Physics

Current Electricity

Unit: - 2nd

Class: - 12th
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Unit :- II (Current and Electricity).

Q: Define Electric current ?

The Current is Rate of flow of charge through the surface of the Conductor with Respect to the time is known as current.

Here ΔQ = flow of charge
Δt = time taken by the charge

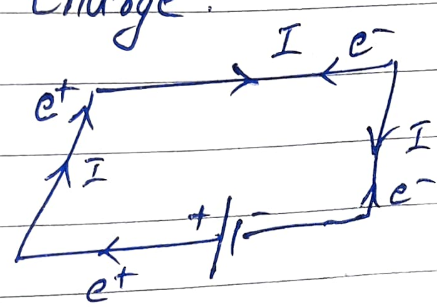
ie $$\boxed{I = \frac{\Delta Q}{\Delta t}}$$

$$\boxed{I = \frac{dQ}{dt}}$$

SI Unit unit of current is (Ampere)

Direction of electric current :-

The direction of electric current is toward the flow of (+ve) charge and opposite to the direction of flow (-ve) charge.



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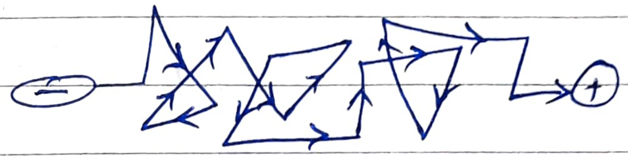
Q Drift velocity :-

drift velocity is defined as the average velocity with which the free electrons get drifted towards the positive end of the conductor under the influence of an external electric field applied.



Consider a metal conductor having large number of free electrons. At Room temperature these electrons moves Randomly every where with in conductor and the average thermal velocity of the electron is zero.
let $\vec{u}_1$, $\vec{u}_2$, $\vec{u}_3$ ---, $\vec{u}_n$ are Random thermal velocities of (n) free electrons.

$$\text{ie} \quad \frac{\vec{u}_1 + \vec{u}_2 + \vec{u}_3 + \dots + \vec{u}_n}{n} = 0 \quad \text{--- (1)}$$

when some potential difference is applied across the two end of a conductor, an electric field is setup inside the conductor and hence electron inside the conductor flow toward (+ve) end of the conductor.

Now (V) is the potential difference applied across the Conductor of length l,

ie $E = \frac{\text{Potential difference}}{\text{length}} = \frac{V}{l}$

Now the charge in the Conductor experience a force due to this electric field

$$\vec{F} = -e\vec{E} \quad \text{—— (11)}$$

(-ve) show that the direction of electric field and flow of electron is opposite to each other.

Now acc. of each electron is

$$\vec{a} = -\frac{e\vec{E}}{m} \qquad \left[\because a = \frac{F}{m}\right]$$

Now there are two velocities thermal and due to electric field.

Now $\vec{v}_1 = \vec{u}_1 + \vec{a}\tau_1$ (at any instand of time)

$\vec{v}_2 = \vec{u}_2 + \vec{a}\tau_2$

— — — — —

$\vec{v}_n = \vec{u}_n + \vec{a}\tau_n$

The average velocity of all the free electrons in a conductor is the drift velocity $\vec{V}_d$

$$\vec{V}_d = \frac{\vec{V}_1 + \vec{V}_2 + \dots + \vec{V}_n}{n} = \frac{(\vec{u}_1 + \vec{a}\tau_1) + (\vec{u}_2 + \vec{a}\tau_2) + \dots + (\vec{u}_n + \vec{a}\tau_n)}{n}$$

$$= \frac{(\vec{u}_1 + \vec{u}_2 + \dots + \vec{u}_n)}{n} + a\frac{(\tau_1 + \tau_2 + \dots + \tau_n)}{n}$$

$$\vec{V}_d = 0 + \vec{a}\tau = \vec{a}\tau$$

where $\tau = \frac{\tau_1 + \tau_2 + \dots + \tau_n}{n}$ (Relaxation time)

$$\vec{V}_d = \frac{-e\vec{E}\tau}{m}$$

Average drift speed $\boxed{V_d = \frac{eE\tau}{m}}$ (Magnitude)

Mobility :-

Mobility of charge carrier (μ), Responsible for the current is defined as the magnitude of drift velocity of charge per unit electric field applied.

$$\mu = \frac{\text{drift velocity}}{\text{electric field}} = \frac{V_d}{E} = \frac{eE\tau}{mE} = \frac{e\tau}{m}$$

$$\boxed{\mu = \frac{q\tau}{m}}$$

Mobility of electron $\boxed{\mu_e = \frac{e\tau_e}{m_e}}$

Mobility of Holes $\boxed{\mu_h = \frac{e\tau_h}{m_h}}$

S.I. Unit of mobility is $= \frac{\text{Drift velocity}}{\text{electric field}}$

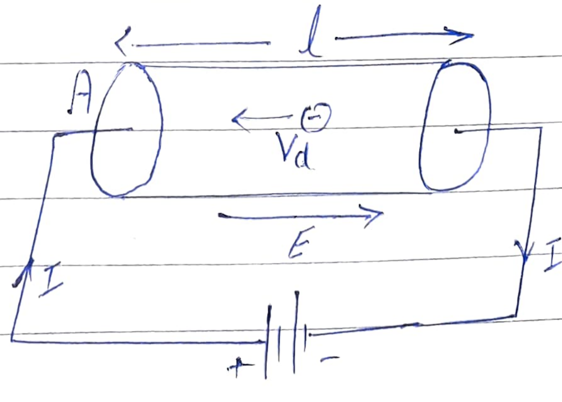
$$= \frac{[L][T]^{-1}}{\frac{[V]}{[L]}}$$

$$= [L]^2[V]^{-1}[T]^{-1}$$

$$= [L^2V^{-1}T^{-1}]$$

$$= m^2V^{-1}s^{-1}$$

Relation between Current and drift velocity:-



Consider a Conductor of length (l) and of Uniform area A.

$\therefore$ Volume $= Al$

If n = number density of electron

Then total number of free electrons in the Conductor $= Aln$.

if (e) is the Charge on each electron.

$\therefore$ total Charge on all free electrons in the Conductor

$$q = Alne \quad \text{— (1)}$$

Let potential difference (V) applied across the Conductor the electric field set up (E)

ie $E = V/l$

Now Due to field the electron drifted toward the (+ve) end of the Conductor (V_d)

Now time taken by the electron to cross the Conductor

$$t = l/V_d$$

Hence Current $I = \dfrac{q}{t} = \dfrac{Alne}{l/V_d}$

$$\boxed{I = Ane v_d}$$

$$v_d = \mu_e E$$

ie $\boxed{I = Ane\mu_e E}$

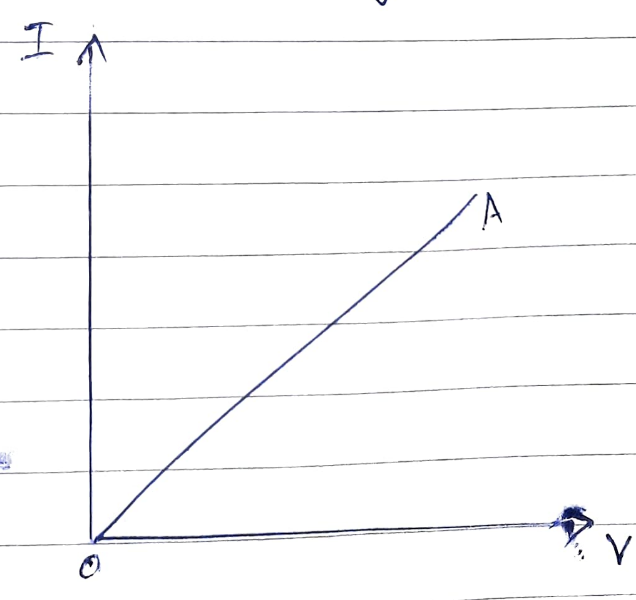
This is the Relation between current and drift velocity.

OHM's Law :- ohm's law State that the current 'I' flowing through a conductor is directly proportional to the potential difference (V) across the conductor, provided physical conditions of the conductor such that temperature, mechanical strain etc. are kept constant.

ie $I \propto V$ or $V \propto I$

$$V = IR \quad \text{or} \quad \boxed{R = \frac{V}{I}}$$

Where R is known as resistance of the conductor.



We know that

$$v_d = \frac{eE\tau}{m}$$

But $E = \frac{V}{l}$

$$v_d = \frac{e\tau}{m}\frac{V}{l}$$

also $I = Ane v_d$

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

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

$$\frac{V}{I} = \frac{ml}{Ane^2\tau} = R = \text{Constant Value}$$

ie $\boxed{\frac{V}{I} = R}$ $\left[R = \frac{ml}{Ane^2\tau}\right]$

ohm's law

Resistance :- The resistance of a Conductor is the obstruction possessed by the Conductor to the flow of electric current through it.

or

Resistance (R) of a Conductor is defined as the ratio of the Potential difference (V) across the end of the Conductor to the Current (I) flowing through it.

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

S.I. Unit of Resistance is ohm (Ω)

Resistance (dimension) = $[M^1 L^2 T^{-3} A^{-2}]$

$$R = \frac{[V]}{[I]} = \frac{[ML^2T^{-3}A^{-1}]}{[A]} = [ML^2T^{-3}A^{-2}]$$

$$V = \frac{\text{work}}{\text{Charge}} = \frac{[ML^2T^{-2}]}{[AT]} = [ML^2T^{-3}A^{-1}]$$

$$I = [A]$$

Cause of Resistance due to the Collision of free electron with with ions or atoms.

