Chapter - 3
CURRENT ELECTRICITY

Q.1 Define electric current?
Q.2 Write the formula of Electric current.
Q.3 Write the Type of electric current.
Q.4 Write SI unit and CGS unit of Electric current.
Q.5 Electric current is scalar or vector quantity?
Q.6 Write the real formula of electric current.
Q.7 Write the charge to flowing through the electric current in solid, liquid and gas.

Ans. 1) The rate of flow of charge is known as the electric current.

Ans. 2) Formula of Electric current :-

$$\boxed{i = \frac{q}{t}}$$ where, $i \rightarrow$ electric current

Ans. 5) Electric current is scalar quantity.
Ans. 4) SI unit of Electric current :-

SI unit :- $\frac{q}{t}$

$= \frac{\text{coulomb}}{\text{second}}$

$=$ Ampere.

CGS unit :- $\frac{\text{Stat coulomb}}{\text{second}}$

$=$ Stat ~~coulomb~~ Ampere

* 1 Ampere = 3×10^9 stat Ampere.

Ans.3) Type of Electric current :-

i) Direct current {D.c}
ii) Alternate current {A.c}

i) Direct current :- In which magnitude and direction can not change with respect to time.

Types of Direct current :-

a) steady Direct current → does not change w.r.t time.
b) Variang Direct current → change w.r.t time.

a) steady D.c ⇒ $\frac{q}{t}$

b) Vareing D.c ⇒ $\frac{dq}{dt}$

ii) Alternate current :- In which magnitude and direction can change w.r.t time.

Q.8 Define current density.
Q.9 What is ohm's law

Ans.1) The rate of flow of electron is known as current electric.

Drift Velocity :-

The average velocity of free electron is known as drift velocity. Generally represented by V_d

$$V_d = \frac{V_1 + V_2 + \dots + V_n}{n}$$

current Density :-

The amount of current flowing through the any conductor per unit area is known as the current density. Generally represented by 'J'.

$\boxed{\text{unit :- Ampere}/m^2}$ $\boxed{J = \frac{I}{A}}$, where $I \rightarrow$ electric current

$A \rightarrow$ Area

Mobility :- Magnitude of the drift velocity per unit electric field is called Mobility. Generally represented by "μ"

$$\mu = \frac{V_d}{E}$$

SI unit :- ~~m^2/V_s~~ m^2/Vs

↳ meter square per volt second.

since $V_d = \frac{e\tau E}{m}$

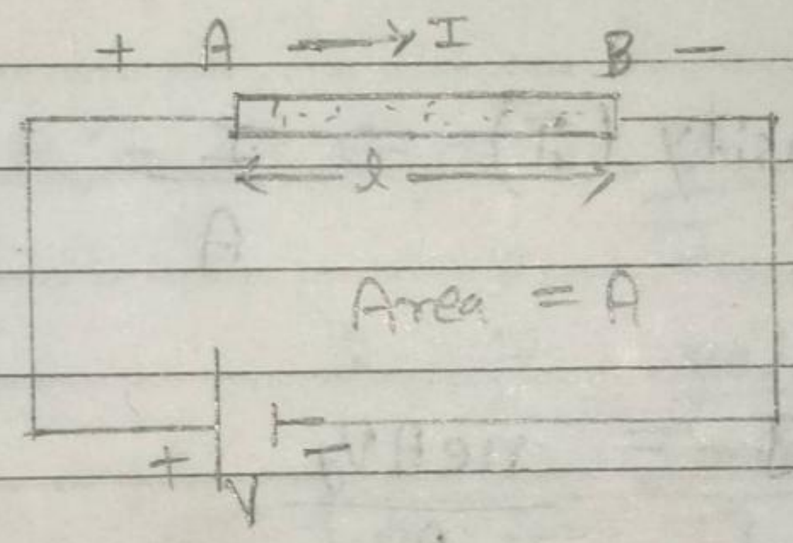
then,

$\Rightarrow \quad \mu = \frac{V_d}{E}$

$\Rightarrow \quad \mu = \frac{\frac{e\tau E}{m}}{E}$

$\Rightarrow \quad \boxed{\mu = \frac{e\tau}{m}}$ where τ is the average collision time for electrons

Ans.6.



Volume $= V = Al$

$\therefore \quad I = \frac{q}{t}$

Total charge $(q) = neV$
$= neAl \longrightarrow (1)$

$\therefore$ velocity $(v) = \frac{\text{distance } (d)}{\text{time } (t)}$

$t = \frac{d}{V}$

$t = \frac{l}{V_d} \longrightarrow (2)$

$\because \quad I = \frac{q}{t}$

from ① & ②,

$$\Rightarrow \quad I = \frac{neAl}{\frac{l}{V_d}}$$

$$\boxed{I = neAV_d}$$ where, $I \rightarrow$ current
$V_d \rightarrow$ Drift velocity
$A \rightarrow$ Area

Now,

$$\text{current density } (J) = \frac{I}{A}$$

$$J = \frac{neAV_d}{A}$$

$$\Rightarrow \quad \boxed{J = neV_d}$$

Q.9 What is ohm's law.
Q.10 What do you understand by the resistance.

Relaxation Time :-

The time interval b/w the two consecutive collision b/w the electrons is known as Relaxation time.

Ans. 9 **Ohm's law:-** If the physical state of any conductor is invariant (not change) then flowing current through the conductor is directly proportional to the applied potential difference.

$\Rightarrow \quad V \propto I$

$\Rightarrow \quad V = RI$ where, R → Resistance

$\Rightarrow \quad R = \frac{V}{I}$ R → proportionality constant

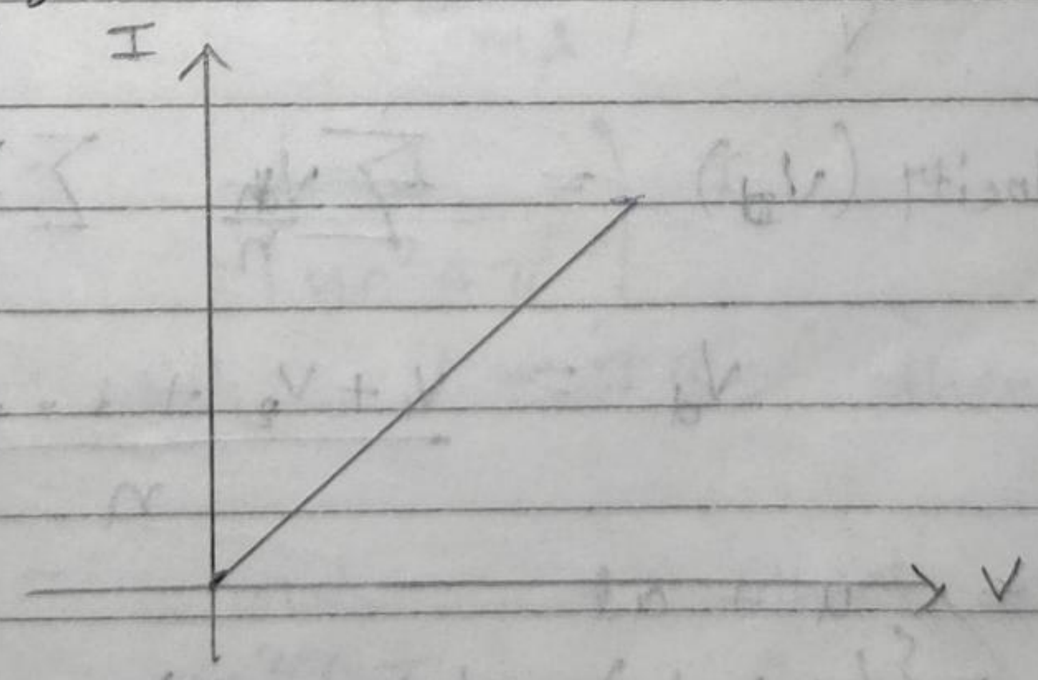
* Resistance of our body = 10 ~~lakh~~ Kilo Ω

