Vikash Polytechnic, Bargarh

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Lecture Note on
BASIC ELECTRICAL ENGINEERING

Diploma 1thSemester

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①FUNDAMENTALS CH-1

Charge :→

charge of electron = $-1.6 \times 10^{-19} C$

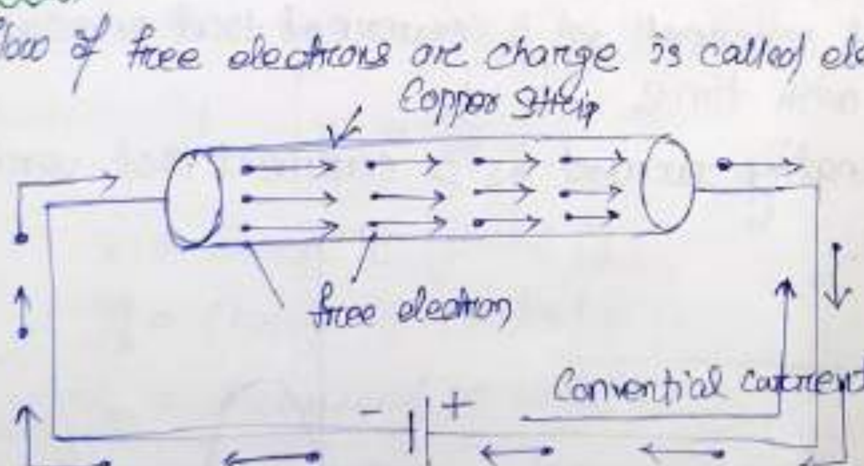
→ The most basic quantity in an electric circuit is the electric charge.

→ charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C). charge positive or negative, is denoted by the letter q or Q.

→ All matter of fundamental building blocks known as atoms and that each atom consists of electron, protons and neutrons we also known that the charge 'e' on an electron is negative and equal in magnitude as the electron and the neutron has no charge. The presence of equal numbers of protons and electrons leaves an atom neutrally charged

Current :→

→ The flow of free electrons or charge is called electric current.



→ Current can be defined as the motion of charge through a conducting material measured in Ampere (A).

→ Electric current is denoted by the letter i or I

→ The unit of current is the ampere abbreviated as (A) and corresponds to the quantity of total charge that passes through an arbitrary cross section of a conducting material per unit second.

Mathematically $\boxed{I = \frac{Q}{t}}$ or $\boxed{Q = It}$

Q = charge measured in coulombs (C)
I = current in amperes (A)
t = time in second (s)

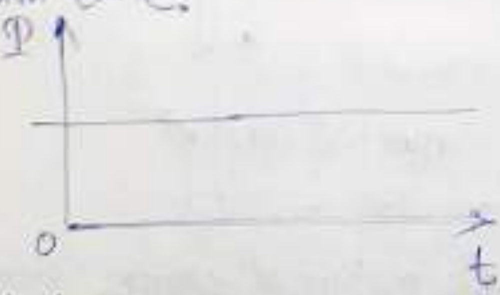
→ The current can also be defined as the rate of charge passing through a point in an electric circuit.

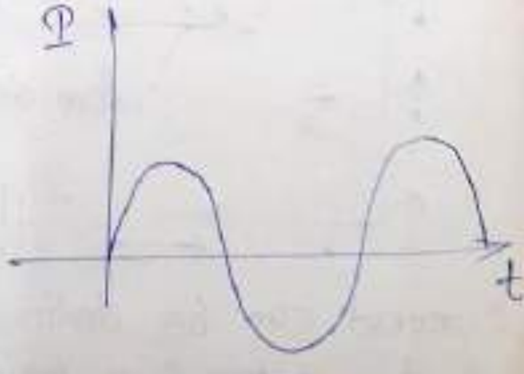
Mathematically $\boxed{i = \frac{dq}{dt}}$

→ Two types of current

1) A direct current is a current that remains constant with time

2) An alternating current is a current that varies with time.



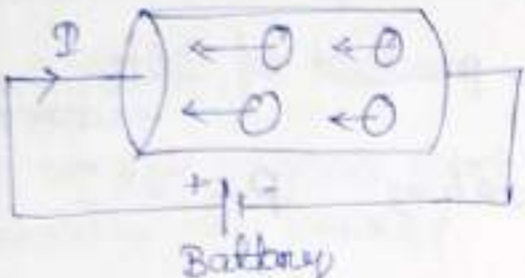


potential :⇒

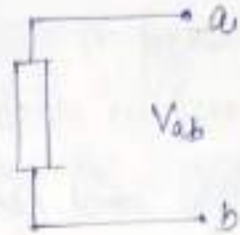
The quantity determining the energy of mass in a gravitational field or of charge in electric field

Voltage :→ The capacity of a charged body to do work is called electric potential. $V = \frac{\text{workdone}}{\text{charge}} = \frac{W}{Q}$

→ To move the electron in a conductor in a particular direction requires some work or energy transfer. This work is performed by an external electromotive force (emf) typically represented by the battery. This emf is also known as voltage or potential difference.



Electric Current in a conductor



Polarity of voltage

→ Voltage or potential difference is the energy required to move charge from one point to the other, measured in volts (V). Voltage is denoted by the letter V or V.

Mathematically $\boxed{V_{ab} = \frac{dw}{dq}}$

w = Energy in joules (J)

q = charge in coulombs (C)

V_{ab} = Measured in volts (V)

$\boxed{1 \text{ volt} = 1 \text{ joule/coulomb}}$ = 1 newton-meter/coulomb

★ The potential difference between two point when 1 joule of work required to move 1 coulomb charge from one point to the other.

Power :-

→ Power is the time rate of expending or absorbing energy measured in watts (W). Power is denoted by the letter p or P.

Mathematically $p = \frac{dw}{dt}$ → Rate of electrical energy transfer by an electric circuit per unit of time

P = power in watts
w = energy in Joules
t = time in seconds

→ product of voltage & current

from voltage and current equations $P = V \times I$

$$P = \frac{dw}{dt} = \frac{dw}{dq} \times \frac{dq}{dt}$$

$$\boxed{P = V \times I}$$

Thus if the magnitude of current I and voltage are given then power can be evaluated as the product of the two quantities and is measured in watts (W).

* + sign → Power is absorbed by the element
  - sign → power is supplied by the element

* passive sign convention

if the current enters through the positive polarity of the voltage, $P = +VI$

if the current enters through the negative polarity of the voltage, $P = -VI$

Energy :→

→ Energy is the capacity to do work and is measured in Joules (J)

→ Electrical Energy :→ It is the work or energy supplied by the source to maintain the flow of electric current.

$$E = P \times t = VI \times t = I^2 R t = \frac{V^2}{R} t$$

Energy sources :→

→ The energy sources which are having the capacity of generating the energy.

→ The most important energy sources are voltage and current sources that generally deliver power/energy to the circuit connected them.

→ There are two kinds of sources

(a) Independent sources

(b) Dependent sources.

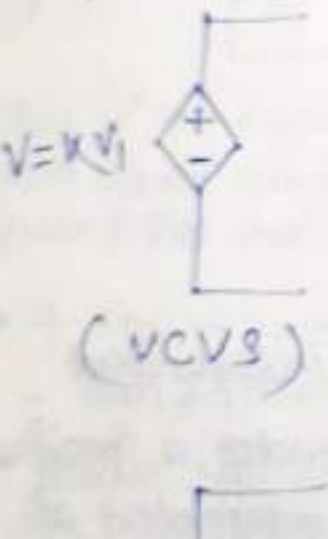
(a) Independent Sources → An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit elements

(i) Ideal Independent voltage sources → An ideal independent voltage sources is an active element that gives a constant voltage across its terminals irrespective of the current drawn through its terminals.

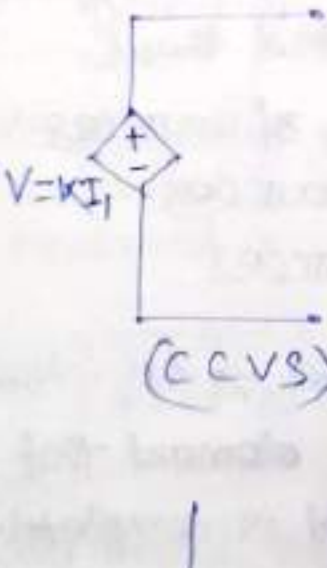
(ii) Ideal Independent current sources → An ideal independent current source is an active element that gives a constant current through its terminal irrespect of the voltage appearing across its terminals.

(b) Dependent sources → An ideal dependent source is an active element in which the source quantity is controlled by another voltage or current.

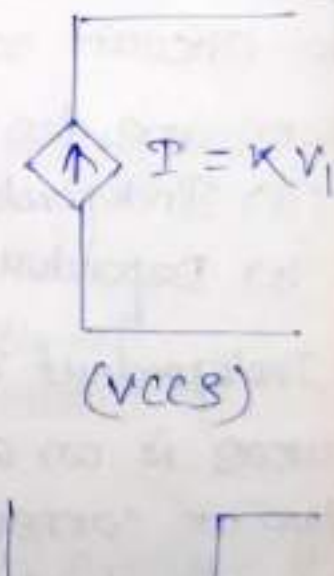
1. voltage controlled voltage source (VCVS)
2. current controlled voltage source (CCVS)
3. voltage controlled current source (VCCS)
4. current controlled current source (CCCS)



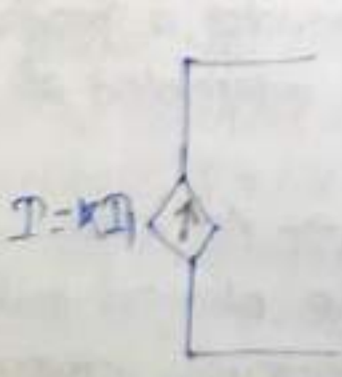
(VCVS)



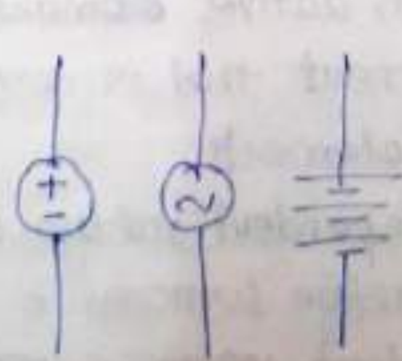
(CCVS)



(VCCS)



(CCCS)


(voltage source)


(Current source)

* Examples of voltage source ⇒
  Cell, Batteries, Generators

* Examples of current source ⇒
  Diode, transistors, operational Amplifiers

Electrical Load :⇒

→ The electrical load is a device that consumes electrical energy in the form of the current and transforms it into other forms like heat, light, work etc.

⇒ The electrical load are
(a) Resistive (b) Inductive (c) Capacitive

(a) Resistive Load ⇒ The Resistive load obstructs the flow of electrical energy in the circuit and converts it into thermal energy
e.g:- Lamp, Heater

$V = IR$ ohm Ω

(b) Inductive Load ⇒ The inductive load has a coil which stores magnetic energy when the current pass through it
e.g:- Generator, Motor, transformer

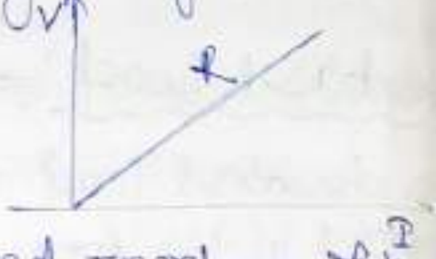
$V = L\frac{di}{dt}$ Henry H

(c) Capacitive load ⇒ The capacitive load include energy stored in materials and device.
e.g:- Capacitor bank & synchronous condenser.

$i = C\frac{dv}{dt}$ Farad F

Ohm's law ⇒

Ohm's law states that at constant temperature, the voltage across a conducting material is directly proportional to the current flowing through the material.



Mathematically $V \propto I$

$V = IR$

R = Proportionality constant called resistance of the material. measured in ohm (Ω)

Circuit ⇒ A complete circular path that electricity flows through.

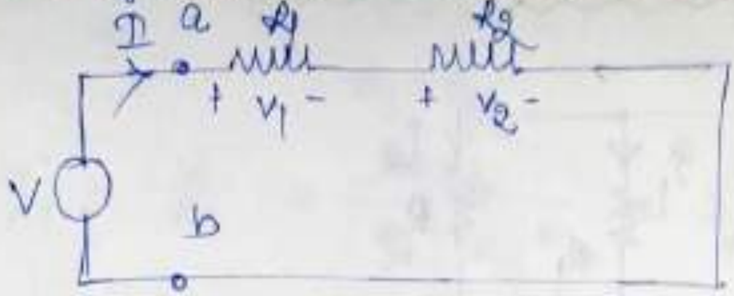
Conductor ⇒ A substance or material, that allows electricity to flow through it.

Resistor ⇒

Material in general have a characteristic behavior of resisting the flow of electric charge. This physical property or ability to resist the flow of current is known as resistance and is represented by the symbol R. The Resistance is measured in ohms (Ω)

★ The property of any conductor that opposes the flow of electric current through it is called resistance

Relation of V, I & R in Series Circuit :→



$V_1 = iR_1,\ V_2 = iR_2$ ——— (1)

Applying $V = V_1 + V_2$ ——— (2)

$= iR_1 + iR_2$

$V = i(R_1 + R_2)$ ——— (3)

$\Rightarrow V = iR_{eq}$ ——— (4)

$R_{eq} = R_1 + R_2$ ——— (5)

→ Resistance are connected end to end so that there is only one path for current to flow is called series circuit

$$i = \frac{V}{R_1 + R_2} \quad \text{——— (6)}$$

Voltage Division ⇒

$V_1 = iR_1$

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

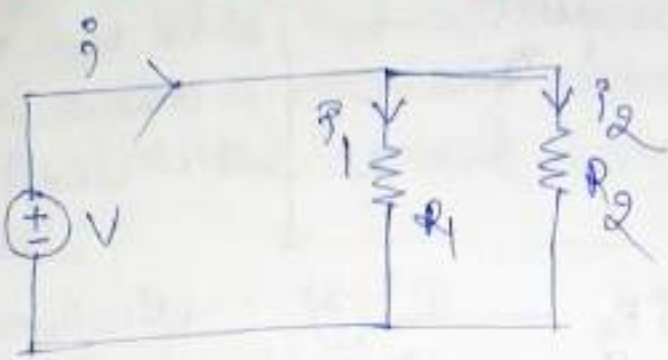
$= \frac{VR_1}{R_{eq}}$

$V_2 = iR_2$

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

$= \frac{VR_2}{R_{eq}}$

Relation of V, I & R in parallel Circuit :→



→ When one end of each resistance is joined to a common point and the other end of each resistance is joined to another common point so that there are as many paths for current flow as the number of resistance, it is called a parallel path.

$$V = i_1 R_1 = i_2 R_2 \quad \text{——— (1)}$$

$$i_1 = \frac{V}{R_1} \quad i_2 = \frac{V}{R_2} \quad \text{——— (2)}$$

$$i = i_1 + i_2 \quad \text{——— (3)}$$

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

$$= V\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{V}{R_{eq}} \quad \text{——— (4)} \Rightarrow V = i R_{eq} \quad \text{——— (5)}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \quad \text{——— (6)}$$

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

$$\Rightarrow R_{eq} = \frac{R_1 R_2}{R_1 + R_2} \quad \text{——— (7)}$$

Current division ⇒

$$V = iR_{eq} = \frac{iR_1R_2}{R_1+R_2} \quad \text{——— (1)}$$

$$i_1 = \frac{V}{R_1} = \frac{iR_1R_2}{(R_1+R_2)R_1} = \frac{iR_2}{R_1+R_2} \quad \text{——— (2)}$$

$$i_2 = \frac{V}{R_2} = \frac{iR_1R_2}{(R_1+R_2)R_2} = \frac{iR_1}{R_1+R_2} \quad \text{——— (3)}$$

Power in Series & Parallel Circuits :⇒

$$P = VI = IRI = I^2R$$

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

$$P = VI = I^2R = \frac{V^2}{R}$$

$$\boxed{P = VI = V\cdot\frac{V}{R} = \frac{V^2}{R}} \text{ watts}$$

Series ⇒

if the electrical appliances of power P_1 & P_2 are connected in series with main voltage V having resistance R_1 & R_2 then

$$R_1 = \frac{V^2}{P_1} \quad R_2 = \frac{V^2}{P_2} \quad \text{——— (1)}$$

when connected in series, then there effective resistance is $R = R_1 + R_2$ ——— (2)

$$\frac{V^2}{P} = \frac{V^2}{P_1} + \frac{V^2}{P_2}$$

$$\Rightarrow \boxed{\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2}} \quad \text{——— (3)}$$

parallel ⇒

if the electrical appliances of power P_1 & P_2 are connected in parallel with main voltage V having resistance R_1 & R_2 then

$$R_1 = \frac{V^2}{P_1} \quad R_2 = \frac{V^2}{P_2}$$

when connected in parallel, then effective resistance,

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \quad \text{—— (4)}$$

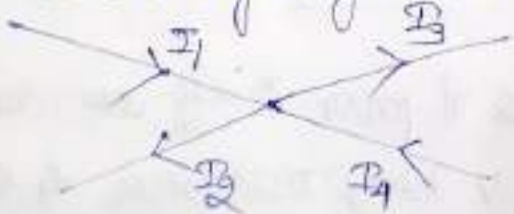
$$\frac{P}{V^2} = \frac{P_1}{V^2} + \frac{P_2}{V^2}$$

$$\Rightarrow \boxed{P = P_1 + P_2} \quad \text{—— (5)}$$

Kirchhoff's Law :⇒

(1) Kirchhoff's Current Law (KCL) :⇒

Kirchhoff's Current Law states that the algebraic sum of the current entering any node is zero.



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

$$\Rightarrow I_1 + I_4 = I_2 + I_3$$

KCL also can be states as :⇒

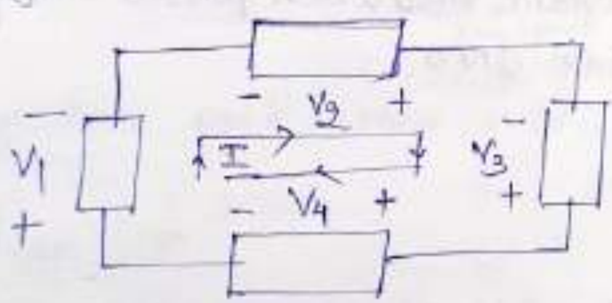
The sum of current entering any node is equal to the sum of current leaving the node.

Sign Rule of KVL :→

Direction of movement → ⊖ ⊣⊢ ⊕ V $V = +ve$	Direction of movement → ⊕ ⊣⊢ ⊖ V $V = -ve$
Direction of movement → ⊕ ∿∿ ⊖ R $V = IR = -ve$ Direction of movement of current (I) →	Direction of movement → ⊖ ∿∿ ⊕ R $V = IR = +ve$ Direction of movement of current (I) ←

(2) Kirchhoff's Voltage Law (KVL) :→

Kirchhoff's voltage law states that the algebraic sum of voltage around any closed path is zero.



$$-V_1 + V_2 + V_3 - V_4 = 0$$

$$\Rightarrow V_1 - V_2 - V_3 + V_4 = 0$$

$$\Rightarrow V_1 + V_4 = V_2 + V_3$$

The sum of voltage rise is equal to the sum of voltage drops around any closed path.

A. C. THEORY CH-2

(1) Generation of Alternating emf :→

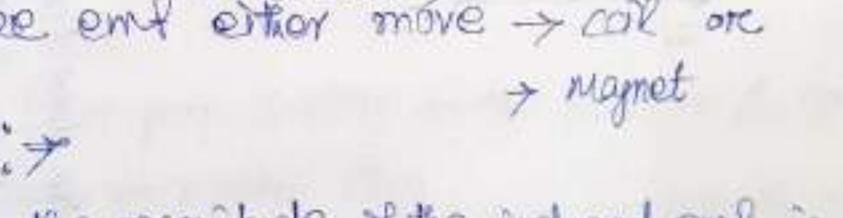
Faradays Laws of Electromagnetic Induction :→

(1) 1st law :→

→ It tells us about the condition under which emf is induced in a conductor or coil.

"It states that if the magnetic flux linking a conductor or coil changed with time an emf is induced in it"

condition (2) < magnetic field + conductor



to produce emf either move → coil or → magnet

(2) 2nd law :→

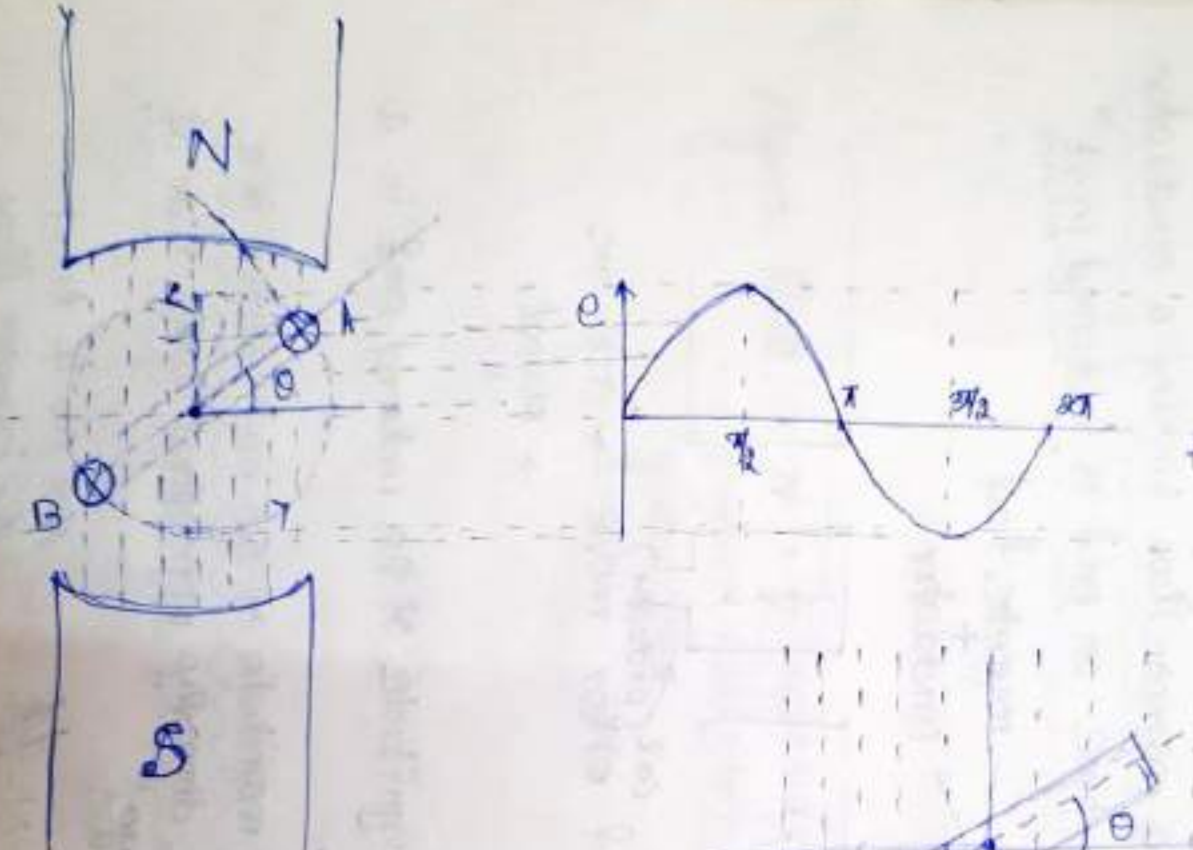
It gives the magnitude of the induced emf in a conductor or coil.