⇒ **RESISTIVITY:-**

The Resistivity of the Conductor $R \propto l$ and also $R \propto 1/A$

$$\therefore R \propto l/A$$

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

Here (ρ) specific resistance (electrical Resistivity) of the material of the Conductor

If $l = 1$, $A = 1$ then $\boxed{R = \rho}$

The specific Resistance of the material of a Conductor is defined as the Resistance offered by unit length and unit area of cross-section by a wire of the given material of Conductor. (It also define as the resistance of unit cube of a material of the given Conductor)

Unit of Resistivity:- $\rho = \frac{RA}{l}$

$= \frac{ohm \times m^2}{m}$

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

Dimensions of Resistivity $= [ML^2T^{-3}A^{-2}][L]$

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

⇒ Current Density:- Current density (J) at a point in a Conductor is defined as the amount of current flowing per unit area of the Conductor around that point provided the area is held in a direction normal to the current.

Let I be the current distributed uniformly across the Conductor of Cross-Section Area (A). It is denoted by (J)

$$J = \frac{I}{A} \quad \text{--- (1)}$$

Now $I = neAv_d$

put in equation ①

$J = \frac{I}{A} = \frac{\cancel{A} n e v_d}{\cancel{A}} = nev_d$

$\boxed{J = nev_d}$ —— ②

The unit of current density is ampere [Am^{-2}]

<u>Conductance (G)</u> :- The inverse of resistance (R) is called conductance of a conductor i.e

$\boxed{G = 1/R}$

The unit of conductance, $(G = 1/R) = \frac{1}{ohm} = (ohm)^{-1}$ = (mho) or siemen.

<u>Electric Conductivity (σ)</u> :- The inverse of resitivity (ρ) of conductor is called its electrical conductivity.

$[\sigma = 1/\rho]$

S.I. Unit = ($mho\ m^{-1}$) or ($S\ m^{-1}$)

dimenstions of electrical conducivity

$\sigma = 1/\rho = [M^{-1} L^{-3} T^{3} A^{2}]$

Imp

Relation b/w J, σ and E

We know

$$I = nAeV_d$$

Here $V_d = \frac{eE\tau}{m}$

$$I = nAe\left(\frac{eE\tau}{m}\right)$$

$$\frac{I}{A} = \frac{ne^2E\tau}{m} \Rightarrow J = \left(\frac{ne^2\tau}{m}\right)E$$

Here $\rho = \frac{m}{ne^2\tau}$

$$\therefore J = \frac{1}{\rho}E$$

$$\boxed{J = \sigma E} \qquad \left[\because \sigma = \frac{1}{\rho}\right]$$

- It is also called microscopic form of ohm's law.

Relation between Resistivity and electron mobility.

We know $I = nAeV_d$ (Here $V_d = \mu E$)

$$\frac{I}{A} = neV_d$$

$$J = ne\mu E \quad — (1)$$

Here $[J = \sigma E]$
Put in equ (1)

$$\tau \cancel{E} = ne\mu \cancel{E}$$

$$\frac{1}{\rho} = ne\mu \Rightarrow \boxed{\rho = \frac{1}{ne\mu}}$$

⇒ Effect of Temperature on Resistance :

Now from ohm's law

$$R = \frac{m}{ne^2\tau}\frac{l}{A}$$

Here m, n, e, l, and A is constant value

$$\boxed{R \propto \frac{1}{\tau}}$$

When the temperature of the metal Conductor is raised the ions/ atoms of metal Vibrat with greater amplitudes and greater frequency about their mean position. So that the Collision of electron drifted toward the (+ve) end of Conductor with these ions/atoms increases. This Reduce Relaxation time. and hence the value of Resistance increase with increase in Temperature.

Let R_1 is the Resistance of Conductor at (t_1°)
And let R_2 is the Resistance of Conductor at t_2°C

Increase in Resistance = $R_2 - R_1$

Change in temperature = $t_2 - t_1$

And $$\alpha = \frac{\text{increase in Resistance}}{\text{original Resistance} \times \text{rise in temp.}}$$

$$\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$$ [S.I unit K^{-1}, C^{-1}]

Here α is temp. Coefficient of Resistance is defined as the increase in Resistance per unit original Resistance per degree increase in temperature.

Variation of Resistivity with temperature:-

Resistivity of a material

$$\rho = \frac{1}{\sigma} = \frac{m}{ne^2\tau}$$

Here m, m, e is constant

$$\boxed{\rho \propto \frac{1}{n\tau}}$$

Here The Resistivity is Related to the two parameters number density of free electron and Relaxation time (τ).

The Relaxation time (τ) Related to the temperature. when temp. is raised the Vibration of atoms/ions increase and the Collision b/w electrons and these ions also increase Result in the decrease in Relaxation time(τ) and hence Resistivity of the Conductor increase.

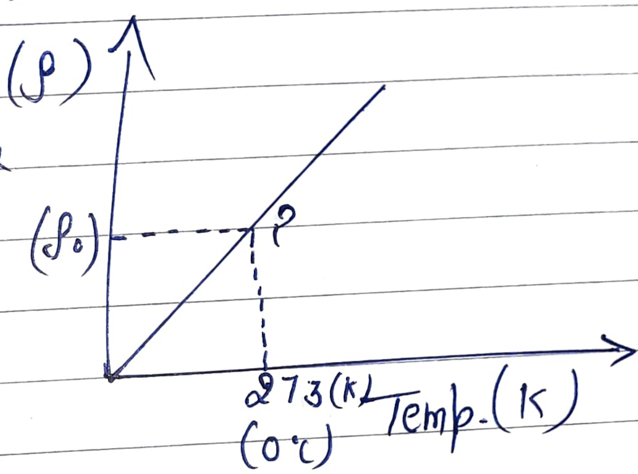
Here $\alpha = \frac{\rho - \rho_0}{\rho_0 (T - T_0)} = \frac{d\rho}{\rho_0} \frac{1}{dT}$

Thus α is also defined as the fractional change in resistivity ($d\rho/\rho_0$) per unit change in temperature (dT).

Graph b/w temperature and Resistivity

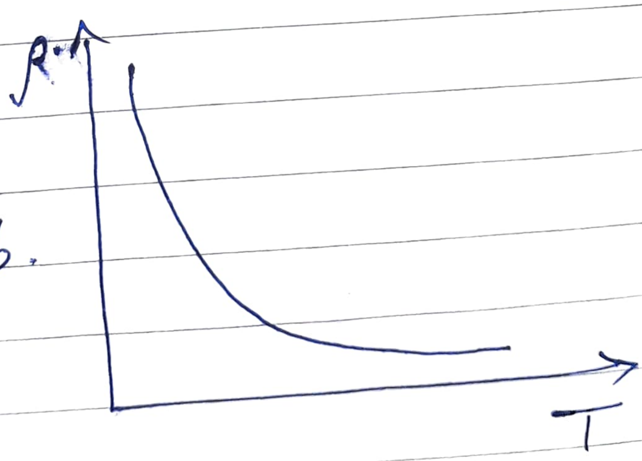
(a) Conductor (Metal) :-

Increase in temperature
Increase in Resistivity.



(b) Semiconductor :-

Decrease the Resistivity with Increase in temp.



NON-OHMIC Conductors

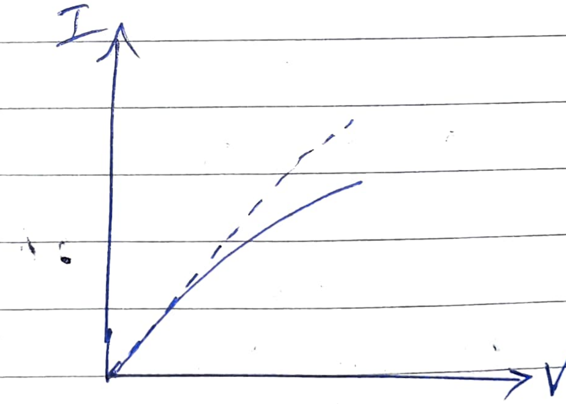
The conductors which do not obey ohm's law are called non-ohmic Conductor.

for example: Vaccum tubes, semiconductor diode, liquid electrolyte, transistor etc.

$\left(\frac{V}{I} = R\right)$ Relation is valid for both ohmic and non-ohmic Conductors.

But the value of (R) is constant for ohmic conductor But not in non-ohmic Conductors.
i.e. Ohm's law fail when V/I is not Constant in case of non-ohmic Conductor.

1) The Relation b/w V and I is non-linear.



(II) ohm law fail In case of semiconductor.

(III) ohm law also fail in case of GAS(light emitting diode)

Q ⇒ Derive The Relation between the e.m.f, cell Resistance and outer Resistance of the circuit.

or

Define and Derive Internal Resistance and Terminal Potential difference of a cell.

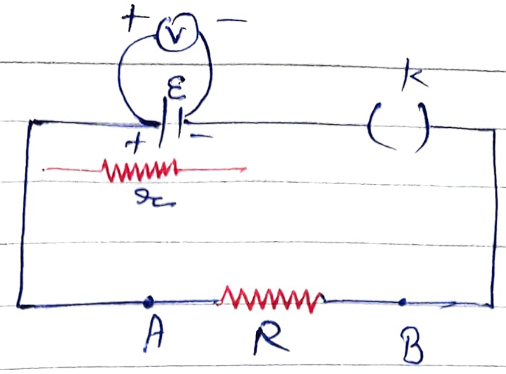
Sol Internal Resistance :- It is defined as the Resistance offered by the electrolyte and electrodes of a cell when electric current flows through it.

