UNIT-10 Current Electricity

1

Current :—

Current in a Conductor is defined as the rate of flow of charge across any cross-section of the Conductor.

or → If a charge q flows across any cross-section of Conductor in time t sec, then Current (i) is given by $\boxed{i = \frac{q}{t}}$ (for uniform flow of charge)

or → if dq amount (indicate small amount) of charge flowing across any cross-section of the Conductor in small interval of time dt then Current (i) is given by $\boxed{i = \frac{dq}{dt}}$ (for non-uniform flow of charge)

Unit :—

① SI unit of Current Ampere

i.e Ampere = Coulomb / Sec.

(2) CGS : electrostatic unit :-

Stat ampere

$$\text{Stat ampere} = \frac{\text{Stat Coulomb}}{\text{sec}}$$

(3) CGS : electro-magnetic unit :-

abampere

$$\text{abampere} = \frac{\text{ab coulomb}}{\text{sec}}$$

$$\boxed{1A = 3\times10^{9}\ \text{stat Ampere}}$$

$$\boxed{1A = \frac{1}{10}\ \text{ab Ampere}}$$

Types of Current

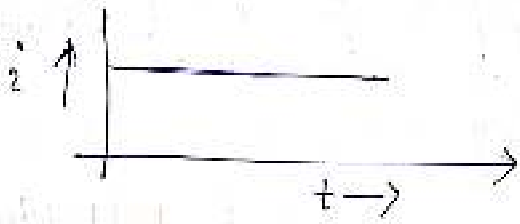
- Current
  - Electronic Current
    - Steady Current.
    - Variable Current.
  - Conventional Current.

→ A current taken to be along the direction of motion of electrons is called electronic current.

→ A current taken to be opposite to the direction of motion of e^- is called conventional current.

→ Steady Current :-

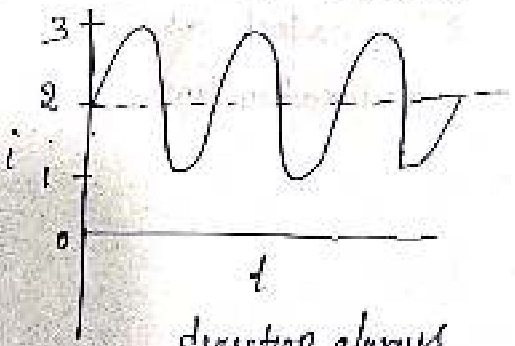
A current is said to be steady if its magnitude is constant and direction is always same.



→ Variable Current :-

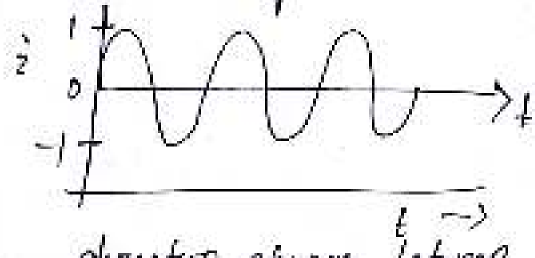
A variable current, in general is defined as the current which changes in magnitude with time while its direction may or may not change.

if direction same direct current



direction always +ve

if direction reversed after equal interval of time is called Alternating Current.



direction change between +ve & -ve

OHM's LAW

Ohm's law stats that,

At Constant temprature Current flowing through a Conductor of uniform area of Cross-section is proportional to the potential difference across its terminals.

i.e $i \propto V$

$\Rightarrow i = \frac{1}{R} V$

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

Here R is proporsonality Constant, known as resistance of the Conductor.

NOTE :—

From the Concept of drift velocity

$$\boxed{v = \frac{eV}{ml} t'}$$

i.e $\boxed{t' = \frac{v}{a}}$

A = Area of Cross section

a = accelaration of e^-

v : drift velocity

V : potential difference

l : Length of Conductor

m : mass of e^-

t' : Average time interval between any two consecutive collision between e^-, called as relaxation time

Resistance —

It is defined as the opposition offered by the Conductor to the flow of electric charge through it.

