ELECTRICAL MAINTENANCE

STD. 11th

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1. Electric Circuits

1. Introduction of Electrical current:

The Concept of various electrical quantities viz. Electromotive Force, Potential Difference, current, resistance is discussed as follows:

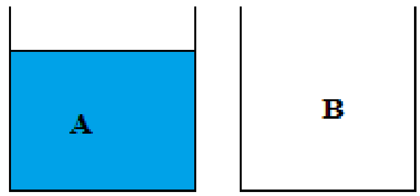


Fig 1.1

Consider the two tank A & B as shown in Fig1.1 Tank A is completely filled and Tank b is empty. If these two tanks are connected through pipe then water from tank A (Higher Level) is starts flowing into tank B (Lower Level) through pipe as shown in Fig 1.2. This water flows continuously till both the tank has equal level of water. Water flow stops when both the tanks reach equal level of water.

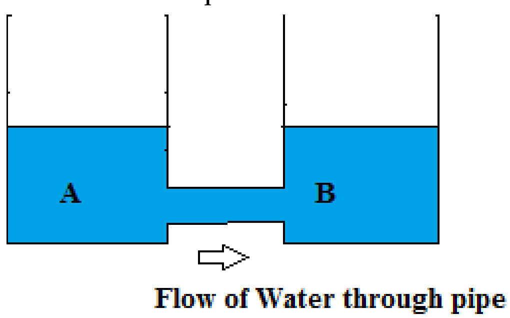


Fig 1.2

Now in order to have a continuous flow of water the arrangement is done which is as shown in fig.1.3 A Pump is connected to tank B and pipe are connected to pump

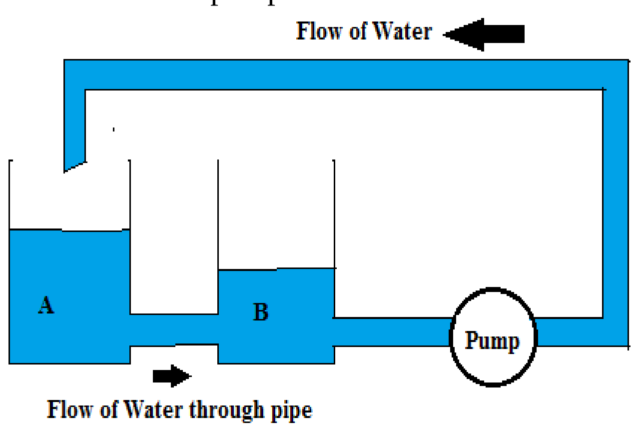


Fig 1.3

When pump starts working it produces a force. Due to this force, the water from tank B is sucked by pump and flows through pipes and finally enters in tank A. The water flows from tank A to tank B then again from tank B the water again flows to tank A through pump.

In above description following points are to be considered:

1. **Force is produced by pump.**
2. **Due to this force difference between the water level in tank A & tank B is maintained.**
3. **Due to the difference in water level, water starts flowing <u>from higher potential to lower potential</u> (Tank A to B).**
4. **If the pump stops working then water level difference is not created & therefore water will not flow.**

Now using above water flowing experiments the concepts of electromotive force (E.M.F), potential difference (P.D.), Current can be easily explained.

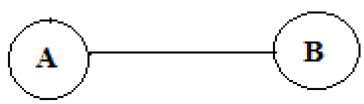


Fig. 1.4

- Consider the two bodies A and B, A is positively charged body and B is negatively charged body. These bodies are connected with each other by connecting wire as shown in fig 1.4
- The electric current flow through the wire from A to B as A is High (Positive) Electrical Level and B is Low (negative) Energy level.
- This current flows continuously till the difference in potential between A and B is maintained. Finally current stops flowing when potential of A is equal to potential of B.
- Now in order to maintain continuous flow of current in the conductor following arrangement is done.

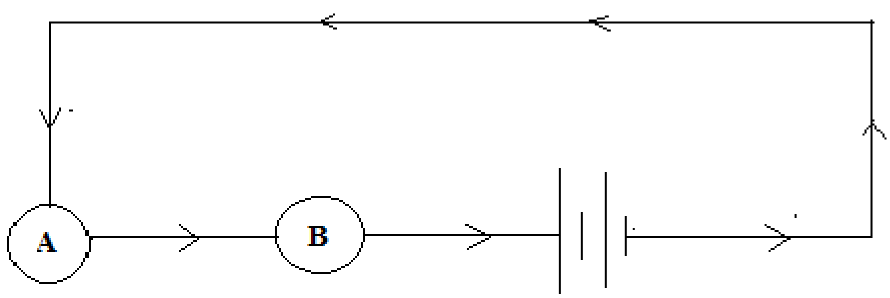


Fig 1.5

- A Battery is connected in a circuit by means of conductor wire as shown in fig.
- Due to the chemical reaction battery produces a force (Analogous to force produced in the pump). Due to this force, battery produces current which flows through the conductor. (current means flow of electron)
- The force produced by the battery is known as Electromotive Force (E.M.F.)
- **<u>Electromotive Force- The Electromotive Force is defined as the source of energy that can cause a current to flow in an electrical circuit or device.</u>**

Or

- **Electromotive force is defined as a force or electric pressure that cause or tends to cause current to flow in the circuit equivalent to the potential difference between the terminals**
- E.M.F is denoted by E and measured in volt.
- As long as there is a potential difference between any two points the current flows from higher potential (Positive) to lower potential (Negative).
- Thus Continuous flow of current is maintained. Following points are noted from above discussion.

1. **A battery produces electromotive force**
2. **Due to battery, potential difference is maintained between the points A & B.**
3. **Due to the potential difference current flows from higher to lower potential.**
4. **If the battery is disconnected then current flow stops.**

Electric voltage- Electrical voltage is a quantitative expression of the potential difference in charge between two points in an electrical field.

Electric current- The electric current is defined as rate of change of flow of electron.
It is denoted by I and measured in Ampere.

2. Concept of Resistance:

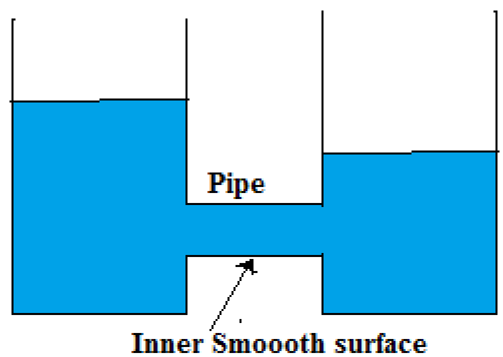


Fig 2.1

- Fig 2.1 shows the two tanks connected by the pipe whose inner surface is smooth then in such a condition the obstruction to water flow is minimum.

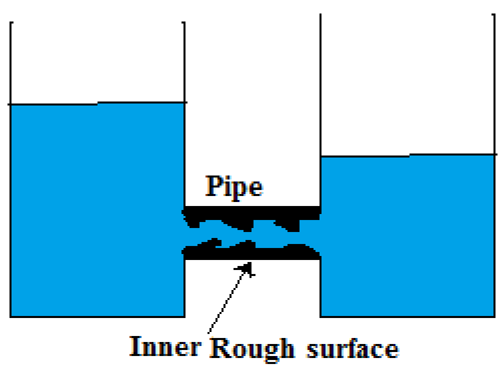
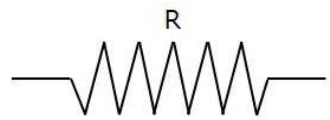


Fig 2.2

- Fig 2.2 shows the two tanks connected by the pipe whose inner surface is rough then in such a condition the obstruction to water flow is more.
- So that flow of water is affected by the roughness of pipe.
- Similarly when electric current flows through conductor in circuit it is opposed by the property of substance.
- This property of substance is known as Resistance.
- **Resistance- The property of substance which opposes the flow of current is known as Resistance.**
- **Its unit is Ω (ohm) and denoted by R**
- **The symbol of resistance is**



Symbol for a resistor

Laws of Resistance –

The Resistance R depends on the following factors:

1. **Length**- Resistance of the conductor is directly proportional to the length of the conductor. If length of the conductor is more, its resistance is more. If the Length of the conductor is doubled then its resistance becomes twice.

$$R \,\alpha\, l \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

2. **Area** – Resistance of the conductor is inversely proportional to the cross sectional area. If cross-sectional area of conductor is made half then resistance becomes two times of previous value.

$$R \,\alpha\, \frac{1}{A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

3. **Resistivity** – Resistance of the conductor also depends on the nature of the material.
If we take two conductors of same length and same cross section area but one conductor is of copper and second is of aluminum then the resistance of aluminum is more than resistance of copper for the same size. Resistivity of material varies from material to material.
Resistivity is denoted by ρ and measured in Ohm-meter
Resistivity of Aluminum is 2.8×10^{-8} Ohm-meter
Resistivity of Copper is 1.72×10^{-8} Ohm-meter

$$R \,\alpha\, \rho \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

4. **Temperature** – Resistance of the conductor is also affected by the temperature (T). If the temperature of the conductor is increases its resistance increases and vice versa.
   - To formulate above things assuming temperature is constant then

$$\boldsymbol{R \,\alpha\, \frac{l}{A}}$$

$$\boldsymbol{R = \rho \frac{l}{A}}$$

Example: Determine the resistance of a conductor having 1 mm^2 cross sectional area and 15m long. The specific resistance of the conductor material is 1.75×10^{-8} Ω.m.

Given Data:-

$\rho = 1.75\times10^{-8}$ Ω-m.

$A = 1\ mm^2 = 1\times10^{-6}\ m^2$

L = 15 m

To find:- R = ?

Solution:-

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

$= 1.75 \times 10^{-8} \times \frac{15}{10^{\wedge}-6}$

= 0.2656 Ω

$\boxed{R = 0.2656\ \Omega}$

Example: A wire is having a diameter of 0.355 mm, the length is 100m and the resistivity of the wire material is 5.2×10^{-9} Ω-m.

Find: (i) The resistance of the wire.

(ii)If the wire is drawn out twice the original length, what will be the effect on its resistance?

Given Data:- d = 0.355mm

L = 100m

$\rho = 5.2\times10^{-9}$ Ω-m

To Find:- R = ?

Solution:-

Cross-sectional area $A = \frac{\pi}{4}(d)^2$

$= \frac{\pi}{4}(0.355)^2$

$= 0.0989\ mm^2$

$\boxed{A = 0.0989 \times 10^{-6}\ m^2}$

Using $\quad R = \rho \frac{L}{A}$

$$= 5.2\times10^{-9}\times \frac{100}{0.0989\times10^{-6}}$$

Now, if the wire is drawn-out (elongated) twice of the original length, then,

1. Its length will be doubled.
2. Its cross sectional area will become half of the original area. Thus, the new resistance will be 4 times it's original resistance.

   i.e. $R_{(new)} = \rho \frac{L_{new}}{A_{new}}$

$$= \rho \frac{2\times L}{\left(\frac{1}{2}\right) A}$$

$$= 4\left(\rho \frac{L}{A}\right)$$

If the wire is drawn out twice the original length, then its resistance is 4 times the original resistance

3. Ohms Law:-

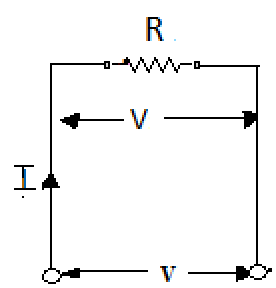


Fig 3.1.- Ohms law

Ohms law states that "when physical state of the conductor remains constant then current flowing through the conductor is directly proportional to the potential difference across the conductor and inversely proportional to resistance of the conductor."

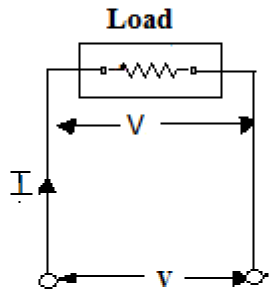
$$I = \frac{V}{R}$$

Where I= Current flow through the conductor

V= Potential difference across the conductor

R= Resistance of the conductor

Example: A voltage of 0.5kV is applied across a load which takes a current of 50 amps. Find the resistance of the load.



Given data-

V = 0.5 kV

I = 50 A

To Find-

R_L =?

Solution:-

V = 0.5kV

= 0.5*1000

V= 500 Volts.

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

$R = \frac{500}{50}$

$\boxed{R = 10\ \Omega}$

Example: -The load of 400Ω resistance is connected across the 230V 50 Hz supply then calculate the current flowing through the load resistance?

Given data: -

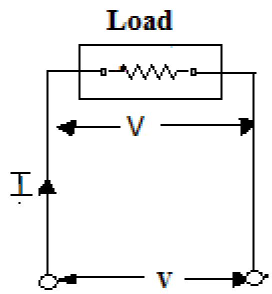
$R_L = 400\Omega$

$V_S = 230V$

F = 50Hz

To find:- I = ?

Solution:-



According to Ohms law

$$I = \frac{V_s}{R_L}$$

$$I = \frac{230}{400}$$

$$\boxed{I = 0.575 \text{ Amp}}$$

3.1. Resistance connected in series:-

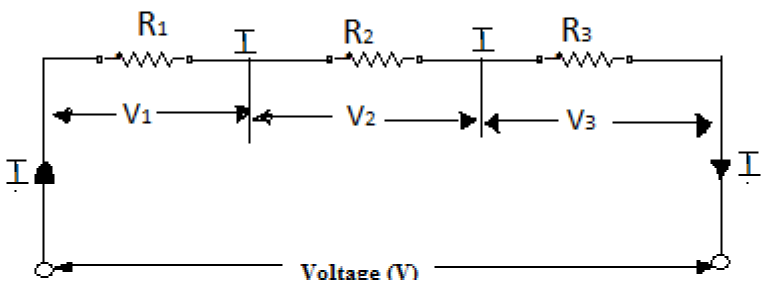


Fig 3.2. Resistances are connected in series

-Fig 3.2 shows the three resistance R_1, R_2, R3 are connected in series across the supply

- Due to series connection same current flows through all resistance.

-The applied voltage gets divided across each resistance.

- The voltage which gets divided is proportional to the value of the resistance.

- Total voltage is given by

$$V = V_1 + V_2 + V_3$$

- According to ohms law

$$V = I\,R$$

- $$\mathrm{I\,R} = IR_1 + IR_2 + IR_3$$
- $$\mathrm{I\,R} = I\,(R_1 + R_2 + R_3)$$
- $$\mathrm{R} = R_1 + R_2 + R_3$$

The equivalent resistance in series connection is denoted by

$$R_{eq} = R_1 + R_2 + R_3 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + Rn$$

3.2. Resistance connected in parallel:-

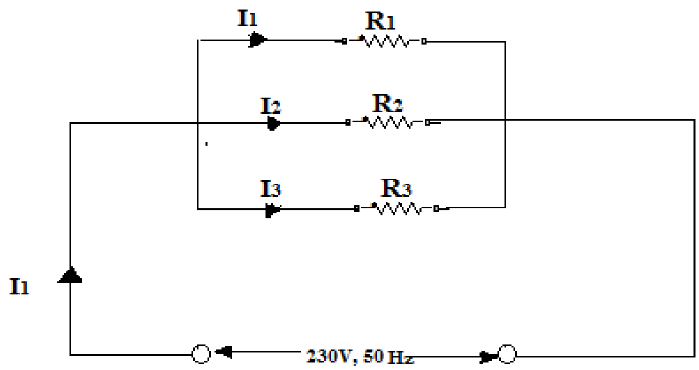


Fig 3.3 resistance are connected in parallel

-Fig 3.3 shows the three resistances R_1, R_2, R_3 connected in parallel across the supply.
- Due to parallel connection voltage is same across all resistance.
-The current gets divided through each resistance.
- Total current is given by

$$I = I_1 + I_2 + I_3$$

- According to ohms law

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

$$\frac{V}{R} = \frac{V_1}{R_1} + \frac{V_1}{R_2} + \frac{V_1}{R_3}$$

But in parallel connection voltage across each resistance is same,
$V_1=V_2=V_3$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

The equivalent resistance in parallel connection is denoted by

$$\frac{1}{\text{Req}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + \frac{1}{Rn}$$

Example: Three resistances of 5Ω, 10Ω and 20Ω are connected in (a) series (b) parallel. Find in each case the following: (i) Total resistance (ii) total current (iii)voltage across each resistance (iv) current through each resistance. The normal supply voltage is 230V, 50Hz.

Given data:-

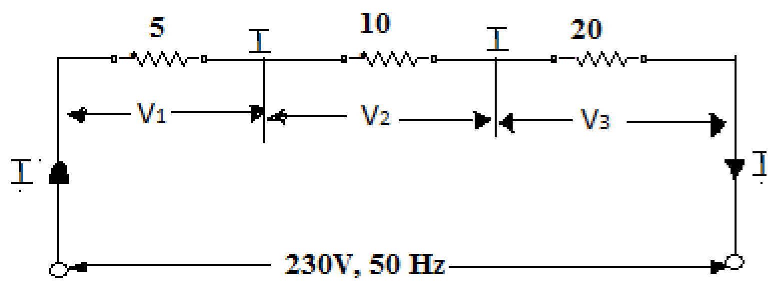
R1 = 5 Ω

R2 = 10 Ω

R3 = 20 Ω

To Find:- R_T , I_T, V_1, V_2 V_3, I_1 I_2. I_3, in both series and parallel connection

Solution : **(A) Series connection** :



i. Total resistance $R_T = R1+R2+R3$

$R_T = 5+10+20$

$$\boxed{R_T = 35\ \Omega}$$

ii. Total current $I_T = \dfrac{\text{total voltage}}{\text{total resistance}}$

$$I_T = \frac{230}{35}$$

$$\boxed{I_T = 6.57 \text{ Amps}}$$

iii. Current is same but voltages are different

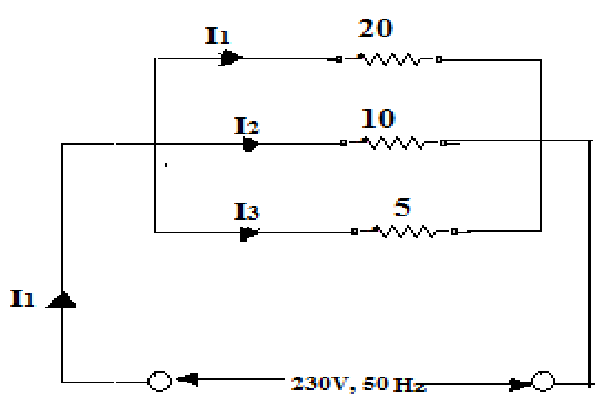
$V_1 = I \times R1$
$= 6.57 \times 5$
$\boxed{V_1 = 32.58 \text{ Volts.}}$

$V_2 = I \times R2$
$= 6.57 \times 10$
$\boxed{V_2 = 65.71 \text{ Volts.}}$

$V_3 = I \times R3$
$= 6.57 \times 20$
$\boxed{V_3 = 131.42 \text{ Volts}}$

iv. Current in all resistance is same as 6.51 Amp.

(B) Parallel connection



i. $$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$$

$$= \frac{1}{5} + \frac{1}{10} + \frac{1}{20}$$

$$= \frac{7}{20}$$

$$R = \frac{20}{7}$$

$$R = 2.857\ \Omega$$

$$\boxed{R_T = 2.857\ \Omega}$$

ii) Total current $I = \frac{\text{Total voltage}}{\text{Total resistance}}$

$$I_T = \frac{230}{2.857}$$

$$I_T = 80.5 \text{ Amp}$$

$$\boxed{I_T = 80.5 \text{ Amp}}$$

(i) Voltage across each resistance will be same as 230 Volts.

(ii) current will be distributed in each branch as …

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

$$I_1 = \frac{230}{5}$$

$$\boxed{I_1 = 46 \text{ Amp}}$$

$$I_2 = \frac{V}{R_1}$$

$$I_2 = \frac{230}{10} = 23 \text{ Amps}$$

$$\boxed{I_2 = 23 \text{ Amps}}$$

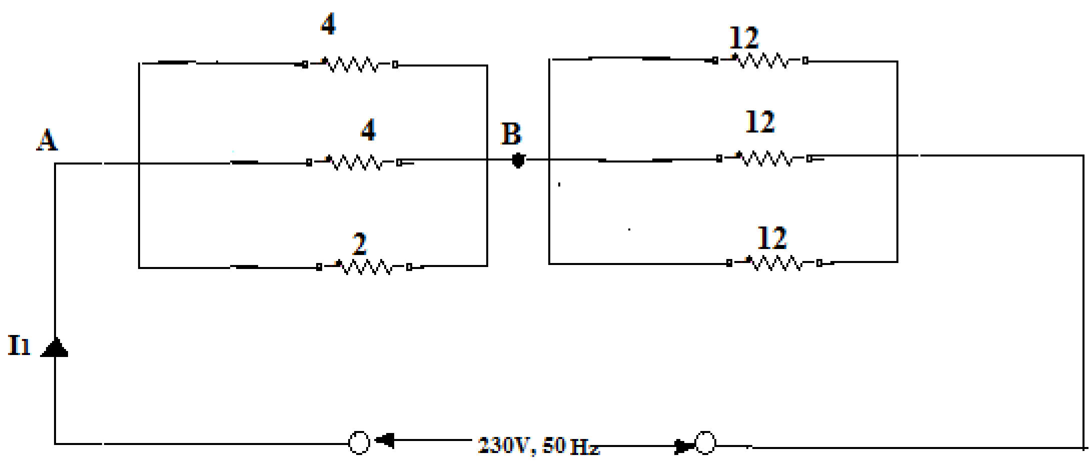
$$I_3 = \frac{V}{R_1}$$

$$I_3 = \frac{230}{20}$$

I_3 = 11.5 Amps

$\boxed{I_3 = 11.5\text{Amps}}$

Example : Find the total resistance and total current of the following circuit.



Given data:-

$R_1 = 4\Omega$, $R_2 = 4\Omega$, $R_3 = 2\Omega$, $R_4 = R_5 = R_6 = 12\Omega$

Resistance between A and B

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

$$\frac{1}{R_{AB}} = \frac{1}{4} + \frac{1}{4} + \frac{1}{2}$$

$$\frac{1}{R_{AB}} = \frac{4}{4}$$

$$R_{AB} = 1\ \Omega$$

Resistance between B and C

$$\frac{1}{R_{BC}} = \frac{1}{12} + \frac{1}{12} + \frac{1}{12} = \frac{1}{4}$$

$$R_{BC} = 4\ \Omega$$

Total resistance $R_{AC} = R_{AB} + R_{BC}$

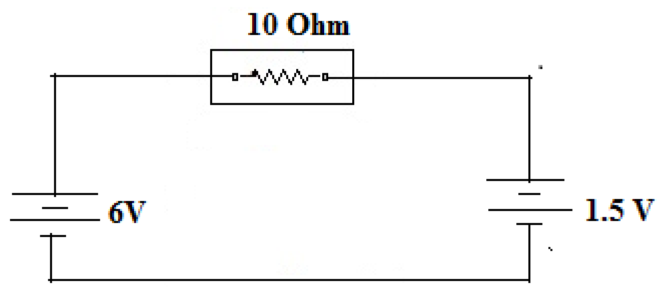
$= 1 + 4$

$\boxed{R_{AC} = 5\Omega}$

Total current $I = \frac{\text{Total voltage}}{\text{Total resistance}} = \frac{200}{5}$

$\boxed{I = 40 \text{ Amp}}$

Example: A resistance of 10Ω is connected to the two batteries as shown in figure. Find the current in the resistance and its direction.



Given data-

$V_1 = 6V$

$V_2 = 1.5V$

$R = 10\Omega$

Solution

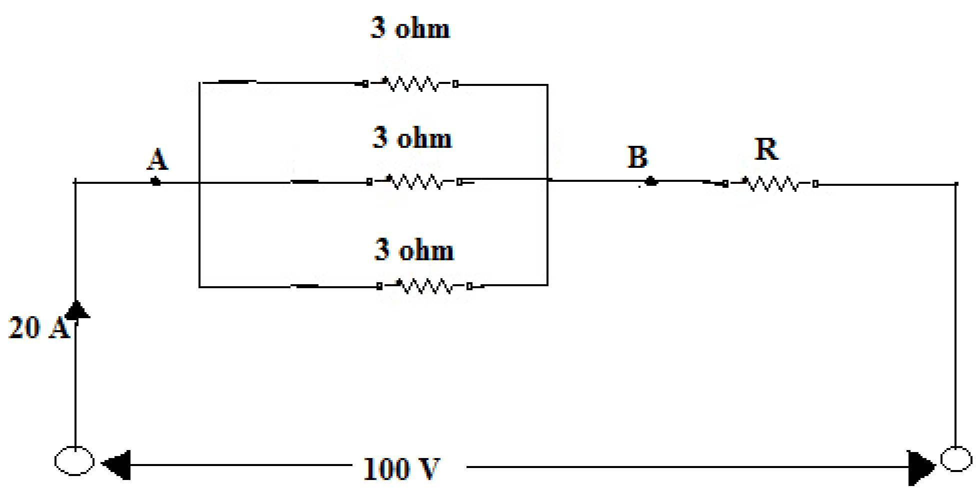
$$I = \frac{\text{Voltage between A and B}}{\text{resistance}}$$

$$I = \frac{4.5}{10}$$

$\boxed{I = 0.45 \text{ Amp.}}$

Note- The students should observe the battery connection carefully.) 6 volt battery is acting in clockwise direction and 1.5 volts battery is acting in anticlockwise direction. So, the effective voltage across the resistance is 6 – 1.5 = 4.5 volts between A and B. A is at higher potential, hence current (T) will flow from A to B in the resistance

Example: - Solve the circuit and find the resistance R.



Given data:-

R1=R2=R3=3 Ω

V = 100V

I = 20 Amp

Solution : Equivalent resistance of the three:

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

$$\frac{1}{R_{AB}} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3}$$

$R_{AB} = 1\ \Omega$

Total resistance = 1+R

Total voltage = 100 volts.

$$I = \frac{V_T}{\text{Total resistance}}$$

$$20 = \frac{100}{1+R}$$

$$\boxed{R = 4\Omega.}$$

4. Practical cases of series and parallel connections:-

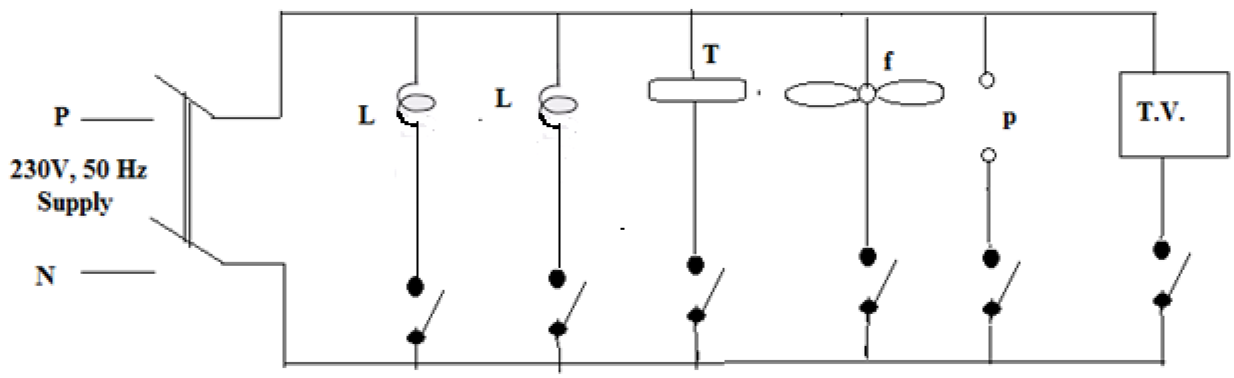


Fig. 4.1. Practical cases of parallel connections

- The fig4.1 shows the circuit diagram of practical series parallel connection
- In the house lightning and factory lighting the connection of various pointes lamps, bulbs, fans, etc form parallel electrical connection
- All the above points receive the same voltages of 230V, 50Hz.
- The decorative lighting is the example of series connection Small bulb which are rated for 6 or 8 volt cannot be connected directly to the main 230V supply.
- The bulb receives their rated voltage of 6 or 8 volt only. In series connection voltage is distributed,

$$V = V_1+V_2+V_3\ldots.V_n$$

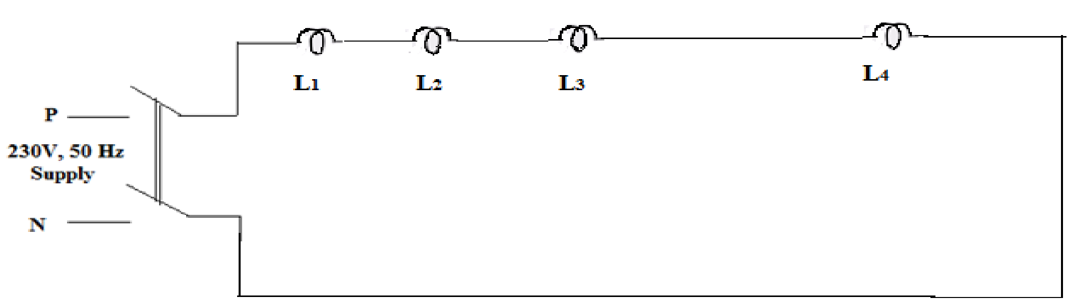


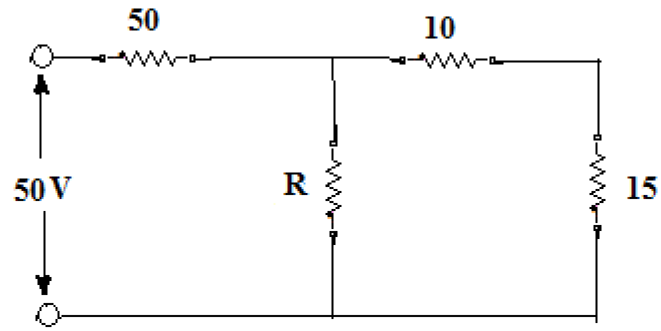
Fig. 4.2. Practical cases of Series connections

Problem for practice:-

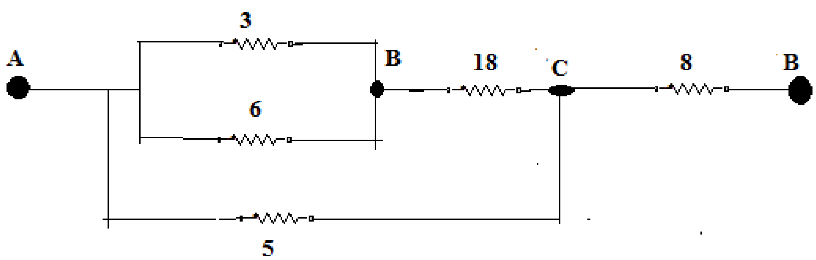
1. A coil consists of 2000 turns of copper wire having a cross-sectional area of 0.8 mm2. The mean length per turn is 80 cm and the resistivity of copper is 0.02 μΩ–m. Find the resistance of the coil when connected across 110 V supply.

2. The resistance of the wire used for telephone is 35 Ω per kilometer when the weight of the wire is 5 kg per kilometer. If the specific resistance of the material is 1.95 × 10−8 Ω-m, what is the cross-sectional area of the wire? What will be the resistance of a loop to a subscriber 8 km from the exchange if wire of the same material but weighing 20 kg per kilometer is used

3. What is the value of the unknown resistor R in Fig.? All resistances are in ohm



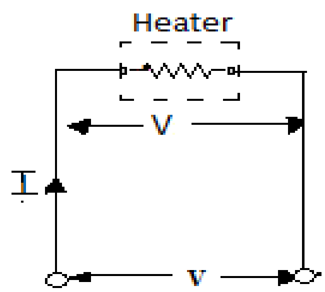
4. Calculate the effective resistance of the following combination of resistances and the voltage drop across 18Ω resistance when a P.D. of 60 V is applied between points A and B.



2. Work –Power-Energy

Electrical Unit:

1. Electric charge (Q or q) unit coulomb: When the current of 1 amp passes in the circuit for 1 second, then the electrical charge passed in the circuit is one coulomb.



Charge Q=$I \times t$ Amp.sec.

So ampere second = one coulomb.

2. Electrical work done (W.D.) unit Joule: When a circuit has an electric pressure of 'V' volts and quantity of Q coulomb is passed in the circuit work is done against the resistance of the circuit.

$$\text{Work done} = V \times Q$$
$$= V \times (I \times t) \text{ Joule}$$

3. Electric Power (P) : Rate of doing the work is known as power. Its unit is 'watt' or joule/sec.

$$\text{Power P} = \frac{\text{W.D.}}{\text{time}} \text{ Joule/sec or watts}$$

$$= \frac{V \times (I \times t)}{t}$$

$$= V.I$$

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

$$= \frac{V^2}{R} \text{ watt.}$$

Thus, the electric power in D.C. is the product of voltage and current. As noted above,

1 joule/sec. = 1 watt.

1 joule= 1 watt-sec.

4.Electrical Energy (E): Capacity of doing the work is known as energy. Energy is also the product of power and time. Its unit is joules or watt.sec.

$$E = P \times t$$

$$= V.I \times t \text{ Joule or watt-sec.}$$

This relation is same as work done. Thus, energy and the work done are the same terms. The unit of energy as watt-sec.It is a smaller unit. For energy measurement, a bigger unit is generally used. This unit is called as board of trade (B.O.T) unit; and it is expressed in K.W.H.

1 KWH $= 1 \times 1000 \times 3600$watt-sec
1 KWH $= 36 \times 10^5$watt.sec.

In practice, K.W.H. is simply said as "unit" i.e. when we say electric energy consumption is 10 units; it means energy consumption is 10 K.W.H.

Example1: Find current taken by a 2 KW heater when working on a 250 volts supply. Also find the resistance of the heater element. What will be the energy consumption if the heater works for 5 hours?

Given data: -

P = 2 KW
V = 250 V
t = 5Hr

To find:- I =?
R = ?

Solution:

Power(P) = V.I

$$\text{Current I} = \frac{P}{V}$$

$$I = \frac{2 \times 1000}{250}$$

Current I = 8 Amp.

Resistance of the heater element:

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

$$= \frac{250}{8}$$

$$R = 31.25\Omega$$

$$\text{Energy (E)} = \text{power} \times \text{time}$$

$$= 2 \times 5 = 10 \text{ K.W.H}$$

Example2: Lamp 'A' is rated as 250 volts 100watt; lamp 'B' is rated 250 volts 150 watt. If they are connected (i)in series (ii) in parallel. Find out the current in each case. Take the supply voltage in both the cases as 250 volts.

Given data: -

Lamp A (P_1) = 100 W
Lamp B (P_2) = 150 W
V = 250 V

To find:- For Series & Parallel Connections
I = ?

Solution:

$$\text{Power} = \frac{V^2}{R}$$

$$R_A = \frac{V^2}{P_1}$$

$$= \frac{(250)^2}{100}$$

$$R_A = 625\Omega$$

Similarly

$$R_B = \frac{(250)^2}{150}$$

$$R_B = 416.66\Omega$$

- For series circuit:

$$\text{Total } R = R_A + R_B$$

$$= 625 + 416.66$$

$$R = 1041.66\Omega$$

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

$= \frac{250}{1041.66}$

$I = 0.2400$ A

- For Parallel circuit: current

$I_A = \frac{V}{R_A}$

$= \frac{250}{625}$

$I_A = 0.4$ A

$I_B = \frac{V}{R_B}$

$= \frac{250}{416.6}$

$I_B = 0.6$ A

Total Current $I = I_A + I_B$

$= 0.4 + 0.6$

$I = 1$ A

Example3: Calculate the energy consumption for the month of July for the following load. Find the bill @ Rs.4 per unit.

(i) Two lamps each of 150 watt working 4 hours a day.
(ii) Electric heater of 1 kW working for 1 hour a day.
(iii) T.V. set of 60 watt working 5 hours a day.
(iv) Electric iron 500 watt 1 hour a day
(v) 2 fan of 40 watt working 8 hours a day.

Solution:

Item	Wattage	Quantity	Hours per day	Energy watt hours
lamp	150	2 No.	4	$150 \times 2 \times 4 = 1200$
Heater	1000	1 No.	1	$1000 \times 1 \times = 1000$
T.V. set	60	1 No.	5	$60 \times 1 \times 5 = 300$
Iron	500	1 No.	1	$500 \times 1 \times 1 = 500$
Fan	40	1 No.	8	$40 \times 1 \times 8 = 320$
				Total=3320

Total energy consumption for one day = 3320 watt hour = $\frac{3320}{1000}$ = 3.320 K.W.H.

Energy consumption for the month of July (31 days) will be

$3.320 \times 31 = 102.92$ K.W.H. = 103 K.W.H.

Energy Bill = $103 \times 4 = 412$ Rs

Example4: Lamp A is rated as 100 watt-220 volt, and lamp B rated at 150 watt 220 volt are connected is series across 220 volt supply. Calculate the respective voltage across each lamp.

Given data: - Lamp A (P_1) = 100 W

Lamp B (P_2) = 150 W

V = 220 V

To find: V_A & V_B =?

Solution:

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

$R_A = \frac{V^2}{P_1}$

$= \frac{(220)^2}{100}$

$R_A = 484\Omega$

Similarly

$$R_B = \frac{V^2}{P_2} = \frac{(220)^2}{150}$$

$$R_B = 322.66\Omega$$

Current flowing through the circuit is given by,

$$I = \frac{R_A+R_B}{V} = \frac{484+322.6}{220}$$

$$I = 0.2727 \text{ A}$$

The respective voltage across each lamp,

$$V_A = I.\ R_A = 0.2727 \times 484$$

$$V_A = 131.92 \text{ V}$$

$$V_B = I.\ R_B$$

$$= 0.2727 \times 322.6$$

$$V_B = 87.9\text{V}$$

Problems for practice:-

Example1: Find current taken by a 2.5 K.W. heater when working on a 220 volts supply. Also find the resistance of the heater element. What will be the energy consumption if the heater works for 5 hours?

Example2: Lamp ‘A’ is rated as 220 volts 200watt; lamp ‘B’ is rated 220 volts 100 watt. If there are connected (i) series (ii) in parallel. Find out the current in each case. Take the supply voltage in both the cases as 250 volts.

Example3: Calculate the energy consumption for the month of july for the following load. Find the bill @ Rs.4 per unit.

(i) Two lamps each of 150 watt working 5 hours a day.
(ii) Electric toaster of 1 kW working for 1/2hour a day.
(iii) T.V. set of 60 watt working 8 hours a day.
(iv) Electric geyser 500 watt 1 hour a day
(v) 2 fan of 40 watt working 6 hours a day.