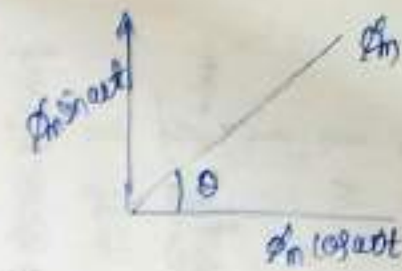
"It states that the magnitude of the emf induced in a conductor or coil is directly proportional to the rate of change of flux linkage"

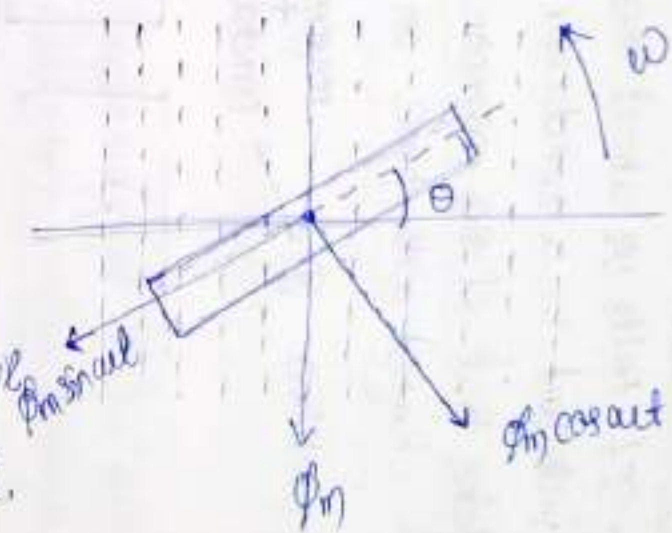
$$e = -N\frac{d\phi}{dt}$$

N = No of turns

ϕ = magnetic flux







★ Fleming's right hand rule

Thumb → motion of conductor

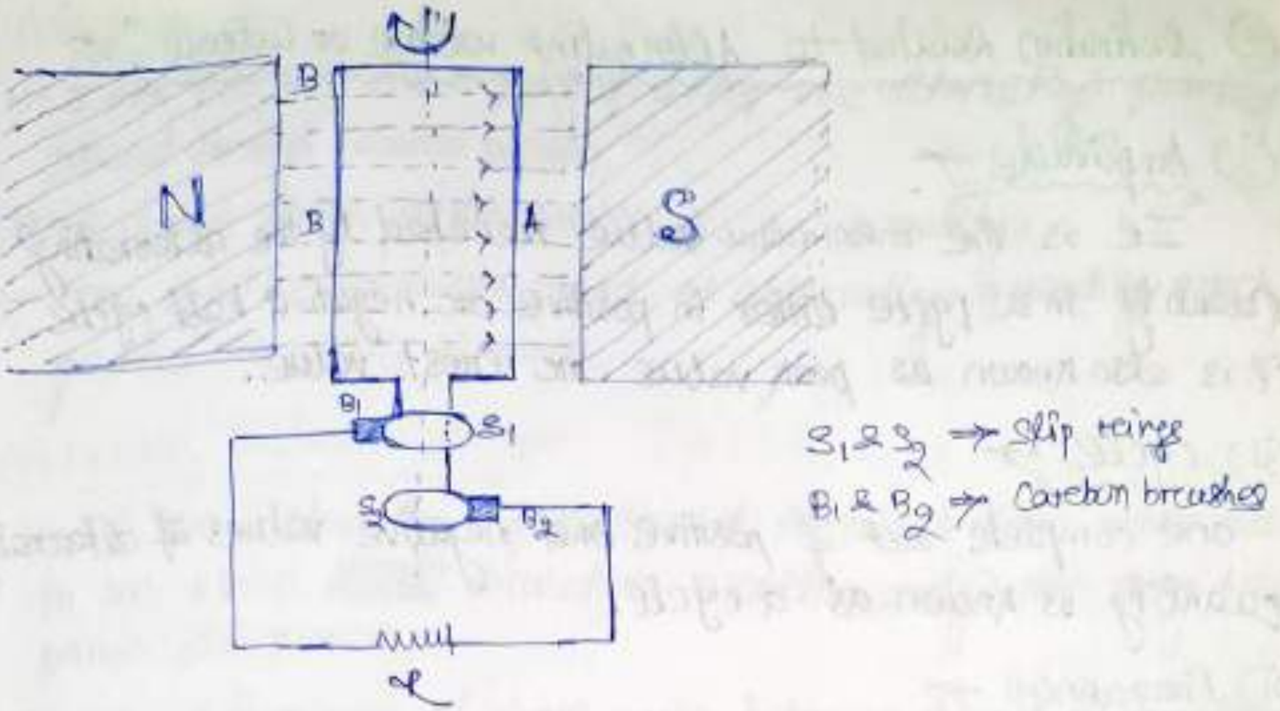
Index finger → direction of magnetic field

middle finger → direction of induced current.

ϕm sin ωt → parallel to the plane of coil

ϕm cos ωt → perpendicular to the plane of coil

↳ induced emf in the coil.



Let us consider that a coil having N no. of turns is rotating in a uniform magnetic field at an angular velocity of ω radian/sec

It starts from initial position and rotate bat an angle θ in time t sec in anticlockwise direction.

$$\theta = \omega t$$

At this instant flux perpendicular to the coil is $\phi_m \cos \omega t$

ϕ_m = maximum possible flux

$\cos \omega t$ → perpendicular components

By faraday's law $e = -N \frac{d\phi}{dt}$

$$= -N \frac{d}{dt} \phi_m \cos \omega t$$

$$= N \phi_m \omega \sin \omega t$$

$$\boxed{i = I_m \sin \omega t} \qquad \boxed{e = V_m \sin \omega t}$$

Hence the voltage produce will depend on the value of $\sin \omega t$ and the curve obtained for different value of θ is sine wa

(2) Defination Related to Alternating voltage or current :→

(i) Amplitude →

It is the maximum value reached by the alternating quantity in a cycle either in positive or negative half cycle. It is also known as peak value or Crest value.

(ii) cycle →

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

(iii) Frequency →

Number of cycles per second is called the frequency of the alternating quantity.

$$\boxed{f = \frac{1}{T}}$$ unit is Hertz (Hz)

1 Hz = 1 cycle/second

(iv) Time period →

The time required to complete one cycle of an alternating quantity is called time period.

$$\boxed{T = \frac{1}{f}}$$ unit is sec

(v) Angular frequency →

It is the angular distance (angle) covered by alternating quantity in one second. It is also known as angular velocity.

$$\boxed{\omega = 2\pi f}$$ rad/sec

(vi) phase →

→ It is part of time period after the alternating quantity passed through zero position.

→ It is the phase angle position of AC quantity

→ The angular measurement of alternating quantity which specifies the position of wave.

(vii) phase Difference →

→ If two alternating quantities do not reach their zero value in the same direction simultaneously then they have phase difference.

→ The difference of phase angle between two A.C quantities on the same reference axis is known as phase difference

(viii) wave form →

→ The nature of graph of alternating quantity againt time is known as wave form

(ix) Periodic waveform →

If the same set of variation is repeated indefinitely after a certain interval of time then the wave form is known as periodic wave form.

(x) Alternation →

one half cycle of an alternating quantity is called an alternation. An alternation spans 180° electrical.

(3) Different Types of values of Alternating voltage & current :→

① Instantaneous value :→

* It is defined as the value of alternating quantity at any instant of time.

* It is represented by $i(t)$ or $v(t)$.

* Ex: $v(t) = V_m \sin(\omega t + \theta)$

② Average value :→

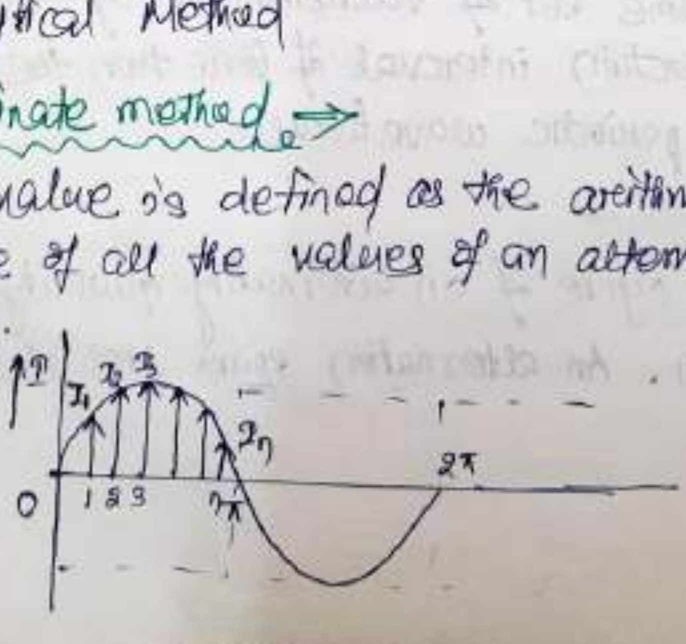
* The Average value of an alternating current is that DC current which transfers across any circuit the same charge as it transferred by that alternating current during the same time.

* It is represented by V_{avg} or I_{avg}

* There are two method to calculate average value
  (i) Mid ordinate method / graphical method
  (ii) Analytical Method

(i) Mid ordinate method →

The average value is defined as the arithmatic average or mean value of all the values of an alternating quantity over one cycle.



Let $i_1, i_2, i_3 \cdots\cdots i_n$ be the mid ordinates

The average value of current I_{avg} = mean of the mid ordinates

$$I_{avg} = \frac{i_1 + i_2 + i_3 + \cdots + i_n}{n}$$

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

If we consider symmetrical waves like sinusoidal current or voltage wave form the positive half cycle will be exactly equal to the negative half cycle. Therefore the average value over a complete cycle will be zero. So the average value is taken for only the positive half cycle.

(ii) Analytical Method ⇒

Consider a sinusoidal wave form, the average value of alternating current is

$$I_{avg} = \frac{\text{Area under the half cycle}}{\text{Length of the base of half cycle}}$$

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

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

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

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

$$= \frac{I_m}{\pi} \left(-\cos\pi + \cos 0\right)$$

$$= \frac{I_m}{\pi}\left[-(-1)+1\right]$$

$$\boxed{I_{avg} = \frac{2 I_m}{\pi}}$$

$$\boxed{I_{avg} = 0.637 \times I_m}$$

(3) RMS value (Root mean square) / effective value :→

★ The RMS value of an alternating current is given by that value of DC current which when flowing through a given circuit for a given time, produces the same amount of heat as produced by the alternating current, which when flowing the same circuit for the same time.

★ In otherwords, the R.M.S value is defined as the square root of means of squares of instantaneous value.

★ It is represented by V_{rms} or I_{rms}.

★ There are two methods calculate RMS value

(i) Mid ordinate method / graphical method

(ii) Analytical method

(i) Mid ordinate method / graphical method →

Let I be the alternating current flowing through a resistor R for time t seconds, which produces the same amount of heat as produced by the direct current. The base of one alternation is divided into 'n' equal parts so that each interval is of t/n seconds.

Let $i_1, i_2, i_3 \cdots\cdots i_n$ be the mid ordinates.

Then the heat produced in first interval $= \dfrac{i_1^2 Rt}{Jn}$ calories

second interval $= \dfrac{i_2^2 Rt}{Jn}$ calories

nth interval $= \dfrac{i_n^2 Rt}{Jn}$ calories

Total heat produced $= \dfrac{Rt}{J}\left(\dfrac{i_1^2 + i_2^2 + \cdots + i_n^2}{n}\right)$ ——— (1)

Since I_{eff} is considered as the effective value of this current, then the total heat produced by this current will be

$\dfrac{I_{eff}^2 Rt}{J}$ calories ——— (2)

Equating eqn (1) and eqn (2)

$$\frac{I_{eff}^2 Rt}{J} = \frac{Rt}{J}\left(\frac{i_1^2 + i_2^2 + \cdots + i_n^2}{n}\right)$$

$$\Rightarrow I_{eff}^2 = \frac{i_1^2 + i_2^2 + \cdots + i_n^2}{n}$$

$$\Rightarrow I_{eff} = \sqrt{\frac{i_1^2 + i_2^2 + \cdots + i_n^2}{n}}$$

(ii) Analytical Method →

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

$$i_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2 \, d(\omega t)}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i_m^2 \sin^2 \omega t \, d(\omega t)}$$

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

$$i_{rms} = 0.707 \times I_m$$

④ Maximum value or peak value :→

* peak value is defined as the maximum value that alternating quantity (current or voltage) reaches in one cycle (either in positive or negative)

* It is represented by I_m or V_m

⑤ Form factor :→

It is the ratio of RMS value to the average val

$$\text{Form factor} = \frac{\text{RMS value}}{\text{Avg. value}}$$

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

$$\text{Form factor} = 1.11$$

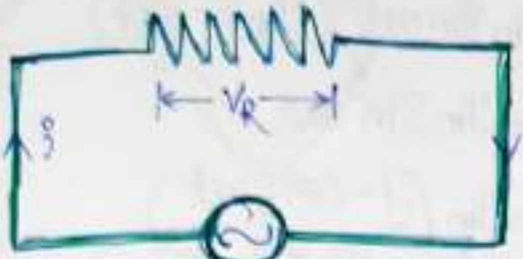
⑥ Peak factor / crest factor / Amplitude factor :→

It is the ratio of maximum value to the RMS val

$$\text{peak factor} = \frac{\text{Max. value}}{\text{RMS value}} = \frac{I_m}{0.707\,I_m}$$

$$\text{Peak factor} = 1.414$$

AC through Pure Resistance :-



$$\boxed{v = V_m \sin \omega t} \quad \text{——— } ①$$

$v = iR$

$$\boxed{i = \frac{v}{R} = \frac{V_m}{R} \sin \omega t} \quad \text{——— } ②$$

i will be maximum (I_m) when $\sin \omega t = 1$

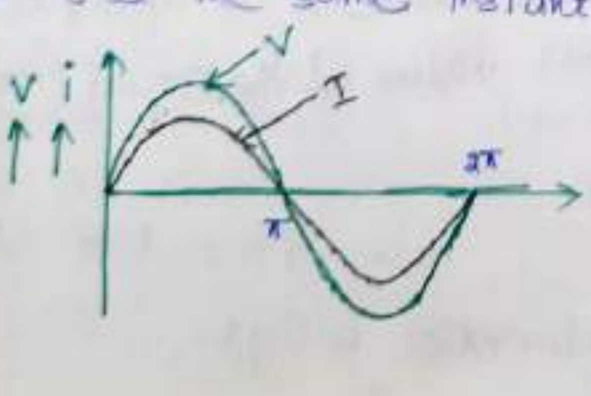
$$I_m = V_m/R$$

$$\boxed{i = I_m \sin \omega t} \quad \text{——— } ③$$

in terms of rms values $\frac{V_m}{\sqrt{2}} = \frac{I_m}{\sqrt{2}} \times R$

or $\quad V = V_R = IR$

★ It is clear from eq^n ① and eq^n ③ that the applied voltage and the circuit current are in phase with each other i.e they pass through their zero values at the same time instant and attain their positive and negative peak at the same instant



Instantaneous power $p = vi$

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

$$= V_m I_m \sin^2 \omega t$$

$$= V_m I_m \left(\frac{1 - \cos 2\omega t}{2}\right)$$

$$= \frac{V_m I_m}{2} - \frac{V_m I_m}{2} \cos 2\omega t$$

This power consists of two part a constant part $\left(\frac{V_m I_m}{2}\right)$ and a fluctuating part $(V_m I_m/2)\cos 2\omega t$.

Since the power is a scalar quantity, average power over a complete cycle is to be considered

power consumed $P = \frac{1}{2\pi}\int_0^{2\pi} \frac{V_m I_m}{2} \, d(\omega t)$

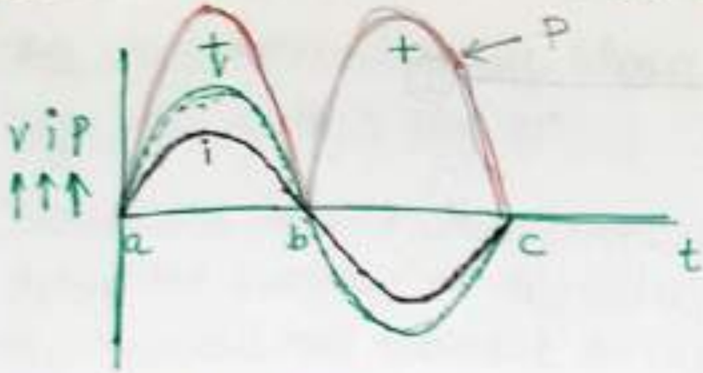
$$= \frac{V_m I_m}{2}$$

$$= \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}$$

$$\boxed{P = V_R \times I}$$

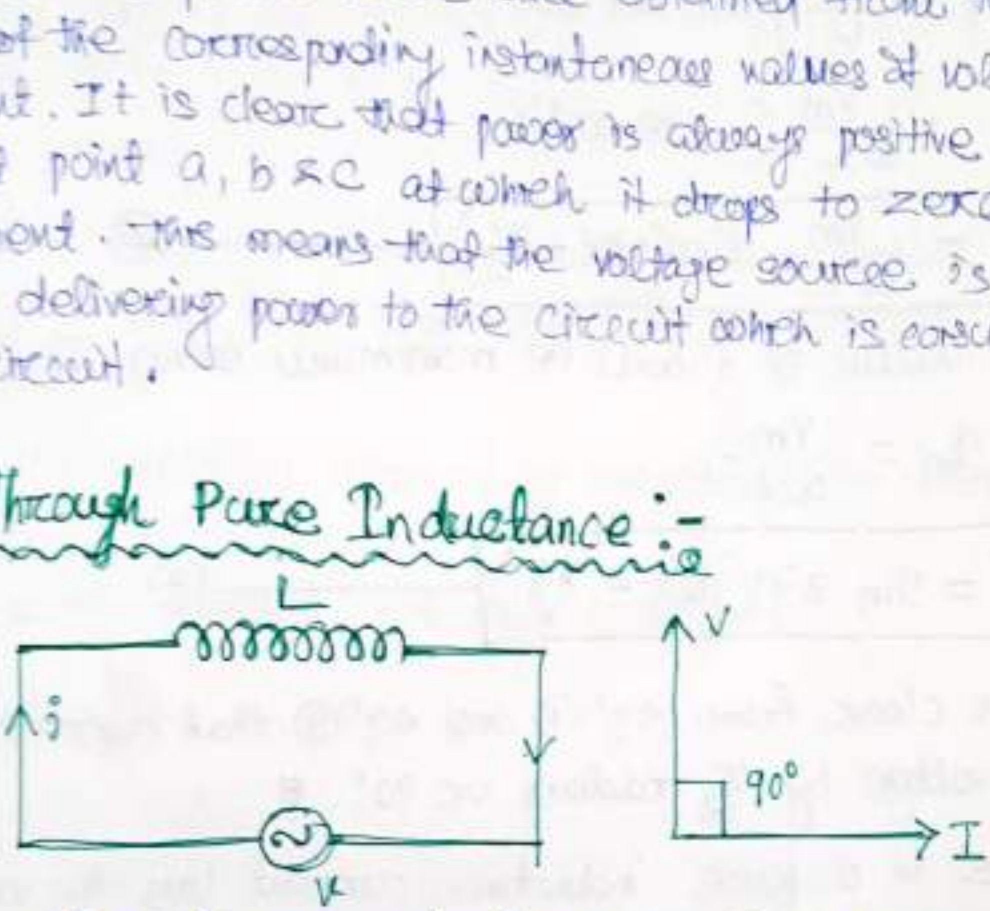
V_R = r.m.s value of the applied voltage

I = rms value of the circuit current



The point on the power curve are obtained from the product of the corresponding instantaneous values of voltage and current. It is clear that power is always positive except at point a, b & c at which it drops to zero for a moment. This means that the voltage source is constantly delivering power to the circuit which is consumed by the circuit.

AC Through Pure Inductance :-



When an alternating current flows through a pure inductive load a back emf is induced due to the inductance of the coil. This back emf at every instant opposes the change in current through the coil. Since there is no ohmic drop, the applied voltage has to overcome the back emf only.

∴ Applied alternating voltage = Back emf

$$\boxed{v = V_m \sin \omega t} \quad \text{--- (1)}$$

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

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

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

$$= \frac{V_m}{\omega L} (-\cos \omega t)$$

$$\boxed{i = \frac{V_m}{\omega L} \sin(\omega t - \pi/2)} \quad \text{--- (2)}$$

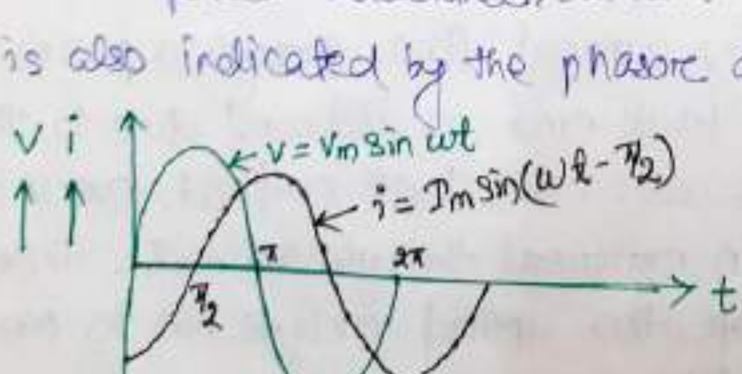
The value of i will be maximum when $\sin(\omega t - \pi/2)$ =

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

$$\boxed{i = I_m \sin(\omega t - \pi/2)} \quad \text{--- (3)}$$

It is clear from eqⁿ (1) and eqⁿ (3) that current lags behind the voltage by $\pi/2$ radians or 90°.

Hence in a pure inductance, current lags the voltage by
This is also indicated by the phasor diagram.



The wave form diagram shown also depicts that current Lags the voltages by 90°.

Inductance opposes the change in current and serves to delay the increase or decrease of current in the circuit. This causes the current to lag behind the applied voltages

★ $$I_m = \frac{V_m}{\omega L}$$

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

Inductance not only causes the current to lag behind the voltage but it also limits the magnitude of current in the circuit.

Clearly the opposition offered by inductance to current flow is ωL.

$\omega L = X_L$ called inductive reactance

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

$$\Rightarrow \frac{I_m}{\sqrt{2}} = \frac{V_m/\sqrt{2}}{X_L}$$

$$\Rightarrow \boxed{I = \frac{V_L}{X_L}} \Rightarrow V_L = I X_L$$

$$\boxed{X_L = \omega L = 2\pi f L} \quad \Omega$$

Instantaneous power $p = vi$

$= V_m \sin \omega t * I_m \sin(\omega t - \pi/2)$

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

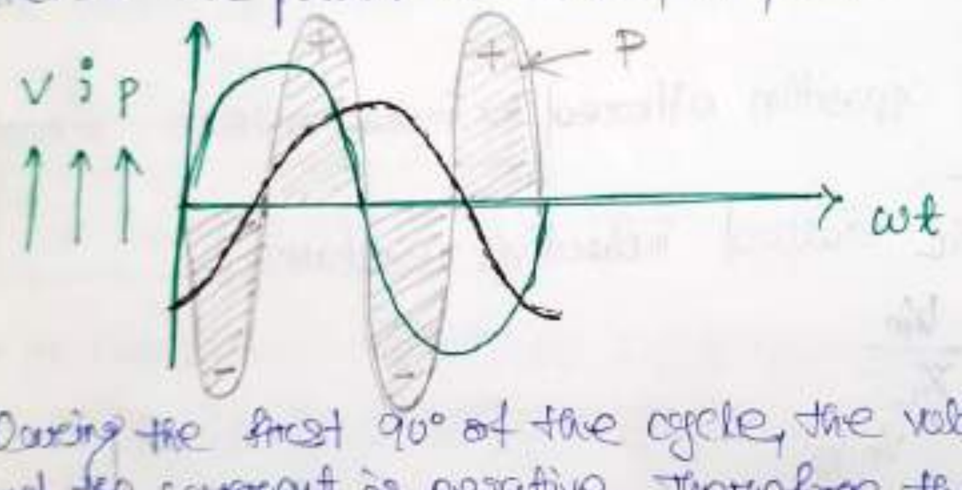
$= -\frac{V_m I_m}{2} \sin 2\omega t$

Average power P = Average of p over one cycle

$= \frac{1}{2\pi} \int_0^{2\pi} -\frac{V_m I_m}{2} \sin 2\omega t \, d(\omega t)$

$= 0$

Hence the power absorbed in pure inductance is

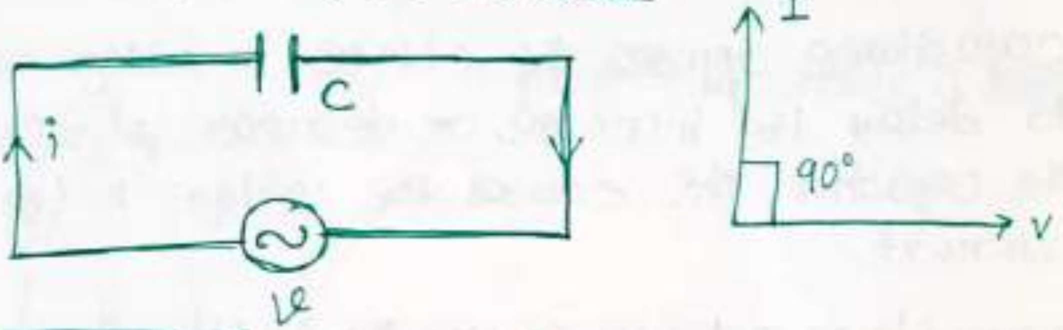


During the first 90° of the cycle, the voltage is posi and the current is negative, therefore the power sup is negative. this means the power is flowing from the c to the source. During the next 90° of the cycle both voltage and current are positive and the power sup is positive. therefore power flows from the source the coil similarly for the next 90° of the cycle power from the coil to the source and during the last 9 the cycle, power flows from the source to the coil.

from the power curve one cycle shows that positive power is equal to the negative power.