Unit:- $R = \frac{V}{I}$

$R = \frac{\text{volt}}{\text{Ampere}}$

$\boxed{R = \Omega \text{ (ohm)}}$

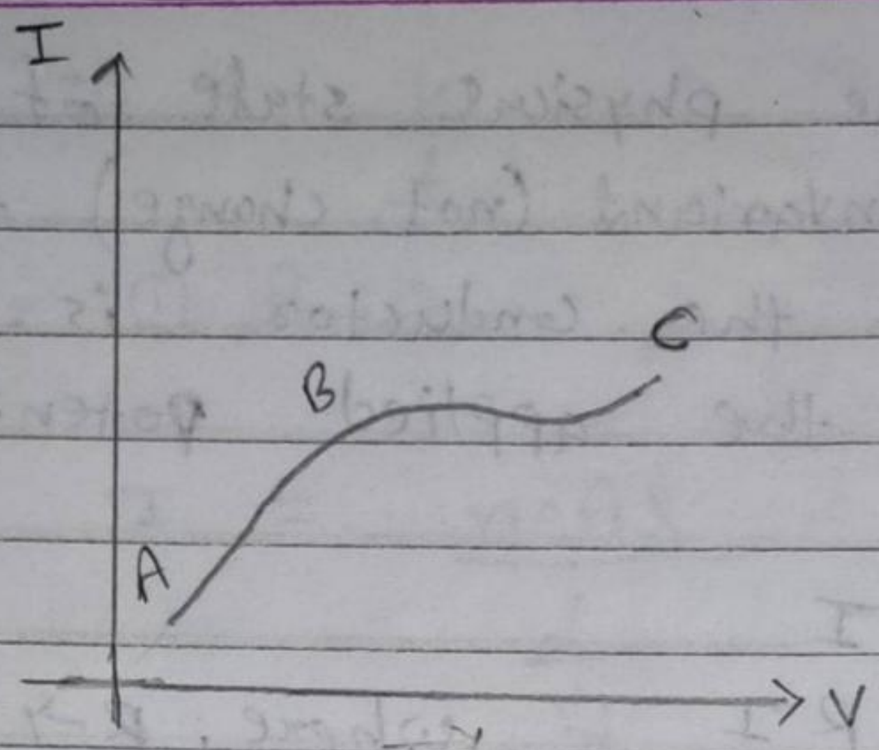
Graph :-



Q.11 prove that resistance is directly proportional to lenghth and inversly proportional to cross section Area of conductor

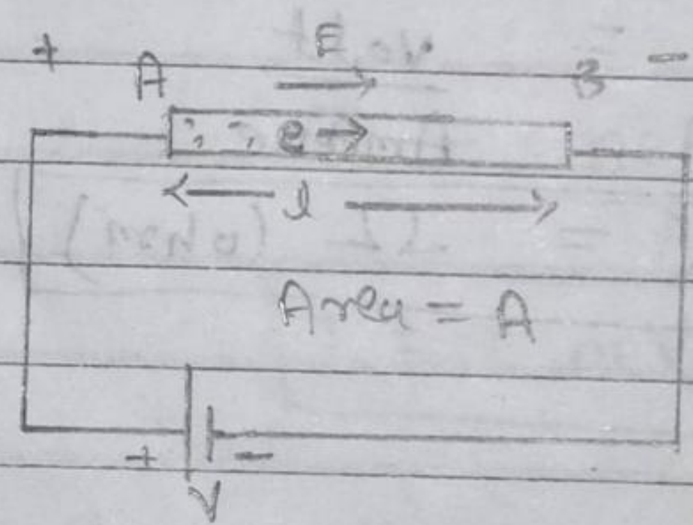
Q.12 ~~By using~~ verify the ohm's law with the help of free electron model

Ohm's law Graph information:-



→ path AB = ohmic resistance
→ path BC = non ohmic resistance

Ans 20) Verification of ohm's law with the help of free electron model:-



Drift velocity (v_d) $= \cancel{\sum \frac{v_n}{n}}$ $\sum \frac{v_n}{n}$

$$v_d = \frac{v_1 + v_2 + \dots + v_n}{n}$$

$\because$ $v = u + at$

$$v_d = \{(u_1 + at_1) + (u_2 + at_2) + \dots + (u_n + at_n)\}/n$$

$$v_d = \frac{(u_1 + u_2 + \dots + u_n)}{n} + a\frac{(t_1 + t_2 + \dots + t_n)}{n}$$

$$v_d = 0 + a\tau$$

$\boxed{v_d = a\tau}$ where $\tau \rightarrow$ average collision Time

$\because \quad a = \frac{F}{m}$

$\Rightarrow \quad V_d = \frac{F\tau}{m}$

$\Rightarrow \quad V_d = \frac{q \cdot E\tau}{m}$

$\Rightarrow \quad \boxed{V_d = \frac{eE\tau}{m}}$

$\Rightarrow \quad \boxed{V_d = \frac{eV\tau}{ml}}$

<u>Now,</u>

According to ohm's law,

$$V = IR$$

$\because \quad I = neAV_d$

$\Rightarrow \quad I = neA\left(\frac{eV\tau}{ml}\right)$

$\Rightarrow \quad V = \left(\frac{ml}{ne^2A\tau}\right) I$

Comparing with $V = IR$, then we get

$R = \frac{ml}{ne^2A\tau}$ which is resistance.

$R \propto l$

$R \propto \frac{1}{A}$

This is called law of resistance.

Q.13 What is resistivity?

Ans. → Resistance of a conductor of unit cross sectional Area and unit lenghth.

(or)

Resistance of a conductor of unit Volume.

$\Rightarrow R \propto l$

$\Rightarrow R \propto \frac{1}{A}$

$\Rightarrow R \propto \frac{l}{A}$

$\Rightarrow \boxed{R = \rho \frac{l}{A}}$ where $\rho \rightarrow$ resistivity (or) specific heat

$\Rightarrow \boxed{\rho = \frac{RA}{l}}$ SI unit :- $= \frac{\Omega \cdot m^2}{m}$

$= \Omega \cdot m$ (ohm meter)

Resistivity depends on :-
i) Nature of material
ii) Temperature.

$\boxed{R \propto t \quad t \rightarrow \text{tem.}}$

* High resistivity → Bad conductor (or) Non-conductor.
* low resistivity → Good Conductor of electricity

If we take a wire of unit lenghth and unit cross section then

Resistance, $R = \frac{\rho l}{A}$ as $l = 1$ And $A = 1$

Thus $R = \rho$.

Therefore the resistivity of a wire of unit lenghth and unit cross section is equal to it's resistance.

Q.14 What is conductivity?

Ans. The resiprocal of resistivity is known as conductivity, represented by 'σ'

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

SI Unit :- $\sigma = \frac{1}{\rho} = \frac{1}{\Omega m}$

$$\sigma = \frac{1}{\Omega} \cdot m^{-1}$$

$$\sigma = \text{Seimens} \cdot m^{-1}$$

$$\boxed{\sigma = \text{Seimens per meter}}$$

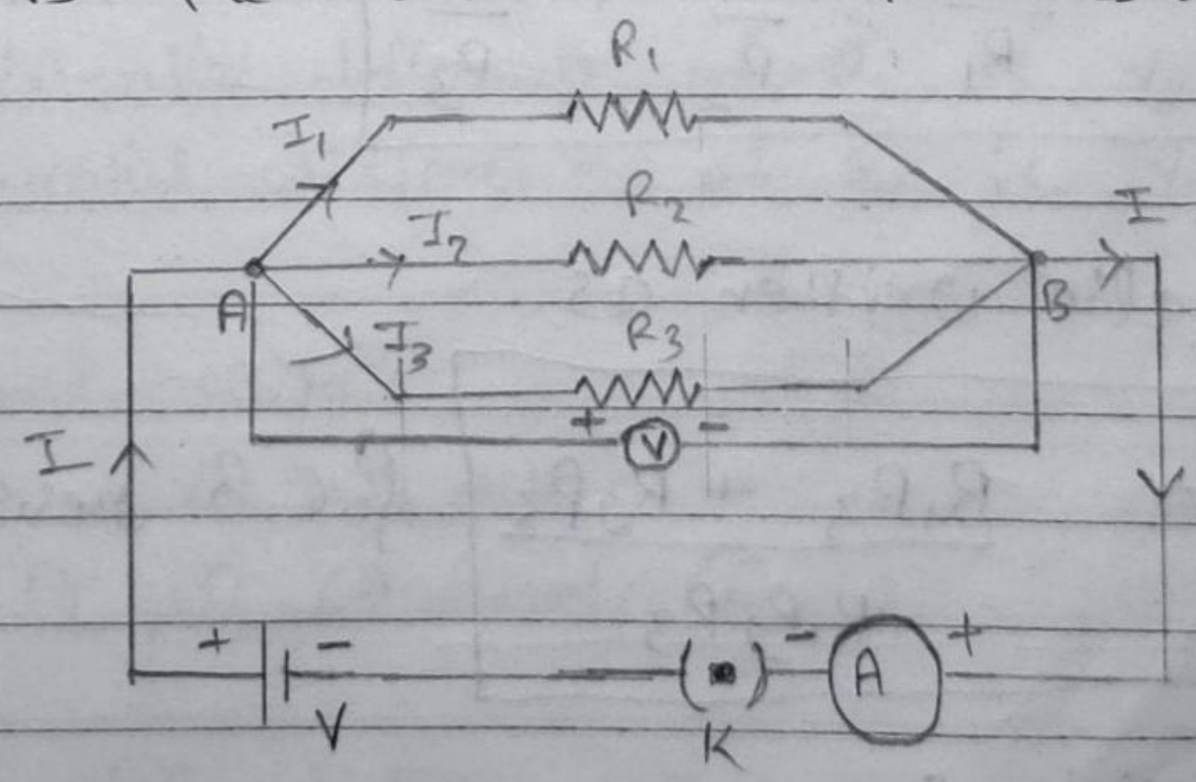
and also $\boxed{\sigma = \Omega^{-1} \cdot m^{-1}}$