Example4:Lamp A is rated as 100 watt-220 volt, and lamp B rated at 150 watt 220 volt are connected is parallel across 220 volt supply. Calculate the respective voltage across each lamp

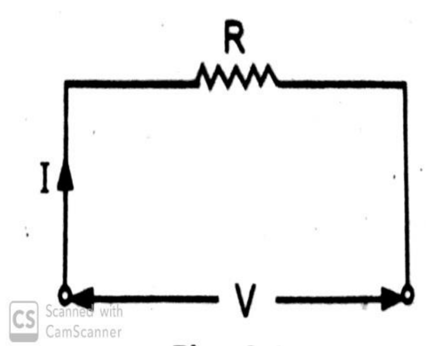
3. EFFECTS OF ELECTRIC CURRENT

Contents:

1. **Heating effect of an electric current**
2. **Chemical effect of an electric current**
3. **Physical effect of an electric current**
4. **X-ray effect of an electric current**
5. **Magnetic effect of an electric current**

1. HEATING EFFECT OF AN ELECTRIC CURRENT

An electric current when passes through an electric circuit produces different effects. These effects can be usually utilized, which are explained in brief in this article. When an electric current passes through the circuit, it is opposed by the resistance of the circuit. Energy required to overcome the resistance is converted into heat by Joule's law. This energy is expressed by the following relation:



Heat $= 0.24\ I^2 R\ t$ calories

Where,

I = Current in amp

R = Resistance in Ω

t = Time in seconds

This heating effect of current is utilized in the following cases:

1. Electric immersion heater

2.Electric geyser

3. Electric stove (Shegadi)

4. Electric iron (press)

5. Electric soldering iron

6.Electric oven

7. Electric kettle

8.Electric coffee percolator

9. Electric room heater

10. **Electric toaster**

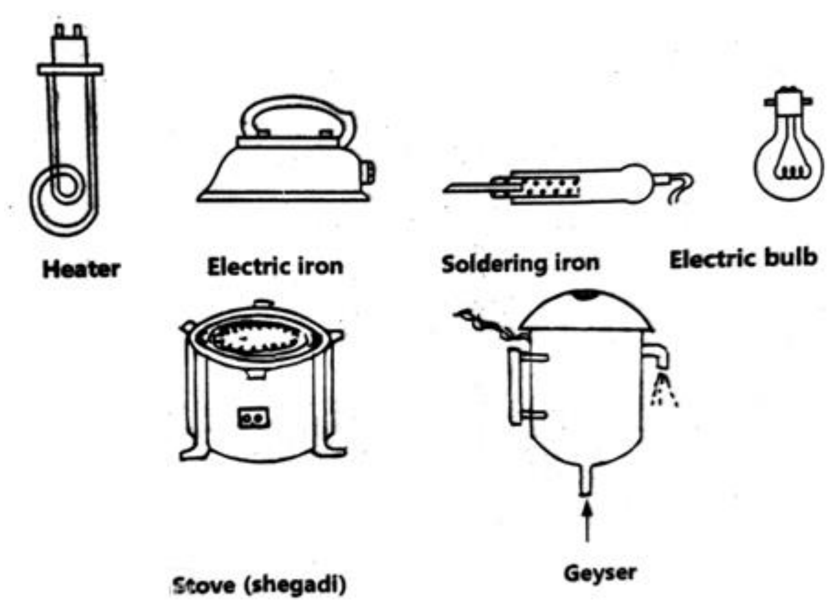
11. **Electric heat sealer**

12.Lamps, bulbs

13. **Electric hot plates**

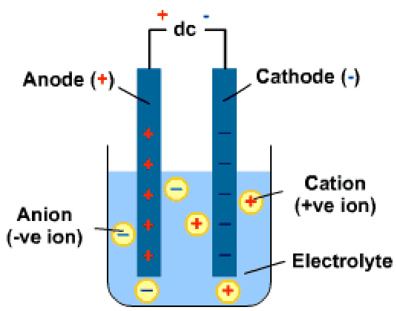
14.Electric welding

15. **Furnace**

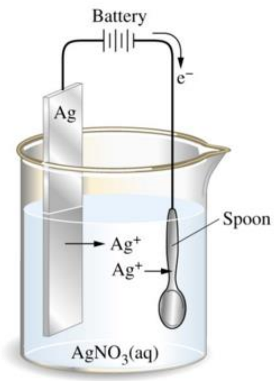


2. CHEMICAL EFFECT OF AN ELECTRIC CURRENT

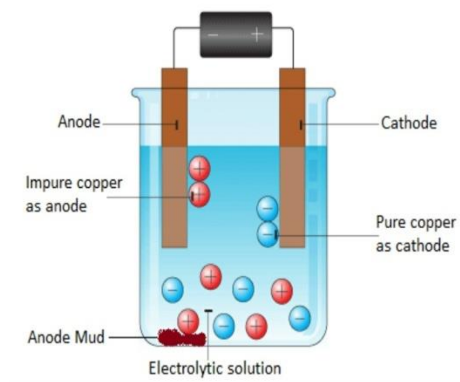
When an electric current is passed through some chemical solutions, a chemical reaction takes place. This chemical effect of an electric current is used in the following cases:



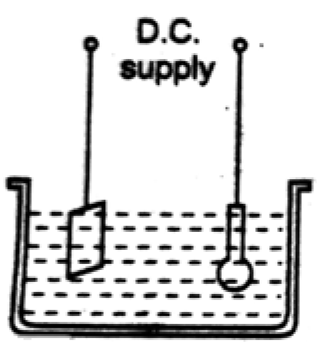
1.Electrolysis



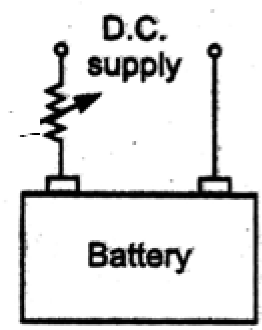
2.Electroplating



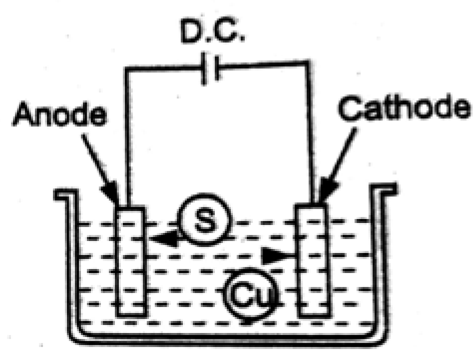
3.Electro refining of metals



Electroplating



Battery charging



Electrolysis

3. PHYSICAL EFFECT OF AN ELECTRIC CURRENT

Human body is a conductor of electricity. The current can very easily pass through the body if any part of the body touches to any live part of electric devices. If any part of our body happens to touch the live part of electricity, current completes the path through our body to earth. We receive a shock and it may result in death. When a severe shock is received, the heart damages into pieces and breathing may stop.

If the current through our body is more than 15 mill amperes, the shock is severe. Our average body resistance is about 50, 000 Ω when body is dry. But when body is wet, then the resistance reduces to about 1000Ω only and hence the shock is server when the body is wet.

4. X-RAY EFFECT OF AN ELECTRIC CURRENT

By some machine a very high frequency voltage is generated. When this high frequency voltage is applied to an X-ray vacuum tube, special types of rays are produced. These rays are known as X-rays. In hospitals various types of X-ray photos can be taken of different defective parts of the body for medical checkup.

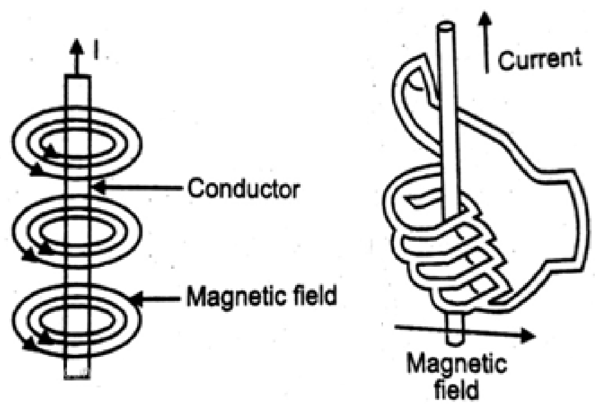
5. MAGNETIC EFFECT OF AN ELECTRIC CURRENT

This is very important effect of an electric current which is made use in various electric appliances and electric equipments and hence this is explained with more details in this chapter.

When the current passes through the conductor wire, a magnetic field is produced around the conductor. (It can be proved experimentally: Hold the magnetic needle near to such a conductor. It gets deflected; this shows that the magnetic field is produced around the conductor).

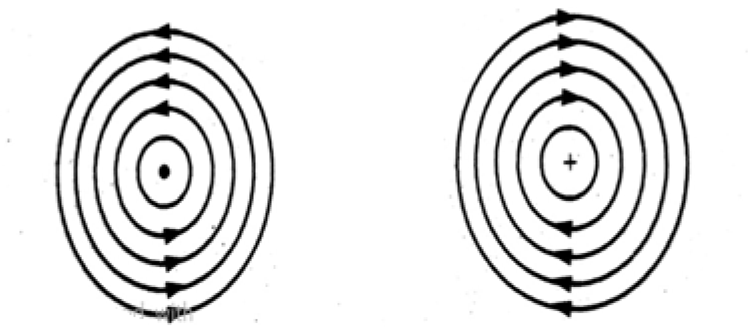
The magnetic field has the direction. This direction depends on the direction of the current in the conductor. If the direction of current in the conductor is changed, the direction of magnetic field produced by the current also changes.

Magnetic field due to straight conductor carrying current: When a straight conductor carries current, the magnetic field produced around it is in the form of circular lines of force. These lines are perpendicular to the axis of the conductor. The direction of these lines is found by right hand rule. As shown in the figure, if the direction of current is shown by the direction of thumb, then direction of fingers give the direction of the magnetic flux-lines.



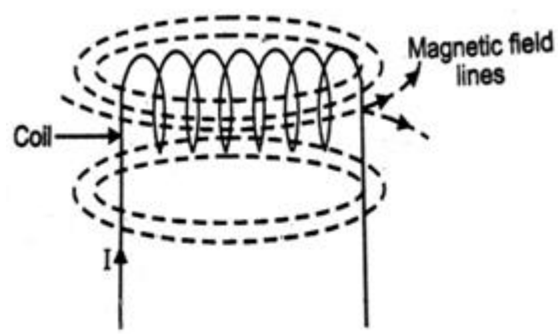
Sometimes the conductor wire is shown by cross-section and the direction of current in the cross-section of conductor is marked by the symbol ⊕ cross or ⊙ dot.

The symbol ⊙ dot means current is coming out and ⊕ cross means the current is going in. For the direction of current as ⊙ dot, the lines are anticlockwise and for ⊕ cross direction of current, the lines are clockwise in direction.

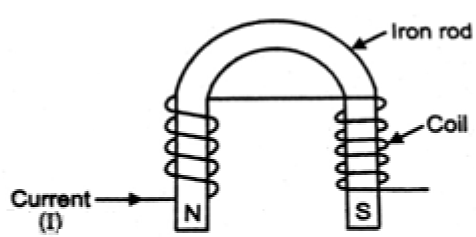


a) for dot - anticlockwise   b) for cross - clockwise

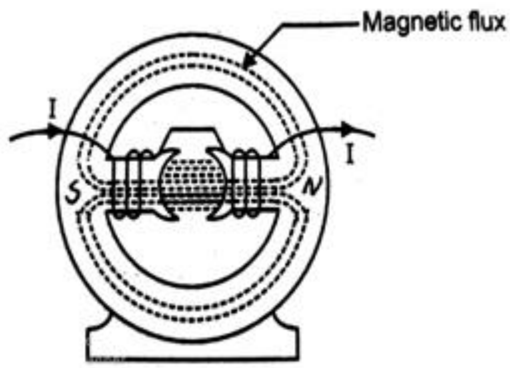
Magnetic field due to a coil having number of turns: The strength of the magnetic field depends on the number of turns of coil as well as on the current in the coil.



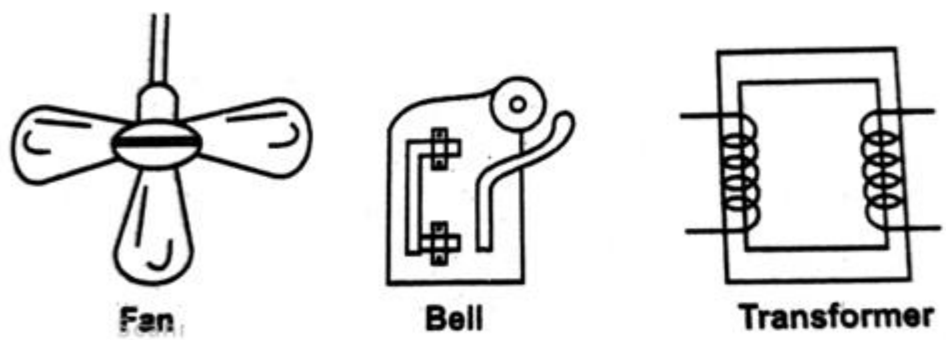
If such a coil is wound on a piece of iron rod, then the rod behaves like a magnet. This simple arrangement of iron rod wound with coil is called as "Electromagnet".



Following is the most popular and important arrangement of electromagnets used in electrical machinery.



Magnetic effect of an electric current is also made use in the following equipments.



EXERCISE

1. Explain various effects of an electric current.

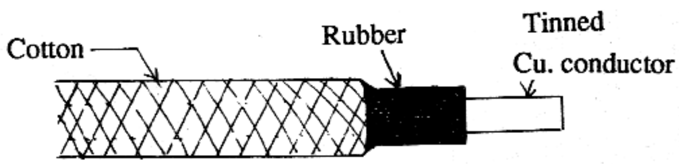
2. Give an example of heating effect.

4. Types of wire and wiring accessories

Types of wires:

1. V.I.R. (Vulcanized Indian Rubber) Wire
2. Lead sheathed Wire
3. CTS or TRS(Cab Tyre Sheathed or Tough Rubber sheathed) Wire
4. Weather proof Wire
5. Flexible wires.
6. P.V.C. wires

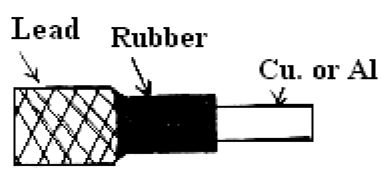
I] V.I.R. or S.B.R.C. (single Braid Rubber covered):



V.I.R. Wire

a) In this type of wire, single tinned copper or aluminum conductor is used. Tinning of conductor prevents the sticking of rubber to the conductor. Conductor is covered with a layer of rubber insulation.
b) Over this rubber insulation is put up a cotton-protective braid which is usually saturated with flame retarding and moisture resistant compound.
c) Finally it is finished with wax for cleanliness and helps pulling action of it into the conduits.
d) Thickness of rubber insulation depends upon the voltage for which wire is required; they are available for 250 V or 600V.

II] Lead sheathed wire:

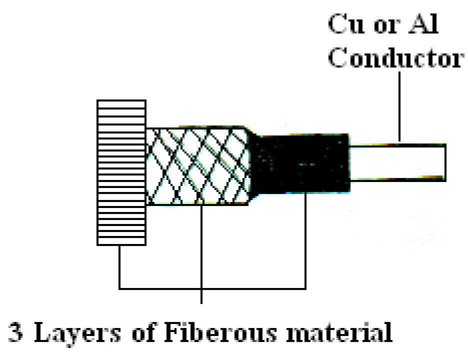


a) Ordinary V.I.R. wires are specified for dry locations.
b) In order to use rubber insulated wire in damp conditions, the ordinary rubber wires are covered with continuous sheath of lead.
c) Lead covering is about 1.25mm thick.
d) Mechanical protection is good but wires are heavy and costly.

III] C.T.S or T.R.S Wire:

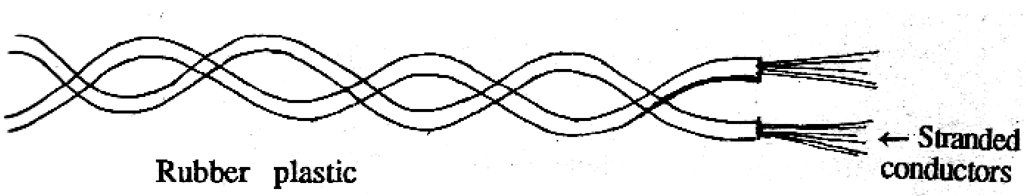
a) Ordinary wire is provided with rubber insulation is not water resistant.
b) But T.R.S. wires are provided with tough rubber compound which does not deteriorate even after long exposure to moisture.
c) It can be used in wet locations

IV] Weather Proof wire:



a) Such type of wires consists of three layers of fibrous yarn provided over Cu conductor.
b) Before these braids are applied conductors are saturated with waterproof compound.
c) It is used for outdoor purposes, since it can withstand rain, sunlight, chemical action.
d) They are resistant to atmospheric variation.

V] Flexible wires:



a) Wires used for household appliances are very flexible.
b) Flexible wires consist of thin hair like conductors grouped together.
c) Flexibility is required firstly from the point of view of handling the equipment and secondly to prevent wires from break.
d) Generally sizes of wires are “14/0.0076 or 162/0.0076”
162/0.0076”
0.0076 inches or 0.1930 mm
It means 14 or 162 strands of Cu conductors having diameter 0.0076 inch.

VI] PVC wires (Poly vinyl chloride):

a) A modern thermoplastic material which is often used as an alternative to rubber.
b) It resists chemical action.
c) It resists adverse climate conditions.
d) It is lighter in weight.
e) It offers mechanical protection.
f) It has a tendency to crack at low temperature and soften at high temperature.

WIRING ACCESSORIES

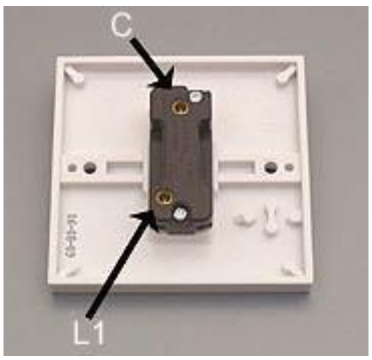
1. SWITCHES
2. LAMP HOLDER
3. CEILING ROSE
4. SOCKET OUTLET
5. PLUG
6. DISTRIBUTION BOX
7. FUSE
8. WIRES

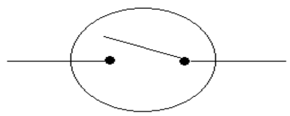
1. **SWITCHES:** A switch is a mechanical device used to make or break the electrical circuit contacts. A switch should so operate that it should make the contact firmly and break the contact instantaneously. For this action there is a spring provided to the movable blades. A switch can perform mainly two functions- ON, by closing its contacts, or fully OFF, by opening its contacts. When contacts are closed, it creates a path for the current to flow, and vice-versa, an open contact will not allow the current to flow. In electrical wiring, switches are most commonly used to operate electric lights, permanently connected appliances or electrical outlets.

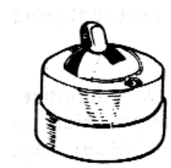
Types of switches:

Sr No.	Types of switches	Specification (Lighting Circuits)	Specification (Power Circuits)
1	Surface switch	5A, 230V	15A, 230V
2	Piano switch/flush switch	5A, 230V	15A, 230V
3	Pull switch or ceiling switch	5A, 230V	-
4	Grid switch	5A, 230V	-
5	Rotary switch	5A, 230V	-
6	Push button switch	5A, 230V	-
7	Intermediate switch	5A, 230V	-
8	Industrial iron clad switch	16A, 32A, 63A, 100A, 200A and so on. 230V, 440V	

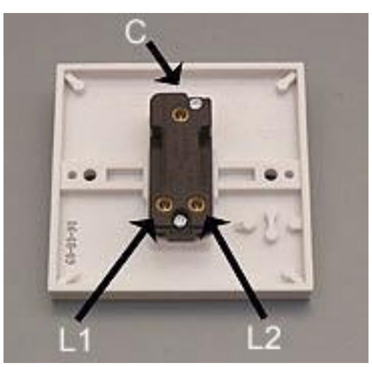
1. Surface switch (or Tumbler Switch): These switches are mounted on mounting blocks or directly fixed over the surface of the wall. Such types of switches project out of the surface of the wall.
They are classified as:
a.One way/single way switch - This switch is provided with single pole. It has two contacts, which is a common marked as COM or C. The common is for the live wire that supplies the input voltage to the switch. The other terminal is marked as L1 and is the output to the light fixture.

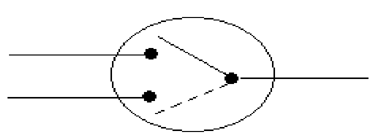




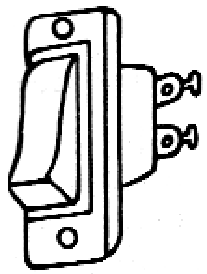


b. Two way switches - A two way light switch is a simple single pole "changeover" switch with three terminals. These are typically labeled COM, L1, and L2 (Some may label the L1 and L2 positions as "1 Way" and "2 Way").The advantage of a two-way switch is the ability to control a single device from two separate locations. A convenient and apt use for them is for locations like stairways, a long corridor or a very large room.






2. Piano switch (or Flush switch): These switches are enclosed in wooden board or P.V.C. board recessed into the wall. Switches does not project out. Current carrying parts are not easily accessible.



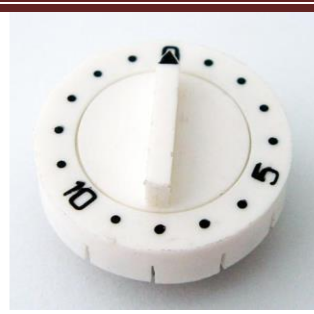
Piano switch

3. Pull switches: Pull switches are fixed on ceiling and all live parts are out of reach of operator. Pull cord is provided with a single pull on the cord for on/off positions. A pull switch is a switch that is actuated by means of a chain or string. An electric pull switch is attached to a toggle type switch.
One pulls to switch on and next pull to switch off. The most common use of a pull switch is to operate a ceiling electric light.

Pull switch

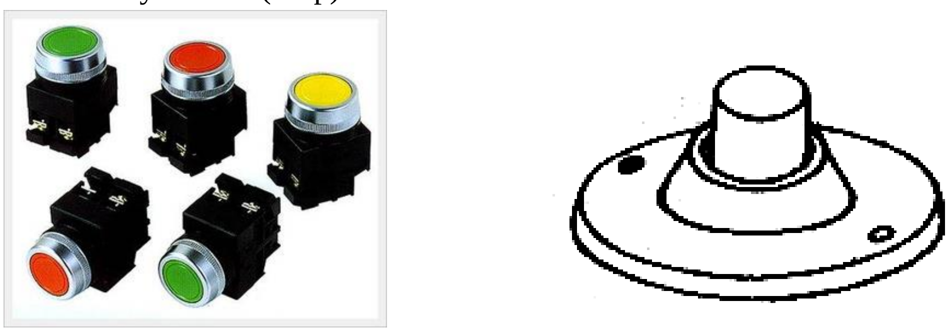
4. Grid switches: These switches are similar to surface switches, only they are lighter. So, they are useful for portable machines and appliances.

5. Rotary switches: These switches consist of an insulated handle to which blades are fixed. These blades move in steps by the movement of handle and make contact with the terminals. A rotary switch is a kind of switch that has a rotating shaft attached to a terminal. That terminal is able to make or break a connection to one (or more) other terminals. Rotary switches may feature different switch positions that can be set by rotating the switch spindle in one or another direction. Some common examples where a rotary switch might be used is in a multi-speed fan or as a band selector on multi-band radios.



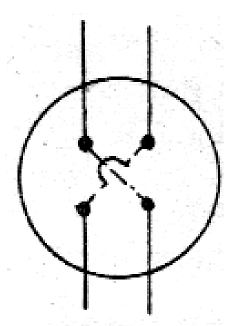
Rotary switch

6. Push button switches: These switches open or close with quick action when pressed. It is used for starting motors or ringing bells. They are widely used in automatic control applications as Normally Open (Start) switch or Normally Closed (Stop) switch.



Push button switches

7. Intermediate switch: This switch has four contacts when dolly is up the top and bottom contacts are bridged and when down, the contacts are cross connected. This kind of switch is used in a hall, go-downs, big rooms, where different lamps are required to turn on and off from different places and in a multistory building, the ground floor or car parking lights can be controlled from any floor.

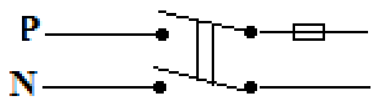


8. Industrial iron clad switch:

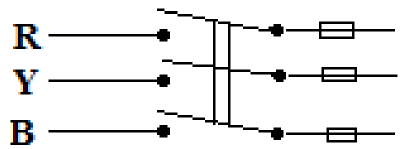
a. This switch is used as a main switch by consumer to have self control of the electric circuit.
b. This switches are heavy duty and strong in construction.
c. This switch is combined with fuses.
d. Fuses are fitted in iron cover.

Two types are: I) I.C.D.P. (Iron clad double pole): It is used in single phase circuit.
II) I.C.T.P. (Iron clad triple pole) : It is used in three phase circuit.

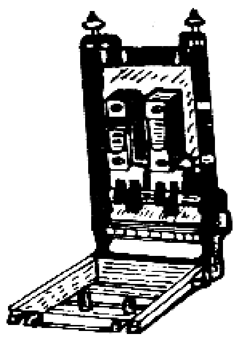
For domestic installations switches are designed for
Voltage rating: 230v, 440v
Current rating: 16A, 32A, 63A, 100A, 200A so on



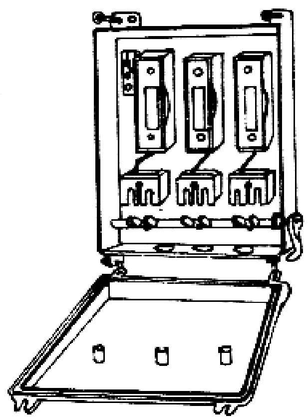
I.C.D.P



I.C.T.P



I.C.D.P.



I.C.T.P

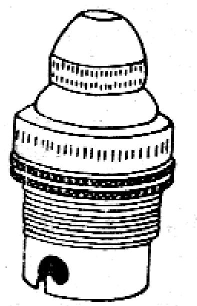
I.C.D.P

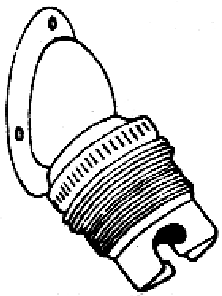
I.C.T.P.

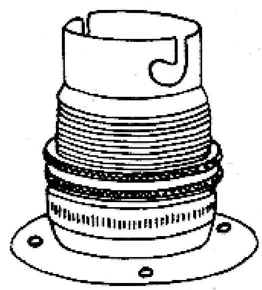
2. LAMP HOLDER: A lamp holder is used to hold the lamp required for lighting purpose. Lamp holders are either molded or porcelain interior with a solid or spring plunger and wire terminals.

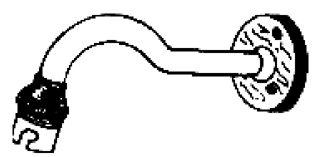
Types are:

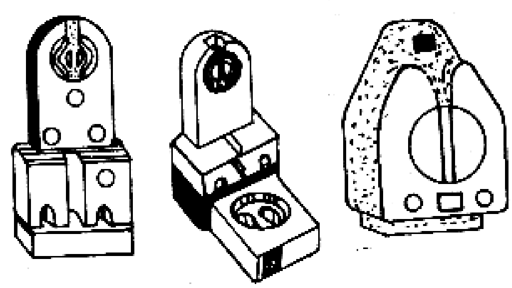
a. Pendant holder
b. Batten holder
c. Bracket holder
d. Edison screw holder.
e. Fluorescent lamp holder
  (i) Bi-pin type
  (ii) Bayonet caped tube holder
f. Starter holder


Pendent holder


Angle holder


Batten holder


bracket Holder

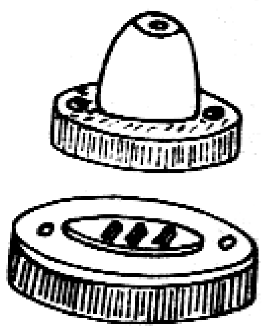

Flourescent tube holder


Pendant holder

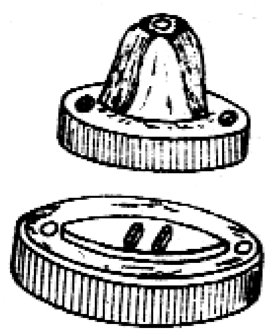

Angle holder


Batten holder

3. CEILING ROSE: A ceiling rose is used to provide a tapping to a pendant lamp holder through a flexible wire or a connection to a fluorescent tube, ceiling fans. Ceiling rose consists of a circular porcelain or Bakelite base provided with two or three terminal plates. To a threaded base porcelain or Bakelite cover is fixed.



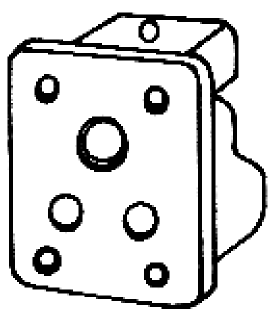
3-plate Ceiling Rose



2-plate Ceiling Rose

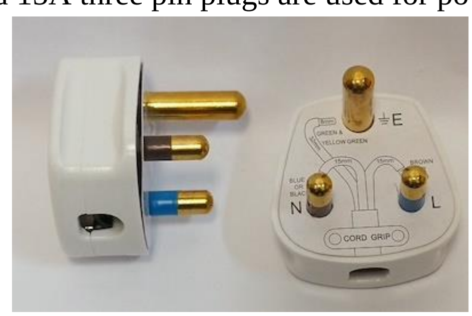
4. SOCKET OUTLET: The socket outlets has insulated base having three terminal sleeves. The two thin terminal sleeves are making connection to the two core cable with the third terminal sleeve thicker in cross section is used for an earth connection.

5A socket outlets are used for lighting circuits.
15A heavy duty is used for power circuits.



5. PLUG: For tapping power from socket outlets three pin plugs are used. The thicker pin is used for earth connection. Three pin 5A for lighting circuits and 15A three pin plugs are used for power circuit.

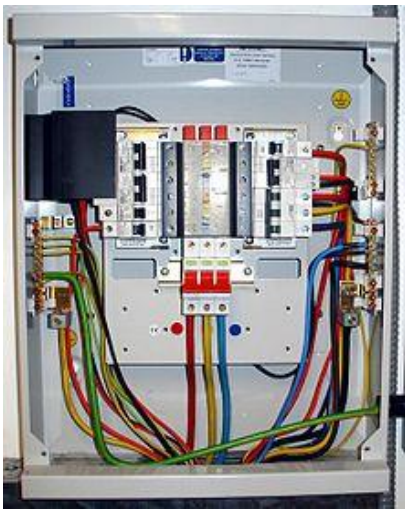
Round 3 pin 5A plug

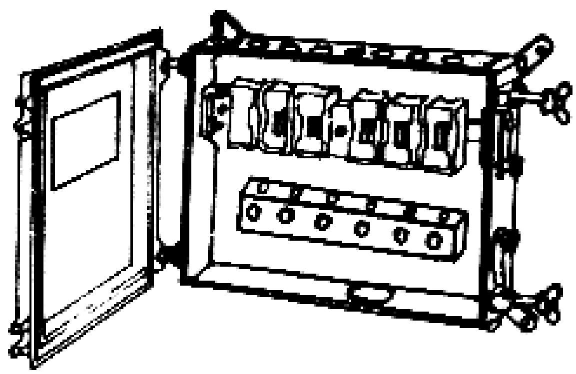


Round 3 pin 15A plug

6. DISTRIBUTION BOX:

a. Distribution boards are iron-clad and houses fuse bank.
b. Fuses in D.B. can be easily removed.
c. D.B. is used for splitting the circuit.
d. For connecting neutral, D.B. is provided with neutral link.



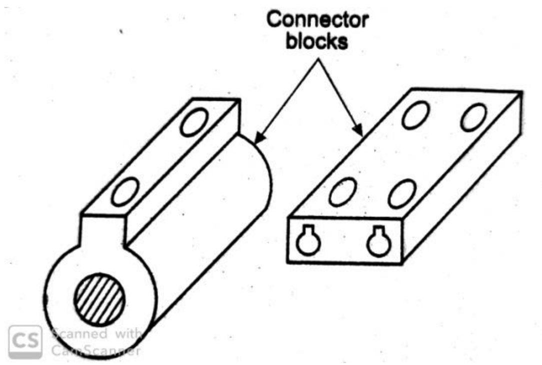


Distribution board

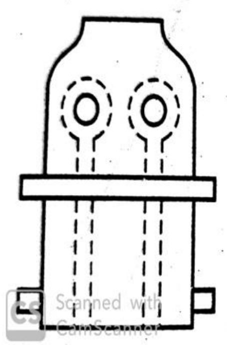
7. FUSE: It is safety device connected in series with the phase wire. When current exceeds its normal rated value fusing element in the fuse melts and breaks the circuit. Fuse element is made up of lead-tin alloy, copper or silver. Following are the types of fuses:

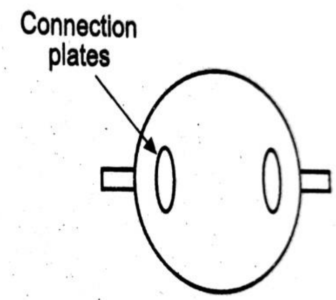
- Typesof fuses
  - Rewirable[semi enclosed]
    - Round type fuse or cut out
    - Kit-Kat fuse
  - NON-Rewirable[totally enclosed]
    - Cartridge fuse
    - H . R. C. FUSE

8. CONNECTOR BLOCKS: It of one or more brass connecting barrel with set screws to clamp the wires. It is surrounded by molded blocks of insulated materials like Bakelite and porcelain. The brass barrel is fitted in the connector block.



9. Adaptors: When the connections are made from lamp holders, the adaptor is used. It consists of portable fitting temporary in place of fixed brackets, batten or pendent holders.The ends of the flexible chord are connected from back side to the two plates in adaptor which make contact with plunger in lamp holder.



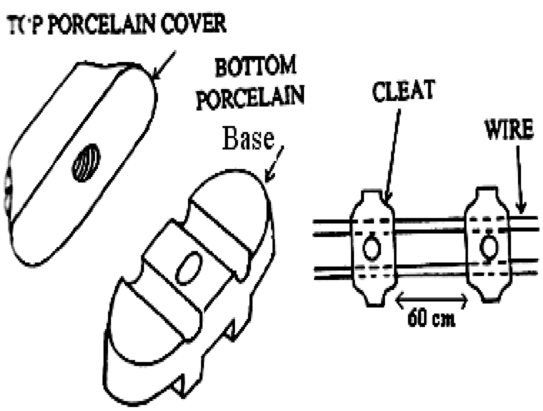


5. WIRING SYSTEM

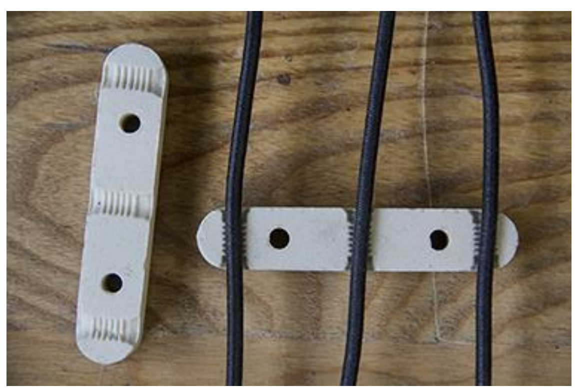
Types of Wiring System:

1. Cleat wiring
2. Batten wiring
   a. C.T.S system
   b. Lead-sheath system
3. Casing & capping wiring
4. Conduit wiring

Cleat Wiring:



Cleat System



Cleat made up of porcelain

1) Wires are supported in porcelain cleats.
2) Cleats are made in two halves. One of which is grooved to receive wire & other is put over it. Whole of it is fixed on wall by means of screws.
3) This system is suitable for temporary purpose.
4) Cleats used should not be more than **60cm** apart horizontally or vertically.
5) Sharp bends should be avoided.

6) Spacing of the cleats under the bend should be reduced.
7) When wires are to pass through walls. They must be taken through conduits

Advantages:-

(i) Very cheap.
(ii) Skilled labors are not required.
(iii) Less time required for wiring.
(iv) Recovery of material can be made when wiring is no longer reqd.

Disadvantages:-

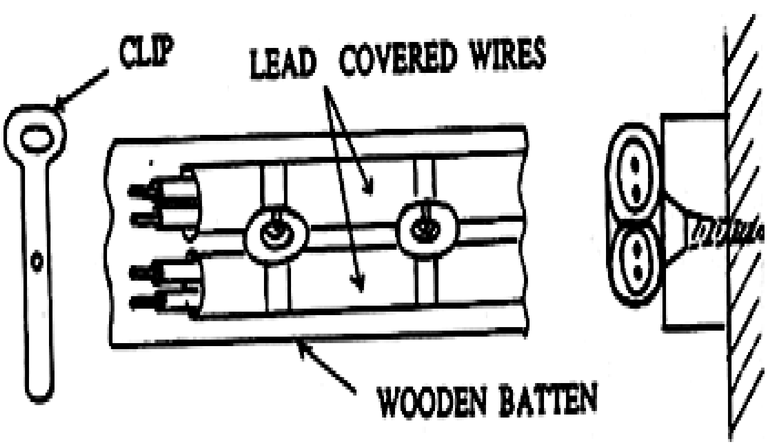
(i) Cannot be used for permanent job.
(ii) Appearance is shabby due to sagging and collection of dust & dirt.
(iii) Cannot be used in damp places, water-pipes, factories, smithy shop.

Application:-
(i) It is used for temporary purpose like Project work.
(ii) Temporary lighting at dry places.

BATTEN WIRING:

1. Lead covered or Metal sheathed
2. C.T.S. type of wiring system

1. Lead covered or Metal sheathed :



1) This type of wiring system consists of rubber insulated conductor covered with an outer sheath of lead alloy containing 95% lead which provides protection from mechanical injury and dampness. Wires are fixed by means of metal clips spaced at regular intervals which must not be more than 30 cm.
2) Metal clips (joint clips) are fixed at an interval of 10 cm horizontally and 15 cm vertically on wooden batten.

3) Lead sheath must be earthed. This is done to avoid electrolytic action due to leakage current, which deteriorate the lead covering.
4) Also earthing provides safety against metal sheath becoming live.

Advantages:

(i) Protection from dampness.

(ii) Fault finding is easy.

(iii) Semi-skilled workers required.

(iv)Mechanical protection is good.

(v)Easy installation

(vi)Cheap in material cost

(vii)Appearance is better.

(viii)Customization is easy

(ix)Less chance of leakage current

Disadvantages:

(i) Costly.

(ii) Continuous earth wire should run along with lead wire in case of lead sheathed wiring system.

(iii)Not suitable for outdoor wiring

(iv)Humidity, smoke, steam etc directly affect on wires.

(v)Heavy wires are not recommended for this wiring scheme.

(vi)Only suitable for voltage below 250 V.

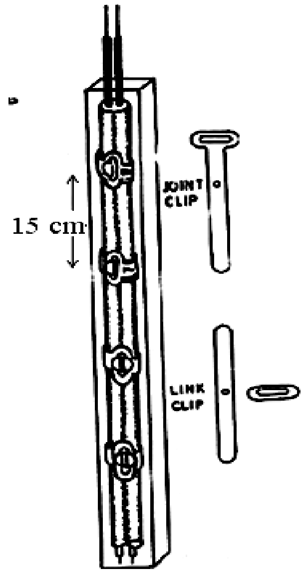
(vii)High risk of fire

Application:-

(i)It is used for domestic work.

2. C.T.S. type of wiring system:

a) In C.T.S. types of wiring system, C.T.S. wires are fixed by means of metal clips on wooden beams or perfectly straight and well varnished wooden batten.
b) Metal clips (joint clips) are fixed at an interval of 10 cm horizontally and 15 cm vertically on wooden batten.
c) The wiring should not be given any right angle bend.
d) It is preferred to pass the wire through the conduit pipe when passing through the walls, ceiling or floor.



Advantages:

(i) Life is long.

(ii) Fault finding is easy.

(iii) Semi-skilled workers required.

(iv)Time required for installation is less.

Disadvantages:

(i)Appearance is shabby.

(ii) Fair possibility of fire.

