CURRENT ELECTRICITY

ELECTRIC CHARGE – It is a physical entity which is defined by excess or deficiency of electrons on a body.

S.I. unit ⇒ coulomb (C)

The total charge acquired by a body is an integral multiple of magnitude of charge on a single electron. This principle is called quantisation of charge.

$$\boxed{q = ne}$$

q = total charge
n = number of electrons
e = charge on 1 electron = 1.6×10^{-19} C

$1\,mC = 10^{-3}\,C$, $1\,\mu C = 10^{-6}\,C$, $1\,nC = 10^{-9}\,C$

CURRENT – Rate of flow of charge.

$$\boxed{I = \frac{Q}{t}}$$

I = current
Q = charge
t = time

S.I. unit ⇒ ampere (A)
$1\,mA = 10^{-3}\,A$, $1\,\mu A = 10^{-6}\,A$

$$I = \frac{Q}{t} = \frac{ne}{t}$$

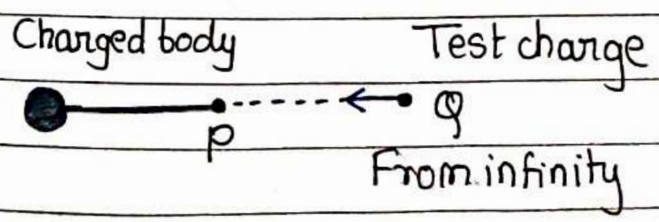
NOTE – Direction of current is taken opposite to the flow of electrons.

ELECTRIC POTENTIAL – Potential at a point is defined as the amount of work done in bringing a unit positive charge from infinity to that point.
It is a scalar quantity

$$\boxed{V = \frac{W}{Q}}$$

V = potential
W = workdone
Q = charge

S.I. unit ⇒ JC^{-1} or volt (V)



POTENTIAL DIFFERENCE (p.d.) – The p.d. between two points is equal to the work done in moving a unit positive charge from one point to the other.

S.I. unit ⇒ volt (V)

$$V_A - V_B = \frac{W}{Q}$$

RESISTANCE – The obstruction offered to the flow of current by the conductor (or wire) is called its resistance.

OHM'S LAW – According to Ohm's law the current flowing in a conductor is directly proportional to the potential difference applied across its ends provided the physical conditions and the temperature of conductor remain constant.

$$I \propto V$$

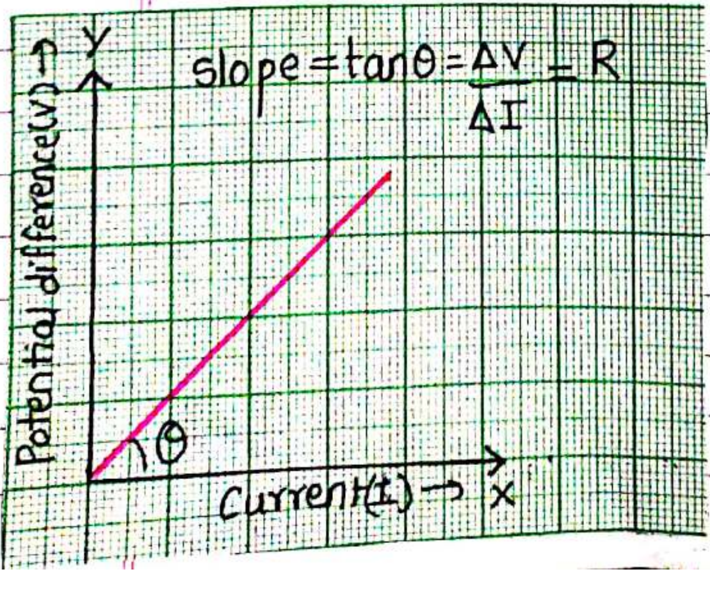
$$\frac{V}{I} = \text{constant}$$

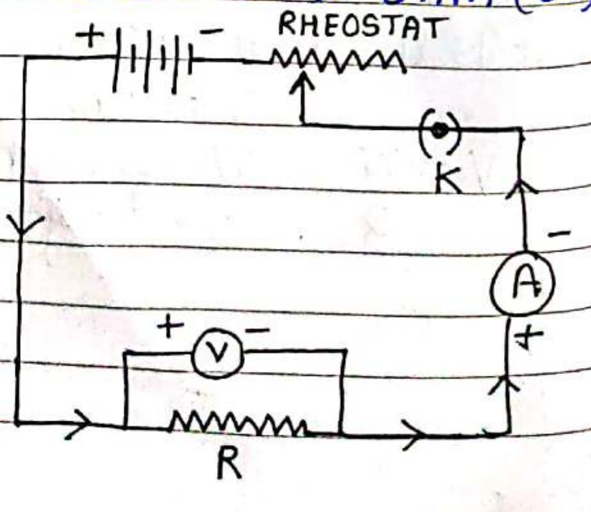
$$V = IR$$

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

Resistance of a conductor is numerically equal to the p.d. across its ends when unit current flows through it.