Q.15 Derive an expression for equivalent resistance for parralel combination for given resistor.

Q.16 Derive an expression for equivalent resistance for series combination for given resistor

Q.17 What is the difference b/w Resistance and resistor.

Ans.15



Let three resistance R_1, R_2 and R_3 are connected in parallel combination with V volt battery.

If the total resistance of circuit is R,
Potential difference = V
and Total current = I, then

According to ohm's law,

$$I = \frac{V}{R} \longrightarrow (1)$$

The current flowing through R_1 is $I_1 = \frac{V}{R_1} \longrightarrow (2)$

The current flowing through R_2 is $I_2 = \frac{V}{R_2} \longrightarrow (3)$

The current flowing through R_3 is $I_3 = \frac{V}{R_3} \longrightarrow (4)$

We know that,

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

$$\Rightarrow \frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \quad \{\because \text{from } (1), (2), (3) \text{ \& } (4)\}$$

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

This is also written as

$$\Rightarrow \boxed{\frac{1}{R} = \frac{R_1R_3 + R_2R_3}{R_1R_2R_3}}$$ for 3 resistance.

for 4 resistance

$$\Rightarrow \boxed{\frac{1}{R} = \frac{R_1R_2R_3 + R_2R_3R_4 + R_1R_2R_4 + R_1R_3R_4}{R_1R_2R_3R_4}}$$

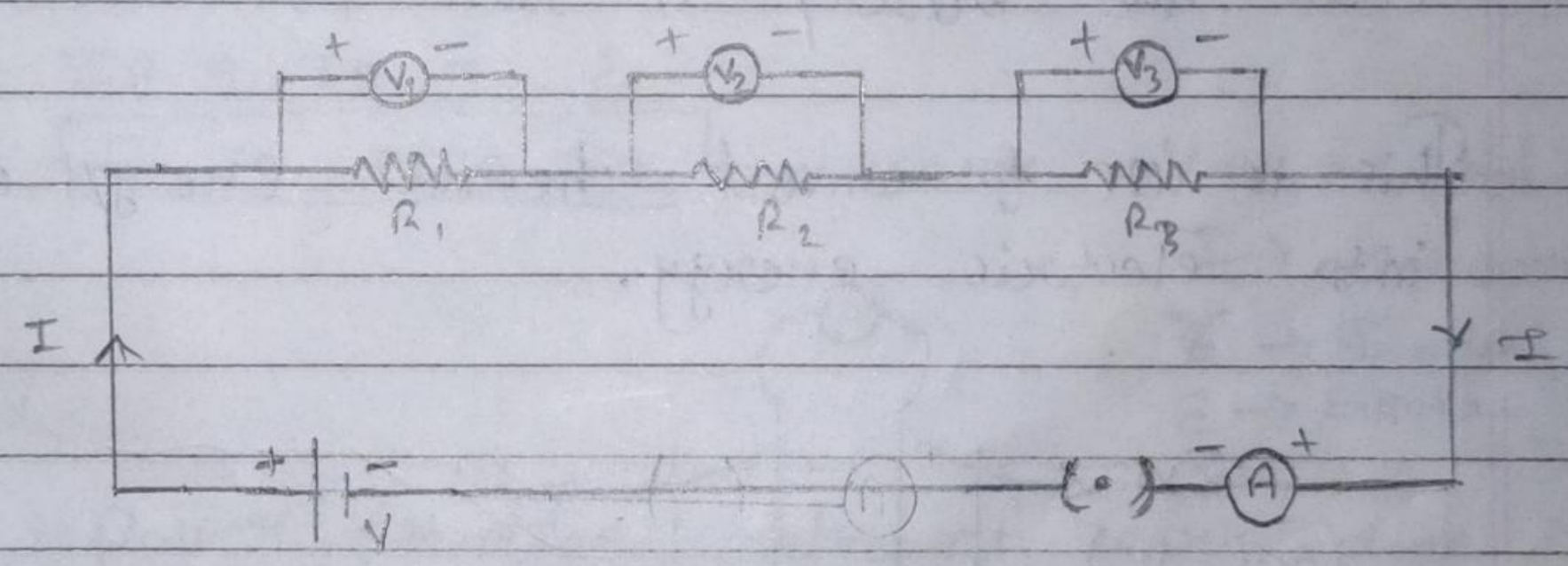
For 2 resistance,

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

Ans.16 → let 3 resistance R_1, R_2 and R_3 are connected in series combination with V volt Battery. If the total resistance of circuit is R, total current is I, then

According to ohm's law,

$$V = IR \rightarrow (1)$$



Now the Potential difference of R_1 is $V_1 = IR_1 \rightarrow (2)$
The Potential difference of R_2 is $V_2 = IR_2 \rightarrow (3)$
The Potential difference of R_3 is $V_3 = IR_3 \rightarrow (4)$

We know that,

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

- from (1), (2), (3) and (4),

$$\Rightarrow IR = IR_1 + IR_2 + IR_3$$

$$\Rightarrow \boxed{R = R_1 + R_2 + R_3} \longrightarrow (M)$$

for no. of resistance,

$$\Rightarrow \boxed{R = R_1 + R_2 + R_3 + \dots + R_n}$$

According to eqn (M) if resistance are connected in series combination then the total resistance of circuit is equal to sum of each resistance, This is law of series combination.

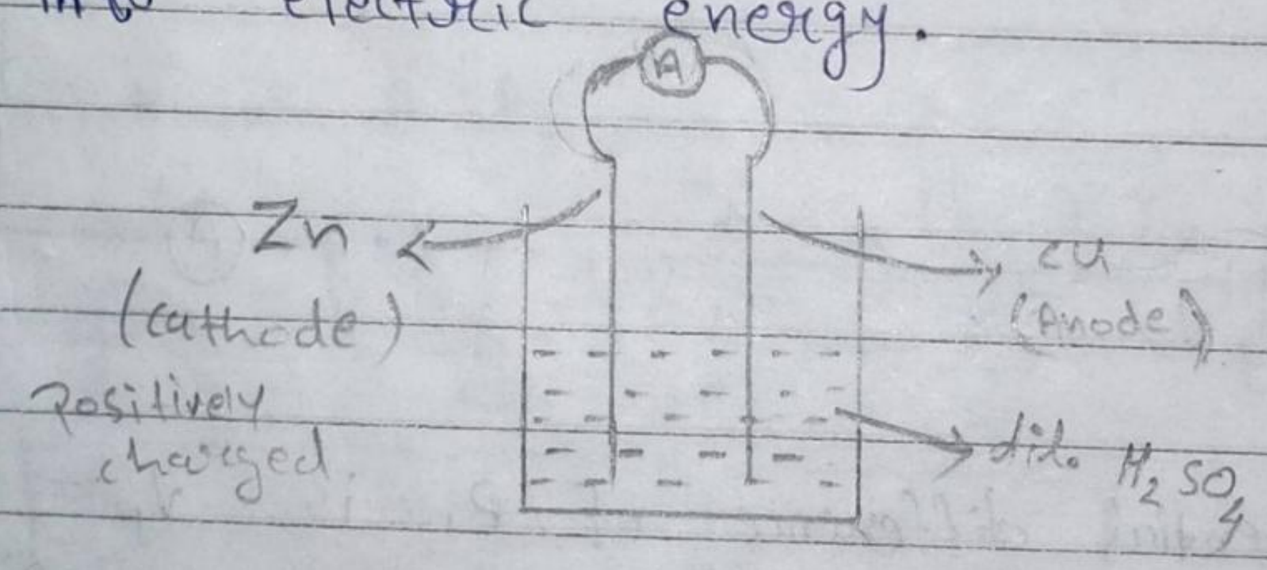
Q.18 Derive an expression for electric energy and power.

