal to electrical signal. There is a very thin film called diaphragm which vibrates with the air pressure exerted on it and produces electrical signal in audio range (20 Hz to 20 KHz)

b) Audio amplifier: output of the microphone is fed to the audio amplifier which improves the strength (amplitude) of the audio signal

c) Oscillator: It is a circuit which produces high frequency signal called carrier signal having frequency in radio frequency (RF) range.

d) Modulator: It is the circuit in which the audio signal is modulated (superimposed) with the help of RF carrier signal.

e) Transmitting antenna: Antenna radiates out the high frequency modulated waveform onto space.

2. Medium of propagation: The very high frequency radio signals (electromagnetic waves) radiated by the transmitter propagates (moves) in all directions in space (air medium) with the velocity of light ($3\times10^8$ m/

3. <u>Receiver</u>: It is the part of communication system in which the received RF signal is again converted to low frequency audio signal and converted to sound signal by a loudspeaker.

a) <u>Receiving antenna</u>: It is an antenna (called ariel) which receives the high frequency (RF) electromagnetic waves from space and provides it to RF amplifier.

b) <u>RF amplifier</u>: The received EM signals are amplified by RF amplifier, to increase its strength (amplitude)

c) <u>Demodulator or detector</u>: Demodulator does the reverse operation of a modulator. i.e, the audio signal is separated from the RF signal.

d) <u>Audio amplifier</u>: Audio amplifier (sometimes multistages) amplifies the weak audio signal to increase its strength.

e) <u>Loudspeaker</u>: It does the reverse operation of a microphone, i.e, converts the electrical signals into sound signals.

## 3.2: <u>Concept of modullation & Demodulation</u>

Modulation is the process of varying some characteristics (i.e, amplitude, frequency or phase) of a carrier wave with the help of modulating signal (information signal)

If we want to transmit a sound (audio) signal or picture (video) signal, then it is the modulating signal. It will modulate the amplitude, frequency or phase of a carrier signal.

modulation is done by a modulator at the transmitter end of the communication system.

Demodulation is a process in which the modulating signal is recovered from the modulated signal (transmitted through the transmitting antenna) with the help of the same carrier signal. (used during modulation) Demodulation is done by a demodulator or detector in the receiver end of a communication system.

difference between modulation and demodulation

| Modulation | Demodulation |
|---|---|
| ① It is the process of changing some characteristics like amplitude, phase or frequency of a carrier signal by the modulating signal. | ① It is the process of recovering the modulating signal from the modulated signal, with the help of the carrier signal. |
| ② Depending upon the characteristic, which is modulated, the name of the modulation process is given like amplitude modulation, phase or frequency modulated. | ② The modulating signal is recovered from the amplitude, frequency or phase modulated signal. |
| ③ Modulation is superimposing (mixing) of modulating | ③ Demodulation is decomposing the modulated signal into modulating and carrier signals. |

signal and carrier signal to produce modulated signal. (2)



④ Modulation is done in the transmitter part of the communication system.

④ Demodulation is done in the receiver part of the communication system.

⑤ modulating signal + carrier signal ⟹ modulated signal.

⑤ modulated signal ⟹ modulating signal + carrier signal.

## 3.3. Different types of modulation

A carrier signal can be represented as -

$$x_c(t) = V_c \sin(\omega_c t + \phi_c)$$

where $x_c(t)$ is ⟹ instantaneous value of the carrier signal at any time instant 't'

$V_c$ ⟹ peak or amplitude of the signal.

$\omega_c$ ⟹ angular frequency of the signal
$\omega_c = 2\pi f_c$, where $f_c$ is the linear frequency.

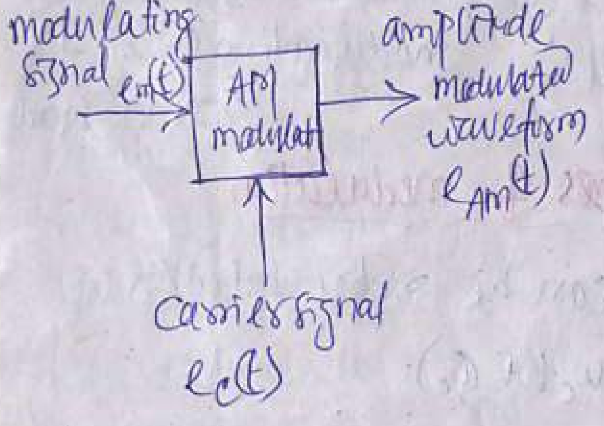
$\phi_c$ ⟹ phase of carrier signal.

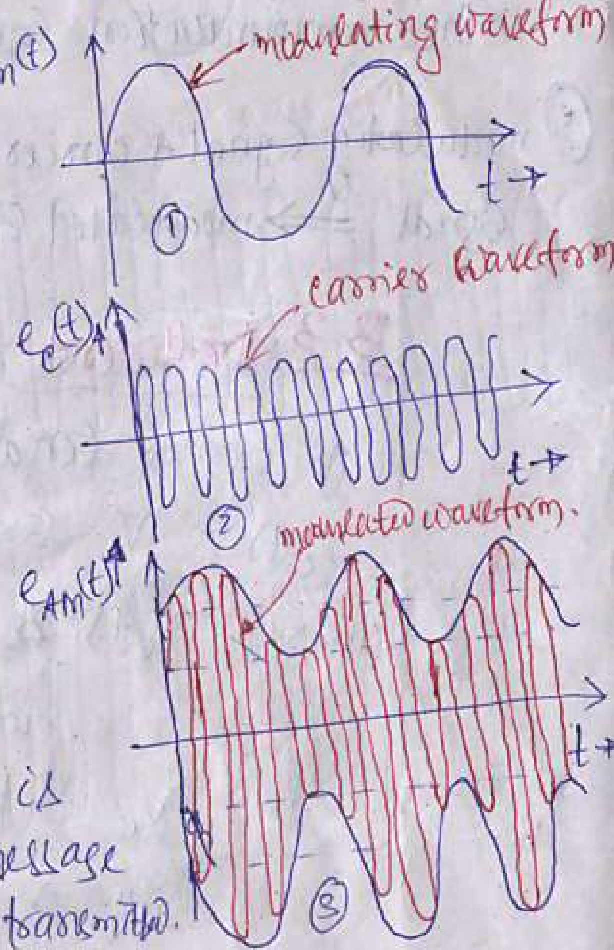
$$\omega_c = \frac{d}{dt}(\phi_c)$$

we can change (modulate) the amplitude or frequency or phase of the carrier signal and accordingly the modulation will be amplitude, frequency or phase modulation respectively.