S.I. unit is ⇒ ohm (Ω)





OHMIC AND NON-OHMIC RESISTORS

Ohmic resistor	Non Ohmic resistor
1) Obey's Ohm's law.	1) Do not obey Ohm's law.
2) V-I graph is a straight line.	2) V-I graph is not straight line.
3) slope of V-I graph is same at all values.	3) Slope of V-I graph is different for different values.
Eg ⇒ silver, iron, copper, nichrome.	Eg ⇒ junction diode, LED, transistor, filament of bulb.

Factors affecting the resistance of a conductor –

1) Nature of conductor
2) length of conductor, $R \propto l$
3) Area of cross section of conductor. $R \propto \frac{1}{A}$
4) Temperature

$R \propto l$

$R \propto \frac{1}{a}$ or $R \propto \frac{1}{\pi r^2}$

$$R \propto \frac{l}{a} \text{ or } R = \frac{\rho l}{a} = \frac{\rho l}{\pi r^2}$$

SPECIFIC RESISTANCE OR RESISTIVITY (ρ)

It is the resistance of a wire of that material of unit length and unit area of cross section.

S.I. unit ⇒ Ωm

CONDUCTIVITY – The reciprocal of specific resistance is known as conductivity (σ)

$$\sigma = \frac{1}{\rho} = \frac{l}{Ra}$$

S.I. unit ⇒ $\Omega^{-1} m^{-1}$

CONDUCTANCE – Reciprocal of resistance.

$$\text{Conductance} = \frac{1}{R}$$

S.I. unit ⇒ Ω^{-1}

SUPERCONDUCTOR - It is a substance of zero resistance (or infinite conductance) at a very low temperature.

ELECTROMOTIVE FORCE (E.M.F.) OF A CELL -

The emf of a cell is defined as the energy spent (or the work done) per unit charge in taking a positive test charge around the complete circuit of cell.

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

Factors affecting the e.m.f. of a cell -

i) Shape of electrodes
ii) distance b/w electrodes
iii) amount of electrolyte

TERMINAL VOLTAGE OF A CELL -

The terminal voltage of a cell is defined as the work done per unit charge in carrying a positive test charge around the circuit connected across the terminals of cell.

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

VOLTAGE DROP IN A CELL - Work done in carrying a unit charge through the electrolyte is called voltage drop in the cell

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

Relationship between e.m.f. and terminal voltage of a cell.

$$\varepsilon = V + v$$

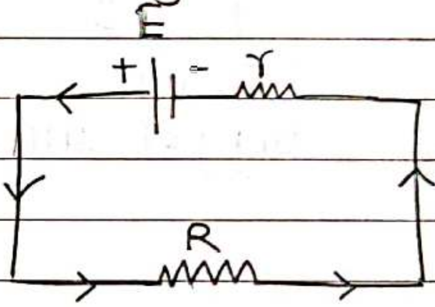
INTERNAL RESISTANCE OF A CELL - Resistance offered by the electrolyte inside the cell, to the flow of current is called internal resistance of cell.

$$\boxed{V = Ir}$$

Factors affecting internal resistance of a cell -

1) Surface area of electrodes
2) distance between the electrodes
3) Nature & concentration of electrolyte
4) Temperature of electrolyte

Relationship between emf, terminal voltage and internal resistance -



Total resistance = $R + r$

Current drawn from cell, $I = \dfrac{E}{R+r}$

emf $(E) = I(R+r)$

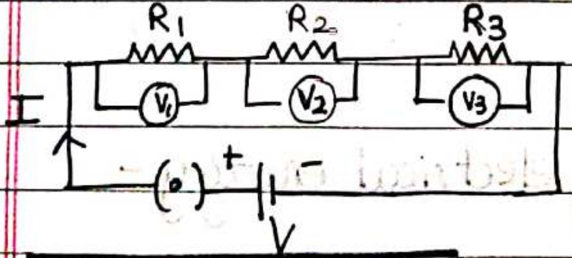
Terminal voltage of cell, $V = IR = E - Ir$

Voltage drop due to internal resistance $= Ir$

Internal resistance, $r = \dfrac{E-V}{I} = \dfrac{E-V}{V/R} = \left[\dfrac{E}{V} - 1\right]R$

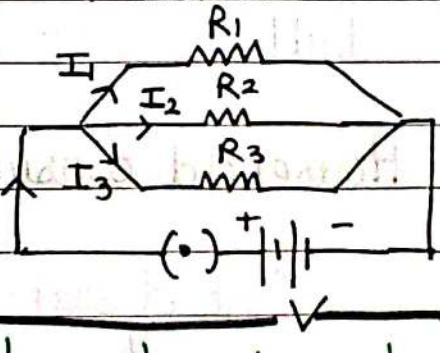
COMBINATION OF RESISTORS

SERIES



$$\boxed{R = R_1 + R_2 + R_3}$$

PARALLEL



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

MEASUREMENT OF ELECTRICAL ENERGY - (E)

E = Work done

$$W = QV = VIt = I^2Rt = \frac{V^2t}{R}$$

S.I. unit ⇒ joule (J)

ELECTRICAL POWER - The rate at which electrical energy is supplied by the source.

