Chapter - 1

Current - The motion of charge through a conducting Material or// the flow of electron is known as current. (Denoted by I)

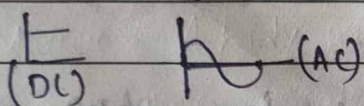
$$\boxed{I = \frac{Q}{t}} \Rightarrow Q = It \;,\; \boxed{i = \frac{dq}{dt}}$$

→ The rate of charge passing through a point in an electric ckt. per unit sec.

Unit - AMperes (A)

2 types of currents, (1) AC - Current varies with time (Alternating current)

(2) DC - Current remain constant with time (Direct ") : or i(t)



Voltage or potential Difference :- The energy required to move charge from one point to the other. Pressure/

Measured in volts (V)

$$v = \frac{dw}{dt}$$ (Work is energy in joules (J))

$$1 \text{ volt} = \frac{1 \text{ joule}}{\text{Coulomb}}$$

Power :- The rate of doing work is called power.

$$P = dW/dt = \frac{dw}{dq} \times \frac{dq}{dt} = VI$$ (Power can be evaluated as the Product of the two quantities)

* Power is the time rate of expanding or absorbing energy.

Source :- Which are having the capacity of generating the energy.

Energy Sources. 2 types - (1) voltage source
current source.

It delivers power to the ckt connected to them.

Two kind of Sources :-

(1) Independent Sources → completely independent of other ckt element

(2) Dependent Sources → The source quantity is controlled by another voltage or current.

E.g-VCVS, CCVS, VCCS, CCCS.

* BJT - Current controlled device   MOSFET, IGBT, FET voltage controlled device

* Delivering energy to the System - Source
Extracting energy from a System - load.

Deliver Power to the load

Load :- The electrical load is a device that consumes elec energy in the form of current & transforms it into other forms like heat, light, work etc.

Electrical load

(1) Resistive load → oppose the flow of electrical energy (lamp, heater)
(11) Inductive load → store electrical energy in magnetic field (gen, mo, transformer)
(111) Capacitive load → store electrical energy in electric field.
E.g → Capacitor bank & synchronous condenser.

Resistance → The natural property of substance which oppose the flow of current through it is called resistance.

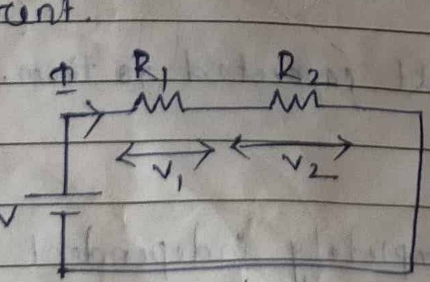
Ohm's law :- The potential difference (voltage) developed across a resistor is directly propotional to the current flowing through the resistor when the resistance, temperature & all other physical condition are kept constant.

* $V \propto I$ R is constant.

$$\boxed{V = I \cdot R}$$

Relation of V, I, R in series circuit.

Series ckt → It that which has one & only path for conduction of current.



$V_T = V_1 + V_2 \ldots V_n$

$R_T = R_1 + R_2 \; --- \; R_n$

$I_T = I_1 = I_2$

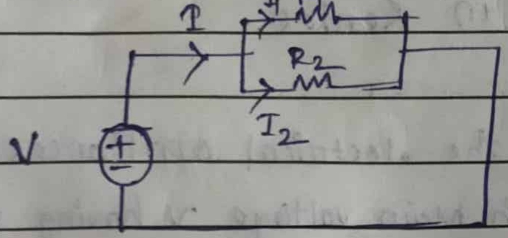
$\boxed{V = i R_{eq}}$

* Current should be same

Ohm's law :- The ratio of potential difference (V) b/w two points on a conductor to the current flowing between them is constant, the temp of the conductor does not change. $\frac{V}{I}$ = constant or $\frac{V}{I} = R$

Relation of V, I, R in Parallel ckt

Parallel ckt – In which all the components are connected across a single source of supply.



$V_T = V_1 = V_2$

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

$I_T = I_1 + I_2 + \dots + I_n$

$V_1 = I_1 \times R_1$, $V_2 = I_2 \times \frac{1}{R_2}$

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

voltage should be same.

Division of current in parallel ckt.

We know that the equivalent resistance has the same voltage in parallel ckt.

so $V = i R_{eq}$

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

~~$i_1 = \frac{V}{R_1}$~~ $i_1 = \frac{i R_2}{R_1 + R_2}$

$i_2 = \frac{i R_1}{R_1 + R_2}$

* This is shows that total current is shared by the resistance in inverse propotion to their resistance. This is known as the principle of current division & the ckt is known as a current divider.

Power in Series & Parallel Circuit :-

Series combination :- 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

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

ohm's law ($I = V/R$)

$P = VI$

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

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

Effective resistance $R = R_1 + R_2$

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

$$\Rightarrow \frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2}$$ — in series.

Parallel combination :- 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. $R = \frac{V^2}{P}$

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

Effective resistance $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

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

$$P = P_1 + P_2$$ — in parallel.

Kirchhoff's Law :-

Kirchhoff's Current Law (KCL)

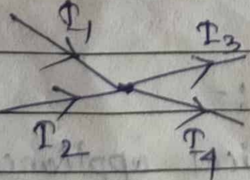
Algebric (+ve or -ve) sum of the currents meeting at any junction or node is zero.

Used for Node Analysis

$$\Sigma I = 0$$

or// Entering current = Leaving current from junction.

$$+I_1 + I_2 = I_3 + I_4.$$

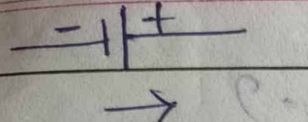


$I_1 + I_2 - I_3 - I_4 = 0$ (Algebric sum is zero)

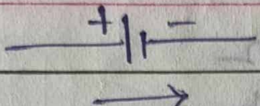
Mesh Analysis

KVL :- Algebric sum of all the voltage around a closed path or closed loop at any instant is zero.

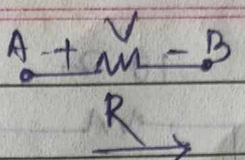
$$\Sigma V_n = 0 \qquad \Sigma IR + \Sigma e.m.f = 0$$



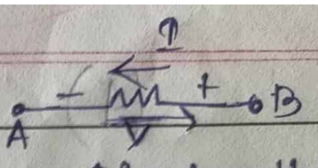
Rise in voltage
+E



Fall in voltage
−E

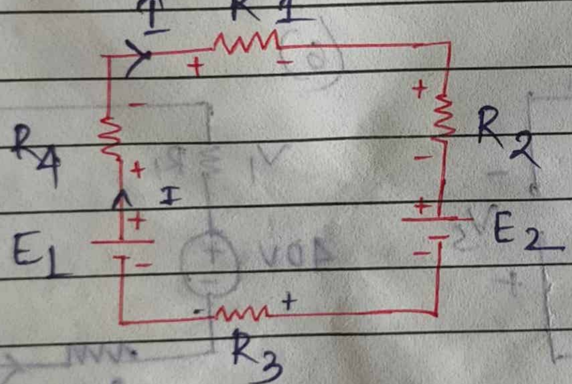


fall in volt.
$-V = -IR$



Rise in volt.
$V = IR$

Note :- EMF is independent of the current
Resistor depends on the direction of current.



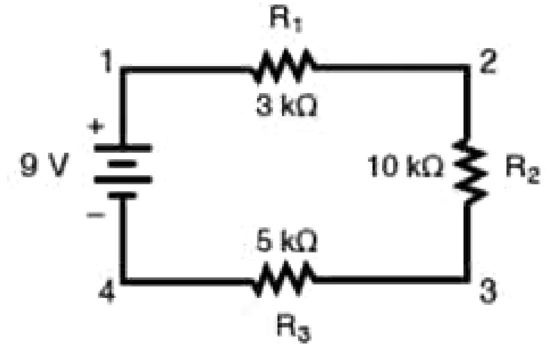
Using KVL

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

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

Statement :- The algebraic sum of the products of current & resistance in each of the conductors in any closed path (or mesh) in a network plus the algebraic sum of the emfs in that path is zero.

Example.1.3. Find the current I passing through and the voltage across each of the resistors in the circuit.



Solution: $R_{total} = R_1 + R_2 + R_3 = 3K\Omega + 10K\Omega + 5K\Omega = 18K\Omega$

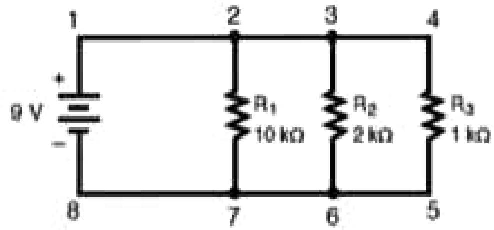
$$I = \frac{V}{R_{total}} = \frac{9}{18\times 10^3} = 0.5 \text{ mA}$$

$$V_{R1} = \frac{VR1}{R_1 + R_2 + R_3} = \frac{9}{18\times 10^3} \times 3\times 10^3 = 1.5V$$

$$V_{R2} = \frac{V}{R_1 + R_2 + R_3} R_2 = \frac{9}{18\times 10^3} \times 10\times 10^3 = 5V$$

$$V_{R3} = \frac{V}{R_1 + R_2 + R_3} R3 = = 2.5V$$

Example.1.4. Find the current I passing through and the current passing through each of the resistors in the circuit below.



Solution:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{10\times 10^3} + \frac{1}{2\times 10^3} + \frac{1}{1\times 10^3} = 0.0016$$

$$R_{total} = 625\Omega$$

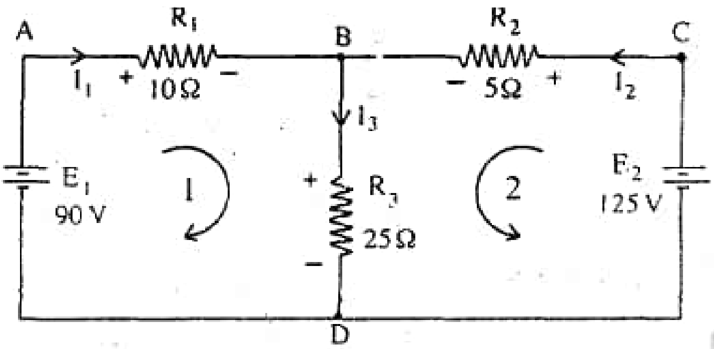
$$I = \frac{V}{R_{total}} = \frac{9}{625} = 0.0144\,Amp = 14.4mA$$

$$I_{R1} = \frac{V}{R_1} = \frac{9}{10\times 10^3} = 0.9mA$$

$$I_{R2} = \frac{V}{R_2} = \frac{9}{2\times 10^3} = 4.5mA$$

$$I_{R3} = \frac{V}{R_3} = \frac{9}{1\times 10^3} = 9mA$$

Example.1.5. Calculate the current supplied by two batteries in the circuit given below



Solution:

The four junctions are marked as A, B, C and D. The current through R_1 is assumed to flow from A to B and through R_2, from C to B and finally through R_3 from B to D. With reference to current directions, polarities of the voltage drop in R_1, R_2 and R_3 are then marked as shown in the figure. Applying KCL to junction B

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

Applying KVL to loop 1

$$E_1 - I_1R_1 - I_3R_3 = 0 \Rightarrow E_1 = I_1R_1 + I_3R_3$$

$$\Rightarrow 90 = 10I_1 + 25I_3 \quad .....(2)$$

Substituting Eq. (1) in Eq. (2)

$$90 = 10I_1 + 25(I_1 + I_2) \Rightarrow 90 = 35I_1 + 25I_2 \quad --------(3)$$

Applying KVL to loop 2

$$E_2 - I_2R_2 - I_3R_3 = 0 \Rightarrow E_2 = I_2R_2 + I_3R_3$$

$$\Rightarrow 125 = 5I_2 + 25I_3 \quad ....(4)$$

Substituting Eq. (1) in Eq. (4)

$125 = 5I_2 + 25(I_1 + I_2)$

$\Rightarrow 125 = 25I_1 + 30I_2$ ....(5)

After solving Eq. (3) & (5) we get

$I_1 = -1A$

$I_2 = 5A$

As the sign of the current I_1 is found to be negative from the solution, the actual direction of I_1 is from B to A to D i.e. 90 V battery gets a charging current of 1 A.

QUESTIONS FOR PRACTICE

Short Answer Questions

1. Define electric current.
2. State and explain Ohm's Law.
3. Define One Ohm.
4. What is meant by source in electricity?
5. State and explain Kirchoff's Voltage Law.