Q.19 What do you underststand by the E.M.F.

Q.20 What is cell.

Ans. 20 cell and battery is source of electric current.

This is use to convert chemical energy converted into electric energy.



$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$$

Ans. 19 ⇒ full form of E.M.F. is Electro motive Force.

Electro Motive Force (E.M.F):- Total amount of work done to travelling a unit charge from 1 electrode to another electrode of any cell is known as ~~E.M.F~~. E.M.F.

Internal Resistance :- The resistance of the cell is called Internal resistance. Represented by 'r'.

E.M.F is use only in cell.

Electro Motive Force (E.M.F) :- Maximum potential difference is known as the E.M.F.

SI unit :- Volt

According to ohm's law,

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

and $$I = \frac{\varepsilon}{R+r}$$

$$\Rightarrow I(R+r) = \varepsilon$$

$$\Rightarrow IR + Ir = \varepsilon$$

$$\Rightarrow \boxed{\varepsilon = V + Ir}$$

where $V \rightarrow$ Potential difference
$I \rightarrow$ Electric current
$r \rightarrow$ Internal resistance
$\varepsilon \rightarrow$ Electro Motive force

Ans. 18) **Power :-** The rate of work done is known as power for electric appliances.

Electric Power :- The rate of consume Electric energy in circuit is known as Electric Power.

Electric Power :- The rate at which electric energy is converted into any other form of energy is known as electric power.

SI Unit :- Watt

Commercial unit :- KWH,

$$(P)\ \text{Power} = \frac{\text{work done } (W)}{\text{time } (t)} \longrightarrow (1)$$

{first formula}

$\because V = \frac{W}{Q}$ where $V \rightarrow$ Electric potential

$$\Rightarrow W = VQ \longrightarrow (2)$$

from eqn (1) and (2),

$$\Rightarrow P = \frac{VQ}{t} \longrightarrow (3)$$

$\because I = \frac{Q}{t}$ where $I \rightarrow$ Electric current

from (3) and $I = \frac{Q}{t}$

$$\Rightarrow \boxed{P = VI} \longrightarrow (4) \longrightarrow \{2^{nd} \text{ formula}\}$$

According to ohm's law,

$$V = IR$$

from (4),

$$\Rightarrow P = IRI$$

$$\Rightarrow \boxed{P = I^2R} \longrightarrow (5) \longrightarrow \{3^{rd} \text{ formula}\}$$

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

$$\Rightarrow \boxed{P = \frac{V^2}{R}} \longrightarrow \{\text{fourth formula}\}$$

Formulas for power,

(i) $P = \frac{W}{t}$ where $W \rightarrow$ work done

(ii) $P = VI$ where $V \rightarrow$ potential difference.

(iii) $P = I^2 R$ where $I \rightarrow$ Electric current

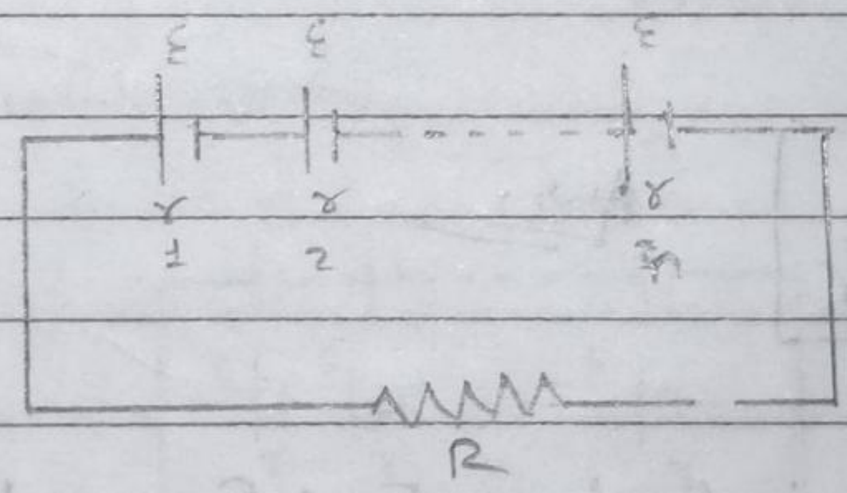
(iv) $P = \frac{V^2}{R}$ where $R \rightarrow$ Resistance,

Q. 21 Derive an Expression for flowing current in Series combination cell's

Q. 22 Derive an Expression for flowing current in parallel combination cell's

Q. 23. Derive an expression for flowing current in Mixed combination cell's.

Ans. 21 >



Total internal resistance $= r + r + r + \dots + r_n$

$= nr$

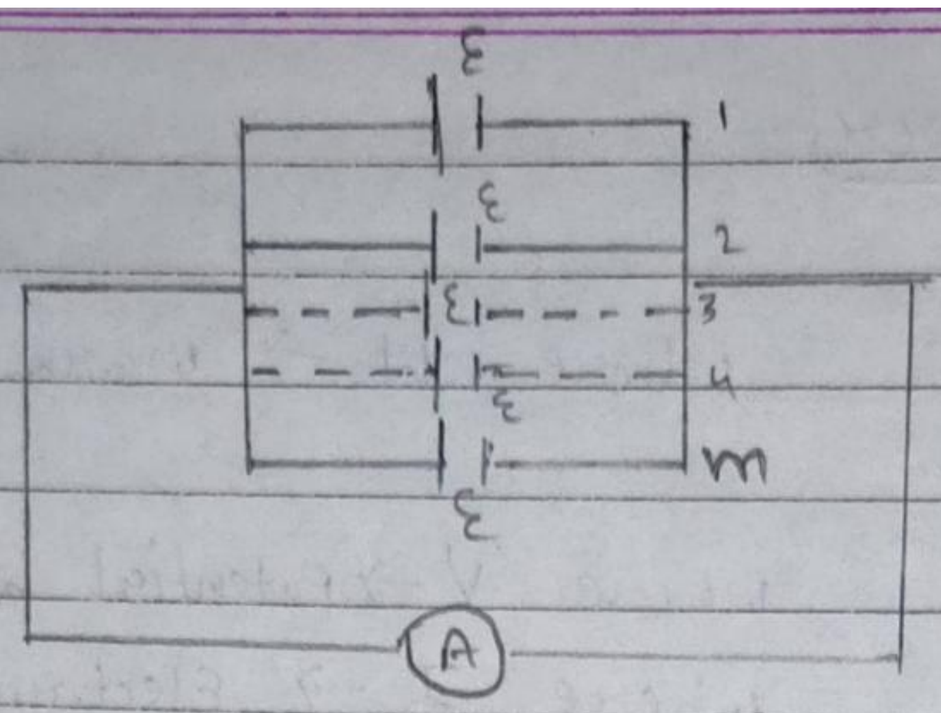
Total resistance $(R_T) = R + nr$

$\Rightarrow$ current $(I) = \frac{V}{R}$

$\Rightarrow$ $I = \frac{\text{total e.m.f}}{\text{total resistance}}$

$\Rightarrow$ $\boxed{I = \frac{n\varepsilon}{R + nr}}$

Ans. 22.