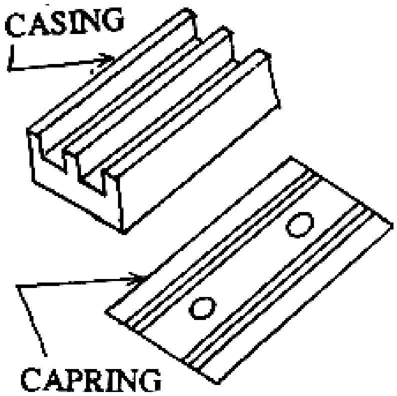
(iii)Maintenance cost more.

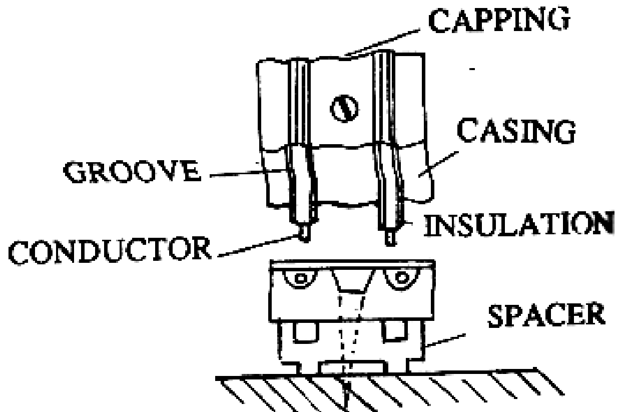
Application:-

(i)It is used for domestic work.

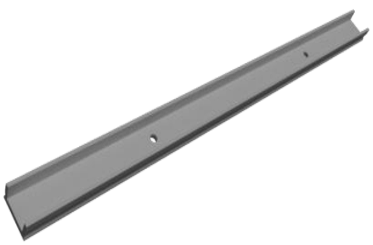
2. CASING AND CAPING:

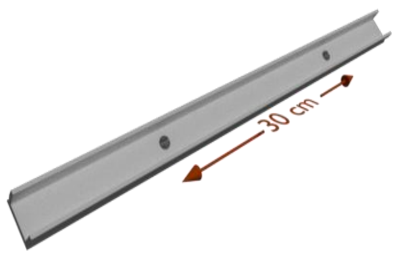
1) This system of wiring is most commonly adopted for residential buildings.
2) It consists of rectangular wooden blocks made of teakwood called casing.
3) It has usually 2 grooves, into which wires are led.
4) Casing at the top is covered by means of rectangular strip of wood called capping.
5) Casing and capping are given double coating of varnish.
6) Nowadays, PVC casing capping system is used. It is more durable, less time required, cost is less & light in weight.

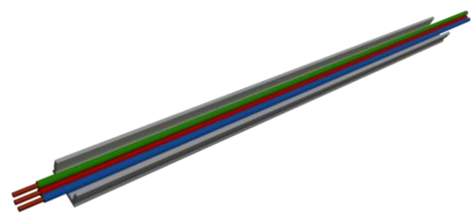


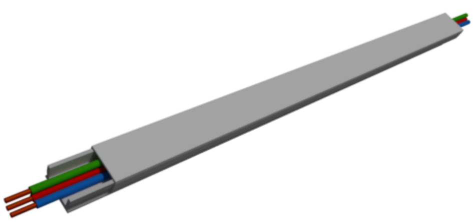


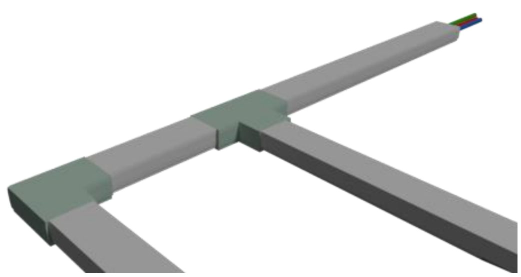
Casing and Capping











7) Points to be considered while installing such wiring system.
    - Teak wood should be used to avoid trouble of white ants.
    - In 20mm casing max no. of wires should not be more than 8.
    - T-junction boxes, outer & inner corners should be used at proper places.
    - Length of casing is generally 6 feet. Joints of casing and capping should not overlap each other.

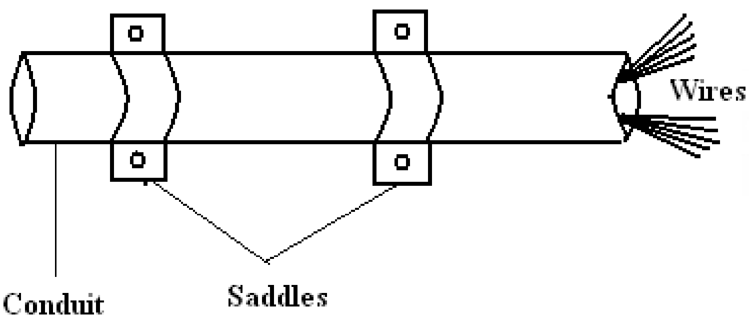
Advantages:-

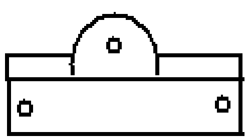
(i) Life is long.
(ii) Cost is medium.
(iii)PVC capping casing can be used at moist places.
(iv)Mechanical protection is more than cleat & batten wiring.

Disadvantages:-
(i) In wooden casing –capping possibility of fire is more.
(ii) Skilled labors required.

Application:-
(i) It is used for domestic work.

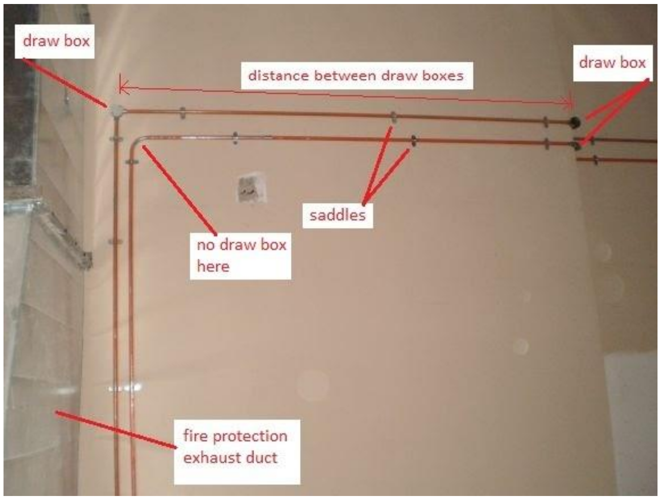
4. CONDUIT WIRING SYSTEMS:

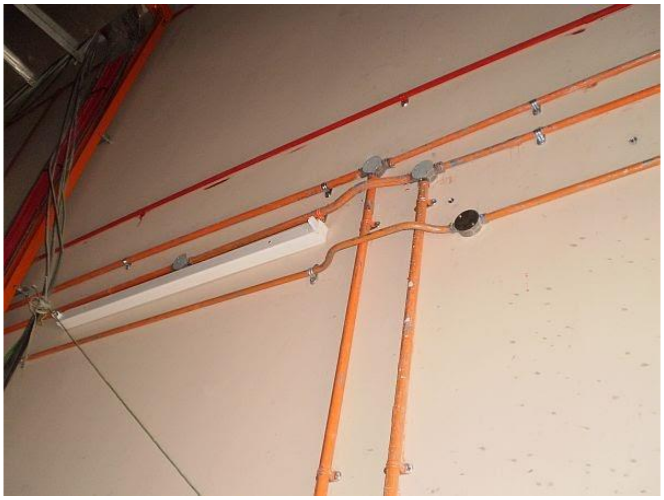




a) In this system, VIR or PVC wires are run in tubes called conduits.
b) Conduits are of two types:
(i) Metal conduits are made of galvanized iron or High grade steel.
(ii) PVC conduits.
c) Conduits can be either buried under plaster or can be supported over the walls by means of saddles or pipe hooks.
d) Wiring with conduit on surface of walls is known as surface conduit wiring used for workshops
e) Whereas wiring with conduits buried under plaster is called concealed conduit wiring.
f) Conduits are generally erected first and wiring is done later.
g) Wires are pulled through the conduits with the help of steel wires.

h) This drawing of wires is called fishing.





Advantages:

(i) It provides protection against fire due to short circuit.

(ii) It provides protection against mechanical injury.

(iii) It provides protection against moisture, fumes in chemical industry & factories.

(iv) Concealed conduit wiring do not spoil the beauty of premises.

Disadvantages:-

(i) Fault finding is difficult inspection bends are necessary.

(ii) Continuous earth wire should run along metal conduit.

(iii) Skilled workers are required.

Application:-

(i) It is used in chemical industries, workshop and black smith's shop.

Precautions:

(i) Use High Grade steel pipe for surface conduit, G.I. for concealed conduit & PVC pipe for general purpose.
(ii) Work must be done by the skilled persons.
(iii) Earth wire should be continuously run through the conduits.
(iv) Appropriate threading must be done not less than 1.5 cm.
(v) Pipes must be properly supported by saddles.
(vi) Inspection bends &tees must be used at proper places.

- **Selection of wiring:**

Factors affecting wiring:

(i) Durability.
(ii) Safety.
(iii) Appearance.
(iv) Cost factor.
(v) Accessibility.
(vi) Maintenance cost.

Durability:-Type of wiring selected should be durable according to the type of building. Ex: Cleat wiring is suitable for temporary purpose.

Safety:-While selecting type of wiring one has to look into the safety aspect .Ex: In chemical factory, where fumes are produced, batten or wooden casing capping should not be used.

Appearance:-Wiring should not spoil beauty of premises.

Cost:-Type of wiring should meet the consumer's requirement within available resources.

Accessibility:-Extension and renewal of wiring should be possible.

Maintenance cost:-Maintenance cost should be low.

- **COMPARISON TABLE OF VARIOUS WIRING SYSTEMS**

Sr. No.	Particulars	Cleat Wiring	Lead sheath	C.T.S system	Casing & Caping	Conduit System
1	Life	Short	long	long	long	Very long
2	Maintenance Cost	Nil	medium	medium	Medium	Nil
3	Initial cost	Low	high	medium	medium	Very High

4	Applications	Temporary purpose	Damp places	House	House, offices	Work- shops, factories
5	Mechanical Protection	Nil	Good	Fair	Fair	Very good
6	Possibility of Fire	Nil	Fair	fair	In wooden casing caping: fair In p.v.c. casing Caping :nil	Nil
7	Protection from Dampness	No	Very high	Good	Wooden: slight Pvc: good	Good
8	Type of labour Required	Skilled labours not required	Semi-skilled	Semi-skilled	Wooden: highly skilled p.v.c.: semi skilled	Highly skilled
9	Appearance	Shabby	Not good	Not good	good	Very good
10	Accessibility	Suitable	Suitable	Suitable	Suitable	Not suitable
11	Recovery of Material when Wiring is no Longer required	Possible	Not possible	Not possible	Not possible	Possible
12	Time require for installation	Very Less	Less	Less	Less	More

- **HOUSE WIRING PROCEDURE:**

1] Plan or layout is made which decides location of meters, points and switch board.

2] Energy meter should be installed outside the room.

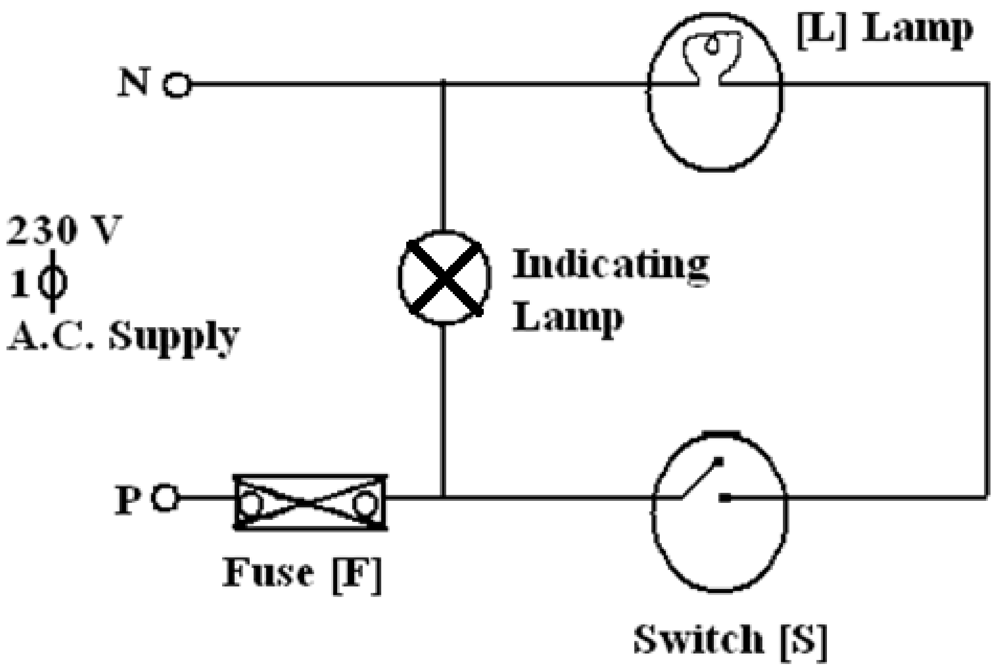
3] Main switch should be provided immediately after the energy meter.

4] Depending upon number of points and their location number of circuits are decided

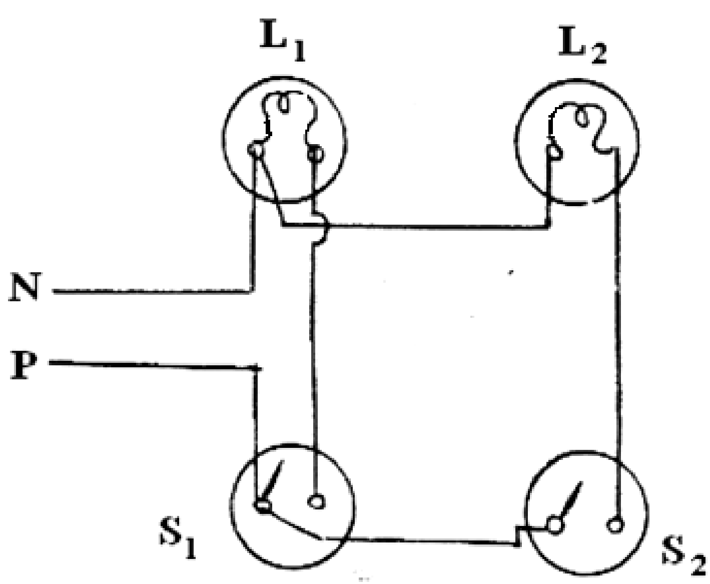
5] Proper distribution board is chosen considering the future demand.

6] Proper fuses and switches at proper places are installed.

- **CONNECTING ONE LAMP ONE SWITCH, INDICATING LAMP AND FUSE IN A CIRCUIT:**

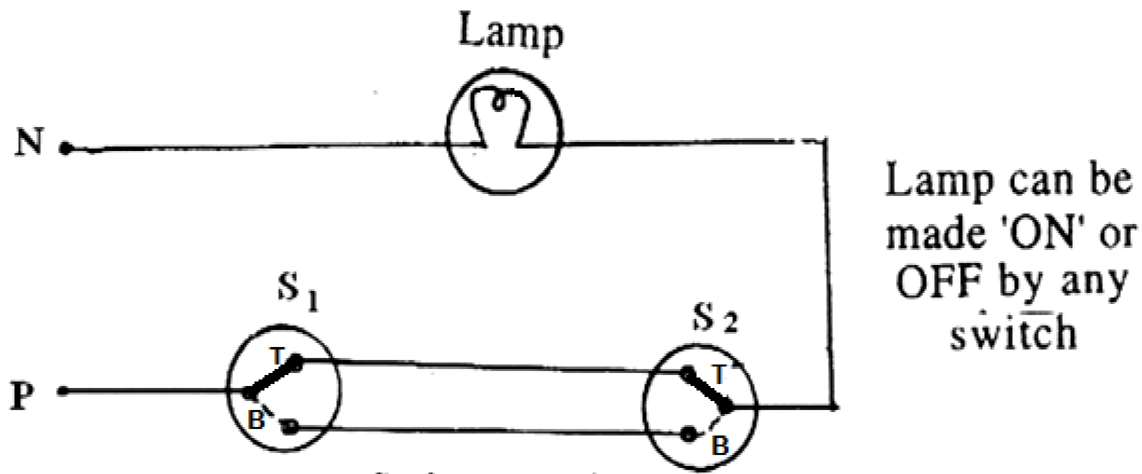


- **CONTROLING TWO LAMPS INDEPENDENTLY IN A CIRCUIT:**



Lamp 1 controlled by switch 1
Lamp 2 controlled by switch 2

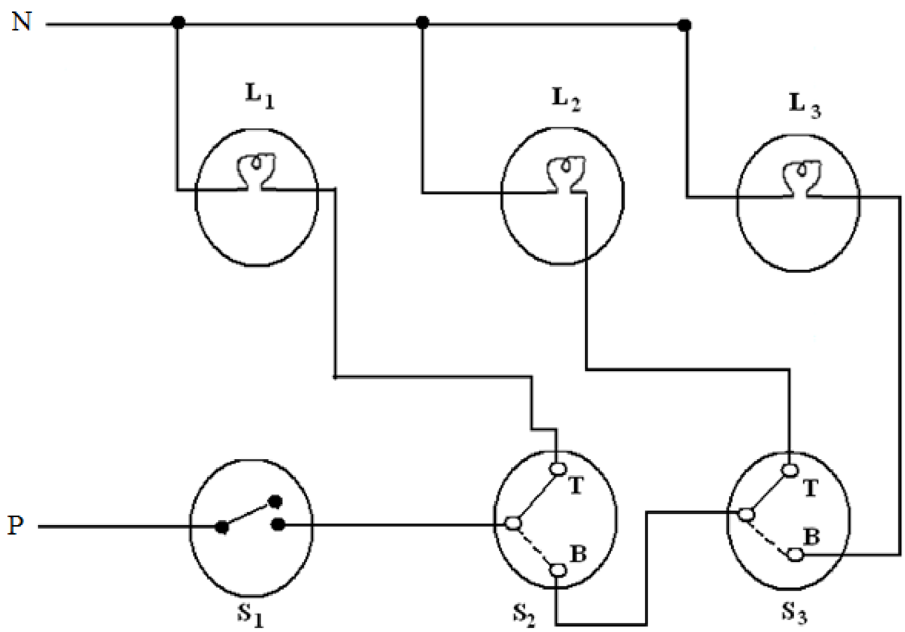
- **STAIRCASE WIRING (CONTROLING ONE LAMP FROM TWO PLACES):**



Stair case wiring
(One lamp controlled from two places)

S_1 & S_2 = Two way Switches

- **GODOWN WIRING:**



S_1 = One way switch
S_2, S_3 = Two way switches

Operation:

When S1 is made 'ON', L1 is light up.

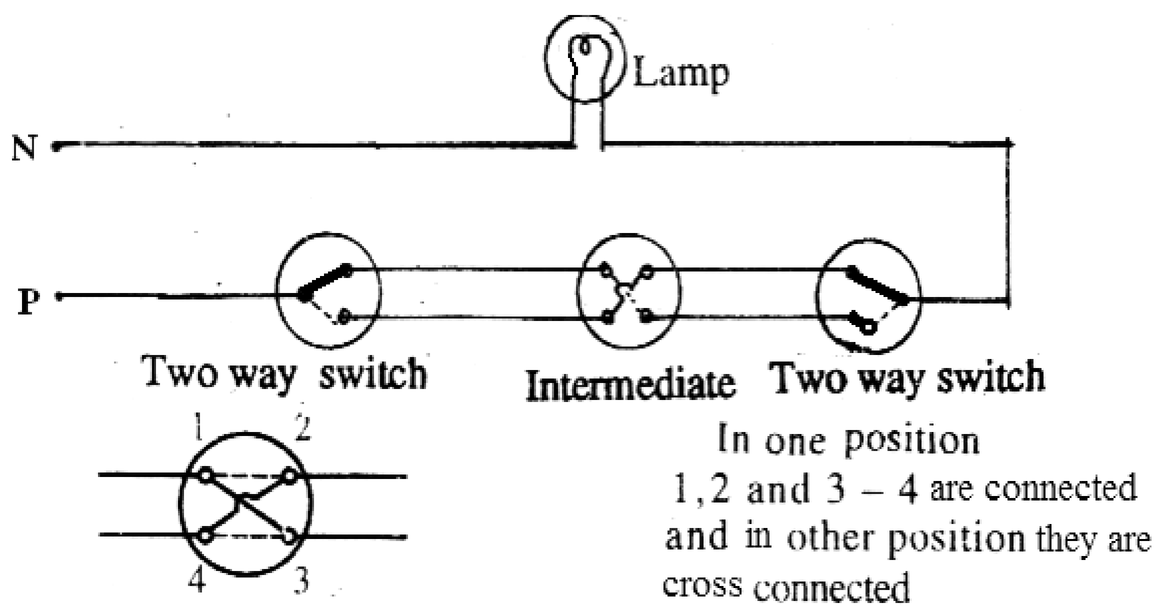
When S2 is operated then L1 is disconnected and L2 is lighted up.

When S3 is operated L2 is switched 'OFF' and L3 is lighted up and so on.

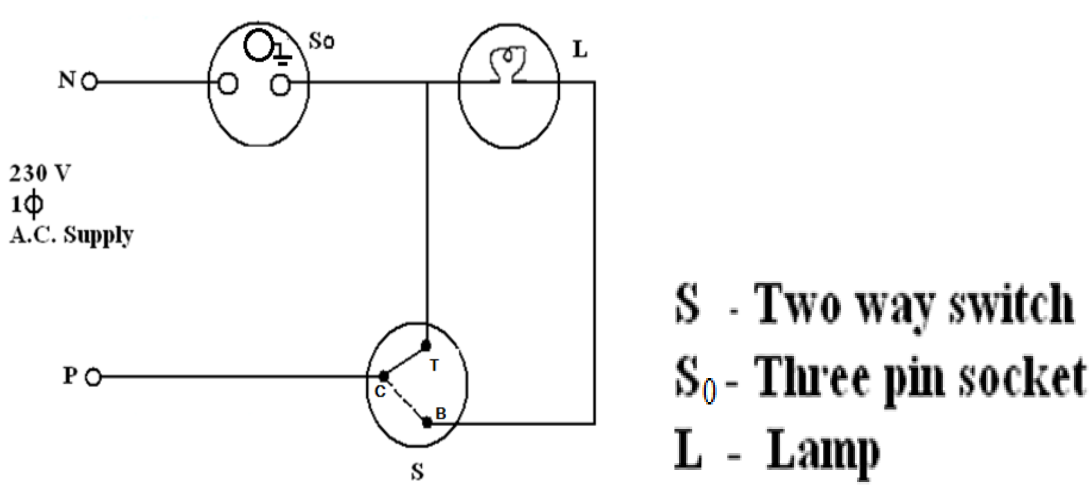
Similarly for making the lamps 'OFF' in sequence, S3 then S2 and finally S1 are operated.

The wiring is suitable for godown and hence the name given is godown wiring.

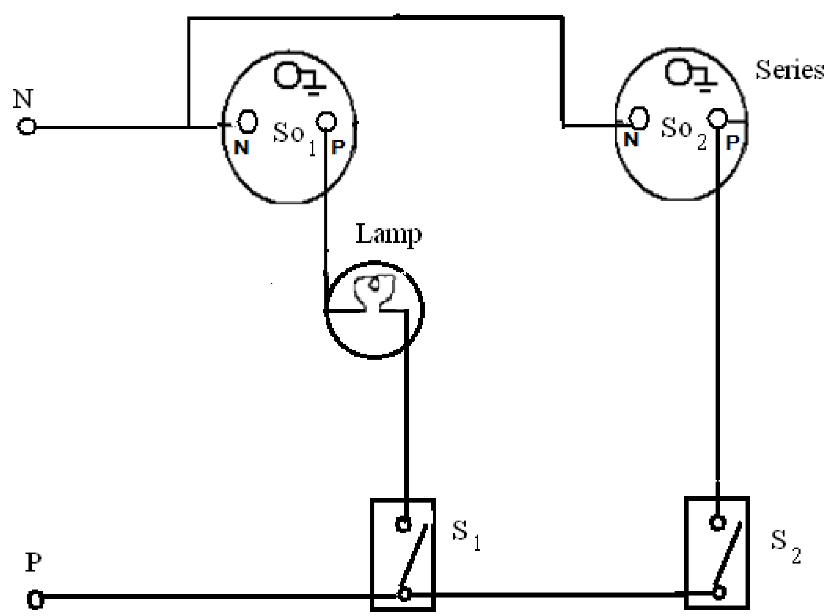
- **ONE LAMP CONTROLLED FROM THREE PLACES:**



ONE POINT SERIES PARALLEL TESTING BOARD:



- **TWO POINT SERIES PARALLEL TESTING BOARD:**



So_2 = Series Socket $\quad$ So_1 = Parallel Socket

S_1 & S_2 = One way Switches

- **Before selecting wiring system, following points should be considered:**

1. Safety $\quad$ 2.Life of wiring $\quad$ 3.Appearance of wiring $\quad$ 4.Cost

1. Safety: In workshops, laboratories, factories etc. the wiring must be completely protected from mechanical damage and also be isolated from the operator. Hence conduit wiring is preferred. For moist places, lead sheath wiring is used.

2. Life of wiring: If the wiring is required for temporary purpose, then cleat wiring is most economical. For house wiring, open batten wire is sufficient. For offices, casing capping is desirable.

3. Appearance of wiring: In places like palace or V.I.P bungalow then the beauty is to be maintained. The beauty of the bungalow should not be spoiled by running the wires along walls etc.The wiring should not appear outside and hence concealed conduit wiring is used.

4. Cost: For low cost, CTS batten wiring is done. For medium cost, casing capping wiring can be done, and if the consumer is capable of paying more, than PVC conduit or concealed conduit wiring can be done.

6. MEASURING INSTRUMENTS

INTRODUCTION:

The various electrical quantities such as voltage, current, power energy etc. are to be measured accurately. For measurement purpose following basic meters is used.

For measuring Current – Ammeter

For measuring Voltage – Voltmeter

For measuring power – Watt meter

For measuring Resistance – Ohmmeter, Megger

In most of the measuring meters following effects of electric current is made use:

1. Magnetic effect of current.

2. Electromagnetic effect

3. Chemical effect

4. Heating effect

5. Electro-static effect etc.

(Refer chapter 6 for detail)

For most of the meters following three basic arrangements are essential:

(A)Deflecting system

(B)Controlling system

(C)Damping system.

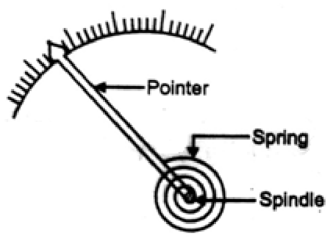
Let us take some preliminary idea of the above three requirements of the meters in brief.

(A) Deflecting system: This is the basic system of the meter which requires the following parts

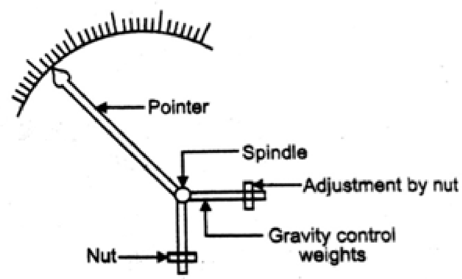
1. A conductor in the form of a coil
2. Some iron parts.
3. Spindle
4. Pointer etc.

When the current passes through the coil, due to the effect of the current iron parts and spindle is subjected to motion due to a force. Due to the movement of the spindle the pointer (indicator) moves on the dial.

(B)Controlling System: This system produces a force which is opposite to the deflecting force. When the deflecting force is equal the controlling force then at that stage the moving system stop rotating. Following are the types of controlling systems.



(Spring control)



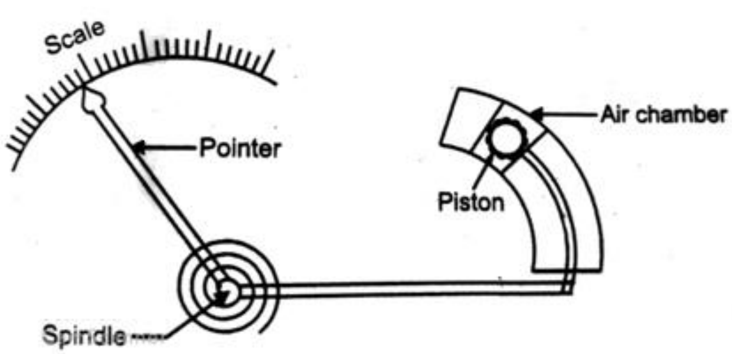
(Gravity control)

Due to deflecting force, the spindle starts rotating but the same time the spring gets wound itself and produces force in the opposite direction. Or when the spindle starts rotating, at the same time the gravity weights are lifted up and produce the gravitational force to oppose the deflecting force.

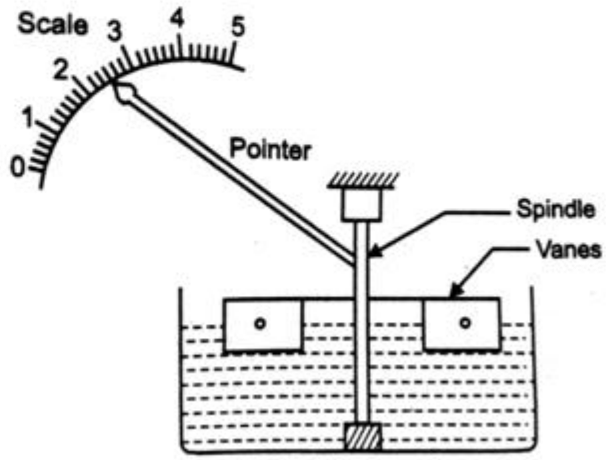
(C) **Damping system:** The third requirement is the damping system explained in A and B when controlling force is equal to the deflecting force at that stage, the moving system should become stable. But this does not happen instantly because of the inertia of the moving parts. The system oscillates momentarily and takes a finite time to become stable. The damming system creates a third force called as damping force which reduces oscillations and brings the system to rest quickly.

- **Following are the main Damping system:**

1.Air friction Damping: The deflecting system and controlling systems come in play, at that time air-piston moves in the closed air-chamber and air is pressed which produces a damping force which helps in bringing the system to rest quickly.



2. Fluid friction damping:

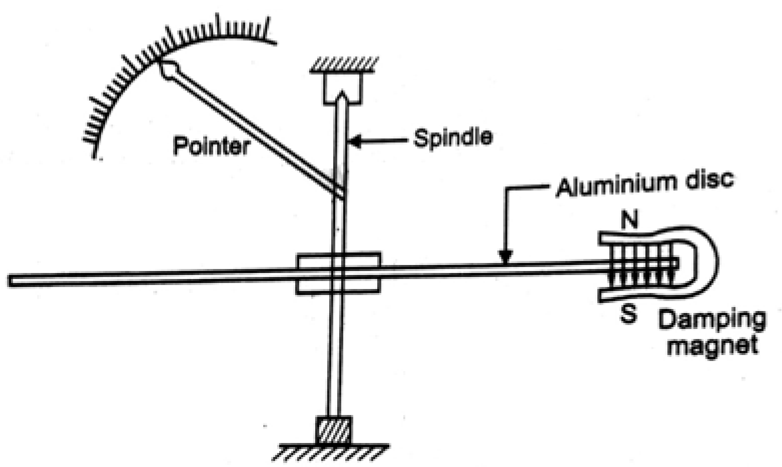


Fluid friction damping

The rectangular vanes are connected to the spindle and they move in the Chamber of a fluid. When moving, the fluid produces opposition to the vane-moment and thus damping force is produced due to fluid friction which helps to bring he deflecting system quickly to rest

3. Eddy current damping:

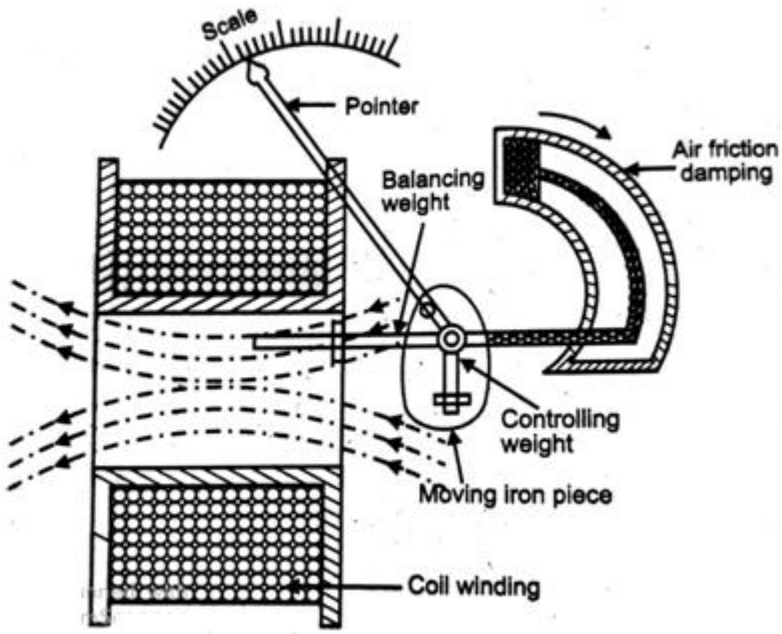
A circular aluminium disc is mounted on the spindle. When the spindle moves, the disc also moves. The disc, while moving cuts the magnetic field of a damping magnet. Due to the cut of flux the e.m.f. is produced in the disc. The e.m.f circulates eddy current in the disc. The effect of these currents is such that it will oppose the motion of the disc and helps in bringing the system to rest quickly.



Eddy current damping

- **MOVING IRON AMMETER AND VOLTMETERS**

(A) **Attraction type:** Magnetic effect of electric current is used in such instruments.



- The coil is wound on the hollow bobbin. When current passes through the coil, magnetic field is produced as shown by the magnetic lines of force in the figure.
- A soft iron piece of a particular shape is pivoted near the coil. Due to magnetic attraction the soft iron piece is attracted towards and inside the coil. Whatever may be the direction of the magnetic field the piece is always attracted.
- Pointer moves when this piece moves. If current is more, field strength will be more and hence force of attraction on the piece is also more. Thus, deflection depends on the strength of current passing through the coil.
- Controlling and balancing weights are also shown. Arrangement of air friction damping is provided. If the instrument is to be used as a Ammeter the coil has comparatively few turns of thick wire so that the ammeter has low resistance to allow to flow maximum current and the instrument is connected in series with the circuit.
- If the instrument is to be used as a voltmeter the coil has high impedance so as to draw as small current as possible since it is connected in parallel with the circuit. As the current through the coil is very small, it has large number of turns of thin wire to produce necessary ampere – turns.
- In such types of instruments the scale on the dial is not uniform but it is uneven. The meter can be used on D.C. and A.C. also. It is not so popular because it is not so strong and acute.

Errors in the instrument:

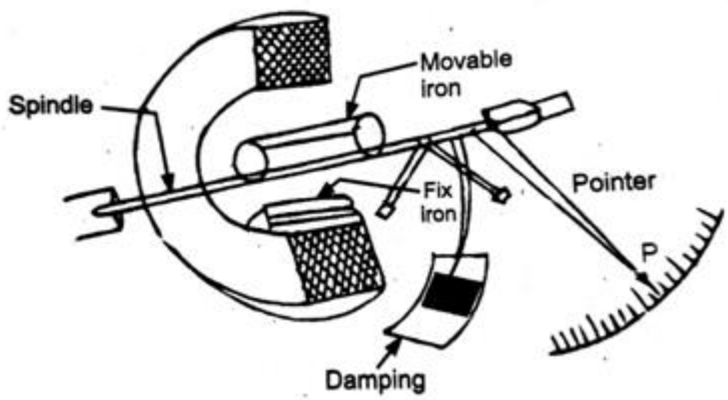
1. Due to hysteresis

2. Due to Eddy currents.

3. Due to change in resistance doe to change in temperature

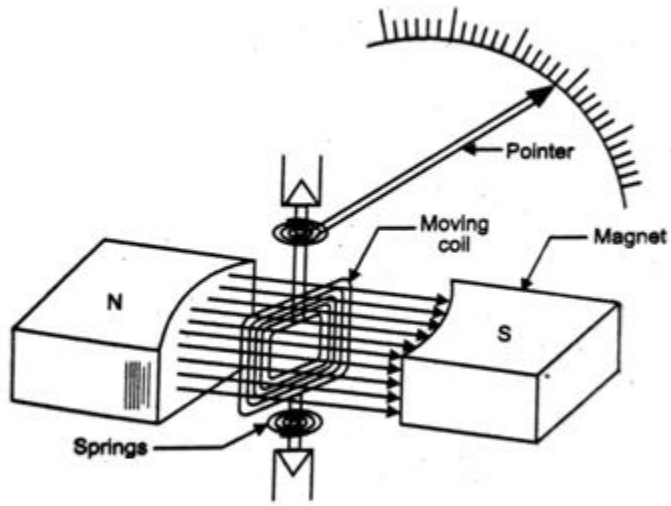
- **Moving Iron Ammeter or Voltmeter:**

(B)Repulsion Type:



- Figure shows the coil in which two soft iron pieces are placed. These pieces are in the form of rods or curved surfaces and are parallel to one another. Piece A is fixed to the bobbin and B is movable and mounted on the spindle. This spindle also carries a pointer. This pointer moves over the graduated scale (dial).
- When current passes through the coil the magnetic field is set up. Due to this magnetic field, the rods A and B are magnetized with the same polarities. They repel each other and movable, B moves and hence spindle and pointer get deflected.
- The force of repulsion and therefore the deflection of the pointer is approximately proportional to the square of the current passing though the coil. The scale is therefore uneven.
- They are generally gravity or spring controlled and air friction damping is provided. Such instruments are widely used. They are cheap and robust and can be used on A.C. and D.C. They are comparatively more accurate.

- **PERMANENT MAGNET MOVING COIL (PMMC) VOLT METERS/ AMMETERS:**



Construction:

1. Permanent Magnet: It is a U-shaped permanent magnet and has N and S pole which produce the magnetic field in the space. There is a cylindrical round iron core located centrally in this magnetic field.

2. Moving Coil: This is very thin and fine coil and supported on the "Aluminium Former".

3. Springs: Thin springs made of phosphor bronze are fixed on the spindle on both sides. The springs of the moving coil are connected to the springs to which supply leads are also connected.

4. Spindle: It is thin-round rod which supports former and spring. It is pivoted in the bearings.

5. Pointer (Indicator): It is attached to the spindle.

6. Dial: It is graduated over which the pointer moves.

Working:

- When the meter is connected to the supply, the current passes through the moving coil. This current carrying coil is located in the magnetic field produced by the permanent magnet. A mechanical force is therefore produced on the coil. It starts rotating in certain direction. The rotational torque depends on the strength of the current passing through the moving coil.
- When the coil moves, the former and spindle move and the springs get wound and produce the necessary controlling torque. When the deflecting torque and controlling torque become equal, at that position the system comes to rest and the pointer shows the reading on the dial.

- The necessary damping effect is produced by the former which is made of aluminium. This former when moves in the magnetic field of the permanent magnet, the eddy currents are produced in the aluminium former and eddy current damping is effected to bring the system quickly to rest.
- When this meter is to be constructed as voltmeter, the moving coil is connected in series with a high resistance and when this meter is to be used as an 'Ammeter' a low "resistance shunt".