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

S.I. unit ⇒ watt (W) or Js^{-1}

Bigger units ⇒ 1 kW = 1000 W

1 MW = 10^6 W

1 HP = 746 W

Commercial unit of electrical energy -

1 kWh = 3.6×10^6 J

Power rating of common electrical appliances -

i) Resistance of filament of bulb, $R = \frac{V^2}{P}$

ii) Safe current limit through the filament of the bulb, $I = \frac{P}{V}$

Household consumption of electrical energy -

Cost of electricity = electrical energy (in kWh) × cost per kWh

Date
Page

HEATING EFFECT OF ELECTRIC CURRENT -

The heat produced in a wire on passing current through it is called heating effect of current. This is known as Joule's law of heating.

$$H = I^2Rt \text{ (in joule)} = 0.24 I^2Rt \text{ (in cal)}$$

FORMULA SHEET

1) $I = \frac{Q}{t} = \frac{ne}{t}$

2) $V = \frac{W}{Q}$, $V_A - V_B = \frac{W}{Q}$

3) $V = IR$

4) Conductance $= \frac{1}{R}$

5) $R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2}$

6) Conductivity $(\sigma) = \frac{1}{\rho} = \frac{l}{RA}$

7) EMF $(E) = \frac{W}{q}$

8) Terminal voltage $(V) = \frac{W'}{q}$

9) $E = I(R+r)$

10) $r = \left(\frac{E}{V} - 1\right)R$

11) Series combination
$R = R_1 + R_2 + \ldots + R_n$

12) Parallel combination
$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$

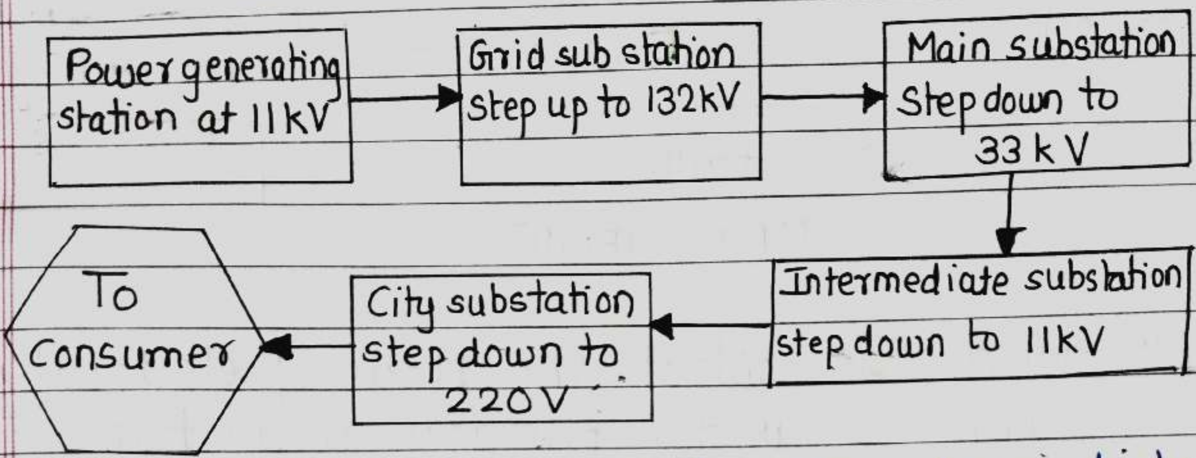
13) Electrical energy
$W = QV = VIt = I^2Rt = \frac{V^2t}{R}$

14) Electrical Power
$P = \frac{W}{t} = VI = \frac{V^2}{R} = I^2R$

15) $H = I^2Rt$ (in joule)
$H = 0.24 I^2Rt$ (cal)