Hence the resultant power over one cycle is zero i.e a pure inductance consumes no power. The electric power merely flows from the source to the coil and back again.

AC through pure Capacitance :-



$$v = V_m \sin \omega t \quad \text{———} \quad (1)$$

$$q = Cv = CV_m \sin \omega t$$

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

$$\Rightarrow i = \omega C V_m \sin(\omega t + \pi/2) \quad \text{———} \quad (2)$$

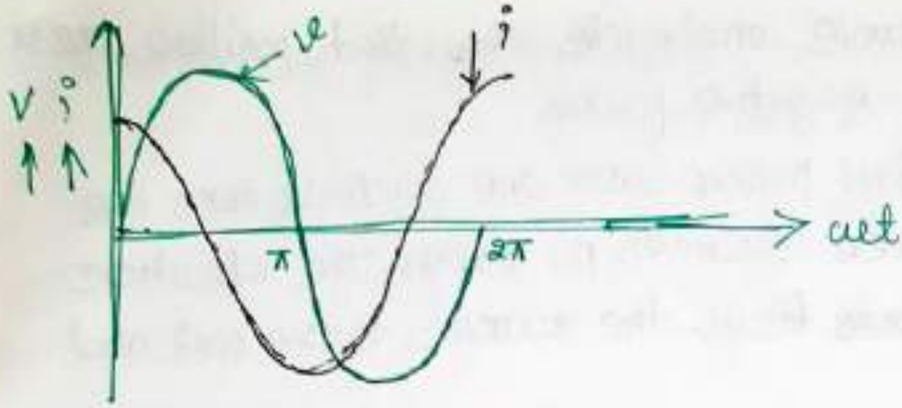
i will be maximum (I_m) when $\sin(\omega t + \pi/2)$ is unity

$$I_m = \omega C V_m$$

$$i = I_m \sin(\omega t + \pi/2) \quad \text{———} \quad (3)$$

It is clear from eq^n (1) and eq^n (3) that current leads the voltage by $\pi/2$ radians or 90°.

Hence in a pure capacitance current leads the voltages by an



The above diagram shown also reveals the same fact that voltage lagging current by 90° in capacitor.

capacitance opposes the change in voltage and serves to delay the increase or decrease of voltage across the capacitor. This causes the voltage to lag behind current.

capacitance not only causes the voltage lags behind current but it also limits the magnitude of current in the circuit.

$$I_m = \omega C V_m$$

$$\Rightarrow \frac{V_m}{I_m} = \frac{1}{\omega C}$$

$$\Rightarrow \frac{V_m}{I_m} = \frac{V_C}{I} = \frac{1}{\omega C} \Rightarrow V_C = \frac{1}{\omega C} I$$

$$\Rightarrow \boxed{V_C = X_C I}$$

clearly the opposition offered by capacitance to current flow in $1/\omega C$. This quantity $\frac{1}{\omega C}$ is called capacitive reactance X_C of the capacitor

$$\boxed{X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}} \; \Omega$$

instantaneous power $p = vi$

$$= V_m \sin\omega t \times I_m \sin(\omega t + \pi/2)$$

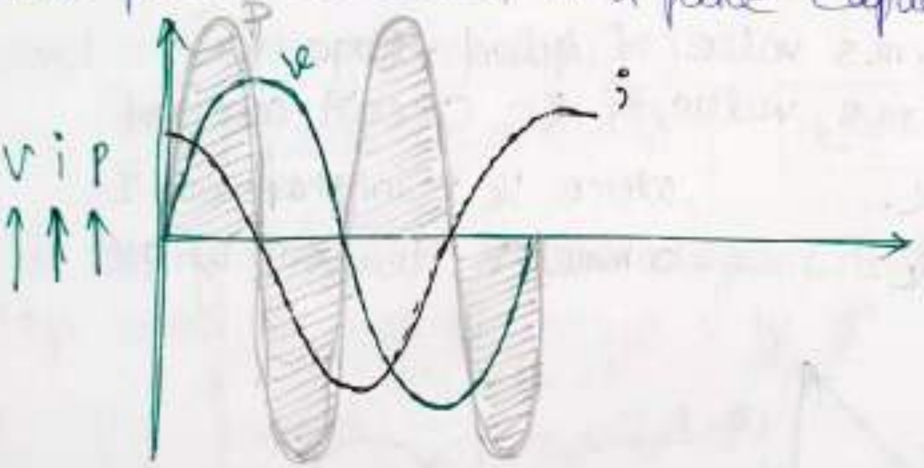
$$= V_m I_m \sin\omega t \cos\omega t$$

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

Average power P = Average of p over one cycle

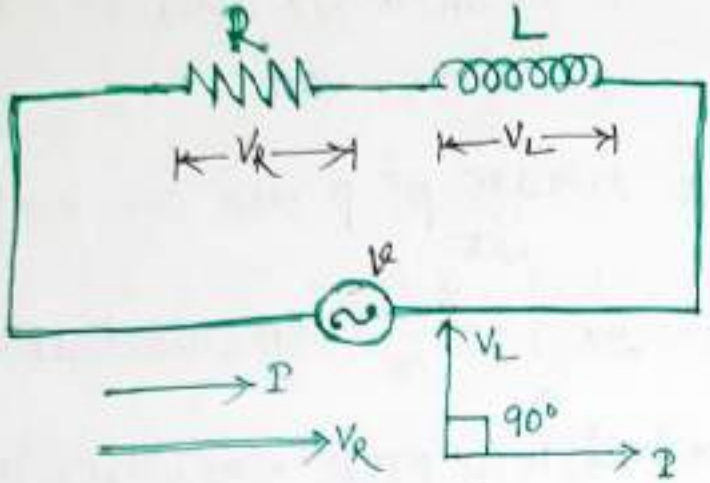
$$= \frac{1}{2\pi}\int_0^{2\pi} \frac{V_m I_m}{2} \sin 2\omega t \, d(\omega t) = 0$$

Hence power absorbed in a pure capacitance is zero.



It is clear that positive power is equal to the negative power over one cycle. Hence net power absorbed in a capacitor is zero.

AC through R-L Series Circuit :-

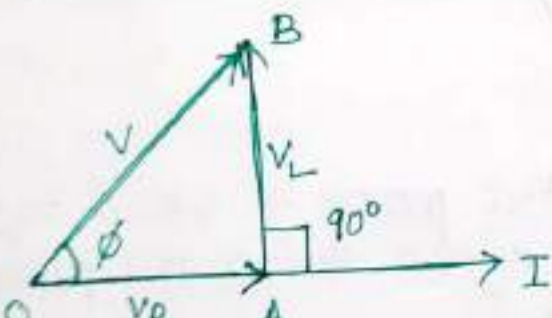


V = r.m.s value of Applied voltage.

I = r.m.s value of the circuit current

$V_R = IR$ .... where V_R is in phase with I

$V_L = IX_L$ .... where V_L leads I by 90°



taking current as the reference phasor, the phasor di of the circuit can be drawn as shown in fig.

The voltage drop V_R is in phase with current and is represen in magnitude and direction by the phasor OA.

The voltage drop V_L Leads the current by 90° and represented in magnitude and direction by the phasor

The applied voltage V is the phasor sum of these two drop

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

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

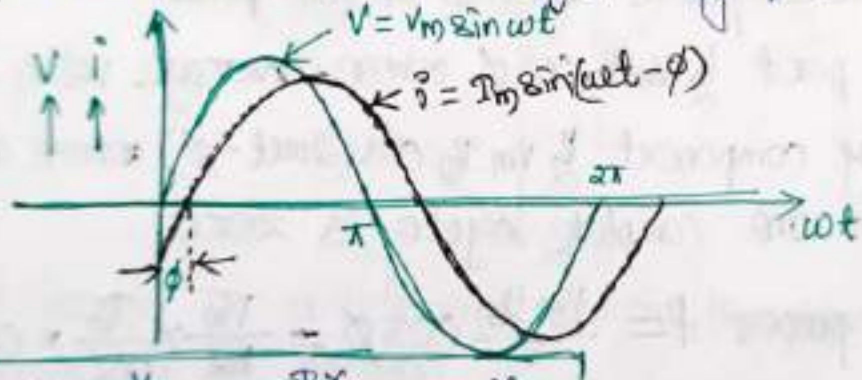
$$\Rightarrow V = I\sqrt{R^2 + X_L^2}$$

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

The quantity $\sqrt{R^2 + X_L^2}$ offers opposition to current flow, and is called impedance of the circuit. It is represented by Z and is measured in ohm (Ω).

$$I = V/Z \qquad Z = \sqrt{R^2 + X_L^2} \qquad X_L = 2\pi f L$$

It is clear from the phasor diagram that circuit current I lags behind the applied voltage V by $\phi°$.



$$\tan\phi = \frac{V_L}{V_R} = \frac{IX_L}{IR} = \frac{X_L}{R}$$

If the applied voltage $v = V_m \sin\omega t$

circuit current $i = I_m \sin(\omega t - \phi)$

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

In an inductive circuit, current lags behind the applied voltage.
The angle (ϕ) of lag is greater than 0° but less than 90°
It is determine by the ratio of inductive reactance to resistance in the circuit.
The greater the value of the ratio, the greater will be the phase angle ϕ.

Instantaneous power $p = vi = V_m \sin \omega t \times I_m \sin(\omega t - \phi)$

$$= \frac{1}{2} V_m I_m [2 \sin \omega t \sin(\omega t - \phi)]$$

$$= \frac{1}{2} V_m I_m [\cos\phi - \cos(2\omega t - \phi)]$$

$$= \frac{1}{2} V_m I_m \cos\phi - \frac{1}{2} V_m I_m \cos(2\omega t - \phi)$$

thus instantaneous power consists of two parts

(a) constant part $\frac{1}{2} V_m I_m \cos\phi$ whose average value is the

(b) A pulsating component $\frac{1}{2} V_m I_m \cos(2\omega t - \phi)$ whose average value over one complete cycle is zero.

so Average power $P = \frac{V_m I_m}{2} \cos\phi = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} \times \cos\phi$

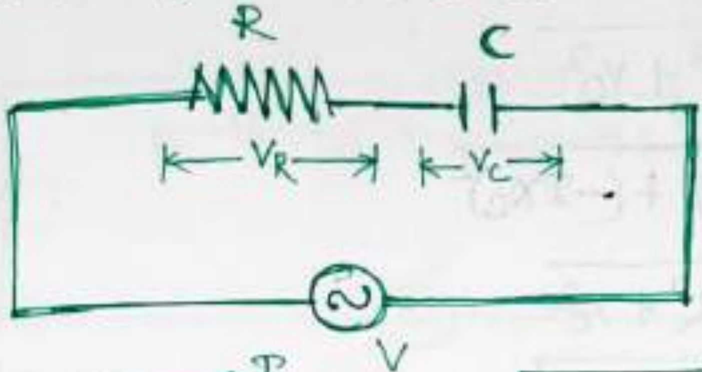
$$P = VI\cos\phi$$

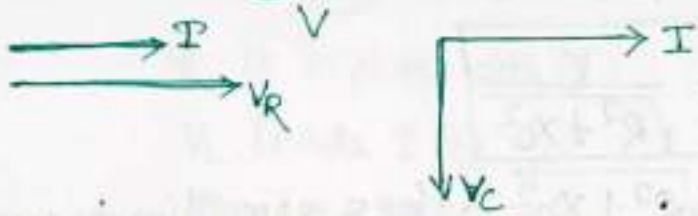
where V = rms value of voltage
I = rms value of current
$\cos\phi$ = power factor of the circuit

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

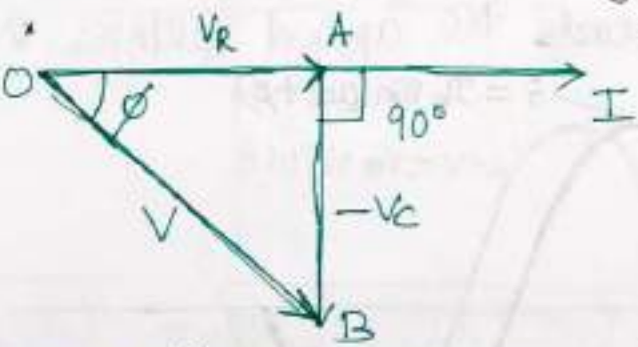
$$P = VI\cos\phi = (IZ) \times I \times R/Z = I^2 R$$

AC through R-C Series Circuit :-





V = r.m.s value of applied voltages
I = r.m.s value of the circuit current
$V_R = IR$ .... where V_R is in phase with I
$V_C = IX_C$ .... where V_C lags I by 90°.



Taking current as a reference phasor, the phasor diagram of the circuit can be drawn.

The voltage drop V_R is in phase with current and is represented in magnitude and direction by the phasor OA.

The voltage drop V_C lags behind the current by 90° and is represented in magnitude and direction by the phasor AB

The applied voltage V is the phasor sum of these two drops

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

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

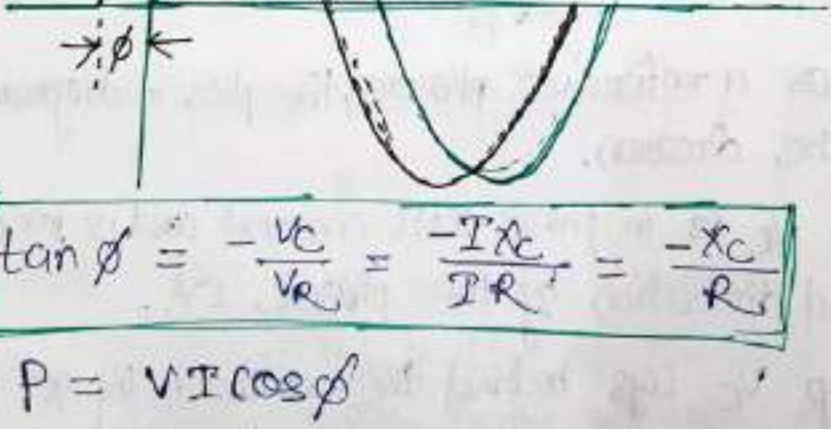
$$= I\sqrt{R^2 + X_C^2}$$

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

The quantity $\sqrt{R^2 + X_C^2}$ offers opposition to current flow and is called impedance of the circuit

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

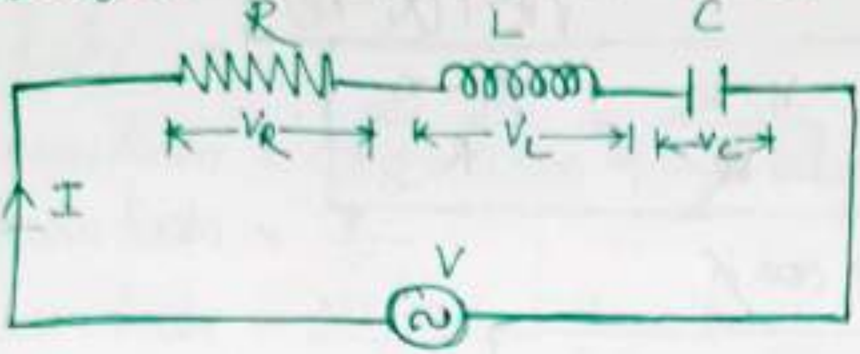
It is clear from the phasor diagram the circuit current I leads the applied voltage V by $\phi°$.



$$\boxed{\tan\phi = -\frac{V_C}{V_R} = \frac{-IX_C}{IR} = \frac{-X_C}{R}}$$

$$P = VI\cos\phi$$

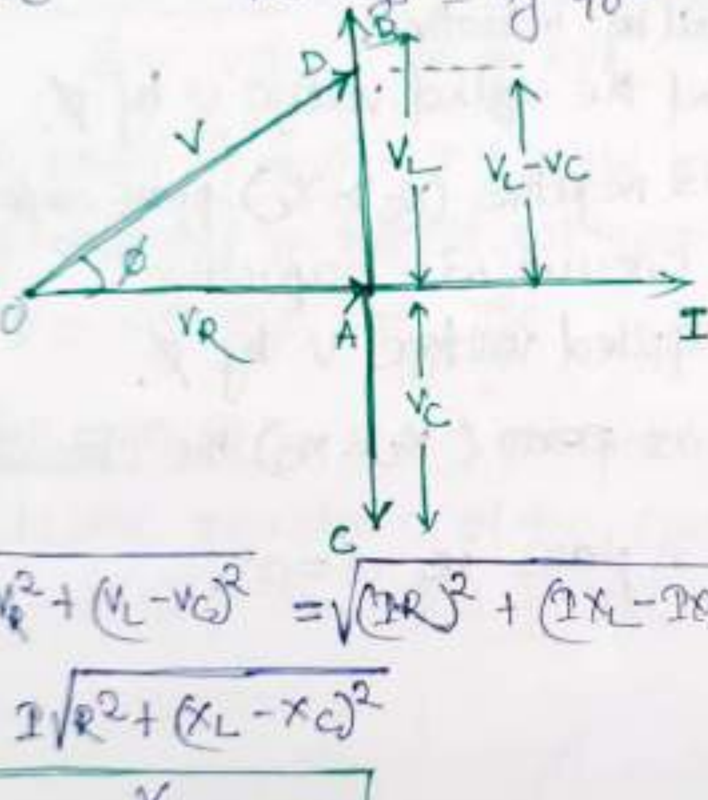
AC through R-L-C Series Circuit:-



$V_R = IR$ ...... V_R is in phase with I

$V_L = IX_L$ ...... V_L leads I by 90°

$V_C = IX_C$ ...... V_C lags I by 90°



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

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

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

The quantity $\sqrt{R^2 + (X_L - X_C)^2}$ offers opposition to current flow and is called impedance of the circuit

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

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

$$P = VI\cos\phi$$

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

(i) when $X_L - X_C$ is positive $(X_L > X_C)$, phase angle ϕ is po[sitive] and the circuit will be inductive.

I will lag behind the applied voltage V by ϕ.

(ii) when $X_L - X_C$ is negative $(X_C > X_L)$ phase angle ϕ is negative and the circuit wis capacitive

I leads the applied voltage V by ϕ.

(iii) when $X_L - X_C$ is zero $(X_L = X_C)$ the circuit is pu[rely] resitive.

I & V are in phase ie $\phi = 0°$.

Concept of Power and Power factor :-

Power factor :-

(i) Power factor $= \cos\phi =$ cosine of angle between V & I

(ii) power factor $= \frac{R}{Z}$

(iii) Power factor $= \frac{VI\cos\phi}{VI} = \frac{\text{true Power}}{\text{Apparent power}}$

power components :-

① Apparent Power (S) - It is the product of voltage & current

$$S = VI \quad VA \text{ or } KVA$$

② Active power (P or W) - It is the power which is actually dissipated in the circuit resistance

$$P = VI\cos\phi \text{ or } I^2R \quad \text{watt or KW}$$

③ Reactive power (Q) - It is the power developed in the inductive reactance of the circuit

$$Q = VI\sin\phi \text{ or } I^2X \quad \text{VAR or KVAR}$$

Difference between AC & DC :-

Alternating Current	Direct Current
① The current changes it magnitude and direction periodically	① The current which does not change its magnitude and direction periodically
② The direction of flow of electron is bidirectional	② The direction of flow of electron is unidirectional.
③ It has a frequency	③ It has a zero frequency
④ power factor lies between 0&1	④ power factor is always 1
⑤ Its passive parameter is impedance.	⑤ Its passive parameter is resistance
⑥ Source - AC Generator	⑥ source - DC generator, battery, solar cell.
⑦ It is represented by sine wave, square wave, triangular wave	⑦ It is represented by straight line
⑧ The load is resistive, Inductive, capacitive	⑧ The Load is resistive
⑨ Dangerous	⑨ very Dangerous
⑩ Converted into DC by rectifier	⑩ Converted into AC by Inverter
⑪ suitable for long distance transmission with minimal power loss	⑪ efficient for short distance transmission.
⑫ Application - Factories, Industries, domestic purposes	⑫ Application - Electroplating, Electrolysis, Electronic Equipment etc.

CH-3 Generation of Electrical Power

(1) Hydroelectric Power plant :-

A generating station which utilizes the potential energy of water at a high level for generation of electrical energy is known as hydro electric power station.

water is stored in dam by using rain water. This stored energy contains potential energy due to height or head of dam when this water is flow towards turbine, at that time the kinetic energy is converted into mechanical energy. The turbine or prime mover is mechanically coupled with generator. whenever turbine starts to rotate with the help of high pressure water, automatically generator starts to rotate & it produced an electrical energy.

selection of site for hydro-Electric power plant -

(1) Quantity of water Required — Hydro electric power plant totally rely on water, so that ample quantity of water is continuously available throughout the year.

(2) Hilly Area Required — For storage of ample quantity of water, both side of dam hilly area or strong mountains required for storage of water.

(3) Civil work - It should have strong foundation or the cost of foundation should be as low as possible.

(4) Large catchment Area - Large catchment area required so that the water in it should never fall below the minimum level.