Mathematically is can be defined as ratio between potential difference and Current through Conductor

i.e $\boxed{R = V/i}$

01 → R directly proportional to Length of Conductor.

02 → R inversely proposnal to area of Cross section of Conductor.

03 → R varies with temperature.

04 → R depends upon the nature of material i.e no of e^- per meter Cube of material.

UNIT:

SI unit

$$\text{ohm} = \frac{\text{Volt}}{\text{ampere}}$$

CGS (electro-static unit)

$$\text{Stat ohm} = \frac{\text{Stat volt}}{\text{Stat amp}}$$

EMS (electro-magnetic unit)

$$\text{ab ohm} = \frac{\text{ab volt}}{\text{ab amp}}$$

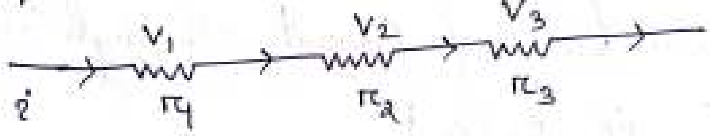
$1\,\text{ohm} = \frac{1}{9\times10^{11}}$ stat ohm

$1\,\text{ohm} = 10^{9}$ abohm

Din^n formula —

$$R = [M^1 L^2 T^{-3} A^{-2}]$$

① Resistance in series: — Combination



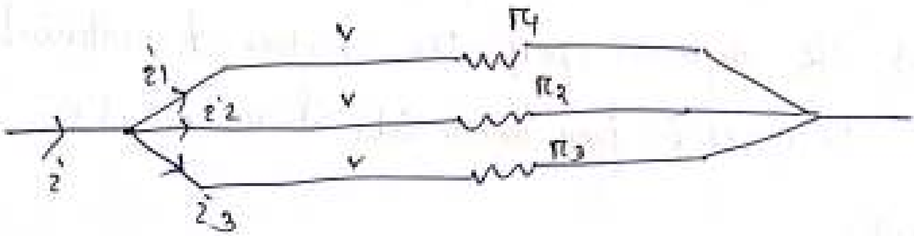
$V = IR$

$\Rightarrow V = V_1 + V_2 + V_3$

$\Rightarrow iR = ir_1 + ir_2 + ir_3$

$\Rightarrow \boxed{R = r_1 + r_2 + r_3}$

② Resistance in parallel: — Combination



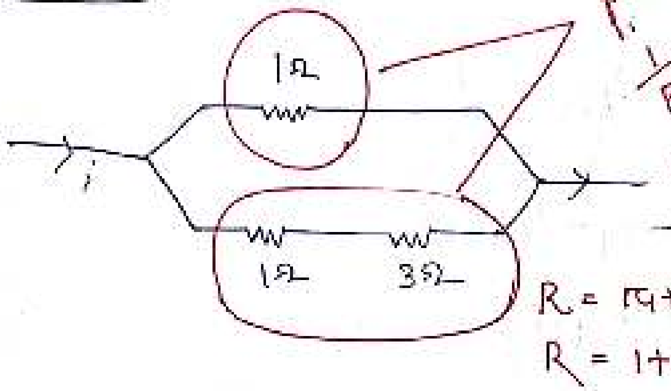
$i = V/R$

$\Rightarrow i = i_1 + i_2 + i_3$

$\Rightarrow \frac{V}{R} = \frac{V}{r_1} + \frac{V}{r_2} + \frac{V}{r_3}$

$\Rightarrow \boxed{\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$

Ex:- 1



parallel

$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2}$

$\frac{1}{R} = \frac{1}{1} + \frac{1}{4}$

$\Rightarrow \frac{1}{R} = \frac{5}{4}$

$\Rightarrow R = \frac{4}{5}$

$R = r_1 + r_2$ (Series)

$R = 1 + 3 = 4\Omega$

Effective resistance $\boxed{R = \frac{4}{5}\,\Omega}$

Imp

Kirchhoff's law

1. Kirchhoff's first law or Kirchhoff's Current Law (KCL)

KCL states that the algebraic sum of Currents meeting at a single point zero. It is based on Conservation of charge.