HOUSEHOLD CIRCUITS

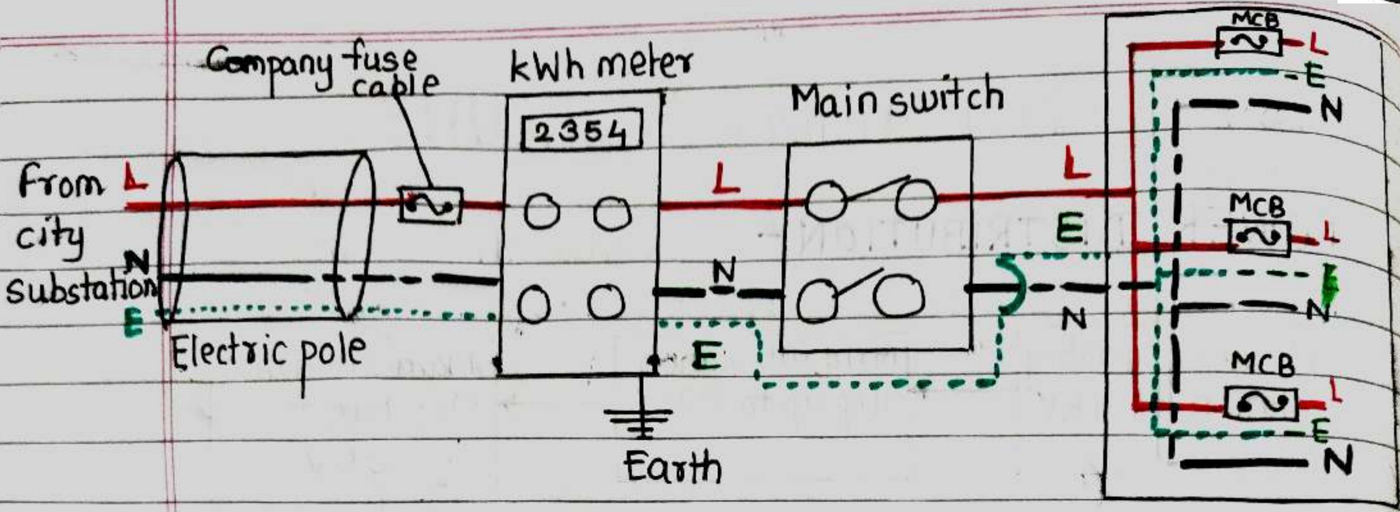
POWER DISTRIBUTION –



The power is transmitted over a long distance at a high voltage to minimise the loss of energy in the form of heat in the line wire. At high voltage, the value of current is very less, therefore heat produced, $H = I^2RT$, will also be less.

POWER DISTRIBUTION TO HOUSE (COMPONENTS OF HOUSEHOLD ELECTRIC CIRCUIT)

1) MAIN CIRCUIT – Electricity is transmitted to home via two wires: the live wire (220V) and the neutral wire (0 V). The live wire carries current, while the neutral wire returns it. An earth wire ensures safety. The main fuse is in live wire and the main switch controls both live and neutral wires. Homes have two separate circuits: a 5 A fuse for lighting and a 15 A fuse for power devices.



MAIN CIRCUIT

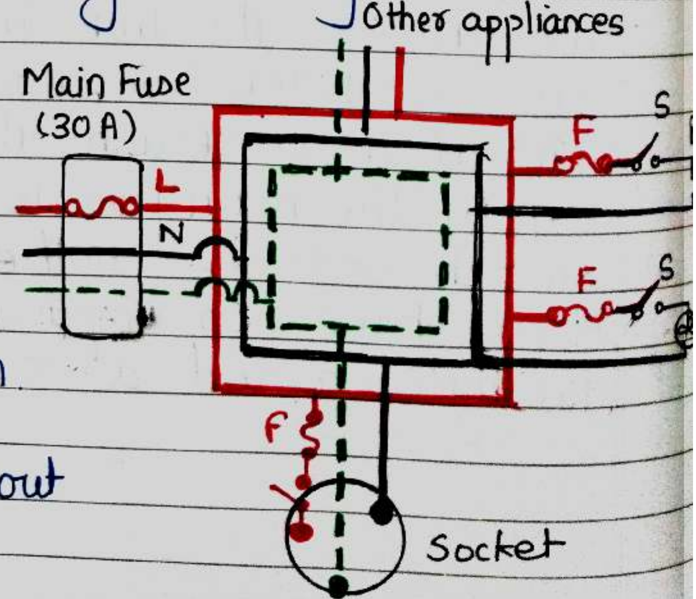
MAIN SWITCH – It controls the flow of electricity to the home. It is the primary connection between the external power supply and home's wiring. The main switch is often a double pole switch, which means it can break the connection to both the neutral wire and live wire at the same time.

HOUSE WIRING (RING SYSTEM) – In this system wires starting from main fuse box run around all the rooms of house and then come back to fuse box again forming the ring.

Advantage –

i) Each appliance can operate independently without affecting the other appliances connected in the system

ii) New appliance can be connected directly without new wiring.



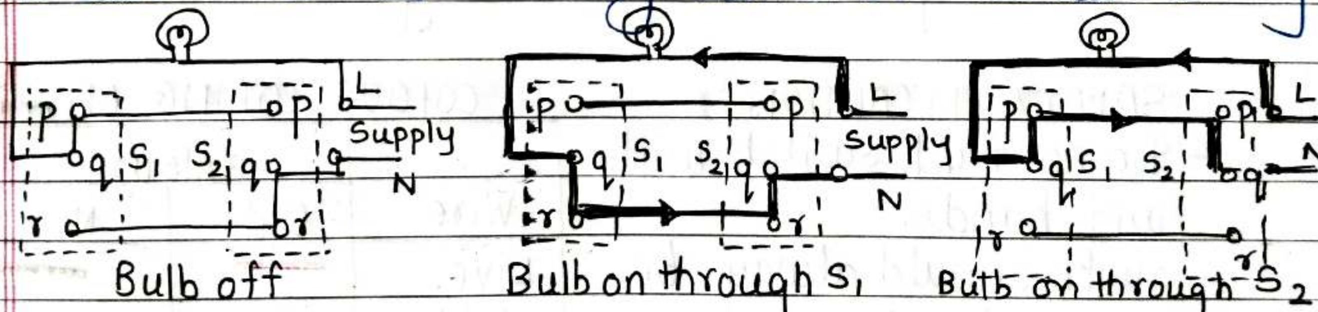
FUSE – An electric fuse is a safety device which is used to limit the current in an electric circuit. Fuse safeguards the circuit and the appliances connected in that circuit from being damaged.