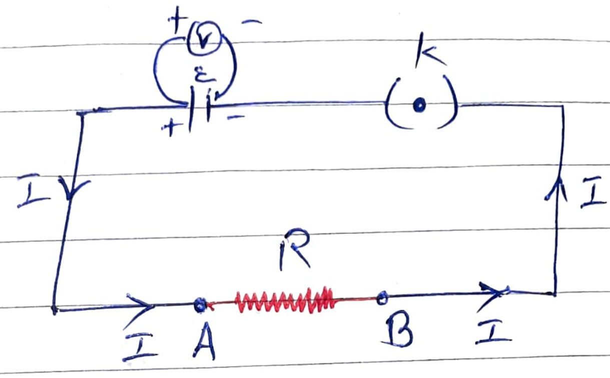
The Internal Resistance of the cell depends upon:

(a) Distance between the electrodes,
(b) The nature of the electrolytes,
(c) The nature of electrodes ((↑) the area (↓) The Resistance)

Terminal Potential difference :- It is the Potential difference between the two electrodes of a cell in a closed circuit.

(The terminal Potential difference of a cell is always less than the e.m.f. of the cell in a closed circuit.





Consider a cell of e.m.f. (ε) having internal Resistance (r) Connected to the external Resistance (R). A high resistance Voltmeter is Connected across the two electrodes of the Cell.

If key (k) is Closed no current flows and Reading in Voltmeter is equal to the e.m.f. (ε) of the Cell.

when key Closed the Current is flowing

Now total Resistance of the circuit = $R+r$

$\therefore$ Magnitude of current $I = \dfrac{\varepsilon}{R+r}$ — (1)

Potendial diff. across interonal Resistance
$r = Ir$

Now Reading in the Voltmeter (V) getting down less than $\mathcal{E}$.
Here Now (V) is called Terminal potential difference

$$\therefore V = \mathcal{E} - Ir \quad \text{—} \quad (2)$$

If $I = 0$ $\boxed{V = \mathcal{E}}$ [In case of Closed switch].

If at Point A and B the Potential is same at positive and negative electrode $\therefore$ the terminal Potential difference of a cell is equal to the potential difference across external Resistance R.

$$V = IR$$

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

Put the value of (I) in equation (1)

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

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

Imortant Notes :- (a) During charging terminal Potential difference become greater than the e.m.f. of the cell.

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

(b) The difference of e.m.f and terminal voltage is called lost voltage as it not indicated by a voltmeter.

Q Difference b/w E.M.F. and Potential difference

Ans

	E.M.F. of a cell	Potential difference
1)	The e.m.f of a cell is maximum potential difference between two terminal when current flowing through circuit.	The Potential difference between the two points is the difference of potential between those two points in a closed circuit.
2)	It is Independent of the resistance of the circuit and depends upon nature of electrodes	It depends upon the resistance between the two points of the circuit and current flowing through the circuit.
3)	The term e.m.f. is used for the source of electric current	The Potential difference is measured between any two points of the electric circuit.

Colour Code for Carbon Resistance :-

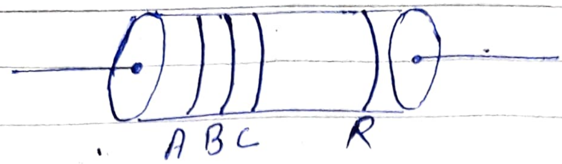
Colour	Letter	Number	Multiplier
Black	B	0	10^0
Brown	B	1	10^1
Red	R	2	10^2
orange	O	3	10^3
Yellow	Y	4	10^4
Green	G	5	10^5
Blue	B	6	10^6
Violet	V	7	10^7
Grey	G	8	10^8
White	W	9	10^9
Gold	G		10^{-1}
Silver	S		10^{-2}

	TOLERANCE
Gold	5%
Silver	10%
No colour	20%

Way to Learn the above Colour Code.

1) BBROY Great Britain Very Good Wife wearing Gold Slilver neaklace.

2) Black Brown Rods Of Your Gate Became Very Good When Given Silver Colour.



A (first), B (second), C (Third) and R (fourth) strip of Colour.

Example :- The given Carbon Resistor, let the first strip be Yellow, second strip be Green, third strip is black and fourth be gold. What is its resistance.

Sol :- Yellow = 4, Green = 5, black = $10^0 = 1$
Gold = 5%
ie $45\Omega \pm 5\%$

Example 2 :- The Resistance of given Carbon is $2.4 \times 10^6 \Omega \pm 5\%$. What are the sequence of colours on the strips provided on Resistance?

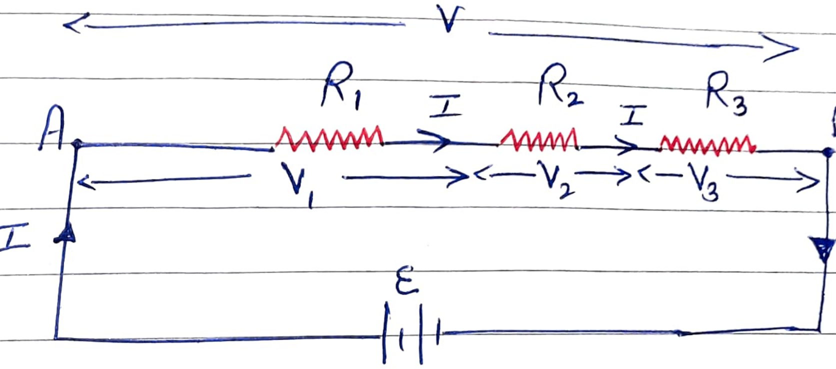
Sol $R = 2.4 \times 10^6 \Omega \pm 5\% = 24 \times 10^5 \Omega \pm 5\%$

Here 2 = Red
4 = Yellow
10^5 = Green
5% = Gold.

∴ Sequence is Red, Yellow, Green and Gold.

Resistance In series:-

Resistors are said to be connected in series, if the same current is flowing through each resistor when some potential difference is applied across the combination.



Let There are three Resistance R_1, R_2, R_3 Connected series. Let (V) be the potential diff. is applied across A and B using battery ε. Let V_1, V_2 and V_3 be the Potential diff. across Resistor R_1, R_2 and R_3 but the current is same across the circuit.

Now acc. to ohm's law $(V = IR)$ —(1)

$\therefore$ $V_1 = IR_1$, $V_2 = IR_2$ and $V_3 = IR_3$

Hence

$$V = V_1 + V_2 + V_3$$

$$V = IR_1 + IR_2 + IR_3$$

$$V = I(R_1 + R_2 + R_3)$$

from equation (1)

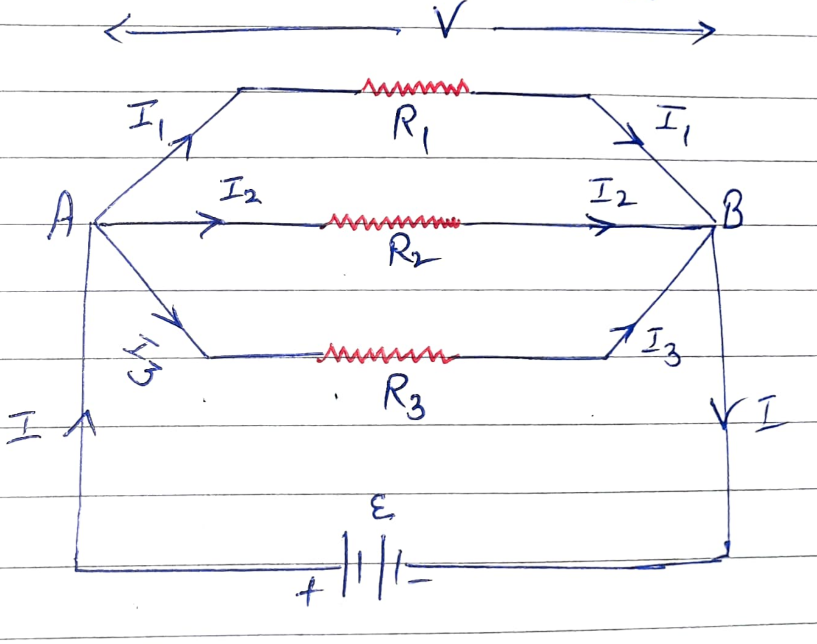
$$\cancel{I}R = \cancel{I}(R_1 + R_2 + R_3)$$

$$\boxed{R = R_1 + R_2 + R_3} \quad \text{—(II)}$$

∴ The equivalent Resistance of a number of resistors connected in series is equal to the sum of individual Resistances.

⇒ **Resistances In PARALLEL :-**

The number of resistors are said to be connected in parallel if potential difference across each of them is the same and is equal to the applied potential difference.



Let three Resistances R_1, R_2 and R_3 are connected in ||el. Let (V) be the Potential difference applied across A and B with the help of battery (ε). Let I be the total current through the circuit and I_1, I_2 and I_3 be the current across Resistance R_1, R_2 and R_3. resp.

$\therefore \quad I = I_1 + I_2 + I_3$ —— (I)

Now acc. to ohm's law $(V = IR)$ —— (II)

$V = I_1 R_1$, $V = I_2 R_2$ and $V = I_3 R_3$

$I_1 = \frac{V}{R_1}$, $I_2 = \frac{V}{R_2}$ and $I_3 = \frac{V}{R_3}$

Put in equation (I)

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

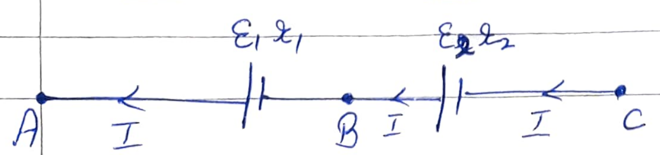
$$\frac{\cancel{V}}{R_p} = \cancel{V}\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

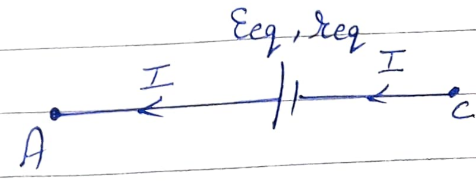
$$\boxed{\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

The Reciprocal of equivalent Resistance of number of Resistors connected in parallel is equal to the sum of the reciprocals of the individual Resistances.