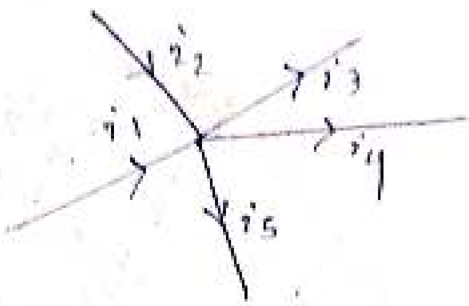
$\Sigma i = 0$

Explanation —

for determining the algebraic sum of Current we can Consider -

a) Current approaching given points are taken +ve.

b) Current leaving given points are taken -ve.



$$i_1 + i_2 - i_3 + i_4 - i_5 = 0$$

$$\Rightarrow i_1 + i_2 = i_3 + i_4 + i_5$$

$$\Rightarrow \Sigma i = 0$$

i.e Current entering the point = Current leaving a point

2. Kirchhoff's Second law / Kirchhoff's Voltage Law :— (KVL)

KVL states that in a closed Circuit the algebraic sum of e.m.f is equal to the algebraic sum of the products of the resistances and Currents flowing through them. i.e $\boxed{\Sigma iR = \Sigma E}$

It is based on the Conservation of Energy.

Explanation :-

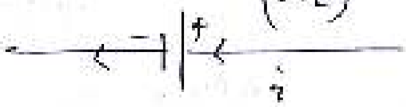
for Carryout of KVL the following sign Conventions are taken into Consideration

→ If (i) current flows from -ve to +ve terminal of electrolyte then e.m.f taken (+ve)

(+E)

→ if (i) current flows from +ve to -ve terminal of electrolyte then e.m.f taken (-ve)

(-E)

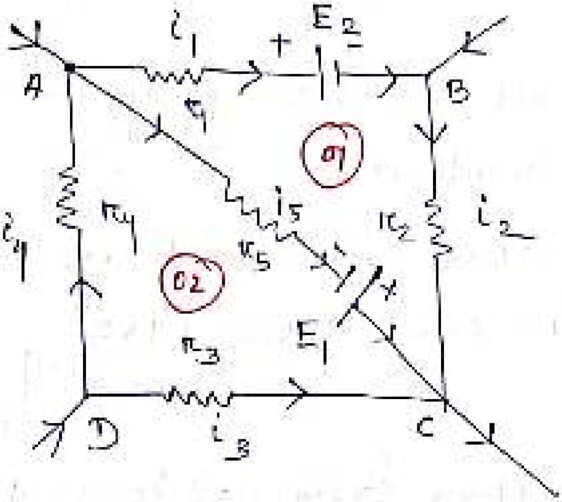


→ If final potential is less than initial then ir taken -ve.

i-e the path taken to traverse the resistance is along the dir^n of current.

→ if final potential is higher than initial then ir taken +ve.

i.e the path taken to traverse the resistance is against the direction of current.