## 3.3(a) amplitude modulation

The process by which amplitude of a carrier signal is varied in accordance with the modulating signal is called amplitude modulation.




- In the figs are shown 3-waveforms.
- The modulating signal is $e_m(t)$ which is the message signal required to be transmitted.
- A high frequency carrier ~~es~~ $e_c(t)$ is utilised for such modulation i.e, amplitude of the carrier signal is varied according to the modulating signal, resulting the amplitude modulated waveform $e_{AM}(t)$.
- only amplitude of the carrier signal varies keeping frequency and phase constant (unchanged).
- In amplitude modulation, amplitude of the

and $e_{Am}(t) = E_c \sin w_c t + \frac{m \cdot E_c}{2} \sin(w_c - w_m)t + \frac{m \cdot E_c}{2} \sin(w_c + w_m)t$ is the amplitude modulated waveform.

carrier signal varies according to the modulating signal in both halfes (+ve & -ve) so that the amplitude modulated waveform is an envelope (as shown in fig ③)

**modulation index or modulation factor**

Modulation index or modulation factor is defined as the ratio of change in amplitude of the carrier to the amplitude of the carrier

$$m = \frac{\text{change in amplitude of carrier signal}}{\text{amplitude of carrier signal}}$$

or $\boxed{m = \frac{E_m}{E_c}}$ where $e_m(t) = E_m \sin w_m t$ is the modulating signal and $e_c(t) = E_c \sin w_c t$ is the carrier signal.

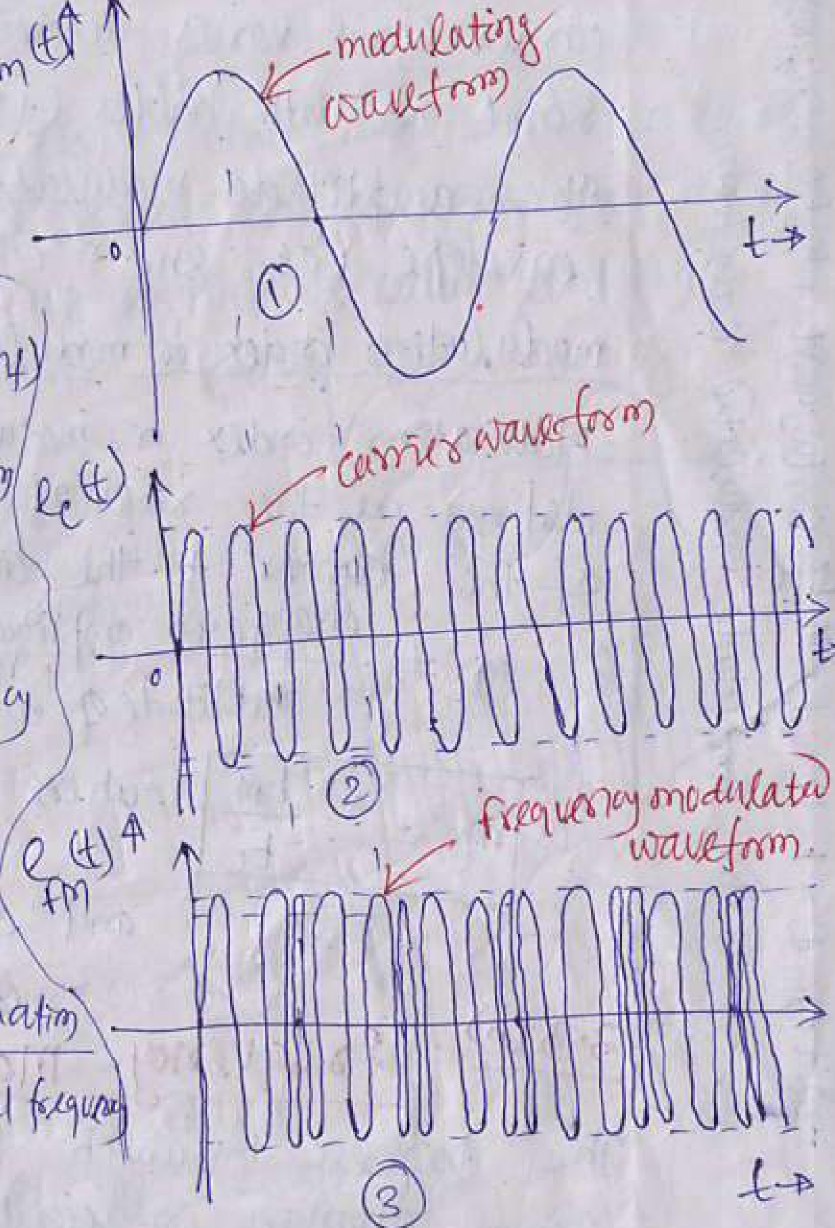
## 3.3 (b) Frequency Modulation

The process by which frequency of the carrier signal changes in accordance with the modulating signal (keeping its amplitude & phase unchanged) is called frequency modulation.