1. The meter is suitable for D.C. only
2. The scale on the dial is uniform
3. Damping is effective
4. Range of the instrument can be extended
5. Power consumption.

But, as the construction of the meter is very delicate, its life is short. More over it is costly.

- **COMPARISON OF MOVING IRON AND MOVING COIL METER:**

	Moving Iron Type		**Moving Coil Type**
1.	Cheap, simple in action	1.	Light and robust.
2.	Suitable for both A.C. or d.c.	2.	Suitable for D.C. only
3.	Not so accurate	3.	Most accurate
4.	Hysteresis and other losses are more	4.	Power consumption is more
5.	Scale is not uniform	5.	Scale is uniform
6.	Gravity controlled	6.	Spring controlled
7.	Air friction damping	7.	Eddy current damping
8.	Life is more	8.	Life is less

These instruments can be used on AC and DC coil FF is known as fixed coil or pressure coil when current in these coils is passing they will produce their magnetic field and deflecting torque will be produces which is α true power circuit.

The current is fed into the moving coil through the springs which also serve as control spring producing controlling torque. He scale is uniform.

- **ENERGY METER:**

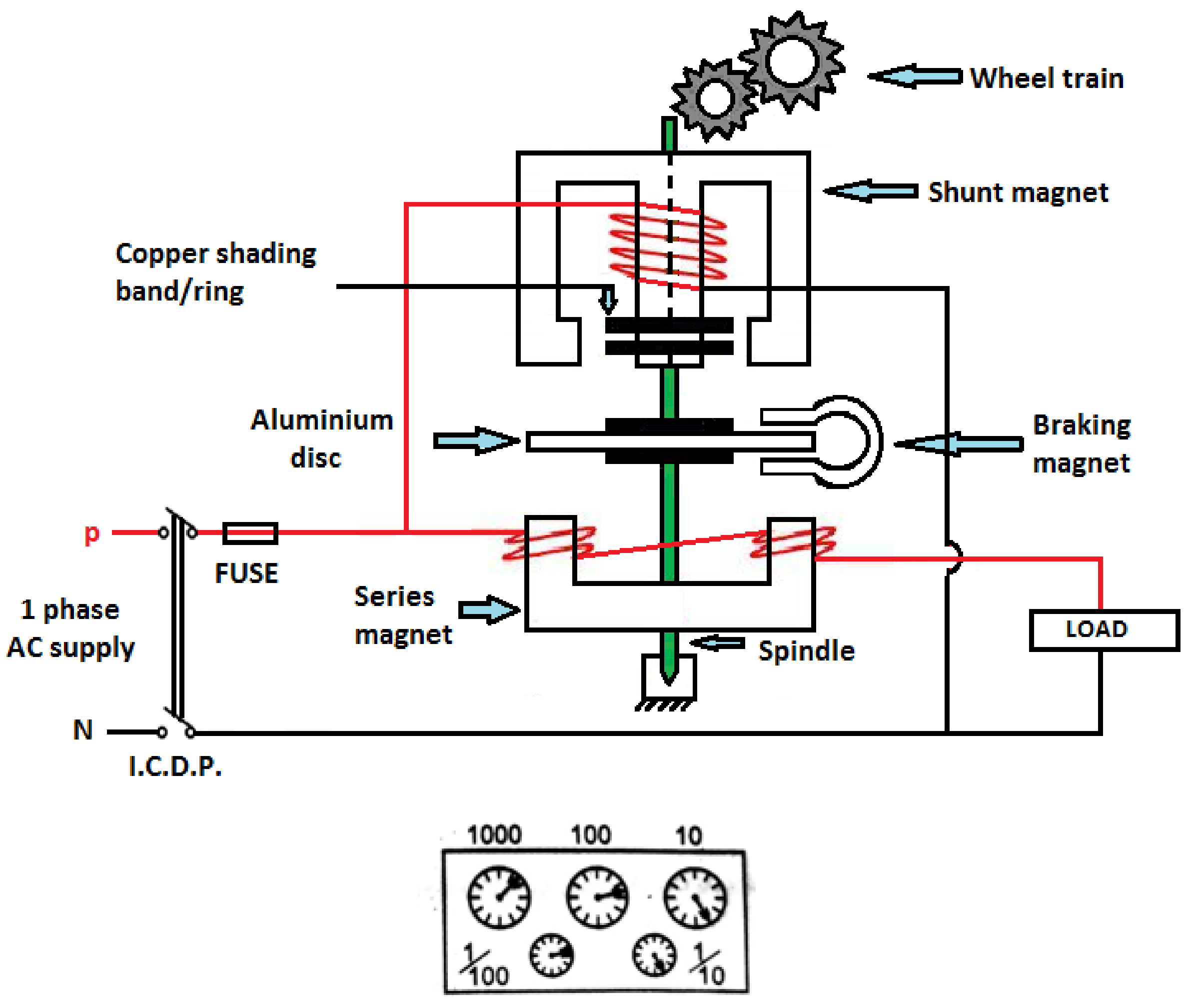
A.C. Single phase KWH type: Energy meter record the energy in Kilo-Watt Hours consumed during the time duration.

a)1 ph. A.C. Induction type (KWH) meter:

This is the most commonly used A.C. meter for domestic and industrial installations. They measure electric energy in kWh.

Principle and construction of such instruments is same as induction type watt meters except that control spring and pointer of watt-meter replaced by braking magnet and register mechanism.

Braking magnet induces eddy currents in aluminum disc which revolves continuously instead of rotating through a fraction as in watt meters.



Two electromagnets:

1. Shunt magnet is connected across the supply and carries line current proportional of voltage.

2. Series magnet is excited by line current. Both produce magnetic fluxes. Flux by shunt magnet lags behind by 90^o.This is also achieved by adjusting copper shading bands. Both the fluxes produce induced e.m.f in the disc which is 90^o behind with their respective fluxes. They produce eddy currents which are in phase with their e.m.f.

3. Thus, the torque is produced and disc begins to rotate continuously.

4. Register mechanism registers the energy which is directly proportional to the revolutions.

ERRORS:

1. As the coils are not purely inductive, flux due to shunt magnet does not lag behind V by 90^o.

2. Errors in speed can be adjusted when it is tested on non inductive load by adjusting the position of brake magnet.

3. Friction on bearings: Minimized with shading bands.

4. Criping: i.e. slow but continues rotation when pressure coil is excited, but to know current in current coil, it is avoided by drilling holes on the disc when hole come under the pole rotation stops.

5. Error due to temperature.

- **INSTRUMENT TRANSFORMERS:**

The ordinary ammeters and voltmeters are used to measure the low value currents and voltages. They are not capable to be used for measuring high currents and high voltages. Even there is limit to design such meters. So, the same low capacity meters are indirectly used to measure high values of current or voltage with the help of transformers. These transformers which are used in conjunction with the meters are called as instrument transformers.

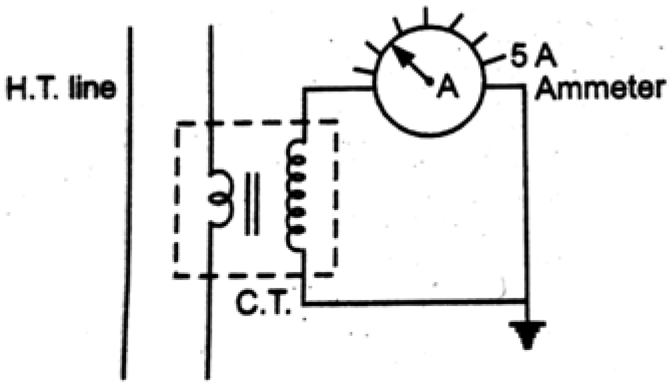
There are two such types of instrument transformers:

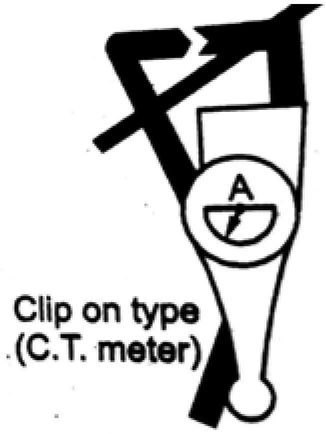
1. Current transformer(C.T.)
2. Potential transformer(P.T)

(A)Current transformer (C.T.):

This is used in conjunction with low capacity (5amp) ammeter to measure higher currents on H.V. lines.

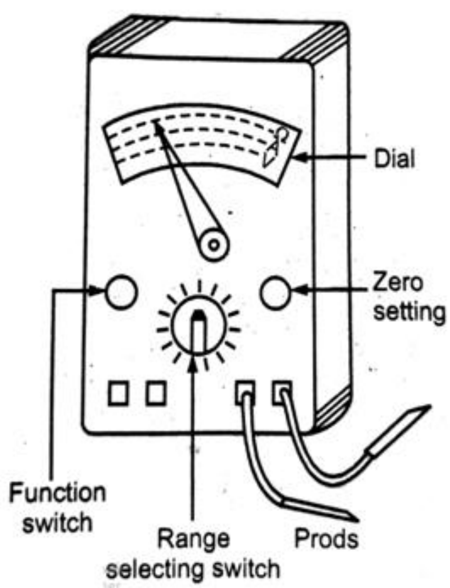
The primary of the C.T. consists of a few turns or even a single turn to carry the current to be measured and is connected in series with the H.V. current. The secondary winding with large number of turns supplies a reduced current to an ammeter. The readings are marked on the ammeter directly in terms of primary circuit current.





- **Multimeter:**

This meter is basically a P.M.M.C. instrument. A multimeter or a multitester, also known as a VOM (volt-ohm-milliammeter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current, and resistance. It comes in both digital as well as analog form. The following is the diagram of digital multimeter. The Digital Multimeter basically consists of a LCD display, a knob to select various ranges of the three electrical characteristics. It has two probes positive and negative indicated with black and red color is shown in figure. The black probe connected to COM JACK and red probe connected by user requirement to measure ohm, volt or amperes.



A shunt resistance is used for the protection and range extension.The working energy is supplied by a dry cell. It is very handy and useful meter used for multipurpose and hence the name multimeter. This meter is a must in laboratories, electric workshops, test shops, radio T.V. repair shops and everywhere.

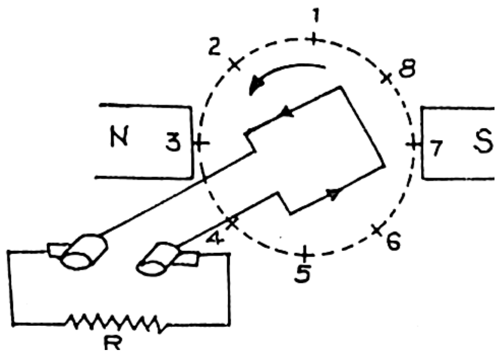
7. ALTERNATING CURRENT (A.C.)

A.C.:

Alternating quantity (current or voltage) is that quantity which changes its magnitude instant to instant and changes its direction in a definite periodic manner.

- **GENERATIONS OF A.C.:**

- Whenever magnetic flux is cut by the conductor (by moving conductor in magnetic field or moving magnetic field and keeping conductor stationary) an E.M.F. induces in the conductor according to Faraday's first law.
- Magnitude of E.M.F. induced depends on the rate of cutting the flux.
- The machine which produces A.C. electricity is known as A.C. generator or Alternator.

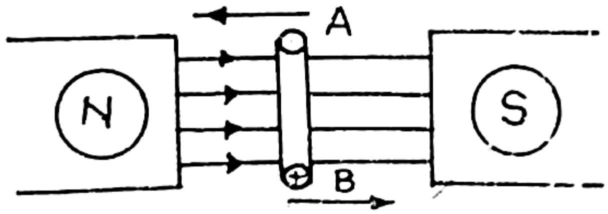


- Taking the case of a primary alternator, the rectangular conductor AB moves in anticlockwise direction with constant angular speed ω radians per second.
- Let us observe the directions and the magnitude of E.M.F. produced, the conductor in one revolution at different instants.

- **MAGNITUDE OF EMF AT DIFFERENT INSTANTS:**

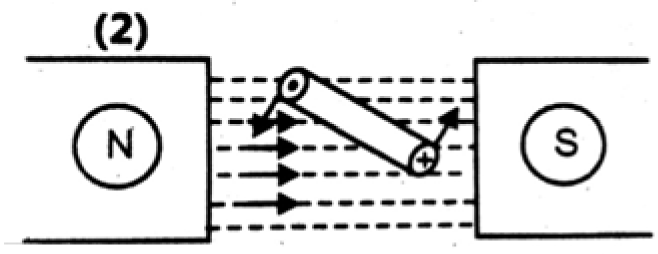
In position (1), the conductor is vertical, side A and B move parallel to the flux. No flux is cut. No E.M.F. [EMF= $BLV\sin\theta$]
Where B = flux density,
L = length
V =Velocity,

$\theta =$ Angle which conductor makes with magnetic flux here, $\theta = 0$



Position (1)

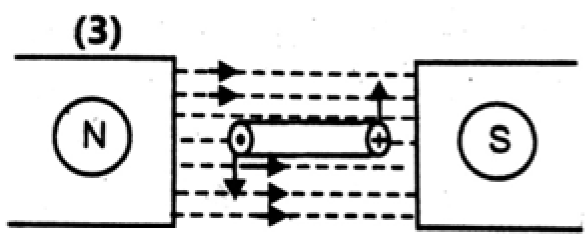
In position (2) the conductor sides A and B move at an angle $(\theta = 45)$ so cutting the flux at some rate and some E.M.F. is produced [EMF=BLV $\sin 45^0$]



Position (2)

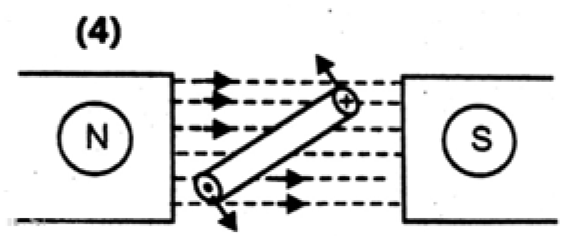
In position (3) the conductor cuts the flux at an angle $\theta = 90$

$\therefore$ EMF = BLV $\sin 90^0$ which is maximum. Observe the direction of emf in position (2) and (3).EMF is coming out from A and going in B.



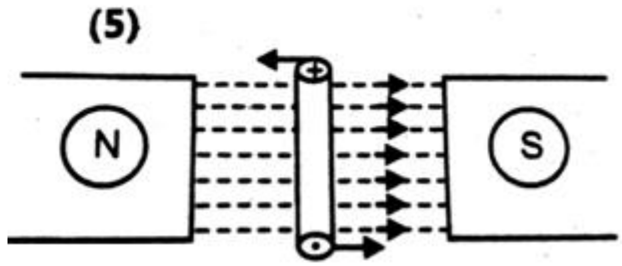
Position (3)

In position (4), the angle is again less than 90^0 and hence EMF is less than maximum.



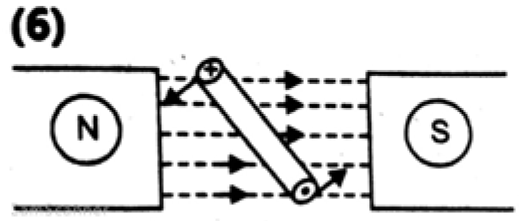
Position (4)

In position (5) No EMF.



Position (5)

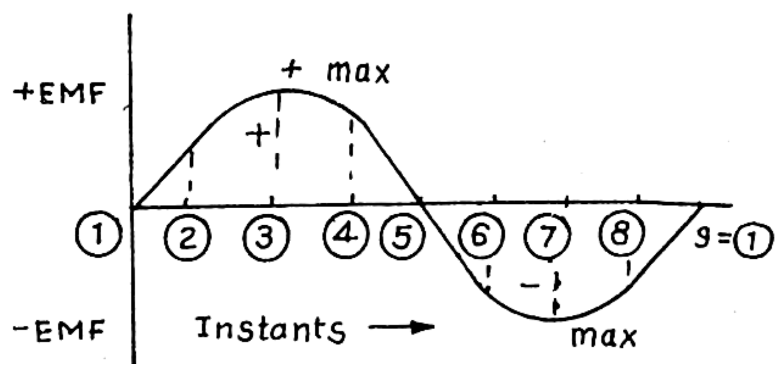
In position (6),some EMF is produced but it changes the direction, It comes out of B and enters in A.



Position (6)

Instants (7) and (8) are similar to (3) and (4) in the below waveform diagram.

Instant (9) is similar to (1). The only change is that current is from B to A



- This variation shows that the E.M.F. changes its magnitude and direction continuously just as a sine-wave. This E.M.F. is called as sinusoidal A.C. E.M.F. and this simple arrangement is called as a simple Alternator.
- The variation of EMF with time can be represented on a graph. Let the coil or conductor rotates with 'N' rpm, let Angular speed or velocity 'ω' in radians/sec.

B = flux density

ω = Angular speed rad/sec.

V = Linear velocity

b = breadth

Coil is rotated through an angle θ

ℓ = length of conductor

As $\omega = 2\pi \times \frac{N}{60}$ rad/sec (as in one sec. revolutions $= \frac{N}{60}$)

Also $V = \omega \times \text{radius}$ 1 rev. = 2π rad

$= \omega \times \frac{b}{2}$ $V = \omega \times r$

Linear velocity = Angular velocity $\times$ radius

As e.m.f. induced at any instant is

$e = B\ell\, V \sin\theta$ in one conductor in series

$e = 2\, B\ell\, V \sin\theta$ in both conductor in series

$= 2\, B\ell\, \omega \frac{b}{2} \sin\theta$

$= (Blb)\omega \sin\theta$ volts

= B.A.ω sin Θ (where l. b. = area of loop)

=Φ max ω sin Θ. (B.A. = max. flux when coil is horizontal)

Let ,

T = No. of turns of coil.

Then e.m.f. in all turns

$e = \phi\,\text{max}.\ T.\ \omega \sin\theta$ when $\theta = 90$, $\sin\theta = 1$

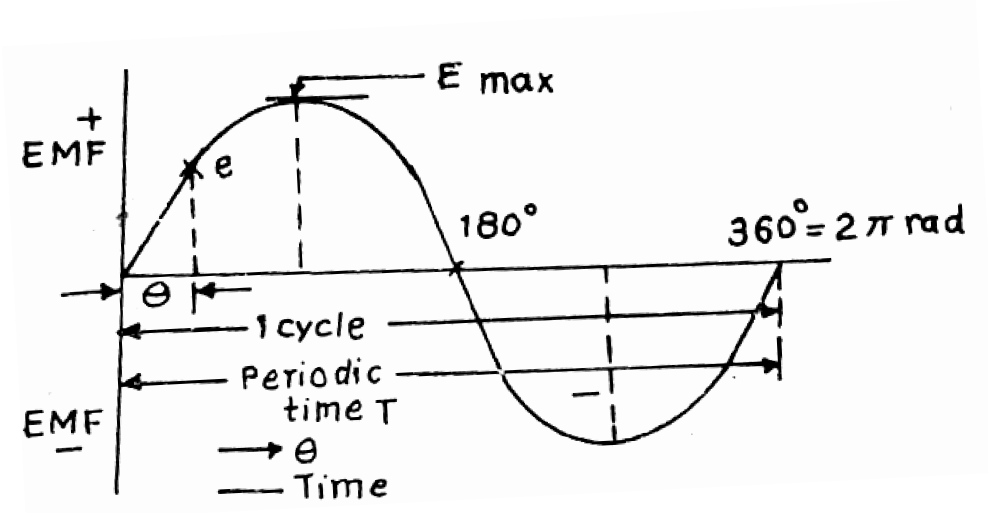
$\therefore$ at this instant $E_{max} = \phi\,\text{max}.T.\omega$

$\therefore$ $e = E_{max} \sin\theta$ (equation of alternating e.m.f.)

$= E_m \sin \omega t$

e = e.m.f. at any instant when coil makes an angle θ with field. Thus, e.m.f. is varying as the sine of the angle θ.If the e.m.f. at different instant is plotted against θ a graph of sine wave is obtained.

- **SINUSODIAL E.M.F.:**



Wave from: The shape of curve obtained by plotting instantaneous values of voltage or current on ordinate and time or θ on X-axis is known as wave from.

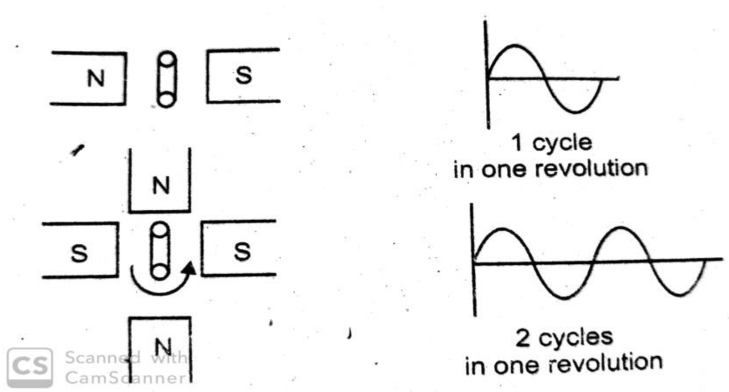
Cycle: One complete set of the positive and negative values of an alternating quantity is known as cycle.

Time Period (T): The time taken by A.C. quantity to complete one cycle is known as time period.

Frequency (f): Number of cycles/second is called frequency of alternating quantity. Its unit is Hertz.

Amplitude: The maximum value positive or negative which the alternating quantity attains during one complete cycle is called as amplitude.

The frequency (f) has got relation with speed and number of poles. The E.M.F. completes one cycle in one revolution when there are two poles.



If poles P = 4, then in one revolution there will be two complete cycles of e.m.f. It means for 2 poles (or 1 pair of pole) there is one complete cycle of e.m.f.

If there are of P poles the number of cycle $= \frac{P}{2}$ ***per revolution.***

Let N = speed of conductor in r.p.m.

Then speed per second $= \frac{N}{60}$ r.p.s.

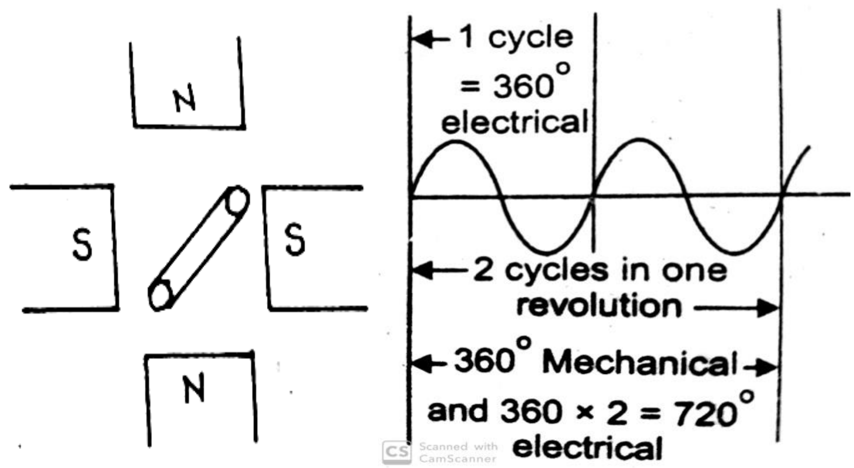
Let f = frequency of e.m.f. in cycles/sec.

$\therefore$ f = number of cycle per rev $\times$ rev. in one sec.

$$= \frac{P}{2} \times \frac{N}{60} = \frac{PN}{120}$$

- **RELATION BETWEEN ELECTRICAL AND MECHANICAL DEGREES:**

Number of cycles of e.m.f. in one revolution $= \frac{P}{2} = \frac{4}{2} = 2$



$\therefore$ Total electrical degrees covered $= 360 \times 2 = 720^0$

Whereas mechanical degree in one rev. = 360

$\therefore$ 360^0 mechanical $= 360^0$ electrical $\times \frac{P}{2}$

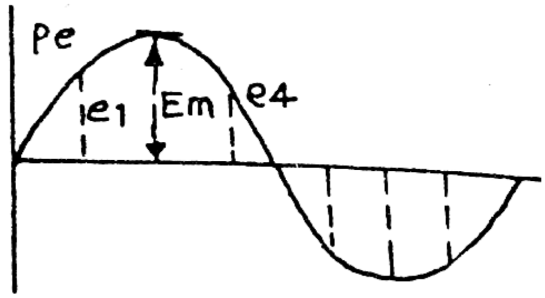
Electrical Degrees = mechanical degrees $\times \frac{P}{2}$

Example.

In a 6 pole generator how many electrical and mechanical degrees are completed?

(Ans. $1080^0 E, 360^0 M$)

Instantaneous value (E or i): Value of alternating quantity at any instant is known as instantaneous value.



Peak value: Maximum value of alternating quantity is known as peak value $\left(E_m = \text{peak value}\right)$

- Different forms of e.m.f. equations $\rightarrow$

$e = E_{max} \sin\theta$

$= E_m \sin wt \ \left(\theta = wt\right)$

$= E_m \sin 2\pi ft$

Where w = rad/sec

f = cycle/sec

1 cycle = 2π radius

$\therefore \omega = 2\pi f$

Example 1: Write down the equation of the alternating E.M.F. which has maximum value of 50 volts and frequency of 50 Hz. Find the instantaneous value after $\frac{1}{300}$ sec from zero increasing in positive direction.

Solution: e = instantaneous value

E_m = maximum value

f = frequency

Equation of E.M.F.

$e \quad = E_m \sin 2\pi f\, t.$

$= 50 \sin 2\pi \times 50 \times t$

$= 50 \sin 100\,\pi t$

Now to find the instantaneous value after $\frac{1}{300}$ sec. $\therefore\ t = \frac{1}{300}$

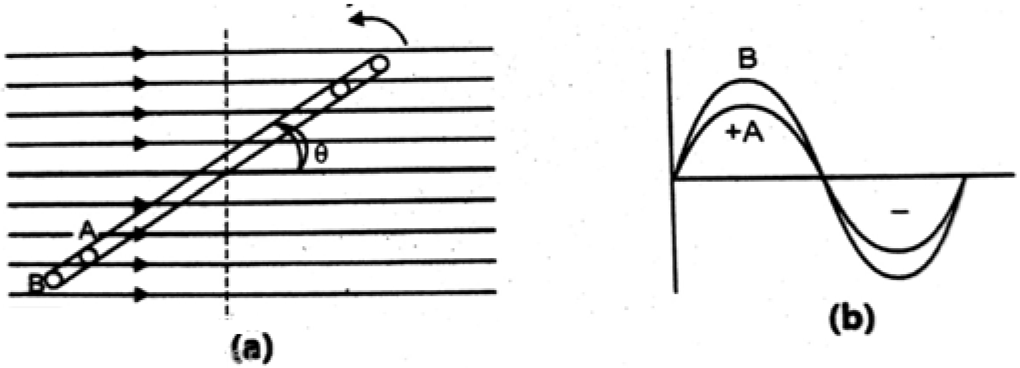
$e \quad = 50 \sin\left[100\pi \times \frac{1}{300} \times \frac{180}{\pi}\right]$

[Hint = in the above equations the angle is in radius. To convert this in degrees; it is to be multiplied by $\frac{180}{\pi}$]

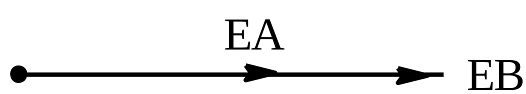
$\therefore\ e = 50 \sin 60^0$

$\therefore\ e = 50 \times 0.866$
$= 43.3$ volts.

- **IDEA OF INPHASE, OUT OF PHASE, PHASE DIFFRENCE, LAGGING, LEADING etc**



- Taking the case of the two conductors A and B. Say B is bigger than A, Both A and B has the same axis and rotates with the same speed. The variation of E.M.F. in them is shown in the above sketch.
- It is seen that E.M.F. has zero value at one instant. E.M.F. in both is increasing. E.M.F. is maximum in both conductors at one instant only. Both are changing the sign simultaneously. Such quantities are said to be in phase with each other.



- In the above diagram the EMF are shown by vectors. As the E.M.F. s are in phase to each other, the phase difference between them is zero. Now take the case of conductors having different axis but rotating with the same speed.

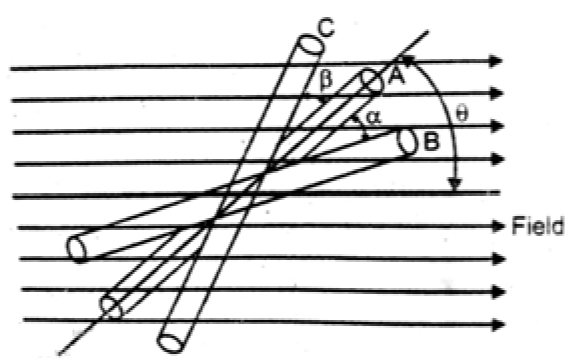
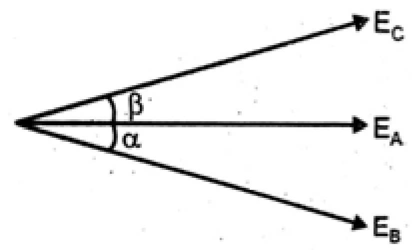


Fig. A

- Let angle between the axis of A and B = α and between A and C $= \beta$ (Fig. A)
  It is obvious that the variation of E.M.Fs in A, B and C is different.

- We say that E.M.F. E_A, E_B and E_C are not in phase, but are out of phase to each other. The phase difference between A and B is α, between A and C is β and between C., and B it is $(\alpha + B)$.

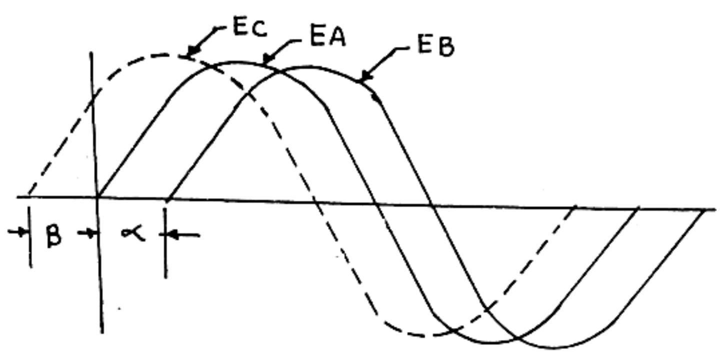


- The E.M.F. E_C reaches maximum value first so we say E_C leads E_A by an angle β.
- Now E_B reaches maximum value later on in comparison with E_A and hence we say that E_B lags E_A by an angle α
- The phase relation of E_c and E_B will be given as:

  E_c leads E_B by an angle $(\alpha + B)$

  E_c lags E_B by an angle $(\alpha + B)$

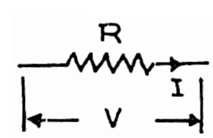
  Thus, leading and lagging are the relative terms.



- **R,L AND C IN A.C. CIRCUITS:**

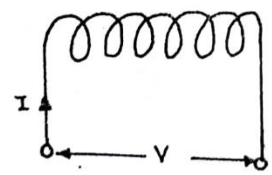
- Generally in A.C. circuits we come across the following three properties namely Resistance (R) Inductance (L) and Capacitance (C).

1) Resistance is the property which opposes the flow of current and it is measured in ohms. As per ohm's law $I = \frac{V}{R}$



2) Inductance: The property of the coil, (when connected to A.C) due which it opposes any change of current i.e. it opposes increase or decrease of current. Inductance (L) is measured in Henry.

The opposition created by inductive nature of the coil is called as Inductive Reactance. It is noted by X_L and measured in Ω.

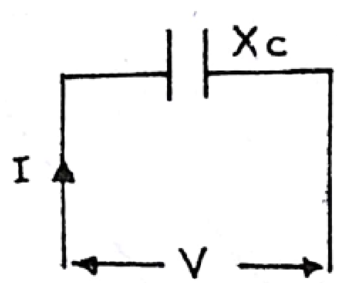


$$I = \frac{V}{X_L}$$

In the inductance (L) of the coil and frequency of the supply to which the coil is connected is known, then the opposition of this coil i.e. X_L is found by the following relation,

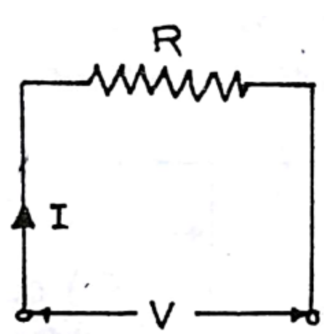
$$X_L = 2\pi f L$$

3)Capacitance: It is property of the capacitor due which it opposes any change of voltage. Capacitance is noted by letter C and measured in Farad.
The opposition created by capacitance is called as capacitive reactance. It is denoted by X_C and measured in ohms. Also $X_C = \frac{1}{2\pi fc}$

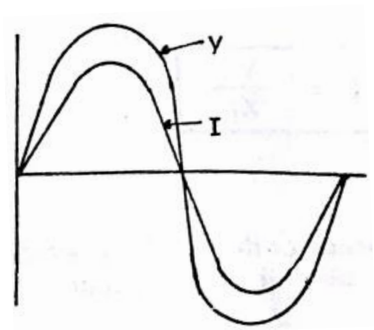


$$I = \frac{V}{X_C}$$

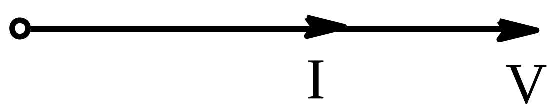
- **Purely resistive circuit:**



- If the voltage is zero, current is also zero. If the voltage increases then current also increases. If the voltage becomes maximum the current becomes maximum.
- Thus variation of current is strictly in accordance with the variation of voltage.
- So in purely resistive circuit, the current is in phase with the voltage. There is no phase difference between them. Phase difference angle $\theta = \text{zero}$.

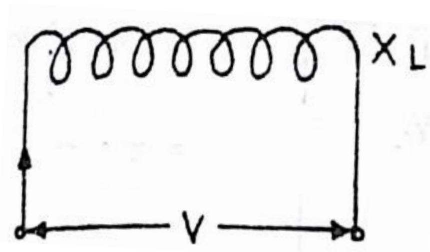


(A) Wave representation

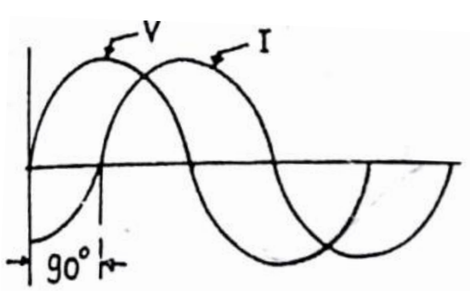


(b) Vector representation

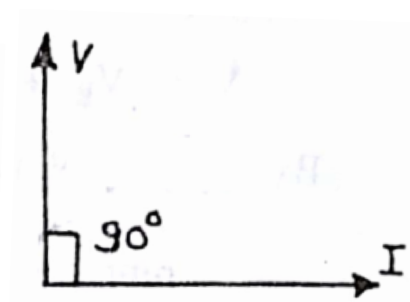
- **Purely Inductive Circuit:**



- The property inductance is to oppose any change of current.
- Hence voltage will reach its maximum value first but current is delayed and will reach the maximum value later on by an angle θ. For pure inductive coil the angle $\theta = 90^0$
- Thus current lags the voltage by an angle $\theta = 90^0$ in case of purely inductive circuit.

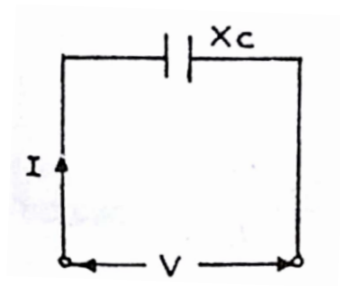


(A) Wave representation

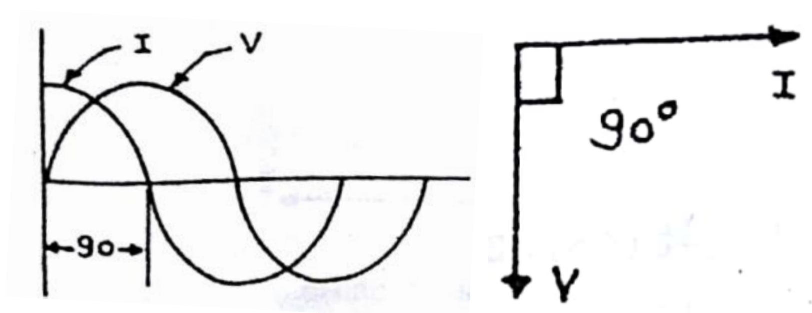


(b) Vector representation

- **Purely Capacitive Circuit:**



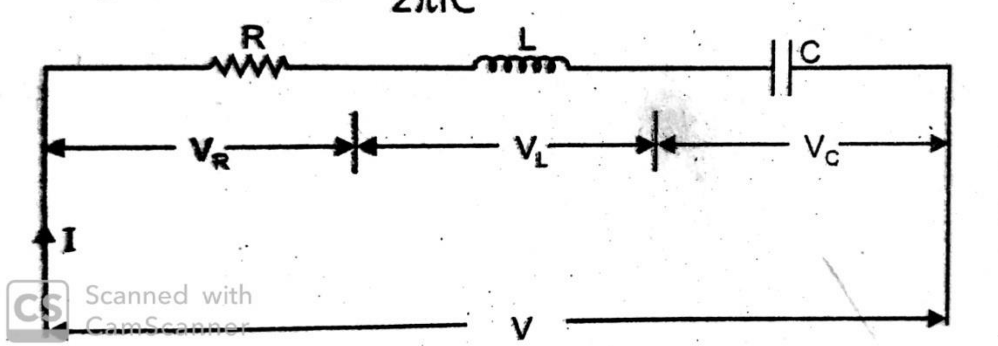
- The property of capacitance opposes the change of voltage hence voltage will become maximum.
- Later on the current will reach maximum value first, and after an angle θ the voltage will become maximum.
- This angle $\theta = 90^0$ for pure capacitance. Thus current leads the voltage by 90^0.



(A) Wave representation (b) Vector representation

- **R, L AND C SERIES CONNECTION:**

$$X_L = 2\pi fL, \quad X_C = \frac{1}{2\pi fC}$$



- As per series circuit law, current in each element is same but voltage is distributed.

$$V = V_R + V_L + V_C$$

By applying ohm's law to the complete circuit,

$$\text{Current } I = \frac{\text{Total V}}{\text{Total opposition}}$$

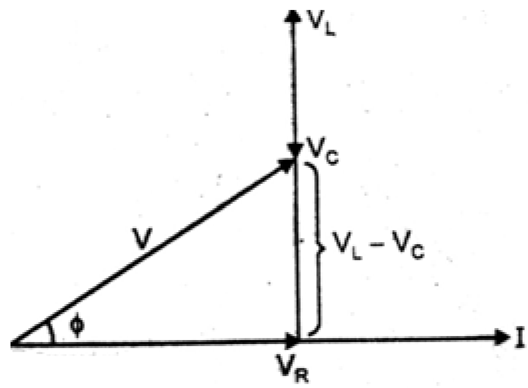
Total opposition is called as impedance. It is denoted by letter 'Z' and measured in ohms.

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

- Applying ohms law to each element:

$$I = \frac{V_R}{R},\ I = \frac{V_L}{X_L},\ I = \frac{V_C}{X_C}$$

Drawing the vector diagram (taking current as reference vector).