Grouping of two Cells In series and Parallel :-

(a) Two cells in Series :-





Let two cells are Connected in series between A and C, If one terminal of each cell is joined together and the other is free.

Let ε_1, ε_2 be the emf of the cell and r_1 and r_2 be the internal Resistance.
Let V_A, V_B and V_C be the Potential at Points A, B and C and I current following though it.

Potential difference between (+ve) and (-ve) of first cell

$$V_{AB} = V_A - V_B = \varepsilon_1 - I r_1 \quad \text{—— (1)}$$

IIrly of second cell

$$V_{BC} = V_B - V_C = \varepsilon_2 - I r_2 \quad \text{—— (2)}$$

Now Potential difference between A and C

$$V_{AC} = V_A - V_C = (V_A - V_B) + (V_B - V_C)$$

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

$$= (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2) \quad \text{—— (3)}$$

If we replace series combination into one cell emf is ε_{eq} and internal Resistance (r_{eq})

$$V_{AC} = \varepsilon_{eq} - I r_{eq} \quad \text{—— (4)}$$

Now from equation (3) and (4)

$$\left.\begin{aligned} \mathcal{E}_{eq} &= \mathcal{E}_1 + \mathcal{E}_2 \\ r_{eq} &= r_1 + r_2 \end{aligned}\right] \text{—— (5)}$$

if n cells of emfs $\mathcal{E}_1, \mathcal{E}_2 \ldots \mathcal{E}_n$ and of internal Resistance $r_1, r_2, \ldots r_n$.

ie $\mathcal{E}_{eq} = \mathcal{E}_1 + \mathcal{E}_2 + \ldots + \mathcal{E}_n$
$r_{eq} = r_1 + r_2 + \ldots + r_n$

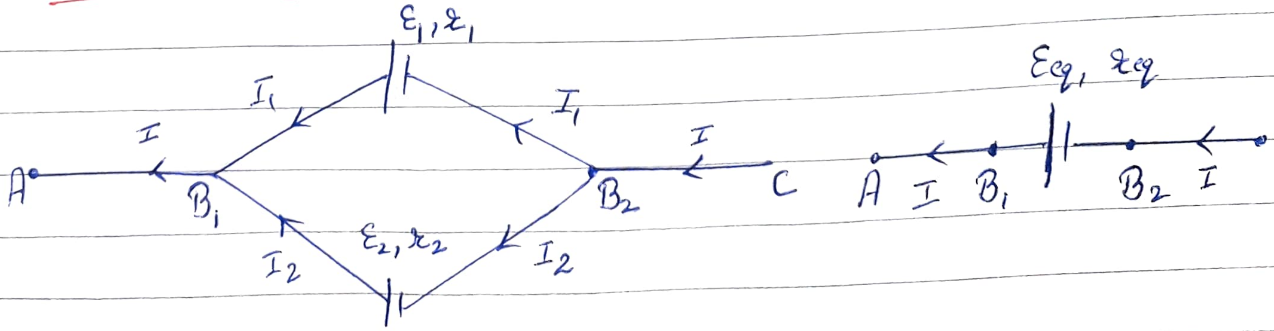
(i) The equivalent emf of a series Combination of Cells is equal to the Sum of their individual emfs.
(ii) The equivalent Resistance of a series Combination of cells is equal to sum of their individual internal Resistance.

Notes:- If the negative terminal of the first cell is connected to the (-ve) terminal of the Second cell.

$V_{BC} = V_B - V_C = -\mathcal{E}_2 - I r_2$

ie equivalent emf : $\mathcal{E}_{eq} = \mathcal{E}_1 - \mathcal{E}_2$
Equivalent Internal Resistance : $r_{eq} = r_1 + r_2$

(b) Two Cells in Parallel :-



Let the two cell are said to connected in ||r| between two points A and c, if positive terminal of each cell connected to one point and negative terminal of each cell at other point.

Here $\mathcal{E}_1, \mathcal{E}_2$ be the emfs of each two cell and r_1 and r_2 be the Internal Resistance and let I_1, I_2 be the current from the two cells and I be the total current of the cell.

$$\text{Here} \quad I = I_1 + I_2 \quad \text{——— (1)}$$

Let V_{B_1} and V_{B_2} be the Potentials at at B_1 and B_2.

Now Potential difference across first cell

$$V = V_{B_1} - V_{B_2} = \mathcal{E}_1 - I_1 r_1 \Rightarrow I_1 = \frac{\mathcal{E}_1 - V}{r_1}$$

||rly Potential difference across second cell

$$V = V_{B_1} - V_{B_2} = \mathcal{E}_2 - I_2 r_2 \Rightarrow I_2 = \frac{\mathcal{E}_2 - V}{r_2}$$

Put I_1 and I_2 in equation (1)

$$I = \frac{\mathcal{E}_1 - V}{r_1} + \frac{\mathcal{E}_2 - V}{r_2} = \left(\frac{\mathcal{E}_1}{r_1} + \frac{\mathcal{E}_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

$$= \frac{\mathcal{E}_1 r_2 + \mathcal{E}_2 r_1}{r_1 r_2} - V\left(\frac{r_2 + r_1}{r_1 r_2}\right)$$

$$V\left(\frac{r_2+r_1}{r_1 r_2}\right) = -I + \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 r_2}$$

$$V = -I\left(\frac{r_1 r_2}{r_2+r_1}\right) + \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{\cancel{r_1 r_2}} \times \frac{\cancel{r_1 r_2}}{(r_2+r_1)}$$

$$V = -I\left(\frac{r_1 r_2}{r_2+r_1}\right) + \left(\frac{\varepsilon_1 r_2 + r_1 \varepsilon_2}{r_2+r_1}\right)$$

$$V = \left[\frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1+r_2}\right] - I\left[\frac{r_1 r_2}{r_1+r_2}\right] \quad —②$$

If we replace Combination into equivalent cell.

i.e $V = \varepsilon_{eq} - I r_{eq}$ —③

equating equation ② and ③

$$\varepsilon_{eq} = \left[\frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1+r_2}\right] \quad —④$$

(5a) ← $r_{eq} = \left[\frac{r_1 r_2}{r_1+r_2}\right] \Rightarrow \frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2}$ — (5b)

dividing (4) by (5a)

$$\frac{\varepsilon_{eq}}{r_{eq}} = \left(\frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{\cancel{r_1+r_2}}\right)\left(\frac{\cancel{r_1+r_2}}{r_1 r_2}\right) = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}$$

$$\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}$$

If n cells be connected in ||el.

$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \cdots + \frac{1}{r_n}$$

$$\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + \cdots + \frac{\varepsilon_n}{r_n}$$

Q. Why it is easier to flow electric current to definate parts by using electrical Insulator, then to flow heat currents along definate path using heat insulator?

Sol. The resistivity of electric insulator is very high as compared to metalic conductor current prefers to flow a path of least resistance so it does not flow in the insulator and Remains confined to definate path. But thermal insulators and thermal conductor have comparitive conductivity so heat flow does not remain confined to definate routes.

Q. Two wires of equal length, one of copper and other is the malganan have the same resistance which wire is thicker ?

Sol :-
$$R_c = \rho_c \frac{l}{A_c}$$

also $$R_m = \rho_m \frac{l}{A_m}$$

acc to question $\boxed{R_c = R_m}$

$$\rho_c \frac{\cancel{l}}{A_c} = \rho_m \frac{\cancel{l}}{A_m}$$

$$\frac{\rho_c}{A_c} = \frac{\rho_m}{A_m}$$

$$\frac{A_m}{A_c} = \frac{\rho_m}{\rho_c}$$

Since $\rho_m > \rho_c$ $\therefore$ $A_m > A_c$

So, the malganan wire is thicker then Copperwire

Q A wire streched to triple its length will the Resistivity of the of the wire Change. if Yes how much ?

Sol :- Since the resistivity of a material is indepedent of its physical dimension so resitivity of the wire will be same even after streching.

How ever Resistance of the wire will change

we know

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

after streaching

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

$$\frac{R'}{R} = \frac{\rho l'}{A'} \div \frac{A}{\rho l} = \frac{l'A}{A'l}$$

$$\frac{R'}{R} = \frac{l'A}{A'l}$$ [Volume is constant But the length is 3 time to the original length]

Here $\frac{R'}{R} = \frac{3\cancel{l}A}{A'\cancel{l}}$

$$\frac{R'}{R} = \frac{3A}{A'} \quad \text{—— (1)}$$

Now $Al = A'l'$

$A\cancel{l} = A'(3\cancel{l})$

$\left[A' = A/3\right]$

Put in equation (1)

$$R'/R = \frac{3\cancel{A} \times 3}{\cancel{A}} \rightarrow \boxed{R' = 9R}$$

Q:→ Is ohm's law is a universal law support your Answer with example?

Ans: No, ohm's law is Valied in Case of most of metalic Conductor and that also physical Condition like temp., stress, pressure etc. of the Conductor remain same this law fail in the Case of Vaccume tubes, Semiconductor dyo thermistor, ~~phy~~ thyristor etc.

Q What happen to the resistance of a wire when its length is increased to twice its original length.

Sol: we know that

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

$$R = \rho\left(\frac{l}{\pi r^2}\right)$$

were (r) is radius of the wire.