Chapter-2

Generation of Alternating EMF :-

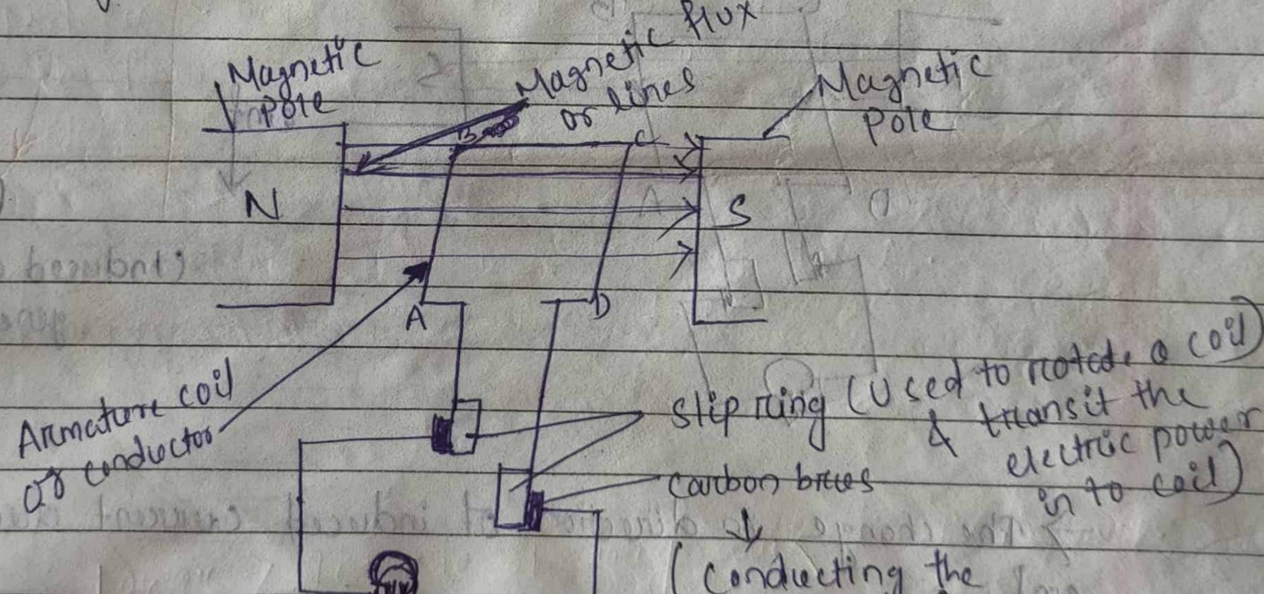
An electrical quantity is said to be alternating if it changes in magnitude & direction continuously with time.

→ AC generator generates AC voltage based on the "Faraday's law of electromagnetic Induction".

Faraday's law of ElectroMagnetic Induction state that - Whenever a conductor cuts magnetic flux, an emf is induced in that conductor.

The armature coil or conductor is rotated as shown in fig. the magnetic field changes, the magnetic flux linked with the coil changes & an emf is induced in it.

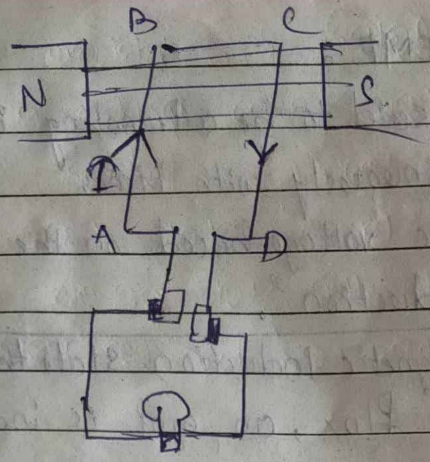
AC gen

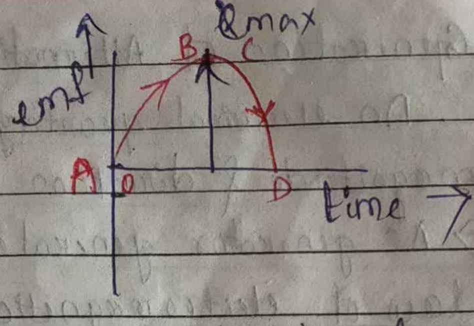


(schematic diagram of AC generator)

Case-1

→ When the plane of coil is vertical to the Magnetic lines, the flux is linked with the coil is zero. When the coil is start rotated then AB moves in & CD moves out causing current I to be induced in the coil in the direction (ABCDA) through the bulb.

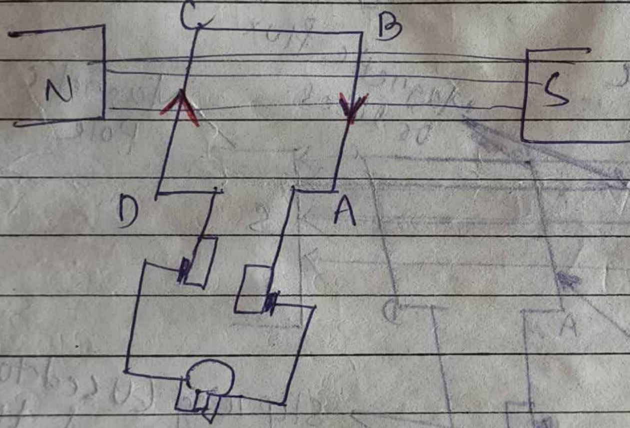


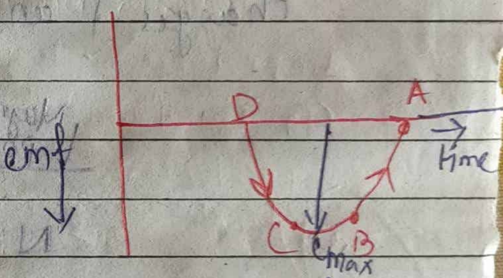


(Induced emf in AC gen. When it moves in forward direction)

Case-2

→ After half rotation of the coil, AB moves out & CD move in to the plane causing current I to be induced in the coil direction (D-C-B-A-D), through the bulb.

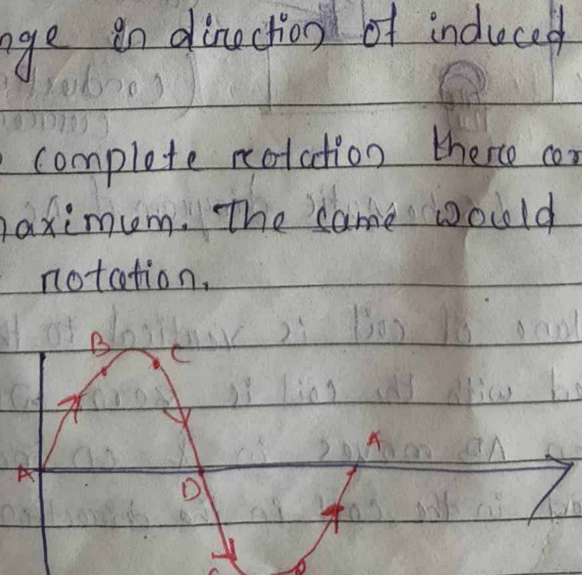




(Induced emf in AC generator)

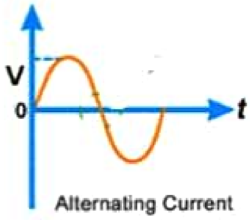
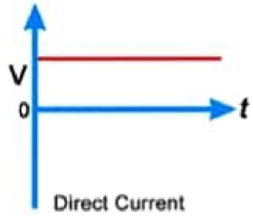
→ The change in direction of induced current due to induced emf.

→ For one complete rotation there are two instants when emf is maximum. The same would be ~~repated~~ repeated for next rotation.

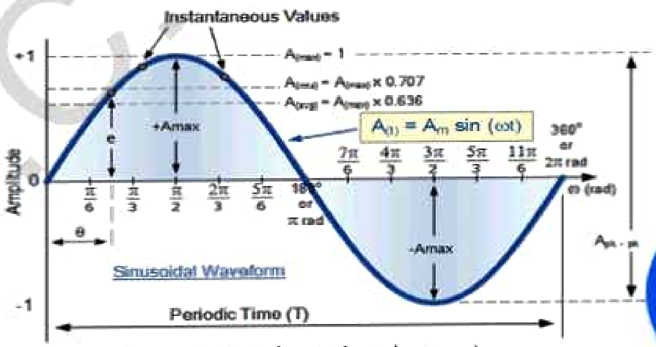


(complete cycle)

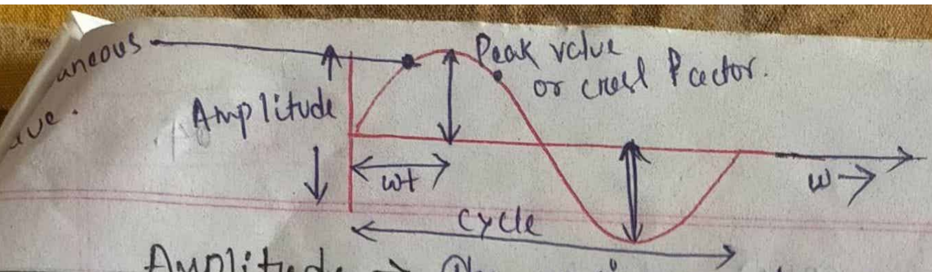
DIFFERENCE BETWEEN AC & DC:-

AC	DC
	
1. The current which change its magnitude & direction periodically (or at regular interval) is called alternating current.	1. The current which does not change its magnitude & direction periodically is called alternating current. i.e the direction of current remains same.
2. The direction of flow of electron is bidirectional	2. The direction of flow of electron is unidirectional
3. It has frequency, like Indian standard frequency is 50Hz.	3. It has zero frequency.
4. It's power factor lies between 0 & 1.	4. It's power factor is always 1
5. It's passive parameter is impedance Combination of Reactance and Resistance.	5. It's passive parameter is resistance.
6. AC generate from AC generator.	6. DC generate from DC generator, battery, solar cell etc.
7. It is represented by sine wave, square wave, triangular wave etc.	7. It is represented by straight line i.e it may be 2 types Pure DC and Pulsating DC
8. Can be transmitted over long distance with some losses.	8. It can be transmitted over very long distance with negligible losses.
9. Their load is resistive, inductive or capacitive.	9. Their load is usually resistive in nature.
10. Dangerous	10. Very Dangerous
11. Easily convert into direct current by rectifier.	11. Easily convert into alternating current by inverter.
12. Application- Factories, Industries and for the domestic purposes.	12. Application- Electroplating, Electrolysis, Electronic Equipment etc.

DEFINITIONS RELATED TO AN ALTERNATING VOLTAGE OR CURRENT: -



(**Fig.2.4.** An alternating sin wave)



Amplitude → The Maximum value, positive or negative, of an alternating quantity is known as amplitude.

Instantaneous Value :- It is defined as the value of alternating quantity at any instant of time. It is represented by $v(t)$ or $i(t)$.

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

$i(t) = I_m \sin(\omega t + \theta)$

V_m = Max^n voltage, I_m = Max Current

Cycle → One complete set of positive & negative values of alternating quantity is known as cycle.

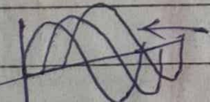
Time Period :- The time taken by an alternating ~~quantity~~ quantity to complete one cycle is called its time period (T).

$\boxed{T = \frac{1}{f}}$, f = frequency. $T = \frac{1}{50}$ sec.

Frequency :- The no of cycles/second is called the frequency. Unit is hertz (Hz)

$\boxed{F = \frac{1}{T}}$

phase Angle :- ωt is called its phase angle.
phase of an alternating quantity is the angular displacement of the phasor representing that alternating quantity.



Phase Difference → The difference between the phases of the two alternating quantities is called as phase difference.

$v(t) = V_m \sin \omega t$ (start from origin)

$= V_m \sin(\omega t - \theta)$ ($\theta°$ to right shift)

$= V_m \sin(\omega t + \theta)$ (left side)

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:-**

For an alternating current, the average value is defined as that value of DC current which transfers across any circuit the same charge as is transferred by the alternating current during the same time under the same conditions. It is represented by V_{avg} or I_{avg}.

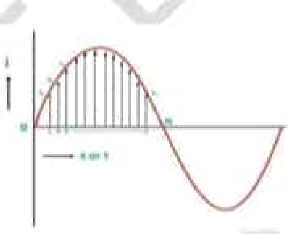
- There are two methods to calculate average value

i. **Mid ordinate method/ graphical method**

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

Let i_1, i_2, i_3........ i_n be the mid ordinates

The Average value of current I_{av} = mean of the mid ordinates



(**Fig.2.6.** Average Value of a positive half-cycle)

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

If we consider symmetrical waves like sinusoidal current or voltage waveform, 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 waveform, the average value of alternating current is

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

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

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

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

$$Iavg = \frac{Im}{\pi} [-\cos\theta]_0^{\pi}$$

$$Iavg = \frac{2Im}{\pi}$$

Hence average value of current = 0.637× maximum value of current (for half cycle)

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 through the same circuit for the same time.

In other words, the R.M.S value is defined as the square root of means of squares of instantaneous values. It is represented by V_{rms} or I_{rms}.