In frequency modulation, the frequency ($f_c$) of the carrier signal $e_c(t) = E_c \sin w_c t$ changes according to the modulating signal $e_m(t) = E_m \sin w_m t$ producing the frequency modulated waveform $e_{fm}(t)$ given by $e_{fm}(t) = E_c \sin\left(w_c + \frac{\delta}{f_m} \sin w_m t\right)t$

where $\delta$ = maximum frequency deviation and $\delta = K E_m f_c$

where $K \Rightarrow$ proportionality constant




__frequency modulation index ($m_f$)__

frequency modulation index is defined as the ratio of maximum frequency deviation to the frequency of the modulating signal.

$$m_f = \frac{\text{max. freq. deviation}}{\text{modulating signal frequency}}$$

or $\boxed{m_f = \frac{\delta}{f_m}}$

As seen from fig ③, the frequency of the frequency modulated waveform varies according to the modulating signal (i.e, where the amplitude of the modulating signal is more, frequency at that point is more in the modulated signal).

__Advantages and Disadvantages of Frequency modulation__

## Advantages:

i) High transmission efficiency
ii) Noiseless reception.
iii) Better audio quality.

## Disadvantages:

i) wider channel is required.
ii) Equipements used are complex and costly.
iii) smaller area of reception (only upto line of sight)

## 3.3(C) Phase Modulation

The process by which phase of the carrier signal is varied in accordance with the modulating signal (keeping its amplitude and frequency unchanged) is called phase modulation.

In phase modulation, the phase deviation is proportional to the amplitude of the modulating signal (Em) but is independent of its frequency (fm). In this case the phasor of the modulated wave leads the reference position during +ve half cycle of the modulating signal and lags the reference position during the -ve half cycle of the modulating signal.

PM can be obtained from FM and vice-versa.

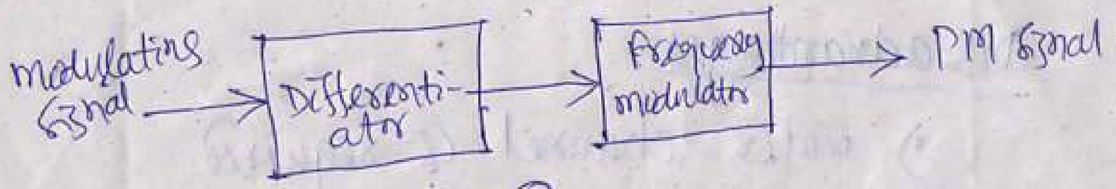



fig (a)

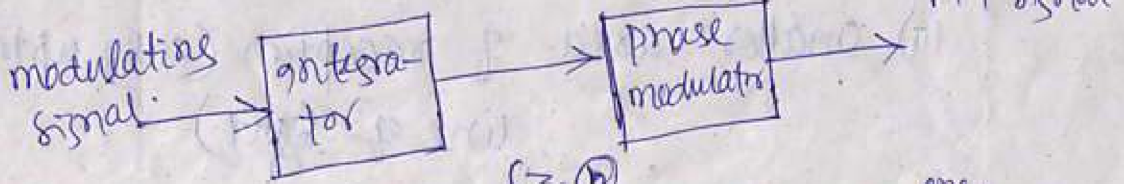



fig (b)

we know, $\omega = \frac{d\theta}{dt}$ where $\omega \rightarrow$ ang. freq.
$\theta \rightarrow$ phase.

- derivative of phase is frequency and integration of frequency is phase.
- therefore if a modulating signal is first differentiated and then applied to a frequency modulator, then phase modulated signal (PM) will be obtained [fig (a)].
- similarly, if the modulating signal is first integrated and then applied to a phase modulator, then frequency modulated (FM) signal will be obtained [fig (b)]

— x —

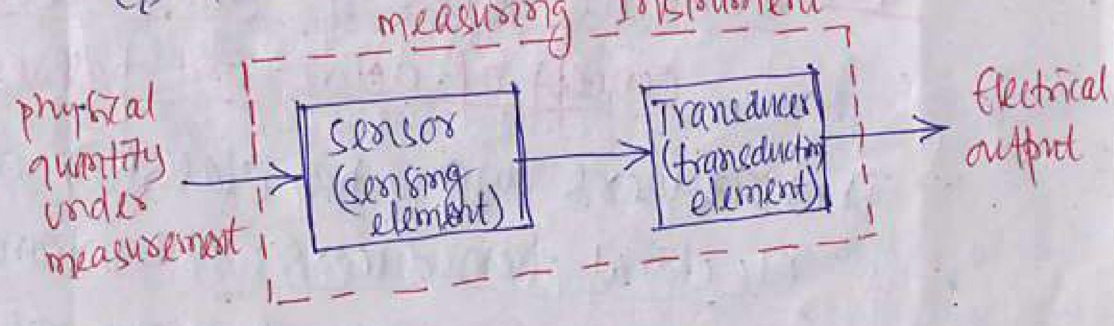
# Ch-4: Transducers and measuring instruments

## 4.1 Concept of Transducer and sensor with their differences

Transducer is a device which converts energy from one form to other. The energy may be of any form like electrical, mechanical, chemical, thermal, solar, tidal, muscular etc --

Sensor is a device, which can sense the presence of any form of energy or its effect which is in a sensible (measurable) form. Sensors are also called detectors.

All measuring instrument (device) consists of two basic elements, the first one is the sensor or detector and second is the transducer.



## Difference between sensor and transducer.

| sensor | transducer |
|---|---|
| 1. Sensor is a device which detects the presence of the measurable quantity. | 1. Transducer is a device which converts energy from one form to another |
| 2. It is the primary or first element of a measuring instrument. | 2. It takes the output of the sensor and converts to suitable form for measurement. |
| 3. Sensor, for its performance may not depend upon a transducer. | 3. A transducer always depends upon a sensor before measuring the quantity. |
| 4. | 4. |

## A.2 Different types of transducers and concept of active and passive transducers

Transducers may be classified as —

1. Electrical transducers: The transducer which produces electrical energy at its output is an electrical transducer. The output may be in the form of voltage, current

or frequency etc.