Now if $l' = 2l$ and Radius of the wire (r')

The volume of wire remain same

∴ original volume of the wire = Final volume of the wire

$$\pi r^2 l = \pi r'^2 l'$$

$$\cancel{\pi} r^2 \cancel{l} = \cancel{\pi} r'^2 2\cancel{l}$$

$$r^2 = 2r'^2$$

$$r'^2 = \frac{r^2}{2}$$

$$\therefore R' = 4R$$

∴ resistance of the wire become 4 time the original volume when its length is increased to twice its original length.

Q Why does the resistivity of Semi-Conductor and insulator decrease with the rise in temp.?

Sol: Temperature dependence of resistivity of semi-Conductor and insulator is given by

$$\rho = \rho_0 e^{E/2KT}$$

where (K) is Voltsmon Constance and (E) is the energy gas. there fore the resistivity of semi-Conductor and insulator decrease with the rise in temperature.

Q Why resistance of a SuperConductor become almost zero?

Ans: The free electron in the Super Conductor are mutually coherent and Coprative at critical temp. and hence they donot Collide with each other and with ions of the Conductor So super Conductor have almost zero resistance

Q: Does e.m.f. represent force? Does e.m.f. have an electrostatic origin?

Sol: No, electromotive force is not a force but it is work done per unit charge.

The em.f. does not have simple electrostatic origin.

Q:- A low voltage supply must have low internal resistance to provide high current. why?

Sol:- Maximum current drawn from the source can be given by $I_{max} = \frac{E}{r}$ where (E) is the e.m.f. of the source and r) is the internal resistance of the source. Clearly for small potential diff. internal resistance must be very low to get high current.

Q:- The light of the electric lamp gets dimmer for a moment when the geyser is switches on. why

Sol:- The resistance of the coil of the geyser is small and hence it draws a large amount of current when switched on which effects the supply voltage. As a result of this the voltage drops across the electric lamp for a moment till it is stabilized by the transmission line.

Q:- An automobile engine starts easily on a warm day than on a Chily day. why?

Ans:- on a warm day due to high temp. the internal resistance of the battery become low and less voltage is dropped in the battery. thus large current is available to start the car easily. on chilly day due to the low temp. the internal resistance of the battery become high and hence there is a large voltage drop in the battery. Now the terminal potential diff. and hence current to the circuit in the car is low so car is not started easily.

Q: When current flows through a coil of heater heat Q_1 is produced. Now the coil is cut into two equal halves and only one half is connected to the same power supply. Heat produced now is Q_2, what is the ratio of $\frac{Q_2}{Q_1}$?

Sol: Heat produced in the coil $Q_1 = I^2Rt$.
When only half part of the coil is connected to the power supply. Resistance of this part of coil becomes $\frac{R}{2}$ (ie half) and current is doubled (ie $2I$) as voltage remains the same

$$\therefore Q_2 = (2I)^2\left(\frac{R}{2}\right)t = 2I^2Rt$$

$$\therefore \frac{Q_2}{Q_1} = 2$$

Q: Out of 100 W and 60 W electric lamps, which has more resistance and why?

Sol: For same voltage a 60 W electric lamp has more resistance than 100 W lamp because $\left(R \propto \frac{1}{P}\right)$

Q: A current in a circuit having constant resistance is doubled. How does it affect on the power dissipation.

Q:- A letter 'A' consists of a uniform wire of resistance of one ohm per cm. The sides of the letter are each 20 cm long and cross-piece in the middle is 10 cm long, while the apex angle is 60°. Find the resistance of the letter b/w two ends of the legs.

Sol:-

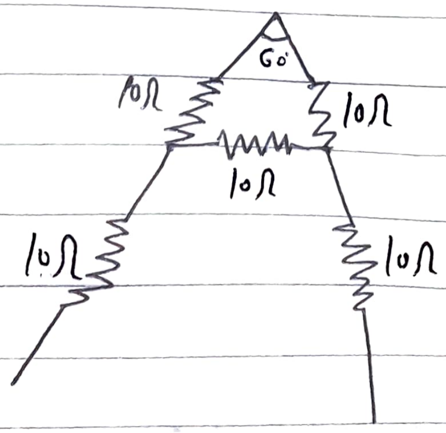
The resistance of 1 cm = $1\,\Omega$

$\therefore$ Resistance of 20 cm = $20\,\Omega$

It means, the resistance of legs AC and AE is $20\,\Omega$ each.

Since cross-piece is 10 cm, so its resistor $= 10\,\Omega$

As the cross-piece is in the middle of each leg.

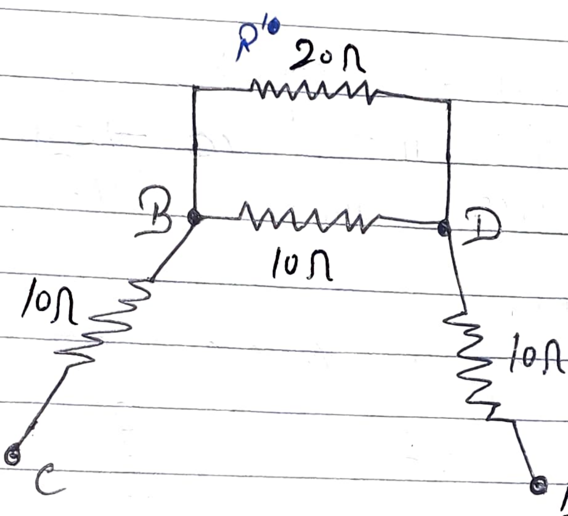


So $AB = BC$

and $AB = DE$ and each resistance $= 10\Omega$

Step I:- Since AB and AD are in series, So their net resistance is given by

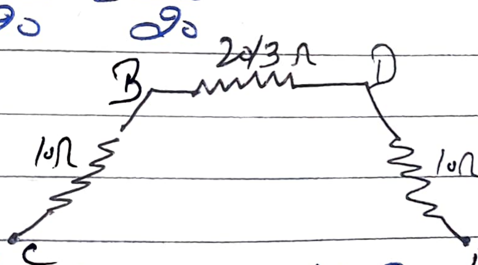
$$R' = 10\Omega + 10\Omega = 20\Omega$$



Step II:- $R' = 20\Omega$ is in parallel to cross-piece of resistance 10Ω. So net resistance b/w B and D is

$$\frac{1}{R''} = \frac{1}{20} + \frac{1}{10} = \frac{1+2}{20} = \frac{3}{20}$$

$$R'' = \frac{20}{3}\Omega$$



Step 3:- Now $R'' = \frac{20}{3}\Omega$ is in series with $B = 10\Omega$ and $DE = 10\Omega$. Hence the equivalent resistance b/w the ends of the legs of the letter A is

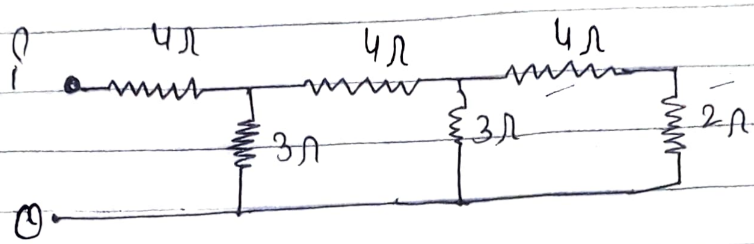
$$R''' = R'' + 10 + 10 = \frac{20}{3} + 10 + 10 = \frac{20+30+30}{3}$$

$$= \frac{80}{3}\Omega$$

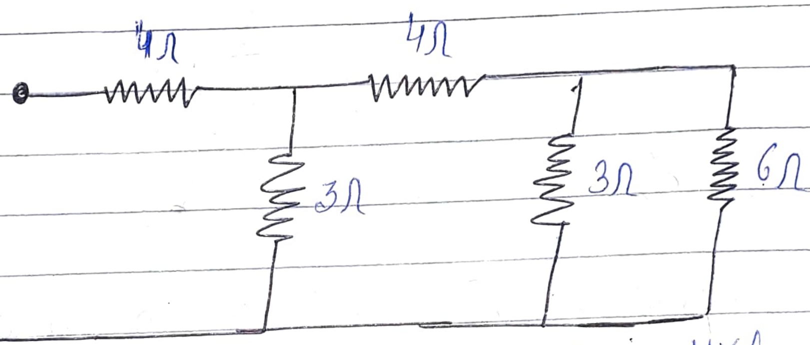
$$R''' = 26.67\Omega$$

Q Calculate the equivalent resistance b/w the points (P) and Q of the net work shown in figure given below.