- Thin wire of tin (25%) & lead (75%) alloy
- Low melting point (≈200°C)
- works on the principle of heating effect of current
- Always connected to live wire before appliance.

$$\text{Current rating of fuse} = \frac{\text{Total power of appliances in circuit}}{\text{Voltage of supply}}$$

SWITCH – A switch is an on-off device for current in a circuit. It is connected to live wire in series.

Dual control switch (Staircase wiring) – Switch that controls a load from two different locations. It is also known as multiway switch or staircase wiring



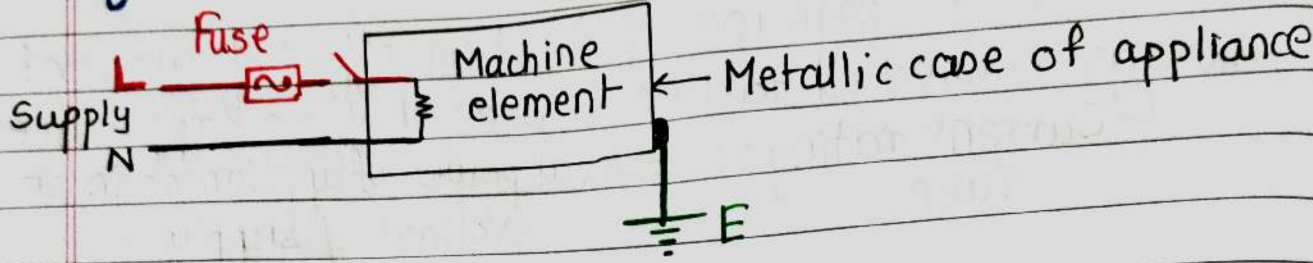
MCB – (Miniature circuit breaker)

- Safety device, automatically shuts off an electrical circuit when there is power surge or short circuit.

Advantage – More reliable than fuses because they can be reset instead of replaced.

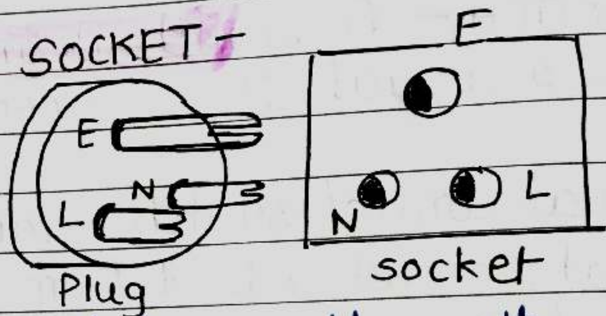
EARTHING - Process of connecting an electrical appliance's metal case to the ground using earth wire.

It is a safety measure that protects people from electric shocks.



THREE PIN PLUG AND SOCKET -

Top pin - Earthing
Left pin - Live
Right pin - Neutral



The earth pin is thicker and longer than other two.

SAFETY PRECAUTIONS -

- Do not touch switch with wet hands.
- switch should always be connected to live wire.
- Appliances should be earthed.
- Use appropriate fuse rating in live wire of circuit.

COLOUR CODING OF WIRES -

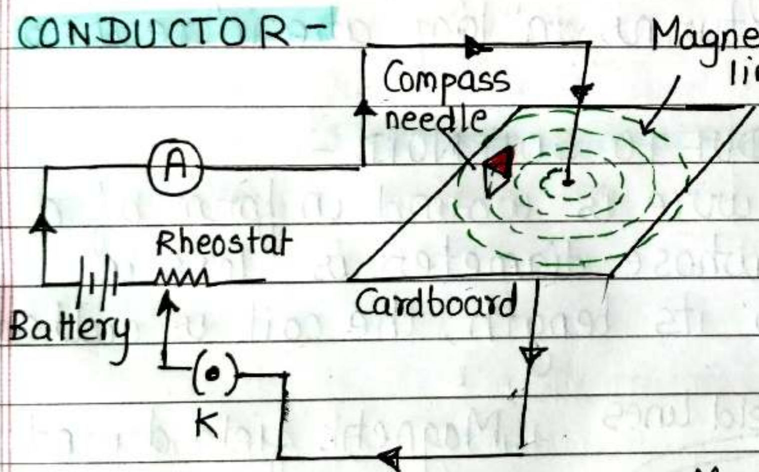
Wire	Colour	
	Old	New convention
Live	red	black
Neutral	black	blue
Earth	green	black or yellow

ELECTRO-MAGNETISM

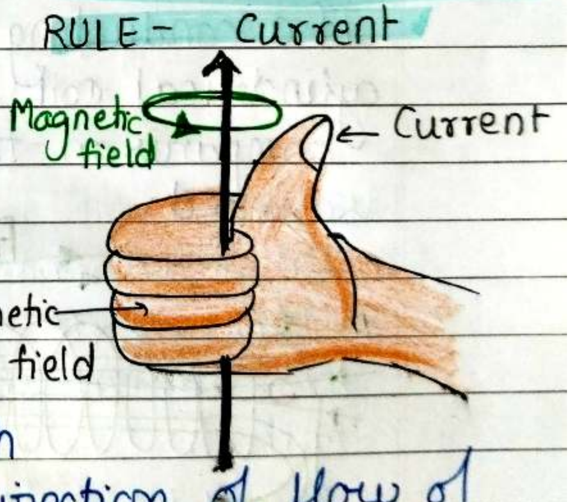
OERSTED'S EXPERIMENT - When an electric current is passed through a conducting wire, a magnetic field is produced around it, which is detected using compass needle.