2. Displacement transducers: These transducers convert mechanical displacement into electrical energy.

3. opto electronic transducers: These transducers converts optical (light) energy into electrical energy.

concept of active & passive transducers.

Electrical transducers are the important and most popular transducers which converts non electrical quantities like force pressure, etc into electrical energy form.

various classifications of electrical transducers

(i) Active and passive transducers.

Active transducers developes their own voltage or current as the output. for this they obtain energy from the physical quantity to be measured.

Ex: thermocouples, piezoelectric transducers, photo voltaic cell etc.

passive transducers donot develope output of their own and need an external power source for the purpose.

Ex: strain gauges, thermistor, LVDT etc.

ii) primary and secondary transducers.

primary transducers converts physical quantity under measurement directly into electrical output after sensing the quantity.

Ex: thermocouple.

secondary transducers, in which physical quantity is sensed and is converted first into an analogous output, which is further converted into an electrical quantity.

Ex: LVDT used with Bourdon tubes to measure pressure.

(iii) Analog and Digital transducer

In Analog transducer the output is displayed in analog form.

Ex: strain gauge & LVDT.

In digital transducer the output is displayed in digital form.

Ex: digital multimeter, digital CRO

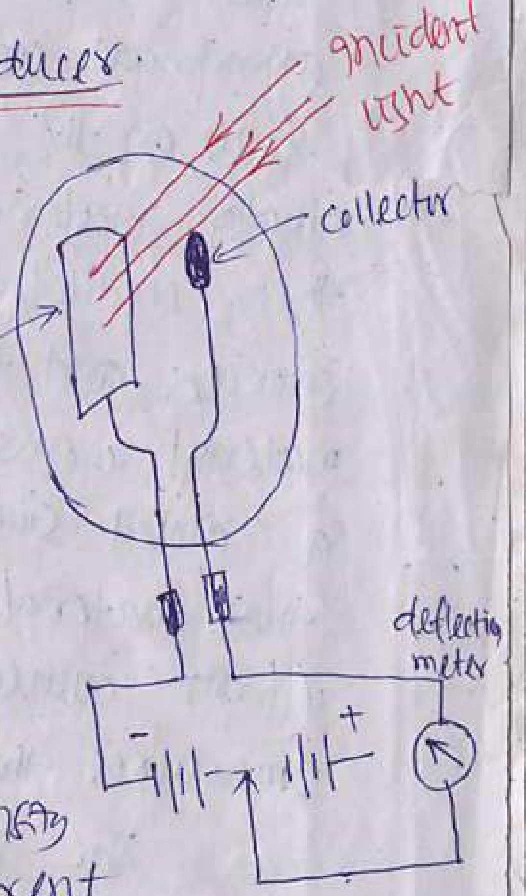
## 4.3 working principle of photoemissive, photo conductive & photo voltaic transducers.

The photoelectric transducer absorbs the radiation of light which falls on their semiconductor material. The absorption of light energizes the electrons of the material and hence the electrons start moving. The mobility of the electrons produces one of the 3 effects— (2)

1. The resistance of the material changes.
2. The output current of the semiconductor changes.
3. The output voltage of the semiconductor changes.

photoelectric transducers are of 3 types—

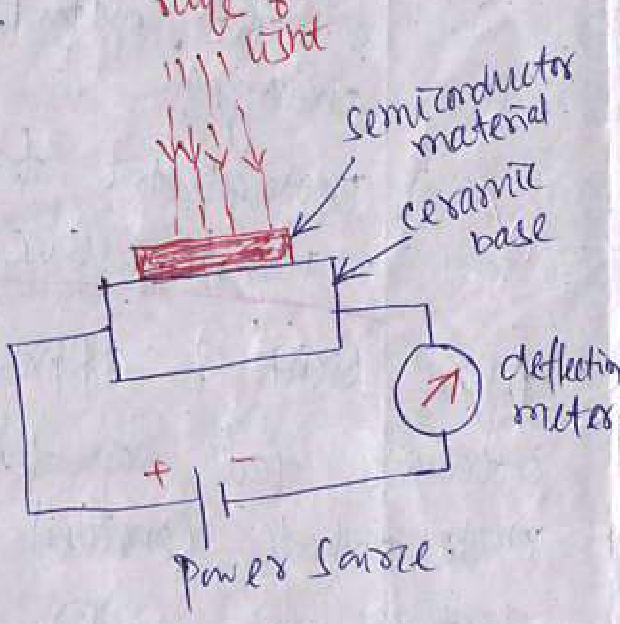
1. photoemissive transducer.




when light of appropriate intensity falls on the photo cathode (emitter) electrons are emitted.
These electrons are collected by a highly +ve anode.
cathode is made -ve.
No. of electrons liberated is proportional to the intensity of light and produces current in the external circuit which can be measured by a meter.
Thus the measured current is a direct measure of the intensity of light.

## photo conductive (cell) transducer

In a photo conductive cell, the conductivity (or resistivity) property of the semiconductor material is utilised. The semiconductor material like cadmium selenide, Ge, Se are used as photo sensing element.

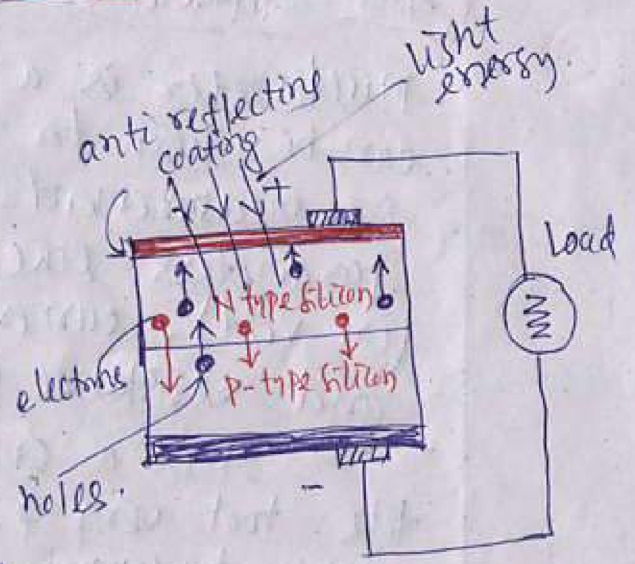



when light of appropriate intensity falls on the semiconductor material, their conductivity increases and the material works like a closed switch. current starts flowing through the material which turns to be a conductor (from insulator) and the deflection meter measures the current.