Total internal resistance $= \frac{1}{r_T} = \frac{1}{r} + \frac{1}{r} + \dots + m$

$\Rightarrow \frac{1}{r_T} = \frac{m}{r} \Rightarrow r_T = \frac{r}{m}$

$\Rightarrow$ Total resistance $= R + \frac{r}{m}$

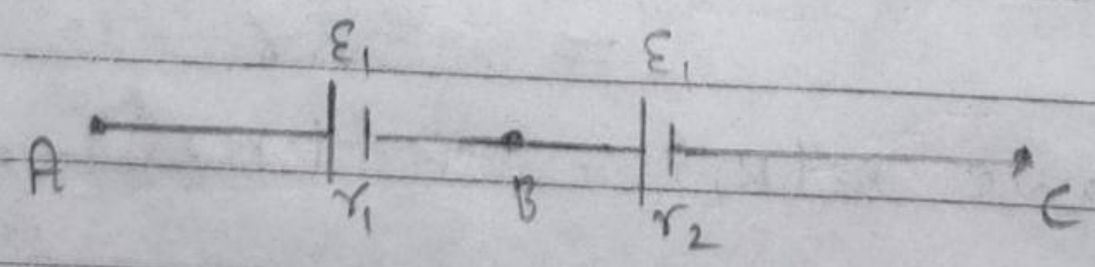
$\Rightarrow$ Total resistance $= \frac{mR + r}{m}$

$\Rightarrow I = \frac{\varepsilon_T}{R_T}$

$\Rightarrow \boxed{I = \frac{\varepsilon m}{mR + r}}$ Ans.

Q. 24. ~~Ans. 23~~ find out equivalent E.M.F and Resistance (internal) for series combination of 2 cells.

Sol.



let 2 cells of ε_1, r_1 and ε_2, r_2 is connected in series.

where, $\varepsilon_1, \varepsilon_2 \rightarrow$ E.m.f

$r_1, r_2 \rightarrow$ internal resistance.

$\Rightarrow V_{AB} = V_A - V_B = \varepsilon_1 - I r_1$

$\Rightarrow V_{BC} = V_B - V_C = \varepsilon_2 - I r_2$

$\Rightarrow V_{AC} = V_{AB} - V_{BC}$

$= (V_A - V_B) - (V_B - V_C)$

$= (\varepsilon_1 - I r_1) + (\varepsilon_2 - I r_2)$

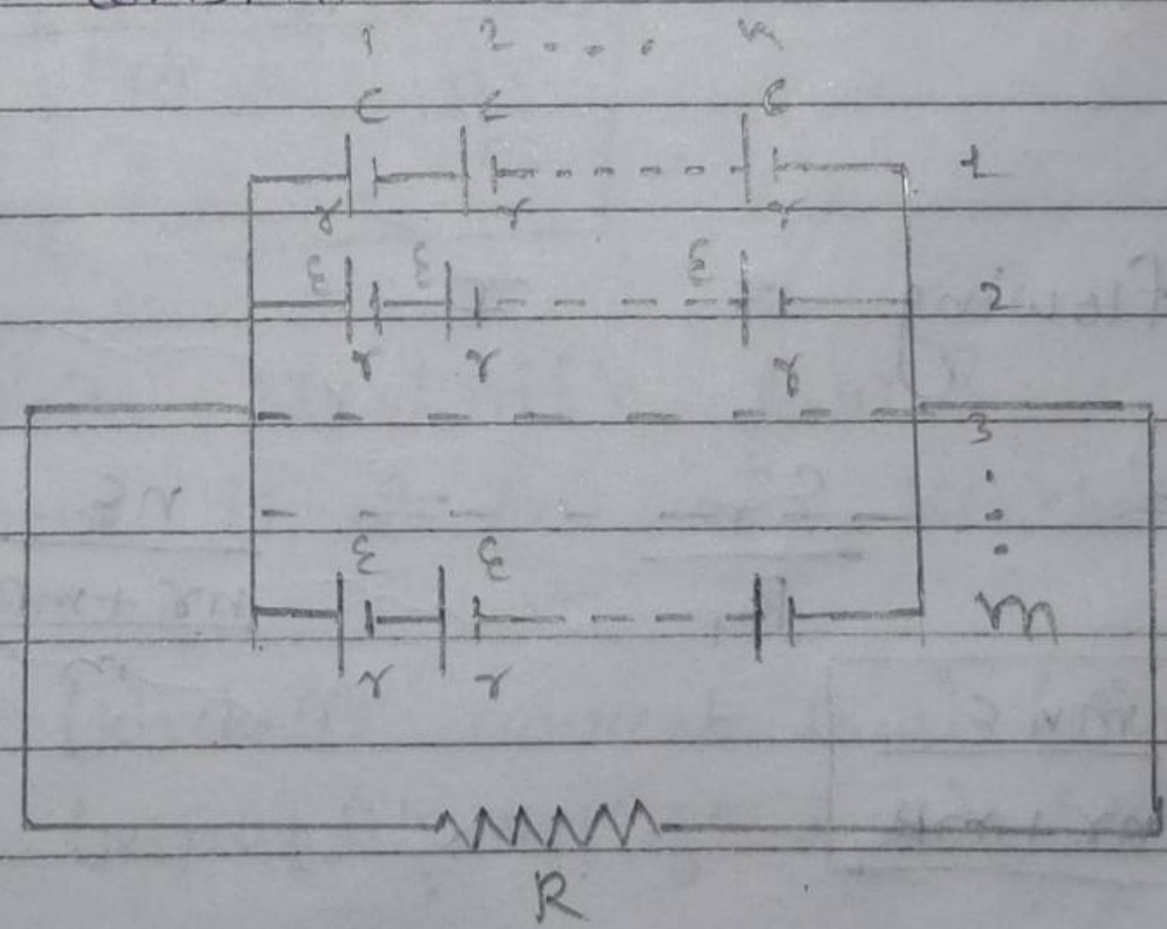
$\Rightarrow V_{AC} = (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2)$

Comparing with $V = \varepsilon_{eq.} - I r_{eq.}$

$\Rightarrow \boxed{\varepsilon_{eq.} = \varepsilon_1 + \varepsilon_2}$

$\Rightarrow \boxed{r_{eq.} = r_1 + r_2}$

Ans. 23. <u>Mixed combination</u> :- The combination of both parallel and series is called mixed combination.



In a Electric circuit, n no. of cells are connected in Series ~~with capacitan~~ and Electric circuit having m no. of rows such that ~~every~~ each cell having capacity C and internal resistance r, and we also connect an

external Resistance R.

Now,

~~Total~~ internal resistance $= r + r + r + r \ldots + r_n$ (in series)

$= nr$

Total internal resistance of circuit $\left(\frac{1}{r_T}\right) = \frac{1}{nr} + \frac{1}{nr} + \ldots + m$

$\Rightarrow \quad \frac{1}{r_T} = \frac{m}{nr}$

$\Rightarrow \quad \boxed{r_T = \frac{nr}{m}}$

Total Resistance $(R_T) = \frac{nr}{m} + R$

$= \frac{nr + mR}{m}$

current flowing $= I$

$\Rightarrow \quad I = \frac{\varepsilon_T}{R_T} = \frac{n\varepsilon}{\frac{nr + mR}{m}}$

$\Rightarrow \quad \boxed{I = \frac{mn\varepsilon}{nr + mR}}$

For maximum current :-

$$I = \frac{mn\varepsilon}{nr + mR}$$

Taking Denominator,

$$I = nr + mR$$

$$I = (\sqrt{nr})^2 + (\sqrt{mR})^2 - 2\sqrt{nmRr} + 2\sqrt{nmRr}$$

$$I = (\sqrt{nr} - \sqrt{mR})^2 + 2\sqrt{nmRr}$$

condition :- $\sqrt{nr} - \sqrt{mR} = 0$

then,

$\Rightarrow$ $0 = (0)^2 + 2\sqrt{nmRr}$

$\Rightarrow$ $0 = 2\sqrt{nmRr}$

$\Rightarrow$ $0 = \sqrt{nmRr}$

$\Rightarrow$ $\sqrt{nr} - \sqrt{mR} = 0$

$\Rightarrow$ $nr = mR$

$\Rightarrow$ $\boxed{R = \frac{nr}{m}}$

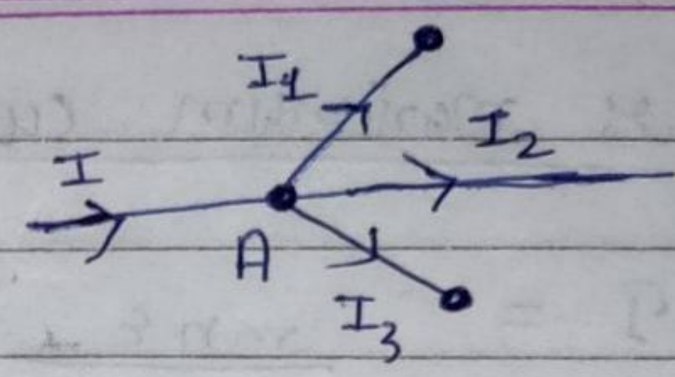
Q.25 Explain Kirchoff's law ?