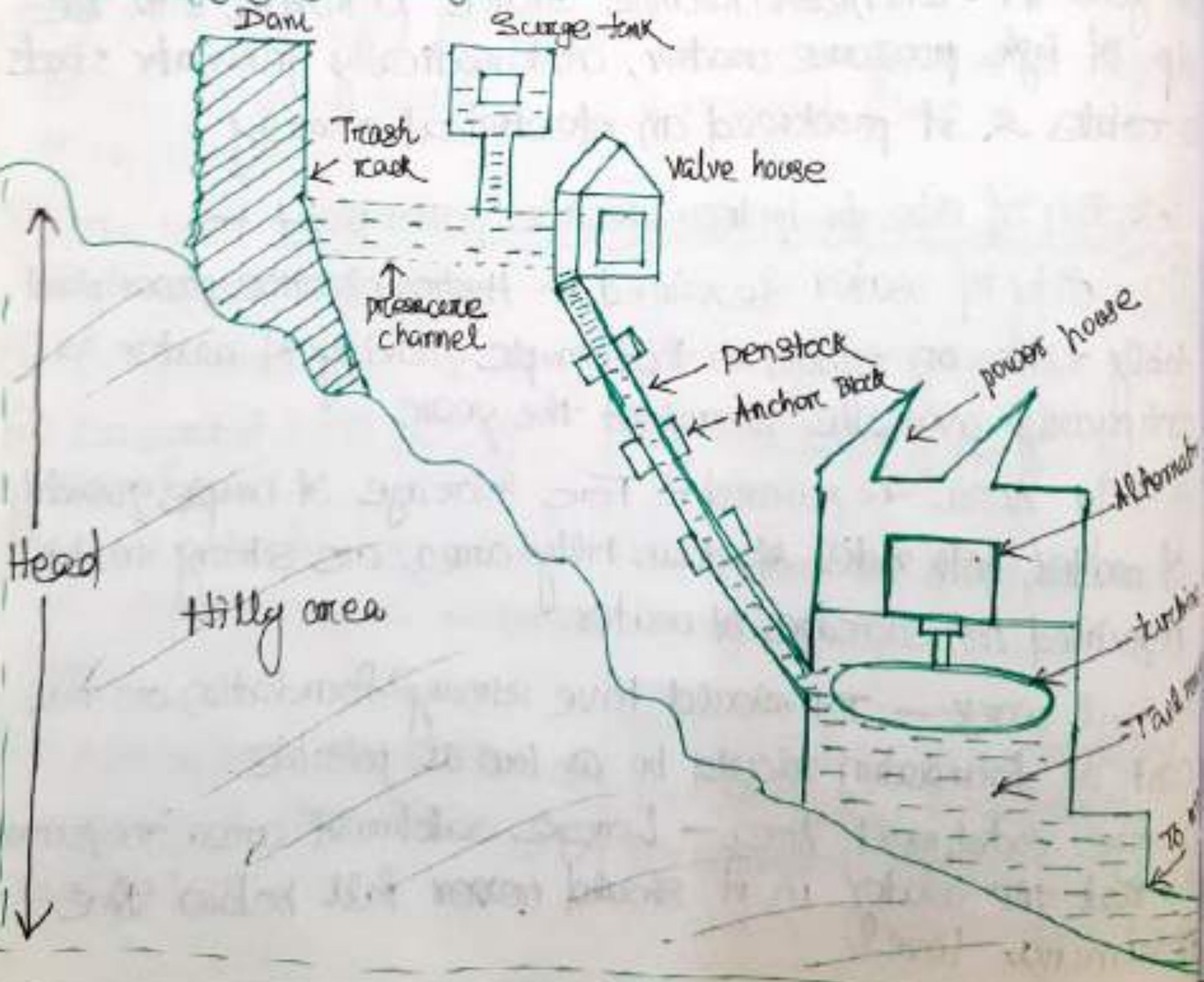
⑤ Transportation Facility – For workers & civil materials required better transportation facility

⑥ Near to Load Centre – To reduce cost of transmission & Distribution the plant should be located near to load centre.

⑦ Availability of Material – At the time of erecting the dam & power house a huge amount of civil materials is easily available without any shortage.

⑧ Future Expansion – For increasing MW capacity of plant the space is available for future expansion.

schematic arrangement –



① Catchment area – In hydro power plant collect the rain water through surrounding hilly area, the surrounding all water collect & stored area to those place is known as catchment area.

② Reservoir – The function of reservoir is to store the water near dam; this water is useful to drive the water turbines the reservoir is useful to provide a head of stored water.

③ Head Race level – The water surface in the reservoir up to the dam is known as head-race level

④ Dam – the dam is used in hydro electric power plant to store the water. whenever the dam stored the water, it provides suitable head to the stored water. This stored water is useful throughout the year to run the hydro electric power plant. Dam is made up of cement, concrete and sand materials.

⑤ Spill way – The excess water from dam is discharges through spillway at a permissible level.

⑥ Penstock – It is the device which is used in hydro electric power plant for the purpose of flow of water. The water flow of from dam towards turbine with the help of penstock.

⑦ Surge tank – It is a device which is connected in between dam and power house. It is of vertical type. when load on power plant or alternator decreases then Governor reduces discharge of water. Due to sudden reduction in water discharge causes increase in pressure of the water in the penstock. Due to high pressure penstock may damage. at this ti[me]
surge tank helps by storing the rejected water immediately

③ Generator – It is used to convert the mechanical energy. For that purpose the turbine & generator are mechanically coupled.

Advantages –

① It requires no fuel as water is used for the generation of Electrical energy.
② It is quite neat & clean as no smoke or ash is produced.
③ Running cost is very less as water is used.
④ It is simple in construction & requires less maintenance.
⑤ In addition to generation of Electrical energy these plants are also helpful in irrigation & control of floods.

Disadvantages –

① It involves high capital cost due to construction of dams
② Generation depends on average rainfall round the year.
③ High cost of transmission as these plants are located in hilly areas quite far off from localities.

Hydro electric power station in India –

① Hirakud – Burla – 347.5 MW
② Chiplima – Sambalpur – 123 MW
③ Rengali – Angul – 250 MW
④ Upper kolab – Koraput – 320 MW
⑤ Upper Indravati – Bhawanipatna – 600 MW
} Odisha

⑥ Tehri – Uttarakhand – 2400 MW
⑦ Koyna – Maharastra – 1960 MW
⑧ Sri Sailam Dam – 1670 MW
⑨ Nathpa Jhakri Dam – 1530 MW

Sardar Sarovar Dam – Gujarat – 1450 MW
Bhakra Dam – Himachal pradesh – 1325 MW
Chamera – Himachal prad[illegible]

(2) Thermal power plant :-

A generating station which converts heat energy of coal combustion in to electrical energy is known as thermal power plant or steam power plant.

steam is produced in the boiler by utilising the heat of coal combustion, The steam is then expanded in the prime mover and is condensed in a condenser to be fed into the boiler gain. The steam turbine drives the alternator which converts mechanical energy of the turbine in to electrical energy. This type of power section is suitable where coal and water are available in abundance and a large amount of electric power is to be generated.

choice of site for steam power stations -

(1) supply of fuel - The steam power station should be located near the coal mines so that transportation cost of fuel is minimum. However if such a plant is to be installed at a place where coal is not available, then care should be taken that adequate facilities exist for the transportation of coal.

(2) ~~supply~~ Availability of water - As huge amount of water is requires for the condenser, therefore, such a plant should be located at the bank of a river or near a canal to ensure the continuous supply of water.

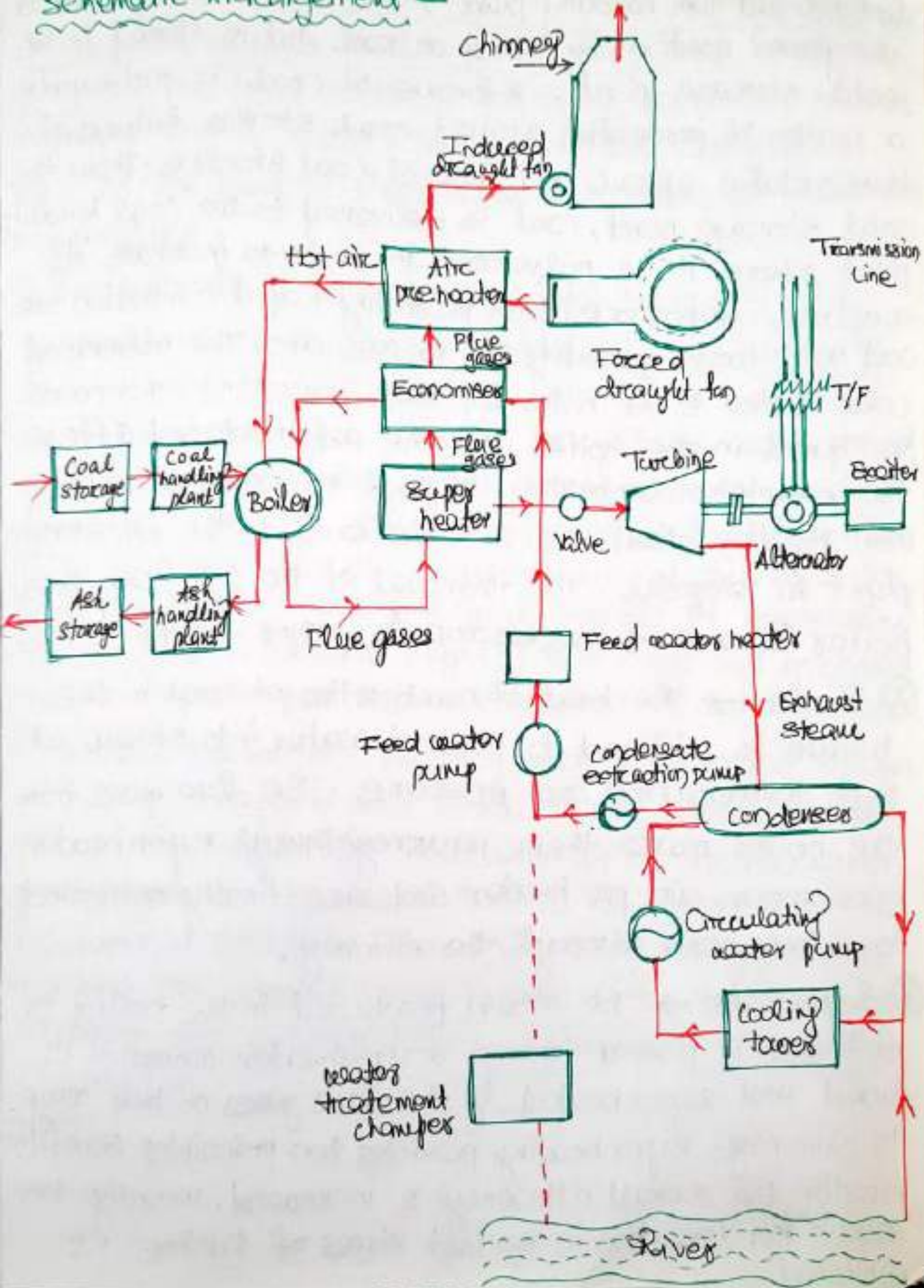
(3) Transportation facilities - A moden steam power station often requires the transportation of material and machinery therefore adequate transportation facilities must exist i.e the plant should be well connected to other parts of country by rail, road etc.

(4) Cost and type of land – The steam power station should located at a place where land is cheap and further extention, if necessary, is possible. Moreover the bearing capacity of the ground should be adequate so that heavy equipment could be installed.

(5) Nearness to load centres – In order to reduce the transmission cost, the plant should be located near the centre of the load. This is particularly important if d.c supply system is adopted. However if a.c supply system is adopted this factor becomes relatively less important. It is because a.c. power can be transmitted at high voltages with consequent reduced transmission cost. Therefore it is possible to install the plant away from the load centre provided other conditions are favourable.

(6) Distance from populated area – As huge amount of coal is burnt in a steam power station therefore, smoke and fumes pollute the surrounding area. This necessitate that the plant should be located at a considerable distance from the populated area.

Schematic Arrangement —



① Coal and ash handling plant → The coal is transported to the power station by road or rail and is stored in the coal storage plant. Storage of coal is primarily a matter of protection against coal strikes, failure of transportation system and general coal shortage. From the coal storage plant, coal is delivered to the coal handling plant where it is pulverised in order to increase its surface exposure, thus promoting rapid combustion without using large quantity of excess air. The pulverised coal is fed to the boiler by belt conveyors. The coal is burnt in the boiler and the ash produced after the complete combustion of coal is removed to the ash handling plant and then delivered to the ash storage plant for disposal. The removal of the ash from the boiler furnace is necessary for proper burning of coal.

② Boiler → The heat of combustion of coal in the boiler is utilised to convert water into steam at high temperature and pressure. The flue gases from the boiler makes their journey through super heater, economiser, air pre heater and are finally exhausted to atmosphere through the chimney.

③ Superheater → The steam produced in the boiler is wet and is passed through a superheater where it is dried and super heated by the flue gases on their way to chimney. Super heating provides two principles benefits. Firstly the overall efficiency is increased. Secondly too much condensation in the last stages of turbine is avoided.

(4) Economiser → An economiser is essentially a feed water heater and derives heat from the flue gases for this purpose. The feed water is fed to the economiser before supplying to the boiler. The economiser extracts a part of the heat of flue gases to increase the feed water temperature.

(5) Air preheater → An air preheater increases the temperature of the air supplied for coal burning by deriving heat from flue gases. Air is drawn from the atmosphere by a forced draught fan and is passed through air preheater before supplying to the boiler furnace. The air pre heater extracts heat from flue gases and increases the temperature of air used for coal combustion. The principal benefits of preheating the air are increased thermal efficiency and increased steam capacity per square metre of boiler surface.

(6) Steam turbine ⇒ The dry and superheated steam from the superheater is fed to the steam turbine through main valve. The heat energy of steam when passing over the blades of turbine is converted into mechanical energy. After giving heat energy to the turbine, the steam is exhausted to the condenser which condenses the exhausted steam by means of cold water circulation.

(7) Alternator → The steam turbine is coupled to an alternator. The alternator converts mechanical energy of turbine into electrical energy.

(8) Feed water → The condensate from the condenser is used as feed water to the boiler. Some water may be lost in the cycle which is suitably made up from external source. The feed water on its way to the boiler is heated by water heaters and economiser. This helps in raising the overall efficiency of the plant.

(9) Cooling arrangement → In order to improve the efficiency of the plant the steam exhausted from the turbine is condensed by means of a condenser. Water is drawn from a natural source of supply such as a river canal or lake and is circulated through the condenser. The circulating water takes up the heat of the exhausted steam and itself becomes hot. This hot water coming out from the condenser is discharged at a suitable location down the river in case the availability of water from the source of supply is not assured throughout the year cooling towers are used. During the scarcity of water in the river, hot water from the condenser is passed on to the cooling towers where it is cooled the cold water from the cooling tower is reused in the condenser.

Advantages -

(i) The fuel used is quite cheap
(ii) Less initial cost as compared to other generating stations
(iii) It can be installed at any place irrespective of the existence of coal. The coal can be transported to the site of the plant by rail or road.
(iv) It requires less space as compared to the hydroelectric power station.
(v) The cost of generation is lesser than that of other power station.

Disadvantages -

(i) It pollutes the atmosphere due to the production of large amount of smoke and fumes.
(ii) It is costlier in running cost as compared to hydroelectric plant.

Thermal power plant in India -

① NTPC talcher - Angul → 3000 MW
② Ib thermal - Jharsuguda → 1740 MW
} odisha

① Vindhyachal TPS → MP → 4760 MW
② Mundra TPS → Gujarat → 4620 MW
③ Sasan Ultra Mega power plant → MP → 3960 MW
④ Tiroda thermal power plant → Maharastra → 3300 MW
⑤ Rihand thermal power station → UP → 3000 MW
⑥ Sipat thermal power plant → Chhattisgarh → 2980 MW
⑦ Chandrapur super thermal power station → Maharashtra → 2920 MW
⑧ NTPC Dadri → UP → 2637 MW

(3) Nuclear Power plant :-

A generating station in which nuclear energy is converted into electrical energy is known as a nuclear power station.

In nuclear power station heavy elements such as Uranium (U^{235}) or thorium (Th^{232}) are subjected to nuclear fission in a special apparatus known as reactor. The heat energy thus released is utilised in raising steam at high temperature and pressure. The steam runs the steam turbine which converts steam energy into mechanical energy. The turbine drives the alternator which converts mechanical energy into electrical energy.

The most important feature of a nuclear power station is that huge amount of electrical energy can be produced from a relatively small amount of nuclear fuel as compared to other conventional types of power stations.

Choise of site for Nuclear power station -

(1) Availability of water — As sufficient water is required for cooling purpose therefore the plant site should be located where ample quantity of water is available.

(2) Disposal of waste — The waste produced by fission in a nuclear power station is generally radioactive which must be disposed off properly to avoid health hazard. The waste should either be buried in a deep trench

are disposed off in sea quite away from the sea shore, therefore, the site selected for such a plant should have adequate arrangement for the disposal of radioactive waste.

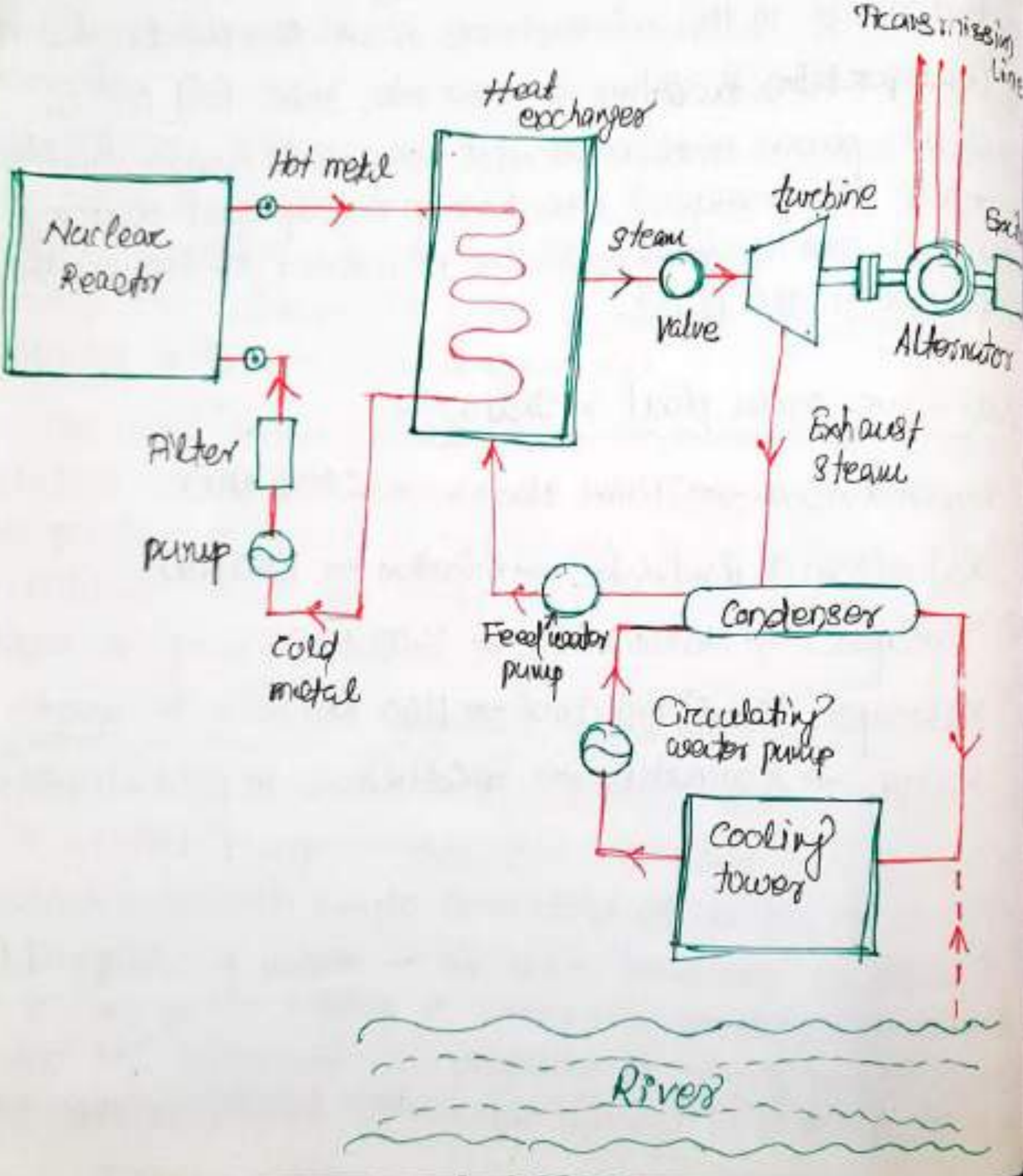
(3) Distance from populated areas → The site selected for a nuclear power station should be quite away from the populated areas as there is a danger of presence of radioactivity in the atmosphere near the plant.

(4) Transportation facilities → The site selected for a nuclear power station should have adequate facilities in order to transport the heavy equipment during erection and to facilitate the movement of the workers employed in the plant.

Nuclear power plant in India :-

(1) Kudankulam → Tamil Nadu → 2000 MW
(2) Rajasthan (Bulandshahr) → Rajasthan → 1080 MW
(3) Tarapur → Maharashtra → 1400 MW
(4) Kakrapar (Surat) → Gujarat → 1140 MW
(5) Kaiga → Karnataka → 880 MW

Schematic arrangement of Nuclear power station -



(i) Nuclear reactor — It is an apparatus in which nuclear fuel is subjected to nuclear fission. It controls the chain reaction that starts once the fission is done. if the chain reaction is not controlled, the result will be an explosion due to the fast increase in the energy released.

(ii) Heat exchanger — The coolant gives up heat to the heat exchanger which is utilised in raising the steam. After giving up heat, the coolant is again fed to the reactor.

(iii) Steam turbine — The steam produced in the heat exchanger is led to the steam turbine through a value. After doing a useful work in the turbine, the steam is exhausted to condenser. The condenser condenses the steam which is fed to the heat exchanger through feed water pump.

(iv) Alternator — The steam turbine drives the alternator which converts mechanical energy into electrical energy. The output from the alternator is delivered to the bus bars through transformer, circuit breaker and isolaters.

Advantages —

(i) The amount of fuel required is quite small. Therefore, there is a considerable saving in the cost of fuel transportation.

(ii) A nuclear power plant requires less space as compared to any other type of the same size.

(iii) It has low running charges as a small amount of fuel is used for producing bulk electrical energy.

(iv) This type of plant is very economical for producing bulk electric power.

(v) The cost of primary distribution is reduced.

(vi) Continued supply of electrical energy for many years.

(vii) It ensures reliability of operation.

Disadvantages —

(i) The fuel used is expensive and is difficult to recover.

(ii) The capital cost is very high.

(iii) The erection and commissioning of the plant requires greater techical know-how.

(iv) It produces dangerous amount of radioactive pollution.

CH-4

Conversion of Electrical Energy

Introduction:-

* A DC Machine is a device which converts mechanical energy to electrical energy or Electrical energy to mechanical energy.

* When the device acts as generator mechanical energy is converted into electrical energy.

* When the device acts as motor electrical energy is converted into Mechanical energy.

Classification of Electrical Machine By Constructional Features:-

Electrical Machines may be classified by constructional features and their sub division into power output ranges and speed ranges.

Electrical Machine as per their power output

(i) Small Size Machine - up to 0.6 KW

(ii) Medium Size Machine - 0.6 KW to 250 KW

(iii) Large Size Machine - 250 KW to 5000 KW

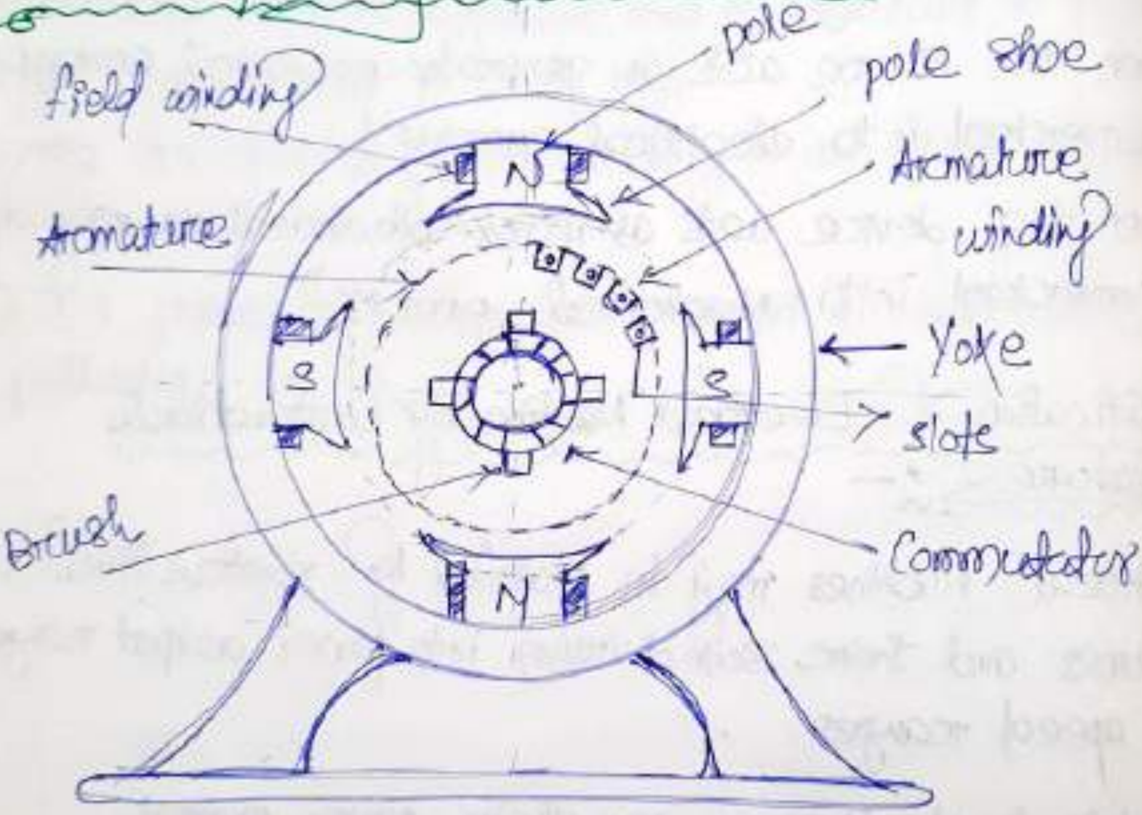
Electrical Machines as per their operating speed

(i) Low Speed Machines - 250 to 400 rpm

(ii) Medium speed Machines - 400 rpm to 1500 rpm

(iii) High speed Machines - speed more then 1500 rpm

Main parts of DC Machines :-



(Different parts of DC Machine)

① Yoke → Purpose of yoke is

(a) It acts as protecting cover for whole Machine

(b) It also provides mechanical supports for poles

(c) It carries the magnetic flux produced by poles.