The current is directly proportional to the increase in (change) conductivity or decrease in resistivity which is directly proportional to the intensity of light.

## photovoltaic transducer

It is a type of active transducer in which a junction is made between a P-type and an N-type silicon material. Anti reflecting coatings are made over them and terminals are taken out. A suitable load is connected.




when light of appropriate wavelength (intensity) falls on the semiconductor material (both P & N types), they absorb light energy and converts it into heat energy. So holes from P type & electrons from N-type cross over the junction and conductivity increases in the form of current in the external circuit with an appropriate load connected across the terminals. the entire arrangement can be utilised as a voltage source and so called a photovoltaic cell.

## 4.4. Multimeter and its application.

Multimeter is a measuring instrument which can be used for multipurpose measurements i.e, measurement of a number of electrical parameters like voltage, both ac & dc (in volt), current AC or dc (in ampere) and resistance (in ohm)

It is a small, handy and very versatile tool very much close to all maintenance personnel.

It can measure in units like Ampere (current), volt (voltage) and Ohm (resistance) therefore it is also called AVO meter.

It is available in analog or digital from. due to better accuracy and less error in reading and measurement now a days, digital multimeters are frequently used.

A multimeter (both analog and digital) has two selector switches on its front (face) pannel.

1. Function selector ~~switch~~: This switch selects the function to be measured (like ac or dc voltage, ac or dc current and resistance).

2. Range selector: After a function is being selected by the function selector, the maximum range is selected (by guess) by the range selector. If the measuring quantity is above the range, then it will show overload, so that next higher range is to be selected

## Applications of multimeter.

1. As it can measure a number of electrical parameters (both in ac & dc circuits), it is used in almost all measuring purposes.
2. In trouble shooting of electronic appliances it plays a vital role.
3. In callibrating units, multimeters are used for callibration.
4. In electrical network analyzers or in electronic circuit analyzers, multimeters are used.
5. In maintenance and repair workshops/ workflows multimeters are used.

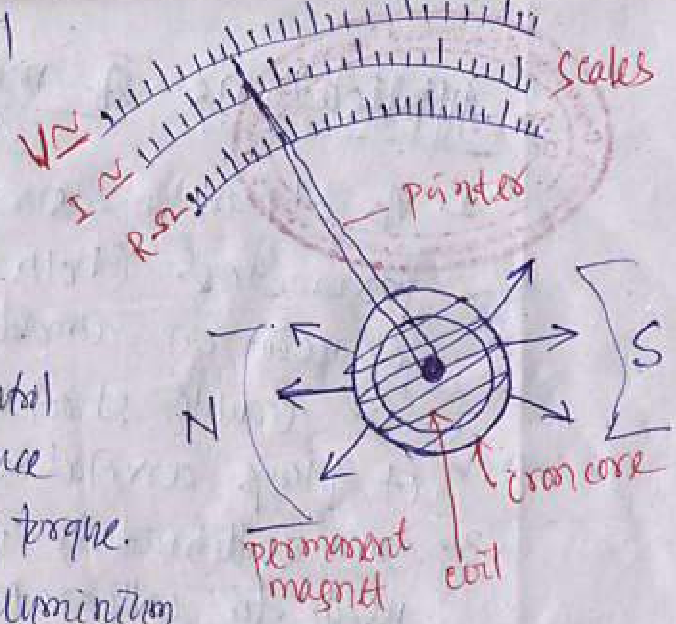
## 4.5 Analog & Digital Multimeters.

Multimeters are available in two forms
1. Analog multimeter 2. Digital multimeter.
The 3 basic parameters like current, voltage and resistance, which are measured by the multimeter, are actually measured by measuring the voltage only, which is then converted to current or resistance as the relationship in Ohm's law $\boxed{V = I.R}$.

Construction of AMM

– A multimeter is basically a permanent magnet moving coil D'Arsonval meter.

– It has a coil wound on an aluminium former which can freely move in the field of a magnet.