There are two methods calculate RMS value.

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 (I_{eff}). The base of one alteration is divided into n equal parts so that each interval is of t/n seconds as shown in the figure below

Let $i_1, i_2, i_3, ...\ i_n$ be the mid ordinates. Then the heat produced in

First interval = $\frac{i_1^2 Rt}{Jn}$ calories

Second interval = $\frac{i_2^2 Rt}{Jn}$ calories

n^{th} interval = $\frac{i_n^2 Rt}{Jn}$ calories

Total Heat produced = $\frac{Rt}{J}\left(\frac{i_1^2 + i_2^2 + ...+ i_n^2}{n}\right) calories$ ....(2.1)

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

$\frac{I_{eff}^2 Rt}{J} calories$ ....(2.2)

Now, equating equation (2.1) and (2.2) we will get

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

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

ii. **Analytical method**

RMS value of sinusoidal current $i = I_m \sin \omega t$

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

$$I_{rms} = \sqrt{\frac{1}{2\Pi}\int_0^{2\Pi} I_m^2 \sin^2 \omega t\, d(\omega t)}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}} = 0.707\, I_m$$

4. **Form Factor**

The form factor is the ratio of RMS value of an alternating quantity to the average value of the same quantity

$$form\ factor = \frac{RMS\ Value}{Average\ Value} = \frac{0.707 \times maximum\ Value}{0.637 \times maximum\ Value} = 1.11$$

F.F=1.11 for sinusoidal alternating quantity only

5. **Peak factor/ crest/ amplitude factor**

Hence RMS value of current =0.707×maximum value of current

Second interval = $\frac{I_2^2 Rt}{Jn}$ calories

n^{th} interval = $\frac{I_n^2 Rt}{Jn}$ calories

$$\text{Total Heat produced} = \frac{Rt}{J}\left(\frac{I_1^2 + I_2^2 + \ldots\ldots + I_n^2}{n}\right) calories \ldots\ldots (2.1)$$

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

$$\frac{I_{eff}^2 Rt}{J} calories \ldots\ldots (2.2)$$

Now, equating equation (2.1) and (2.2) we will get

$$\frac{I_{eff}^2 Rt}{J} = \frac{Rt}{J}\left(\frac{I_1^2 + I_2^2 + \ldots\ldots + I_n^2}{n}\right)$$

$$I_{eff} = \sqrt{\frac{I_1^2 + I_2^2 + \ldots\ldots + I_n^2}{n}}$$

ii. <u>Analytical method</u>

RMS value of sinusoidal current $I = I_m \sin \omega t$

$$I_{rms} = \sqrt{\frac{1}{2\Pi}\int_0^{2\Pi} I^2 d(\omega t)}$$

$$I_{rms} = \sqrt{\frac{1}{2\Pi}\int_0^{2\Pi} I_m^2 \sin^2 \omega t d(\omega t)}$$

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

4. Form Factor

The form factor is the ratio of RMS value of an alternating quantity to the average value of the same quantity

$$form\ factor = \frac{RMS\ Value}{Average\ Value} = \frac{0.707 \times maximum\ Value}{0.637 \times maximum\ Value} = 1.11$$

F.F=1.11 for sinusoidal alternating quantity only

5. Peak factor/ crest/ amplitude factor

Hence RMS value of current =0.707×maximum value of current

Peak factor or crest factor of an alternating quantity is the ratio of maximum value (peak value) to RMS value

$$\textbf{Peak factor} = \frac{maximum\ Value}{RMS\ Value} = \frac{maximum\ Value}{0.707 \times maximum\ Value} = 1.414$$

Example 2.1:- Write down the equation for a sinusoidal voltage of 50 Hz and its peak value is 20 V. Draw the corresponding voltage versus time graph.

Solution

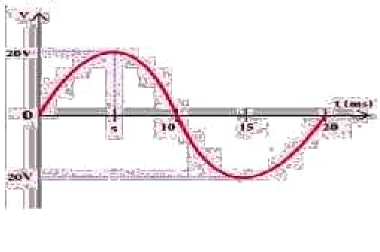
$f = 50Hz \quad ; \quad V_m = 20V$

Instantaneous Voltage =

$$\begin{aligned} v &= V_m \sin \omega t \\ &= V_m \sin 2\Pi\ ft \\ &= 20\sin(2\Pi \times 50)t \\ &= 20\sin(2 \times 3.141 \times 50)t \\ &= 20\sin 314t \end{aligned}$$

Time for one cycle = $T = \frac{1}{f} = \frac{1}{50} = 0.02\sec$

The waveform is:



Example 2.2:-

The equation for an alternating current is given by $i = 77 \sin 314t$. Find the peak value, frequency, time period and instantaneous value at t = 2 ms.

Solution

$i = 77 \sin 314t$; $t = 2$ ms $= 2\times10^{-3}$ s
The general equation of an alternating current is $i = I_m \sin \omega t$. On comparison,
(i) Peak value, $I_m = 77$ A
(ii) Frequency, $f = \omega/2\pi = 314 / 2 \times 3.14 = 50$ Hz

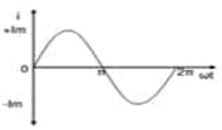
Time period, $T = 1/f = 150 = 0 .02$ s
(iv) At t = 2 m s,
Instantaneous value,
$i = 77 \sin(314\times2\times10^{-3})$
$i = 45.24$ A

<u>REPRESENT AC VALUES IN PHASOR DIAGRAMS:-</u>

An alternating quantity can be represented using
i) Waveform
ii) Equations
iii) Phasor

A sinusoidal alternating quantity can be represented by a rotating line called a **Phasor.** A phasor is a line of definite length rotating in anticlockwise direction at a constant angular velocity

The waveform and equation representation of an alternating current is as shown. This Sinusoidal quantity can also be represented using phasors.

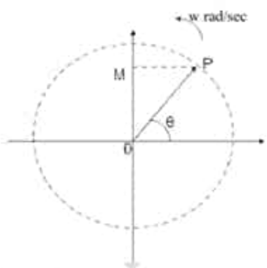


$i = I_m \sin \omega t$

(**Fig.2.7.** Waveform of alternating quantity)

In phasor form the above wave is written as $\bar{I} = I_m \angle 0°$

Draw a line OP of length equal to I_m. This line OP rotates in the anticlockwise direction with a uniform angular velocity ω rad/sec and follows the circular trajectory shown in figure. At any instant, the projection of OP on the y-axis is given by $OM = OP\sin\theta = I_m \sin\omega t$. Hence the line OP is the phasor representation of the sinusoidal current.

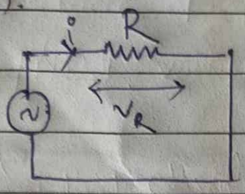


(**Fig.2.8.** Phasor representation of alternating wave)

AC Through Pure Resistance :-

whenever an alternating voltage is applied to a pure resistance let the applied voltage be given by the equation.

$v = V_m \sin \omega t$ ——— (i)



(circuit diagram)

R = Ohmic Resistance

i = Instantaneous current

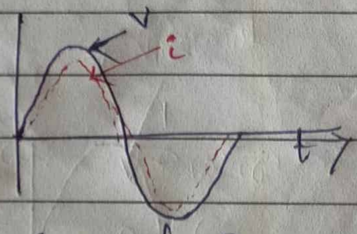
Obviously the applied voltage has to supply ohmic voltage drop only.

$v = iR$ → According to ohm's law.

Putting the value of v.

$\Rightarrow V_m \sin \omega t = iR$

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



(wave form)

i is max^m when sin ωt is unity (1)

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

(Phasor diagram)

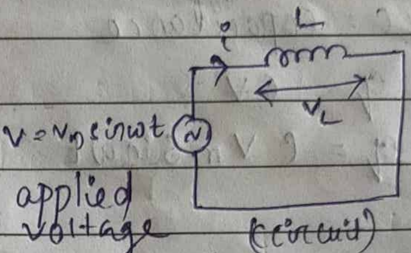
$\boxed{i = I_m \sin \omega t}$ ——— (ii)

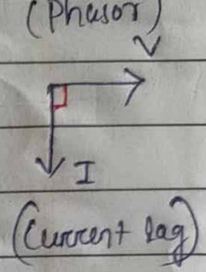
Comparing (i) & (ii) we find that the alternating voltage & current are in phase with each other.

AC Through Pure Inductance :-

Whenever an alternating voltage is applied to a purely inductive coil, a back emf is produced due to self inductance of coil. The back emf opposes the rise or fall of current through the coil. The applied voltage has to overcome this self induced emf only.

$v = L \frac{di}{dt}$
↳ developed emf





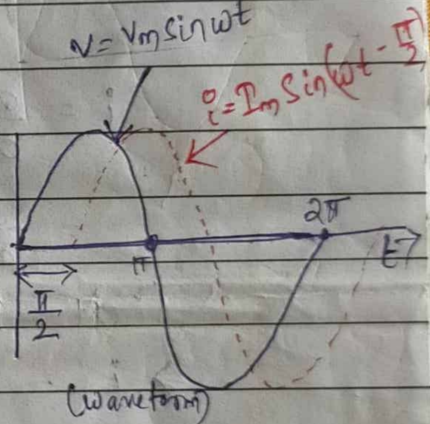
$v = V_m \sin \omega t$
↳ Instantaneous voltage or applied voltage

comparing both the value, so we get

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

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

Integrating both side, we get



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

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

formula :- $\cos(\omega t) = \sin(\omega t - \frac{\pi}{2})$

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

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

$X_L = \omega L$
X_L = Inductive Reactance
↓
The opposition offered by L is called X_L.

Max^m value of i is

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

when $\sin(\omega t - \frac{\pi}{2}) = 1$

Hence the equation of the current becomes $i = I_m \sin(\omega t - \frac{\pi}{2})$

So we find that is applied voltage is represented by v ($v = V_m \sin \omega t$), then current flowing in a purely inductive circuit is given by $\boxed{i = I_m \sin(\omega t - \frac{\pi}{2})}$

AC Through Pure Capacitance :-

When an alternating voltage is applied to ~~the~~ a capacitor, the capacitor is charged.

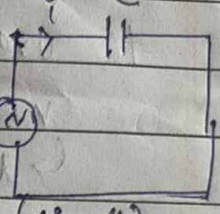
v = potential developed at any instant = $V_m \sin \omega t$

q = charge

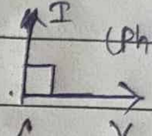
C = capacitance

$q = CV$

$q = C V_m \sin \omega t$ (Putting value of v)



(circuit)



(Phasor)

(Current lead)

Now, current i is given by the rate of flow of charge

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

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

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

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

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

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

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

$$= \frac{V_m}{1/\omega C} \left[\sin\left(\omega t + \frac{\pi}{2}\right)\right]$$

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

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

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

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

$$= \frac{V_m}{1/\omega C} \left[\sin\left(\omega t + \frac{\pi}{2}\right)\right]$$

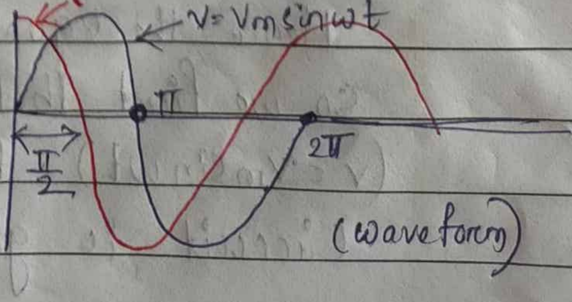
Max^m value of i is

$$I_m = \frac{V_m}{1/\omega C} = \frac{V_m}{X_C}$$

$X_C = \frac{1}{\omega C}$ → Capacitive Reactance

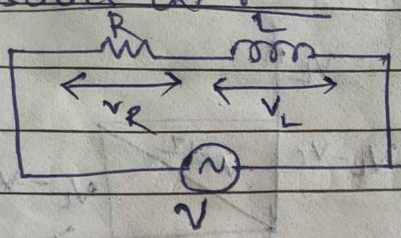
$$\Rightarrow \boxed{i = I_m \sin\left(\omega t + \frac{\pi}{2}\right)}$$

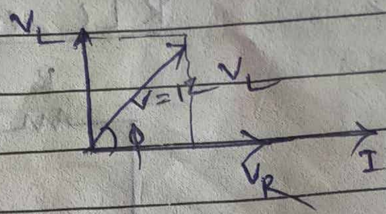
∴ Hence we find that the current in a pure capacitor leads its voltage by 90°.