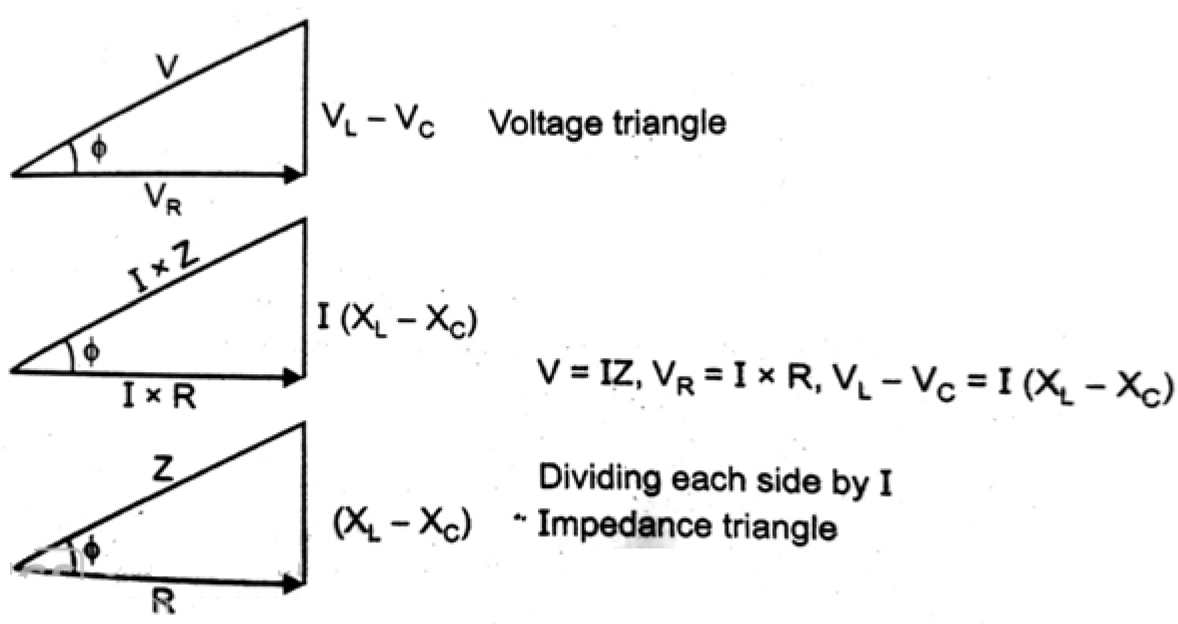


- It is seen that current and total 'V' is not in phase. Hence in A.C. Power = V.I. is not true power.

True power = V.I.cos ϕ

Where cos ϕ is called as power factor.

- Power factor is therefore defined as the cosine of the angle between voltage and current.



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

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

Hence, other definition of power factor is the ratio of resistance to impedance.

Example: The coil has the inductance of 0.1 Henry, find out its inductive reactance. What current it will draw if connected to 250 volts 50 Hz. A.C.?

Solution:

Inductive reactance $X_L = 2\pi f_L$

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

$= 31.42\ \Omega$

Current I $= \frac{V}{X_L} = \frac{250}{31.42}$

$= 7.956$ Amp.

Example: A capacitor has a capacitance of 100 micro-farad. Find its capacitive reactance. If the capacitor is connected across 250 Volts 50 Hz A.C. supply. What current will it take?

Solution: Capacitive reactance $X_C = \frac{1}{2\pi fc}$

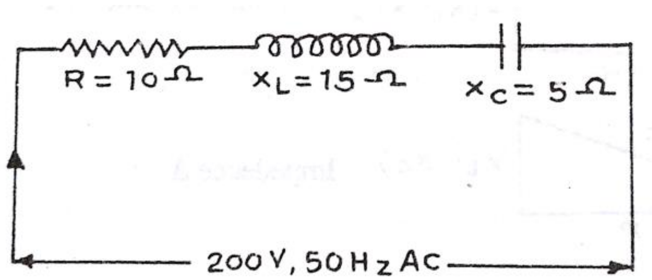
$= \frac{1}{2\pi \times 50 \times 100 \times 10^{-6}}$

$= 21.83\ \Omega$

Current $= \frac{V}{X_C} = \frac{250}{31.83}$

= 7.853 Amp.

Example: Solve the given series circuit.



Find out (1) Impedance (2) Current (3) Power factor (4) Power of the circuit (5) P.f. angle.

Solution:

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

$= \sqrt{(10)^2 + (15-5)^2} \quad = \sqrt{200}$

$= 14.142\,\Omega$

Current I $= \dfrac{V}{Z} = \dfrac{200}{14.142} = 14.142$ Amp.

Power factor $(\cos\phi)$ $= \dfrac{R}{Z} = \dfrac{10}{14.142} = 0.707$ lagging.

Power (P) = V. I $\cos\phi = 200 \times 14.142 \times 0.707$

= 2000 watts = 2 kW.

P.f. angle ϕ = $\cos^{-1} 0.707 = 45^0$

8. D.C. AND A.C:

D.C Introduction:

- The long form of D.C is direct current is that current which flows in one direction only, it does not change the direction as well as magnitude unless and otherwise we change it purposely.
- The direct current is produced by the primary and the secondary cells and also by D.C. generators.
- The D.C. supply is marked with positive and negative polarities. The current flows from positive to negative. The general electric supply is not D.C. but it is A.C.

ADVANTAGES OF D.C:

- For chemical process such as electroplating, electrolysis, electro-refining. D.C. supply is required for battery charging. DC is used for arc lamps and for search lights and cinema projectors D.C. supply is required.
- For relay, time operated switches and circuit breakers D.C. is used.
  For electric trains and trolley, cars, cranes, lift where higher starting torque is required, the D.C. series motor is well suited.

- For Fine speed control in both directions such as paper mills and rolling mills d.c. motor is required. D.C. arc welding is superior. D.C. can be easily obtained from A.C. with the use of rectifier units.

DISADVANTAGE OF D.C.:

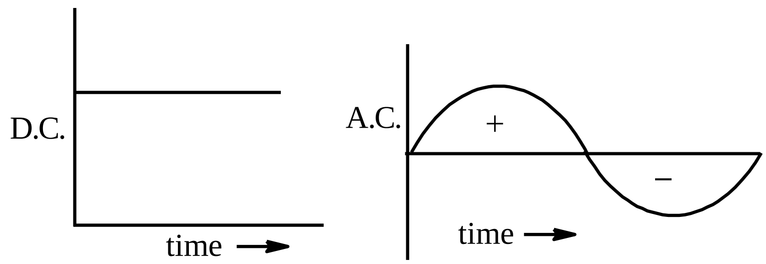
- The transformer cannot be used on D.C. and hence it is not possible to increase or decrease D.C. Voltage.
- The shock of D.C. supply is more dangerous than A.C.

A.C.

- A.C. means alternating current. Alternating current is that current which changes its magnitude and direction periodically. About 99% A.C. power is required. Most of the electrical drives are three phase induction motors which are very cheap and efficient which works on A.C.
- The device transformer is a very important which changes the A.C. voltage from one value to other. High voltage generation and transmission of A.C. is very economical. When required, A.C. can be

converted into D.C. very easily. A.C. motors are cheap and light in weight if compared with D.C. motor for the same capacity.

- A.C. is generated by alternator. Shocks on A.C. are less severe than D.C. Transmission power loss is lesser. Polarities of A.C. are not marked as positive negative because polarities are continuously changing.



Importance of Transformer in A.C.:

Faraday's Law of Electromagnetic Induction: Where magnetic flux linking with the coil changes the E.M.F. is produced in the coil.

REVISION AND USEFUL THEORY:

Useful Laws to understand the working principle of transformer.

- **Faraday's First Law:** When magnetic flux linking with the coil changes, the E.M.F. (Voltage) is induced in the coil.
- **Faraday's Second Law:** The magnitude of E.M.F. induced in the coil depends on rate of change of flux-linking with the coil.
- **E.M.F. of self induction:** Whenever flux linking with the coil changes due to change of current of the coil itself then E.M.F. induces in the coil which is called as self induced E.M.F. This E.M.F. opposes the supply voltage and hence called back E.M.F.

$e_s = N.\frac{d\phi}{dt}$ Where N = No. of turns of coil and $\frac{d\phi}{dt} =$ rate of change of flux.

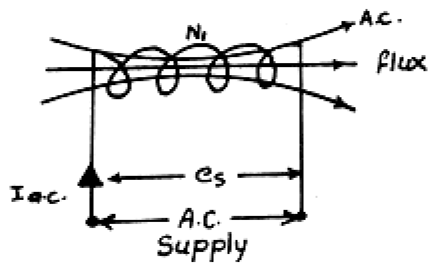
- **E.M.F. of Mutual Induction:**

If there are two coils kept near to each other or one over the other and if one coil is connected to A.C. supply so that A.C. flux is produced, the changing flux links with the turns of the second coil and hence E.M.F. is produced in the second coil due to change of current in the first coil, called as Mutually induced E.M.F.

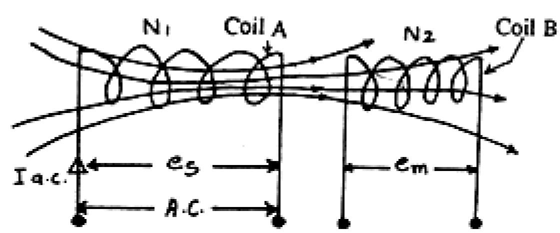
$e_m = N_2 \frac{d\phi_1}{dt}$ or $N_2 = \frac{dI_2}{dt}$

- Where N_2 is number of turns of secondary coil and
- $\frac{DI_1}{dt}$ is the rate of change of current (or flux) due to first coil.

The above things are explained in the following sketches.



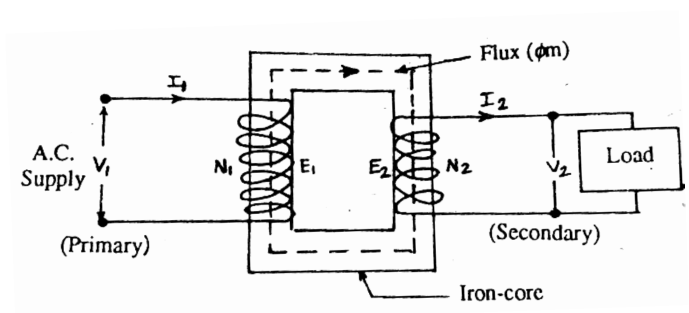
- $c_s =$ E.M.F. Of self induction is produced in the coil when it is connected to A.C. supply.
- The value of c_s will depend on turns N_1 and on rate of change of flux. If rate of change of flux is same then this E.M.F. depends on number of turns of the coil. More the turns more is the E.M.F.
- Instead of A.C., if D.C. is connected to the coil then there will be a "steady flux" produced. Thus flux-linking the coil will not change and hence there will not be any E.M.F. produced in it.



- Now take the case of two coils A and B. If 'A' is connected to A.C. supply then it produces A.C. (changing) flux. This links with coil A and produces in it E.M.F. of self induction $(e_s) = N_1 \frac{d\phi_1}{dt}$.
- At the same time the same A.C. (changing) flux also links with coil B which has N_2 number of turns. Hence in E.M.F. (e_m) and $e_m = N_2 \frac{d\phi_1}{dt}$.
- Hence its magnitude depends on number of turns of coil 'B'.

- In the above case if instead of coil 'A' connected to A.C. supply, coil 'B' is connected to A.C. supply and 'A' is kept near to it, then there will be self induced E.M.F. in coil B $\left(e_s = N_2 \frac{d\phi_2}{dt}\right)$ and mutually induced E.M.F. in coil A $\left(e_m = N_1 \frac{d\phi_2}{dt}\right)$.
- In short, self and mutually induced E.M.F. depends on number of turns of the respective coils. More the number of turns more is the E.M.F. and vice-versa. If D.C. is connected there will not be any self or mutually induced E.M.F. in the coils.
- The above theory helps in understanding the working principle of the "Transformer". The transformer works on the principle of Mutual Induction.

- **BASIC CONSTRUCTION OF THE TRANSFORMER:**
- A transformer has two windings made of enameled (insulated) copper. These two windings are supported on the iron core. One winding is connected to A.C. supply and is called as primary winding. Primary winding has number of turns $= N_1$. The second winding is also supported on the same core.It is not connected to the supply. It has N_2 number of turns. It is called as secondary winding.
- Following is the simple sketch of a transformer.



$V_1 =$ primary supply voltage
$E_1 =$ primary (self induced) E.M.F.
$N_1 =$ Primary number of turns.
$N_2 =$ Secondary number of turns.
$E_2 =$ Secondary (mutually induced) E.M.F.
$V_2 =$ Secondary output terminal voltage.
$\phi_m =$ mutual flux in the core.
$f =$ frequency of the A.C. supply which is generally 50 Hz.

- **E.M.F. EQUATION OF THE TRANSFORMER:**

Primary induced E.M.F. (E_1) secondary E.M.F. (E_2)

$$\boxed{\begin{aligned} E_1 &= 4.44\ \phi_m\ f\ N_1 \\ E_2 &= 4.44\ \phi_m\ f\ N_2 \end{aligned}}$$

Now, due to the resistance of the windings and due to leakage flux some voltage is lost in actual case. Loss of voltage is called as voltage drop.

$$\boxed{\begin{aligned} V_1 &= E_1 + \text{voltage drop} \\ E_2 &= V_2 + \text{voltage drop} \end{aligned}}$$

For ideal case, if voltage drop is neglected then $V_1 = E_1$ and $E_2 = V_2$. Number of turns of the respective windings.

- **WORKING PRINCIPLE:**

- The transformer works on the principle of mutual induction when primary winding is connected to A.C. supply. A.C. flux (ϕ_m) is produced.
- This flux is carried by iron core and hence also links with secondary winding. E.M.F.by mutual induction is produced in the secondary winding.
- The secondary voltage depends on number of secondary turns (N_2). More the turns on secondary (in comparison with primary) more is the secondary voltage.
- So by properly designing and selecting the number of turns of primary (N_1) and secondary (N_2) turns, we get a desired voltage on the secondary from the available voltage of the primary.

- **TRANSFORMATION RATIO:**

- Now when secondary is connected to the load then secondary gives out the power output to the load. This power output $= V_2 \times I_2$ approximately.
- In order to give out this output, the transformer takes the input power from the supply $= V_1 \times I_1$.
- Thus it can be said that the transformer transforms the power from primary circuit to the secondary circuit.
- For the ideal case, neglecting the power loss in the transformer:

$$\boxed{V_1\, I_1 = V_2\, I_2}$$

$$\therefore \frac{V_2}{V_1} = \frac{I_1}{I_2}$$

Transformation Ratio (K):

Taking the ratio of E.M.F. Equations:

$$\frac{E_2}{E_1} = \frac{4.44\phi_m f\ N_2}{4.44\,\phi_m\ N_1}$$

$$\therefore \quad \frac{E_2}{E_1} = \frac{N_2}{N_1}$$

From the above discussion we can write:

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

Where "K" is called as a transformation ratio.

- **CAPACITY OF THE TRANSFORMER:**

- We can connect any type of load on the secondary of transformer. Load has any power factor. For output power $= V_2.I_2, \text{Cos}\,\phi_2$. But $\text{C os}\,\phi_2$ is dependent on nature of load.
- Hence the practice to express the output capacity is only by the product $V_2.I_2$ i.e. in Volt. Amperes. Bigger unit is Kilo Volt ampere (K.V.A)

$$\boxed{\text{KVA} = \frac{V_1.I_1}{1000} = \frac{V_2.I_2}{1000}}$$

9. DC Generator

Basic Laws:-

- **Faraday's first law of Electromagnetic Induction:-** Faraday's first law of Electromagnetic Induction states that whenever there is change in magnetic flux linked with conductor E.M.F. is induced in the conductor. This E.M.F. is known as induced EMF and if the conductor circuit is closed, the current will also circulate through the circuit and this current is called induced current.
- **Faraday's Second law: -** Faraday's Second law states that the Magnitude of E.M.F. induced is directly proportional to rate of change of flux linkage with coil. The strength of magnetic field depends on number of turns of coil and current passing through the coil.

  Flux $\emptyset \propto$ N.I. where, N= no. of turns of the coil

  I= current through coil

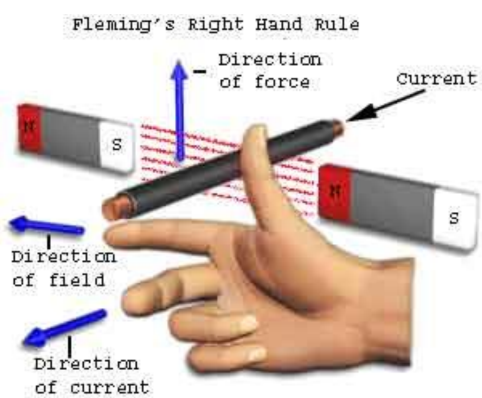
  $$E \propto \frac{d\emptyset}{dt}$$

  Where E = induced E.M.F.

  $\emptyset$ = flux in Wb

- **Fleming's right hand rule: -** Whenever a current carrying conductor comes under a magnetic field, there will be force acting on the conductor. The direction of this force can be found using Fleming's Right Hand Rule.

  Fleming's Right Hand Rule states that When the right hand is held with the thumb, index finger and middle finger mutually perpendicular to each other (at right angles), as shown in the diagram. The index finger indicates direction of the flux and middle finger indicates direction of induced EMF/ current & thumb indicates direction of the motion of the conductor.



• Introduction to DC Generators:

The function of generator is to convert mechanical energy into electrical. It works on Faraday's law of electromagnetic induction. The generator which produces DC power is called as DC Generator.

Basic Requirement of DC Generators:-

The DC generator must have the following requirement:

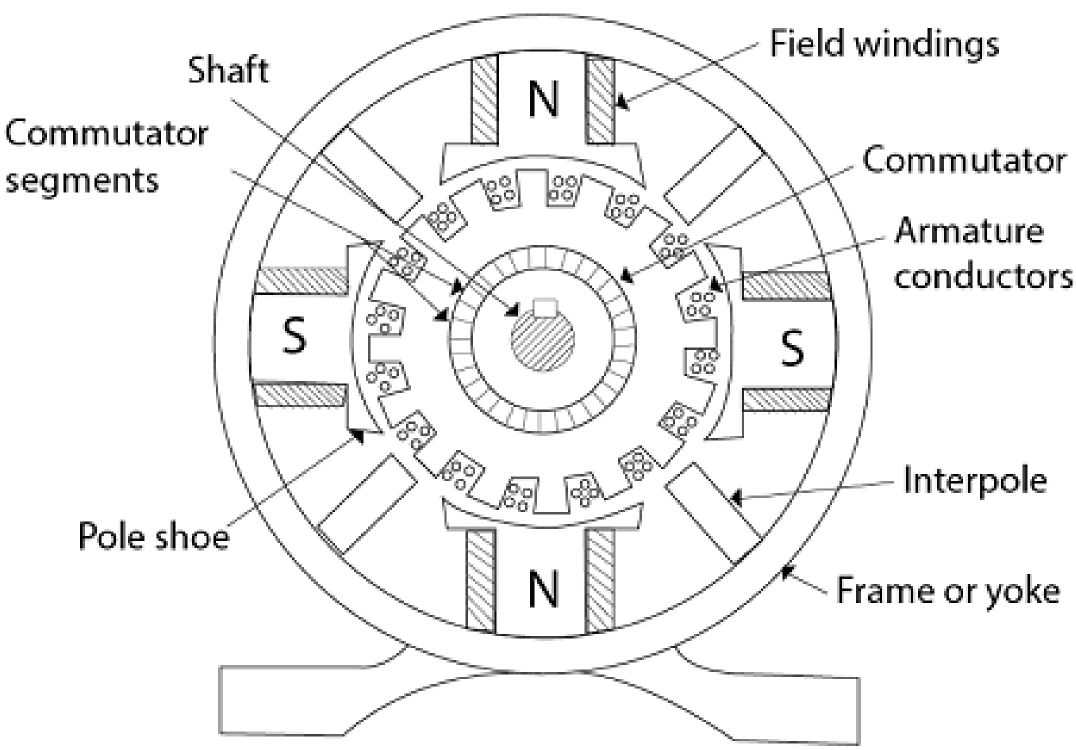
- Flux producing arrangement
- Conductor
- Motion

1. Flux producing arrangement: - It includes electromagnets having iron core wound with copper coil. These electromagnets are called as field poles and the winding is called as field windings.

2. Conductor: - The conductors are suitably arranged in the cylindrical parts called as armature. The Conductor is made of copper & are called as armature conductor.

3. Motion: - The Mechanical power is required for rotating armature conductor and this power is obtained from hydro station turbine, thermal power station etc.

• Construction of DC Generator:-

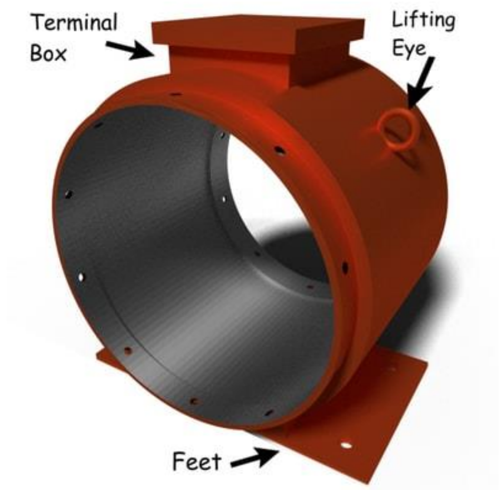


DC Generator

DC generator has the following parts:

1. Yoke
2. Pole of generator
3. Field winding
4. Armature of DC generator
5. Brushes of generator and Commutator
6. Bearing

1. Yoke of DC Generator:-



Yoke

Yoke or the outer frame of DC generator serves two purposes,

- It holds the magnetic pole cores of the generator and acts as cover of the generator.
- It carries the magnetic field flux

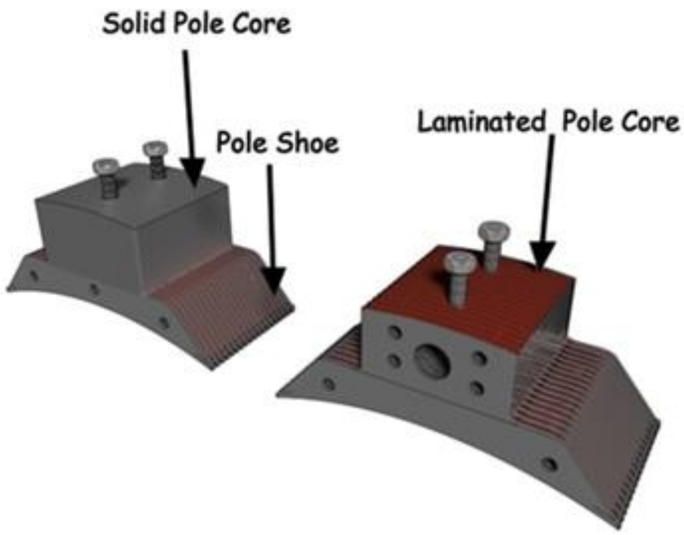
In DC generator, yoke are made of any magnetic material like Cast iron or rolled steel which has very low reluctance.

2. Pole of generator:-

Poles are joined to the yoke with the help of bolts or welding. They carry field winding and pole shoes are fastened to them. Pole shoes serve two purposes

- They support field coils and

- Spread out the flux in air gap uniformly



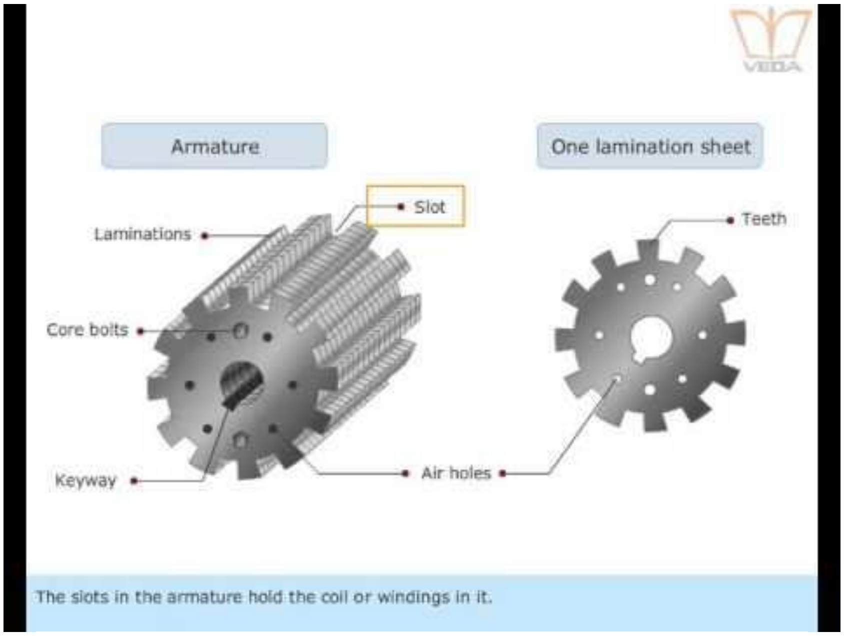
3. Field winding:-

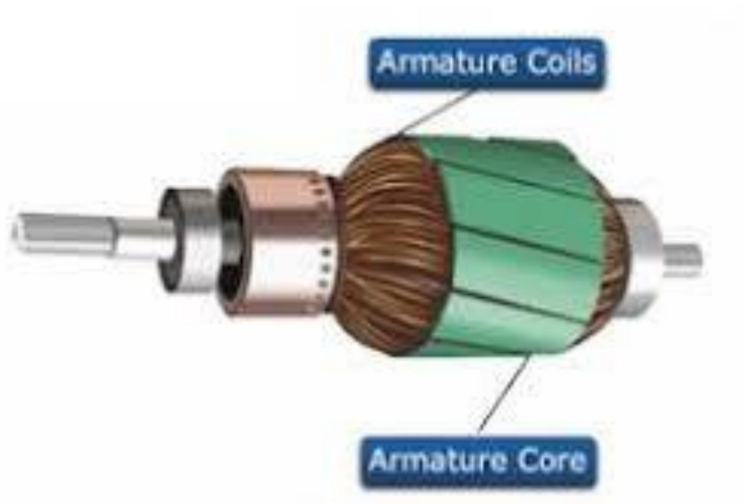
Field Winding

- They are usually made of copper. Field coils are former wound and placed on each pole and are connected in series. They are wound in such a way that, when energized, they form alternate North and South poles.

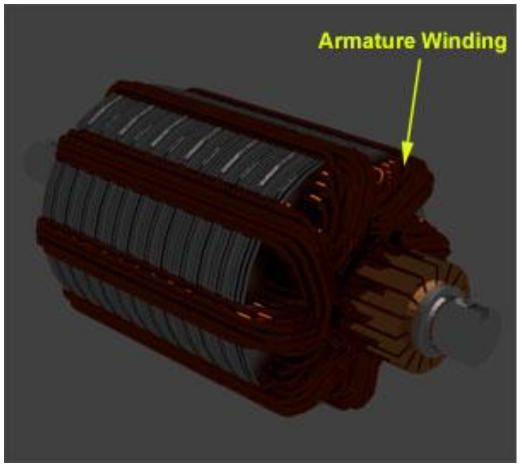
4. Armature core:-

- Armature core is the rotor of a dc machine. It is cylindrical in shape with slots to carry armature winding. The armature is built up of thin laminated circular steel disks for reducing eddy current losses. It may be provided with air ducts for the axial air flow for cooling purposes. Armature is keyed to the shaft.





5.Armature Winding:

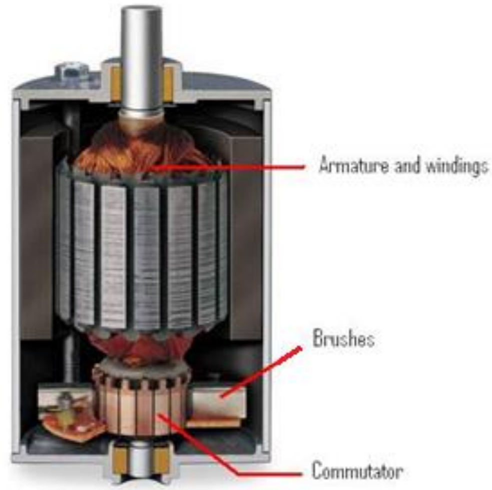


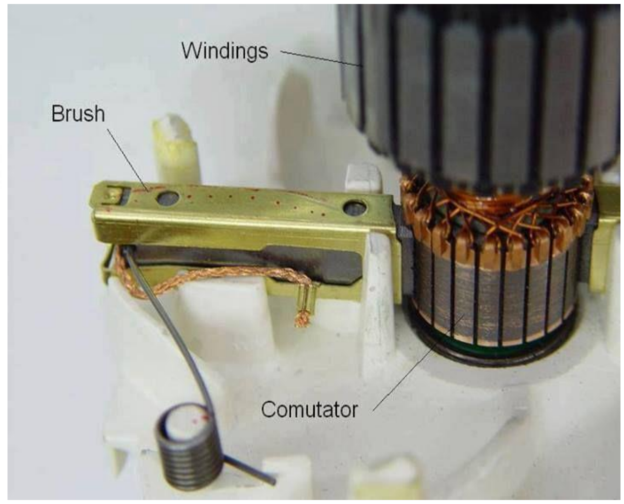
- It is usually a former wound copper coil which rests in armature slots. The armature conductors are insulated from each other and also from the armature core.
- Armature winding can be wound by one of the two methods; lap winding or wave winding. Double layer lap or wave windings are generally used. A double layer winding means that each armature slot will carry two different coils.

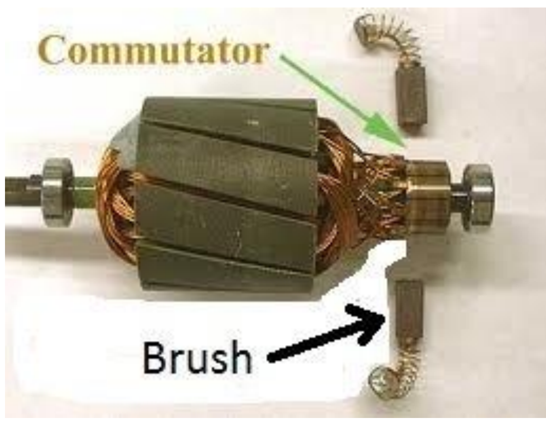
6. Commutator & Brush:-

- Armature winding is made through a commutator-brush arrangement. The function of a Commutator in a dc generator is to collect the current generated in armature conductors. Whereas, in case of a dc motor, commutator helps in providing current to the armature conductors.
- A commutator consists of a set of copper segments which are insulated from each other. Brushes are usually made from carbon or graphite. They rest on commutator segments and slide on the segments when the commutator rotates keeping the physical contact to collect or supply the current**.**

Commutator







Commutator & brush arrangement

- **Working of DC Generator:-**

- DC Generator works on the principle of faradays law of electromagnetic induction.
- All Armature Conductors are placed in the armature Slot & Armature is fitted on the Shaft. The shaft is coupled mechanically to prime mover (Turbines, Engines).
- When Supply is given to the Field winding field poles acts as an electromagnet as produces magnetic field.
- When armature is rotated with the help of prime mover in magnetic field then according to Faraday's law of electromagnetic induction, EMF is induced in the armature winding.
- The nature of EMF produced in armature conductor is AC.

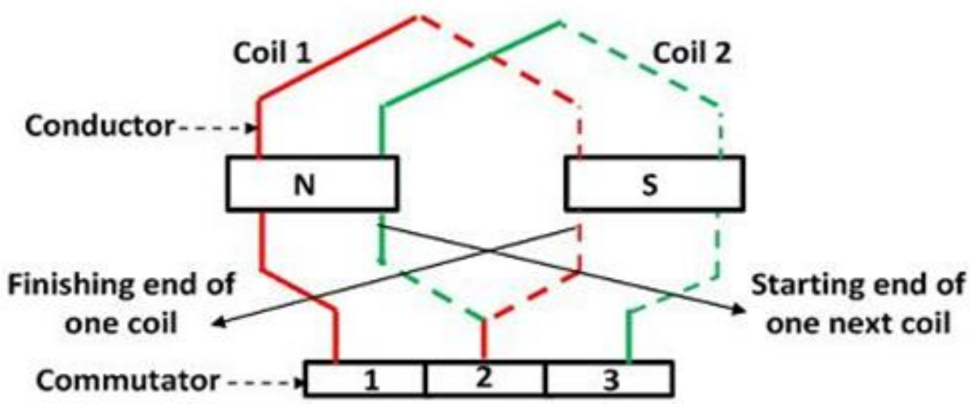
- One End of armature conductors is connected to commutator. The commutator is fitted on the same shaft on which armature is fitted.
- The Commutator converts the alternating EMF into DC EMF.
- The brushes are kept in stationary brush holder and kept touching with the commutator under the tension of spring.
- The brushes are used to collect the DC EMF from Commutator to external circuit.

Armature Windings:

The armature winding is the most important part of the rotating machine. It is the place where energy conversion takes place.The armature winding is mainly classified into types, i.e., the lap winding and the wave winding.

Lap winding:

- Lap winding is the winding in which successive coils overlap each other. It is named “Lap” winding because it doubles or laps back with its succeeding coils.
- In lap winding, the conductors are joined in such a way that their parallel paths and poles are equal in number.
- The end of each armature coil is connected to the adjacent segment on the commutator. The number of brushes in the lap winding is equal to the number of parallel paths, and these brushes are equally divided into negative and positive polarity.
- In this winding the finishing end of one coil is connected to one commutator segment and the starting end of the next coil situated under the same pole and connected with same commutator segment

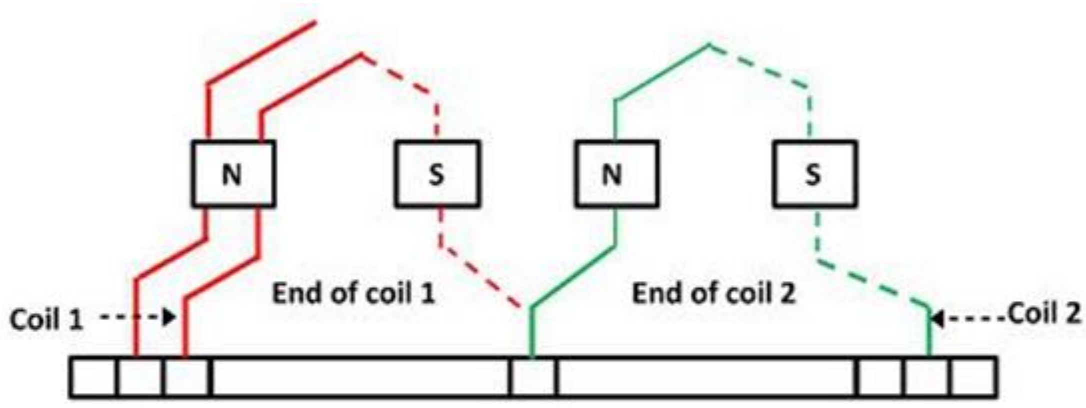


Lap Winding

- The lap winding has many paths and hence it is mainly used in low voltage, high current machine applications. The only disadvantage of the lap winding is that it requires many conductors which increase the cost of the winding.
- They are three types:
  1. Simplex Lap Winding 2. Duplex Lap Winding 3.Triplex Lap Winding

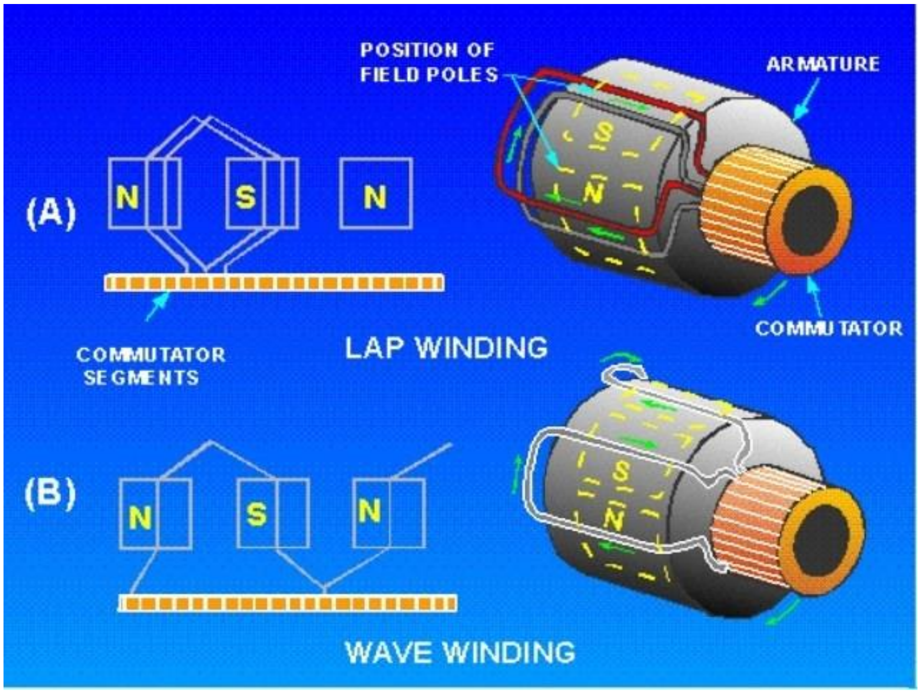
Wave winding:

- In wave winding, only two parallel paths are provided between the positive and negative brushes.
- The finishing end of the one armature coil is connected to the starting end of the other armature coil commutator segment at some distance apart.



Wave Winding

- In this winding, the conductors are connected to two parallel paths irrespective of the number of poles of the machine. The number of brushes is equal to the number of parallel paths. The wave winding is mainly used in high voltage, low current machines.



- **EMF Equation of DC Generator:-**

Let,

P = Number of poles of the machine

ϕ = Flux per pole in Weber.

Z = Total number of armature conductors.

N = Speed of armature in revolution per minute (r.p.m).

$= \frac{N}{60}$ Revolution per Second

A = Number of parallel paths in the armature winding.

As per faradays law of electromagnetic induction magnitude of induced EMF is given by

$$E \propto \frac{d\varnothing}{dt}$$

During one revolution of armature total flux cut will be ØP Wb & time required for one revolution is,

$\frac{60}{N}$ Second

Therefore EMF generated by one conductor,

$$E = \frac{\text{Ø}\,P}{\frac{60}{N}}$$

$$E = \frac{\text{Ø}PN}{60} \text{ Volt}$$

Conductor per parallel path = $\frac{Z}{A}$

EMF in one path = $\frac{\text{Ø}PN}{60} \times \frac{Z}{A}$

$$= \frac{\text{Ø}\,PNZ}{60\,A}$$

$$\boxed{\text{EMF} = \frac{\text{Ø}\,PNZ}{60A}}$$

For Lap Winding A = P
For Wave Winding A= 2

Example 1. A DC generator has four poles and total five hundred conductors. The flux per pole is 0.02 Wb find the generator EMF if rotated at 900 RPM for lap & Wave windings.

Solution:-

Given data:-

P = 4
Ø = 0.02
Z = 500
N = 900

To Find:-

E_{lap} & E_{wave}

Solution:- **i) For Lap Connection (A=P)**

$$E_{lap} = \frac{\text{Ø}\,P\,N\,Z}{60\,A}$$

$$E_{lap} = \frac{0.02 \times 500 \times 900 \times 4}{60 \times 4}$$

$$\boxed{E_{lap} = 150 \text{ Volt}}$$

ii) For wave Connection (A=2)

$$E_{wave} = \frac{\text{Ø}\, P\, N\, Z}{60\, A}$$

$$E_{wave} = \frac{0.02 \times 500 \times 900 \times 4}{60 \times 2}$$

$$\boxed{E_{wave} = 300 \text{ Volt}}$$

Example 2. The armature of a 4 pole lap wound shunt generator has 128 slots and 4 conductors per slot. The flux per pole is 48 mWb. Find at what speed the armature is to be rotated so as to generate 256 Volt on open circuit.