② Pole shoes → purpose of pole shoes

(a) They ~~spread~~ Spread out the flux in the air gap

(b) They support the exciting coils

③ Field winding → The field winding is wound on the pole core with a definite direction.

Function of field winding is to carry current due to which pole core on which the winding is placed behaves as an electromagnet, producing necessary flux.

④ Armature Core → Armature core is cylindrical in shape mounted on the shaft.

Function of armature core is

(a) Armature core provides house for armature winding i.e armature conductors

(b) To provide a path of low reluctance path to the flux

It is made up of magnetic material like cast iron or cast steel.

⑤ Armature winding → Armature winding is the inter connection of the armature conductors placed in the slots provided on the armature core.

Function of Armature conductor

(a) Generation of emf takes place in the armature winding in case of generators.

(b) To carry the current supplied in case of dc motors.

(c) To do the useful work in the external Circuit

⑥ Commutator → The function of commutator is to facilitate collection of current from the armature conductors and converts the alternating current induced in the armature conductors into unidirectional current in the external load circuit.

The commutator is made up of insulated copper segment.

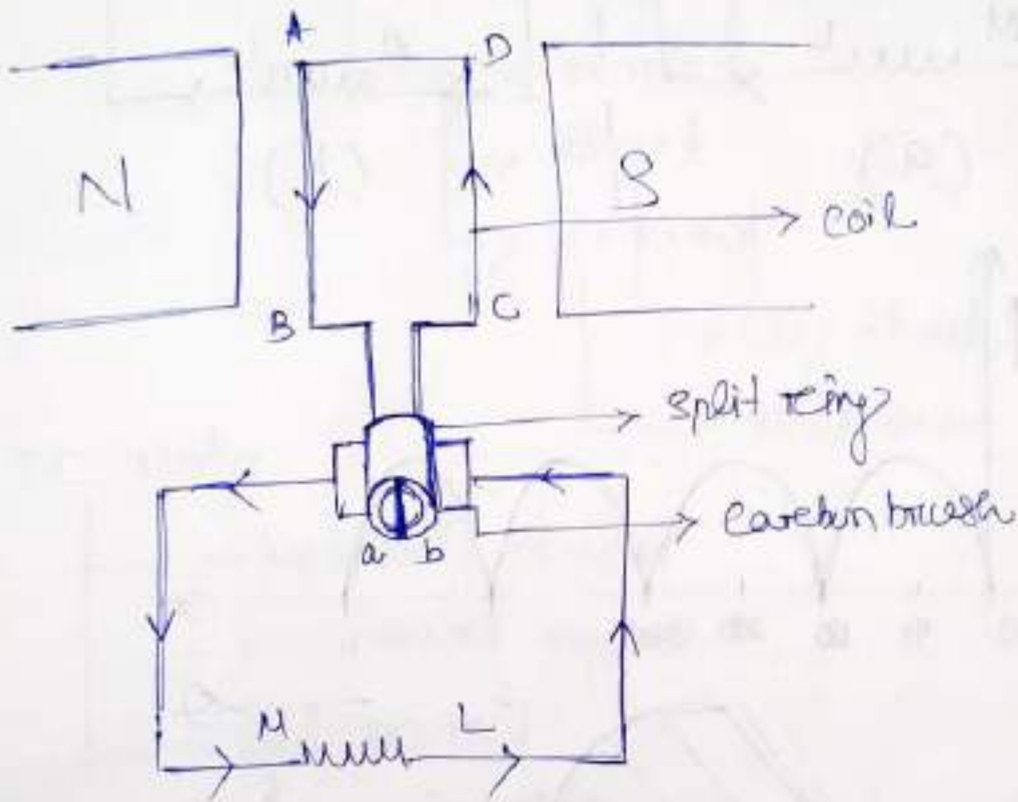
purpose of commutator

(a) It provides the electrical connection between the rotating armature coils and the stationary external circuit

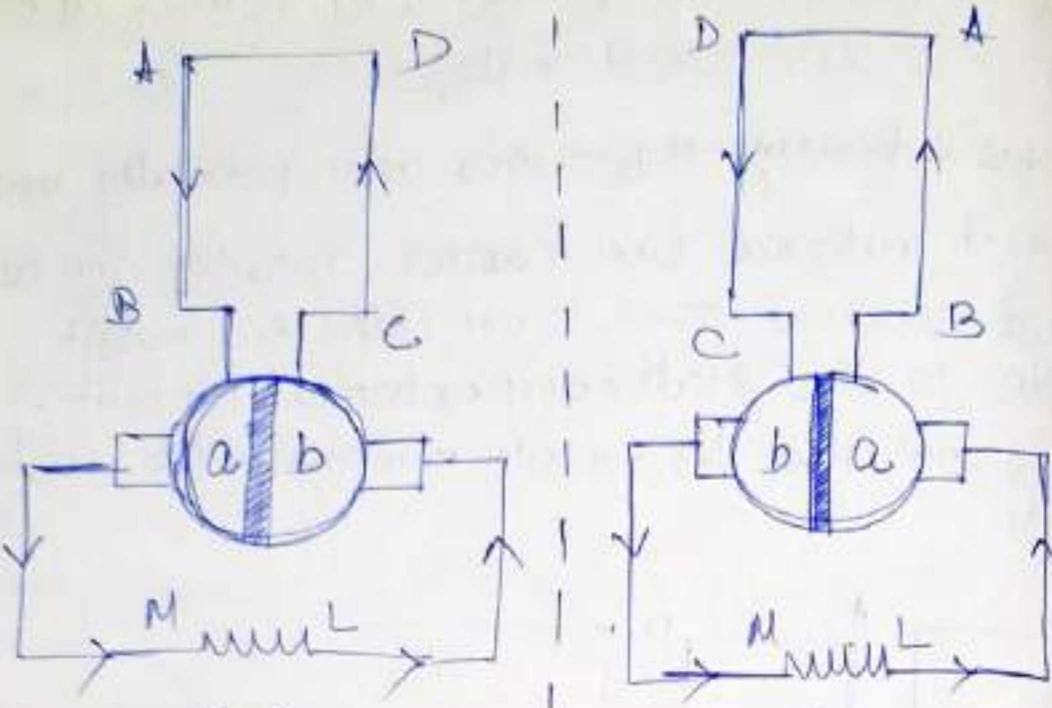
(b) It keeps the rotor or armature mmf stationary in space

(c) It performs switching action reversing the electrical connection between the external circuit and each armature coil in turn so that the armature coil voltages add together and result in a dc output voltage

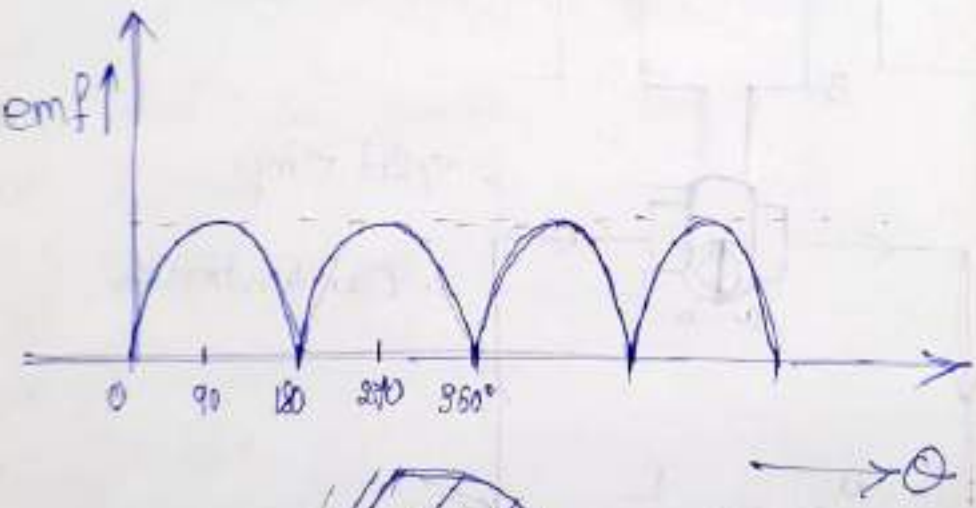
(7) Brushes & Bearing → Brushes are normally made up of soft material like carbon. Brushes are used to collect current from commutator and make it available to the stationary external circuit.
Bearing are used for smooth running of the machine

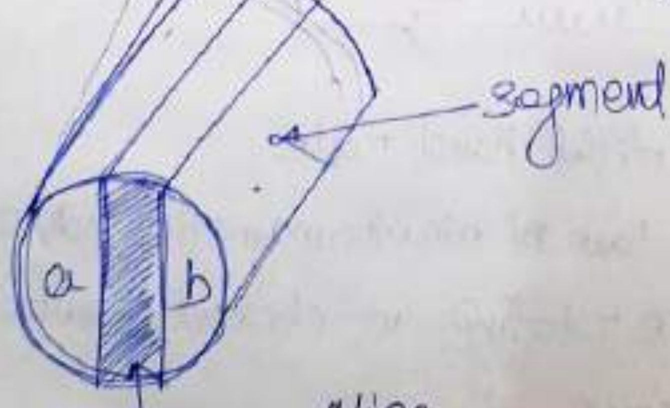


→ Flemings right hand rule
→ Faradays law of electromagnetic induction
→ armature rotating in clockwise direction
→ split rings



(a) (b)





Classification of DC Generator & DC Motors :-

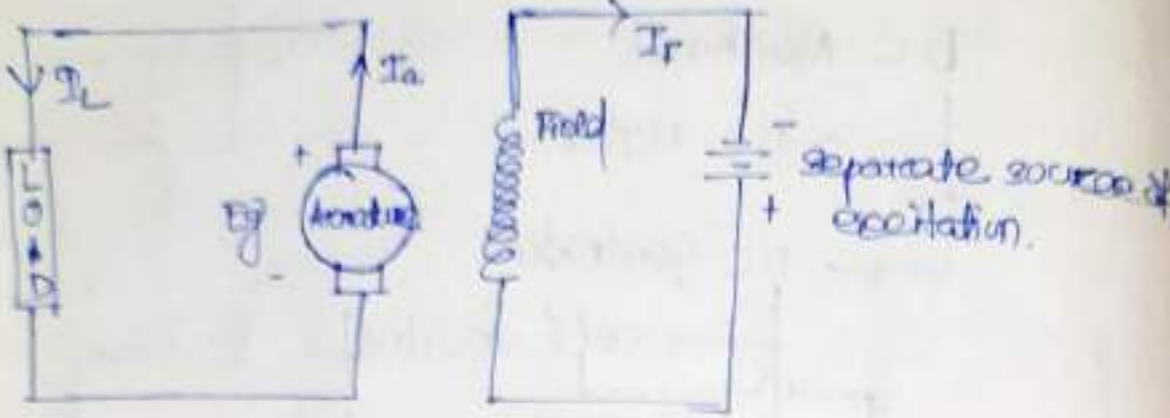
6

DC Machine
- DC Motor
- DC Generator
  - self excited
    - series
    - Shunt
    - Compound
      - Long Shunt
      - Short Shunt
  - Separately excited

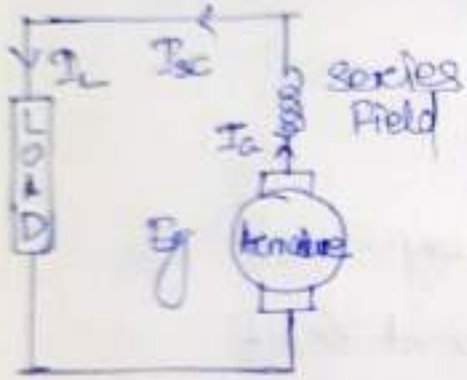
DC Motor
- Separately excited
- permanent magnet
- self excited
  - series
  - Shunt
  - Compound
    - Long shunt
    - Short Shunt

D.C. Generator :-

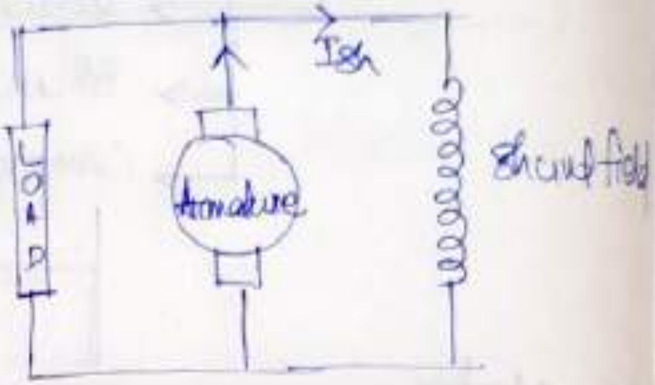
Separately Excited :-



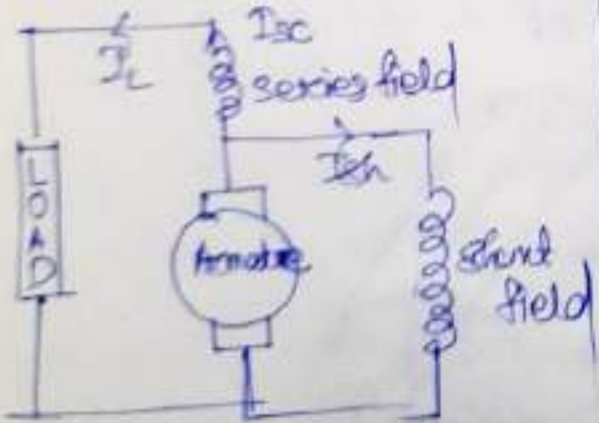
Series wound :-



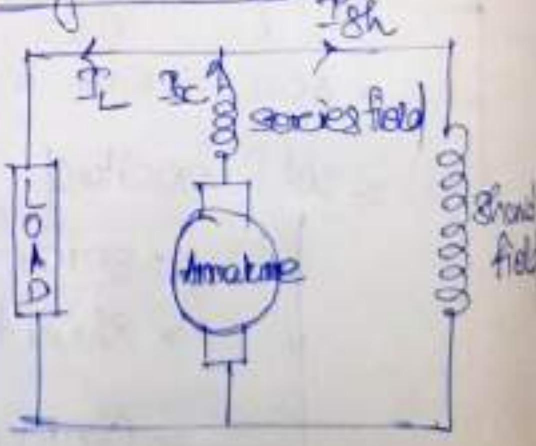
Shunt wound :-



Short Shunt :-

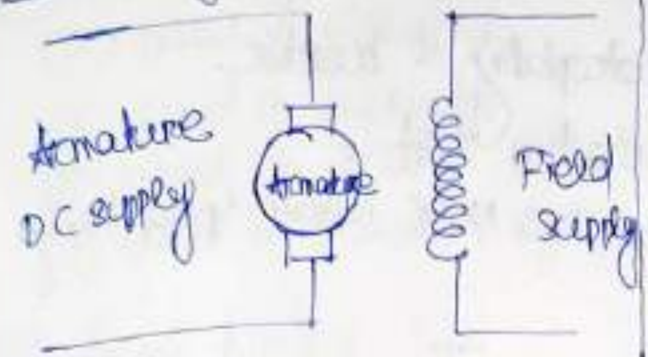


Long Shunt :-

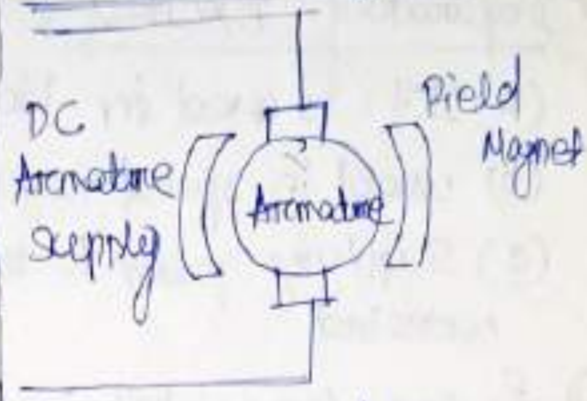


DC Motors :-

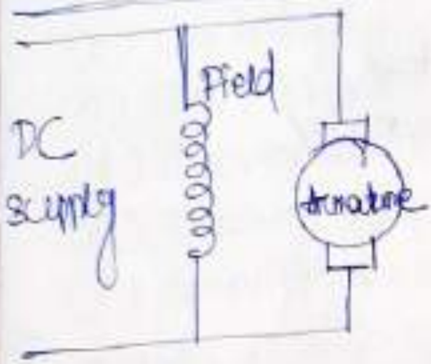
separately excited :-



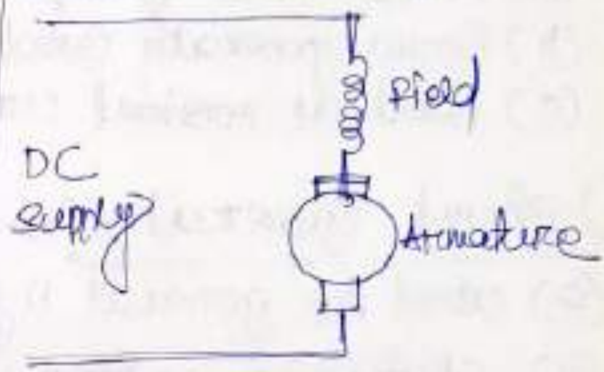
permanent Magnet :-



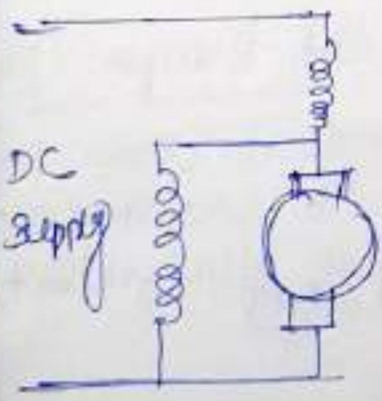
Shunt wound :-



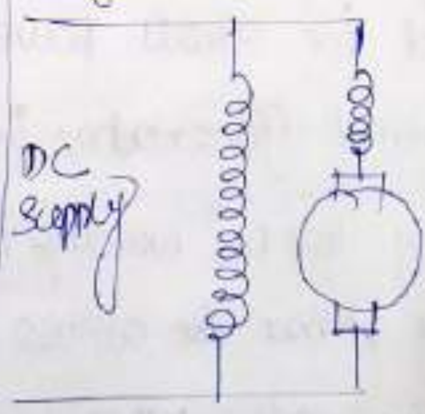
Series wound :-



Short Shunt :-



Long Shunt :-



Uses of DC Generator :→

(1) Separately Excited :→

(a) It is used for Electroplating & booster

(b) used in speed regulation test

(c) supplying power to the DC Motor whose speed being controlled

(2) Series Generator :→

(a) series ARC lighting

(b) Series generator used for booster

(c) used as constant current generator

(3) Shunt Generator :→

(a) used for general lighting

(b) chargeing battery

(c) Giving excitation to Alternator

(d) used for small power supply

(4) Compound Generator :→

(a) supply to DC welding Machines

(b) supply power for offices, hotels & Lodges

(c) Rolling mills, punches, Elevators.

(c) used for driving motor.

Uses of DC Motors :→

(1) Separately excited :→

(a) used in industry
(b) used in actuator
(c) used in train
(d) used in traction system

(2) Shunt Motor :→

(a) Lathe Machines
(b) centrifugal pumps
(c) Fan, Blowers
(d) conveyors, Lifts
(e) weaving Machine
(f) Spinning Machines

(3) Series Motor :→

Cranes, Air compressor, Lifts, Elevators, Electric traction, Hair driers, sewing machine

(4) Compound Motor :→

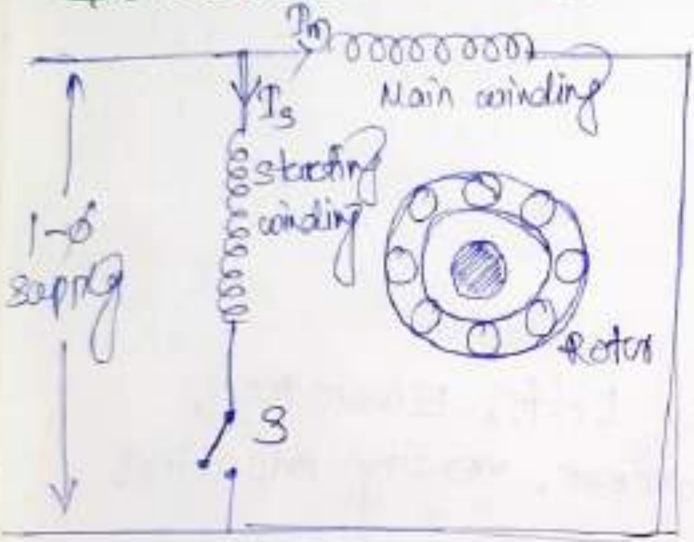
presses, Electric shovels, Reciprocating machine, conveyors, stamping Machine, Elevators, compressors, Rolling Mills, Heavy planners.

Types of single phase Induction Motor :-

And uses of I.M

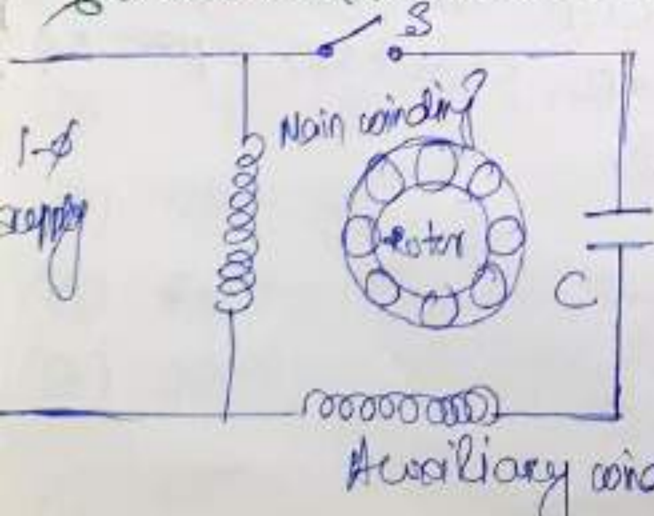
1. Split phase Motor
2. Capacitor start Motor
3. Capacitor start Capacitor run motor
4. Shaded pole Motor
5. Repulsion Motor.

