

Electric Current -

The flow of charge in conductor produce electric current.

The branch of physics which deals with the charges in motion is called Current Electricity.

The rate of flow of Electric charge through any cross-section is called Electric current.

If total charge flow in any conductor is Q in time T , then electric current

$$I = \frac{Q}{T}$$

The unit of electric current is Coulomb per second (C/s) i.e. Ampere.

$$1 \text{ Ampere} = \frac{1 \text{ Coulomb}}{1 \text{ second}}$$

★ Electric current is Scalar Quantity

Current Density

The current flowing normally to unit cross-section area at any point of conductor is called current density at that point.

★ It is denoted by j .

If I current flow normally at any point having cross-section area A then current density at that point —

$$j = \frac{i}{A}$$

★ It is a vector quantity (\vec{i})

★ Its unit is ampere/m²

OHM'S LAW

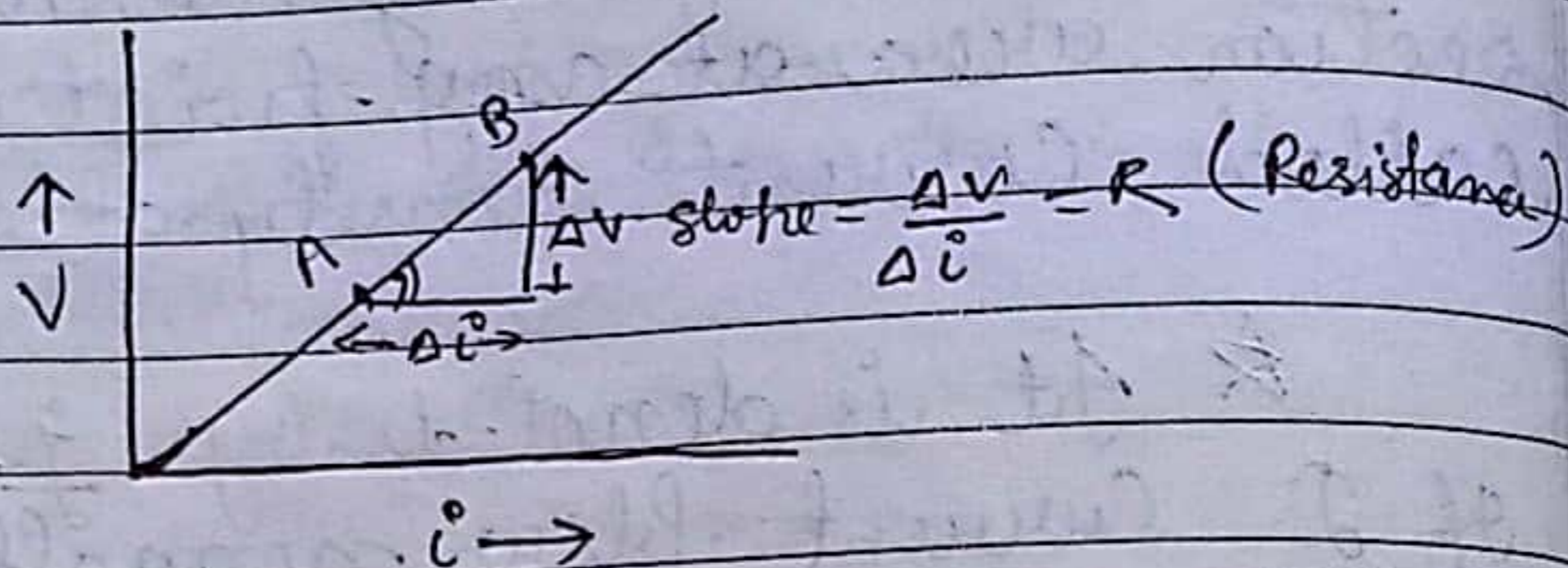
This law states that if the physical conditions like temperature are kept constant then applied voltage across a conductor will be directly proportional to the electric current flow in the conductor i.e.

$$V \propto i$$

$$\text{or, } [V = Ri]$$

where R is a constant which depend upon the length, shape & the nature of material of the conductor.

$$[R = \frac{V}{i}]$$



The S.I. unit of Resistance is Volt/amp
 i.e. called ohm (Ω)
 ↳ Latin symbol

Dimensional formula of Resistance

$$1 \text{ ohm} = \frac{1 \text{ Volt}}{1 \text{ amp}} = \frac{\text{Joule}}{\text{C}}$$

$$= \frac{\text{Joule}}{\text{C} \times \text{amp}}$$

$$= \frac{\text{ML}^2 \text{T}^{-2}}{\text{ATA}}$$

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

Electric Current In Conductors

The electric conduction in conductors

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can be explain by electronic theory

According to this theory every substance are made by atoms there is a nucleus and electrons in different orbit around the nucleus. The outer electron remove by some agitation these electrons are called Free electrons

When no electric field is applied on a solid conductor the free electron in them moves like molecules in a gas there is no certain direction for the velocities of electron Hence no current flow in it.

When an electric field is applied on a solid conductor then an electrical force is applied on every electrons by which they move in a particular direction, Therefore, an electric current flows opposite to the motion of electron in conductor.

In liquid and gases electric conduction take place by movement of both +ve and -ve ions. while in solid conductor electric conduction occurs by the movement of negative charge carriers i.e. electrons only.

There are some other material in which the electron will be bounded and they will not be accelerated even if the electric field is applied such materials are called insulators or dielectric for ex- wood, plastic, paper, rubber etc

Specific Resistance

The resistance of the conductor depends on following factors —

i) $R \propto l$

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

Combine i & ii

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

$$\left[R = \rho \frac{l}{A} \right]$$

where ρ is a constant which is known as specific resistance or Resistivity.

It depends upon the nature of material

* The unit of Resistivity is ohm-m .

Effect of Temperature on Resistance

The resistance of a substance at temperature (t) is —

$$[R_t = R_0 (1 + \alpha t)]$$

where R_0 = Resistance at 0°C

α = Temperature coefficient of Resistance

R_t = Resistance at $t^\circ\text{C}$

- 1) For metal - the value of α is +ve, therefore the resistance of metal increase when we rise temperature.
- 2) For Insulator and Semiconductor - The value of α is -ve, therefore, the resistance decreases when we rise the temperature.
- 3) For alloys - The value of α is very small and it is different at different temperature.

Drift Velocity of free electron

- 1) Thermal velocity of free electron - In a conducting body there are number of free electrons they move just like gaseous molecule move in gas those velocity by which the free electron moves is called their thermal velocity.
- 2) Average thermal velocity of free electron - The average of thermal velocities of all free electrons is called average thermal velocity. for ex - If in a conductor there are n free electrons having thermal velocities $u_1, u_2, u_3, \dots, u_n$ then the average thermal velocity of free electron -

$$\bar{u} = \frac{u_1 + u_2 + u_3 + \dots + u_n}{n}$$

3- Drift velocity of free electron - The average velocity with which the free electrons get drift towards the +ve end of the conductor under the influence of electric field applied across the conductor is called the drift velocity of free electron.

It is denoted by V_d (V_d)

4- Mean free path of free electron - The distance covered by free electron b/w two successive collision with +ve ion is called Mean free path.

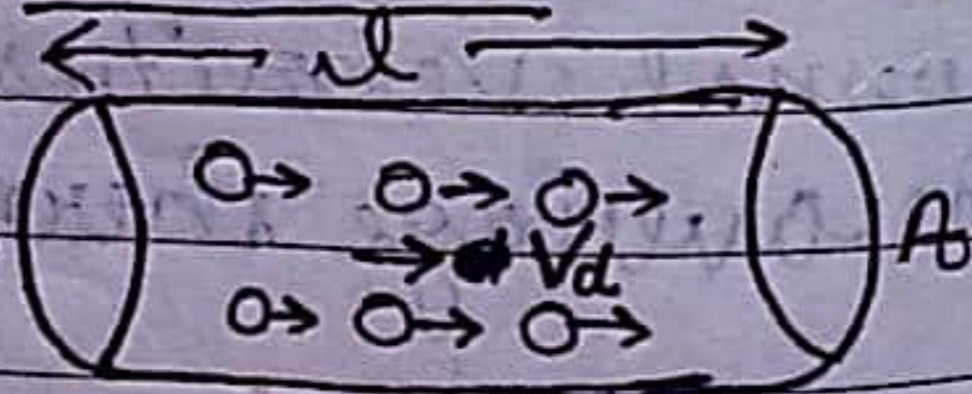
It is denoted by λ

5- Relaxation Time - The time taken b/w two successive collision is called relaxation time.