MAGNETIC FIELD - The region around a magnet in which its effect can be experienced. It is denoted by B.
- Vector quantity
- S.I unit ⇒ tesla(T)

MAGNETIC FIELD DUE TO STRAIGHT CURRENT CARRYING CONDUCTOR -

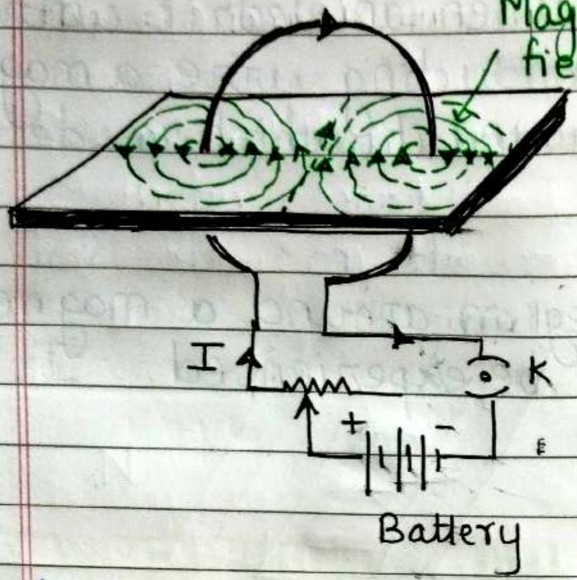


MAXWELL'S RIGHT HAND RULE -

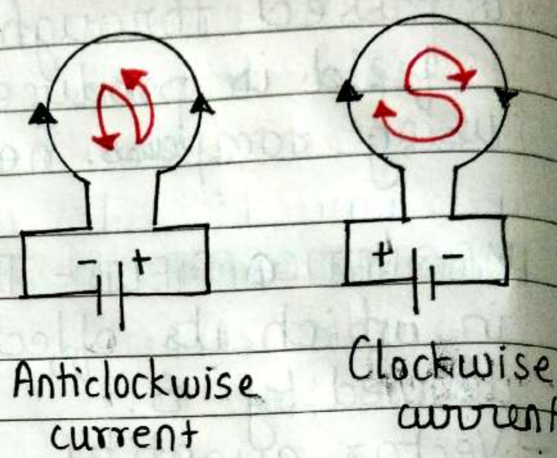


If we hold the current carrying conductor in our right hand such that the thumb points in the direction of flow of current, then the fingers encircle the wire in the direction of magnetic field lines.

MAGNETIC FIELD DUE TO CURRENT IN A LOOP -



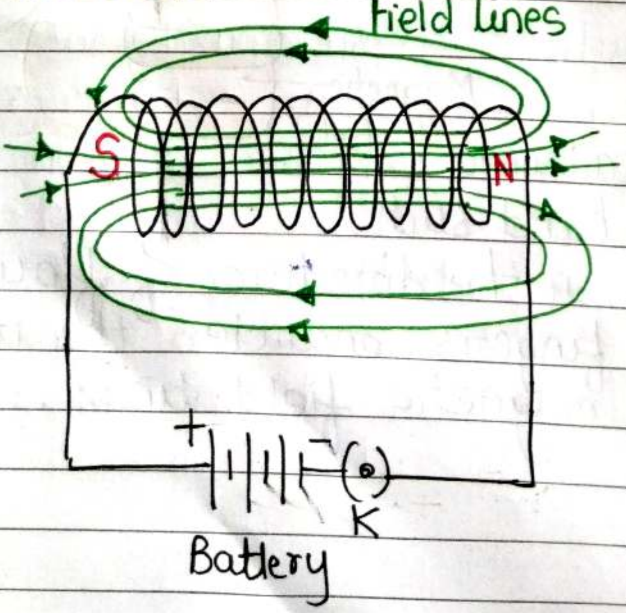
CLOCK RULE -



Magnetic field lines become dense if -
1) the strength of current in the loop is increased
2) the number of turns in loop are increased.

MAGNETIC FIELD DUE TO SOLENOID -

If a conducting wire is wound in form of a cylindrical coil whose diameter is less in comparison to its length, the coil is called solenoid.



Magnetic field depends on -
1) No. of turns of solenoid
$B \propto N$
2) Strength of current, $B \propto I$
3) Nature of core material used to make solenoid