(1) Split phase Motor :-



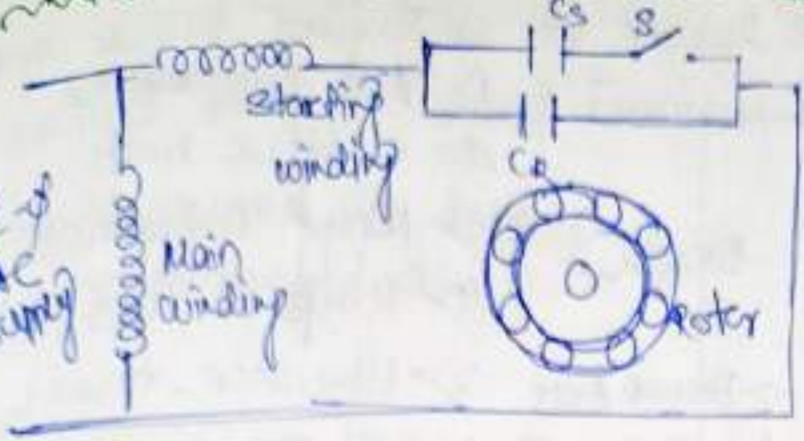
Application
- → Fans
- → Blowers
- → washing Machines
- → Grinders
- → Air conditioning fans

(2) Capacitor start Motor :-



Application
- → Compressor
- → Pumps
- → refrigerators
- → Air conditioner

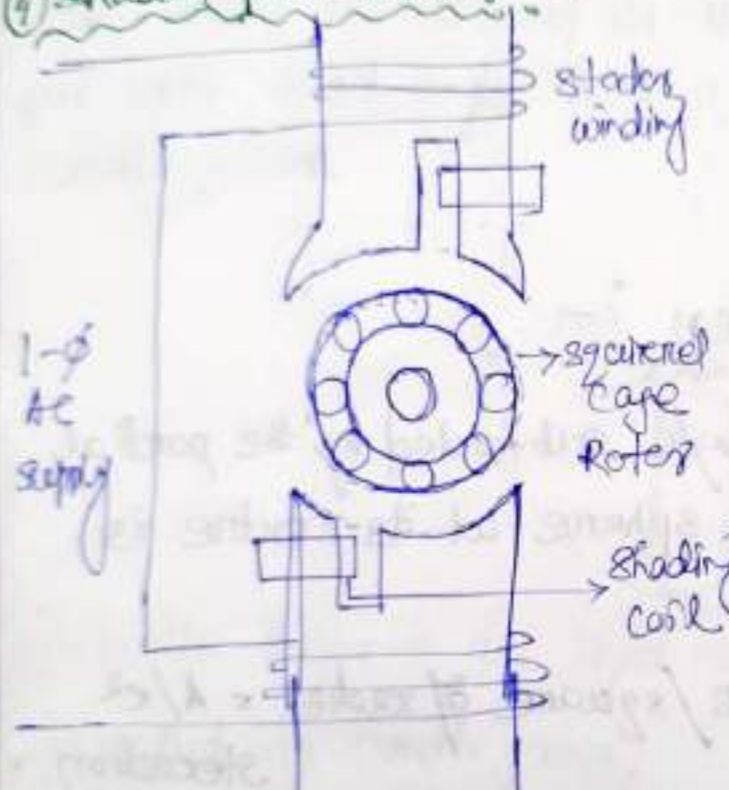
(3) Capacitor start Capacitor run Motors :-



Application

→ Compressor of Air conditioner
→ water cooler
→ Refrigerators

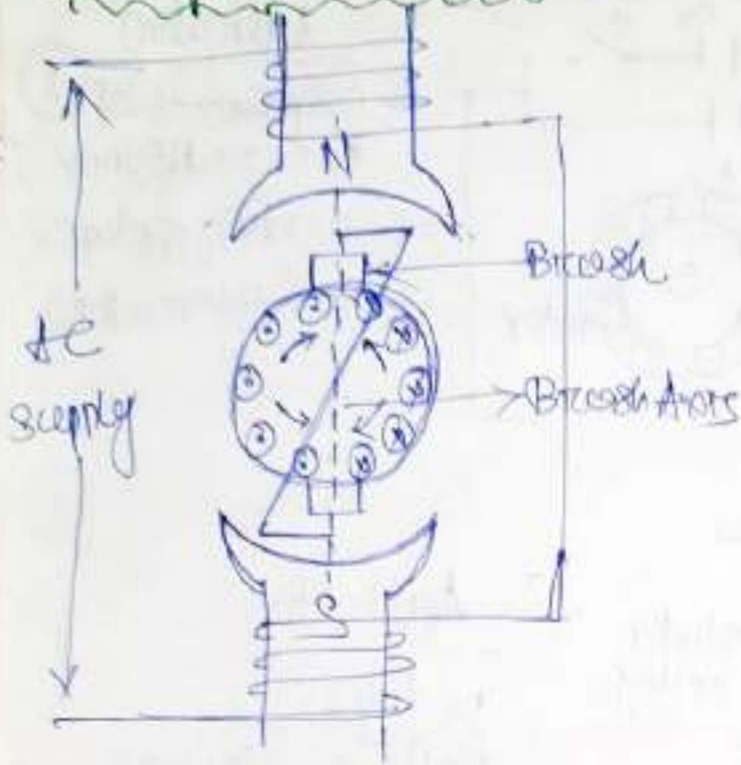
(4) Shaded pole Motor :-



Application

1> toys
2> Hair dryers
3> Desk fans
4> cooling fans
5> slide projectors
6> Advertising displays
7> Air conditioners.

(5) Repulsion Motor :-



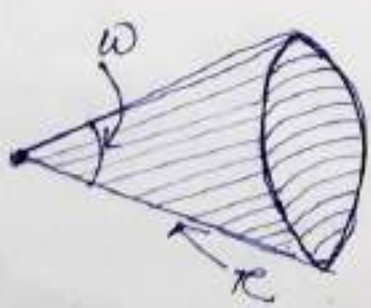
Application

1> Air compressors
2> Lifts & hoists
3> Mining Industries
4> Pumps & fans
5> Electric trains

Concept of Lumen :-

(1) Solid Angle → The angle subtended by the partial surface area of a sphere at its centre is called solid Angle

ω = area of surface / square of radius = A/r^2 steradian.



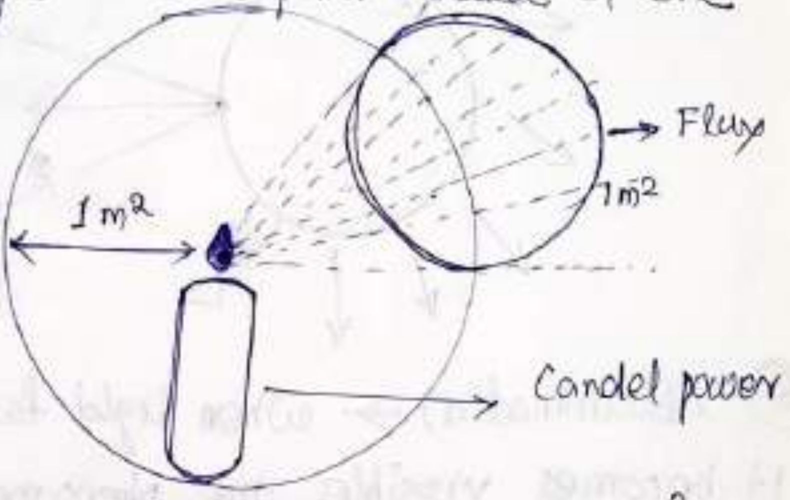
② Laminces flays → The total quantity of radiant energy per second responsible for visual sensation from a luminces body is called luminces flays.

→ Measured in lumen

→ represented as F or ϕ

③ Lumen → It is the unit of laminaces flays

one lumen is defined as the laminaces flays emitted per unit solid angle from a point source of one candle power.



④ Candle Power → The light radiating capacity of a source is called its candle power.

The number of lumens given out by a source per unit solid angle in a given direction is called its candle power.

★ It is denoted by CP

★ Total flays emitted or lumen = CP × solid angle

= 1 × 4π = 4π lumens

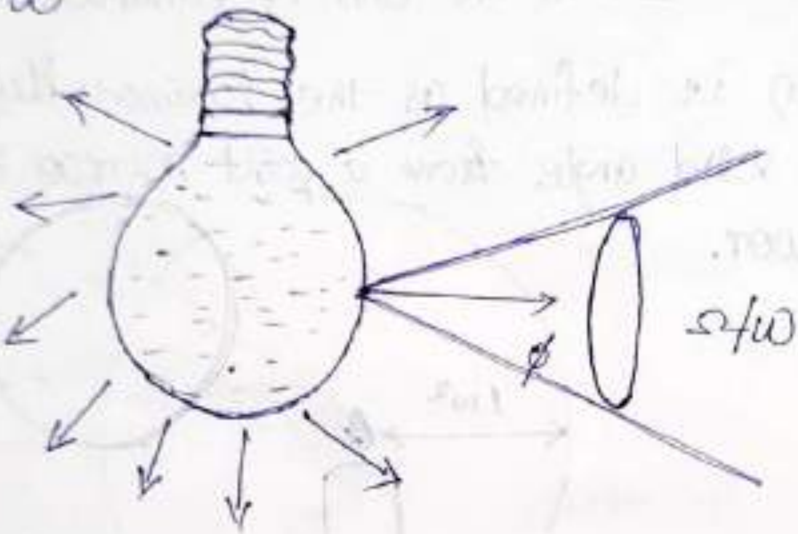
(5) Luminous Intensity → Luminous intensity in any particular direction is the luminous flux emitted by the source per unit solid angle in that direction.

→ It is denoted by I

→ Unit is candela or candle power

→ Luminous intensity of source in a particular direction

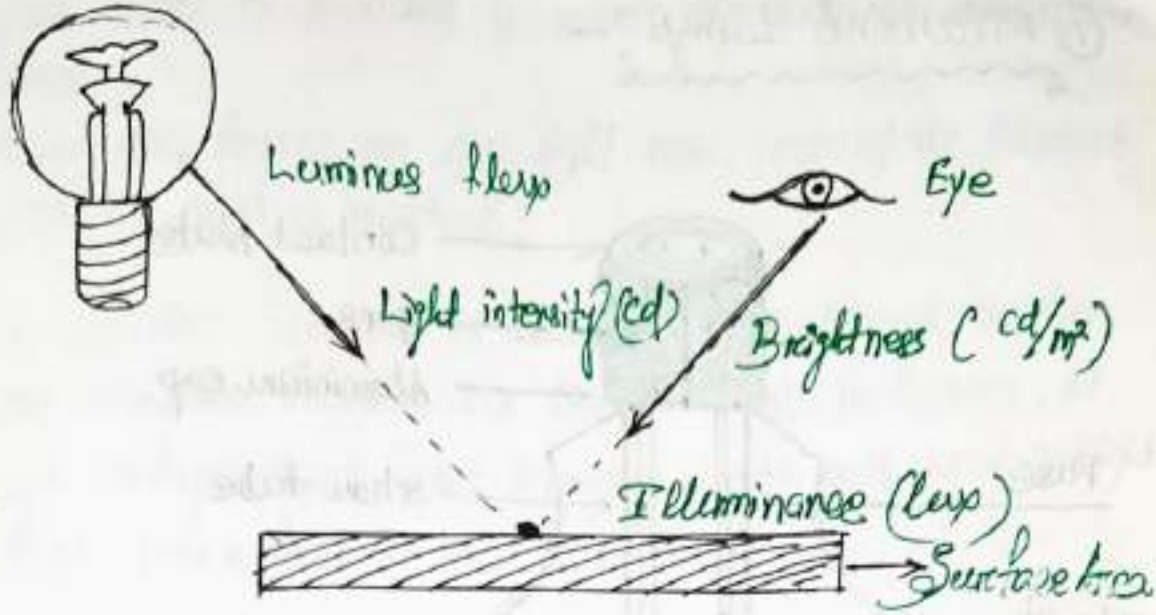
$$I = \frac{\phi}{\omega}$$



(6) Illumination → When light falls on a surface it becomes vissible the phenomenon is called as illumination.

It is defined as luminous flux falling on a surface per unit area. It is denoted by E and measured in lumen per square meter or meter candle

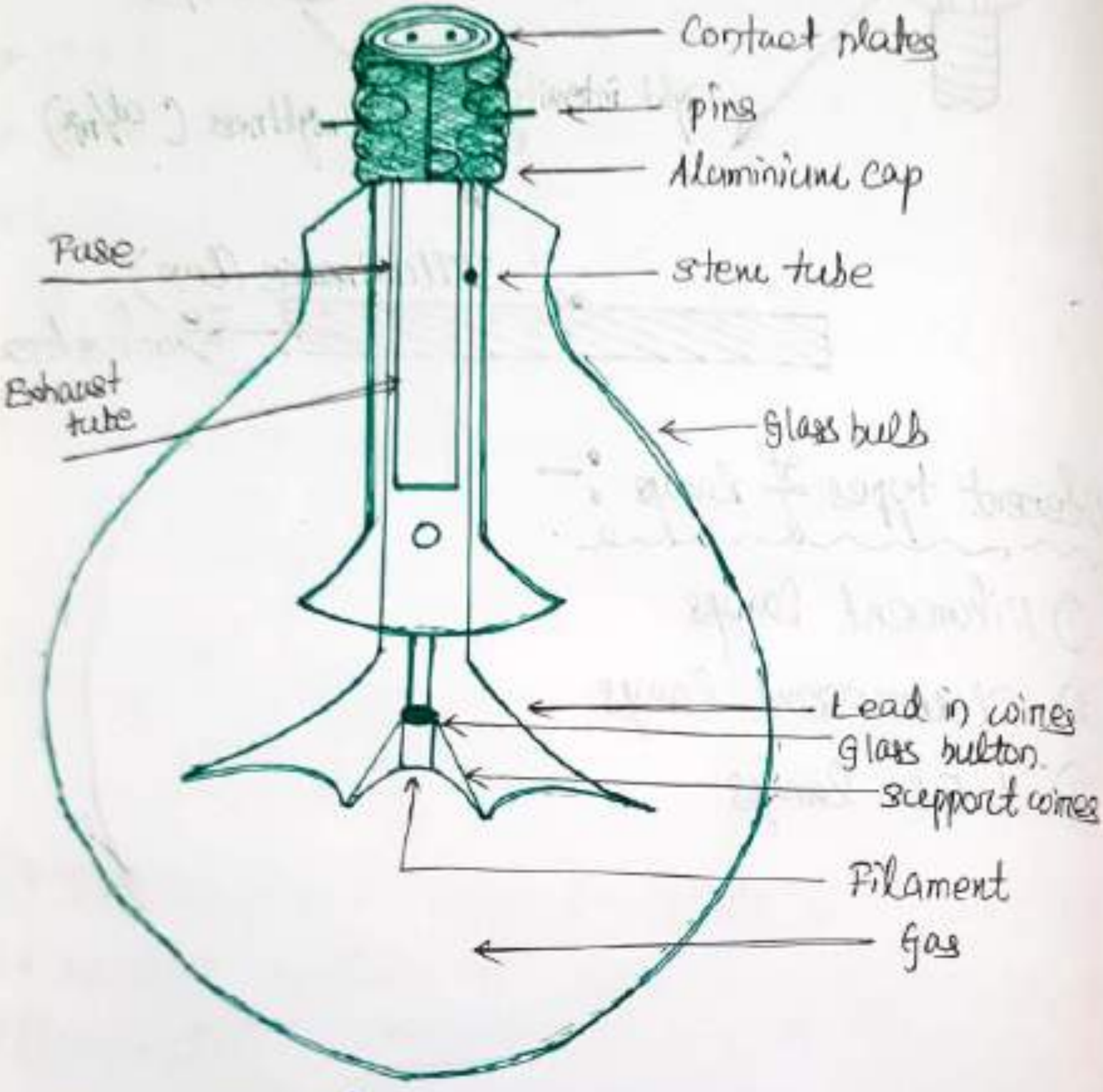
$$E = \frac{\phi}{A} \text{ lux}$$



Different types of lamps :-

1. Filament lamps
2. Fluorescent lamps
3. LED lamps

① Filament Lamp :-



→ It consists of an evacuated glass bulb and an aluminium or brass cap is provided with two pins to insert the bulb into the socket.

→ The inner side of the bulb consists of a tungsten filament and the support wires are made of molybdenum to hold the filament in proper position.

→ A glass bulb is provided in which the support wires are inserted

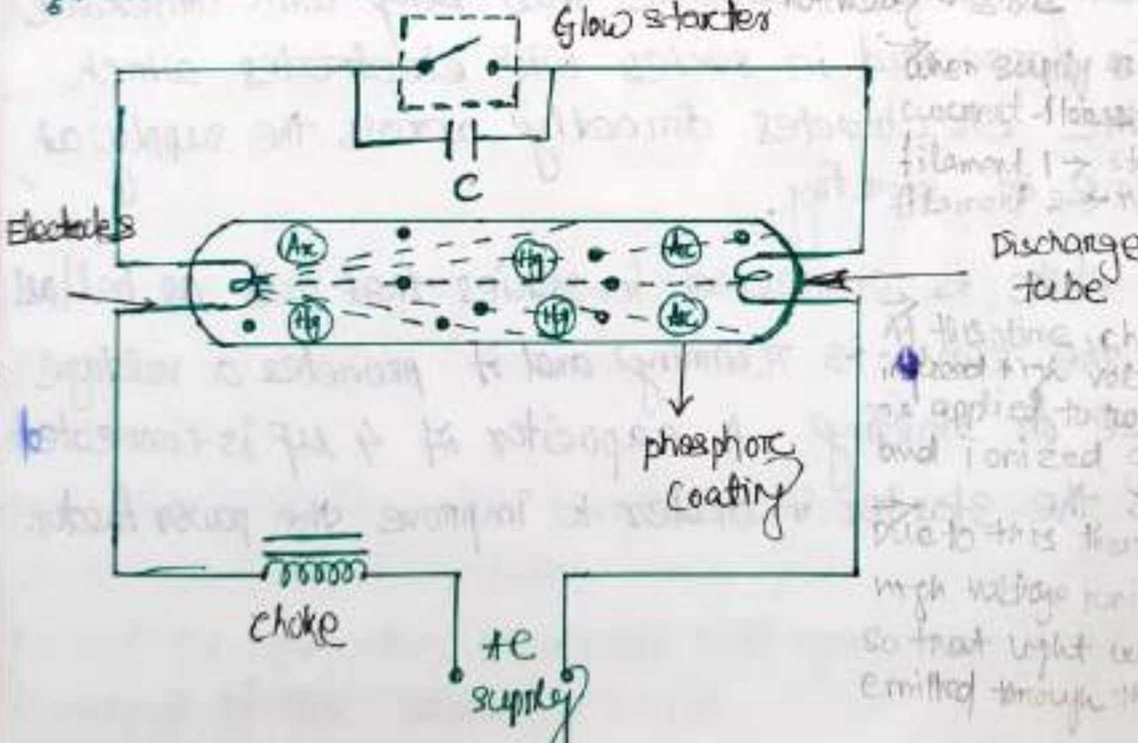
→ A stem tube forms an air tight seal around the filament whenever the glass is melted

→ when electric current is made to flow through the fine metallic tungsten filament, its temperature increases. At very high temperature, the filament emits both heat and light radiations which fall in the visible region.

→ The tungsten filament lamps can be operated efficiently beyond 2000°C, it can be attained by inserting a small quantity of inert gas nitrogen with small quantity of argon.

the ability of certain chemicals to give visible light after absorbing radiation which is normally invisible

② Fluorescent Lamp :-



→ When supply is on, current flows through filament 1 → starter → filament 2 → neutral

→ At this time, choke induced high voltage which is applied to two filaments and ionized gas

→ Due to this there will be high voltage ionization so that light will be emitted through the tube

Construction:-

→ Fluorescent lamp is a hot cathode low pressure mercury vapor lamp.

→ It consists of a long horizontal tube, due to low pressure maintained inside of the bulb, it is made in the form of a long tube.

→ The tube contains small quantity of argon gas and certain amount of mercury at a pressure of 2.5mm of mercury.

→ Normally low pressure mercury vapor lamps suffer low efficiency and they produce an objectionable colour light. Such drawback is overcome by coating the inside of the tube with fluorescent powders. They are in the form of solids which are usually known as phosphors.

→ A glow starter switch contains small quantity of argon gas having a small cathode glow lamp with bimetallic strip is connected in series with electrodes which puts the electrodes directly across the supply at the time of starting.

→ A choke is connected in series that acts as ballast when the lamp is running and it provides a voltage impulse for starting. A capacitor of 4 μF is connected across the starter in order to improve the power factor.

Operating principle :-

At the time of starting when both the lamp and the glow starters are cold, the mercury is in the form of globules.

→ When supply is switched on the glow starter terminals are open circuited and full supply voltage appeared across these terminals due to low resistance of electrodes and choke coil.

→ The small quantity of argon gas gets ionized which establishes an arc with a starting glow.

→ This glow warms up the bimetallic strip thus glow starts gets short circuited. Hence the two electrodes come in series and are connected across the supply voltage

→ Now the two electrodes get heated and start emitting electrons due to the flow of current through them.

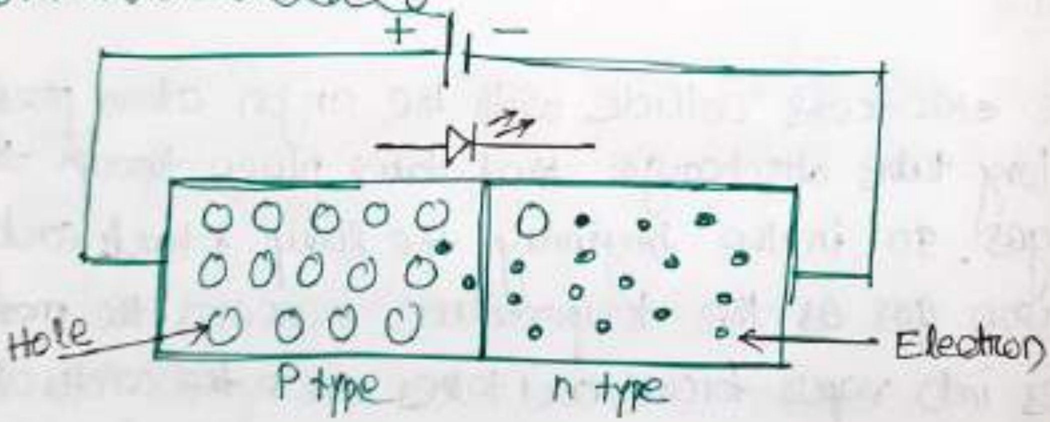
→ These electrons collide with the argon atoms present in the long tube discharge that takes place through the argon gas. So in the beginning the lamp starts conduction with argon gas as the temperature increases, the mercury changes into vapour form and takes over the conduction of current.

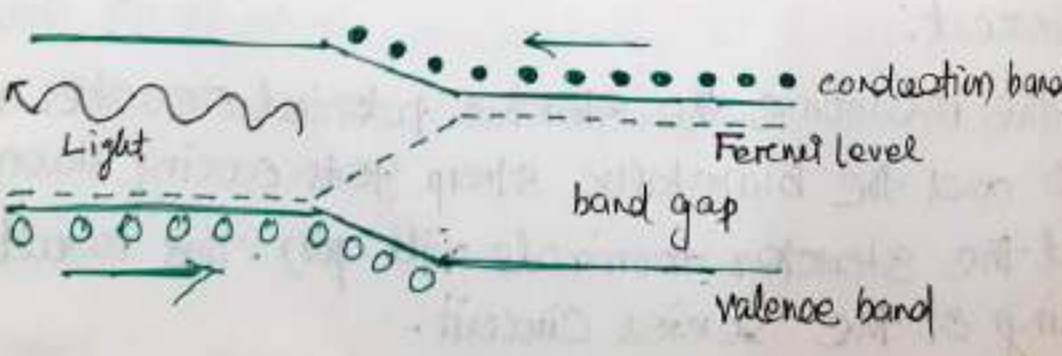
→ In the meantime the starter potential reaches to zero and the bimetallic strip gets cooling down. As a result the starter terminals will open. This results breaking of the series circuit.

→ A very high voltage around 1000V is induced because of the sudden opening of starter forming in the series circuit. But in the long tube electrons are already present this induced voltage is quite sufficient to break down the long gap. Thus more num of electron collide with argon and mercury vapor atoms.