It is denoted by τ (τ)

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Relation between drift velocity and electric current

Let the no. of free electrons per unit volume = n



The total no. of free e^- in one sec = $V_d A \times n$

The total carrying charge in unit second = $n A V_d \times e$

Therefore, $[i = neAv_d]$

Current density \propto drift velocity

$$j = \frac{i}{A}$$

$$j = \frac{neAv_d}{A}$$

$$[j = nev_d]$$

Imp $\&$

Deduction Ohm's law $\frac{100\%}{\checkmark}$

Let there is a conductor of length l and having cross-section area A there is n free electrons in per unit volume we applied V potential across the conductor then they flow a current i .
If the drift velocity of electron is v_d then -

$$i = nev_d \quad \text{--- (1)}$$

Let the thermal velocities of free electrons are u_1, u_2, \dots, u_n

If the relaxation time of first electron is T_1 then the velocity acquired by electron -

$$v_1 = u_1 + at_1$$

Similarly the velocity gain the other electrons will be $u_2 + at_2, u_3 + at_3, \dots, u_n + at_n$

Therefore the drift velocity of free electrons

$$V_d = \frac{u_1 + a\tau_1 + u_2 + a\tau_2 + \dots + u_n + a\tau_n}{n}$$

$$V_d = \left(\frac{u_1 + u_2 + \dots + u_n}{n} \right) + a \left(\frac{\tau_1 + \tau_2 + \dots + \tau_n}{n} \right)$$

1)
0

$$V_d = a\tau \quad \text{--- (ii)}$$

where $\tau = \left(\frac{\tau_1 + \tau_2 + \dots + \tau_n}{n} \right)$ average

relaxation time

$$\therefore a = \frac{F}{m} = \frac{eE}{m} \quad \dots \quad E = \frac{V}{l}$$

$$a = \frac{eV}{ml}$$

from eq (ii)

$$V_d = \frac{eV}{ml} \times \tau$$

from eq (i)

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

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

$$\frac{E}{I} = \left(\frac{ml}{ne^2 A \tau} \right) \quad \text{--- (iii)}$$

If temperature remain constant

$$\left[\frac{V}{i} = \text{Constant}(R) \right]$$

This is Ohm's law.

Therefore Resistance (R) in Parameter

$$R = \frac{ml}{ne^2AT}$$

$$\Rightarrow R \propto l$$

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

Conductance

The reciprocal of resistance is called Conductance of a conductor.

$$\left[G = \frac{1}{R} \right]$$

The S.I. unit of Conductance is - Ω^{-1} or Siemens

Conductivity

The reciprocal of resistivity of a conductor is called Conductivity.

$$\left[\sigma = \frac{1}{\rho} \right]$$

The S.I unit of conductivity is $\Omega^{-1} \cdot m^{-1}$

current density, conductivity, electric field

Relation between \underline{j} , $\underline{\nabla}$ and \underline{E}

The resistivity of a conductor is also equal to the ratio of intensity of electric field and current density i.e.

$$\rho = \frac{E}{j}$$

$$E = j\rho$$

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

$$E = j \times \frac{1}{\sigma}$$

$$j = \sigma E$$

It is microscopic form of ohm's law

mobility

The magnitude of drift velocity of charge per unit electric field is called mobility of charge. It is denoted by μ

$$\left[\mu = \frac{vd}{E} \right]$$

The unit of mobility is $m^2 \cdot v^{-1} \cdot sec^{-1}$

For free electrons drift velocity.

$$v_d = \frac{eTE}{m}$$

Therefore, $\frac{dc}{dE} = \frac{eTE}{m}$

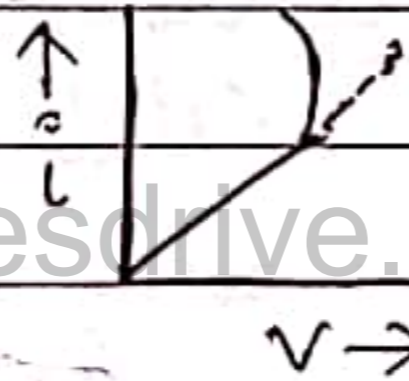
$$\left[\mu_c = \frac{eT}{m} \right]$$

Limitation of Ohm's law

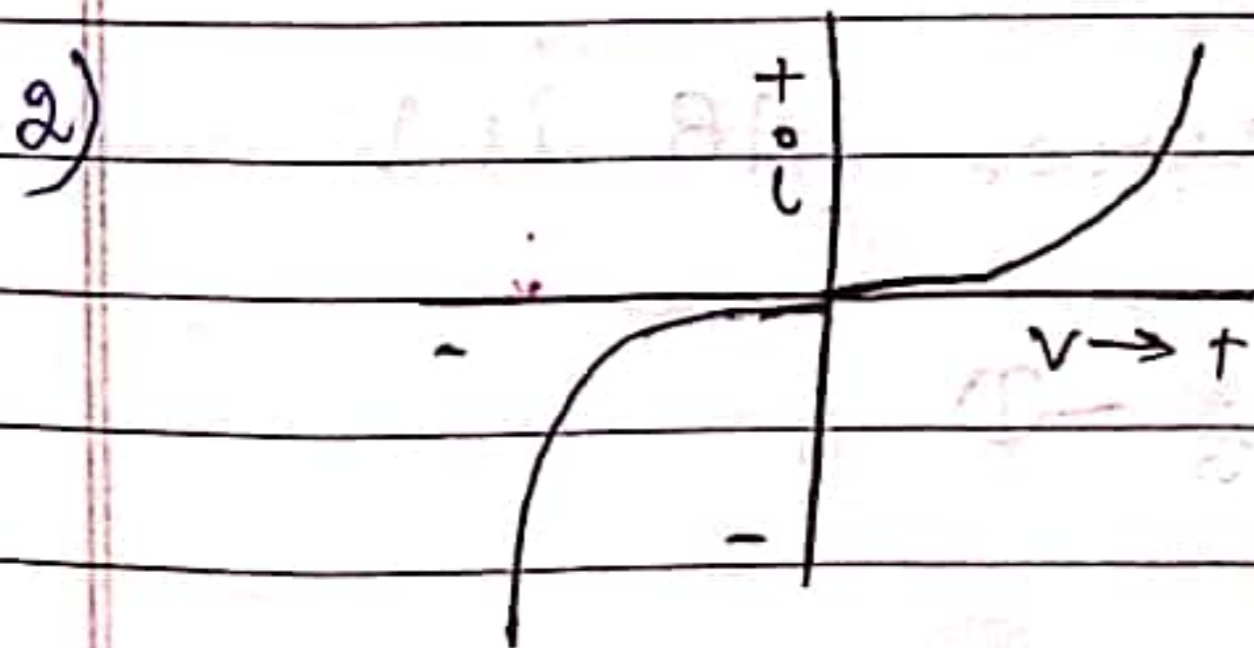
The devices which obey Ohm's law are called ohmic circuit and the devices which do not obey Ohm's law that is called non-ohmic circuit

The limitations of Ohm's law are following

1) Potential difference may vary non-linear with current.