(waveform)

RL Series ckt :-





$V_R = IR, \; V_L = IX_L$

$\boxed{Z = \sqrt{R^2 + X^2}}$ → impedance

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

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

$\tan = \frac{P}{b}$

$V = IZ$

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

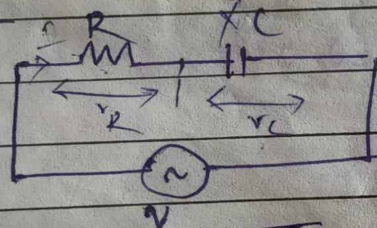
Power factor

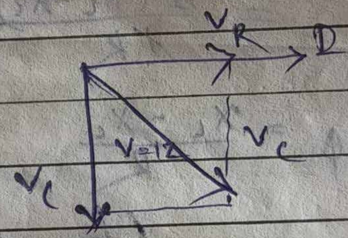
$\cos\phi = \frac{R}{Z}$

Phase Angle ($\tan\phi$) $= \frac{V_L}{V_R} = \frac{IX_L}{IR} = \frac{X_L}{R}$

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

RC





$V_R = I \cdot R$

$V_C = I \cdot X_C$

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

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

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

$\Rightarrow V = IZ$

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

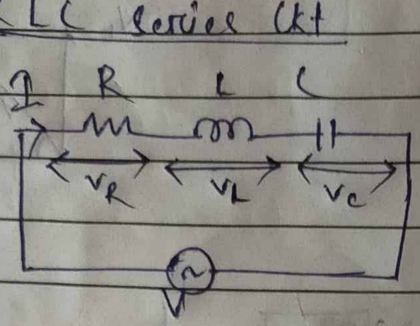
Power factor

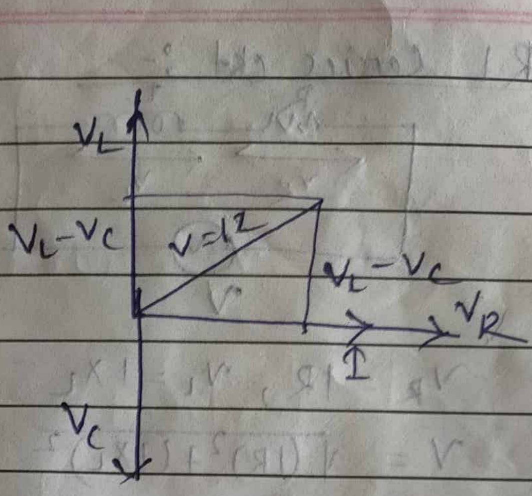
$\cos\phi = \frac{R}{Z}$

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

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

RLC series Ckt





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

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

$$= IZ$$

$V_R = I \cdot R$

$V_C = I \cdot X_C$

$V_L = I \cdot X_c$

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

$$= \frac{IX_L - IX_C}{IR}$$

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

Phase Angle

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

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

$X_L = X_C$, $i = I_m \sin\omega t$

$X_L > X_C$ $\quad i = I_m \sin(\omega t - \phi)$

$X_L < X_C$ $\quad i = I_m \sin(\omega t + \phi)$

Power factor

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

Power - Power consumed by a load will be comprised of several individual power components.

Power Components :-

(1) Apparent Power (S) - Product of volt & current only.

$S = VI$ (VA or kVA)

(2) Active Power (P or W) → dissipated in circuit resistance.

$P = VI\cos\phi$ or I^2R (kW or watt)

(3) Reactive Power (Q) → power developed in the inductive reactance of the ckt.

$Q = VI\sin\phi$ or I^2X (kVAR or VAR)

$X_L = \omega L$, $X_C = \frac{1}{\omega C}$

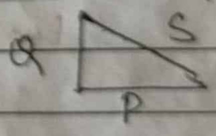
P.F → Angle between voltage & current.

Power Triangle :-

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

	Active power	Reactive Power	Apparent Power
RL series ckt	$VI\cos\phi$	$VI\sin\phi$ or I^2R	I^2R
RC	$VI\cos\phi$ (I^2X_L)	$VI\sin\phi$ (I^2X_C)	$I^2(X_L - X_C)$
RLC	$VI\cos\phi$	$VI\sin\phi$	I^2Z or VI

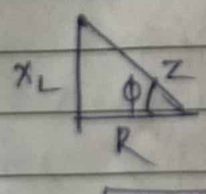
Power Triangle



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

Impedance triangle.

RL



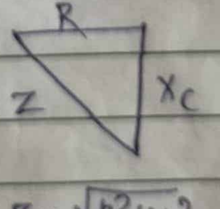
$Z = \sqrt{R^2 + X_L^2}$

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

$P.F = \cos\phi = \frac{R}{Z}$

$\sin\phi = \frac{X_L}{Z}$

RC

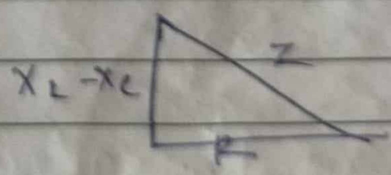


$Z = \sqrt{R^2 + X_C^2}$

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

$\sin\phi = \frac{X_C}{Z}$

$P.F = \cos\phi = \frac{R}{Z}$



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

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

$\sin\phi = \frac{X_L - X_C}{Z}$

$P.F = \cos\phi = \frac{R}{Z}$

Example 2.3:- A Capacitor of capacitance 79.5μF is connected in series with a non-inductive resistance of 30 ohm across a 100V, 50Hz supply. Find (i) impedance (ii) current (iii) phase angle.

Solution:

$$X_c=\frac{1}{2\pi fC}=\frac{1}{2*3.14*50*79.5*10^{-6}}=40\Omega$$

i) $Z=\sqrt{R^2+X_c^{\,2}}=\sqrt{30^2+40^2}=50\Omega$

ii) $I=\frac{V}{Z}=\frac{100}{50}=2A$

iii) Phase angle = $tan^{-1}(\frac{X_c}{R})$ = $tan^{-1}(\frac{40}{30})$= 53°

Example 2.4:- A resistance of 20 Ω and inductance of 0.2H and a capacitance of 100μF are connected in series with 220 volt, 50 Hz mains. Determine (a) impedance (b) current (c) voltage across R, L, C (d) power in watts and VA (e) p.f. and angle of lag.

Solution

R= 20Ω; L=0.2 H; C=10^{-4}F

$X_l=2\pi fL$ =0.2×314 = 62.8 Ω ≈ 63 Ω

$X_c=\frac{1}{2\pi fC}=\frac{1}{314*10^{-4}}$=31.847 ≈ 32Ω; X_L-X_c = 63-32 = 31Ω (inductive)

(a) Z=$\sqrt{20^2+31^2}$ = 37Ω (b) I = 220/37= 6A

(c) V_R = I × R = 6 × 20 = 120 v; V_L = 6 × 63 = 278 V; V_c = 6 × 32 = 192 V

(d) Power in VA = 6×220 = 1320 VA

Power in watts = 6×220×0.54= 713 W

(e) p.f. = $cos\,O=\frac{R}{Z}=\frac{20}{37}$= 0.54; $O=cos^{-1}(0.54)$= 57°18′

Example 2.5:-_A 230 V, 50 Hz ac supply is applied to a coil of 0.06 H inductance and 2.5 Ω resistance connected in series with a 6.8 μF capacitor. Calculate (i) Impedance (ii) Current (iii)Phase angle between current and voltage (iv) power factor

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Solution

$X_L=2\pi fL=2\times 3.141\times 50\times 0.06=18.84ohm$

$$X_C=\frac{1}{2\pi fc}=\frac{1}{2\times 3.141\times 50\times 6.8\times 10^{-6}}=468ohm$$

(i) $Z=\sqrt{(R)^2+(X_L-X_C)^2}=\sqrt{(2.5)^2+(18.84-468)^2}$ =449.2 ohm

(ii) $I=\frac{V}{Z}=\frac{230}{449.2}=0.512A$

(iii) $O=\tan^{-1}\left(\frac{X_L-X_C}{R}\right)=\tan^{-1}\left(\frac{18.84-468}{30}\right)=-89.7°$

(iv) $power\ factor=\ cosO=\cos(-89.7°)=0.0056lead$

Generation of Electrical Power :-

The conversion of energy available in different forms in nature into electrical energy is known as generation of electrical energy.

* Bulk electric power is produced by special plants known as generating station or power plant.

Steam Power Station (Thermal station)

A generating station which converts heat energy of coal combustion into electrical energy is known as a steam power station.

Steam is produced in the boiler by utilising the heat of coal combustions. The steam is then expanded in the prime mover (steam turbine) & is condensed in a condenser to be fed into the boiler again. The steam turbine drives the alternator which converts mechanical energy of the turbine into the electrical energy. The electrical energy transmitted & distributed to various consumers.

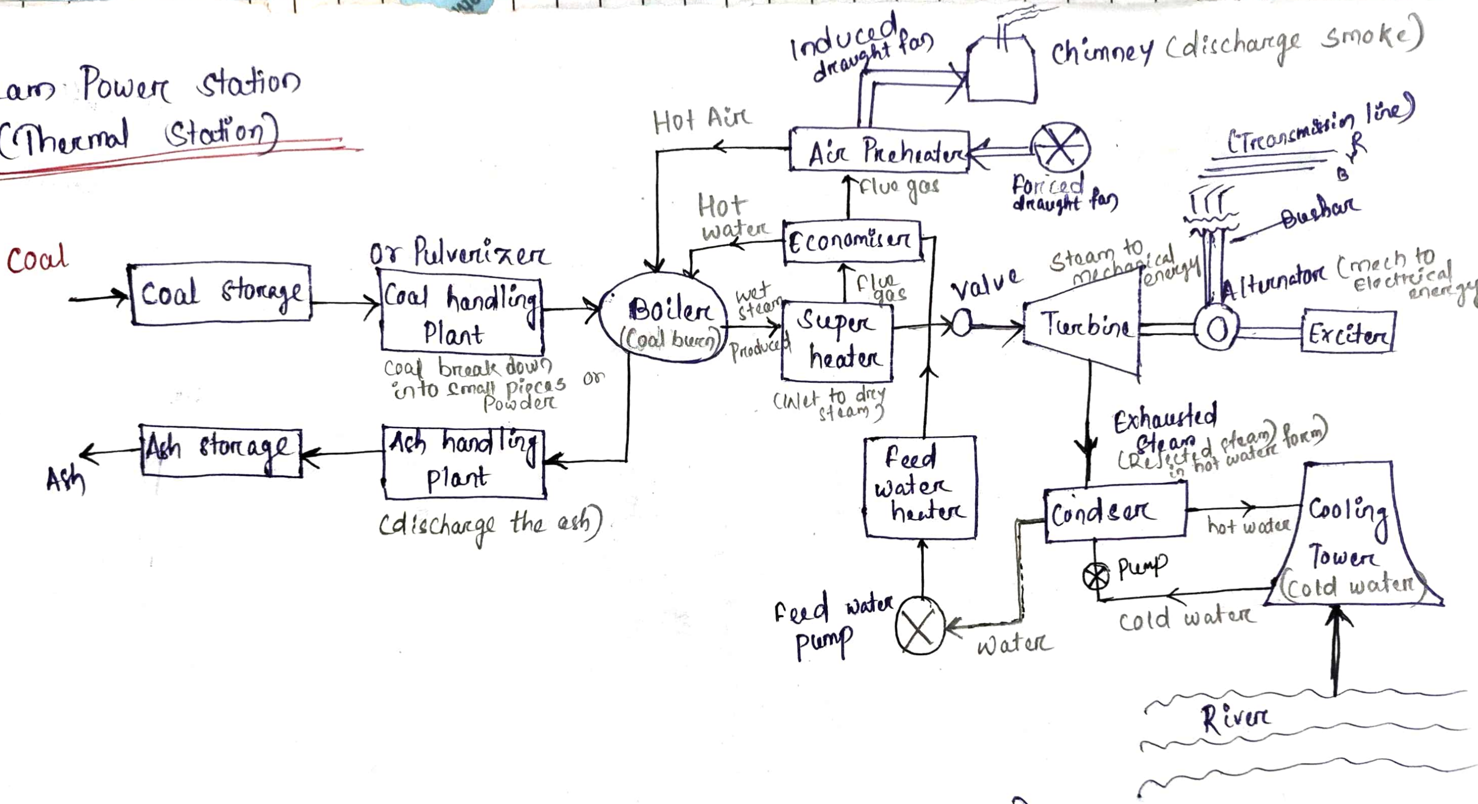
It works on the Rankine cycle.

▶ Schematic Arrangement of steam power station :-

The schematic arrangement of steam power station is shown in fig. The whole arrangement can be divided into the following stages :-

(1) Coal & ash handling plant :- The coal is transported to the power station & it stored in the coal storage plant. From the coal storage plant, coal is delivered to coal handling plant where it is pulverised (crushed into small pieces). pulverised coal is fed to the boiler. The coal is burn in the boiler & ash produced after the complete combustion of coal is removed to ash handling plant & then delivered to the ash storage plant for disposal.

Steam Power station (Thermal Station)



(Schematic Arrangement of steam Power station)

(2) Steam generating plant :- The steam generating plant consist of a boiler for production of steam.