→ The excited atom of mercury gives UV radiat which will not fall in the visible region meanwhile these UV rays are made to strike phosphor mater it causes the remission of light of different wavelength producing illumination. The phenomenon the emission is called as luminescence.

(3) LED Lamp :-





→ A light emitting diode bulb consists of two semiconducting material i.e p type material and n type material. A p-n junction is formed, by connecting these two types of material.

→ when the p-n junction is forward biased the majority carriers, either electrons or holes start moving across the junction.

→ As shown in the figure above electrons start moving from n-region and holes start moving the p region. when they moved from their regions they start to recombine across the depletion region. Free electron will remain in the conduction band of energy level while holes remain in the valence band of energy level.

→ The Energy level of electrons is higher than holes because electrons are more mobile than holes i.e current conduction due to electrons are more. During the recombination of electron and holes some portion of energy must be dissipated or emitted in the form of heat and light.

→ The phenomenon of into which light emits from the semiconductor under the influence of electric field is known as electroluminescence.

→ Always remember that the majority of light is produced from the junction nearer to the p-type region. so diode is designed in such a way that this area is kept close to the surface of the device to ensure that the minimum amount of light is absorbed.

→ The electrons dissipate energy in different forms depending on the nature of the diodes used. like for silicon and germanium diodes, it dissipates energy in the form of heat while for gallium phosphide (GaP) and gallium arsenide phosphide (GaAsP) semiconductors it dissipates energy by emitting photons.

→ For the emission of different colors different semiconductors are used

red light ⇒ phosphorus

green ⇒ Gallium Indium phosphide

yellow ⇒ Gallium phosphide

orange ⇒ Aluminum indium gallium phosphide

Start rating of Home Appliances :-

Terminology :-

White goods → Home Appliances

Ex:- Refrigerators, Airconditioners, washing Machines, Dryers, Dishwashers, ovens, etc.

Brown goods ⇒ portable appliances

Ex:- Television, microwave ovens, coffe makers wireless set, Mixers, Grinders, Irons

BEE ⇒ Bureau of Energy Efficiency

EER ⇒ Energy Efficiency Ratio

BTU ⇒ British thermal unit

Energy efficieny? :-

It is defined as energy service per unit of energy consumption.

Star Rating? :-

→ An energy efficiency rating scheme of Electrical appliances is known as star rating

→ Star rating is the average amount of electricity used by the equipment in a year i.e kwh/year or unit/year under standard test conditions.

→ Star rating are provided to all the major kind of appliances in the form of labels. These star ratings are given out of 5 and they provide a basic sense of how energy efficient each product is.

CH-5 Wiring And Power Billing

Electrical Wiring:→

A network of cables connecting various electrical accessories for distribution of electrical energy from the supplier meter board to the various electrical energy consuming devices such as lamps, fans, radio, TV and other domestic appliances through controlling and safety devices is known as wiring system.

Types of Wiring For Domestic Installations:→

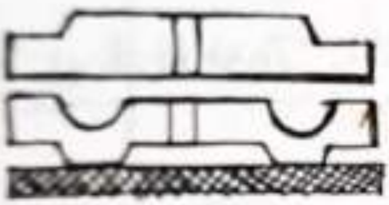
① Cleat Wiring
② Wooden casing and capping wiring
③ CTS or TRS or PVC sheath wiring
④ Lead sheathed or metal sheathed wiring
⑤ Conduit wiring
   (a) Surface or open conduit type
   (b) concealed or underground type conduit

(1) Cleat Wiring :-

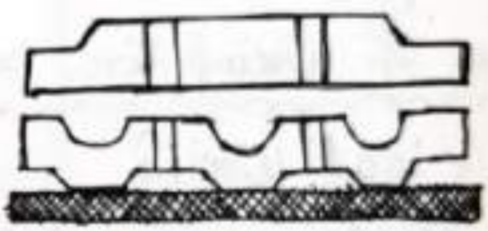
→ In this system of wiring cables are supported and gripped between porcelain cleats above the wall or roof.

→ The porcelain cleats are made in two halves. The main part is base, which is grooved to accommodate the cables, the other part is the cap which is put on the base.

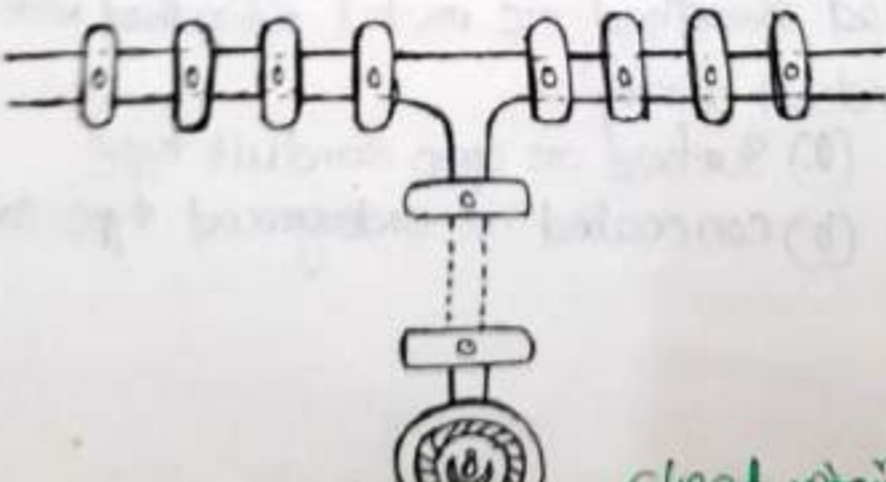
→ The lower cleat (base) and upper cover (cap) after placing cables between them are then screwed on wooden gutties.



Cleat with two grooves



Cleat with three grooves



Cleat wiring

Advantages :→

* It is cheapest system
* Installation and dismantling is easy
* Less skilled persons are required
* Inspection is easy
* Alternation and additions are easy
* As the cables and wires of cleat wiring system is in open air therefore fault in cables can be seen and repair easily.

Disadvantages :→

* It is purely temporary wiring system
* Appearance is not good
* cables are exposed to atmosphere and there is a possibility of mechanical injury.
* This system should not be used in damp places otherwise insulation gets damaged.
* It is not lasting wire system because of the weather effect and wear & tear
* There is always a risk of fire and electric shock
* It can't be used in important and sensitive location and places.
* It is not reliable and sustainable wiring system

Applications :→

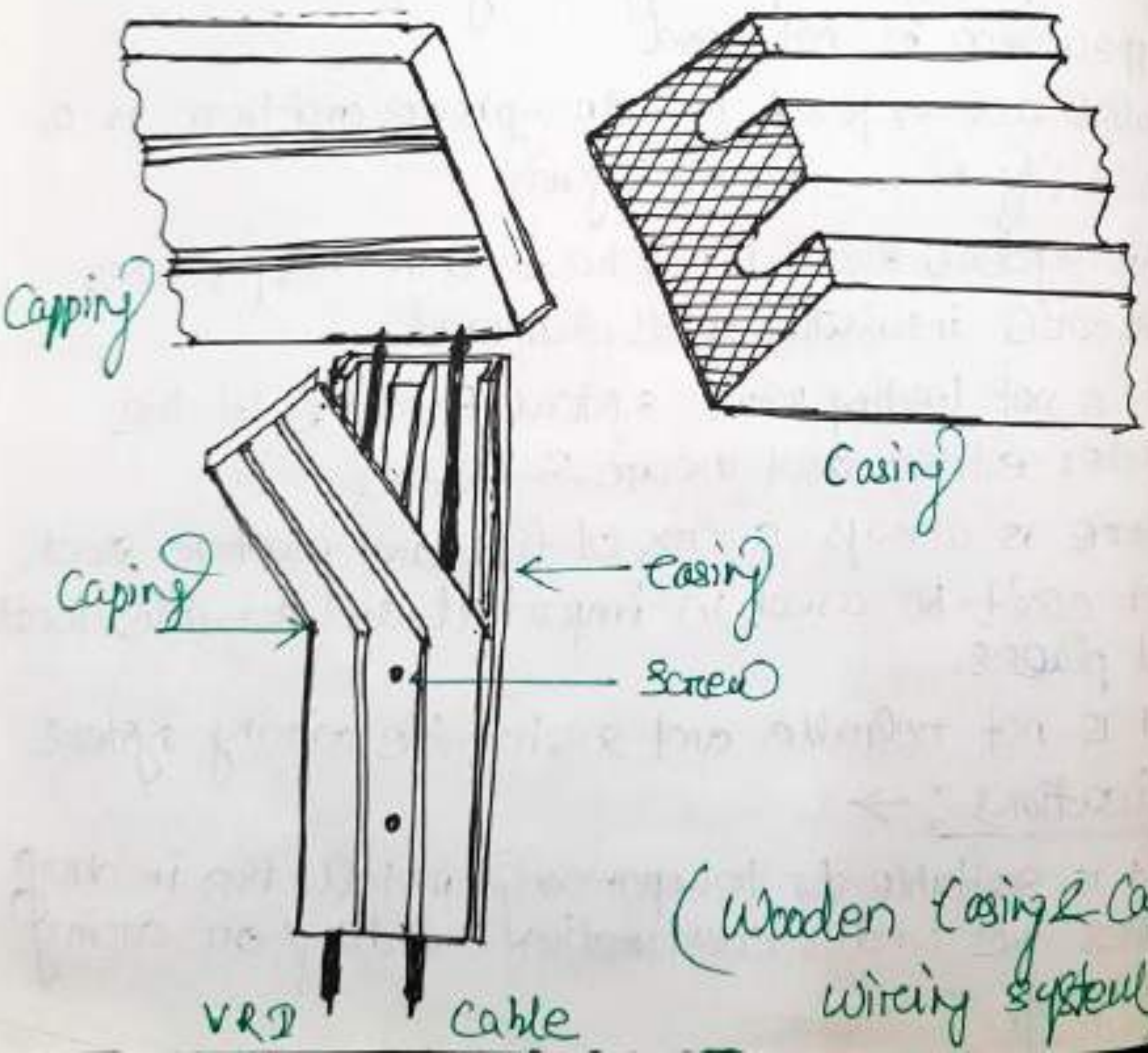
It is suitable for temporary installation in dry places i.e under construction building or army camping.

(2) Casing & Capping wiring :-

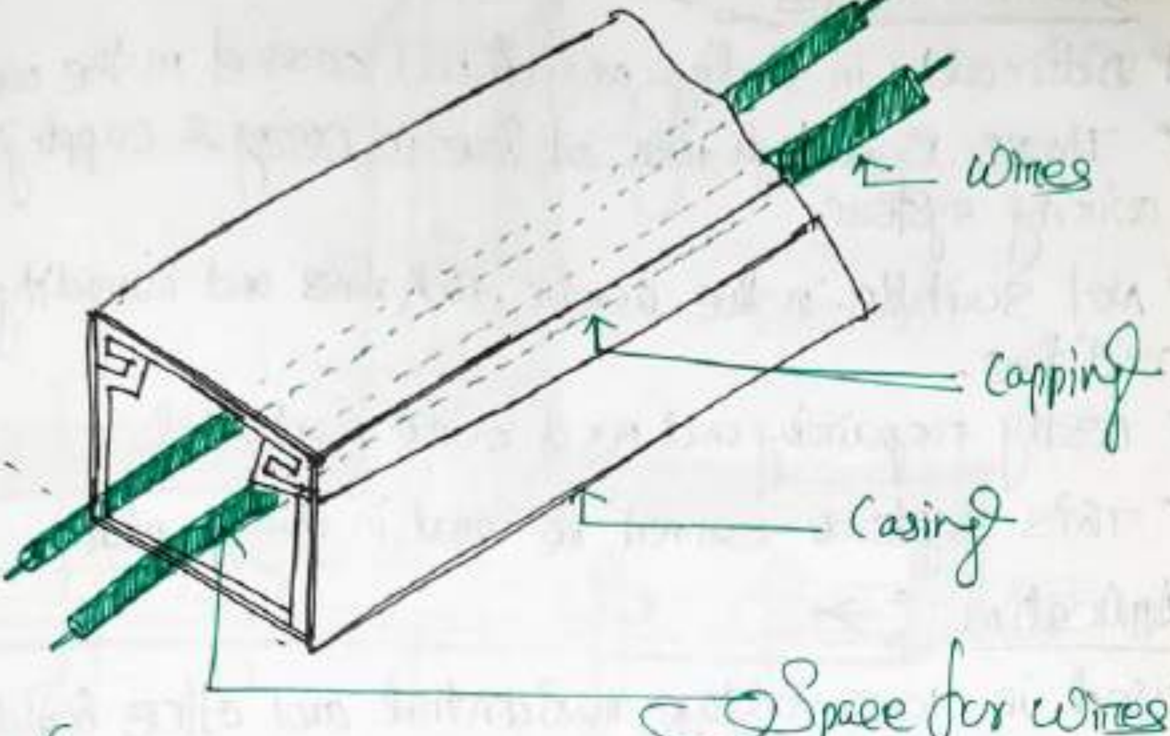
→ It consists of rectangular blocks made from seasoned and knots free wood or PVC.

→ The casing has usually two or three U shaped grooves into which the VIR or PVC cables are laid in such a way that the opposite polarity cables are laid in different grooves.

→ The casing is covered by means of a rectangular strip of the same width as that of casing known as capping and is screwed to it.



(Wooden Casing & Capping wiring system)



(PVC (casing capping) wiring system)

Advantages:→

* ★ It provides good Mechanical strength
* ★ Easy to inspect by opening the capping
* ★ It is cheap wiring system as compared to sheathed and conduit wiring system
* ★ It is strong and long lasting wiring system
* ★ stay for long time in the field due to strong insulation of capping and casing
* ★ It stays safe from oil steam, smoke and rain
* ★ No risk of electric shock due to covered wires and cables in casing & capping.

Disadvantages :→

* Difficulty in finding any fault caused in the wire
* There is a high risk of fire in casing & capping wiring system.
* Not suitable in the acidic, alkalies and humidity conditions.
* costly repairing and need more material
* This system cannot be used in damp places

Application :→

used in low voltage residential and office building

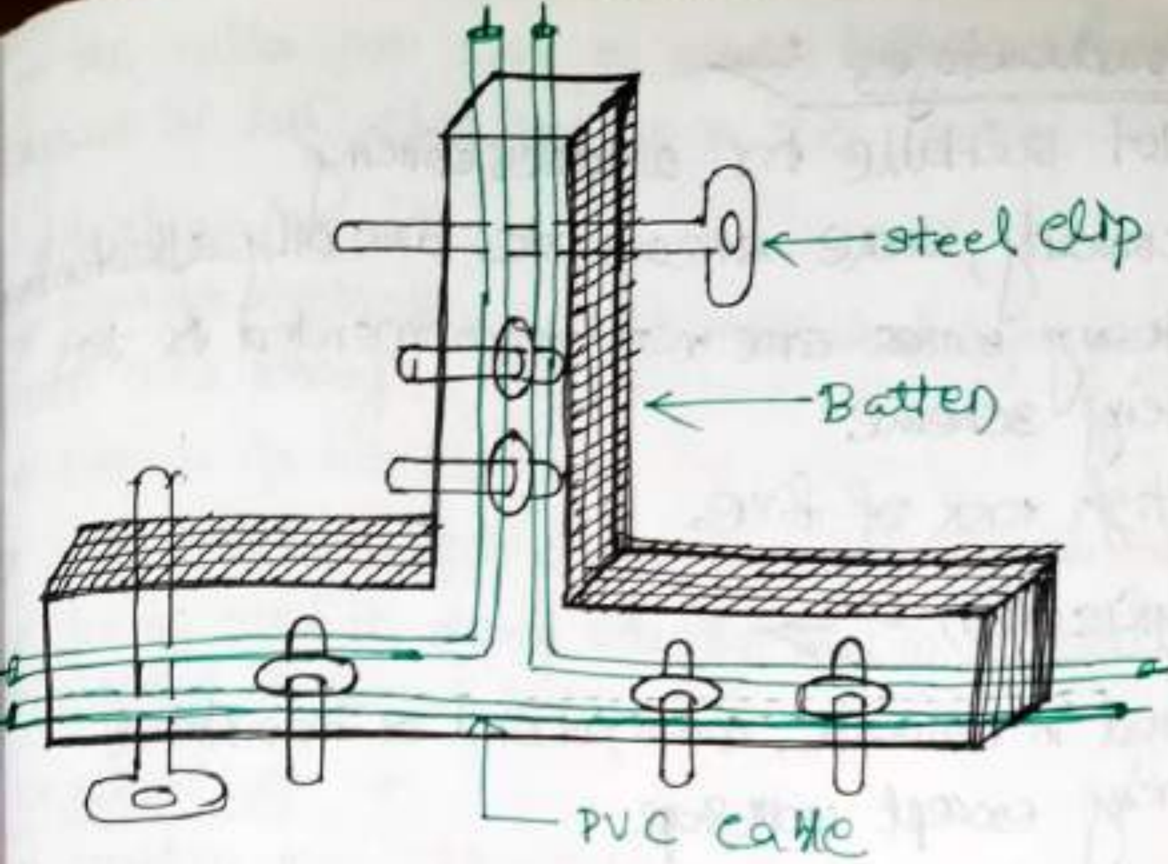
⑧ Batten wiring (CTS or TRS) :-

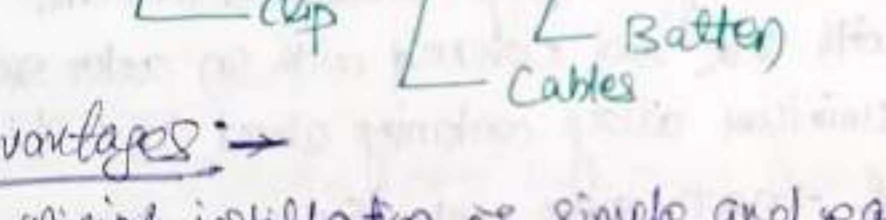
CTS ⇒ Cable Type Sheath
TRS ⇒ Tough Rubber Sheath

→ The cables are run or carried on well seasoned perfectly straight and well varnished teak wood batten of thickness 10 mm at least

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

→ The wooden battens are fixed to the wall or ceilings by means of PVC gutties or wooden plugs with flat head wooden screws, the wooden screws should be fixed on the batten at an interval not exceeding 75 cm





Advantages :→

* ★ wiring installation is simple and easy
* ★ cheap as compared to other electrical wirings
* ★ Repairing is easy
* ★ strong and long lasting
* ★ Appearance is better.
* ★ customization is easy
* ★ Less chance of leakage currents

Disadvantages :→

* Not suitable for outdoor wiring.
* Humidity, smoke, steam etc directly affect on
* Heavy wires are not recommended for this wiring scheme.
* High risk of fire.

Application :→

* used in domestic, commercial or industrial wiring except workshops.
* used for low voltage installation.

④ Lead sheathed & Metal sheathed :—

→ This type of wiring employs conductors that are insulated with VIR and covered with an outer sheath of lead aluminium alloy containing about 95% of lead.
→ The metal sheath gives protection to cables from mechanical damage, moisture and atmospheric corrosion.
→ The whole lead covering is made electrically continuous and is connected to earth at the point of entry to protect against electrolytic action due to leaking current and to provide safety in case the sheath becomes alive.

* The cables are run on wooden batten and fixed by means of link clips just as in TRS wiring.

Advantages :→

* provides protection against mechanical injury better than TRS wiring
* Easy to fix and look nice
* Long life if proper earth continuity is maintained
* Can be used in damp situation and in situation exposed to rain & sun.

Disadvantages :→

* costlier then TRS wiring
* Not suitable for chemical corrosion
* In case of damage of insulation the metal sheath becomes alive & give shock
* skilled labour & proper supervision is required

Application :→

commonly used for laying sub mains from pole to electric meter.

(5) Conduit wiring :-

(a) Surface conduit wiring —

If conduits installed on roof or wall, It is known as surface conduit wiring. In this wiring method they make holes on the surface of wall on equal distances and conduit is installed there with the help of rawal plugs.

(b) Concealed conduit wiring —

→ If the conduits is hidden inside the wall slots with the help of plastering, it is called concealed conduit wiring. In other words the electrical wiring system inside wall roof or floor with the help of plastic or metallic piping is called concealed conduit wiring.

→ It is the most popular beautiful stronger and common electrical wiring system nowdays.

Advantages :-

- ★ The safest wiring
- ★ Appearance is better
- ★ No risk of fire or mechanical wear & tear
- ★ No risk of damage of cable insulation
- ★ Safe from humidity, smoke, steam etc
- ★ no risk of shock

* Long Lasting
* Repairing and maintenance is easy

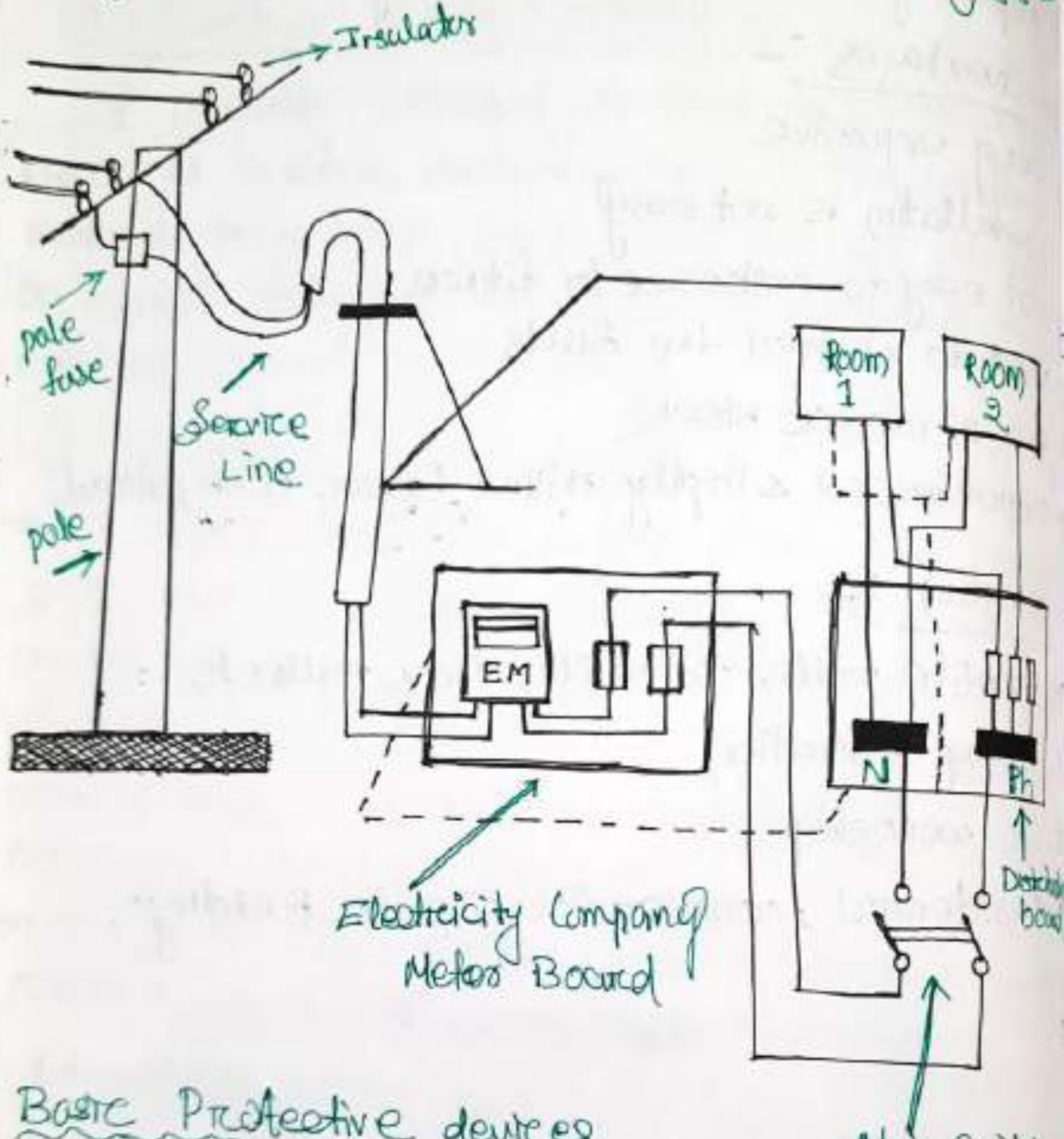
Disadvantages :-

* very expensive
* Installation is not easy
* Not easy to customize for future
* Hard to detect the faults
* Risk of electric shock
* Experienced & highly skilled labour is required

Application :-

* textile mills, sawmills, flour mills etc.
* Damp situation
* In workshop
* Residential, commercial & public building.