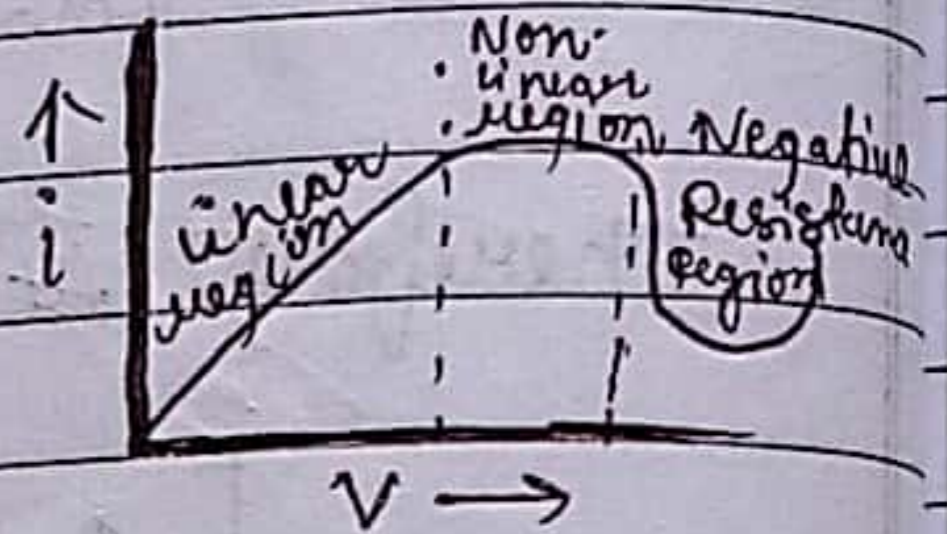
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The variation of current with p.d. may

depend on the sign of p.d. applied.

iii) The relation b/w p.d. & current is not unique.



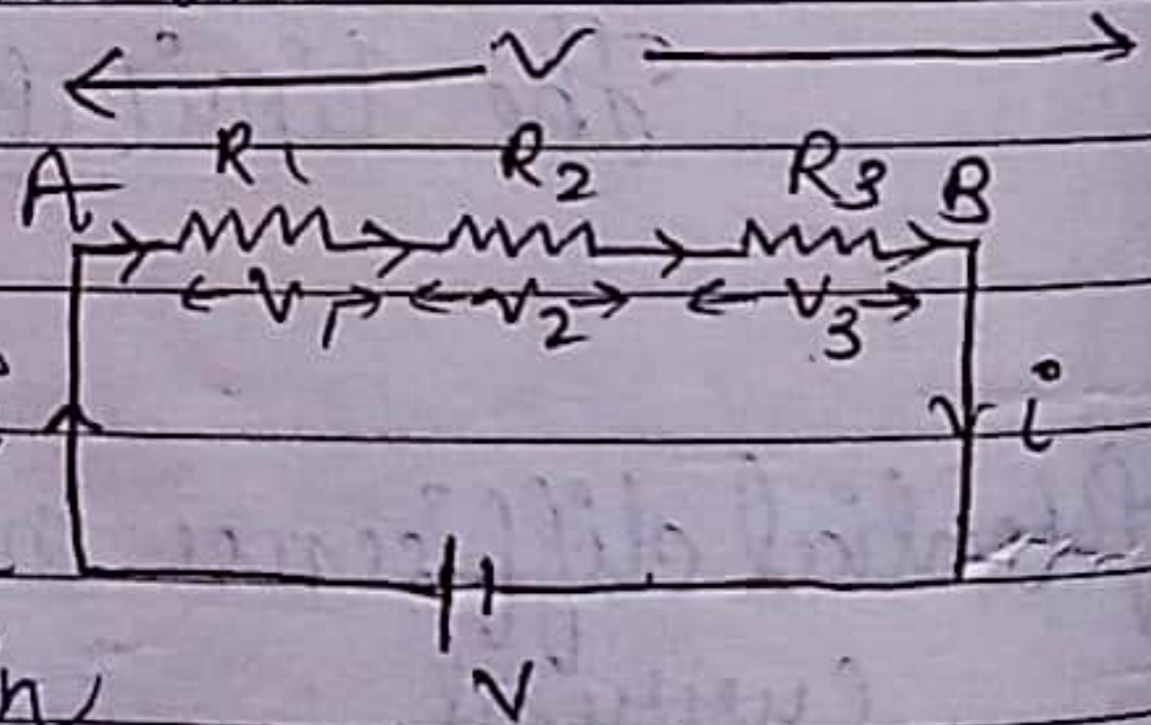
Combination of Resistors

Resistors can be combine in two form.

i) In series

In this combination the resistors are combine end to end. i.e. Second end of first resistor is connected to first end of second resistor and so on.

* In series combination of resistor the potential across the resistor will be different while current in every resistor will be same.



Let, 3 resistors $R_1, R_2, & R_3$ are combined in series b/w A & B

Let, Potential across AB is V then.

$$V = V_1 + V_2 + V_3 \quad \text{--- (1)}$$

$$V_1 = i R_1$$

$$V_2 = i R_2$$

$$V_3 = i R_3$$

Let, equivalent resistance b/w A & B is R
 then $V = IR$
 from eqn ①

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

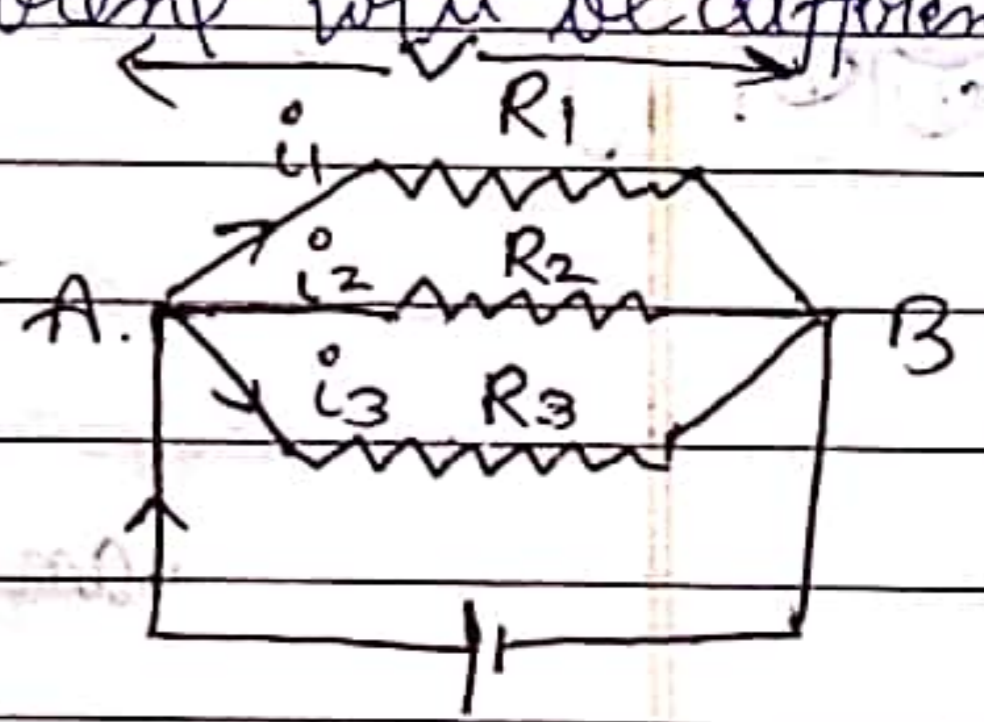
$$[R = R_1 + R_2 + R_3]$$

ii) In Parallel

In parallel combination one end of all resistors are combine at one point and another ends are combine at second point.

★ In this combination the potential across every resistors will be same but current will be different

Let, three resistors $R_1, R_2,$
 & R_3 are combined in
 parallel b/w A & B



The potential across AB is V
 and the current in R_1 is i_1

in R_2 is i_2
 & R_3 is i_3

Therefore, $i = i_1 + i_2 + i_3$ - ①

$$i_1 = \frac{V}{R_1}$$

$$i_2 = \frac{V}{R_2}$$

$$i_3 = \frac{V}{R_3}$$

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

from eq (1)

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

$$\left[\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right]$$

Electrical Energy & Power

Electrical Energy

The electrical energy is the total work done by the source in maintaining the electric current in the given circuit for a specific time.