Ans.25 There is 2 law of Kirchoff's :-

i) KCL (kirchoff's current law) (Junction law)
ii) KVL (kirchoff's voltage law) (Loop law)

i) KCL :- The algebric sum of current flowing in to any point or junction of a circuit is equivalent to the sum of current flowing out of that point or junction. This rule of Kirchoff is also known as nodal rule of current.

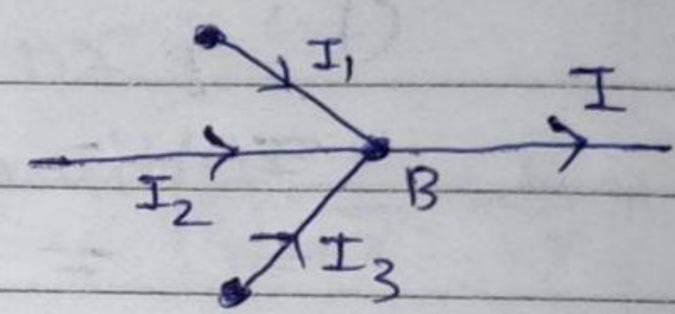
At point A,



$\Rightarrow I = I_1 + I_2 + I_3$

$\Rightarrow \boxed{I - I_1 - I_2 - I_3 = 0}$

At point B,



$\Rightarrow I_1 + I_2 + I_3 = I$

$\Rightarrow \boxed{I_1 + I_2 + I_3 - I = 0}$

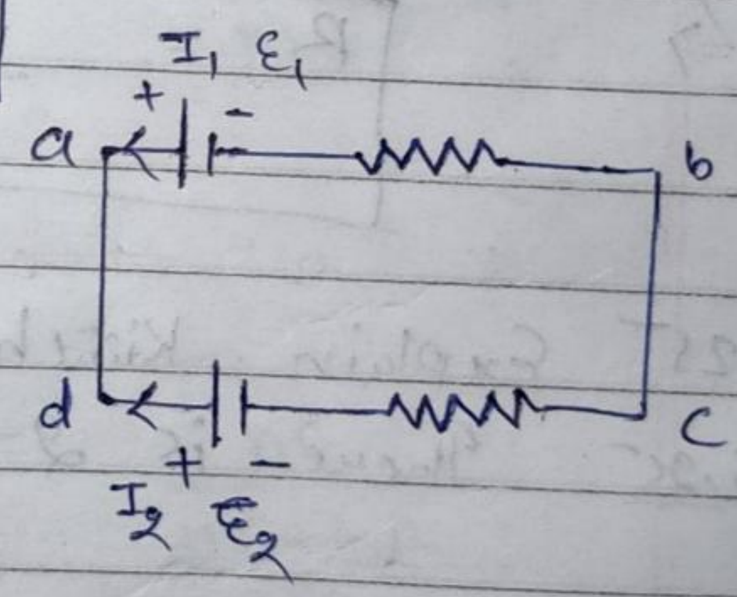
ii) <u>KVL</u> :- The algebraic sum of E.M.F. or Potential difference in any loop /mesh (closed circuit) is zero.

(or)

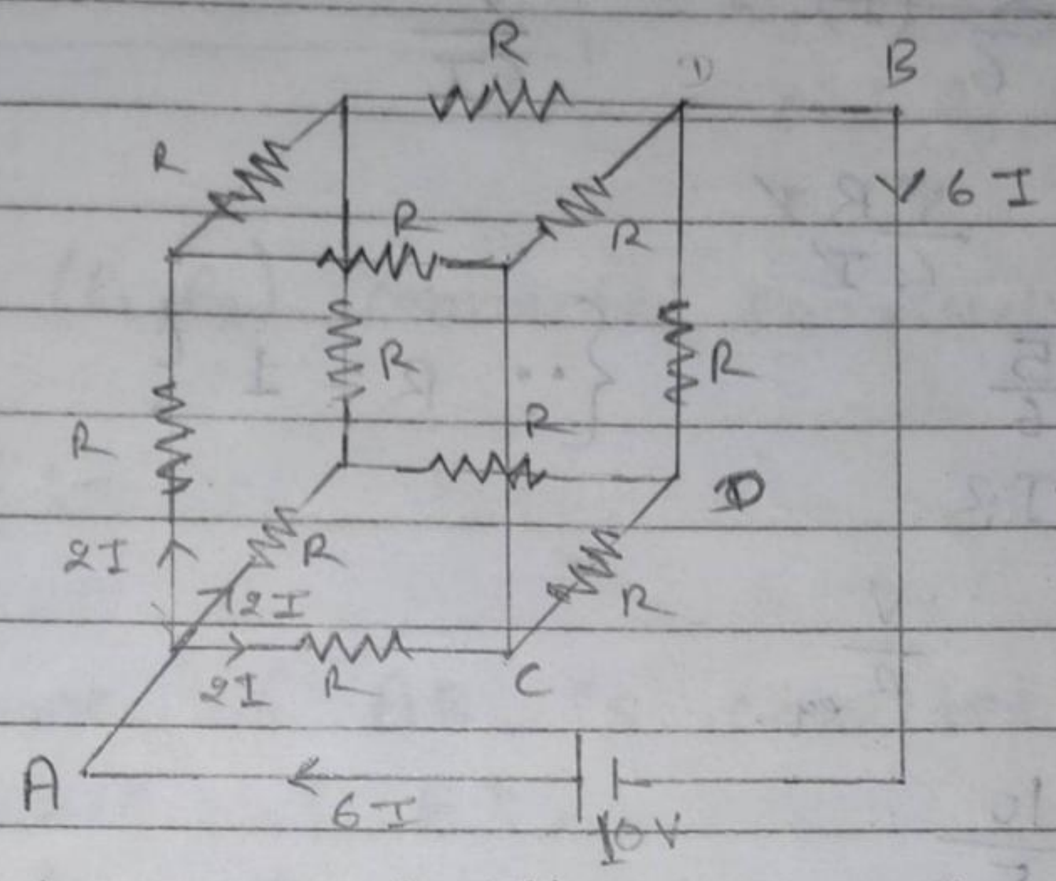
The total E.M.F (Potential difference) in closed circuit (in loop) is equal to algebric sum of product of resistance and corresponding flowing current.