(i) Boiler → The heat of combustion of coal in the boiler is utilised to convert water into steam at high temperature & pressure.

(ii) Superheater - The steam produced in the boiler is wet & is passed through a superheater where it is dried.

(iii) Air Preheater - increase the temperature of air. Air is drawn from the atmosphere by a forced draught fan & is passed through air preheater.

(3) Steam Turbine :- Superheater is fed to the steam turbine. The heat energy of steam when passing over the blades of turbine is converted to mechanical energy.

→ After giving heat energy to the turbine, the steam is exhausted to the condenser which used to cold water circulation.

(4) Alternator - It converts mechanical power to electrical power. The electrical o/p from the alternator is delivered to the load through transformer, transmission line.

(5) Feed water - Condenser water is used as feedwater to the boiler.

(6) Cooling Arrangement - It is used to cold the water. The cold water from the cooling tower is received in the condenser.

▶ Advantages :- Less cost, less space required.

Disadvantages - Pollute the atmosphere due to the production of large amount of smoke & fumes.

Hydro Power Plant

A generating station which uses the potential energy of water to produce electricity.
Or Hydropower plant uses hydraulic energy of water to produce electricity.
* Hydraulic energy is energy which store in the water or energy present in the water.

▶ Working :-

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

▷ Elements /Component of hydro power plant :-

(1) Reservoir → Reservoir is a large collection of water behind a hydroelectric dam that makes use of potential energy of water for generating electricity.

(2) Dam - Water is stored in dam by using river. This stored water is useful throughout the year to run the hydro-electric power plant. Dam is made up of cement, concrete & sand material.

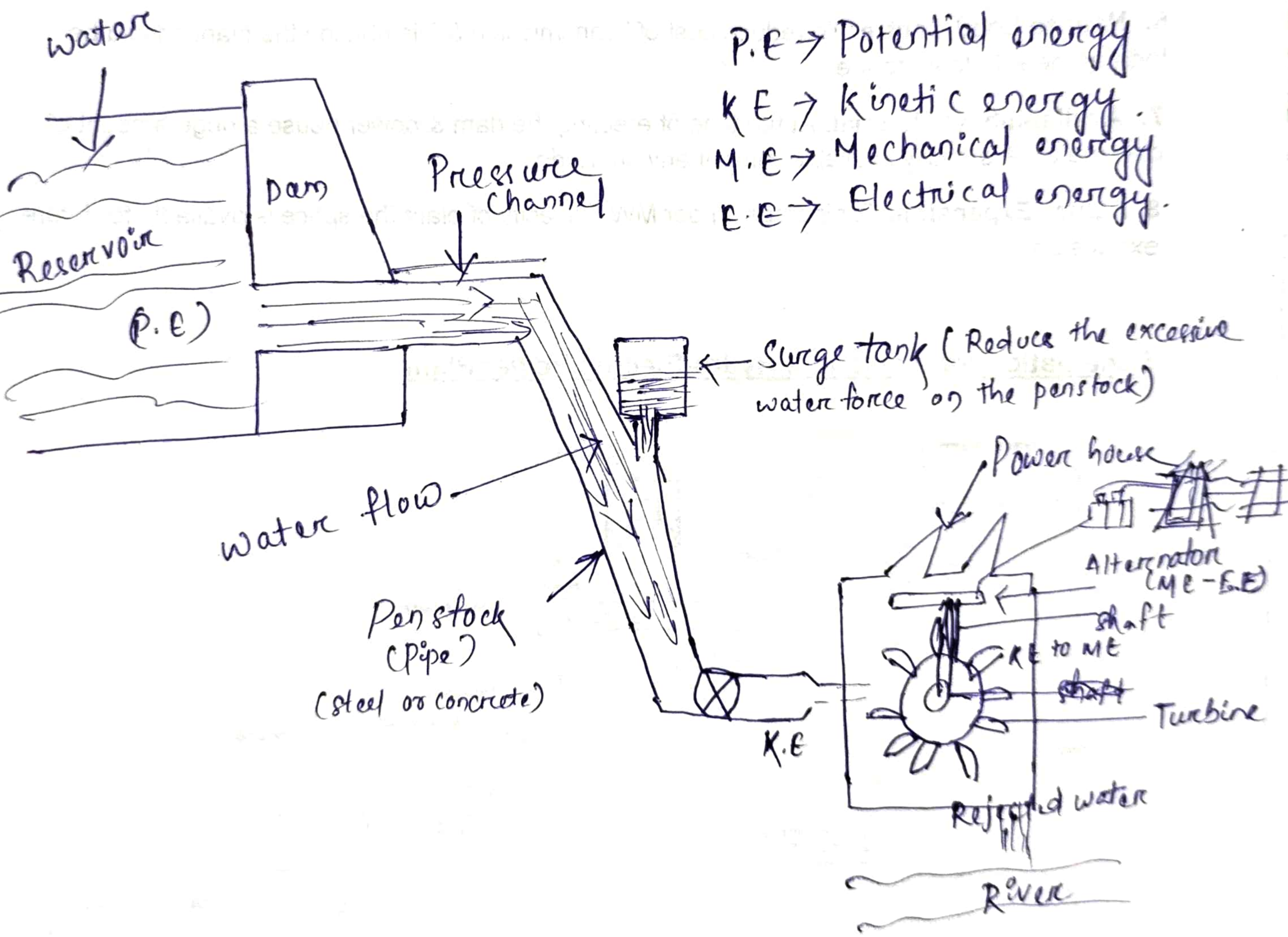
(3) Penstock - A penstock is a group of pipes that transport pressurised water from a reservoir (dam) to the turbine.
Or The water flow of from dam towards turbine with the help of penstock.
It is made up of steel or concrete.

(4) Surge Tank - It is a device which is connected in between dam & ~~Surge~~ Power house.

→ Due to sudden reduction in water discharge causes increase in pressure of the water in the penstock. Due to high pressure penstock may damage. Surge tank helps by storing this excessive water force on the penstock.

(5) Turbine :- It is used to convert kinetic energy to mechanical energy. Turbine & generator coupled with each other. They are connected by shaft.

(6) Generator :- It is used to convert mechanical energy to electrical energy. Generator produce electrical energy.


P.E → Potential energy
K E → Kinetic energy
M.E → Mechanical energy
E.E → Electrical energy
water
Dam
Reservoir
(P.E)
Pressure Channel
Surge tank (Reduce the excessive water force on the penstock)
water flow
Penstock (Pipe) (steel or concrete)
K.E
Power house
Alternator (ME-E.E)
Shaft
KE to ME
Turbine
Rejected water
River

ADVANTAGES

i) It requires no fuel as water is used for the generation of Electrical Energy.

ii) It is quite neat & clean as no smoke or ash is produced.

iii) Running cost is very less as water is used.

iv) It is simple in construction & requires less maintenance.

v) It can be started quality as compared to Thermal Power Station.

vi) In addition to generation of Electrical Energy these plants are also helpful in irrigation & control of floods.

DISADVANTAGES

i) It involves high capital lost due to construction of dams.

ii) Generation depends on average rainfall round the year.

iii) High cost of transmission as these plants are located in hilly areas quite for off from localities.

Nuclear Power Plant :-

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

▷ Working :- As we known that, the freely moving neutrons boombarded with radioactive material (Uranium) the heat energy produced, with the help of this heat energy water a steam produced at high pressure & temperature. High pressure steam passes towards turbine where kinetic energy is converted in to mechanical energy. Turbine & generator are mechanically coupled ~~their~~ each other. Generator produced electrical energy. In this way electrical plant will be worked.

▷ Component used in Nuclear Power Plant :-

(1) Nuclear Fuel :- In Nuclear power plant the fuels used ~~are~~ uranium or Thorium. The fuel is required in nuclear power plant to produce a huge amount of heat energy. The fuel are inserted in fuel rod.

(2) Moderator → It is reduce the speed of neutrons & increases the fission processes. Moderator rod is made up of heavy water or graphite.

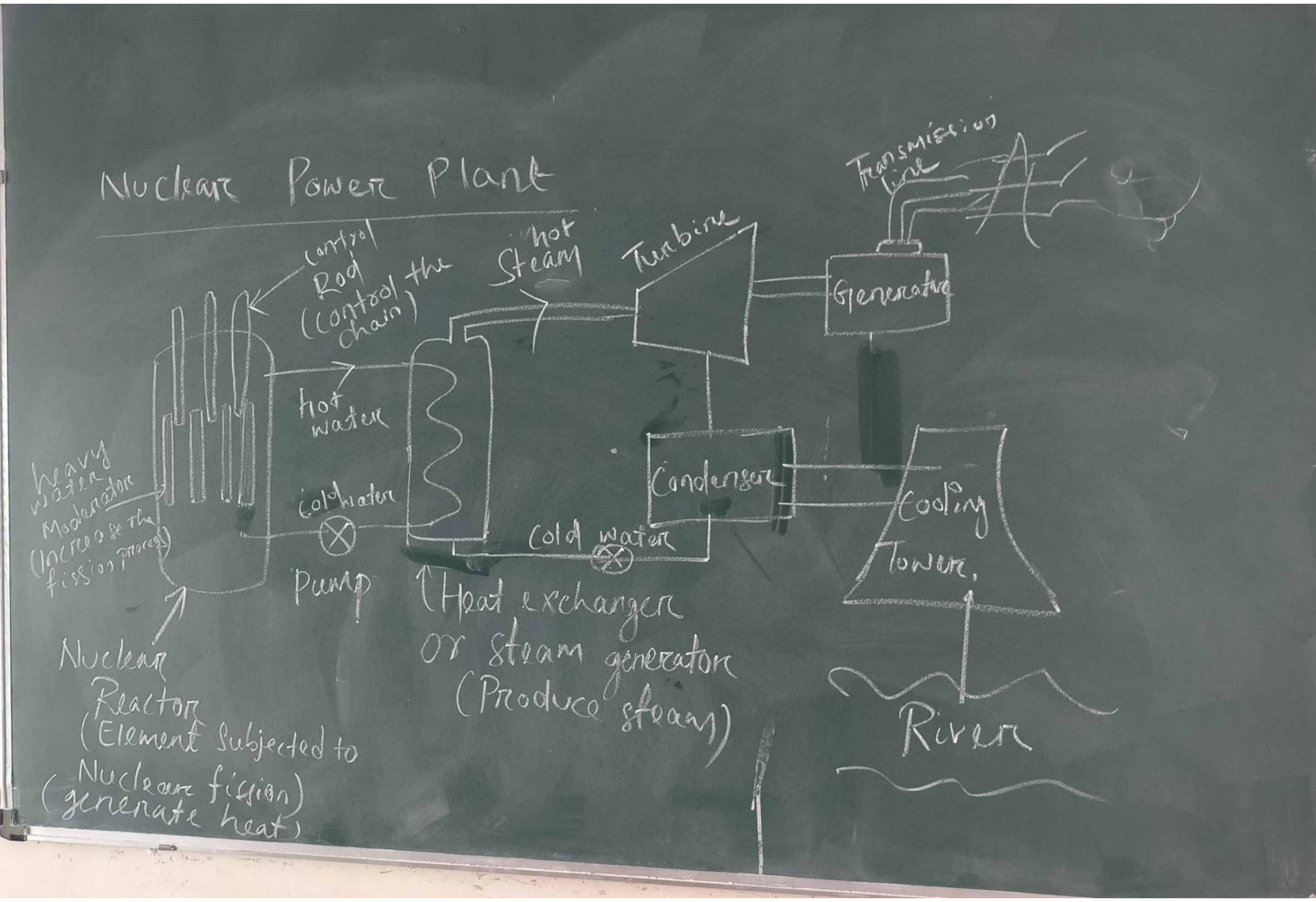
(3) Control Rods → Control are placed in between nuclear fuel rod, & moderator.
→ Used to control the chain reaction.

(4) Nuclear Reactor → It is an apparatus in which the nuclear fuel is subjected to nuclear fission.

(5) Heat Exchanger → It is used to convert hot water to steam energy. It is also called as steam generator which produced steam.

(6) Turbine → It is used to convert steam to mechanical energy.

(7) Generator → converts mechanical energy to electrical energy. It produced electrical energy.


Nuclear Power Plant
Control Rod (Control the chain)
hot Steam
Turbine
Transmission line
Generator
hot water
cold water
heavy water Moderator (Increase the fission process)
Pump
Condenser
Cooling Tower.
cold water
Heat exchanger or steam generator (Produce steam)
Nuclear Reactor (Element Subjected to Nuclear fission) (generate heat)
River

ADVANTAGES

i) There is saving in fuel transportation as amount of fuel required is less.

ii) A Nuclear Power Plant requires less space as compared to other plants.

iii) This type of plant is economical for producing bulk Electrical Energy.

DISADVANTAGES

i) Fuel is expensive and difficult to recover.

ii) Capital lost is higher than other plants.

iii) Experienced workman ship is required for plant erection & commissioning.

iv) The Fission by-products are radioactive & can cause dangerous radio-active pollution.