Let the Emf of source is V
electromotive force
and i current flow in time t

If the charge carry is q

Then work in flowing the current is

$$W = qV$$

$$\therefore q = it$$

$$\therefore \left[\text{Electrical Energy (E)} = Vit \right] \text{ 1st Formula}$$

$$\therefore V = iR$$

$$\text{Electrical Energy } E = iR \times it$$

$$\left[E = i^2 R t \right] \text{ 2nd formula,}$$

$$\therefore i = \frac{V}{R}$$

$$E = \frac{V^2}{R} \times R t$$

$$\left[E = \frac{V^2 t}{R} \right] \text{ 3rd formula}$$

The S.I unit of the electrical energy is Joule

$$1 \text{ Joule} = \text{Volt} \times \text{amp} \times \text{sec}$$

$$\left[1 \text{ Joule} = \text{Watt} \cdot \text{Sec} \right]$$

Electrical Power

The work done in per unit time is called power.

$$P = \frac{W}{t} = \frac{V i t}{t}$$

$$\left[P = Vi \right] \text{ 1st formula}$$

$$P = \frac{i^2 R \cancel{R}}{\cancel{R}}$$

$$[P = i^2 R] \text{ 2nd formula (series)}$$

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

$$[P = \frac{V^2}{R}] \text{ 3rd formula}$$

The S.I unit of Electrical Power is watt

$$1 \text{ watt} = 1 \text{ volt} \times 1 \text{ amp}$$

1 watt

"The power of an electric circuit is 1 watt if 1 amp current is flow in it against the potential difference of 1 volt"

$$1 \text{ kW} = 10^3 \text{ W}$$

$$1 \text{ MW} = 10^6 \text{ W}$$

$$1 \text{ HP} = 746 \text{ W}$$

Commercial unit of Electrical Energy

The commercial unit of electrical energy is kilo-watt-hour is it also called unit.

"(1 kwh) 1 kilo-watt-hour or 1 unit is the amount of electrical energy dissipated in a hour in the circuit when the electrical Power of the circuit is 1 k-watt"

$$1 \text{ kwh} = \frac{\text{Watt} \times \text{hour}}{1000}$$

$$\{ 1 \text{ kwh} = 3.6 \times 10^6 \text{ Joule} \}$$

Electric Cell

It is a device which convert chemical energy into electrical energy

Electromotive force of cell

The work done by the cell in moving unit testing charge through the whole circuit is call the E.m.f. of the cell.

If the work done is w in flowing the charge q then emf of the cell :-

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

The S.I unit of emf is Joule/Coulomb i.e also called volt

Internal Resistance of Cell

The resistance created by electrolyte of the cell to flow the current through it is called Internal resistance of cell.

It is denoted by r

★ The internal resistance of cell depend upon following factors

i) The internal resistance of cell is directly proportional to the distance b/w electrode of cell.

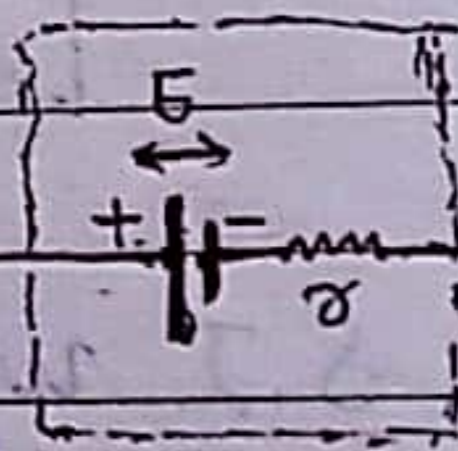
ii) The internal resistance of cell is inversely proportional to the area of electrode.

iii) Internal resistance of cell depend upon the concentration of electrolyte. If the concentration is more internal resistance will be more.

Terminal Potential Difference

The representation of cell is following

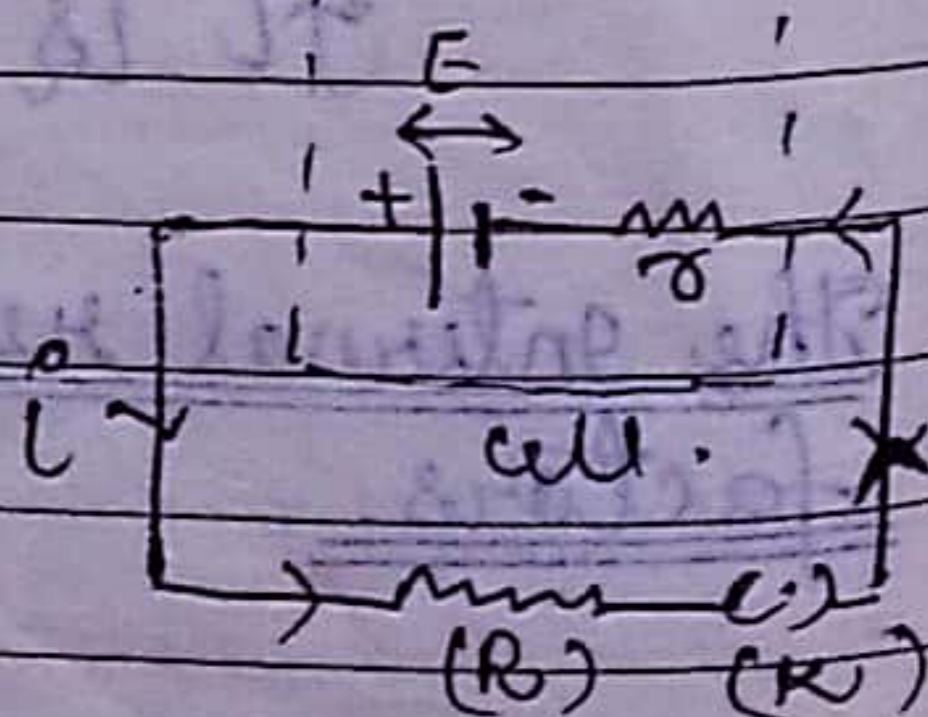
When a cell in close circuit i.e. when current is drawn from the cell the potential difference b/w the two terminal of the cell is called terminal potential of the cell.



Relation b/w terminal potential (V), Emf of the cell (E) and Internal resistance (r) of a cell.

$$i = \frac{\text{total e.m.f.}}{\text{total Resistance}}$$

$$i = \frac{E}{R+r} \quad \text{--- (1)}$$



But by ohm's law

$$V = iR$$

$$i = \frac{V}{R} \quad \text{--- (2)}$$

from (1) & (2)

$$\frac{E}{R+r} = \frac{V}{R}$$

$$ER = VR + Vr$$

$$Vr = (E - V)R$$

$$r = \frac{(E - V)R}{V}$$

$$\left\{ r = \left[\frac{E - V}{V} \right] R \right\}$$

from eqn (1)

$$E = iR + ir$$

$$\therefore V = iR$$

$$[V = E - ir]$$

① If the cell is in close circuit i.e. when the cell is given current then the terminal potential will be every time less than e.m.f of the cell. $V < E$

② If no current is drawn from the cell i.e. cell is in open circuit then e.m.f of the cell will be equal to the terminal potential difference of the cell i.e. $V = E$.

Carbon Resistors

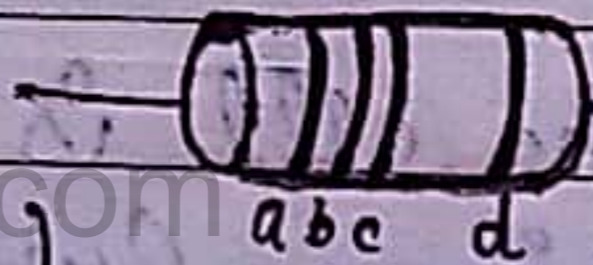
This resistance is based on colour code their value range from kilo Ohm to mega Ohm. Their % accuracy is indicated by a colour code printed on them.