$\therefore V = RI$

$\boxed{\mathcal{E}_2 - \mathcal{E}_1 = R_2 I_2 - R_1 I_1}$

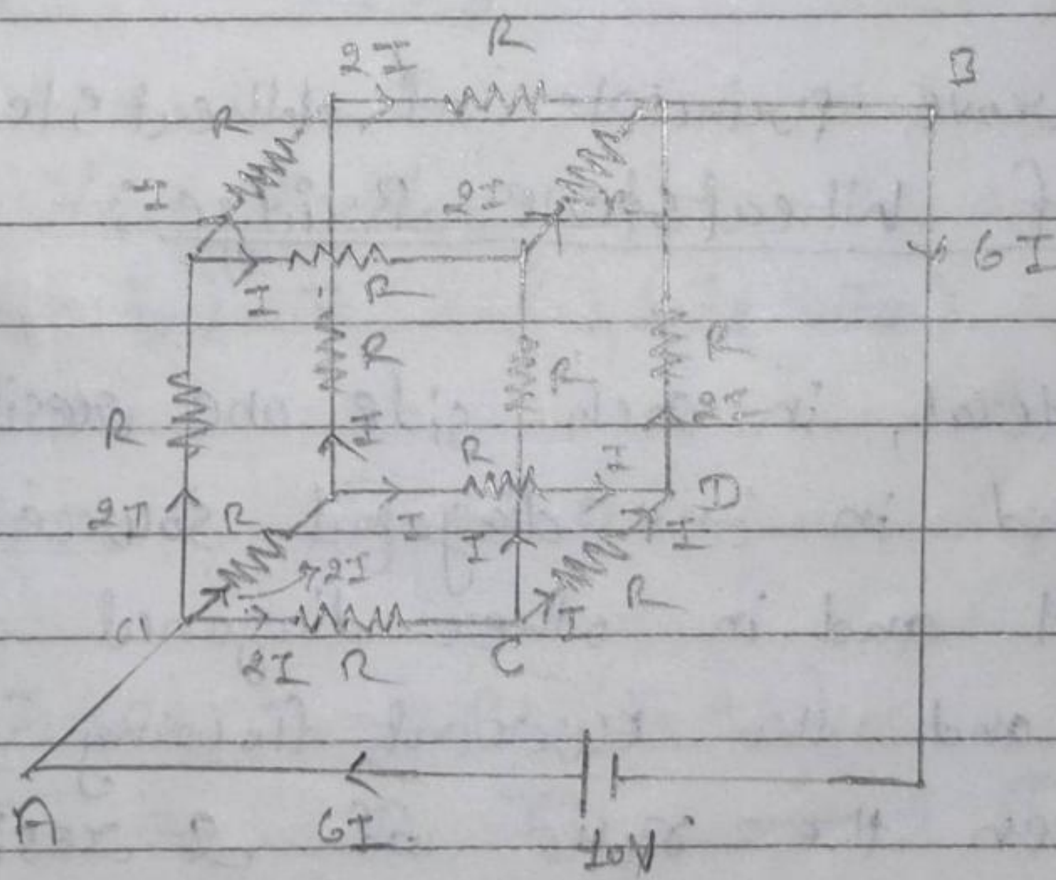


Application of Kirchoff's law :-



By using Kirchoff's law, determine equivalent resistance and flowing current.

Now,



According to second law of Kirchoff (KVL)

$$V = AC + CD + DB.$$

$$\Rightarrow V = R \times 2I + R \times I + R \times 2I$$

$$\Rightarrow V = 2RI + RI + 2RI$$

$$\Rightarrow V = 5RI$$

$$\Rightarrow V = \frac{5}{}RI \Rightarrow V = 5RI$$

$\Rightarrow R_{eq.} = \cancel{\frac{5}{6}(1)I} \quad \frac{V}{6I}$

$\Rightarrow R_{eq.} = \frac{5RI}{6I}$

$\Rightarrow R_{eq.} = \frac{5}{6} \quad \{\because R = 1\}$

$\because V = IR.$

$\Rightarrow I = \frac{V}{R_{eq.}}$

$\Rightarrow 6I = \frac{10}{\frac{5}{6}}$

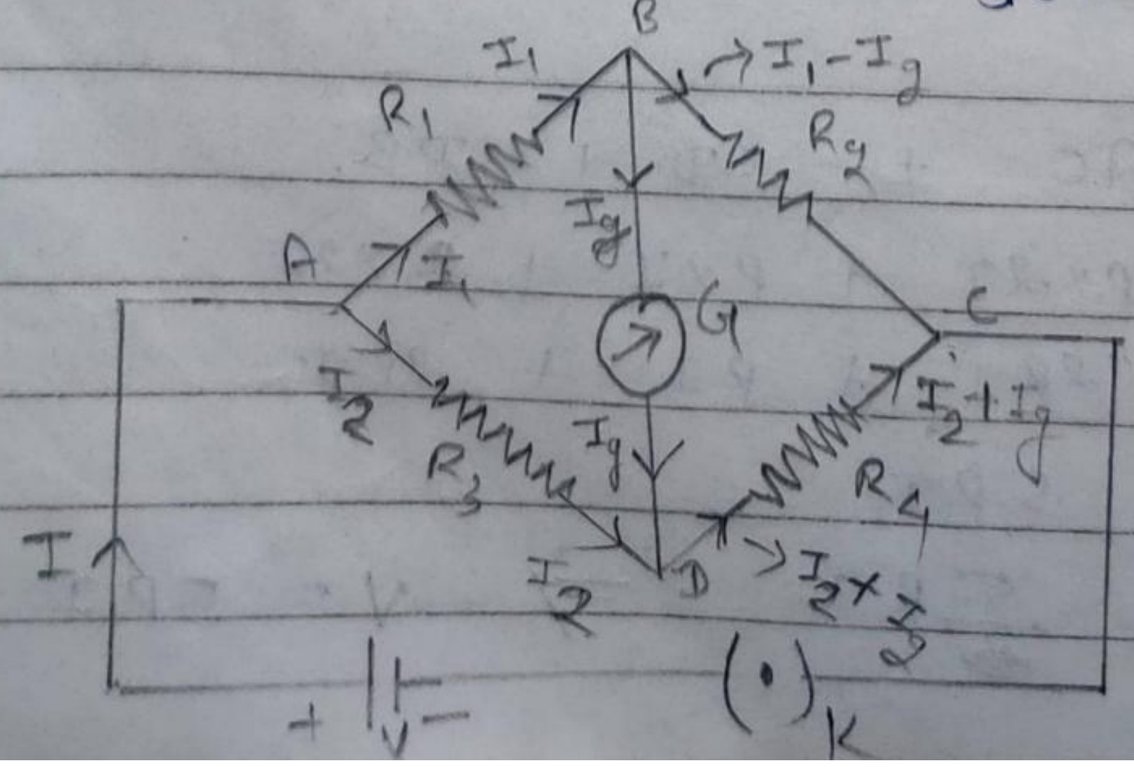
$\Rightarrow 6I = 12$

$\Rightarrow I = 2$ Ampere.

Q. 26. Write and prove principle of Wheatstone Bridge.

Ans. <u>Principle of Wheatstone Bridge :-</u>

In a quadrilateral, in each side one resistance is connected and in one diagonal source of energy is connected and in other diagonal one Galvanometer is connected and the current flowing on Galvanometer is zero then the ratio of 2 resistance in series combination is equal to the ratio of 2 resistance of other series combination.



$$\Rightarrow \boxed{\frac{R_1}{R_2} = \frac{R_3}{R_4}}$$

where,
$R_1, R_2 \rightarrow$ is in series
and $R_3, R_4 \rightarrow$ is in series.

but (R_1, R_2) connected parrallely with (R_3, R_4)

<u>Proof</u> :-

Resistance of AB is connected parrallely with resistance of AD.
Similarly BC is connected parrallely with CD.

$$\Rightarrow V_{AB} = V_{AD}$$

$$\Rightarrow R_1 I_1 = R_3 I_2 \longrightarrow (1)$$

<u>Now,</u>

$$\Rightarrow V_{BC} = V_{CD}$$

$$\Rightarrow R_2(I_1 - I_g) = R_4(I_2 + I_g)$$

<u>Condition</u> : $I_g = 0$

$$\Rightarrow R_2(I_1 - 0) = R_4(I_2 + 0)$$

$$\Rightarrow R_2 I_1 = R_4 I_2 \longrightarrow (2)$$

on (2) / (1)