COMPARISON OF ELECTROMAGNET AND PERMANENT MAGNET

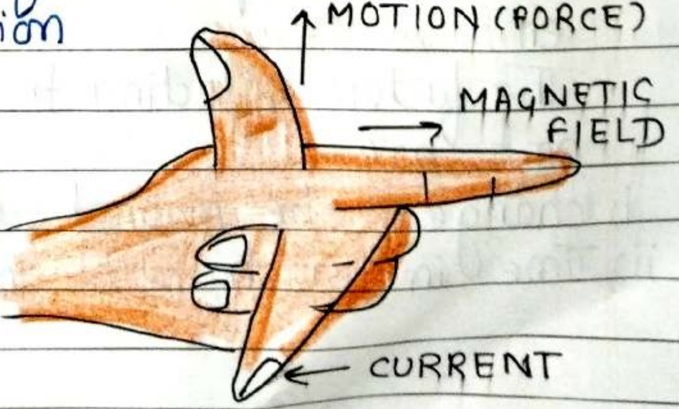
Electromagnet	Permanent Magnet
1) It is made of soft iron.	1) It is made of steel
2) Produces temporary magnetic field.	2) Produces permanent magnetic field.
3) Magnetic field strength can be changed.	3) Magnetic field strength cannot be changed.
4) Polarity can be reversed.	4) Polarity cannot be reversed
5) Can be easily demagnetised.	5) Cannot be demagnetised

Uses of electromagnet-

1) Lifting & transporting large masses of iron scrap.
2) Loading furnace with iron.
3) Magnetic separation.
4) Removing iron pieces from wounds.

FORCE ON A CURRENT CARRYING CONDUCTOR

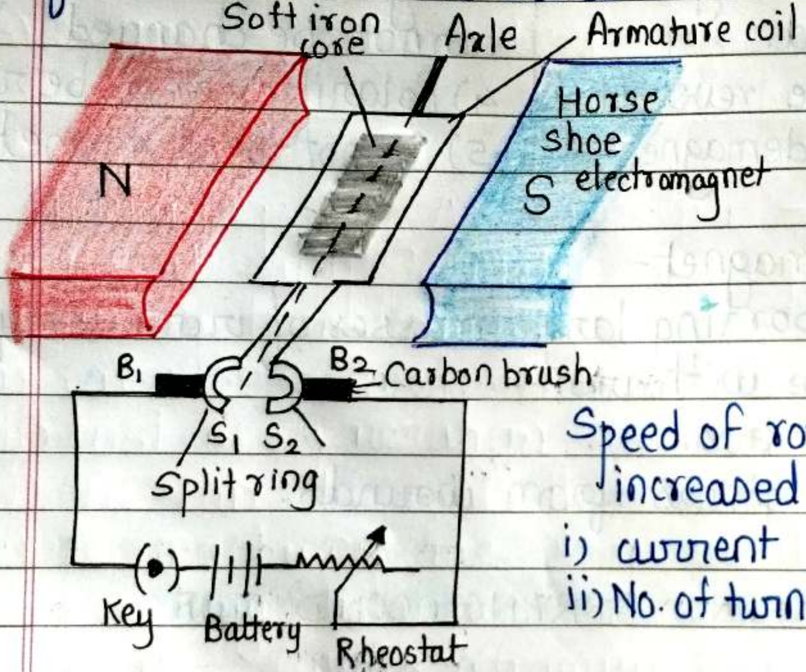
FLEMING'S LEFT HAND RULE - Stretch the forefinger, central finger and thumb of your left hand mutually perpendicular to each other. If forefinger indicates the direction of magnetic field and the central finger indicates the direction of current, then the thumb will indicate the direction of motion of conductor. (i.e. force on conductor)



SIMPLE D.C. MOTOR-

An electric motor is a device which converts the electrical energy into the mechanical energy

Principle - When current is passed through a conductor placed normally in a magnetic field, force acts on the conductor.



PARTS OF MOTOR-

1) Armature
2) Split rings
3) Brushes
4) Magnet
5) DC source

Speed of rotation of motor can be increased by-

i) current
ii) No. of turns
iii) Area of coil
iv) Magnetic field strength

ELECTROMAGNETIC INDUCTION-

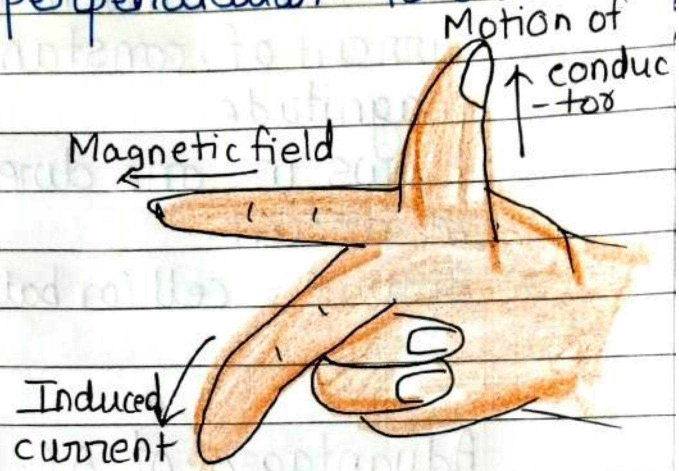
The phenomenon of production of emf in a conductor on changing the magnetic field around it. The emf produced is called induced emf.

The factors affecting the magnitude of induced emf are-

i) change in the magnetic flux
ii) Time in which the magnetic flux changes.