The colour code are following.

B B R O Y is Good Boy & Very Good wife.

B	Black	0
B	Brown	1
R	Red	2
O	Orange	3
Y	Yellow	4
G	Green	5
B	Blue	6
V	Violet	7
G	Grey	8
W	White	9

$$\left[\text{Resistance} = ab \times 10^c \pm d\% \right]$$



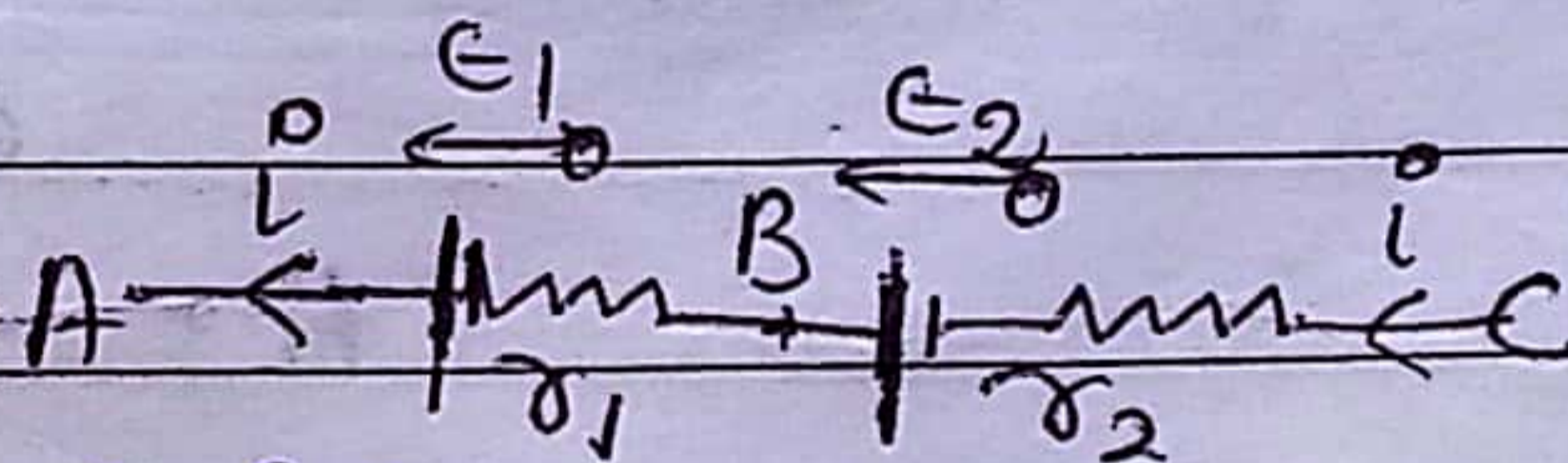
The fourth colour band (d) represent the tolerance of resistance. If d = Colourless 20%.

" d = Gold 5%

" d = Silver 10%

Combination of two cells in Series & Parallel

① In Series



Let two cells having emf \mathcal{E}_1 & \mathcal{E}_2 and internal resistance r_1 & r_2 are combine in series b/w A and C [the terminal potential b/w A and B]

$$V_{AB} = V_A - V_B = \mathcal{E}_1 - ir_1$$

The Terminal potential b/w B & C

$$V_{BC} = V_B - V_C = \mathcal{E}_2 - ir_2$$

Therefore the terminal potential b/w A & C

$$V_{AC} = V_{AB} + V_{BC}$$

$$V_{AC} = (E_1 + E_2) - i(\tau_1 + \tau_2)$$

$$V_{AC} = (E_1 + E_2) - i(\tau_1 + \tau_2)$$

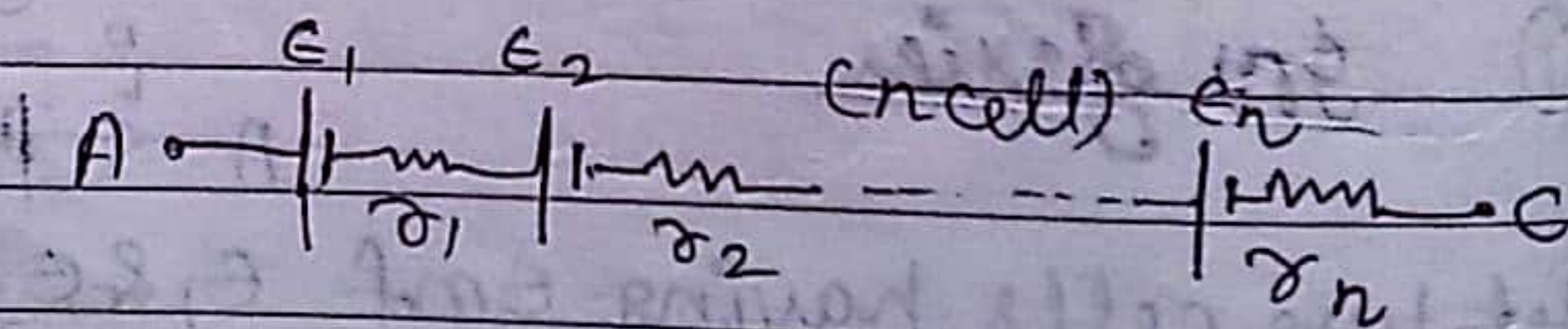
$$[V_{AC} = E_{eqv} - i\tau_{eqv}]$$

Therefore

$$E_{eqv} = E_1 + E_2$$

$$\tau_{eqv} = \tau_1 + \tau_2$$

If there are n cells having emf E_1, E_2, \dots, E_n and internal resistance R_1, R_2, \dots, R_n are combine in series