$$\Rightarrow \frac{R_2 I_1}{R_1 I_1} = \frac{R_4 I_2}{R_3 I_2}$$

$$\Rightarrow \frac{R_2}{R_1} = \frac{R_4}{R_3}$$

doing resiprocal,

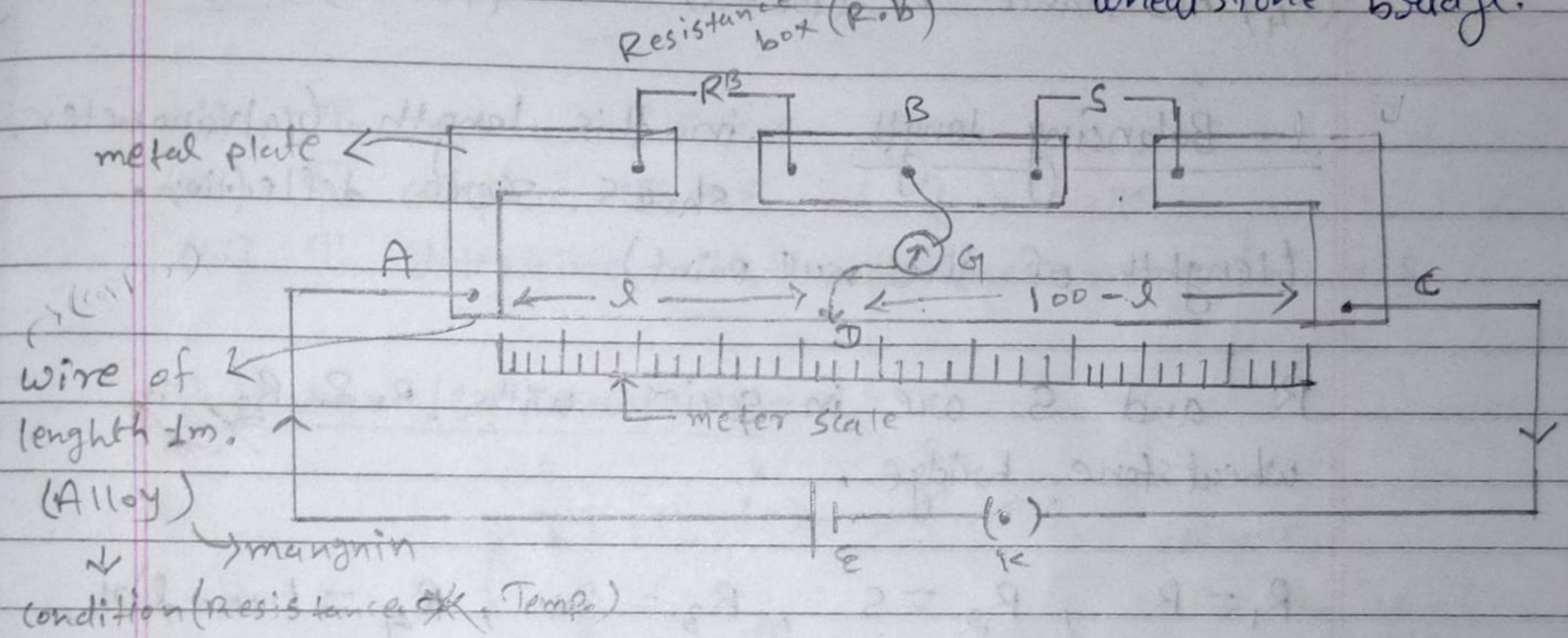
$$\Rightarrow \boxed{\frac{R_1}{R_2} = \frac{R_3}{R_4}}$$ Proved.

Galvanometer :- Galvanometer is a device (electrical device) which is used to detect the flowing current in any circuit or find the direction of current.

Q.27 What is meter bridge.
Q.28. Explain the principle of meter bridge
Q.29 Why this operator is known as meter bridge?
Q.30 What is resistance box?
Q.31 What is the precaution for meter bridge.
Q.32 if the position of cell and galvanometer is change then what is the ~~lenghth~~ affect on balancing lenghth?
Q.33. What do you understand by the potential gradient.
Q.34 What is potentiometer.
Q.35 What is the use of meter bridge.
Q.36. What is the use of potentiometer.
Q.37. a wire of resistance R is streched double lenghth what is the value of new resistance of wire?
Q.38. n no. of wires connected in series after that the given wires are connected in parrallel if the resistance of each wires is R then find out the ratio of series and parrallel combination of the wire.

Ans. 27) Meter bridge is a instrument to determine the resistance and resistivity of the given unknown resistor wire.

Ans. 28) Principle of meter Bridge :- it is based on wheatstone bridge. {same as principle of wheatstone Bridge}



Null point → where Galvanometer G shows no defflection i.e., no current in the branch CD.
(Founded by moving the jockey)

Principle of meter bridge is based on the wheat stone bridge.

From the Z above on plates $\left[\frac{R_1}{R_2} = \frac{R_3}{R_4}\right]$ [when $i_g = 0$ or equilibrium condition]
[no current following in Galvanometer]
↓ will be considered from wire and the null point.

To find the resistance -
Suppose the resistance of the given wire for unit length is = $x\,\Omega$

(R3) Resistance of l = $lx - \Omega$ (length, unit lenghth)

eg. - 3 = 3×1

(R_4) Resistance of $(100-l) = (100-x)\, l\, \Omega$

l – Balancing length - in this length Galvanometer, shows zero deflection.
(lenghth of the null point)

R and S are in series with R_1 & R_2 in wheatstone bridge.

$R_1 = R$, $R_2 = S$, $R_3 = lx$, $R_4 = (100-l)x$.

By wheatstone Bridge,

$$\Rightarrow \frac{R_1}{R_2} = \frac{R_3}{R_4}$$

$$\Rightarrow \frac{R}{S} = \frac{lx}{(100-l)x}$$

$$\Rightarrow R = \frac{lS}{(100-l)}$$

$$\Rightarrow \boxed{S = \frac{R(100-l)}{l}}$$ where S → unknown resistance

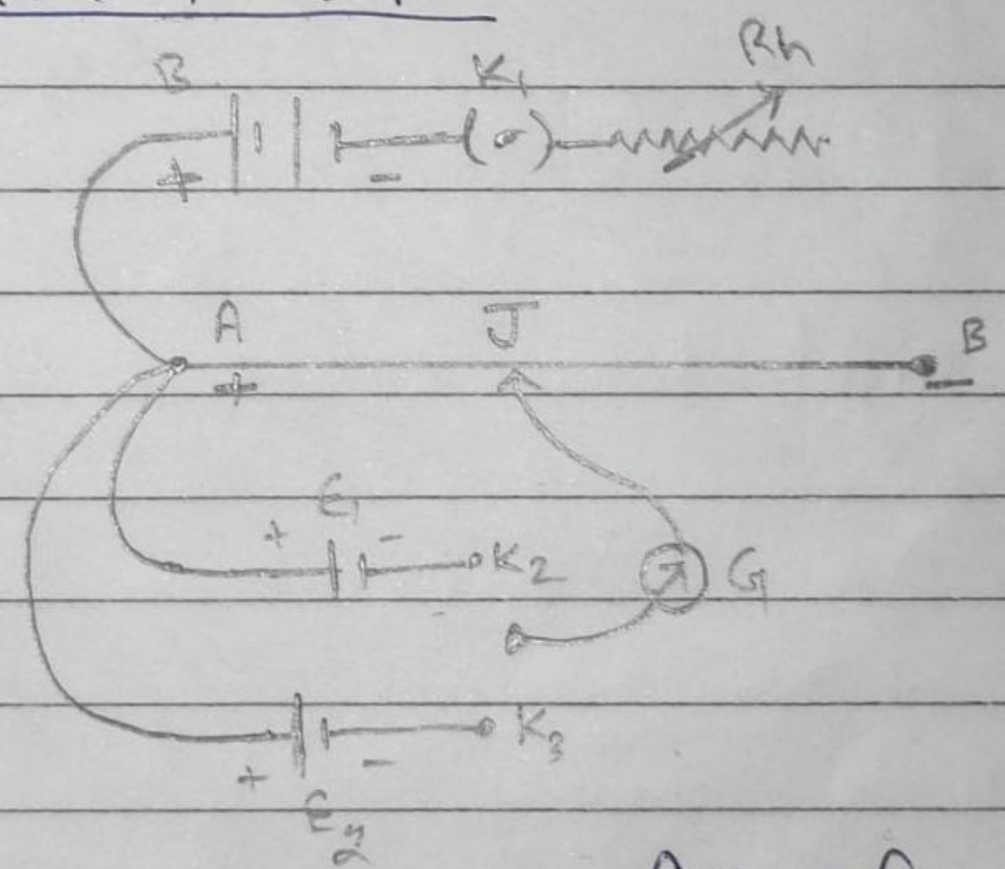
Ans.34 **Potentiometer :-** potentiometer is the device which is mainly used to find the ratio of E.M.F. of two cells and determine the internal resistance.

used manganin Alloy

Uses :-

(i) To measure E.M.F. of a cell
(ii) To compare E.M.F. of two cells.
(iii) To determine internal resistance of cell.

Potentiometer Principle:-



where,
Rh → Rehostant (variable resistance)

Potential gradient → fall of potential per unit length is called potential gradient which is represented by 'K'.

unit:- volt/meter

$$\boxed{K = \frac{V}{l}} \quad \text{or} \quad \boxed{K = \frac{\varepsilon}{l}}$$

$$\Rightarrow K = \frac{V}{l} = \frac{\varepsilon}{l}$$

$\Rightarrow \quad \mathcal{E} = kl$

$\Rightarrow \quad \mathcal{E}_1 = kl_1$

$\Rightarrow \quad \mathcal{E}_2 = kl_2.$

Now,

$$\frac{\mathcal{E}_1}{\mathcal{E}_2} = \frac{kl_1}{kl_2}$$

$$\Rightarrow \quad \boxed{\frac{\mathcal{E}_1}{\mathcal{E}_2} = \frac{l_1}{l_2}}$$

This is principle of potentiometer.