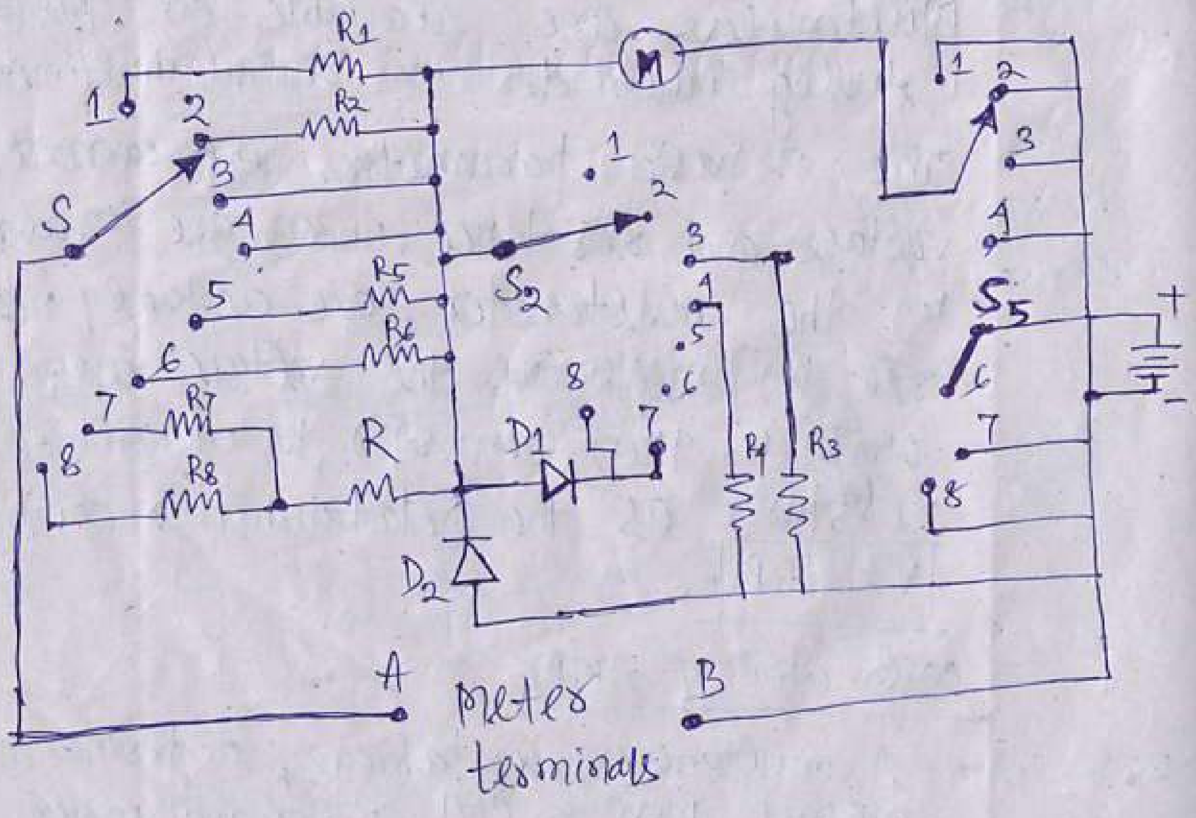



– There are two control springs which produce controlling/restoring torque.

– With the coil an aluminium pointer is attached which moves on calibrated scale.

– The coil is mounted on a fixed iron core, which makes the magnetic field of the permanent magnet as radial within the air gap, in which the coil is to move.

Schematic diagram of AMM.



## Measurement of dc current & dc voltage

- In the fig (a) is shown the arrangement for dc current measurement when the function selector is on current (DC)

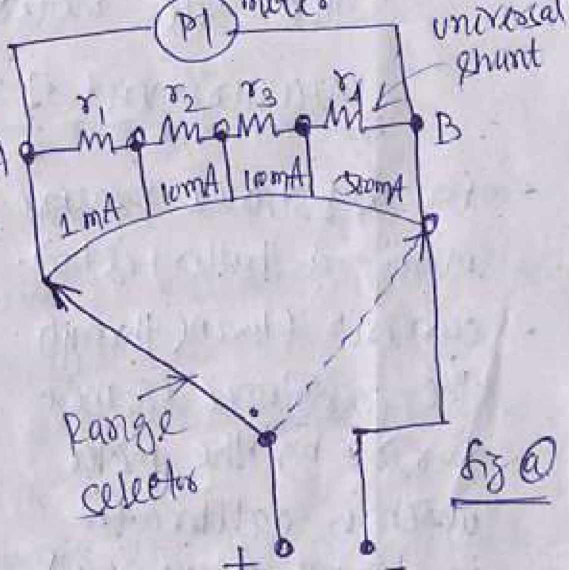



fig (a)

- any range of dc current can be measured by the universal ~~shunt~~ shunt AB.
- A no. of low resistances are connected in parallel with the meter, through the selector switch.

- In the fig (b) is shown the arrangement for dc voltage measurement when the function selector is on voltage (DC) and the range selector is set to a particular range.

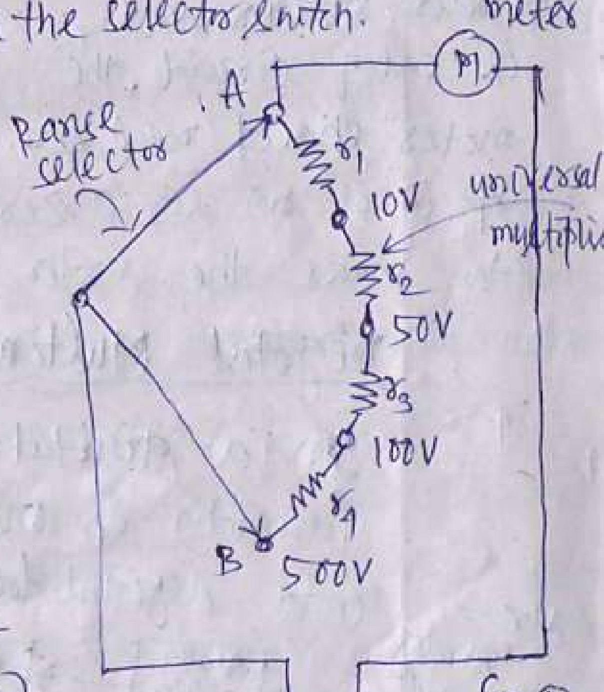
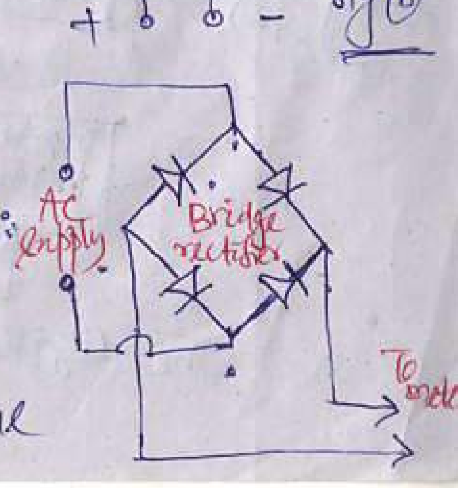



fig (b)

- A number of high resistance values are connected in series called the universal multiplier AB.