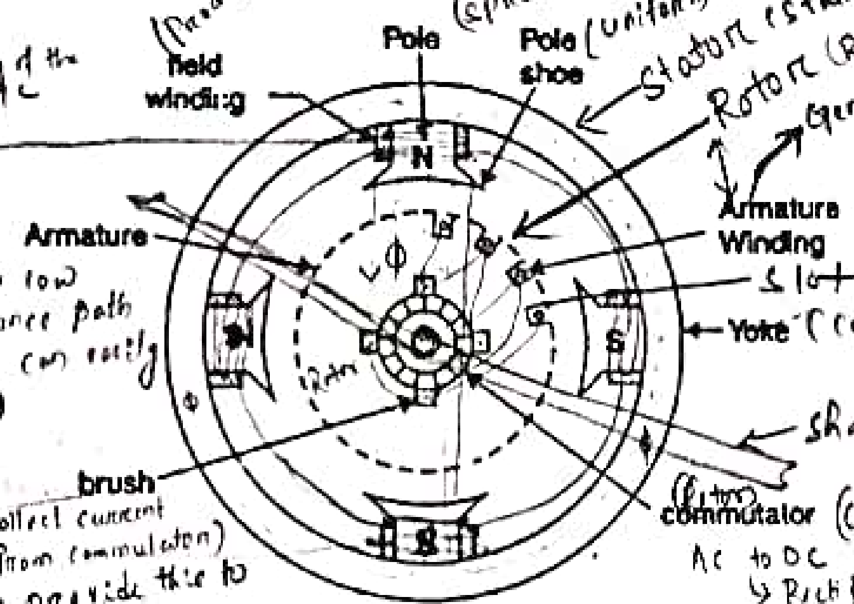
CHAPTER - 4

CONVERSION OF ELECTRICAL ENERGY

INTRODUCTION:-

A DC machine is a device which converts mechanical energy into electrical energy. When the device acts as a generator mechanical energy is converted into electrical energy. On the other hand when the device acts as a motor, the electrical energy is converted into mechanical energy. However, during the conversion process a part of the energy is converted into heat, which is lost and is not reversible. Thus an electrical machine can be made to work either as a generator or a motor.

PARTS OF DC MACHINE:-



(Fig.4.1. Different Parts of DC Machine)

The DC machine consists of the following essential parts:

Magnetic frame or Yoke: - Purpose of Yoke is:

(a) It act as a protecting cover for whole machine.

(b) It also provides mechanical support for poles.

(c) It carries the magnetic flux produced by poles

Pole Cores and Pole Shoes: - The field magnets consist of pole cores and pole shoes. The Pole shoes serve two purposes:

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

(b) They support the exciting coils

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.

Armature Core: - Armature core is cylindrical in shape mounted on the shaft. It is made up of laminated construction to keep eddy current loss as low as possible. Function of armature core is:

1. Armature core provides house for armature winding i.e., armature conductors.

2. To provide a path of low reluctance path to the flux it is made up of magnetic material like cast iron or cast steel.

Armature Windings or Conductors: - Armature winding is the inter connection of the armature conductors, placed in the slots provided on the armature core. Function of armature conductor is:

1. Generation of emf takes place in the armature winding in case of generators.
2. To carry the current supplied in case of dc motors.
3. To do the useful work it the external circuit.

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 segments.

Brushes and Bearings: - 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. Bearings are used for smooth running of the machine.

CLASSIFICATION OF DC GENERATOR/MOTOR:-

DC generators/motors are usually classified according to the way in which their fields are excited.

DC generators/motors may be divided into

(a) Separately excited DC generators/motors

(b) Self-excited DC generators/motors

a) Separately excited DC generators/motors: - Separately excited generators/motors are those whose field magnets are energized from an independent external source of dc current.

b) Self-excited DC generators/motors: - Self excited generators/motors are those whose field magnets are energized by the current produced by the generators/motors themselves.

There are three types of self-excited dc generators/motors named according to the manner in which their field coils (or windings) are connected to the armature.

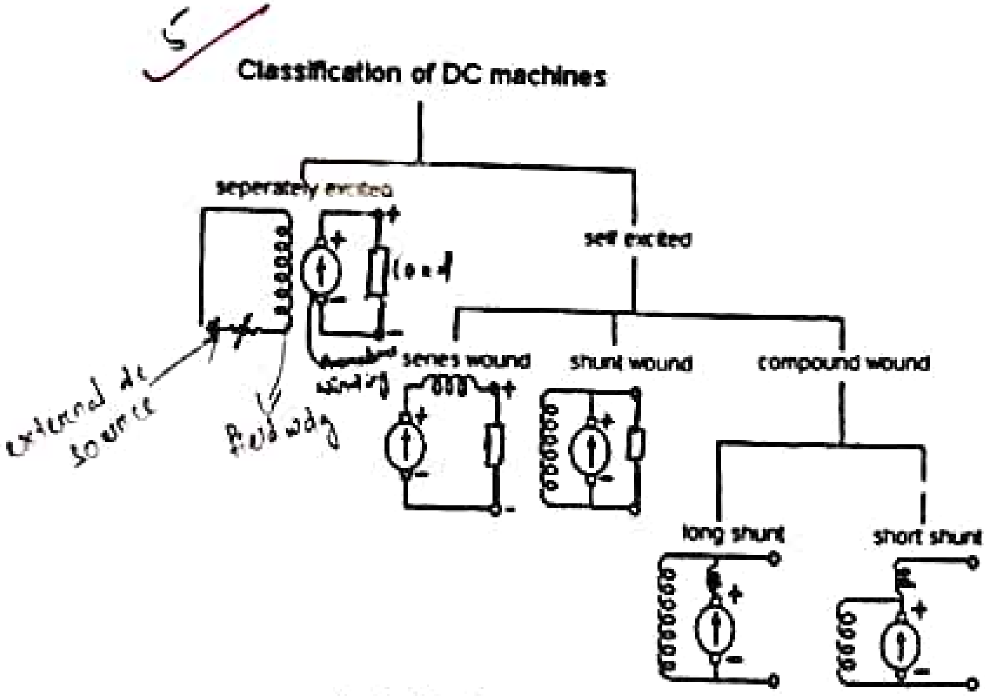
(i) Shunt wound DC generator/motor: - In shunt the two windings, field and armature are in parallel.

(ii) Series wound DC generator/motor: - In series type both field and armature winding are in series.

(iii) Compound wound DC generator/motor: - There are two types of compound wound DC generator/motor.

(a) Long shunt compound DC generator/motor: - The shunt field winding is parallel with both armature and series field winding.

(b) Short shunt compound DC generator/motor: - The shunt field winding is in parallel with armature winding only.



(Fig.4.2. Classification of DC machine)

USES OF D.C. GENERATORS:-

(1) Shunt Generator

(i) Lighting and Power Supply → gives constant o/p voltage

(ii) Charging batteries.

(2) Series Generator

(i) Boosters. to compensate the voltage drop in the feeders, Regenerative braking

(3) Compound Generator – constant voltage

(i) Large range load

(ii) Power Supply

giving excitation to the alternator. Electroplating. For short question

USES OF D.C. MOTORS:-

(1) Shunt Motor →

(i) Constant speed drive

(ii) Drilling machine, lathes, elevators, water pump, cutting machine.

(2) Series Motor → High starting torque

(i) Electric Cranes

(ii) Electric Trains

(iii) Hoists

(3) Compound Motor → constant speed + High starting torque is required.

(i) Heavy tool machines

(ii) Printing machines

TYPES OF SINGLE PHASE INDUCTION MOTOR:-

(1) Split phase motor
(2) Capacitor start motor
(3) Capacitor start – Capacitor run single phase Induction Motor.
(4) Shaded Pole Motor
(5) Repulsion Motor

USES :

(1) Split phase motor:
- (i) Small Pumps
- (ii) Grinders

(2) Capacitor start motor
- (i) Compressor
- (ii) Pumps

(3) Capacitor start capacitor Run Motor
- (i) Compressor of Air-conditioner
- (ii) Water Cooler

(4) Shaded Pole Motor
- (i) Small fans

(5) Repulsion Motor
- (i) Mixing Machine
- (ii) Blowers

for short question

2 **CONCEPT OF LUMEN:-**

It is the unit of luminous flux. It is defined as the luminous flux emitted by a source of one candle power per unit solid angle in all directions.

Lumen = candle power of source × solid angle.

$$\text{Lumen} = CP \times \omega$$

Total flux emitted by a source of one candle power is 4π lumens.

Q10 5 Marks

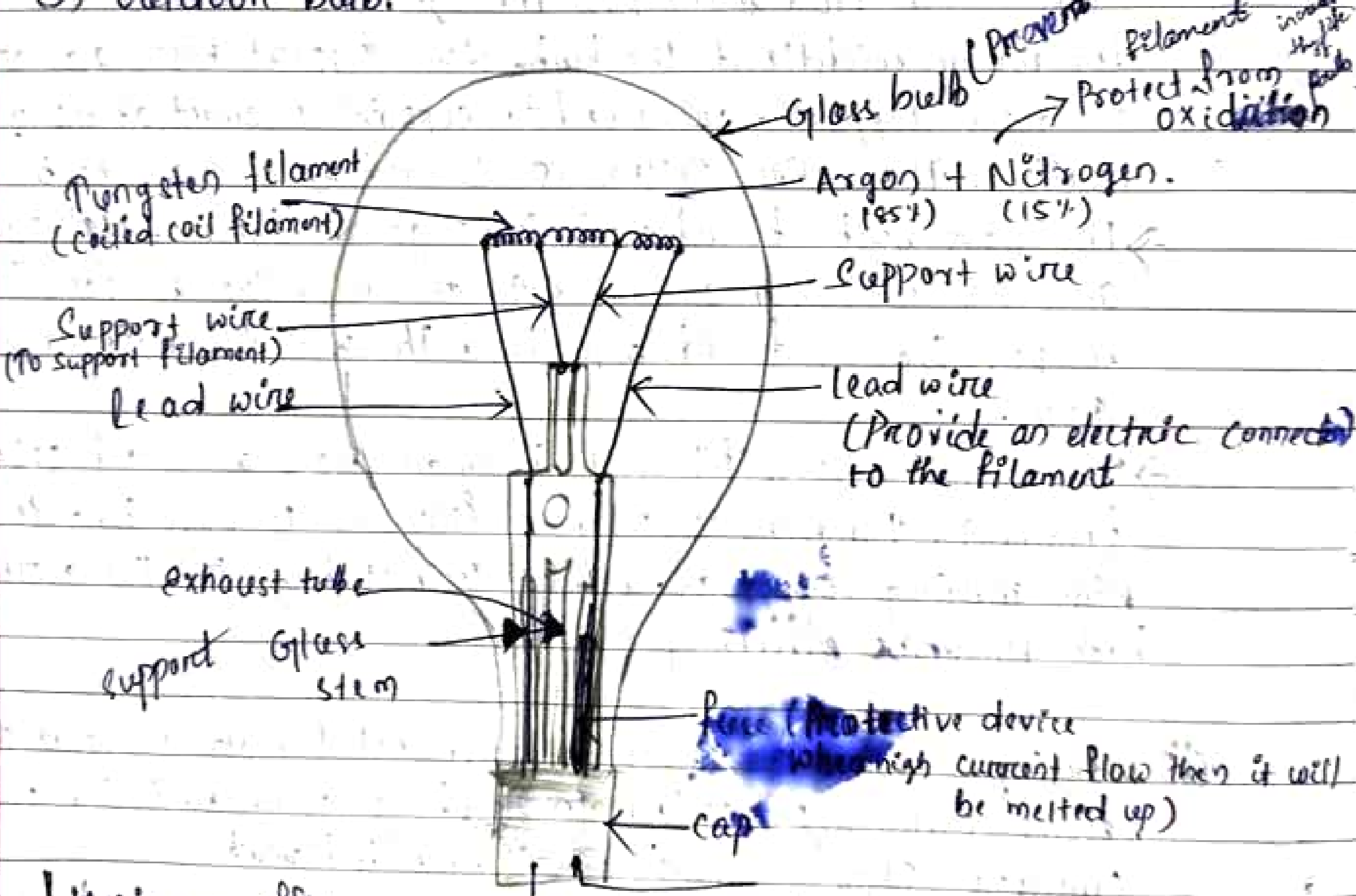
Incandescent lamp / Filament lamp :-
Incandescent means producing visible light by heating an object. An incandescent lamp works in the same principle. In other words, the lamp working due to glowing of the filament caused by electric current through it is called filament lamp.