Sol



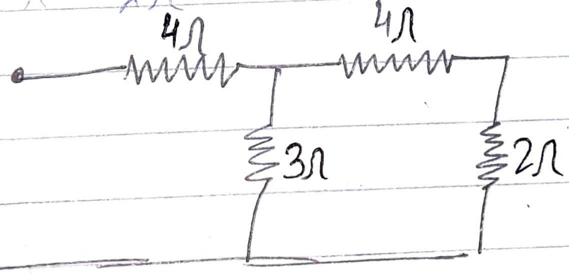
Step I :- 4Ω and 2Ω at the right end are in series and hence they are replaced by single resistance $(4+2) = 6\Omega$



Now 6Ω and 3Ω resistances are in ||rl. So they are replaced by a single resistance

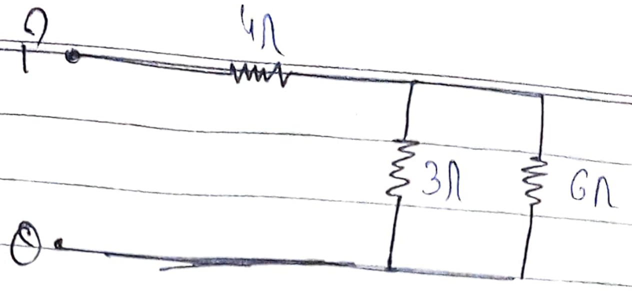
$$\frac{1}{R} = \frac{1}{3} + \frac{1}{6} = \frac{2+1}{6} = \frac{3}{6} = \frac{1}{2}$$

$R = 2\Omega$



The resistance 4Ω and 2Ω are in series, so they are replaced by a single resistance

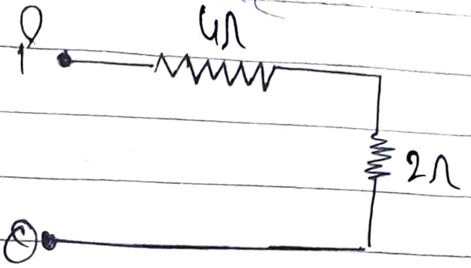
$(4\Omega + 2\Omega) = 6\Omega$



The resistance 6Ω and 3Ω are in ||el. So they are replace by a single resistance

$$\frac{1}{R} = \frac{1}{3} + \frac{1}{6} = \frac{1}{2}$$

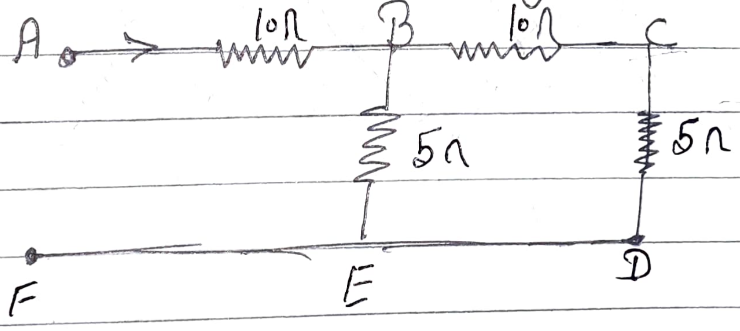
$R = 2\Omega$



Step II :- Now the resistances 4Ω and 2Ω are in serices. So the equivalent resistance b/w P and Q

$R_{eq} = 4+2 = 6\Omega$

An e.m.f. of 2.2 volt is connected to the combination of resistors shown in figure. What is the equivalent resistance connected across the terminals of the cell ? what is the value of the current ?



Step I : (i) Resistance BC and CD are in series, so resistance along BCD = 10+5 = 15Ω

(ii) Resistance 15Ω is in ||el with the resistance 5Ω along BE, so equivalent resistance b/w B and E is given by

$$\frac{1}{R} = \frac{1}{5} + \frac{1}{15} = \frac{3+1}{15} = \frac{4}{15}$$

$$R = \frac{15}{4} = 3.75\Omega$$

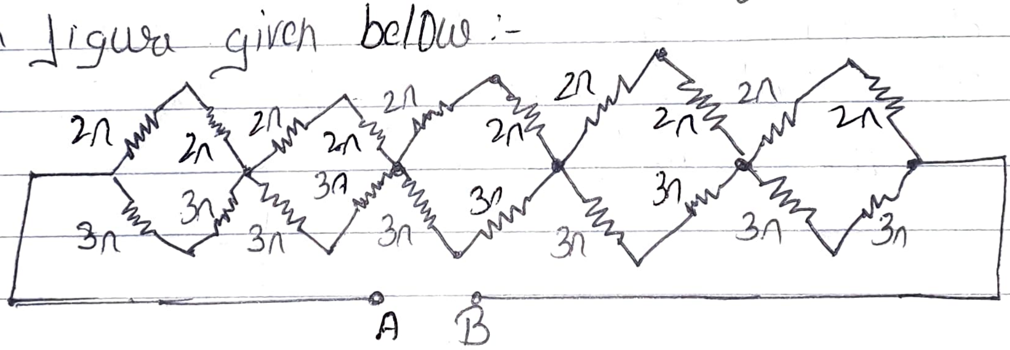
(iii) The resistance 3.75Ω is in series with the resistance 10Ω so the equivanet resistance b/w the terminals of the source is given by

$$R_{eq} = 10 + 3.75$$
$$= 13.75\ \Omega$$

Step 2 Current

$$i_1 = \frac{E}{R_{eq}} = \frac{2.2}{13.75}$$
$$= 0.16A$$

Q:- Find the total resistance of the network shown in figure given below :-

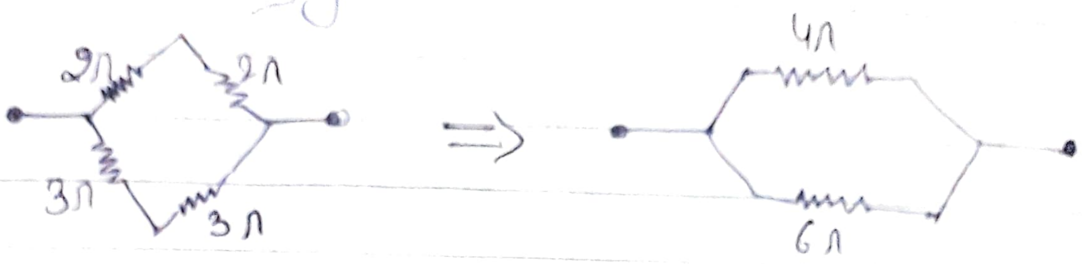


Sol Step I:- The given network is the series combination of 4 equal units

In a unit 2Ω and 2Ω are in serices, so they can be replaced by a single resistance $(2+2) = 4\Omega$

\|\|arly, 3Ω and 3Ω are this unit are in series.

So they are also replaced by a single resistance $(3+3) = 6\Omega$
hence the equivalent circuit of a unit becomes as show in fig.



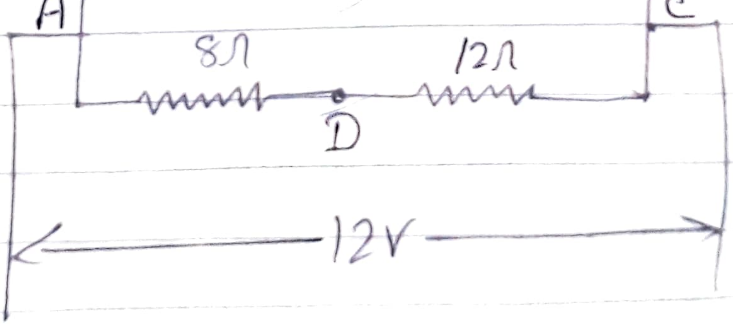
Step II: Now 4Ω and 6Ω are in ||el to each other, So the equivalent resistance of a unit is

$$\frac{1}{R} = \frac{1}{4} + \frac{1}{6} = \frac{10}{24} = R = \frac{12}{5}\,\Omega$$

Now all the four units have resistance $= \frac{12}{5}\,\Omega$
∴ equivalent resistance of the given Network is

$$R' = \frac{12}{5} + \frac{12}{5} + \frac{12}{5} + \frac{12}{5} = \frac{4\times 12}{5} = 9.6\Omega$$

Q Calculate the potential difference b/w B and D points is the given figure. A e.m.f of 12V is connected to the circuit.



Sol: P.D. across ABC = Potential diff. across ADC = 12V.

Step1:- Now potential diff b/w C and B is

$$(V_A - V_B) = \frac{6}{(6+2)} \times 12 = 9V \quad -(1)$$

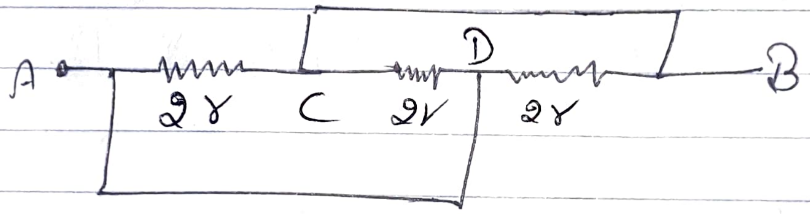
potential diff b/w A and B is

$$(V_A - V_B) = \frac{8}{8+12} \times 12\,V = 4.8\,V \quad -(2)$$

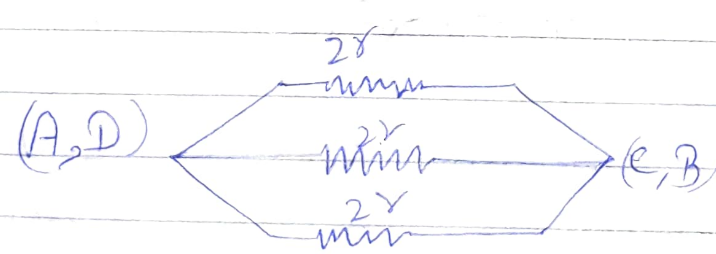
Step(2) sub (2) from (1)

$$(V_A - V_B) - (V_A - V_B) = 9 - 4.8$$
$$= 4.2V.$$

Q What is the equivalent resistance b/w points A and B in the following circuit?