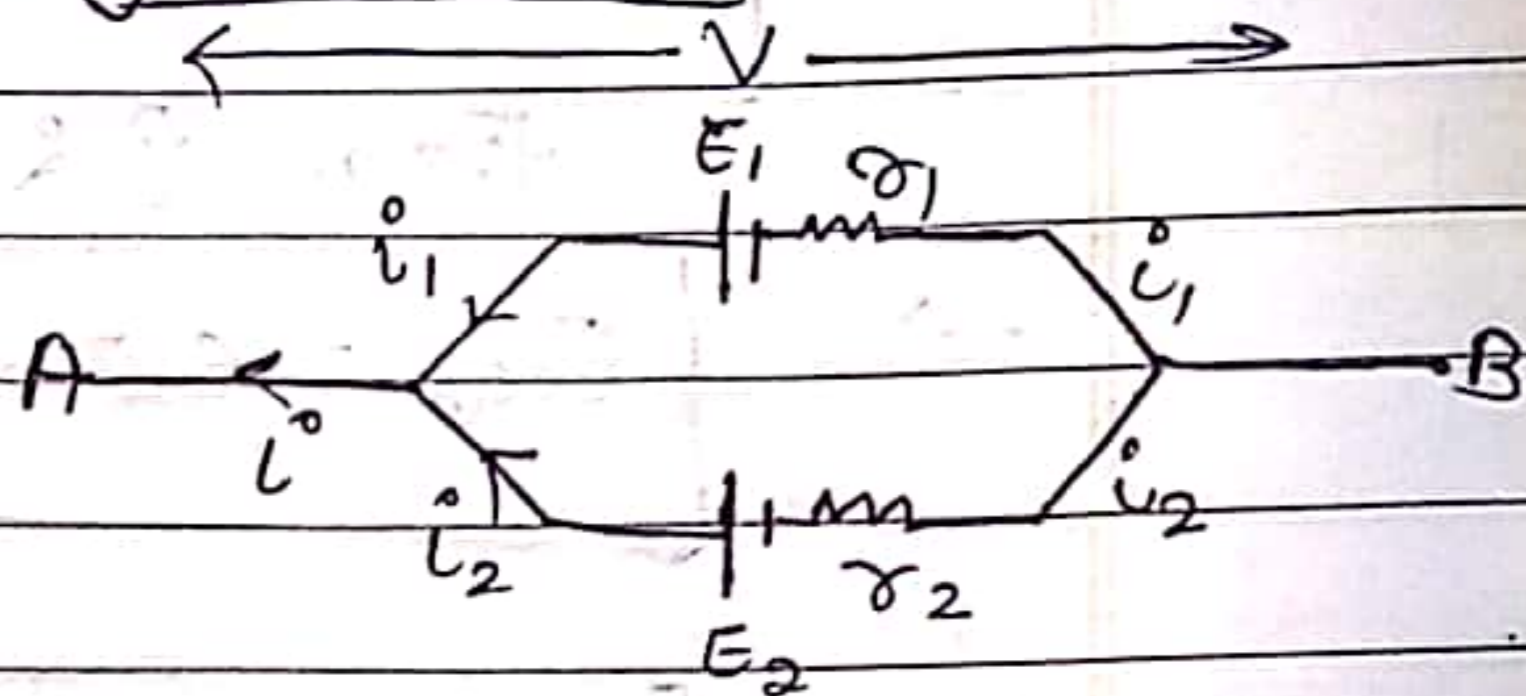


$$[E_{eqv} = E_1 + E_2 + \dots + E_n]$$

$$[R_{eqv} = \tau_1 + \tau_2 + \dots + \tau_n]$$

Combination of cells in parallel

$$i^0 = i_1 + i_2 \quad \text{--- (1)}$$



For first cell

$$V = E_1 - i_1 r_1$$

$$i_1 = \frac{E_1 - V}{r_1} = \frac{E_1}{r_1} - \frac{V}{r_1}$$

For second cell

$$i_2 = \frac{E_2 - V}{r_2}$$

From eqn (1)

$$i^0 = \frac{E_1}{r_1} - \frac{V}{r_1} + \frac{E_2}{r_2} - \frac{V}{r_2}$$

$$i^0 = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2} \right) - V \left(\frac{1}{r_1} + \frac{1}{r_2} \right)$$

$$i^0 = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 r_2} \right) - V \left(\frac{r_1 + r_2}{r_1 r_2} \right)$$

$$V \left(\frac{r_1 + r_2}{r_1 r_2} \right) = \frac{E_1 r_2 + E_2 r_1}{r_1 r_2} - i^0$$

~~$$V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 r_2} \right) \times \frac{r_1 r_2}{r_1 + r_2} - i^0 \frac{r_1 r_2}{r_1 + r_2}$$~~

$$V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} \right) - i^0 \left(\frac{r_1 r_2}{r_1 + r_2} \right) \quad \text{--- (11)}$$

$$V = E_{\text{cell}} - i_{\text{cell}} r \quad \text{--- (iii)}$$

From (ii) & (iii)

$$\Rightarrow E_{\text{cell}} = \frac{\epsilon_1 r_2 + \epsilon_2 r_1}{r_1 + r_2} \quad \text{(iv) 1st formula}$$

$$\Rightarrow r_{\text{cell}} = \frac{r_1 r_2}{r_1 + r_2} \quad \text{(v) 2nd formula}$$

From eqn (v)

$$\frac{1}{r_{\text{cell}}} = \frac{1}{r_1} + \frac{1}{r_2}$$

$$E_{\text{cell}} \text{ (iv)} \div r_{\text{cell}} \text{ (v)}$$

$$\frac{E_{\text{cell}}}{r_{\text{cell}}} = \frac{\epsilon_1 r_2 + \epsilon_2 r_1}{r_1 + r_2} \times \frac{r_1 + r_2}{r_1 r_2}$$

$$\frac{E_{\text{cell}}}{r_{\text{cell}}} = \frac{\epsilon_1}{r_1} + \frac{\epsilon_2}{r_2}$$

If there are n cells having e.m.f $\epsilon_1, \epsilon_2, \dots, \epsilon_n$ and internal resistance R_1, R_2, \dots, R_n Combined in parallel then

$$\left[\frac{1}{r_{\text{cell}}} = \frac{1}{r_1} + \frac{1}{r_2} + \dots + \frac{1}{r_n} \right]$$

$$\left[\frac{C_{eqv}}{\sigma_{eqv}} = \frac{C_1}{\sigma_1} + \frac{C_2}{\sigma_1} + \dots + \frac{C_n}{\sigma_n} \right]$$

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Kirchoff's Law

This law represent the distribution of current in any electrical circuit. Kirchoff's given two laws

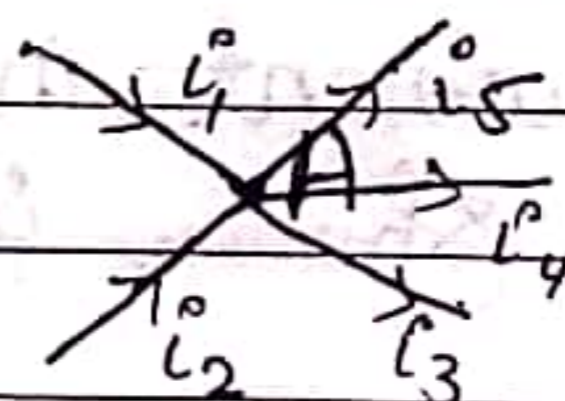
i) First Law → This law states that algebraic sum of currents meeting at any junction of circuit will be zero.
i.e. $[\sum i = 0]$

Let there are 5 currents meet at junction A. i_1 & i_2 upcoming towards the junction while i_3 , i_4 & i_5 are going away from the junction.

According to sign convention the currents incoming towards the junction will be taken +ve, & the currents going away the junction will be taken -ve.

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

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



This law follow Conservation Law of Charge

ii Second law — According to this law the algebraic sum of multiplication of current & Resistance in any loop will be equal to the algebraic sum of E.m.f. of the cell.

NOTES → Sign Convention → If the resistance is in direction of electric current then product of current and resistance will be taken +ve.

★ The E.m.f. of the cell will be +ve if it is directed from -ve plate to +ve plate.

$$\left[\sum iR = \sum E \right]$$

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Wheat Stone Bridge

An English scientist wheat stone construct a device by which we can calculate an unknown resistance.

Four resistances P, Q, R, S are connected in series & connected in the form of tetragonal rectangle.

In diagonal BD and a galvanometer (G) and key (K_2) are connected in another diagonal AC a cell and key (K_1) are connected.