(i) Construction :- The filament is attached across two lead wires. Both of the lead wires pass through glass support mounted at the lower middle of the bulb. Two support wires also attached to glass support, are used to support filament at its middle portion. The entire system is covered by a glass bulb.
→ The glass bulb filled with inert gasses (argon & Nitrogen) argon & nitrogen are used to minimize the evaporation of the lamps. Gas is filled into the bulb with the rating more than 40W.
→ To adjust the large filament in small space we used coiled coil filament. Tungsten is used in filament. Because tungsten has high melting point as well as it has high resistive material, high luminous efficiency.

(ii) Working :- When an object is made hot, the atoms inside the object become thermally excited. In this, lamp are connected to the supply. Current flow across filament. ~~When the filament~~
→ Tungsten filament has high resistance that's why temperature increases along the filament. When the filament highly heated, it start glowing.
→ The outer orbit electrons of the atoms jump to higher energy & its again fall back to lower energy levels, the electron release their extra energy in a form of photons. These photons are then emitted light in the form of electromagnetic radiation.
→ The electromagnetic wave with the wavelengths within visible range is light energy.
→ Thus incandescent lamp provide visible light.

Based on the availability of wattage the bulbs are common in the market with 25 W, 40W, 60W, 75W, 100W, 150 W & 200W etc
Tungsten has high resistivity (5.6 Ω).
high Melting point (3400°C)

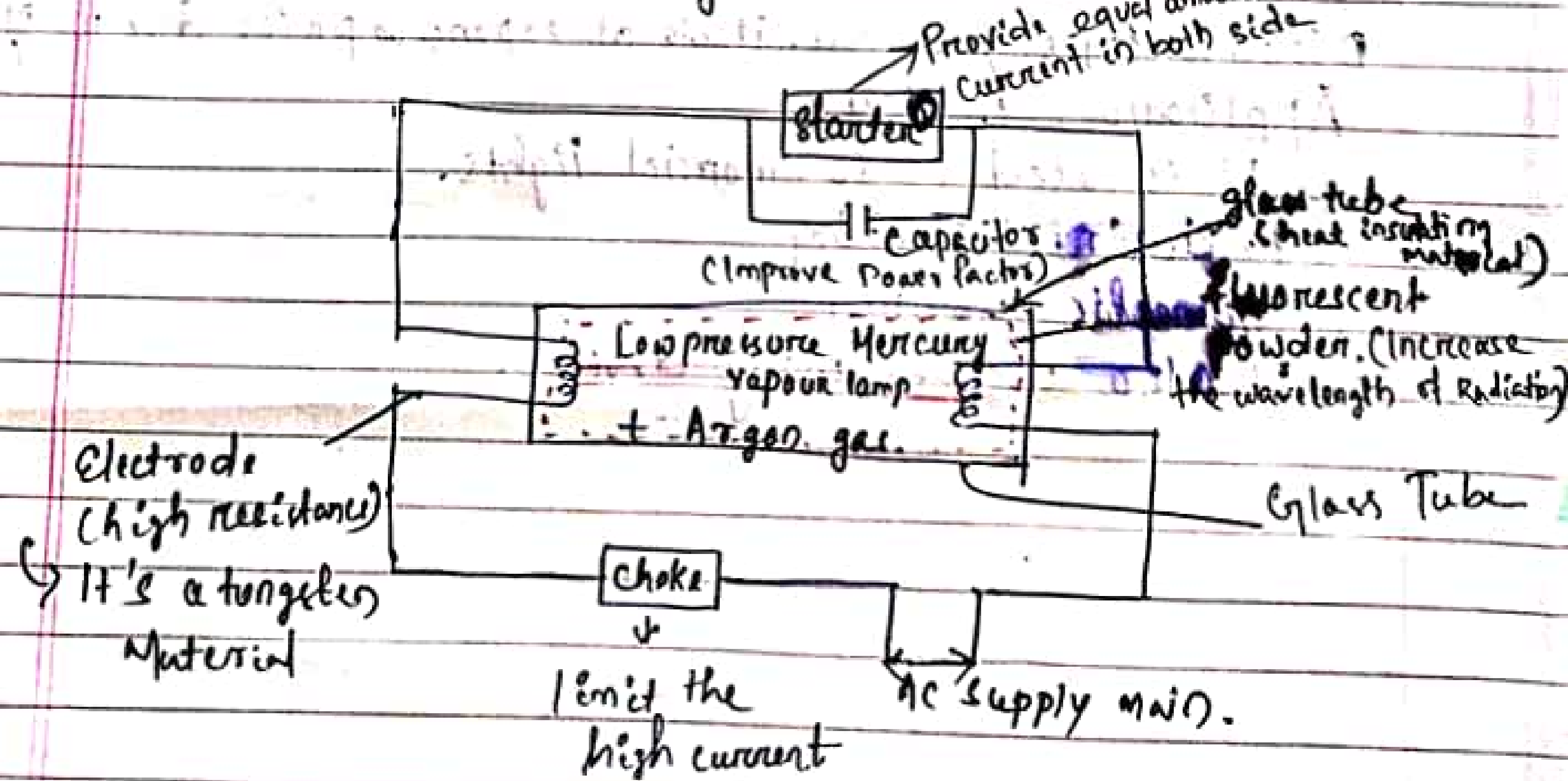
Application :-
(1) Desk lamp
(2) table lamp
(3) Outdoor bulb.



Luminous efficiency = 10 lumens/watt
Life span = 1000 working hours

Fluorescent lamp :- Fluorescent lamp is a type of low pressure Mercury vapour lamp which produce the visible light using fluorescent powder.

Construction :- Electrodes placed inside the tube. Tip of electrodes made up a spiral form, spiral coil is made up of tungsten material. Coil is coated with ~~electrod~~ electron emitting material.
Tube is made up of lime glass, which is a heat insulating Material. Inner surface of tube coated with fluorescent powder.
Low pressure Mercury vapour & argon gas contain inside the tube. In this ckt starter & choke are connected.
Choke help in keeping the current through the ionised medium within safe limits.
Starter is allows in required amount current flow across two electrodes. capacitor is improve power factor & avoid the noise signal.

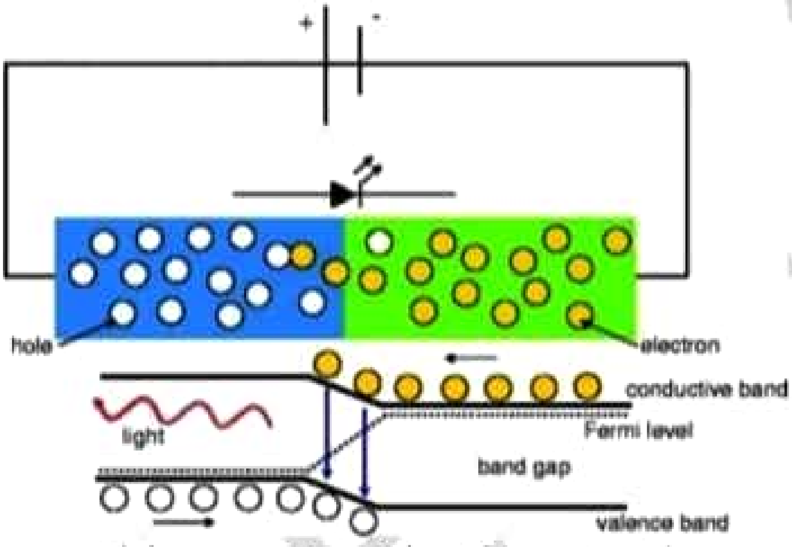


Working :- When we get supply to the ckt then the current will pass through the choke. it will reach at starter.
Starter provide some current to the electrodes. So electrodes started to heat when current flow.
Then it's temp will increases due to heat temperature increase.
→ Inside the tube mercury vapour & argon gas ionized due to heat. When medium is ionized bet^n two high voltage electrodes arc is formed.
Arc among electrons releases energy in the form of electro-magnetic radiation.
In the tube it will be coated with fluorescent powder which increase the wavelength of radiation. And produce the visible light. Thus fluorescent lamp works.

Advantages :- efficiency fluorescent lamp is higher as compared to incandescent lamp.
→ It designed different shape & length.
→ It produced desired colour.
Disadvantages → It is available at expensive price due to starter choke.
Application :- ~~It is~~
It is used as commercial lights.
→ Industrial lighting.
→ Domestic lighting
→ It also used in many devices.

(c) 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 materials.
- When the p-n junction is forward biased, the majority carriers; either electrons or holes; start moving across the junction.



(**Fig.4.5.** Construction of LED Lamp)

- As shown in the figure above, electrons start moving from n-region and holes start moving from p-region. When they moved from their regions they start to recombine across the depletion region. Free electrons will remain in the conduction band of energy level while holes remain in the valence band of energy level.
- The Energy level of the electrons is high than holes because electrons are more mobile than holes i.e. current conduction due to electrons are more. During the recombination of electrons and holes, some portion of energy must be dissipated or emitted in the form of heat and light.
- The phenomenon into which light emits from the semiconductor under the influence of the 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 diode 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. For example; phosphorus is used for a red light, gallium phosphide for the green light and aluminum indium gallium phosphide for yellow and orange light.

Previous year

STAR RATING OF HOME APPLIANCES:-

- **Terminology**

White goods :- White goods are relatively high priced heavy & slow moving electronics goods.

→ Practical application specialized knowledge is needed in servicing the white goods.

→ House hold appliances such as the washing machine, Air conditioner, microwave oven & Refrigerator etc. These products are often factory finished in white enamel & thus referred to as white goods.

Brown goods → Brown goods are relatively light & low priced & fast moving electronic goods.

→ Brown goods are electronics domestic appliances like TV, radio, video recorders etc.

→ Since they are traditionally finished in brown due to their wooden or Bakelite make, they were known as Brown goods.

It is an agency.

→ Bureau of Energy efficiency (BEE) :- The mission of BEE is to be enable delivery mechanisms in the country & provide leadership to energy efficiency in all sector of the country.

Object of BEE → To reduce energy intensity in the economy.

→ It will increase the conservation & efficient use of energy in India.

Energy Efficiency Ratio (EER) :- It is the ratio of an amount of heat removed or cooling capacity ~~from your~~ to the power consumed.

$$EER = \frac{\text{Amount of heat Removed/hr in watt}}{\text{Amount of power Consumed/hr in watt}}$$

British Thermal Unit (BTU) :- Unit of heat.

The amount of heat needed to raise the temperature of one pound (0.454Kg) water by 1° Fahrenheit.

Energy efficiency :- It is the ratio of useful power output to the total electrical power consumed.

$$\eta = \frac{\text{Useful power o/p}}{\text{Total power i/p}}$$

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

Efficiency means production of more products with the same amount of raw material.

↳ Using less energy to perform the same task.

→ It reduce the energy wastage.

- **Star Rating**
    - An energy efficiency rating scheme for Electrical appliances is known as Star labelling.
    - 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 ratings 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.

(**Fig.4.6.** Star rating of appliance)

CHAPTER-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.

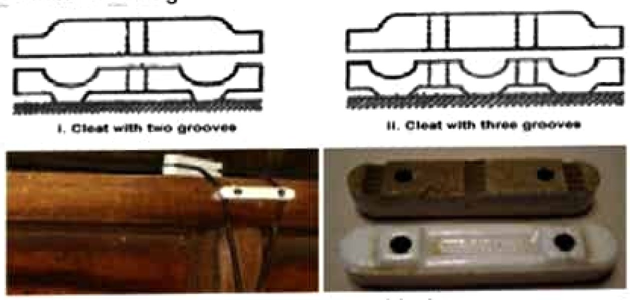
TYPES OF WIRING FOR DOMESTIC INSTALLATIONS:-

Electrical wiring system is classified into five categories:

- Cleat wiring
- Wooden casing and capping wiring
- CTS or TRS or PVC sheath wiring
- Lead sheathed or metal sheathed wiring
- Conduit wiring
  - Surface or open Conduit type
  - Concealed or underground type Conduit

- **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 over the base
  - The lower cleat (base) and upper cover (cap), after placing cables between them are then screwed on wooden gutties.



(Fig.5.1. Cleat Wiring)

Advantages:

- It is the cheapest system.
- Installation and dismantling is easy.
- Less skilled persons are required.

- Inspection is easy.
- Alterations 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
- It can be only used on 250/440 Volts on low temperature.
- 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.

Application:

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

- <u>**Casing and Capping wiring**</u>

- It consists of rectangular blocks made from seasoned and knots free wood or PVC.
- The casing has usually two (or three) 'U' shaped grooves, (two in number) 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.

Push fit joint   Elbow joint   T-joint

(**Fig.5.2.** Casing & Capping Wiring)

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 systems.