Solution:-

Given Data:-

$P = 4$

$Z = 128 \times 4 = 512$

$\text{Ø} = 48 \times 10^{-3}$ Wb

$E = 256$ Volt

To Find:- N

Solution:-

$$E = \frac{\text{Ø}\, P\, N\, Z}{60\, A}$$

$$256 = \frac{48 \times 10^{-3} \times 4 \times N \times 512}{60 \times 4}$$

$$N = \frac{265 \times 15}{48 \times 10^{-3}}$$

$$\boxed{N = 625 \text{ rpm}}$$

Example 3. A DC generator has following details poles = 4, flux per pole = 7×10^{-3} Wb, Slot = 51, Conductor per slot = 20, speed = 1500 rpm. Find generated EMF for lap connection.

Given data:-

P = 4

$\text{Ø} = 7 \times 10^{-3}$

Slot = 51

Conductor per slot = 20

N = 1500 rpm

To Find:- E_{lap}

Solution:-

$Z = 51 \times 20$

$$E = \frac{\text{Ø} P N Z}{60 A}$$

$$E = \frac{7 \times 10^{-3} \times 1020 \times 1500 \times 4}{60 \times 4}$$

$$\boxed{E = 178.51 \text{ Volt}}$$

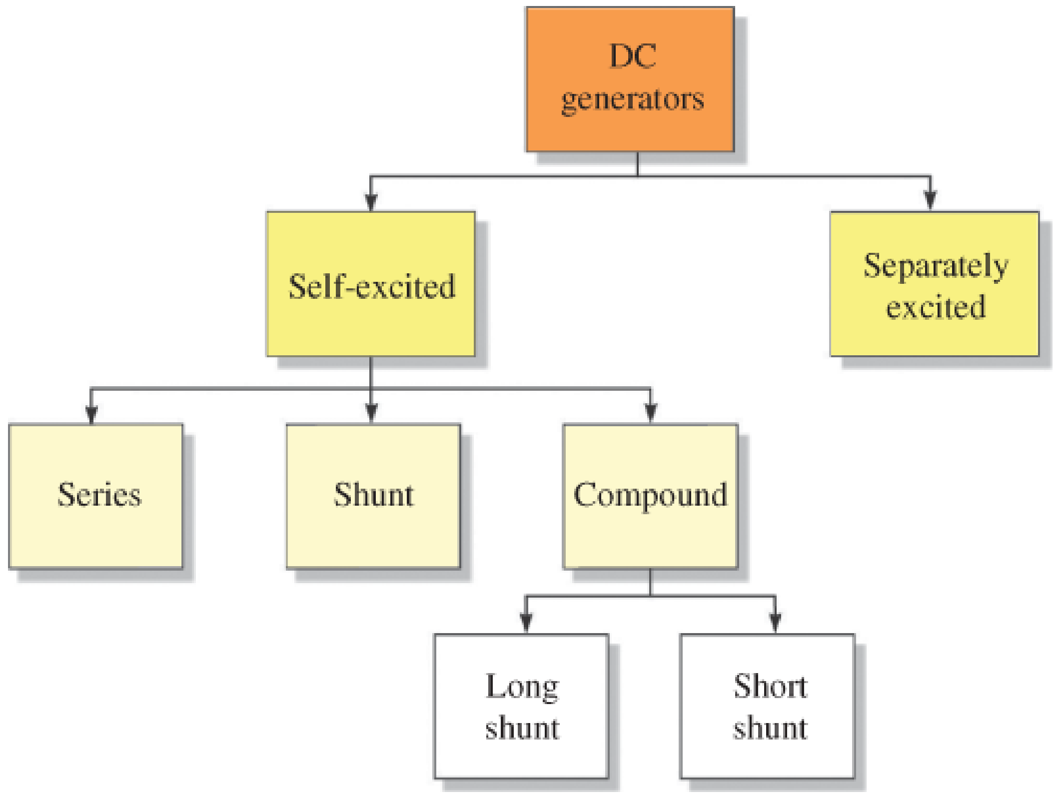
- **Types of DC Generator:-**

Field Coil

Armature Coil-

- The DC generator converts the mechanical power into electrical power. The magnetic flux in a DC machine is produced by the field coils carrying current. The circulating current in the field windings produces a magnetic flux, and the phenomenon is known as **Excitation** or in the case of a machine with field coils, a current must flow in the coils to generate the field; otherwise no power is transferred to or from the rotor. **The process of generating a magnetic field by means of an electric current is called excitation.**

- DC Generator is classified according to the methods of their field excitation.



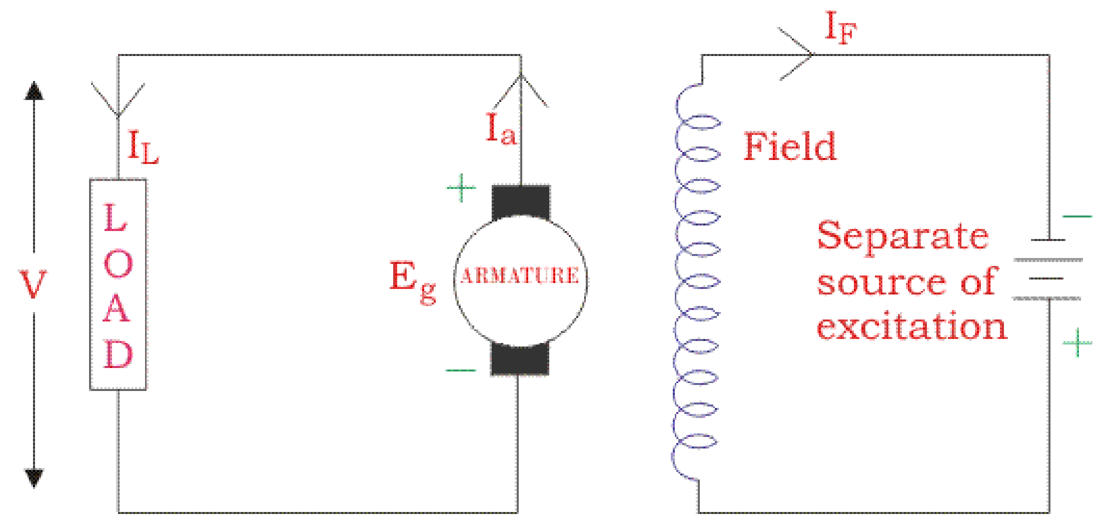
(A)Separately Excited DC Generator:

- A DC generator whose field winding or coil is energized by a separate or external DC source is called a separately excited DC Generator.
- The flux produced by the poles depends upon the field current with the unsaturated region of magnetic material of the poles. i.e. flux is directly proportional to the field current. But in the saturated region, the flux remains constant.

$$\boxed{I_a = I_L = I}$$

Then Voltage across the load is

$$\boxed{V_a = I_a R_a}$$



Separately Excited DC generator

Where,

R_a = Armature resistance

R_f = Field resistance

I_f = Field Current

I_a = Armature current

I_L = Load current

V = Terminal voltage

E_g = Generated EMF

Applications

- It is used for Electroplating.
- It is used for power & lighting purpose.
- It is used as an exciter.

(B)Self Excited DC generator:

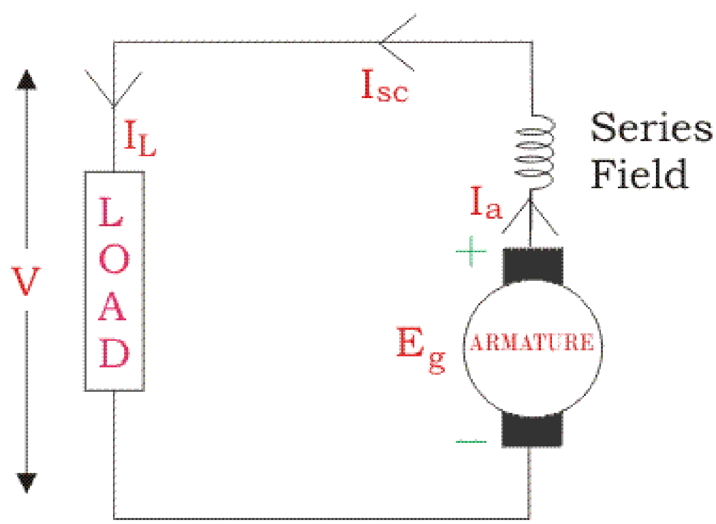
- Self-excited DC generators are generators whose field magnets are energized by the current supplied by themselves.
- In these types of machines, field coils are internally connected with the armature. Due to residual magnetism (magnetization left behind after removing the external magnetic field from the circuit.), some flux is always present in the poles.

- When the armature is rotated, some EMF is induced. Hence some induced current is produced. This small current flows through the field coil as well as the load and thereby strengthening the pole flux.
- As the pole flux strengthened, it will produce more armature EMF, which cause the further increase of current through the field. This increased field current further raises armature EMF, and this cumulative phenomenon continues until the excitation reaches the rated value.

According to the position of the field coils, self-excited DC generators may be classified as:

- Series generator
- Shunt generator
- Compound generator

i) Series generator:-



Series generator

R_{SC} = Series winding resistance
I_{SC} = Current flowing through the series field
R_a = Armature resistance
I_f = Field Current
I_L = Load current

V = Terminal voltage
E_g = Generated EMF
R_F = Field resistance
I_a = Armature current

- In these types of generators, the field windings are connected in series with armature conductors.
- Whole current flows through the field coils as well as the load. As series field winding carries full load current it is designed with relatively few turns of thick wire. The electrical resistance of series field winding is therefore very low (nearly 0.5Ω)
- When the generator is loaded, its terminal voltage increases. So it is not a constant voltage machine. It has a rising voltage characteristics.In series wound generators, the output voltage is directly proportional with load current.

$$I_a = I_L = I_{sc} = I$$

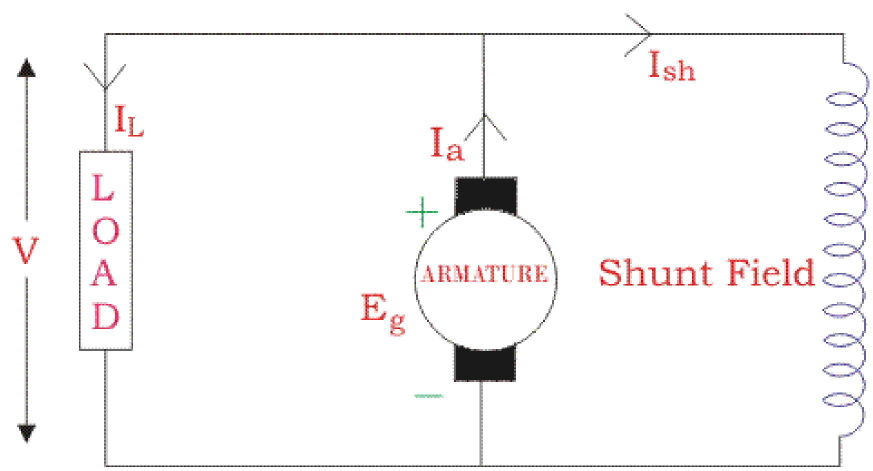
Then Voltage across the load is

$$Va = E_g - Ia^2 Ra$$

Applications

- It is used as a booster for making up the voltage of the feeder line
- It is used for lightning arc lamp**.**

i. Shunt generator:-



Shunt generator

R_{sh} = Shunt winding resistance
I_{sh} = Current flowing through the shunt field
R_a = Armature resistance
I_a = Armature current
I_L = Load current
V = Terminal voltage
E_g = Generated EMF

- In a shunt generator, the field winding is connected in parallel with the armature winding so that the terminal voltage of the generator is applied across it.
- The shunt field winding has many turns of fine wire having high resistance. Therefore, only a part of armature current flows through shunt field winding and the rest flows through the load.
- This generator has almost constant voltage at all loads, and hence used where constant voltage is required. In shunt wound generators, the output voltage is inversely proportional with load current.

$$\text{Shunt field current, } I_{sh} = \frac{V}{R_{sh}}$$

$$\text{Armature current, } I_a = I_L + I_{sh}$$

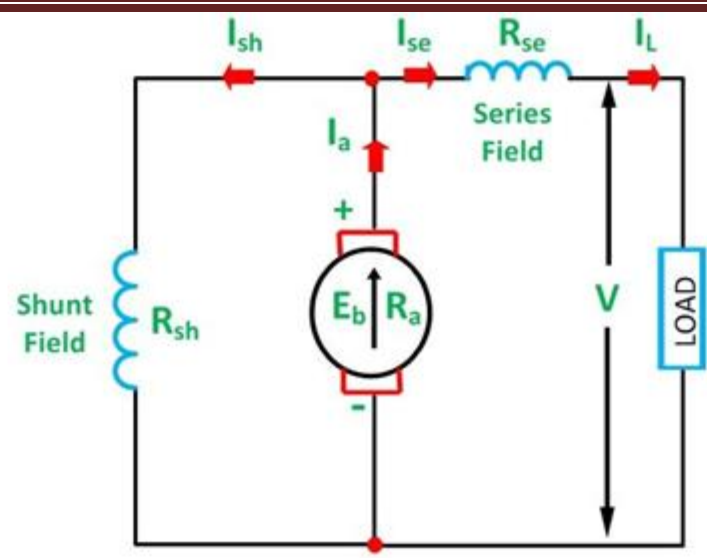
$$\text{Terminal voltage, } V = E_g - I_a R_a$$

Applications

- It is used for electric lighting and power supply purpose.
- Is is used for battery charging purpose.

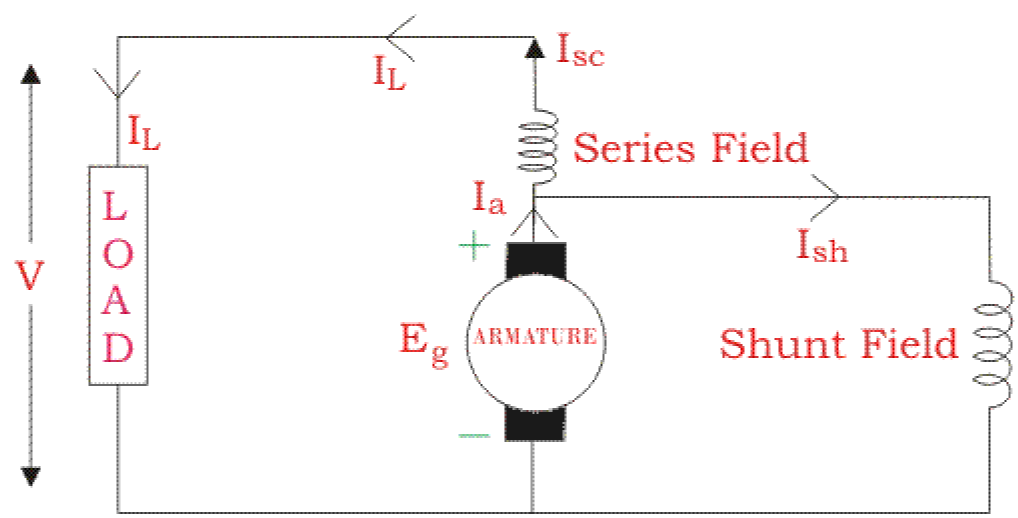
iii)Compound Generators:-

- In series wound generators, the output voltage is directly proportional with load current.
- In shunt wound generators, the output voltage is inversely proportional with load current.
- A combination of these two types of generators can overcome the disadvantages of both. This combination of windings is called compound wound DC generator.
- Compound wound generators have both series field winding and shunt field winding. One winding is placed in series with the armature, and the other is placed in parallel with the armature.
- This type of DC generators may be of two types- short shunt compound-wound generator and long shunt compound-wound generator.



Compound Generator

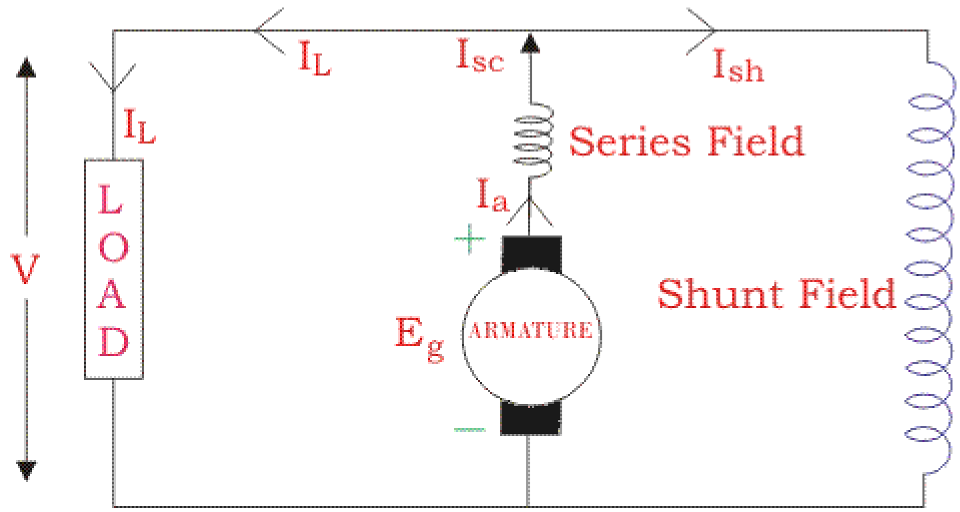
- **Short Shunt Compound generator:**



Short Shunt Compound generator

- Short Shunt Compound Wound DC Generators are generators where only the shunt field winding is in parallel with the armature winding.
- Shunt field current is equal to $I_{sh} = \frac{V + I_{sc}R_{sc}}{R_{sh}}$
- Voltage across the load is equal to, $V = E_g - I_aR_a - I_{sc}R_{sc}$.

- **Long Shunt Compound generator:**



long Shunt Compound generator

- Long Shunt Compound Wound DC Generator are generators where the shunt field winding is in parallel with both series field and armature winding, as shown in the figure.
- Shunt field current is equal to $I_{sh} = \frac{V}{R_{sh}}$
- Voltage across the load is equal to $V = Eg - I_a R_a - I_{sc} R_{sc}$

Applications:

- Compound generators are used as a compensators of line drops in traction.
- It is used for power & lightning purpose

Examples for Practices

1. A 6 pole generators has 400 armature conductors & useful flux is 0.06Wb. It runs at the speed of 100 rpm. Find the e.m.f of the generator if it is a) Lap Connected b) Wave Connected.
   (E_{wave} = 120V , E_{lap} = 40 Volt)
2. The armature of 6 pole wave wound shunt generator has 200 slot & 4 conductors per slot. The flux per slot is 50 mwb. Find at what speed the armature is to be rotated so as to generate 230Volt on open circuit.(N= 115 rpm)
3. A DC generator has following details calculate e.m.f. for lap connections Poles (p) = 4, Flux per pole (Φ) = 8×10^{-2} Wb, slot = 35, Conductor per slot = 15, speed (N) = 1000 rpm.(E= 700 Volt)
4. The Speed of 6 pole lap wound shunt generator is 1500 rpm. The flux per pole is 48 mWb find the total conductor of the generator if the generator has voltage 250V. (Z = 208)

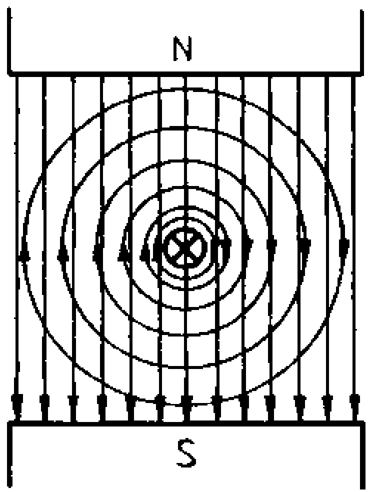
10. D.C. MOTOR

Introduction:

According to construction the DC motor is similar to the DC generator. Same DC machine can be run as a motor as well as generator. When mechanical input is provided to the machine & it gives electrical output then machine is termed as Generator and if electrical input is provided to the machine & it gives mechanical output then machine is termed as motor.

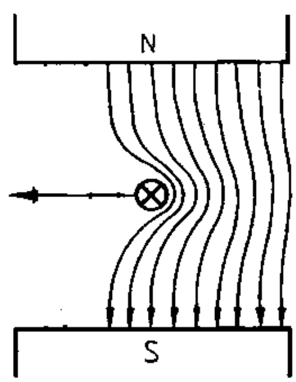
Direction for force on the conductor

Motoring action:-.



Conductor kept in the magnetic field

Fig. shows the current carrying conductor placed in the magnetic field. On right hand side field flux and flux due to current carrying conductor both will have same direction therefore the effective flux becomes stronger similarly on left hand side both the flux becomes in opposite direction so that it will cancel each other therefore effective flux becomes weaker (It will cancel each other).

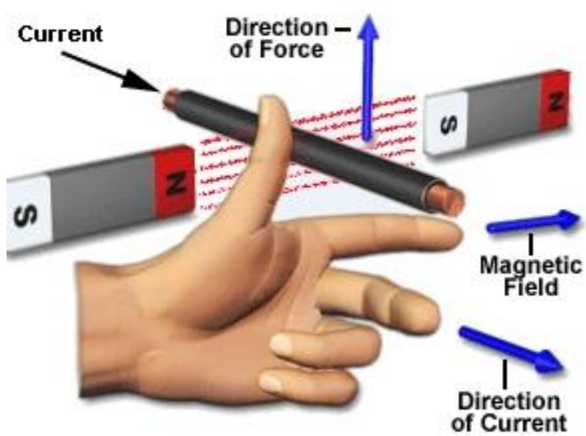


Force produced on the conductor

Thus when current carrying conductor is placed in magnetic field a force is produced on the conductor. The direction of the force depends on the direction of the magnetic field in which it is kept and direction of the current in the conductor.

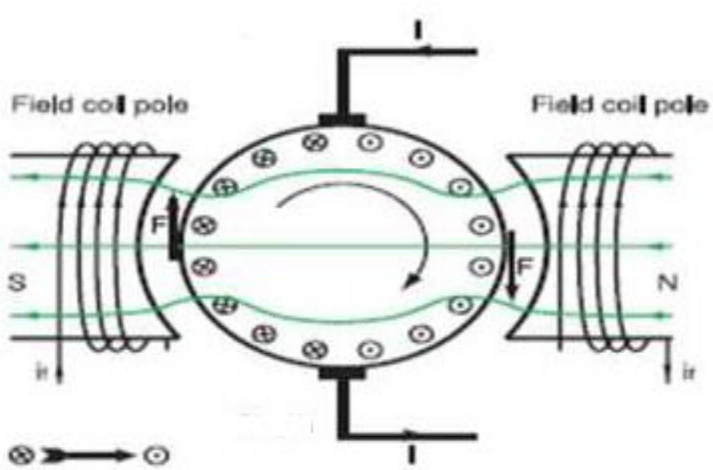
- **Fleming's left hand rule:**

According to **Fleming's left hand rule**, if the thumb, fore-finger and middle finger of the left hand are stretched and kept mutually perpendicular to each other as shown in the figure below then the fore finger represents the direction of magnetic field, the middle finger represents the direction of current, then the thumb represents the direction of force. Fleming's left hand rule is applicable for motors.



Fleming's left hand rule

Working Principle of DC motor :



Dc motor Working

Consider DC motor as shown in the figure. When the terminals of the motor are connected to an external source of DC supply:

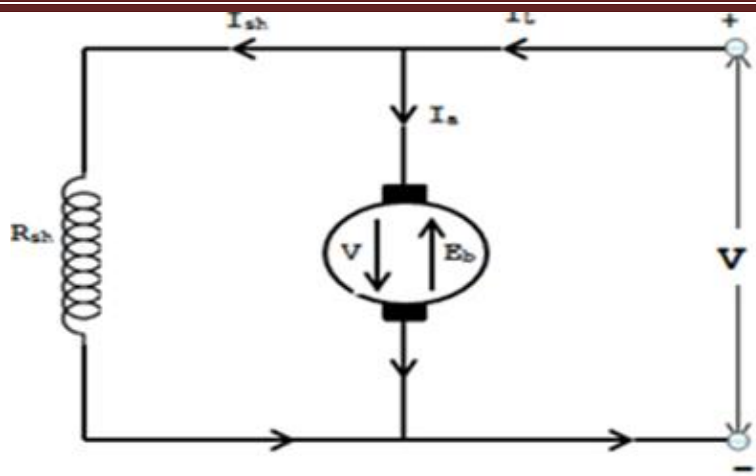
- The field magnets are excited developing alternate North and South poles.
- The armature conductors carry currents.
- All conductors under North-pole carry currents in one direction while all the conductors under South-pole carry currents in the opposite direction.
- The armature conductors under N-pole carry currents into the plane of the paper. And the conductors under S-pole carry currents out of the plane of the paper.
- Since each armature conductor is carrying current and is placed in the magnetic field, a **mechanical force** acts on it. On applying **Fleming's left-hand rule**, it is clear that force on each conductor is tending to rotate the armature in the anticlockwise direction.
- All these forces add together to produce a **driving torque** which sets the armature rotates.
- When the conductor moves from one side of a brush to the other, the current in that conductor is reversed. At the same time, it comes under the influence of the next pole which is of opposite polarity. Consequently, the **direction of the force on the conductor remains the same**. It should be noted that the **function of a commutator** in the motor is the same as in a generator. By reversing current in each conductor as it passes from one pole to another, it helps to develop a **continuous and unidirectional torque**.

The Magnitude of force is given by $F = B\,I\,L \sin \varnothing$

When B = Flux Density of Field
I = Current in the Conductor
L = length of the Conductor

Back E.M.F:

- When a dc voltage V is applied across the motor terminals, the armature starts rotating, as the armature rotates, armature conductors cut the pole magnetic field, and therefore, according to the law of electromagnetic induction, e.m.f is induced in them this e.m.f is known as Back e.m.f. Therefore, back e.m.f is always directed opposite to supply voltage V.



Back emf

Supply voltage of DC motor is given by

$$V = E_b + I_a R_a$$

Back emf is given by

$$E_b = \frac{\emptyset\, PN\, Z}{60\, A}$$

Where, P=number of poles of dc motor

Φ= flux per pole

Z=total number of armature conductors

N=armature speed

A=number of parallel paths in armature winding

As the back e.m.f opposes supply voltage V, therefore, supply voltage has to force current through the armature against the back e.m.f, to keep armature rotating. The electric work done in overcoming and causing the current to flow against the back e.m.f is converted into mechanical energy developed in the armature.

Starting the DC motor:

Consider the DC motor of 200V, 10A, 1000rpm armature resistance $R_a = 2\Omega$.
At the time of starting of motor N = 0, therefore E_b of motor is zero.

$$V = E_b + I_a R_a$$

$$I_a = \frac{V - E_b}{R_a}$$

$$I_a = \frac{200-0}{2}$$

$$\boxed{I_a = 100A}$$

The current rating of the motor is 10A but at the time of staring it takes 100A (10 times greater than rated). If the winding is allowed to take that much amount of current it will burn out. To protect the motor from burning the motor is started with the help of starter. The starter is basically variable resistance (Rs) to be connected in series with armature.

Let the starter resistance Rs = 98Ω then if with resistance the motor is stared then,

$$I_a = \frac{V - E_b}{R_a + R_s}$$

$$I_a = \frac{200-0}{2+98}$$

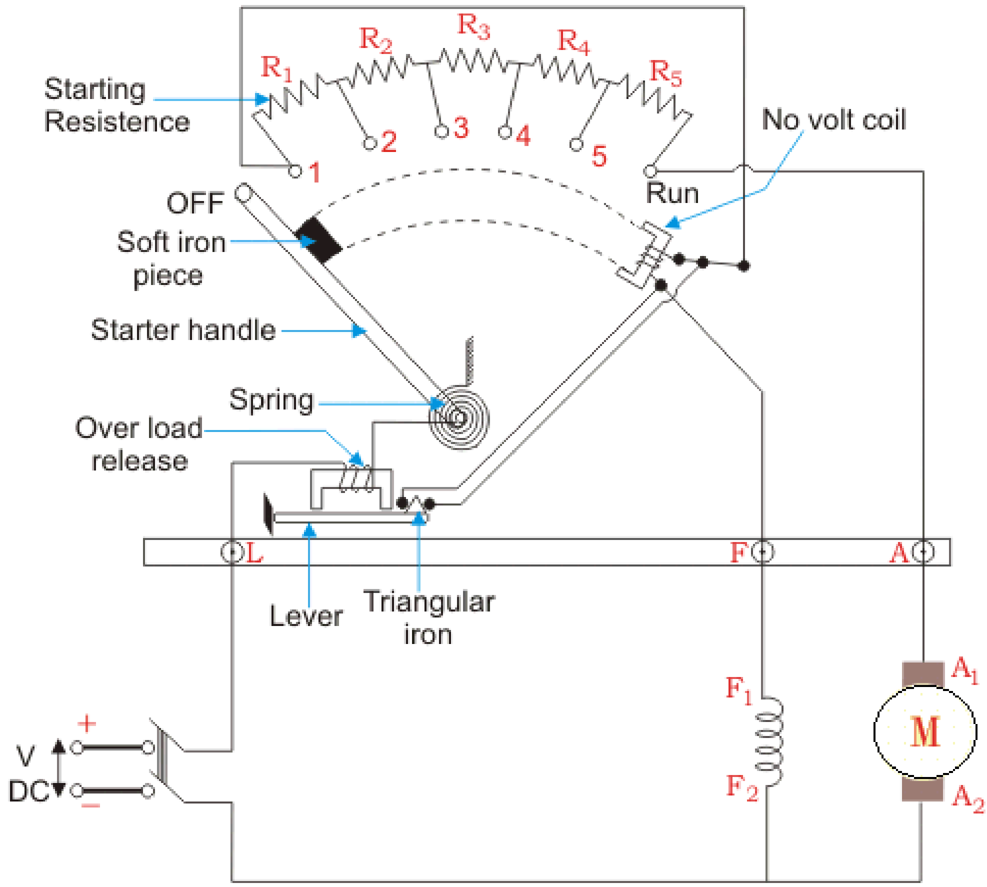
$$\boxed{I_a = 2\ A}$$

This is the safe value of starting current which we get by using starter. Hence, the motor is started and the starting current is controlled to the safe value. Now once the motor is started it gains the speed and back e mf is developed. Let this back e mf is 10V, 20V, 30V………… and say finally 196V then the starter resistance need not to be kept in armature circuit and gradually it cuts down.

$$I_a = \frac{200-196}{2+0} = 2A$$

Thus current is controlled by Back e mf so the motor needs the starter at the time of starting once the motor is started it develops back e mf and starter resistance gradually cut down.

• Starters of DC Shunt motor



Three point starter

Construction of 3 Point Starter:

- Construction wise a starter is a variable resistance, integrated into the number of sections as shown in the figure above.
- The contact points of these sections are called studs and are shown separately as **1, 2, 3, 4, and 5.** Other than that there are three main points, referred to as,

  ‘L’ Line terminal (Connected to positive of supply)

  ‘A’ Armature terminal (Connected to the armature winding)

  ‘F’ Field terminal (Connected to the field winding)

- The point ‘L’ is connected to an electromagnet called overload release (OLR) as shown in the figure. The other end of OLR is connected to the lower end of conducting lever of starter handle where spring is also attached with it.

- The starter handle also contains a soft iron piece housed on it. This handle is free to move to the other side RUN against the force of the spring. This spring brings back the handle to its original OFF position under the influence of its own force. Another parallel path is derived from the stud '1', given to another electromagnet called No Volt Coil (NVC) which is further connected to terminal 'F.' The starting resistance at starting is entirely in series with the armature. The OLR and NVC act as the two protecting devices of the starter.

Working of Three Point Starter:

- When the supply to the DC motor is switched on. Then handle is slowly moved against the spring force to make contact with stud No. 1
- At this point, field winding of the shunt or the compound motor gets supply through the parallel path provided to starting the resistance, through No Voltage Coil. While entire starting resistance comes in series with the armature. The high starting armature current thus gets limited as the current equation at this stage becomes

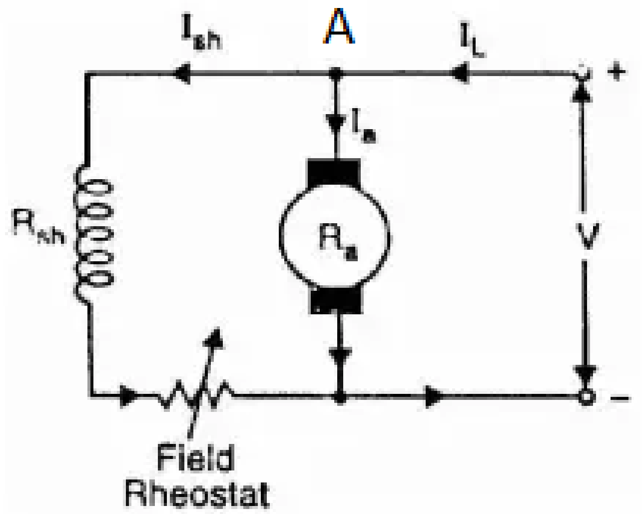
$$I_a = \frac{E}{(R_{st} + R_a)}$$

- As the handle is moved further, it goes on making contact with studs 2, 3, 4, etc., thus gradually cutting off the series resistance from the armature circuit as the motor gathers speed. Finally, when the starter handle is in 'RUN' position, the entire starting resistance is eliminated, and the motor runs with normal speed.

Types of DC Motor:

1. DC shunt Motor:

- A **DC shunt motor** is a type of self-excited DC motor, and it is also known as a shunt wound DC motor. The field windings in this motor can be connected in parallel to the armature winding. So both windings of this motor will expose to the equal voltage power supply, and this motor maintains an invariable speed with any kind of load. This motor has a low starting torque and also runs at a constant speed.

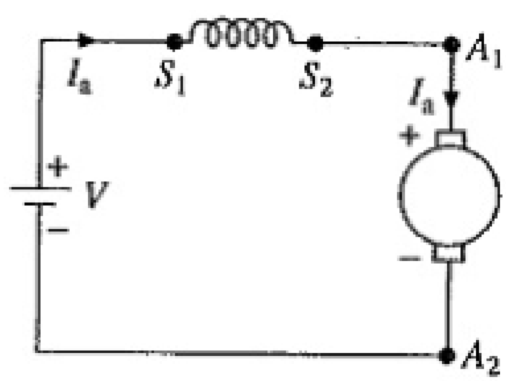


Dc Shunt motor

- The current through the shunt field winding is not the same as the armature current. Shunt field windings are designed to produce the necessary m.m.f. by means of a relatively large number of turns of wire having high resistance. Therefore, shunt field current is relatively small compared with the armature current.

  Application
- Lathes
- Drills
- Boring mills
- Spinning and Weaving machines

2. DC series Motor



Dc Series motor

- In series wound motor the field winding is connected in series with the armature. Therefore, series field winding carries the armature current. Since the current passing through a series field winding is the same as the armature current, series field windings must be designed with much fewer turns than shunt field windings for the same mmf. Therefore, a series field winding has a relatively small number of turns of thick wire and, therefore, will possess a low resistance.

Applications

- Electric traction
- Cranes
- Elevators
- Lifts

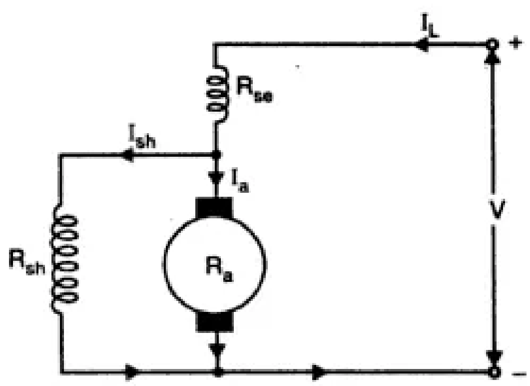
<u>3. DC compound motor:</u>

Compound wound motor has two field windings; one connected in parallel with the armature and the other in series with it. There are two types of compound motor connections,

a. Short Shunt Compound motors
b. Long shunt Compound motors.

a) Short shunt compound motors:

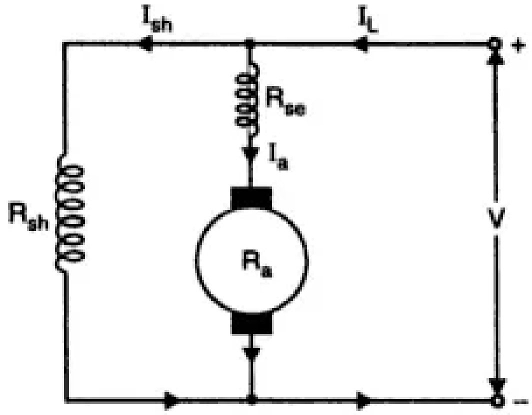
When the shunt field winding is directly connected across the armature terminals it is called short-shunt connection**.**



Dc Short shunt motor

b) Long shunt compound motors:

When the shunt winding is so connected that it shunts the series combination of armature and series field it is called long-shunt connection.



Dc long shunt motor

Applications:

- Shearing machine
- Punching machine
- Rolling machine
- Shaping machine

Speed control of DC Motor:

- Back emf of a DC motor is nothing but the induced emf in armature conductors due to rotation of the armature in magnetic field. Thus, the magnitude of E_b can be given by EMF equation of a DC generator.

$$E_b = \frac{\emptyset\, PN\, Z}{60\, A}$$

where, P=number of poles of dc motor

Φ= flux per pole

Z=total number of armature conductors

N=armature speed

A=number of parallel paths in armature winding

thus, from the above equations

$$N = \frac{E_b \times 60\, A}{\emptyset\, P\, Z}$$

but, for a DC motor A, P and Z are constants

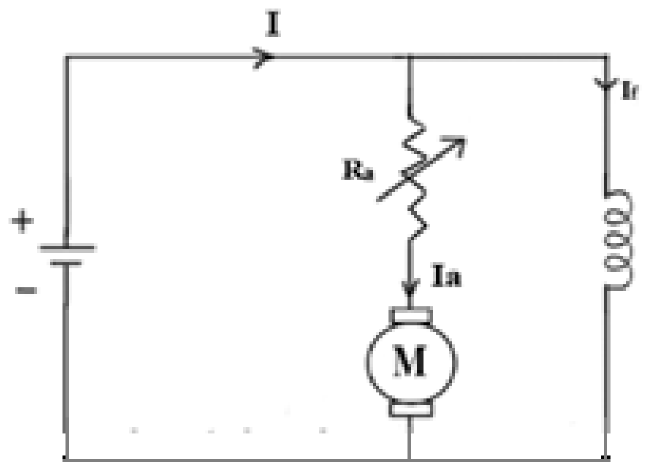
$$N \propto \frac{E_b}{\emptyset}$$

This shows the **speed of a dc motor** is directly proportional to the back emf and inversely proportional to the flux per pole.

Speed control methods of DC Motor are as follows:

1 Armature control method
2. Field control method

1. **Armature voltage control method:**

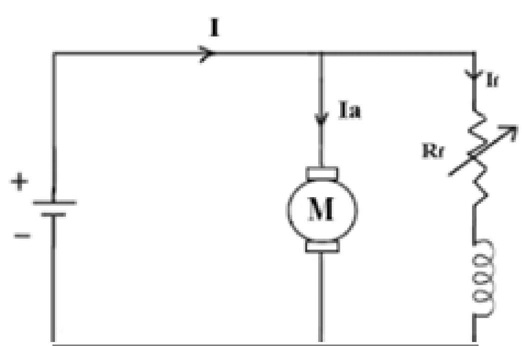


Armature voltage control method

Speed of a dc motor is directly proportional to the back e.m.f E_b and $E_b = V - Ia\,Ra$.