Principle :-

Wheat stone arrange the resistance such type after which

when we press key K_1

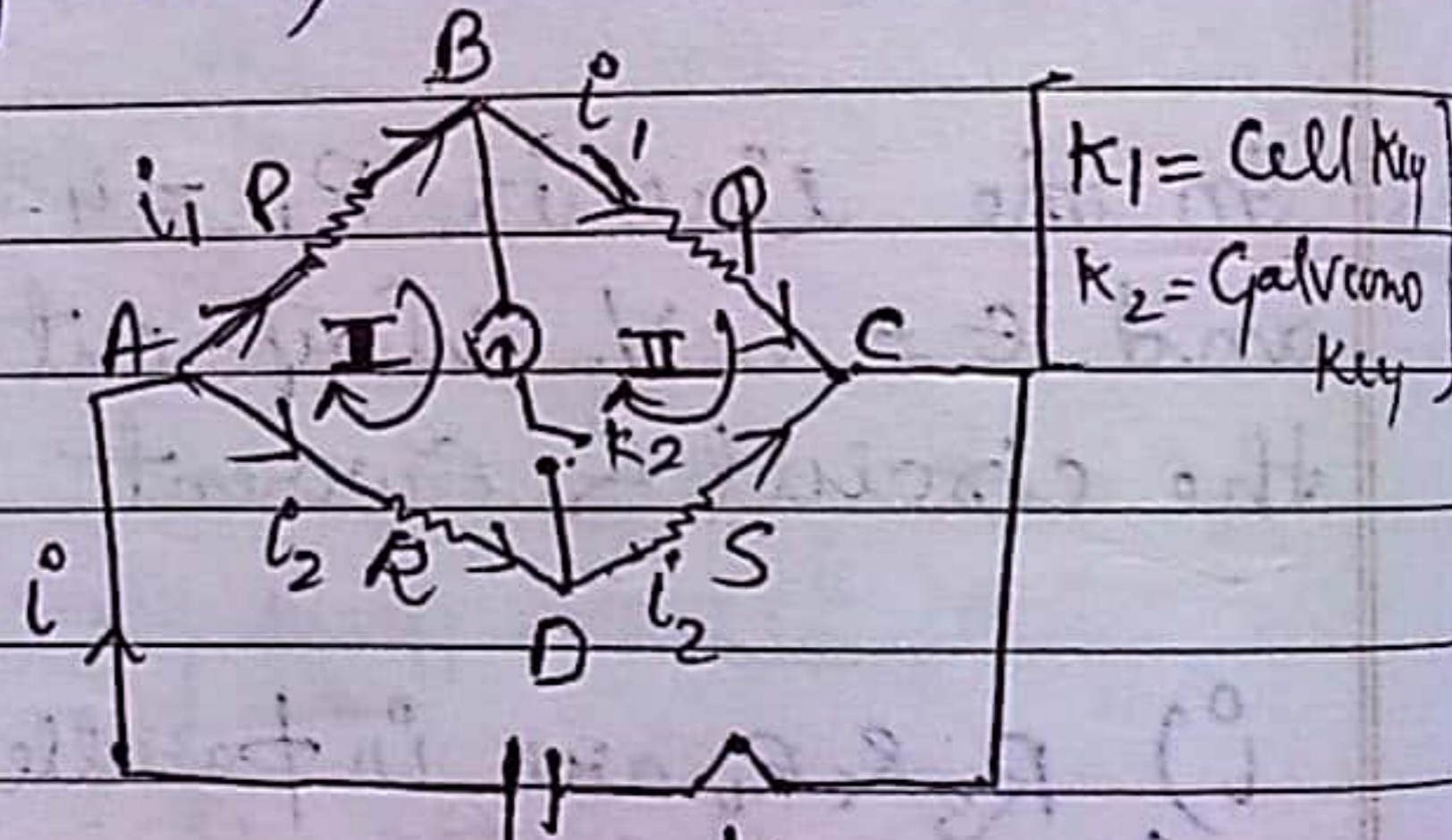
& K_2 then there is no

deflection in galvanometer in this condition

B & D will be at same potential i.e. there

will not flow any current in BD . then we

say that Bridge is at Balanced position



In Balanced position -

$$\left[\frac{P}{Q} = \frac{R}{S} \right]$$

Proof :-

In closed mesh (I)

$$i_2 P - i_2 R = 0$$

$$i_1 P = i_2 R \quad \text{--- (1)}$$

In closed mess II.

$$i_1 Q - i_2 S = 0$$

$$i_1 Q = i_2 S \quad \text{--- (2)}$$

eq (1) \div eq (2)

$$\left[\frac{P}{Q} = \frac{R}{S} \right]$$

P and Q are called ratio arm

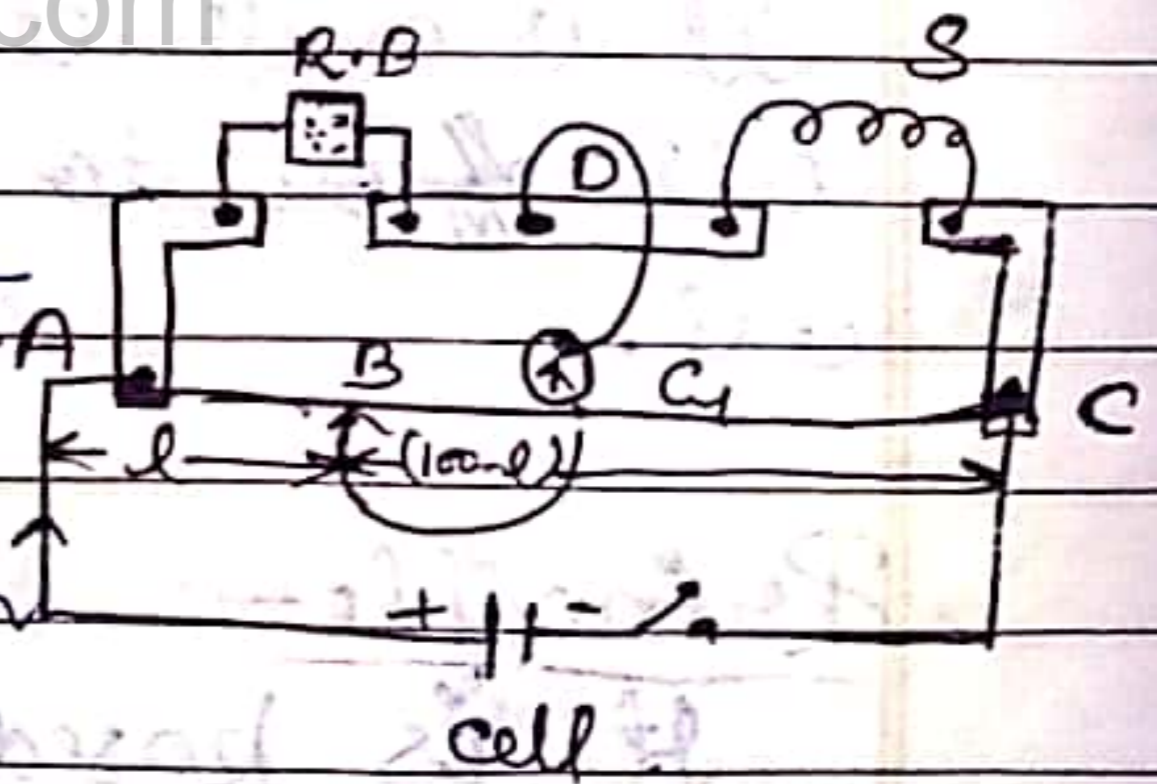
R = Known arm

S = Unknown arm

NOTE - wheat stone Bridge have more accuracy when every resistor will be at same order.

Metre Bridge

Metre Bridge is an instrument based upon balance wheat stone bridge to measure unknown resistance.



Principle -

It is constructed on the principle of balanced wheat

stone bridge i.e. when a wheat stone bridge is balanced —

$$\left[\frac{P}{Q} = \frac{R}{S} \right] \text{ — (1)}$$

Null deflection point
↓
Balanced

$$P = f \frac{l}{A}$$

$$Q = f \frac{100-l}{A}$$

$$\frac{P}{Q} = \frac{l}{100-l}$$

from eq (1)

$$\frac{l}{100-l} = \frac{R}{S}$$

$$\left[S = R \left(\frac{100-l}{l} \right) \right]$$



Potential metre

It is a device used to compare emf of two cells or to measure internal resistance of a cell.