FLEMING'S RIGHT HAND RULE -

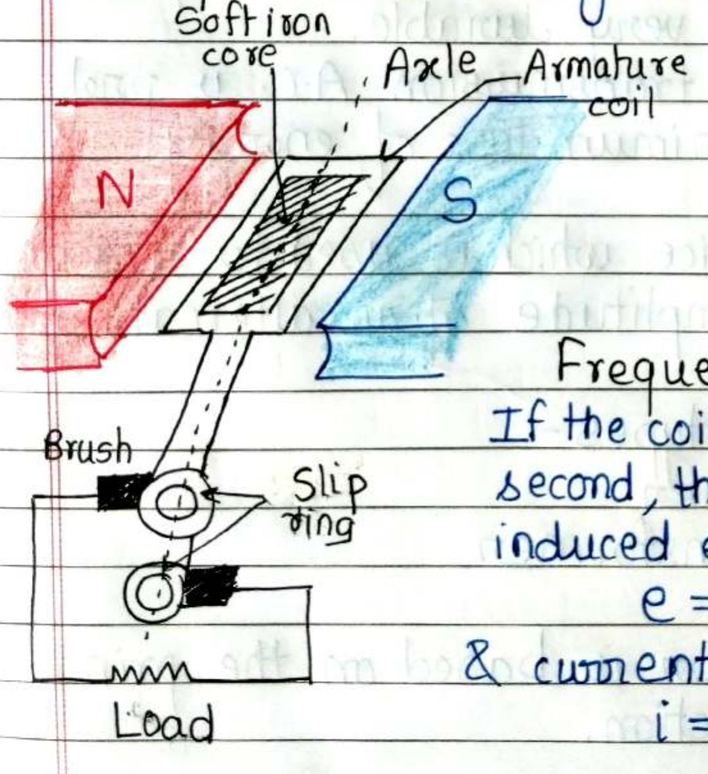
Stretch the thumb, central finger and forefinger of your right hand mutually perpendicular to each other. If the forefinger indicates the direction of magnetic field and thumb indicates the direction of motion of conductor then the central finger will indicate the direction of induced current.



A.C. GENERATOR -

Device which converts mechanical energy into electrical energy is called generator.

Principle - Electromagnetic induction.



PARTS OF GENERATOR

1) Field magnet
2) Armature coil
3) Slip rings
4) Brushes

Frequency of Alternating current -

If the coil makes n rotations per second, then the magnitude of induced emf is given as -

$$e = e_0 \sin 2\pi n t$$

& current is -

$$i = i_0 \sin 2\pi n t$$

DIFFERENCE BETWEEN A.C. and D.C.

Direct current (D.C.)	Alternating current (AC)
1) Current of constant magnitude.	1) Current of varying magnitude.
2) Flows in one direction in circuit.	2) Reverses its direction while flowing in circuit.
3) Source → cell (or battery)	3) Source - AC generator or mains.

Advantages of A.C. over D.C. -

i) A.C. at any desirable voltage can be obtained using transformer.
ii) Can be converted to DC using rectifier.
iii) cost of generation is less
iv) AC can be controlled without much power loss.
v) AC machines are very durable.
vi) For long distance transmission A.C. is preferred as it causes minimum loss of energy.

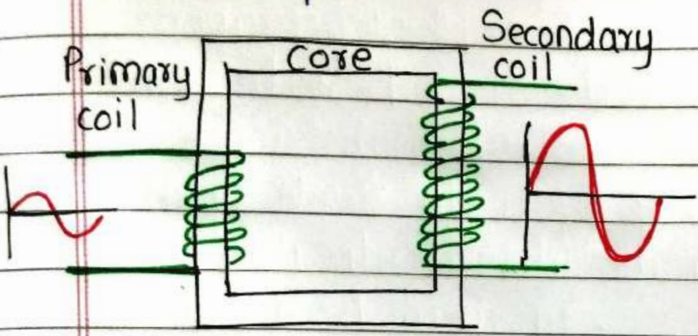
TRANSFORMER - Device which is used to increase or decrease the amplitude of an alternating emf.

They are of two types -
1) Step - up transformer
2) Step - down transformer

Principle - Transformer is based on the principle of mutual induction.

Step-up transformer

Changes low alternating voltage to high alternating voltage. ($E_s > E_p$)
($N_s > N_p$)

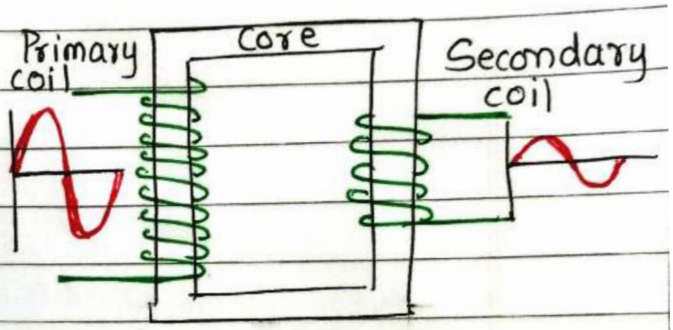


Uses -

1) transmission of electric power at the power generating station to step up the voltage.
2) television
3) Wireless sets
4) X-ray tubes to provide high accelerating voltage.

Step-down transformer

Changes high alternating voltage to low alternating voltage. ($E_s < E_p$, $N_s < N_p$



Uses-

1) Electric bells, night bulbs, mobile phones, computers.
2) At the power substation to step down the voltage before its distribution to consumers.