That means, when supply voltage V and the armature resistance Ra are kept constant, then the speed is directly proportional to armature current Ia. Thus, if addition of resistance in series with the armature, Ia decreases and, hence, the speed also decreases. Greater the resistance in series with the armature, greater the decrease in speed.

2. **Flux control method (Field Control Method) :**



Field Control methods

The speed of a dc motor is inversely proportional to the flux per pole. Thus by decreasing the flux, speed can be increased and vice versa. To control the flux, a rheostat is added in series with the field winding, as shown in the circuit diagram. Adding more resistance in series with the field winding will increase the speed as it decreases the flux. In shunt motors, as field current is relatively very small, I_{sh}^2R loss is small. Therefore, this method is quite efficient.

Characteristics and Applications of DC motors:

Sr.no.	Type of motor	Characteristic	Application
1.	DC shunt motor	1.Almost constant speed 2.speed can be increased/decreased 3.Medium starting torque	1.In w/s driving shaft 2. lathe machine 3.Driving pumps 4.Fans/blowers
2.	DC series motor	1. Speed not constant. 2. High starting torque. 3.Adjustable speed(speed control possible)	1.Electric trains 2.Electric cranes 3.Electric trolley-car 4.Conveyer belts. 5.lifts
3.	DC compound motor	1.Speed not constant 2.speed can be adjusted 3.Starting torque is better	1.Shearing machine 2.Punching machine 3.Planning machine 4.Shaping machine 5.Rolling machine

11. SINGLE PHASE MOTORS

Why Single Phase induction Motors are not self starting?

Ans.

1. When a 1ϕ a.c. supply is given to stator of a 1ϕ motors only alternating flux is produced in stator. It is not of rotating type.
2 .Hence rotational torque is not produced.
3. Alternating magnetic flux cannot move the rotor.
4. Therefore the motors are not self starting.

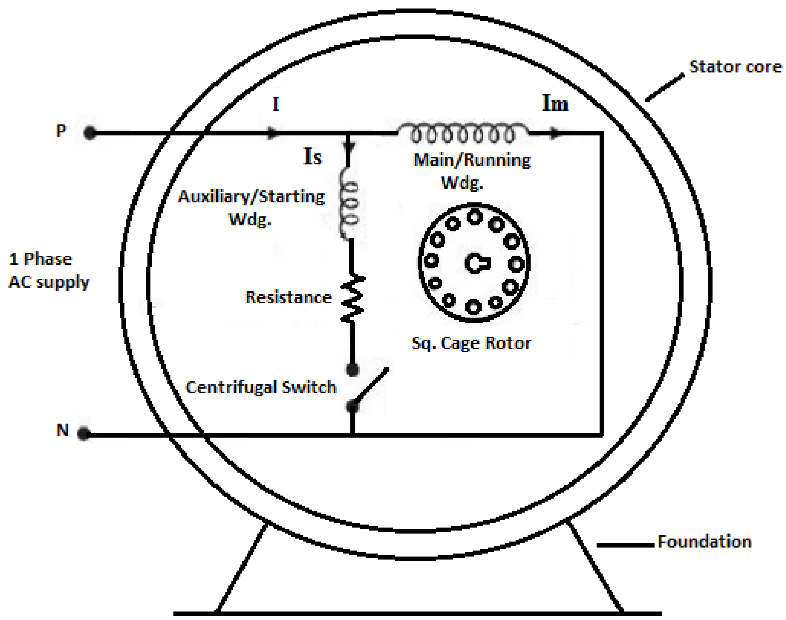
Broad Classification of 1ϕ motors

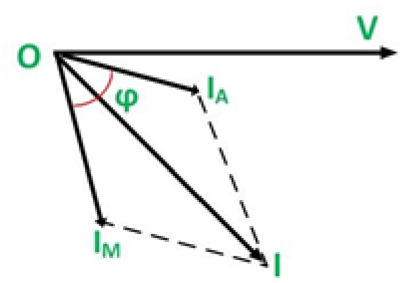
1ϕ Motors

- 1ϕ IM
  - split phase motor
  - capacitor motor
    - capacitor start Induction Run motor
    - Permanent capacitor motor
    - Capacitor start capacitor Run motor
  - Shaded pole motor
- Repulsion motor
- A.C.Series Motor
- unexcited synchronous motor

1. Split Phase motors (Resistance Start Induction Run Motors)

(a) Constructional Diagram:





Phasor Diagram

(b) Construction:

(i) Stator: It is made up of silicon steel stamping having internal slots for receiving single phase stator winding.

(ii) Stator winding: - It is made up of good quality enameled copper and is split into starting winding and running winding.

(iii) Rotor: It is a round cylindrical part having slots on the periphery for Round Cu bars and is made of silicon steel stamping.

(iv) Rotor conductors: These are round Cu bars embedded in the rotor slots & permanently short circuited (squirrel cage rotor)

(v) Centrifugal Switch: It is connected in series with the starting winding.

(c)Working:

(i) When an A.C supply is given to the stator of the motor, the current (I) splits into Im & Is flowing in the main winding& starting winding.

(ii) The current (Im) lags the applied voltage by greater angle since more inductive & (Is) lags the applied voltage by a smaller angle since more resistive less inductive.

(iii) The currents Im and Is produces its own flux ϕ_m & ϕ_S having a phase angle difference which interact and r.m.f is set and the rotor start rotating.

(iv) When the rotor reaches 70 – 80% of the normal speed, the centrifugal switch is operated and the starting winding is disconnected electrically from the circuit. Hence the name (resistance start induction Run motor)

(v)As starting torque is proportional to phase angle between Im & Is , starting torque is less.

D.O.R: can be changed by interchanging the connection of either starting winding or running winding but not both.

Application: Small machine tools, duplicating machines, oil burners,

2.Capacitor motors:

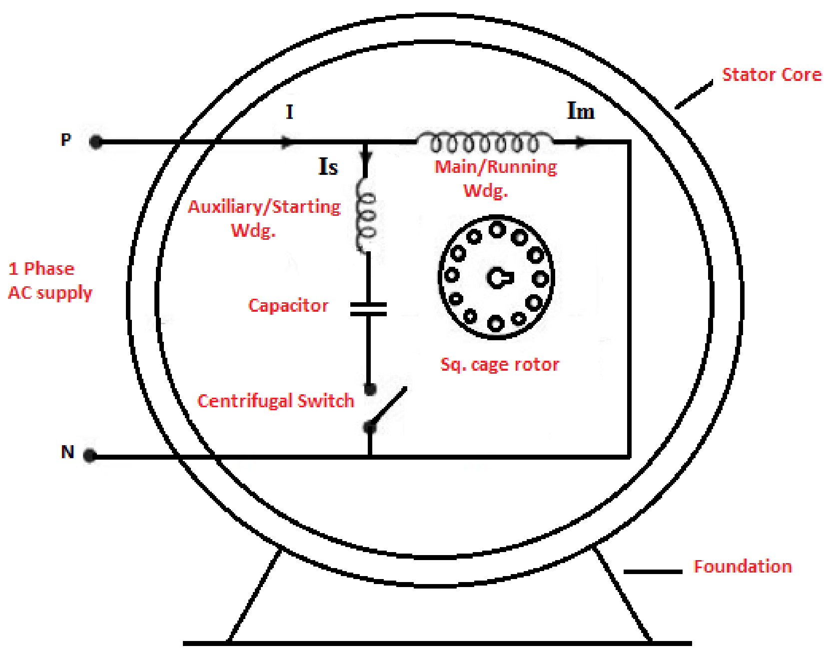
(a) Capacitor start induction run motors

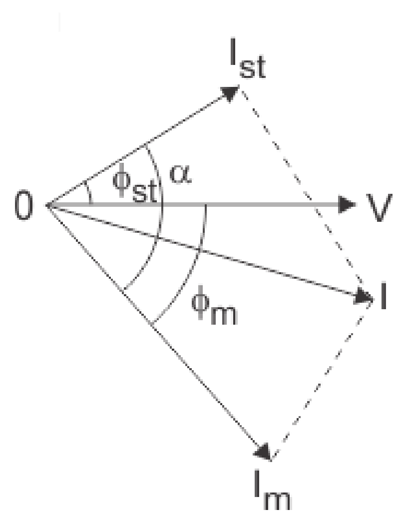
(b) Permanent capacitor motors.

(c) Capacitor start capacitor run motors.

(a) Capacitor start Induction run motor:

(i) Constructional diagram:





Phasor diagram

Starting Current = $I_{st} = Sin\alpha$

(ii) Construction:

(a) Stator. It is made up of silicon steel stamping having internal slots for stator winding.

(b) Stator winding: it is made up of good Quality enameled Cu & split as starting winding and running winding.

(c) Rotor: It is round cylindrical part having slots for round copper bars and is made of silicon steel.

(d) Rotor conductors: These are round copper bars embedded in the rotor slots and permanently short circuited (squirrel cage rotor).

(e) Centrifugal switch: It is connected in series with the starting winding.

(iii) Working:

(a) When an AC supply is given to the motor, the current (I) splits into I_m and I_s flowing in the main winding and starting winding.

(b) The Current (I_m) lags by a greater angle since more inductive and Current (I_s) leads by a smaller angle since more capacitive and less inductive.

(c) The current (I_m) and (I_s) produces its own flux ϕ_m and ϕ_s having a phase angle difference which interacts and rotor starts rotating.

(d) When the rotor reaches 70- 80% of the normal speed, the centrifugal switch is operated and starting winding is disconnected electrically from the circuit.

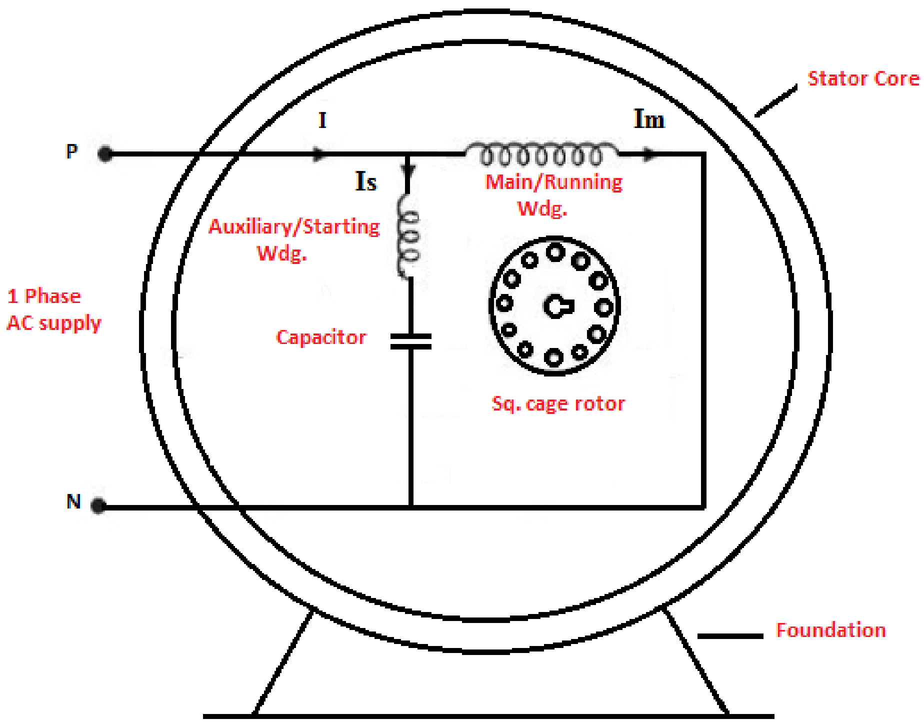
D.O.R Can be changed by making starting winding as running and vice versa.

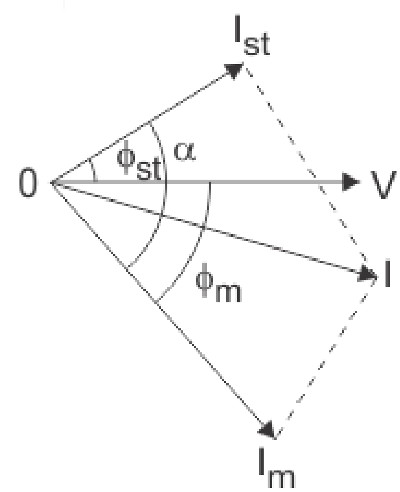
(iv)Uses :

(i) Refrigerator (ii) drilling machine (iii) lathe machine (iv) pumps (v) cooler (vi) printing press

(b) Permanent Capacitor motors:

(i) Constructional diagram:





Phasor diagram

(ii) Construction:

(a) Stator: It is made up of silicon steel stamping having internal slots for stator winding.

(b) Stator winding: It is made up of good quality enameled copper and is split into starting winding and running winding

(c) Rotor: It is round cylindrical part having slots for round copper bars and is made up of silicon steel stamping.

(d) Rotor conductors: These are round copper bars embedded in the rotor slots and permanently short circuited (Squirrel cage rotor).

(iii) Working:

(a) When an AC supply is given to the motor, the current (I) splits into I_m and I_s flowing in the main winding and starting winding.

(b) The Current (I_m) lags the applied voltage by a greater angle since more inductive and Current (I_s) Leads the voltage by a smaller angle since more capacitive and less inductive.

(c) This creates a phase angle difference between main winding flux and starting winding flux and rotating magnetic flux is set up .Thus rotor starts rotating.

(d) The capacitor remains permanently in the circuit even in the running condition.

D.O.R (Direction of rotation):

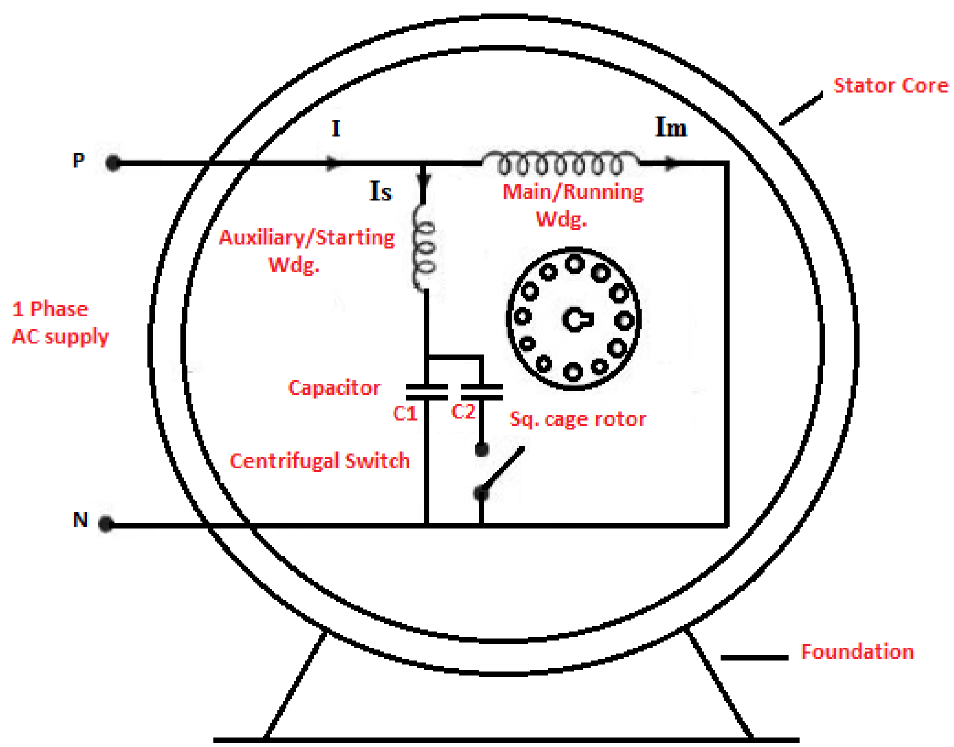
It can be changed by making starting winding as running and vice versa.

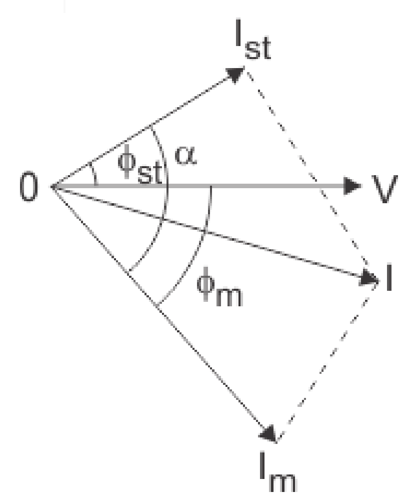
Uses:

(I) Ceiling fan (ii) table fan

(C) Capacitor start Capacitor Run Motor:

(I) Constructional diagram:





Phasor diagram

(ii) Construction:

(a) Stator. It is made up of silicon steel stamping of having internal slots for stator winding.

(b) Stator winding: it is made up of good Quality enameled Cu and is split as starting winding and running winding

(c) Rotor: It is round cylindrical part having slots for round copper bars and is made of silicon steel.

(d) Rotor conductors: These are round copper bars embedded in the rotor slots and permanently short circuited (squirrel cage rotor).

(e) Centrifugal switch: It is connected in series with the capacitor C_1.

(iii) Working:

(a) The two capacitors are used Cap1 and Cap2. Cap1 is of higher value but short duty and Cap2 is of lower value but continuous duty.

(b) When the supply is switched ON the current (I) splits into splits into I_m and I_s flowing in the main winding and starting winding.

(c) The Current (I_m) lags by a greater angle since more inductive and Current (I_s) leads by a smaller angle since more capacitive and less inductive.

(d) This creates a phase angle difference between main winding flux and starting winding flux and rotating magnetic flux is set up .Thus rotor starts rotating.

(e) When the rotor reaches 70- 80% of the normal speed, the centrifugal switch is operated and the cap1 is disconnected from the circuit whereas Cap2 remains permanently in the circuit.

(iv) Uses:

(I) Room Cooler (II) Refrigerator (III) Compressor

(v) Specialty:

(i) p. f. is improved

(ii) Higher efficiency

(iii) Higher torque

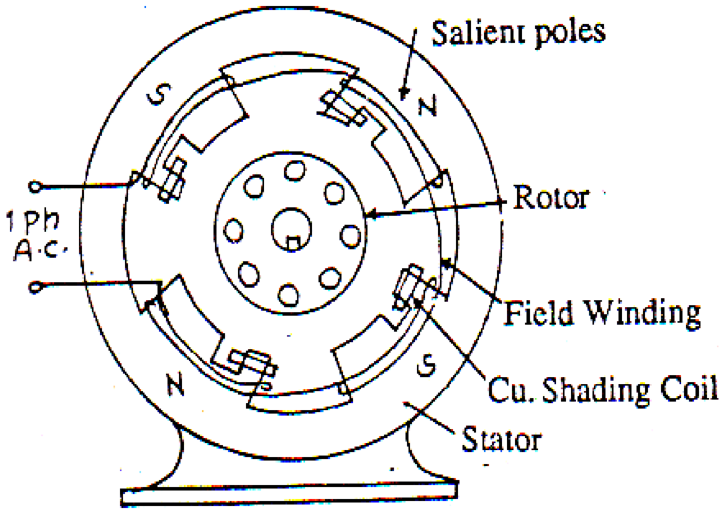
(iv) Starts quickly

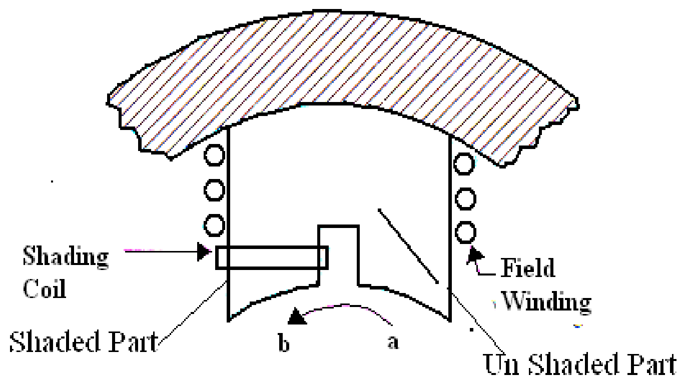
D.O.R:

It can be changed by making starting winding as running and vice versa.

(D) Shaded Pole Motor:

(I) Constructional diagram:





(II) Construction:

(i) Stator: It is made up of silicon steel stamping having salient poles. A slot is cut in the pole and a Cu coil is placed at one corner. Copper coil is known as shading coil. This part of the pole is known as shaded part and the remaining as unshaded part.

(ii) Stator winding [field winding]: It is made up of good quality enameled copper and wound on salient poles.

(iii) Rotor: It is cylindrical part made up of silicon steel stamping having slots for rotor bars.

(iv) Rotor conductors: Made up of round copper bars which are placed in rotor slots and are permanently short circuited (sq. cage)

(iii) Working:

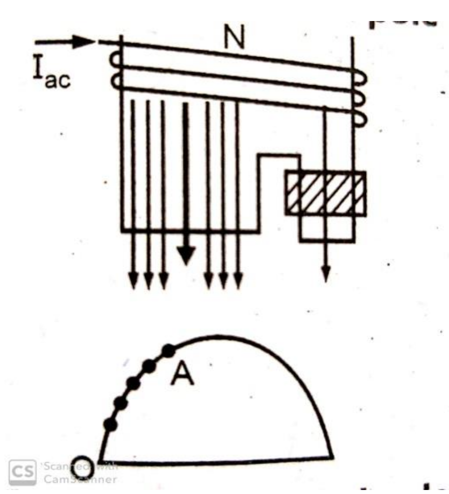


Fig. A

- When the supply is switch "ON" the field current is rapidly increasing along OA (fig.A) in the field winding which produces flux in the poles.
- According to transformer action e.m.f. is induced in the shading coil causing heavy current to circulate in it. According to Lenz's law, an induced electric current flows in a direction such that the current opposes the change that induced it. Hence flux shifts mostly to the unshaded part and the magnetic axis lies along the middle of unshaded part..

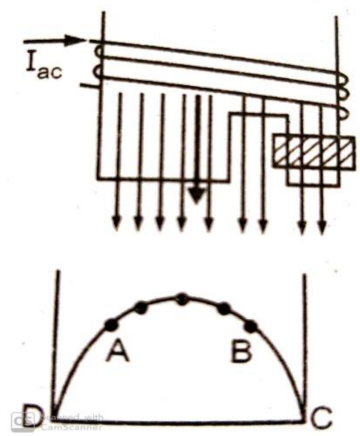


Fig. B

- Consider the moment (Fig. B) when field current is near its peak value (instant AB) & change in exciting [field current] is less. So the induced current in the shading coil is very less. Hence the flux is uniformly distributed over the pole face. So the magnetic axis lies to the center of the whole pole.

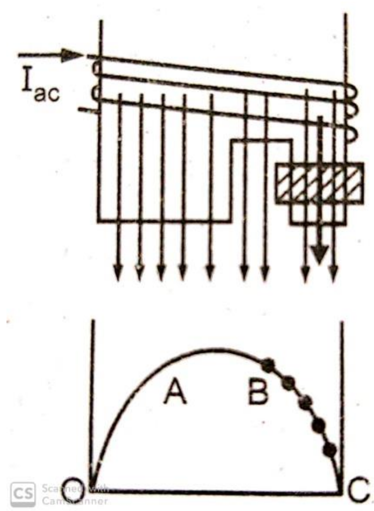


Fig. C

- At one instance (Fig.C) the current in the shading coil decreases very rapidly (instant BC) and hence the M.A shifts towards the shaded pole. It seems as if the M.A is moving from the unshaded pole to shaded pole and the rotating magnetic field is setup and the rotor starts rotating.

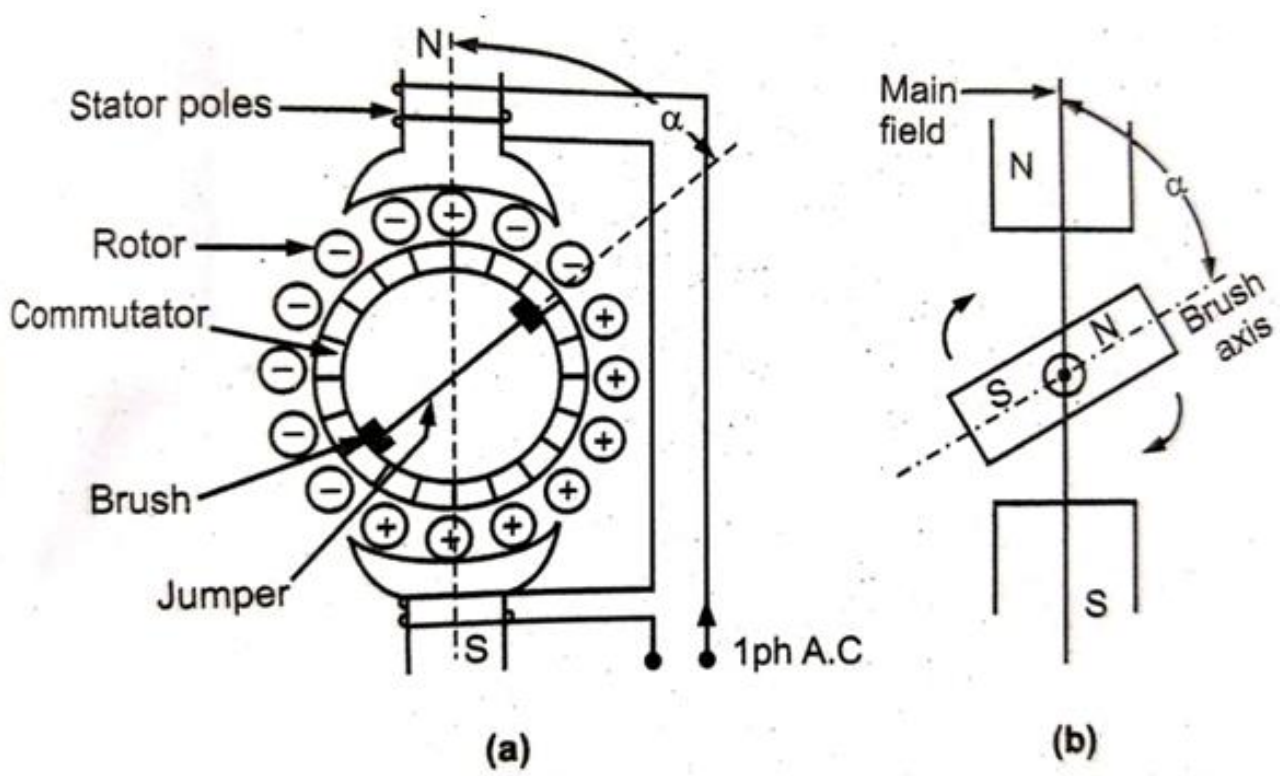
D.O.R. - It is not possible to change the D.O.R. of these motor as the position of the copper rings are fixed.

Uses:

(I) Small fans (II) Toys (III) hair dryers

(4) Repulsion Motor (Repulsion Start Induction Run Motor)

(i)Constructional Diagram:



(II) Construction:

(i) Stator: It is made up of silicon steel stamping having non salient poles for stator winding.

(ii) Stator winding: It is made up of good quality enameled copper and is wound on the stator pole.

(iii) Rotor : It is round cylindrical part having slots for copper winding and is made up of silicon steel stampings .It is same as the armature of D.C..motor.

(iv) Rotor winding: These are made up of good quality enameled cu and placed in the rotor slots the ends of which are connected to the carbon brushes.

(v) Commutator: It consist of alternate layers of copper and mica segments

(vi) Brushes: It is made up of carbon or graphite placed in the holder and ride against commutator .The brushes are shorted by connecting them directly with a cu wire (jumper).

(iii) Working:

- When current is given to the stator winding field is set up .Let an instant the field is such that N pole is at the top and S pole is at the bottom and the MA lies vertical
- The Brush Axis is neither horizontal nor vertical, but at an intermediate angle α .
- The like poles of the stator and rotor repel each other and the rotor starts rotating.
- Since the rotor rotates because of repulsive force it is called Repulsion Motor.
- The speed of this motor can be changed by shifting the position of brushes.
- The D.O.R can be change by shifting the brushes in reversed direction.

Uses :

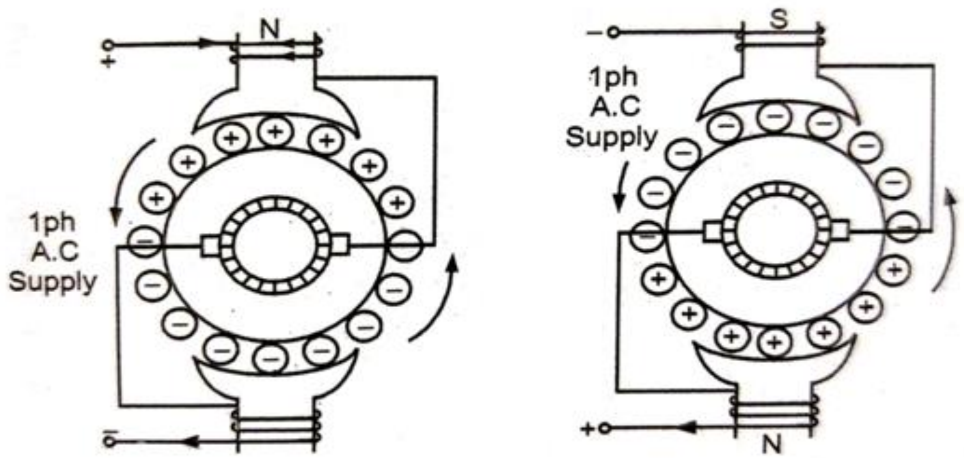
(i) Refrigerator (ii) mixing machine (iii) Floor polishing machine (iv) lifts (v) compressor

AC series Motor

Introduction:-

Universal Motor is a small version of a.c. series motor. It works on a.c. supply as well d.c. supply.

(I) Circuit diagram :



(II) Construction:

A.C. series motor is similar in construction as d.c. series motor and has the main parts.

(i) Field pole: It is made up of silicon steel stamping and salient type for field winding.

(ii) Field winding: It is made up of good quality enameled copper and is wound on the field pole.

(iii) Armature: It is round cylindrical part having slots on the periphery for the armature winding.

(iv) Armature winding: It is made up of good quality enameled copper placed in the armature slots the ends of which are connected to the commutator.

(v) Commutator: It consist of alternate layers of copper and mica segments.

(vi) Brushes: There are made up of carbon or graphite.

(iii) Working:

(i) If D.C. series motor is connected to AC. supply. It will rotate with unidirectional torque which can be explained as follows.

(ii) For the instantaneous polarity the direction of the current in the series field coil and armature coil is as shown in figure (a). As per the theory, When a current carrying conductor is placed in the magnetic field it experiences a force in certain direction and its direction is given by Flemings Left Hand Rule.

(iii)In the first case, armature starts rotating in anticlockwise direction.

(iv)In the next half cycle of a.c. instantaneous polarities are changed as shown n the figure (b).the direction of field as well as direction of current in the armature is also changed.

(v) By Fleming's left hand rule, we find that direction of rotation of armature is same that is anticlockwise. Thus we can conclude that to the D.C. series motor even if a.c. supply is given the motor develops at unidirectional torque.

(vi)But for the good performance of a.c. series motor or universal motor some modifications are to be made in the motor.

D.O.R –

It can be changed by reversing the terminals of armature with respect to field coil.

Application:-

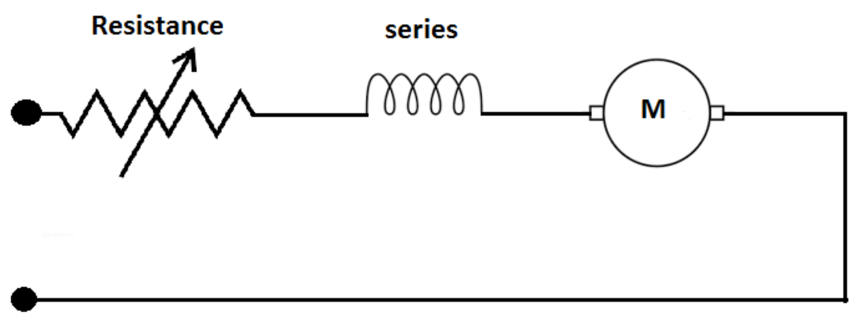
(i) Vacuum cleaner (ii) Mixers (III) Sewing Machine (iv) Drill Machine (v) Cinema projector.

Sr no.	Problems	Modification
1	As magnetic field is alternating large eddy current and hysteresis loss	Structure is made of silicon steel Stamping
2	Sparking due to poor commutation	Commutating poles are provided.
3	Power factor is low	Compensating winding is provided.

Speed control of universal motor: (3 Marks)

1. Resistance Method
2. Tapping –field method.
3. Centrifugal mechanism

1. Resistance Method: Motor speed is controlled by connecting a variable resistance R in series with the motor.



2. Tapping –field method: Field pole is tapped at various points and speed is controlled by varying the field strength.

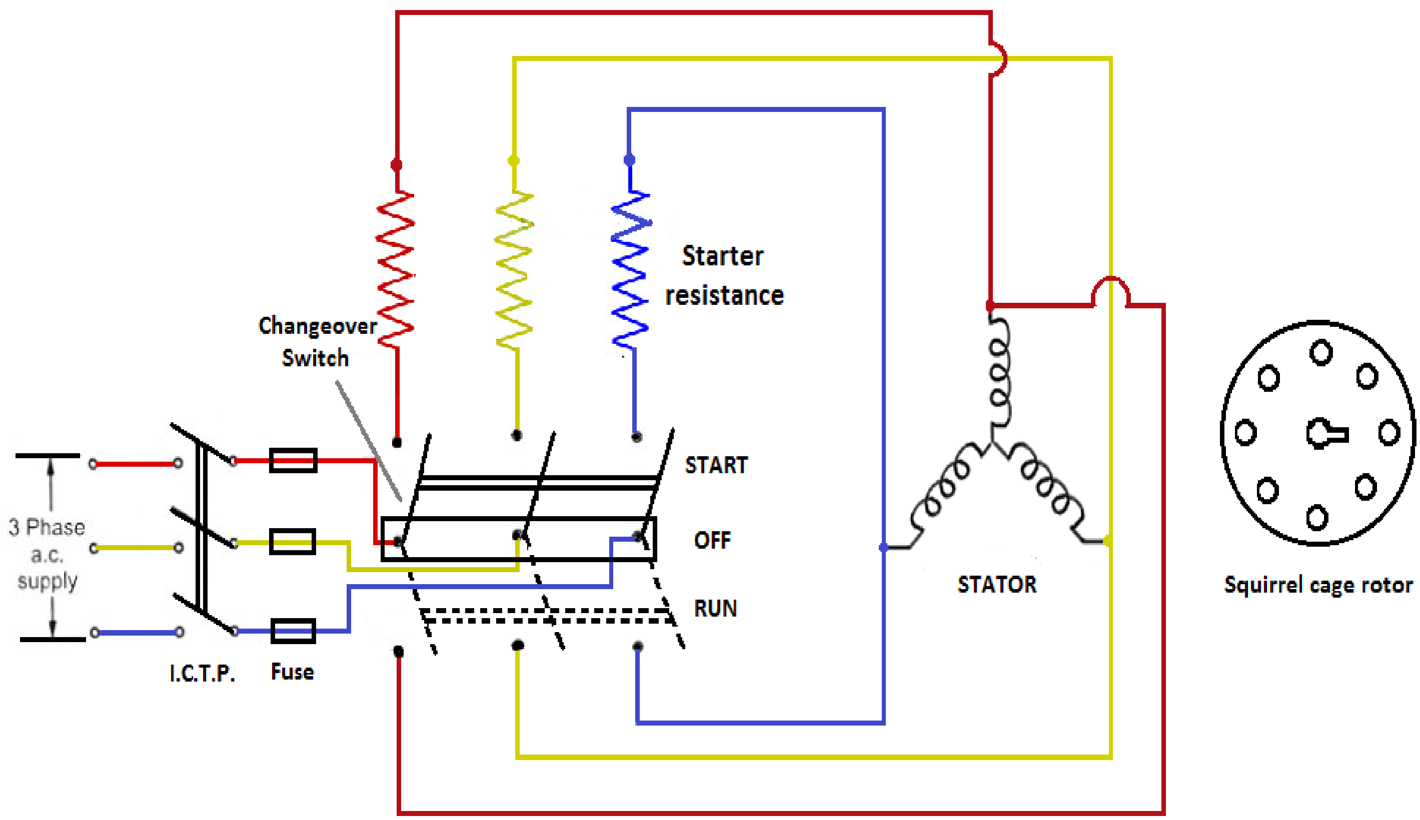
Chart of types of motors and its application

Sr. No.	Purpose	Suitable Motor
1	Printing Press	Capacitor Start Motor
2	Lathe Machine	Capacitor Start Motor
3	Centrifugal Pump	Capacitor Start Motor
4	Electric Drill Machine	Universal Motor
5	Mixer	Universal Motor
6	Sewing Machine	Universal Motor
7	Radiogram Tape Recorder	Shaded pole or synchronous motor
8	Shaving Machine	Shaded pole or synchronous motor
9	Refrigerator	Shaded pole or Capacitor Start / Run Motor
10	Cooler	Capacitor Start Motor
11	Cinema Projector	Universal Motor
12	Ceiling or Table fan	Permanent Capacitor type Motor
13	Wall Clocks	Shaded Pole or 1phase Synchronous Motor
14	Floor Polishing Machine	Repulsion Type Motor
15	Vacuum Cleaner	Universal Motor
16	Toy Motor	Shaded Pole Motor
17	Tape Recorder	1phase Synchronous Motor

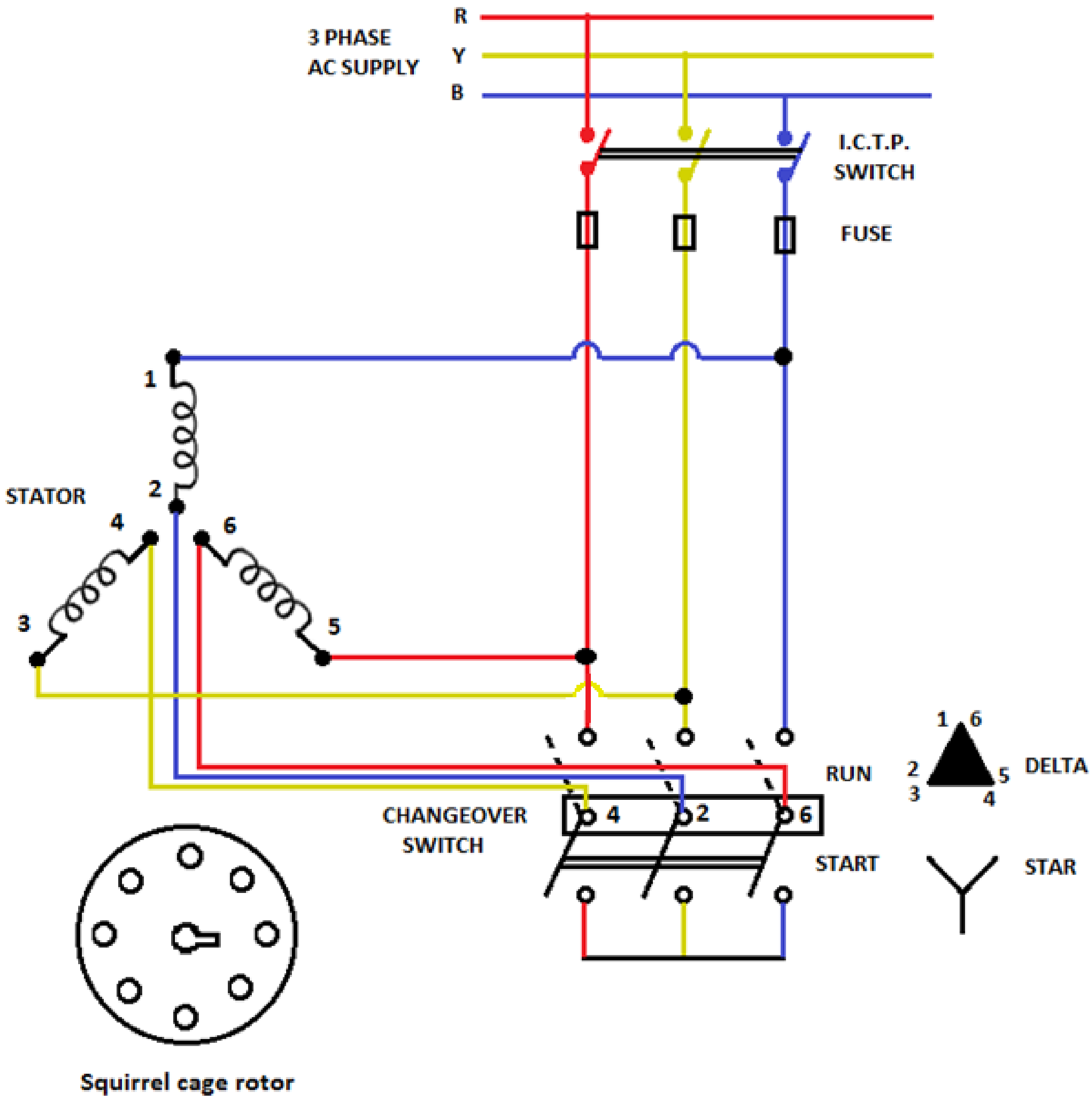
12. STARTERS

1. Stator – Resistance Starter:

- Three equal resistances are connected in each phase of the stator. As these resistances are connected in series with stator windings of the motor, some voltage drops across series resistances and reduced voltage is applied to the motor.
- Thus, motor starts with a reduced voltage & draws less current.
- When the rotor gains 70 to 80% of rated speed, back e.m.f is developed and current gets automatically limited. The handle is moved to 'RUN' position.
- At this position the resistances are cut out & stator receives full voltage & the motor runs with the desired speed
- This starter is used up to 7.5 H.P. motors.