### Measurement of ac current & voltage:

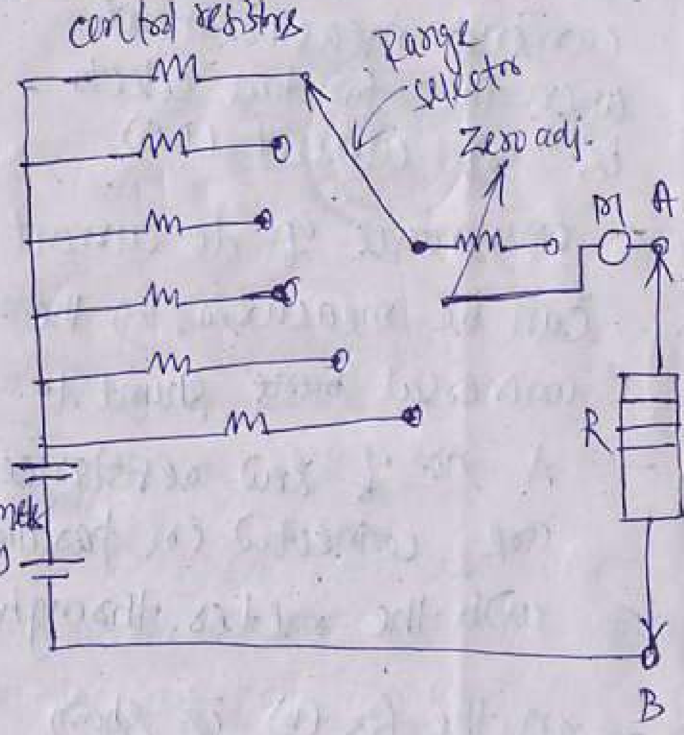
For measurement of ac current and voltage, a bridge rectifier is used to convert the ac value



into dc form and then it is measured by the dc meters.

## Measurement of resistance

- For resistance measurement a battery is used.
- current flowing through the resistance is measured by the meter which is calibrated in terms of ohm(Ω)
- when the resistor, under measurement is out of circuit, the meter should read zero.

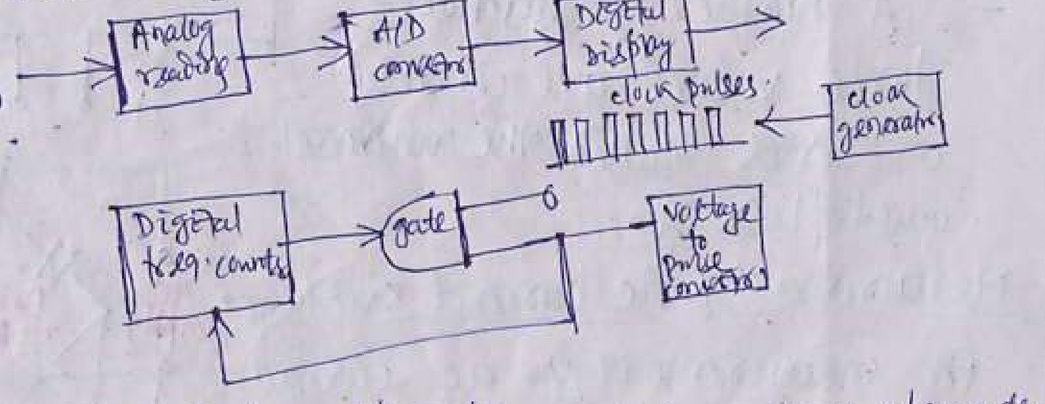



If it is not so, a zero adjustment resistor is used to make the meter zero, before measurement.

## Digital Multimeter (DMM)

In a digital multi meter, the analog quantity is measured and then converted into digital form with the help of an ADC.

(ADC — Analog to digital converter)



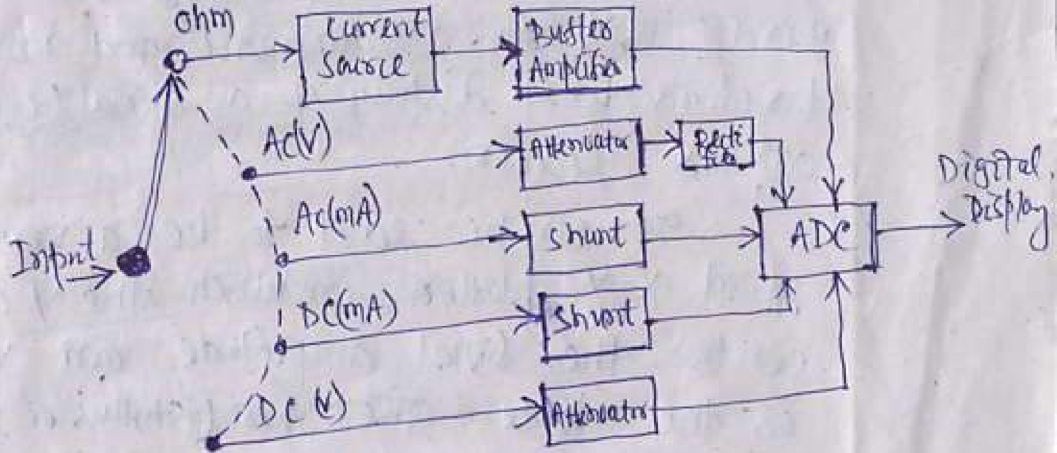

The digital multimeter contains three elements -

A digital meter contains 3 elements (4)

1. clock generator which produces fixed freq. clock pulses.
2. A circuit which converts the quantity to be measured into pulses (where width is linearly proportional to the amplitude of the quantity).
3. A digital frequency counter.

## Block diagram of Digital multimeter.

A digital multimeter is basically a digital voltmeter and may be used for measurement of dc/ac voltages, dc/ac currents & resistance. All quantities other than voltage is first converted into equivalent dc voltage. In the fig. is shown the block diagram.