ABC => Mesh-01

ACD => Mesh-02

In Mesh-01

$$i_1 r_1 + i_2 r_2 - i_5 r_5 = E_1 - E_2$$

In Mesh-02

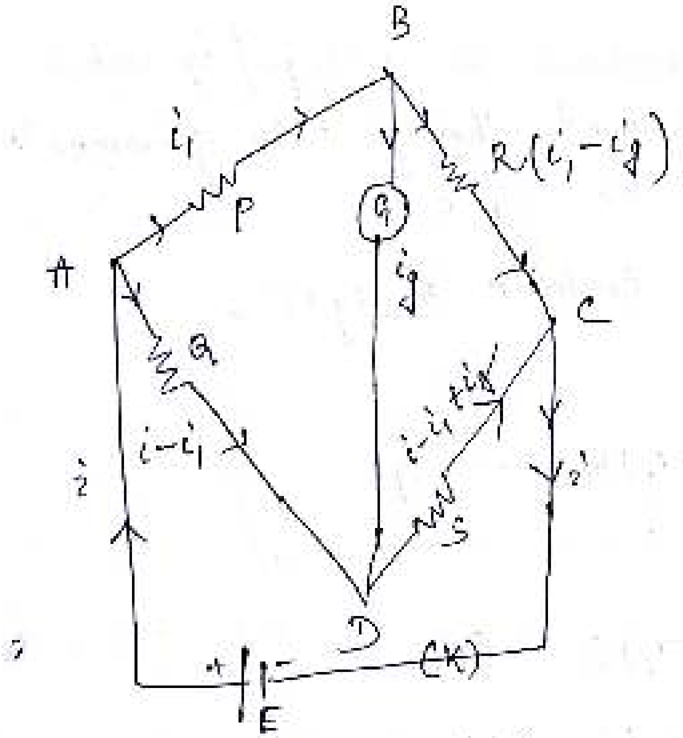
$$i_5 r_5 - i_3 r_3 - i_4 r_4 = E_1$$

i.e. $\boxed{\sum i r = \sum E}$

11 WHEATSTONE BRIDGE :—

W.B is an electrical arrangment which forms the basis of most of the instruments used to determine an unknown resistance.

Arrangment:—



→ 4 resistance P, Q, R & S are Connected in a form of a square ABCD.

→ A galvonometer with resistance (G) is Connected between the points B & D.

→ The Current is different branches are obtained by applying Kirchhoff's 1st law.

Let i_g be the Current through the galvanometer.

Applying K.V.L in the mesh ABD

$$i_1 P + i_g G - (i - i_1) Q = 0 \quad \text{——— (1)}$$

Applying K.V.L in the mesh BCD

$$(i_1 - i_g) R - i_g \cdot G - (i - i_1 + i_g) S = 0 \quad \text{——— (2)}$$

Now known resistances are arranged in such a way that the Current through the galvanometer is made zero. i.e $i_g = 0$.

So at balanced Condition i.e $i_g = 0$,

Eqn (1) becomes

$$i_1 P = (i - i_1) Q \quad \text{——— (3)}$$

Eqn (2) becomes

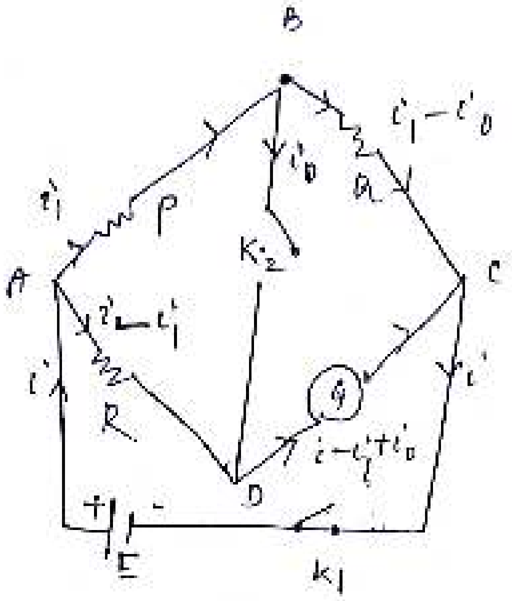
$$i_1 R = (i - i_1) S \quad \text{——— (4)}$$

dividing eqn (3) by eqn (4)

$$\boxed{\frac{P}{R} = \frac{Q}{S}}$$

Special Case :—

WB can also be balanced by connecting a key (K_2) in place of galvanometer and galvanometer connected one of its arm.



→ when K_2 open & K_1 is closed there is deflection in galvanometer.

→ when K_2 & K_1 closed no deflection in galvanometer i.e $i_g = 0$ balanced condition.

Now $\frac{P}{Q} = \frac{R}{G}$

$\Rightarrow G = R \cdot Q/P$.

This is used to determine to find resistance of galvanometer.