Sol The circuit can be redrawn as



In this case all the three resistors are in ||el
So the equivalent resistance is given by

$$\frac{1}{R} = \frac{1}{2r} + \frac{1}{2r} + \frac{1}{2r} = \frac{3}{2r}$$

$$R = \frac{2r}{3}$$

CHAPTER :- 2

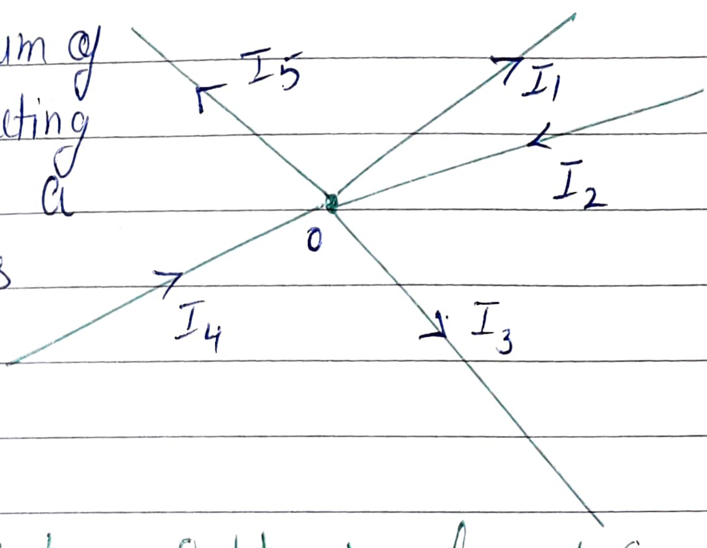
Electric Measurement :-

Kirchhoff's laws :- Kirchhoff's law in 1942 put forward two laws to solve Complicated Circuits.

(1). Kirchhoff's first law, Kirchhoff's junction law or Kirchhoff's Current law.

The algebraic sum of all the currents meeting at a junction in a open and Closed circuit is zero

ie $\sum I = 0$



Kirchhoff's first law supports law of Conservation of Charge.

Consider a junction O in the electrical Circuit at which the five Conductors are meeting.

Let I_1, I_2, I_3, I_4 and I_5 be the current in the Conductors.

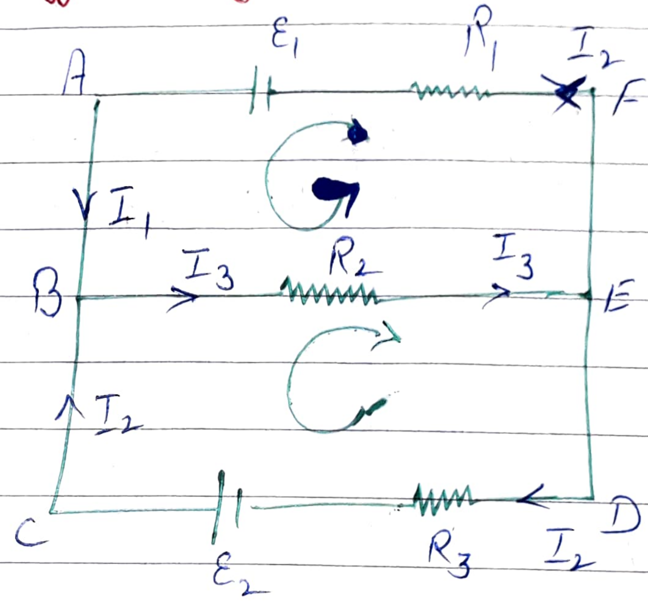
According to Kirchhoff's first law

$(-I_1) + (I_2) + (-I_3) + (I_4) + (-I_5) = 0$

$-I_1 + I_2 - I_3 + I_4 - I_5 = 0$

$$\boxed{\Sigma I = 0}$$

2 Kirchhoff's Second law or Kirchhoff's loop law or Kirchhoff's Voltage law:-



It states that the algebraic sum of changes in potential around any closed path of electric circuit involving resistors and cells in the loop is zero ie $\Sigma \Delta V = 0$.

→ This law supports the law of conservation of energy.

Consider a closed circuit containing two cells of e.m.f. ε_1 and ε_2 and three Resistors of Resistance R_1, R_2 and R_3

[Note: while traversing a loop if negative pole of the cell is encountered first, then its emf is negative otherwise positive].

Acc. to kirchhoff's second law to the closed loop ABEFA.

$$I_3R_2 + I_1R_1 - \varepsilon_1 = 0 \Rightarrow \varepsilon_1 = I_1R_1 + I_3R_2$$

llrly closed loop ABCDEF

$$\varepsilon_2 - I_2R_3 + I_1R_1 - \varepsilon_1 = 0$$

$$\varepsilon_1 - \varepsilon_2 = I_1R_1 - I_2R_3 \quad \text{or} \quad \boxed{\Sigma\varepsilon = \Sigma IR}$$

Hence prove.

Q: Difference between first and second law of kirchhoff's.

first law	second law
1) This law supports the law of conservation of charge.	This law supports the law of conservation of energy.

2)	According to this law $\Sigma I = 0$	According to this law $\Sigma E = \Sigma IR$
3)	This law can be used in open and closed circuits	This law can be used in a closed circuit.

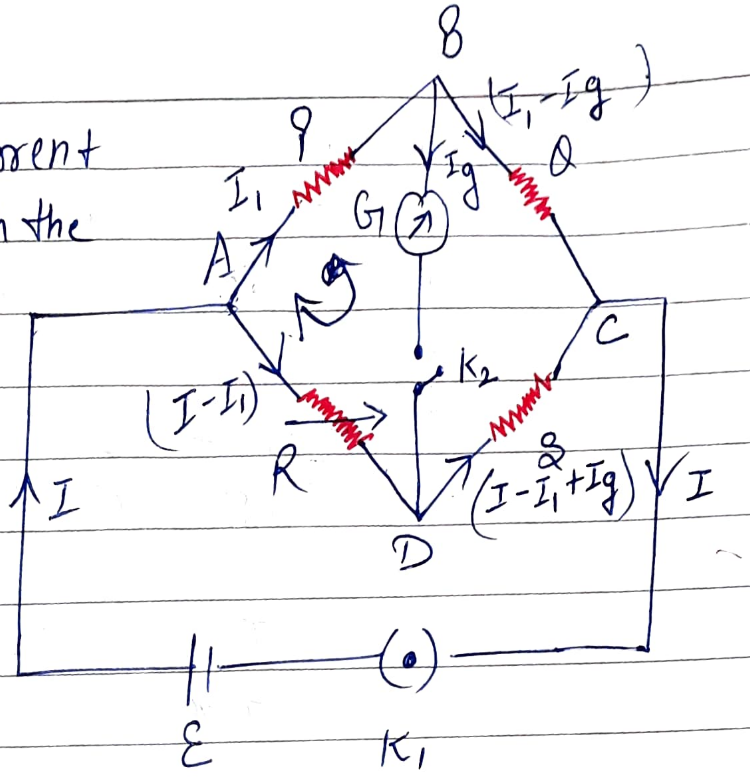
Q State and explain principle of wheat stone bridge.

Sol Wheat stone Bridge :- wheat stone bridge is a arrangement of four resistances used for measuring one unknown resistance in terms of other three known Resistance.

Principle :- It based on principle that if four resistances P, Q, R and S are arranged to form a bridge with a cell (E) and one way key K_1 between the points A and C and a galvanometer G and tapping key (K_2) between the point B and D, on closing K_1 first and K_2 later on, if galvanometer shows no deflection then bridge is balanced.

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

Proof:- Let I be the Current following through the Circuit.



$\Rightarrow$ I_1 = Current through P Resistance
$I - I_1$ = Current through the R
$I - I_g$ = Current through th Q
I_g = Current through the galvanometer (G)

$I - I_1 + I_g$ = Current through the Resistance S.

when (K) is Closed Current flowing through the diff. arms of the wheatstone bridge :-

applying Kirchoff law to the loop (ABDA)

$$I_1 P + I_g G - (I - I_1) R = 0 \quad \text{— (I)}$$

applying Kirchoff law to the loop (BCDB)

$$(I_1 - I_g) Q - (I - I_1 + I_g) S - I_g G = 0 \quad \text{— (II)}.$$

Now we can adjusted the value of R in such a way that the value of galvanometer is zero

$\therefore \quad I_1 P - (I - I_1) R = 0$

$I_1 Q - (I - I_1) S = 0$

$I_1 P = (I - I_1) R$ — (III)

$I_1 Q = (I - I_1) S$ — (IV)

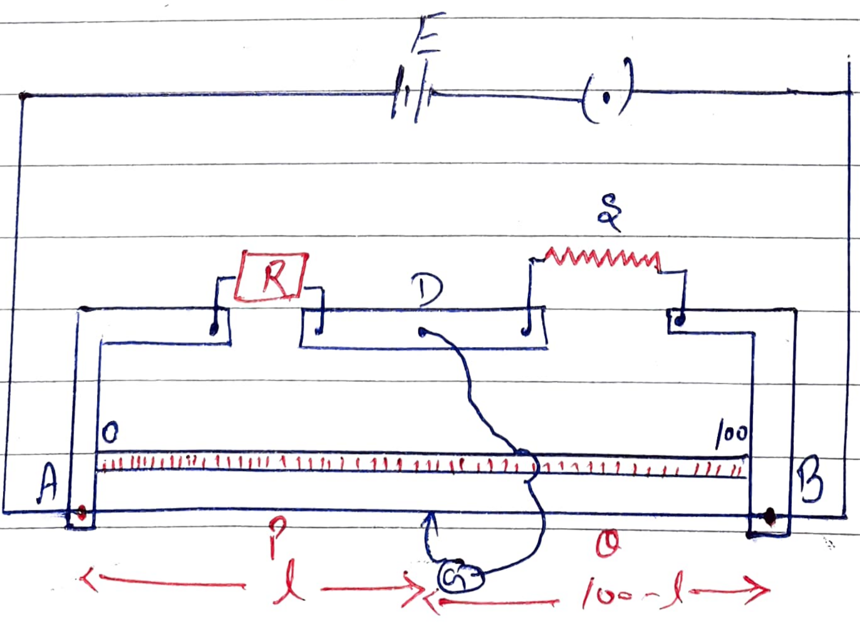
dividing equation (III) and (IV)

$$\frac{\cancel{I_1} P}{\cancel{I_1} Q} = \frac{\cancel{(I - I_1)} R}{\cancel{(I - I_1)} S}$$

$$\boxed{\frac{P}{Q} = \frac{R}{S}}$$ hence proof.