Principle—

It is based on the fact that fall of potential across any portion of a wire is directly proportional to the length i.e. —

$$V \propto l$$

$$V = k \cdot l$$

$$k = \frac{V}{l}$$

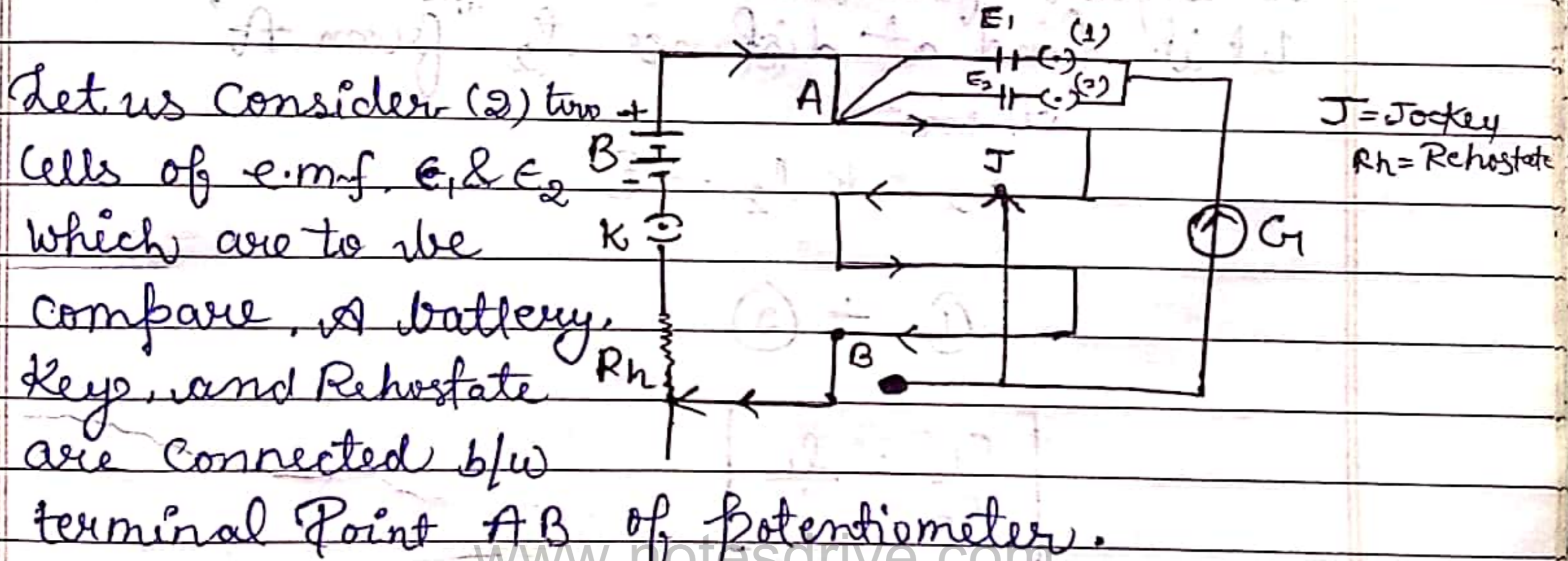
where k is a constant which is called potential gradient

“ The fall of potential per unit length is called potential gradient.

Its unit is Volt/meter ~~v/m~~ Volt/m

Application-

① To compare the e.m.f of two cell.



The positive end of both cell are connected to terminal A & -ve terminal of both cells are connected to a double way key and it is connected with Galvanometer & Galvanometer connected with jockey (J)

first on the key (K) to flow a constant current in potentiometer.

and plug one Kepton of double way key and turn (2) off. And now slide jockey from end A let it at point J when we touch the jockey on wire there is no deflection in galvanometer this is non-deflection position

Now measure the distance from A to J let it is l_1 then —

$$E_1 = K l_1 \quad \text{--- (1)}$$

where K is potential gradient.

Now the plug (2) kept on and plug (1) off & again find the non-deflection position let it find at distance l_2 from A then —

$$E_2 = K l_2 \quad \text{--- (2)}$$

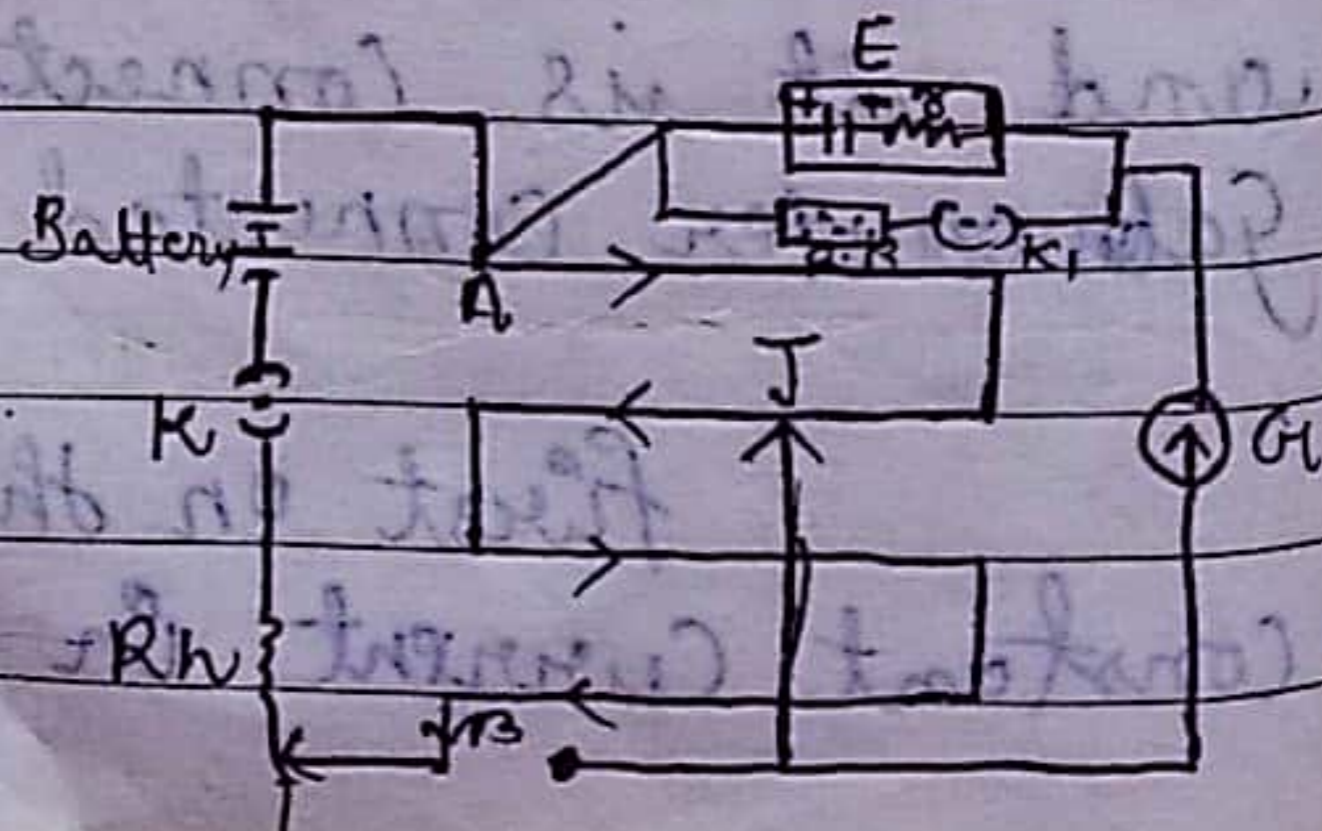
$$\text{(1)} \div \text{(2)}$$

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

②

To measure internal resistance of a cell.

To measure the internal resistance of the cell first a constant current is maintain



through potentiometer wire with the help of battery and Rheostat.

The plug key K_1 is kept out & jockey J is moved on the wire of potentiometer & find the non-deflection point. Let the distance of non-deflection point from end A is l_1 , then —

$$E = k l_1 \quad \text{--- (1)}$$

Now, the plug key K_1 put in the circuit and a resistance R is taken from the resistance box & again find the non-deflection point.

Let in this position the distance of non-deflection point from A is l_2 then terminal potential b/w the electrodes of cell.

$$V = k l_2 \quad \text{--- (2)}$$

$$\text{(1)} \div \text{(2)}$$

$$\frac{E}{V} = \frac{l_1}{l_2}$$

The internal resistance of cell

$$r = R \left[\frac{E}{V} - 1 \right]$$

$$r = R \left[\frac{l_1}{l_2} - 1 \right]$$

Internal Now put the value of $l_1 = \frac{E}{V}$ & R in above equation we can find the internal resistance of cell

$$\therefore r = R \left[\frac{l_1}{l_2} - 1 \right]$$