2. Star –delta Starter:

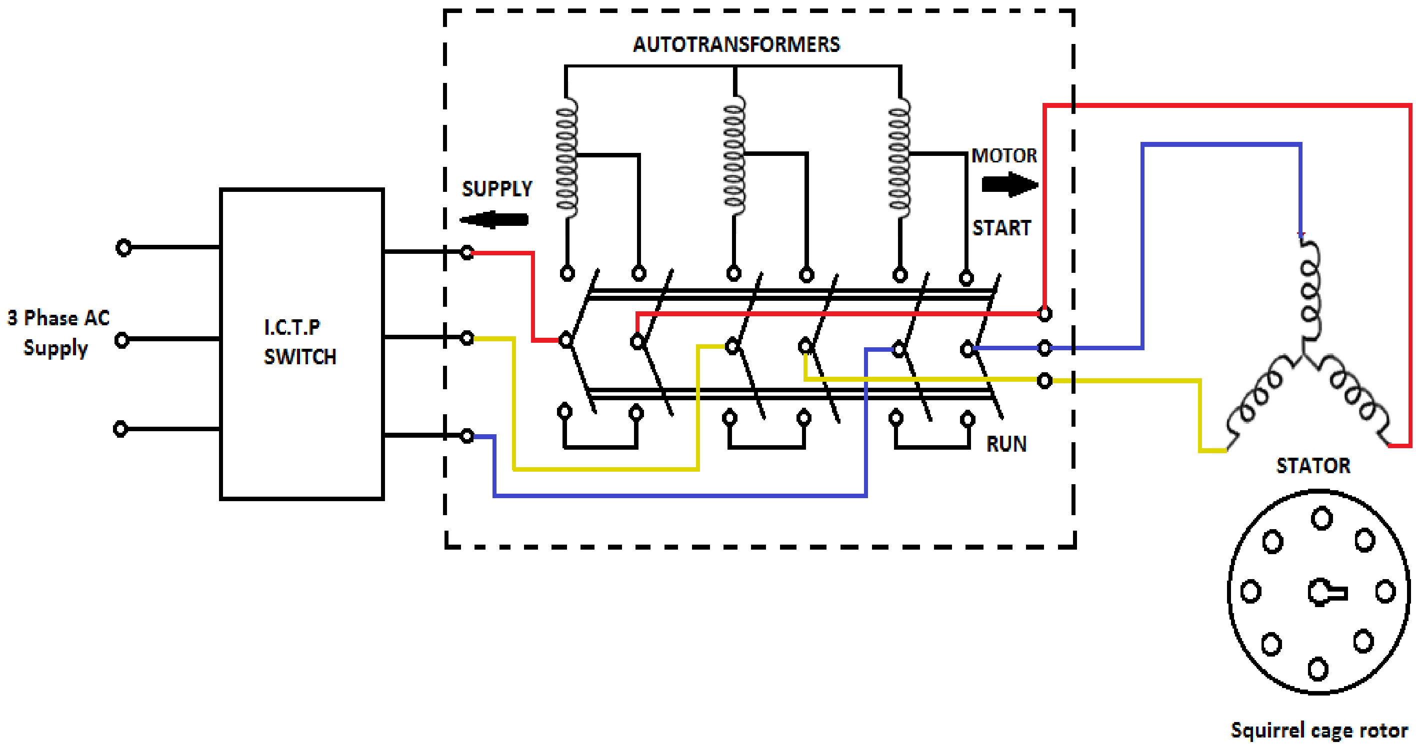


- It is a simple manually operated starter which connects the stator to the supply. At the time of starting the stator windings are connected in star.

- These reduces the voltage, per phase by $\frac{1}{\sqrt{3}}$ times V_L
- This, motor starts with a safer value of current.
- Once the motor gains speed back e.m.f is developed and current gets automatically limited.
- The handle is moved to 'RUN' position and the windings are connected in delta.In delta phase voltage is equal to line voltage. Thus rated line voltage is applied to the motor in running condition.

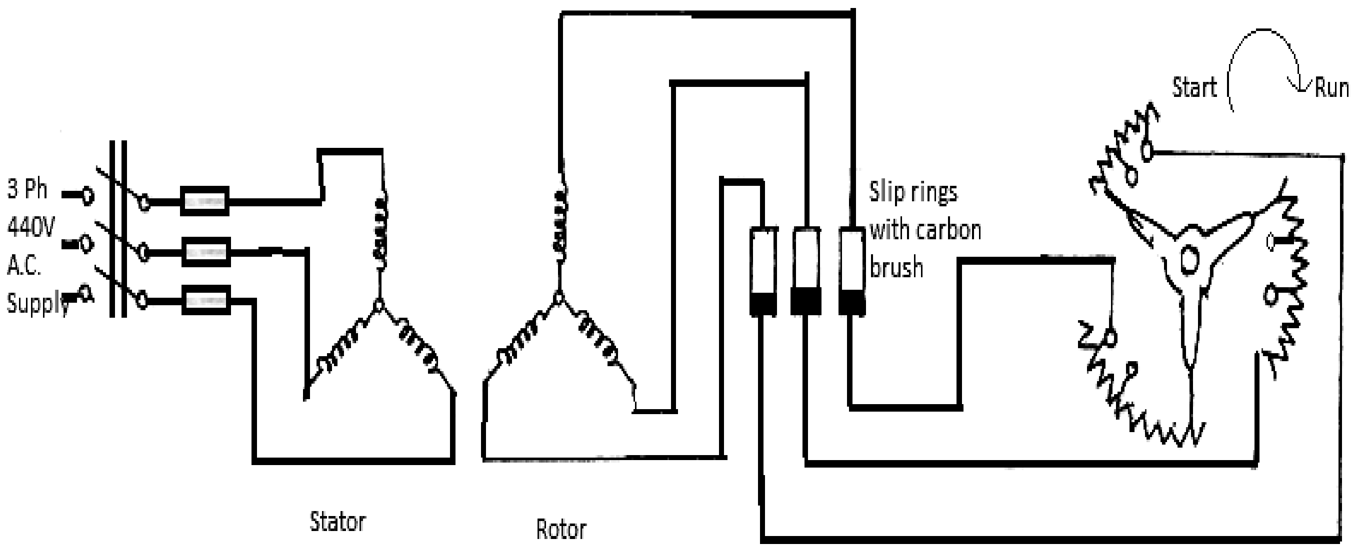
3. Auto transformer starter: -

- Three 1ϕ auto transformers are used for each phase of a 3ϕ motor.
- The tapings are identical for each autotransformer.
- This steps –down the voltage in every phase.
- Thus, the motor starts with the safe current at 'START' & when motor catches speed back e.m.f is developed and current gets automatically controlled , the handle is moved to the 'RUN' position & the motor runs with it, rated capacity.



- **Starter for slip ring (Wound rotor) Motor:**

1. Rotor resistance starter:



(Slip Ring Induction Motor)

Explanation:

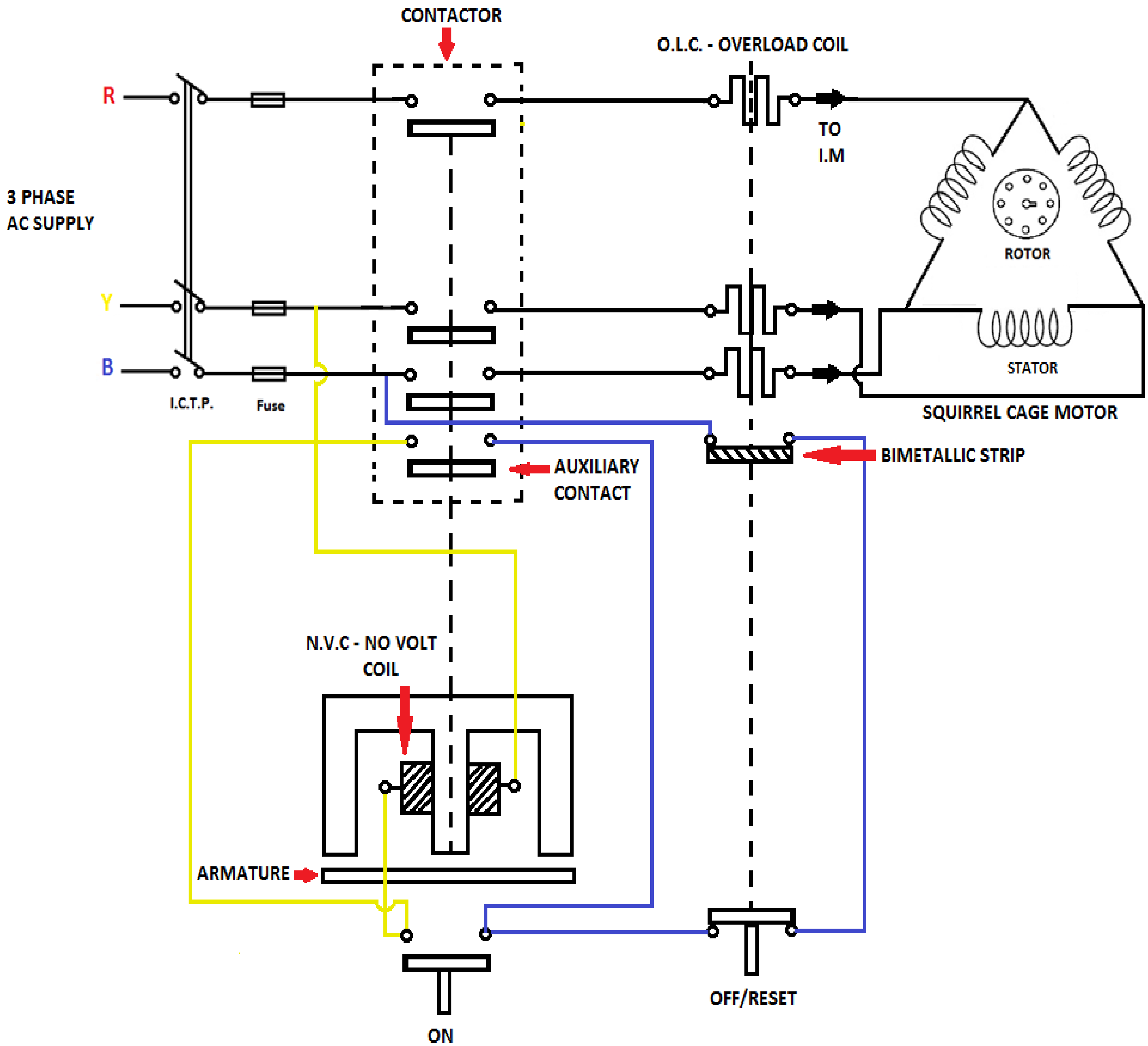
1. At start the three equal resistances in the form of a circular arrangement are connected in the rotor circuit.

2. As external resistance is added in the rotor circuit, the motor starts with safe current.

3. When motor catches speed the handle is moved from 'START' to 'RUN' position gradually, cutting off the resistances from the rotor circuit.

4. There is a switch which prevents starting the motor directly in 'RUN' position of the handle.

- **Direct online starter:**



Starter for both types of motors

D.O.L (Direct ON- LINE Starters): -

Explanation:

- This is called direct on line starter because when the starter is switched 'ON' the motor is connected directly to the supply lines.

- The working voltage of N.V.C is 440 V
- It is suitable for motors up to 5 H.P.
- The starter has a magnetic coil 'A' wound on the attracted armature type of relay. When switch is 'ON' it gets energized and the armature 'B' is attracted. The set of contacts 'C' in the contactor is made 'ON' and supply is given to the motor. The auxiliary contact at the bottom enables the coil to remain in the circuit even if the 'ON' button is released. The motor is thus started through bimetallic strips 'D'.
- If supply fails the coil releases the armature and motor is disconnected from supply.
- If motor is over loaded the strips 'D' bend downwards disconnecting the motor from the supply.

13. Poly-Phase Circuits

Introduction:

There are two types of system available in electric circuit, single phase and three phase system. In single phase circuit, there will be only one phase, i.e. the current will flow through only one wire and there will be one return path called neutral line to complete the circuit. So in single phase minimum amount of power can be transported.

Three phase circuit is the poly phase system where three phases are send together from the generator to the load. Each phase is having a phase difference of 120^o, i.e. 120^o angle electrically. So from the total of 360^o, three phases are equally divided into 120^o each. The power in three phase system is continuous as all the three phases are involved in generating the total power.

In three phase circuit, connections can be given in two types:

1. Star connection 2. Delta connection

Poly phase Supply:

1. **Production of three phase Voltage**

- In a 3 phase system, there are three equal voltages or EMFs of the same frequency having a phase difference of 120 degrees.
- These voltages can be produced by a three-phase AC generator having three identical windings displaced apart from each other by 120 degrees electrical.
- When these windings are kept stationary and the magnetic field is rotated as shown in the figure below or when the windings are kept stationary, and the magnetic field is rotated as shown below in figure B, an e.m.f is induced in each winding.
- The magnitude and frequency of these EMFs are same but are displaced apart from one another by an angle of 120 degrees.

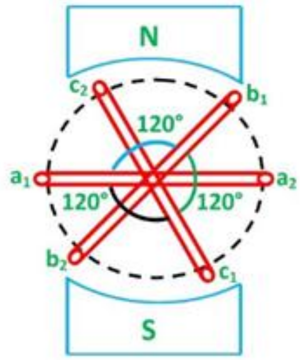


Fig. A three phase windings

- Consider three identical coils a_1a_2, b_1b_2 and c_1c_2 as shown in the above figure. In this figure a_1, b_1 and c_1 are the starting terminals, whereas a_2, b_2 and $c_2$are the finish terminals of the three coil.
- The phase difference of 120 degrees has to be maintained between the starts terminals a_1, b_1 and c_1. Now, let the three coils mounted on the same axis, and they are rotated by either keeping coil stationary or moving the magnetic field or vice versa in an anticlockwise direction at (ω) radians per seconds. Three EMFs are induced in the three coils respectively.

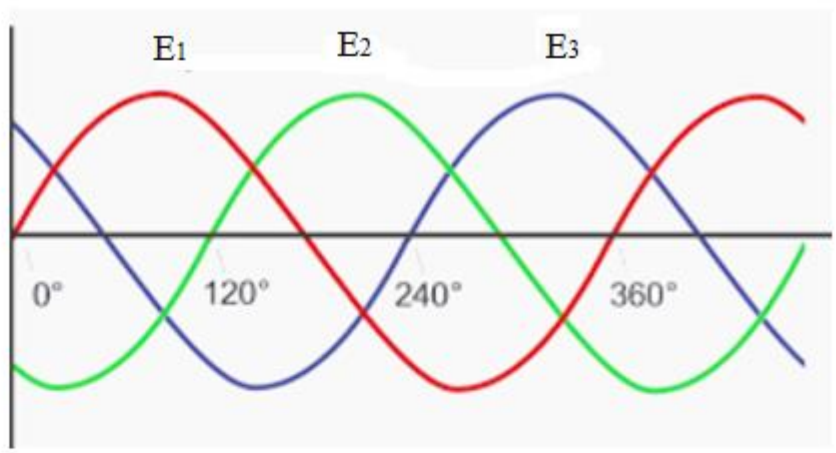


Fig.B three phase wave

- The e.m.f induced in the coil a_1a_2 is zero and is increasing in the positive direction as shown by the waveform in the above fig. represented as E_1
- The coil b_1b_2 is 120 degrees electrically behind the coil a_1a_2. The e.m.f induced in this coil is negative and is becoming maximum negative as shown by the wave E_2

- Similarly, the coil c_1c_2 is 120 degrees electrically behind the coil b_1b_2, or we can also say that the coil c_1c_2 is 240 degrees behind the coil a_1a_2. The e.m.f induced in the coil is positive and is decreasing as shown in the fig.B represented by the waveform E_3.
- The EMFs induced in the three coils in a 3 phase circuits are of the same magnitude and frequency and are displaced by an angle of 120 degrees from each other as shown below in the phasor diagram.

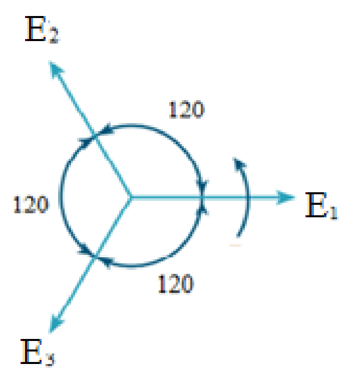


Fig. C phasor diagram

$E_R = E_m \sin \omega t$
$E_Y = E_m \sin (\omega t - 120)$
$E_B = E_m \sin (\omega t - 240)$

Thus three are produced which are out of phase by 120^0 electrical.

Star Connection:

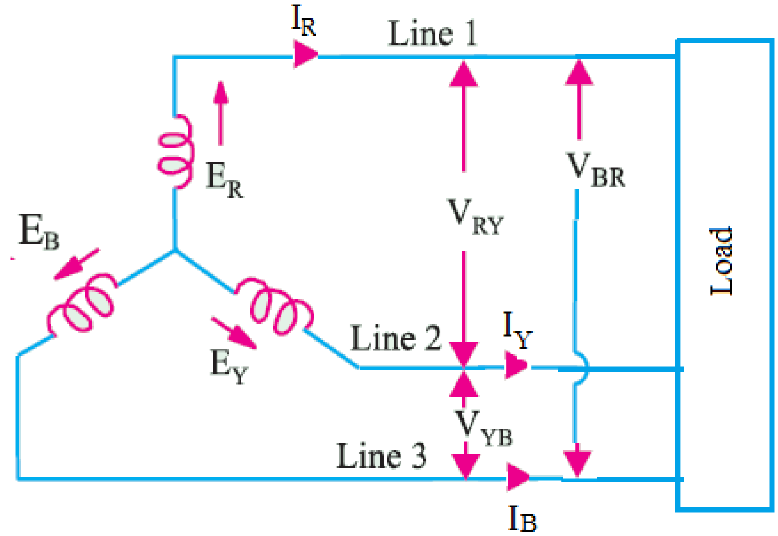


Fig. Star Connection

- The voltage induced in each winding is called the phase voltage and current in each winding is known as phase current.
- However, the voltage available between any pair of terminals (or outers) is called line voltage (V_L) and the current flowing in each line is called line current (I_L).
- As seen from Fig. D in this form of interconnection, there are two phase windings between each pair of terminals but since their similar ends have been joined together, they are in opposition. Obviously, the instantaneous value of voltage between any two terminals is the arithmetic difference of the two phase e.m.f. Concerned. However, the r.m.s. value of this voltage is given by the vector difference of the two phase e.m.f.

Line voltage V_{RY} between line 1 and line 2 is the vector difference of E_R and E_Y.
Line voltage V_{YB} between line 2 and line 3 is the vector difference of E_Y and E_B.
Line voltage V_{BR} between line 3 and line 1 is the vector difference of E_B and E_R.

- **Line Voltages and Phase Voltages**

The Voltage between line 1 and 2 is

$$\mathbf{V_{RY} = E_R - E_Y}$$

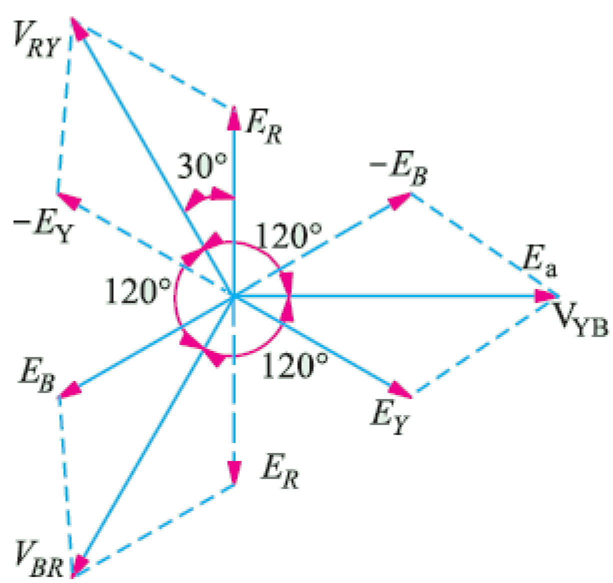


Fig. E phasor diagram of Star Connection

Hence, V_{RY} is found by compounding E_R and E_Y reversed and its value is given by the diagonal of the parallelogram of Fig. E Obviously, the angle between E_R and E_Y reversed is 60°. Hence if $E_R = E_Y = E_B$ = Eph (phase e.m.f.) then

$$V_{RY} = 2 \times E_{ph} \times \cos(60^0/2)$$
$$= 2 \times E_{ph} \times \cos(30^0)$$
$$= 2 \times E_{ph} \times \frac{\sqrt{3}}{2}$$
$$V_{RY} = \sqrt{3}\, E_{ph}$$

Similarly, $V_{YB} = E_Y - E_B = \sqrt{3}\, E_{ph}$

$V_{BR} = E_B - E_R = \sqrt{3}\, E_{ph}$

Hence, in star connection

$$\boxed{V_L = \sqrt{3}\, V_{ph}}$$

- **Line Current and Phase Current**

It is seen from Fig. D that each line is in series with its individual phase winding; hence the line current in each line is the same as the current in the phase winding to which the line is connected.

Current in line 1 = I_R ;

Current in line 2 = I_Y;

Current in line 3 = I_B

$$\boxed{I_R = I_Y = I_B = I_{ph}}$$

The total active or true power in the circuit is the sum of the three phase powers.
Hence,

$$P = 3 \times V_{ph}\, I_{ph} \cos \varphi$$

For Star connection $V_{ph} = \frac{V_L}{\sqrt{3}}$ & $I_{ph} = I_L$

Hence, in terms of line values, the above expression becomes

$$\boxed{P = \sqrt{3} \times V_L\, I_L \cos \varphi}$$

- **Delta Connection:**

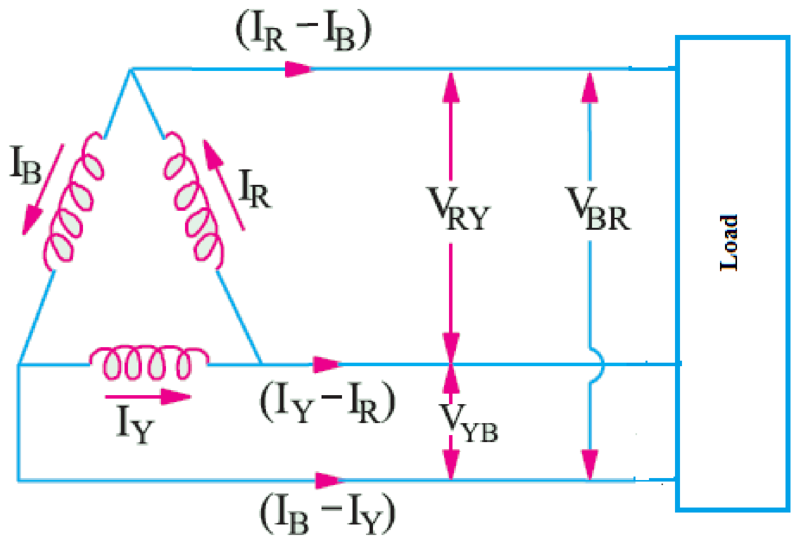


Fig. Delta Connection

- In this form, of interconnection the dissimilar ends of the three phase winding are joined together i.e. the ‘starting’ end of one phase is joined to the ‘finishing’ end of the other phase and so on as showing in fig.above.
- In other words, the three windings are joined in series to form a closed mesh. Three leads are taken out from the three junctions as shown as outward directions are taken as positive. It might look as if this sort of interconnection results in short circuiting the three windings.
- However, if the system is balanced then sum of the three voltages round the closed mesh is zero, hence no current of fundamental frequency can flow around the mesh when the terminals are open. It should be clearly understood that at any instant, the e.m.f. in one phase is equal and opposite to the resultant of those in the other two phases.

Line Voltages and Phase Voltages

- It is seen from Fig.above that there is only one phase winding completely included between any pair of terminals. Hence, in Δ-connection, the voltage between any pair of lines is equal to the phase voltage of the phase winding connected between the two lines considered.
- Since phase sequence is R Y B, the voltage having its positive direction from R to Y leads by 120° on that having its positive direction from Y to B. the voltage between lines 1 and 2 as V_{RY} and that between

lines 2 and 3 as V_{YB}, we find that V_{RY} lead V_{YB} by 120°. Similarly, V_{YB} leads V_{BR} by 120º. $V_{RY} = V_{YB} = V_{BR}$ = line voltage V_L. Then, it is seen that

$$\boxed{V_L = V_{ph}.}$$

- **Line Currents and Phase Currents:**

It will be seen from Fig. Above that current in each line is the vector difference of the two Phase currents flowing through that line. For example

Current in line 1 I_1 is the vector difference between I_R & I_B

Current in line 2 I_2 is the vector difference between I_Y & I_R

Current in line 2 I_2 is the vector difference between I_B & I_Y

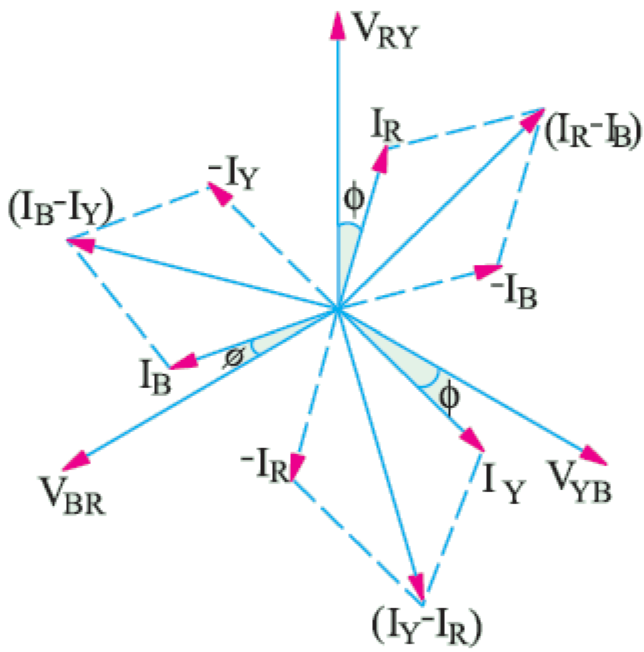


Fig.b Phasor diagram Delta Connection

Current in line No. 1 is found by compounding I_R and I_B reversed and its value is given by the diagonal of the parallelogram of Fig. 19.25. The angle between I_R and I_B reversed

(i.e. – IB) is 60°. & $I_R = I_Y = I_C = I_{ph}$

Current in line No. 1 is

$I_1 = 2 \times I_{ph} \times \cos(60º/2)$

$I_1 = 2 \times I_{ph} \sqrt{3}/2$

$I_1 = \sqrt{3}\, I_{ph}$

Similarly Current in line No. 2 is $I_2 = \sqrt{3}\, I_{ph}$

Current in line No. 3 is $I_3 = \sqrt{3}\, I_{ph}$

Therefore for delta connection

$$\boxed{I_L = I_{ph}}$$

The total active or true power in the circuit is the sum of the three phase powers.
Hence,

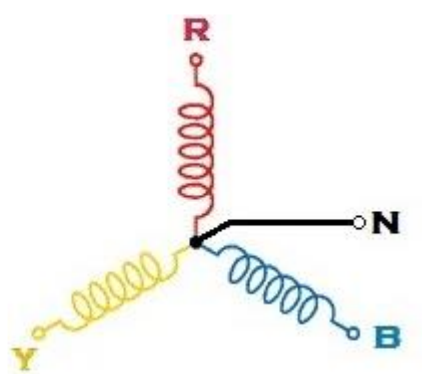
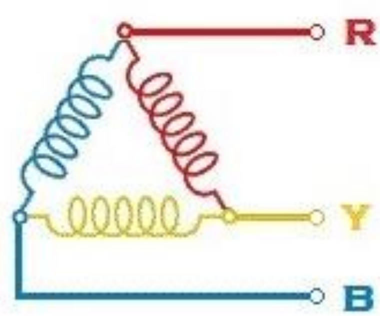
$$P = 3 \times V_{ph}\, I_{ph} \cos \varphi$$

For delta connection $I_{ph} = \frac{I_L}{\sqrt{3}}$ & $V_{ph} = V_L$

Hence, in terms of line values, the above expression becomes

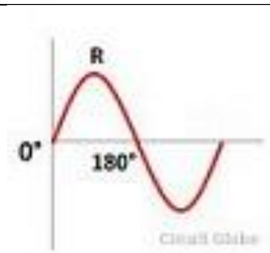
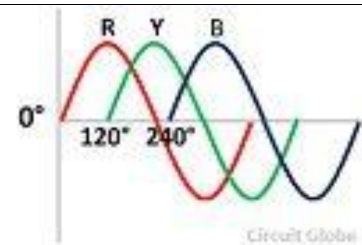
$$\boxed{P = \sqrt{3} \times V_L\, I_L \cos \varphi}$$

- **Comparison between Star & Delta Connection:**

Basics	Star Connection	Delta Connection
Diagram		
Basic Definition	The terminals of the three branches are connected to a common point. The network formed is known as Star Connection	he three branches of the network are connected in such a way that it forms a closed loop known as Delta Connection
Neutral point	Neutral or the star point exists in the star connection.	Neutral point does not exist in the delta connection.

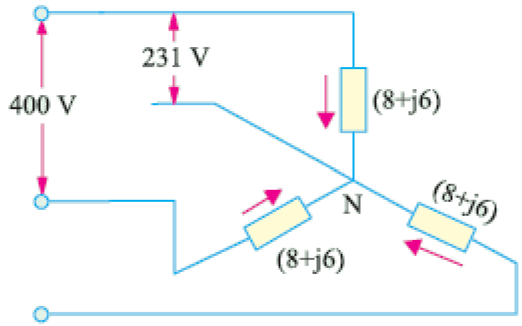
Relation between line and phase current	Line current is equal to the Phase current. $I_L = I_{ph}$	Line current is equal to root three times of the Phase Current. $I_L = \sqrt{3} I_{ph}$
Relation between line and phase voltage	Line voltage is equal to root three times of the Phase Voltage $V_L = \sqrt{3}\, V_{ph}$	Line voltage is equal to the Phase voltage $V_L = V_{ph}$.
Power	Power in star connection is 1/3 of the power in delta for same connection	Power in delta connection is 3 times of the power in star for same connection
Applications	Alternator and distribution transformer secondary is star Connected	Transmission transformer secondary is delta connected

- <u>**Comparison between Single phase & three phase:**</u>

Basis For Comparison	Single Phase	Three Phase
Definition	The power supply through one conductor.	The power supply through three conductors
Wave Shape		
Number of wire	Require two wires for completing the circuit	Requires four wires for completing the circuit
Voltage	Carry 230V	Carry 415V
Power Transfer Capability	Minimum	Maximum
Circuit Construction	Simple	Complex
Loss	Maximum	Minimum
Efficiency	Low	High
Economical	Less	More
Uses	For home appliances.	In large industries and for running heavy loads

Solved Problems:

Example:- A balanced star-connected load of (8 + j6) Ω per phase is connected to a balanced 3-phase 400-V supply. Find the line current, power factor, power and power.



Given data:- $R = 8\Omega$

$X = 6\Omega$

$V_L = 400V$

To Find:- I_L, $\cos ø$, P

Formula:- For Star Connection

$V_L = \sqrt{3}\, V_{ph}$

$I_L = I_{ph}$

Solution:- $Z_{ph} = \sqrt{(8^2 + 6^2)} = 10\Omega$

$Vph = \dfrac{V_L}{\sqrt{3}}$

$= 400 / 3$

$\boxed{V_{ph} = 231\ V}$

$I_{ph} = V_{ph} / Z_{ph}$

$= 231/ 10$

$\boxed{I_{ph} = 23.1\ A}$

Power Factor $\cos ø = \dfrac{R_{ph}}{Z_{ph}}$

$= 8/10$

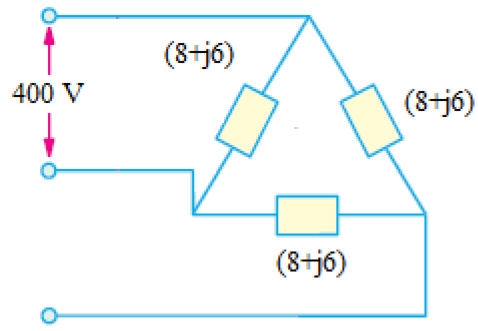
$\boxed{\cos ø = \mathbf{0.8\ (lag)}}$

Power $P = \sqrt{3}\, V_L\, I_L \cos ø$

$= \sqrt{3} \times 400 \times 23.1 \times 0.8$

$\boxed{P = \mathbf{12,800\ W}}$

Example- A balanced Delta-connected load of (8 + j6) Ω per phase is connected to a balanced 3-phase 400-V supply. Find the line current, power factor, power and power.



Given data:- $R = 8\Omega$

$X = 6\Omega$

$V_L = 400V$

To Find:- I_L, $\cos ø$, P

Formula:- For Delta Connection

$V_L = V_{ph}$

$I_L = \sqrt{3}\, I_{ph}$

Solution:- $Z_{ph} = \sqrt{(8^2 + 6^2)} = 10\Omega$

$V_{ph} = V_L = 400V$

$I_{ph} = \frac{V_{ph}}{Z_{ph}}$

$I_{ph} = \frac{400}{10}$

$\boxed{I_{ph} = 40A}$

$I_L = \sqrt{3}\, I_{ph}$

$= \sqrt{3}\; 40$

$\boxed{I_L = 69.28\ A}$

Power Factor $\cos ø = \frac{R_{ph}}{Z_{ph}}$

$= 8/10$

$\boxed{\cos ø = \mathbf{0.8\ (lag)}}$

Power $P = \sqrt{3}\, V_L\, I_L \cos ø$

$= \sqrt{3} \times 400 \times 69.28 \times 0.8$

$\boxed{P = \mathbf{38{,}398\ W}}$

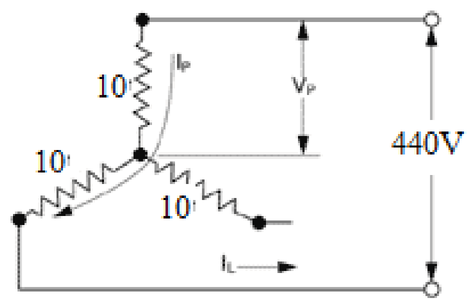
Example- Three resistance each of 10Ω resistance are connected in a) Star b) Delta across 440V 3 phase AC supply Find the power consumed in each case find the ratio of power in delta to star.

Given data:- $R_{ph} = 10\ \Omega$

$V_L = 440V$

To find :- P_{star} , P_{delta}

Solution :- **For Star Connection**



$Z_{ph} = \sqrt{(10^2 + 0^2)} = 10\Omega$

$Z_{ph} = 10\ \Omega$

$I_{ph} = \frac{V_{ph}}{Z_{ph}}$

$I_{ph} = \frac{\frac{440}{\sqrt{3}}}{10}$

$\boxed{I_{ph} = 25.4\ A}$

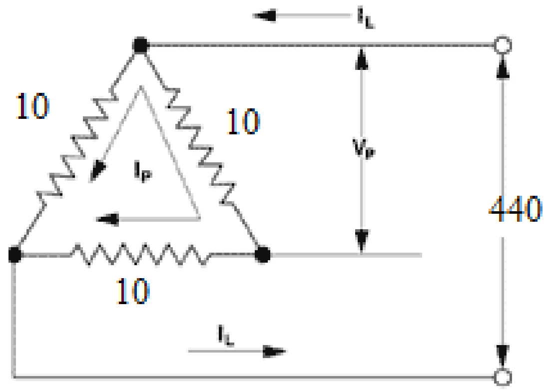
cos ø = 1

$P = \sqrt{3}\, V_L I_L \cos ø$

$= \sqrt{3}\ 440 \times 25.4\ \times 1$

$\boxed{P_{star} = 19{,}357\ \text{Watt}}$

For Delta Connection



$V_L = V_{ph} = 440$ V

$I_p = V_{ph} / 10$

$I_p = 44$ A

$P_{delta} = \sqrt{3}\, V_L\, I_L \cos ø$

$= \sqrt{3} \times 440 \times 44 \times 1$

$\boxed{P_{delta} = 33{,}532 \text{ Watt}}$

Example for practice

Example:- .A balanced 3 phase delta connected load consisting in each phase a resistance and inductive reactance of 5 Ω and 4Ω respectively is connected to 3 phase 400V 50 Hz. Calculate Line current phase current line voltage phase voltage and total power.

Example:- A balanced 3 phase star connected load of (10+j6) is supplied from 3 phase 440V 50 Hz supply Calculate the total power and power factor .

Example:- A balanced 3 phase star connected load is supplied with 3 phase 400V 50 Hz supply the phase current of 10 A and p f is 0.6 Lagging calculate total power.

Example:- A balanced 3 phase delta connected load consisting in each phase a resistance and inductive reactance of 9 Ω and 6 Ω respectively is connected to 3 phase 400V 50 Hz. Calculate Line current phase current line voltage phase voltage and total power