Layout of House hold electrical Wiring



Basic Protective devices used in House Hold wiring :→

- ★ Fuse
- ★ MCB (Miniature Circuit breaker)
- ★ Lightening arrestor
- ★ Earthing wire

Fuse :→

* Fuses are the protectors, these are the safety devices which are used to protect the home appliances like televisions, refrigerators, computers with damage by high voltage.

* The fuse is made up of thin strip or strand of metal whenever the heavy amount of current or an excessive current flow in there in an electrical circuit the fuse melts and it opens the circuit and disconnects it from the power supply.

MCB :→

It is an automatically operated electrical switch used to protect low voltage electrical circuits from damage caused by excess current from an overload or short circuit.

Lighting arrester :→

* Lighting arrester is a device used for the protection of electrical equipment against lighting stroke.

Earthing :→

The process in which the instantaneous discharge of the electrical energy takes place by transferring charges directly to the earth through low resistance wire.

Electrical Energy :→

Electrical power is the rate of consumption of electrical energy

Energy = power × Time

$E = P \times t$

when $P = 1$ watt $t = 1$ sec

$E = 1$ watt × 1 second = 1 watt second

1 watt second = 1 joule

usual practice is to take 1 hour as the time unit

$P = 1$ watt $t = 1$ hour

$E = 1$ watt × 1 hour = 1 watt hour

1 watt hour = 1 watt × (60×60) sec

= 60 × 60 watt sec

= 3600 joules

$= 3.6 \times 10^3$ joules

1 kWh = 1000 watt hour $= 3.6 \times 10^6$ joules

1 kWh is also called the board of trade unit

1 kWh = 1 BOT unit

1 KWh = 1 unit of electricity

cost of energy consumed

cost = cost of one unit (1 KWh) × number of unit consumed

Calculation of Electrical Energy consumed by An Appliance :→

1. A building has following electrical Appliances
   (i) A 1 Hp motor running for 5 hrs in a day
   (ii) Three fans each of 80W running for 10 hrs in a day
   (iii) Four tube lights 40W running for 15 hrs per day

Find the monthly bill for the month of November if unit cost of bill is Rs 2.50.

Sl.No	Name of Appliances	Quantity	power rating in KW	working Hrs in a day	Energy consumed in KWH
1	Motor	1 No.	1 Hp = 746 W = 0.746 KW	5	1×0.746×5 = 3.73
2	Fans	3 Nos	80W = 0.08 KW	10	3×0.08×10 = 2.4
3	Tubelight	4 Nos	40W = 0.04 KW	15	4×0.04×15 = 2.4
total Energy consumed in kWh				=	3.73+2.4+2.4 = 8.53

As we know 1 KWH = 1 unit

8.53 KWH = 8.53 units

in the month of November total energy consumed

= 8.53 × 30 = 255.9 units

Monthly bill = 255.9 × Rs 2.5 = Rs 639.75 P

Q A building has following electrical Appliances

(i) Two bulb each of 60 watt and one bulb of 100 w

(ii) Tube light 40 watt - 2 nos

(iii) Three Fans of 60 watt each

(iv) One refrigerator of 150 watt

All the lighting devices works for 6 hrs a day, fan works for 10 hrs and refrigerator works for 24 hrs. The electric tariff is as follows For first 100 units @ Rs 1.40/-, next 100 units @ Rs 2.30/- Rest @ Rs 3.10/-. calculate the bill for the month of 30 days.

SL NO	Name of Appliances	Quantity	Power rating in KW	Working hr in a day	Energy consumed
1	Bulb	2	0.060	6	2×0.06×6 = 0.72
2	Bulb	1	0.100	6	1×0.1×6 = 0.6
3	Tube light	2	0.040	6.	2×0.04×6 = 0.48
4	Fan	3	0.060	10	3×0.06 ×10=1.8
5	Refrigerator	1	0.150	24	1×0.15× 24 = 3.6
	Total energy consumed.				7.2 kWh

As we know 1 KWH = 1 unit

7.2 KWH = 7.2 units

In the month of 30 days, total Electrical energy consumed = 7.2×30 = 216 units

Monthly bill = 100 × Rs 1.40/- = Rs 140/-

100 × Rs 2.30/- = Rs 230/-

16 × Rs 3.10/- = Rs 49.6/-

total = Rs 419.6/-

CH-6

Measuring Instruments

Introduction To Measuring Instruments :-

- The measurement of a given quantity is the result of comparison between the quantity to be measured and definite standard. The instruments which are used for such measurements are called <u>measuring instruments</u>.
- Measure physical quantity.
- The quantities in the electrical measurement are current, voltage, power, energy, frequency,
- The instrument which measures the <u>current flowing</u> in the circuit is called <u>ammeter</u>.
- The instrument which measures the <u>voltage across</u> any two points of a circuit is called <u>voltmeter</u>.
- The instrument which are used to measure the <u>power</u> are called <u>wattmeter</u>.

Types of Electrical Measuring Instruments :-

- Measuring Instruments
  - Digital Type
  - Analog Type
    - Absolute Instruments
    - Secondary Instruments
      - Indicating Instruments
      - Recording Instruments
      - Integrating Instruments

Digital Instrument –

The instrument which represents the measured value in the form of digital number is known as Digital instrument.

Analog Instrument –

The Analog instrument is defined as the instrument whose output is the continuous function of time and they have a constant relation to the input.

Absolute Instruments –

Absolute instruments are those which give the value of the quantity to be measured in terms of the constants of the instrument and their detection only. No previous calibration or comparison is necessary in their case.

Ex:- Tangent galvanometer

Secondary Instruments –

Secondary instruments are those in which the value of electrical quantity to be measured can be determined from the deflection of instruments only when they have been pre calibrated by comparison with an absolute instruments.

Ex:- Ammeter, voltmeter etc.

Indicating Instruments –

In this type of instrument, the magnitude of electrical quantity to be measured is indicated by deflection of a pointer over a pre calibrated scale.

Ex:- Ordinary ammeter, voltmeter,

Recording Instruments –

These instruments give a continuous record of the variation of the electrical quantity being measured over a time interval. A pen attached to the moving system traces the magnitude of quantity measured on a sheet of paper in motion.

Ex:- Energy meter, ECG machine.

Integrating Instruments –

The electrical quantities are added up or integrated over the period of measurement and then recorded in an integrating instrument.

Ex:- Energy meter.

Torques In Instruments :→

In case of measuring instruments, the effect of unknown quantity is converted into a mechanical force which is transmitted to the pointer which moves over a calibrated scale. The moving system of such instrument mounted on a pivoted spindle. For satisfactory operation of any indicating instrument following torques must be present is an instrument.

1. Deflecting Torque
2. Controlling Torque
3. Damping Torque

Torque → A measure of the force that can cause an object to rotate about an axis.

(1) Deflecting Torque –

* In most of the indicating instruments the mechanical force proportional to the quantity to be measured is generated. This force or torque deflects the pointer. The system which produces such deflecting torque is called deflecting system and the torque is denoted as T_d.

* Deflecting torque can be produced by utilization of any one of the following effects produced by the current or voltage

1) Magnetic
2) Electrodynamic
3) Electromagnetic induction
4) Electrostatic
5) chemical
6) Thermal

② Controlling Torque —

* This system should provide a force so that current or any other electrical quantity will produce deflection of the pointer proportional to its magnitude.

* It produces a force equal and opposite to the deflecting force in order to make the deflection of pointer at a definite magnitude. If this system is absent, then the pointer will swing beyond its final steady position for the given magnitude and deflection will become indefinite.

* It brings the moving system back to zero position when the force which causes the movement of the moving system is removed. It will never come back to its zero position in absence of controlling system.

★ There are two types of controlling system
1) Gravity control
2) Spring control

③ Damping Torque —

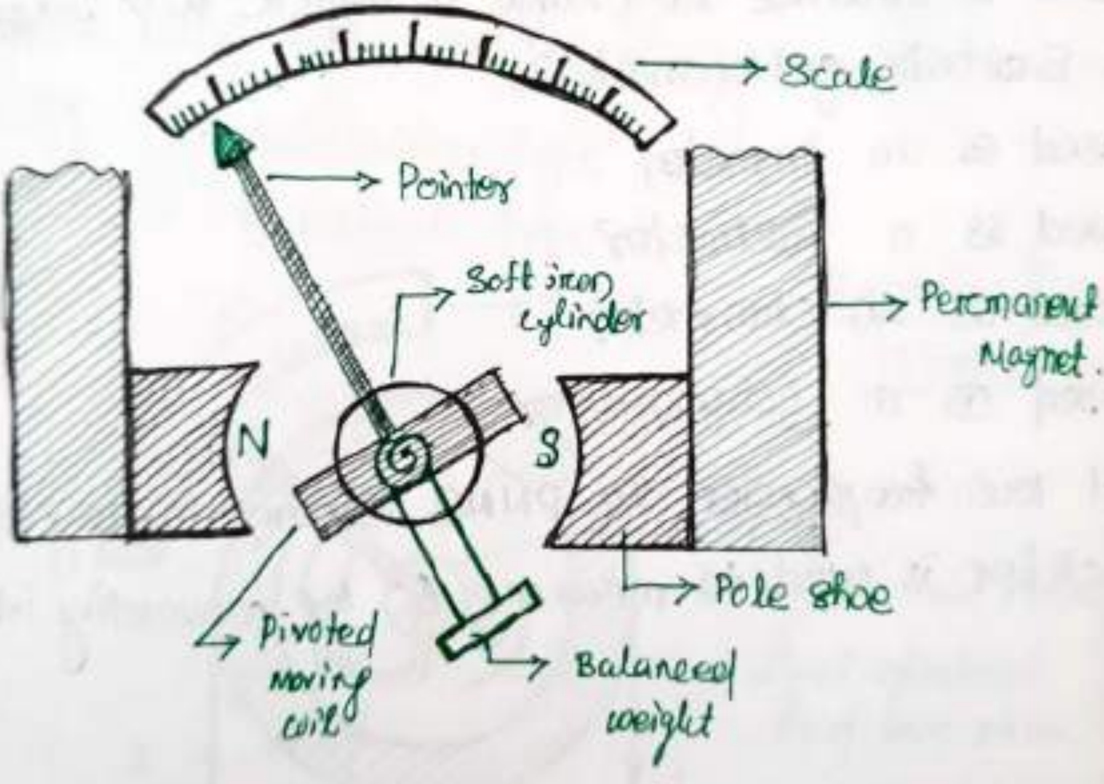
★ The deflecting torque provides some deflection and controlling torque acts in the opposite direction to that of deflecting torque. so before coming to the rest pointer always oscillates due to inertia about the equilibrium position. Unless pointer rests final reading cannot be obtained. so to bring the pointer to rest within short time, damping system is required. The system should provide a damping torque only when the moving system is in motion.

★ Damping torque is proportional to velocity of the moving system but it does not depend on operating current.

★ Methods used for produce damping torque
(a) Air friction damping
(b) Fluid friction damping
(c) Eddy current damping
(d) Magnetic damping.

PMMC Instruments :→

* The instruments which use the permanent magnet for creating the stationary magnetic field between which the coil moves is known as the permanent magnet moving coil or PMMC instrument.
* Instruments that allows you to measure the current through a coil by observing the coil angular deflection in a uniform magnetic field.
* PMMC is one of the most accurate types of instrument used for D.C Measurements of current and voltage.



* The operation is based on the principle that when a current carrying conductor is placed in a magnetic field, mechanical force act on a conductor. When the conductor is in shape of a rectangular coil, the coil experience a deflecting torque. A pointer attached to the coil moves over a pre calibrated scale to indicate the value of current and voltage.

Uses :-

* It is used in the measurement of direct voltage and currents.
* used to detect small currents in DC galvanometer
* used to measure the change in magnetic flux linkage in Ballistic galvanometers.
* used as an Ammeter
* used as a voltmeter
* used as an Ohmmeter
* used as a Galvanometer
* At low frequencies, the PMMC instrument along with rectifier is used to measure AC by converting into

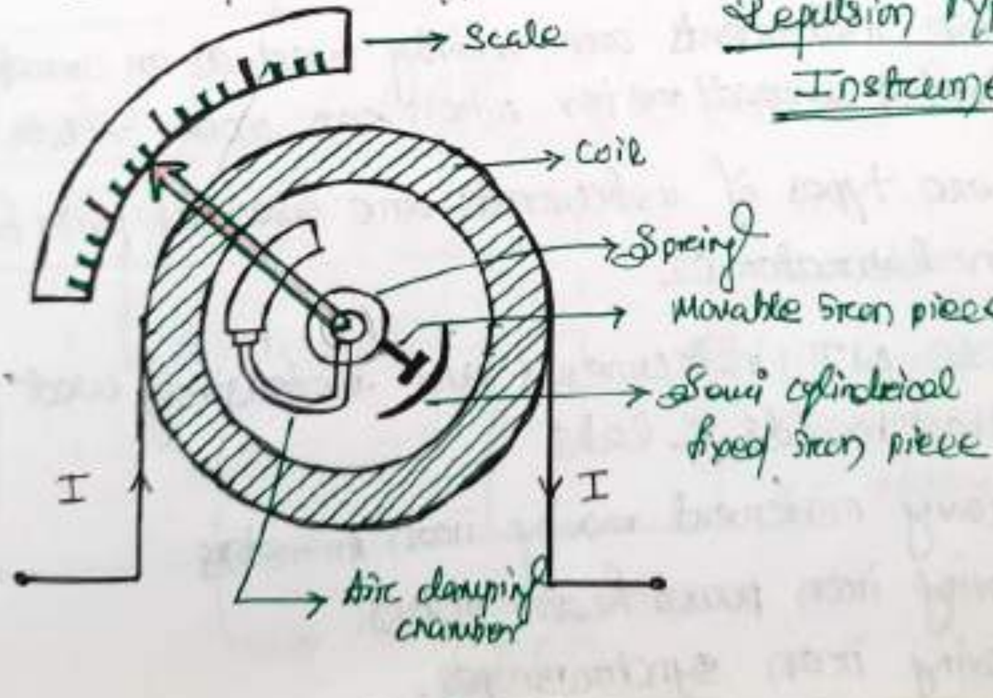
MI Instruments :-

* The instrument in which the moving iron is used for measuring the flow of current or voltage is known as moving iron instrument.

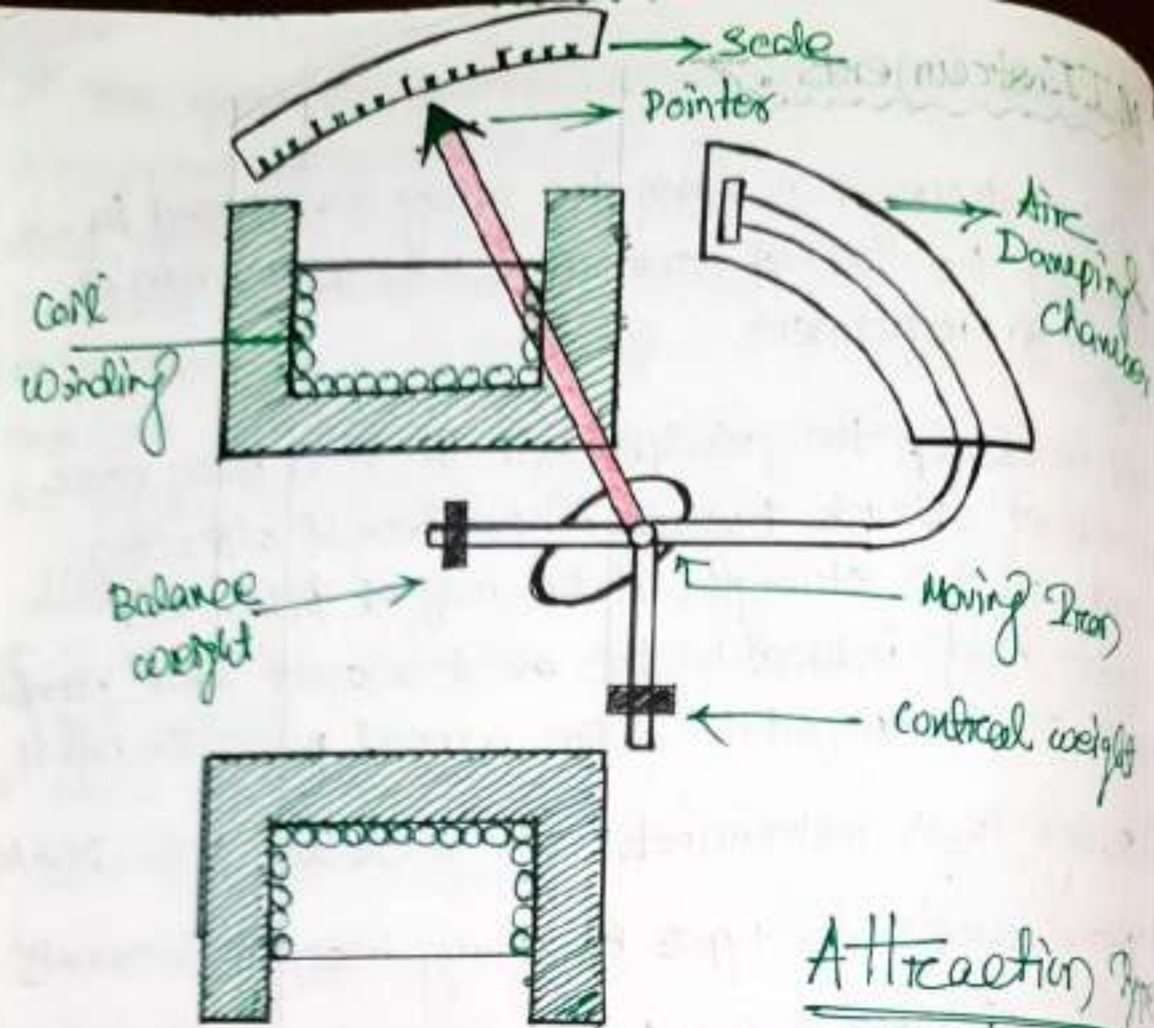
* It works on the principle that the iron place near the magnet attracts towards it. The force of attraction depends on the strength of the magnet field. The magnetic field induces by the electromagnet whose strength depends on the magnitude of the current passes through it.

* Moving iron instruments can measure both DC & AC.

* There are two types of moving iron instruments namely (i) Attraction type
(ii) Repulsion type



Repulsion Type Instrument



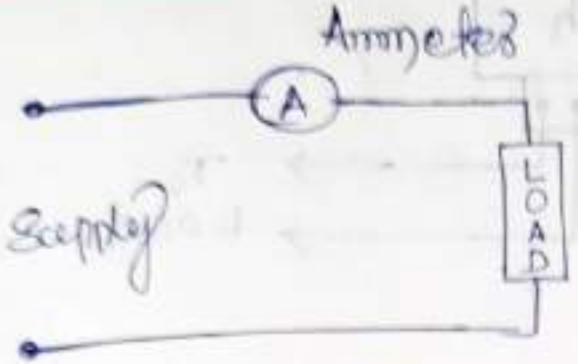
Attraction Type Instrument

Uses :-

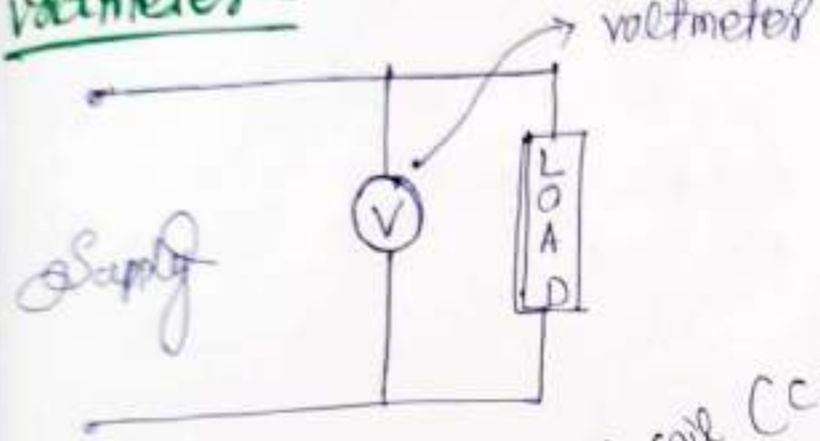
- ★ These instruments are mainly used as an ammeter, voltmeter & wattmeter which can work on both AC & DC
- ★ These types of instruments are used at power frequency within Laboratories.
- ★ These MI instruments are extensively used in switched boards & labs.
- ★ Heavy current moving iron Ammeters
- ★ Moving iron power factor meters
- ★ Moving iron synchroscopes.

Connection Diagram :->

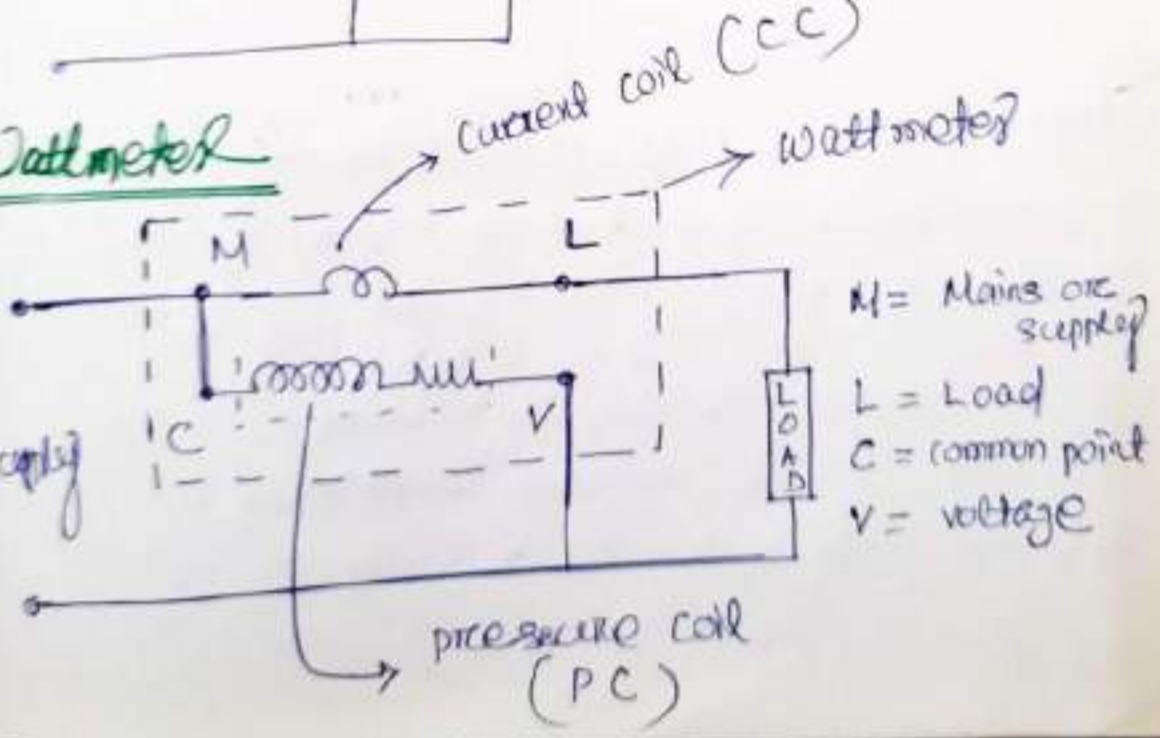
Ammeter



Voltmeter



Wattmeter



Energy Meter