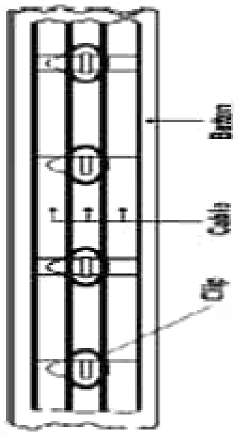
- It is strong and long-lasting wiring system.
- If Phase and Neutral wire is installed in separate slots, then repairing is easy.
- Stay for long time in the field due to strong insulation of capping and casing..
- It stays safe from oil, Steam, smoke and rain.
- No risk of electric shock due to covered 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

- **Batten Wiring (CTS or TRS)**

- The cables are run or carried on well-seasoned, perfectly straight and well varnished (on all four sides) teak wood batten of thickness 10 mm. at least.
- The width of the batten depends upon the number and size of cables to be carried by it..
- The wooden battens are fixed to the walls 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 **75cm**.



(**Fig.5.3.** Batten Wiring)

Advantages:

- Wiring installation is simple and easy
- cheap as compared to other electrical wiring systems
- Repairing is easy
- Strong and long-lasting
- Appearance is better.

- Customization is easy
- Less chance of leakage current

Disadvantages:

- Not suitable for outdoor wiring
- Humidity, smoke, steam etc. directly affect on wires.
- Heavy wires are not recommended for this wiring scheme.
- Only suitable for below 250 V.
- High risk of fire.

Application:

- Used in domestic, commercial or industrial wiring except workshops
- Used for low voltage installation

- **Lead Sheathed Wiring**

  - The type of wiring employs conductors that are insulated with VIR and covered with an outer sheath of lead aluminum alloy containing about 95% of lead.
  - The metal sheath given 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 looks nice
- Long life if proper earth continuity is maintained.
- Can be used in damp situation and in situation exposed to rain & sun.

Disadvantages:
- Costlier than 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

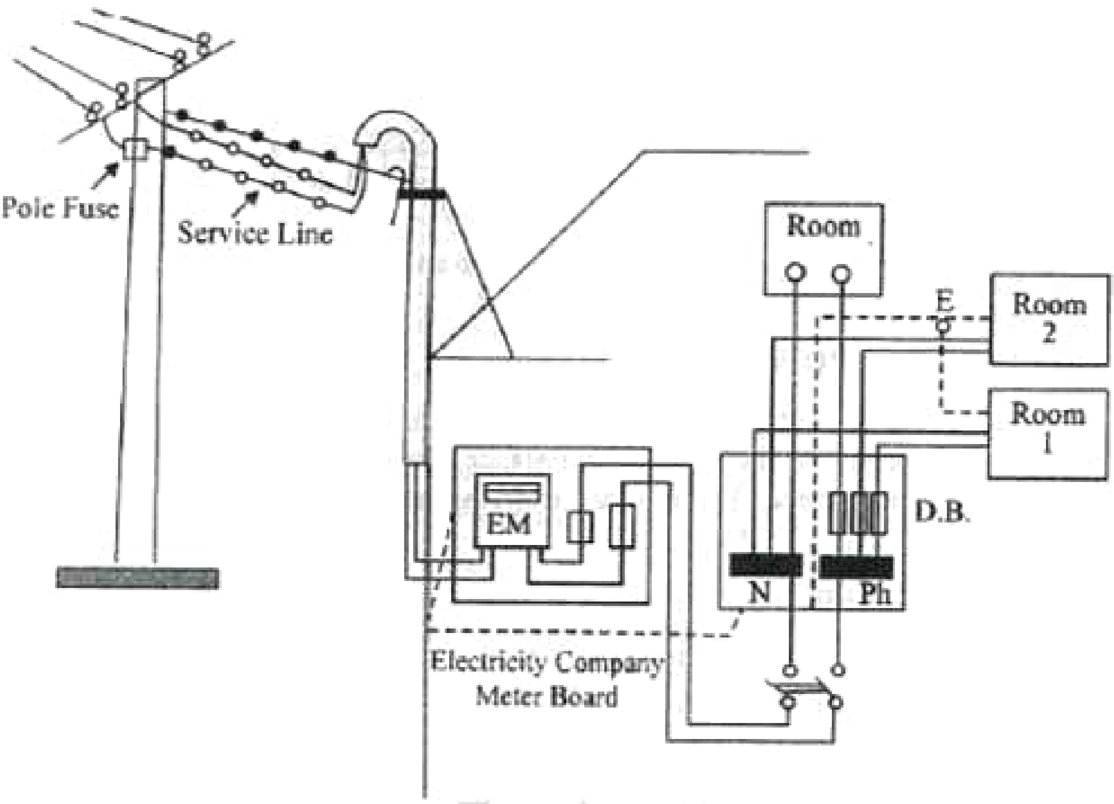
- **Conduit Wiring**

  - There are two additional types of conduit wiring according to pipe installation
    - **Surface Conduit Wiring**

    - **Concealed Conduit Wiring**

- **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 then with the help of rawal plugs.
- **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. obliviously,
- It is the most popular, beautiful, stronger and common electrical wiring system nowadays.

LAYOUT OF HOUSEHOLD ELECTRICAL WIRING:-



(**Fig.5.5.** Layout of Household Electrical Wiring)

BASIC PROTECTIVE DEVICES USED IN HOUSE HOLD WIRING:-

- Fuse
- MCB (Miniature Circuit Breaker)
- Lightening arrester
- Earthing Wire

ELECTRICAL ENERGY:-

- Energy is the capacity to do work, and is measured in joules (J).
- The electric power utility companies measure energy in watt-hours (WH) or Kilo watt-hours (KWH)

Example 5.1. A building has the 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 of 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.

Solution:

Sl.No.	Name of Appliances	Quantity	Power Rating in KW	Working Hrs in a day	Energy consumed in KWH
01	Motor	1No.	1HP = 746W=0.746KW	5	1×0.746×5=3.73
02	Fans	3Nos	80W = 0.08KW	10	3×0.08×10=2.4
03	Tubelight	4Nos	40W = 0.04KW	15	4×0.04×15=2.4
				Total Energy consumed in KWH=	3.73+2.4+2.4=8.53

As we know 1KWH = 1unit
So, 8.53 KWH = 8.53 units.
In the month of November total Electrical Energy Consumed = 8.53 X 30 = 255.9 units.
Monthly bill = 255.9 X Rs.2.5 = Rs. 639.75P.

Example 5.2. A building has the following electrical appliances

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

(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, fans work 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.

Solution:

Sl.No.	Name of Appliances	Quantity	Power Rating in KW	Working Hrs in a day	Energy consumed in KWH
01	Bulb	2	0.060	6	2×0.06×6=0.72
02	Bulb	1	0.100	6	1×0.1×6=0.6
03	Tube light	2	0.040	6	2×0.04×6=0.48
04	Fan	3	0.060	10	3×0.06×10=1.8
05	Refrigerator	1	0.150	24	1×0.150×24=3.6
				Total energy consumed	7.2 KWH

As we know 1KWH = 1unit
So, 7.2KWH = 7.2units.
In the month of 30 days, total Electrical Energy Consumed = 7.2 X 30 = 216 units.
Monthly bill = 100 X Rs.1.40/- = Rs. 140/-

100 .X Rs 2.30/- = Rs. 230/-

16 X Rs 3.10/- = Rs. 49.6/-

Total = Rs. 419.6/-

CHAPTER-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 a definite standard. The instruments which are used for such measurements are called **measuring instruments**.
- The three basic quantities in the electrical measurement are current, voltage and power.
- The instrument which measures the current flowing in the circuit is called ammeter while the instrument which measures the voltage across any two points of a circuit is called voltmeter. The instruments which are used to measure the power are called wattmeter.

CLASSIFICATIONS OF ELECTRICAL INSTRUMENTS:-

Electrical instruments are broadly classified into two types

1) 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.

Example: Tangent galvanometer, which gives the value of current, in terms of the tangent of deflection produced by the current, the radius and number of turns of wire used and the horizontal component of earth's field.

2) Secondary instruments

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

Example: Ammeter, Voltmeter etc.

- The secondary instruments are again divided into the following three types

a) Indicating instruments

b) Recording instruments

c) Integrating instruments

a) Indicating instruments:

Indicating instruments are those which indicate the instantaneous value of the electrical quantity being measured at the time at which it is being measured. Their indications are given by pointers moving over calibrated dials.

Example: Ordinary ammeters, voltmeters and wattmeter

b) Recording instruments:

These instruments give a continuous record of the given electrical quantity which is being measured over a specific period. The examples are various types of recorders. In such recording instruments, the readings are recorded by drawing the graph. The pointer of such instruments is provided with a marker i.e. pen or pencil, which moves on graph paper as per the reading.

Example: X-Y plotter, ECG.

c) Integrating instruments:

These instruments measure the total quantity of electricity delivered over period of time.

Example: a household energy meter.

TORQUES IN INSTRUMENT:-

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 is mounted on a pivoted spindle. For satisfactory operation of any indicating instrument, following torques must be present in an instrument.

1) Deflecting system producing deflecting torque (T_d)

2) Controlling system producing controlling torque (T_c)

3) Damping system producing damping torque

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 a deflecting torque is called deflecting system and the torque is denoted as

Example: X-Y plotter, ECG.

c) Integrating instruments:

These instruments measure the total quantity of electricity delivered over period of time.

Example: a household energy meter.

TORQUES IN INSTRUMENT:-

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 is mounted on a pivoted spindle. For satisfactory operation of any indicating instrument, following torques must be present in an instrument.

1) Deflecting system producing deflecting torque (T_d)
2) Controlling system producing controlling torque (T_c)
3) Damping system producing damping torque

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 a deflecting torque is called deflecting system and the torque is denoted as T_d.

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. The important functions of this system are,

1) 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.

2) 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 the absence of controlling system.

The controlling torque in indicating instruments may be provide by one of the following two methods.

a) By weighting of moving parts i.e., Gravity Control

b) By one or more springs i.e., 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.

DIFFERENT USES OF PMMC TYPES INSTRUMENT:-

(i) Ammeter: - When PMMC used as an ammeter, except for a very small current range, the moving coil is connected across a suitable low resistance shunt, so that only small part of the main current flows through the coil.

(ii) Voltmeter: - When PMMC used as voltmeter, the coil is connected in series with high resistance. The same PMMC instrument can be used as voltmeter or ammeter

(iii) Galvanometer: - It is used to measure a small value of current along with its direction and strength.

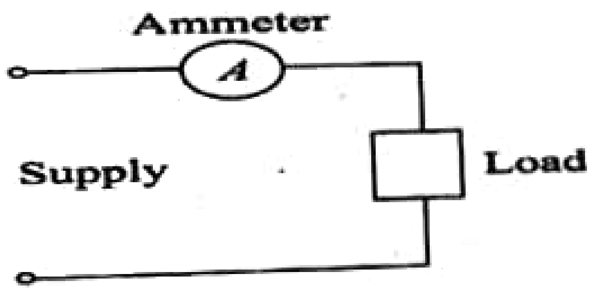
(iv) Ohm meter: - It is used to measure the resistance of the electric circuit by applying a voltage to a resistance with the help of battery.

DIFFERENT USES OF MI TYPES INSTRUMENT:-

- They are suitable for measurement of current, voltage and power factor in electrical circuit.
- They are used for DC as well as low frequency AC in high power circuits.
- MI ammeter can be designed for full scale deflection current of 0.1Amp to 30Amp without use of shunt
- MI voltmeter of ranges over 50V without series resistance are in common use.

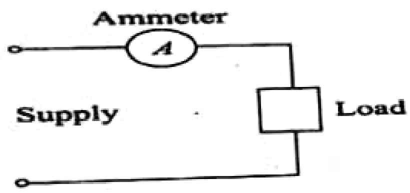
CONNECTION DIAGRAM:-

(i) Ammeter:



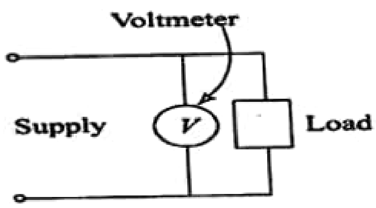
(**Fig.6.1.** Connection Diagram of Ammeter)

(ii) Voltmeter:



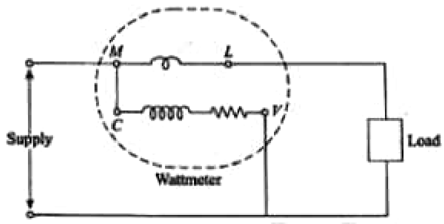
(**Fig.6.1.** Connection Diagram of Ammeter)

(ii) Voltmeter:



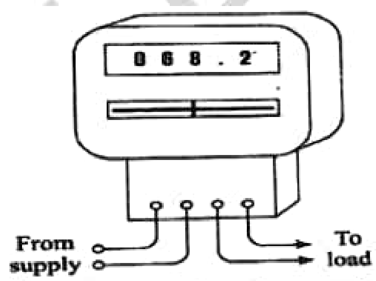
(**Fig.6.2.** Connection Diagram of Voltmeter)

(iii) Wattmeter



(**Fig.6.3.** Connection Diagram of Wattmeter)

(iv) Energy meter



(**Fig.6.4.** Connection Diagram of Energy meter)