## Differences between AMM & DMM.

| A Meter | D. Meter |
| --- | --- |
| ① These display quantity in terms of deflection of a pointer on a calibrated scale. | ① These instruments display a quantity in decimal number format. |
| ② It has comparatively poor accuracy. | ② It has much better accuracy. |

| | |
|---|---|
| (3) Resolution is comparatively poor. | (3) Resolution is very high. |
| (4) Analog instruments consume large power. | (4) They consume negligible power. |
| (5) They load the circuit while measurement is made. | (5) They donot load the circuit. |
| (6) Simple in construction | (6) Complex in construction |
| (7) Less affected by environment | (7) Greatly affected by environment |
| (8) Suffer from parallax and other human errors | (8) Free from human errors |

## 4.7 Cathode Ray Oscilloscope (CRO)

CRO is the most versatile electronic equipement used for measurement and many other functions like display of a signal (its waveshape) on its screen.

It can be said to be a very high speed X-Y plotter, in which the Y axis represents the signal amplitude and X- axis is the time. The pen (stylus or needle) of this plot is the luminous spot which moves on the screen and draws the waveshape of the signal.

**Block diagram of the CRO.**

Important components of a CRO are -

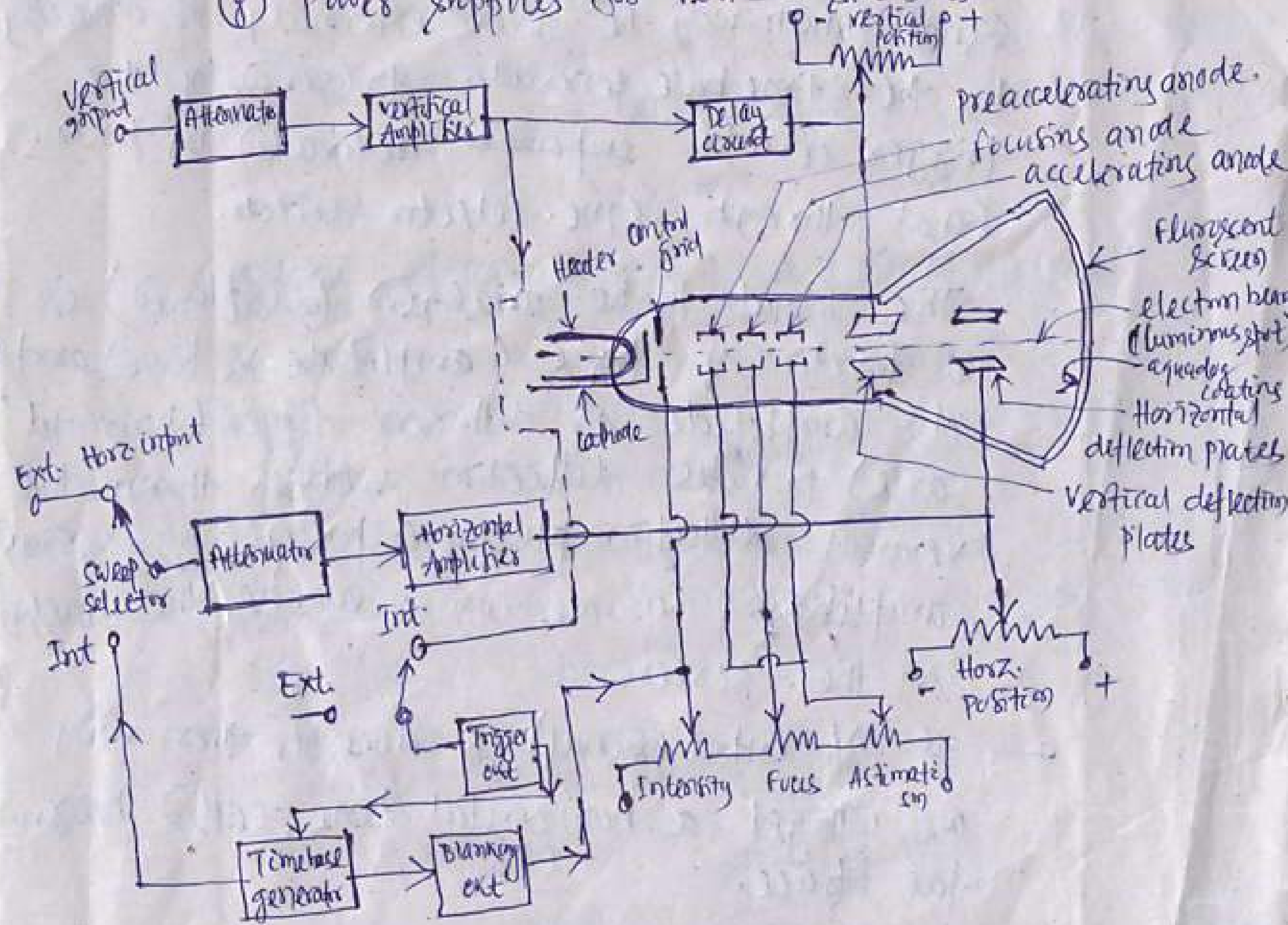
a) Electron gun assembly — consisting heater, cathode and control grid, accelerating and focussing anodes

b) Horizontal & vertical amplifiers and H/V deflection systems.

(c) Time base circuits, synchronizing circuits and blanking circuits.

(d) Astigmatism. (e) Attenuators (f) CRO probes

(g) Power supplies for various sections.




Block diagram of CRO.

## working of CRO:

- An electron beam is generated from a cathode, heated by a heater. The surface of the cathode is coated with a material of low work function.
- control grid controls the flow of electrons in the beam
- The electron beam get accelerated by the pre accelerating and accelerating anodes and get focused on the centre of the screen by focusing anodes which are supplied with +ve voltages.