Q State and explain Meter bridge (Slide wire Bridge) also write its construction, principle and working?

Sol:



Construction:- It Consist of a magnian wire AB of length (1m) having uniform area of Cross-section. This wire is fixed on the wooden board ||rl to the meter scale. Two thick Copper strip bend at right angle and fixed at the two ends of the wire. A Resistance box (R) is fixed on one gap and unknown Resistance (S) fixed on another gap. A jocky (j) Connected at point (D) and a Resistive galvanometer (g) is Connected which moved over wire AB.

Principle:- It based on the Principle of wheatstone bridge.

Working: Close key (K) and adjust the known Resistance box for a suitable resistance R. Adjust the position of jockey on the wire where on pressing, galvanometer shows no deflection.

Note length (AB = l) say of the wire. Also note the length BC (100 - l) of the wire. Now as the bridge is balanced, therefore according to the wheatstone-bridge principle

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

If (x) is the Resistance per cm length

P = Resistance of length l ie lx

Q = Resistance of length $(100-l)$ ie $(100-l)x$

Now $P/Q = R/S$

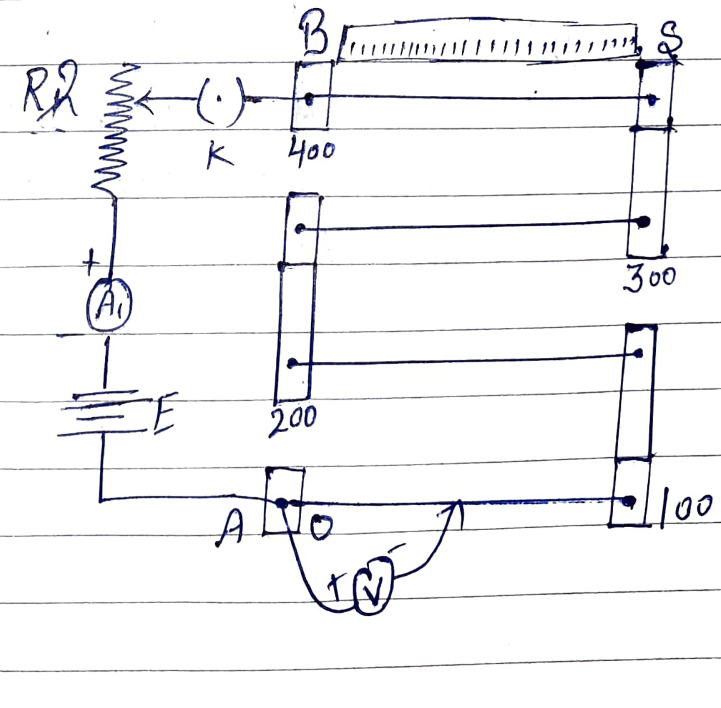
$$\frac{lx}{(100-l)x} = R/S$$

$$\boxed{S = \frac{(100-l) \times R}{l}}$$

Knowing the value l and R, S can be determined.

→ Discuss the Principle, Construction and determine the final Result? Potentiometer?

Sol:-



Principle:- It's working is based on the fact that the fall of potential across any portion of the wire is directly proportional to the length of that portion provided the wire is of uniform area of cross-section and constant current flowing through it.

Construction:- It consist long uniform wire (manganin) or (constantan), streched on a wooden board. A meter scale is fixed on the board parallel to the length of the wire. The Potentiometer is provided with jockey (J) with the help of which the contact can be made at any point on the wire. A battery (E) is connected across A and B sends the current through the wire which is kept constant by using a rheostat Rh.

Here A = area of cross-section

ρ = Specific Resistance.

V = Potential difference across the portion of the wire.

l = length of the wire whose Resistance is R.

I = current flowing through the wire.

Here Acc. to OHM's law

$$V = IR$$

and $R = \rho l / A$

so that $V = I \rho l / A$ $\quad [K = I\rho / A]$

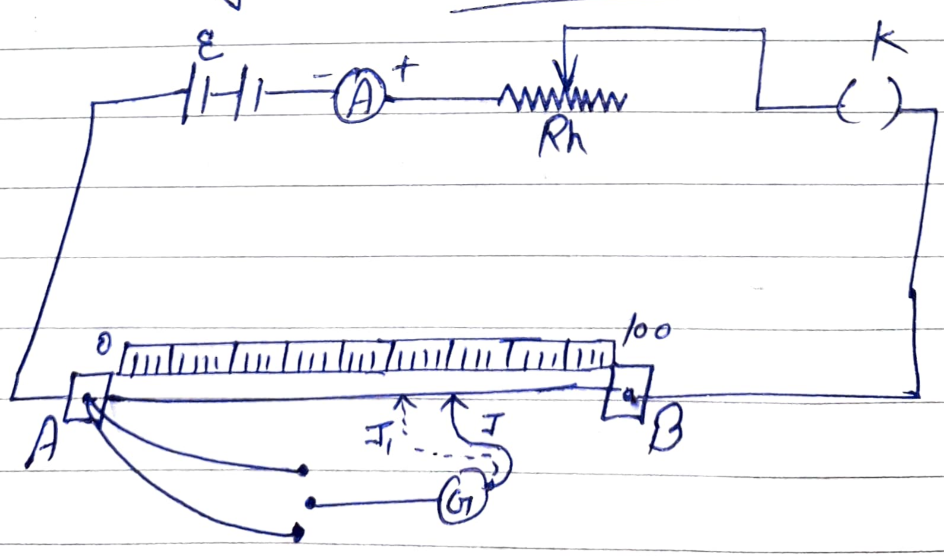
$$V = kl$$

$$\boxed{V \propto l}$$

where $V/l = k$ [Potential gradient]

Potential gradient :- The fall of potential per unit length of wire.

Comparision of E.M.F. of Two Cells using Potentiometer :-



A battery of e.m.f. ($\mathcal{E}$) is connected between the end terminals A and B of potentiometer wire with rheostat (Rh), ammeter (A_1) and key (K) in series.

We can compare the e.m.f. of two cells $\mathcal{E}_1$ and $\mathcal{E}_2$ connected to the circuit.

The positive terminals of both cells are connected to point (A) and negative terminal are connected to two terminal 1 and 2 of two way key, while its common terminal (3) is connected to jockey (J) through a galvanometer (G).

Close the key (K) and adjust a suitable current in the potentiometer with the help of rheostat.

Now plug in the gap between the terminal 1 and 3 of two way key so that the cell of e.m.f $\mathcal{E}_1$ comes in the circuit. Now adjust the jocky in such a way that galvanometer show zero deflection. Let it at be point (J). Note the length ($AJ = l_1$) of the wire.

It mean the potential of the positive terminal of cell = potential of the point A and the potential of negative terminal of cell = potential of the point J.

∴ the e.m.f of the cell = $\mathcal{E}_1$ is equal to potential difference between the points A and J of the potentiometer wire.

$$\text{ie} \quad \mathcal{E}_1 = Kl_1 \quad \text{—} \; (1)$$

Now Remove the plug from (3) from (1) and Connected to the key (2) 11rly do same process as in case of key (1).

Now the length of the wire is $(AJ_1 = l_2)$

$$\text{ie} \quad \mathcal{E}_2 = Kl_2 \quad \text{—} \; (11)$$

dividing (1) by (11)

$$\frac{\mathcal{E}_1}{\mathcal{E}_2} = \frac{Kl_1}{Kl_2}$$

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

Q Sensitiveness of Potentiometer :-

The sensitiveness of potentiometer means the smallest difference that can be measured Potential with it's help.

The sensitiveness of a potentiometer can be increased by decreasing it potential gradient

$$K = V/l$$

ie

(1) by Increasing the length of potentiometer wire.

2) If the potentiometer wire is of fixed length, the potential gradient can be decreased by reducing the current in the potentiometer with the help of rheostat.

⇒ Difference between Potentiometer and Voltmeter.

	Potentiometer	Voltmeter
(1)	It measures the e.m.f of a cell very accurately	It measures the e.m.f of a cell approximately.
2)	While measuring e.m.f. it does not draw any current from the source of known e.m.f.	While measuring e.m.f it drawn some current from the ~~can~~ source e.m.f.
3)	It's sensitivity is high.	Its sensitivity is low.

(4)	while measuring e.m.f the Resistance of potentiometer becomes infinite.	while measuring e.m.f. the Resistance of Voltmeter is high but finite.
5)	It is based on null deflection method.	It is based on deflection method.
6)	It can be used for Various purposes	It can be used only to measure e.m.f or potential difference.

Q:- Conductivity of a Super Conductor is
(a) infinite (b) very large (c) very small (d) zero

Sol (a) infinite.

Q The unit of Resistivity is
(a) ohm (b) ohm m (c) ohm m^{-1} (d) mho m^{-1}

Sol: (b) ohm m.

Q:- if the wire of Radius (r) is drawn to another wire of Radius (2r) the new resistance of the wire will.

(a) 2r (b) $r/2$ (c) 4r (d) $\frac{r}{16}$

Sol (d) $r/16$

Q The resistivity of Conductor does not depends upon

(a) Nature of the matirial
(b) Cross-actional area.
(c) temp.
(d) length

Sol (c) temperature.

Q apropracte matirial to be used in the Contruction of resistance box out of the following
(1) Copper (2) iron (3) Magnian (4) Aluminium.

Sol (3) Magnian.

Q:- which one of the flowing is best matirial for making Connacting wire.

(a) Magnian (b) Constantum (c) Copper
(d) nichoom.

Ans:- (c) Copper.

Q: If the length of the potentiometer wire is increased then the accuracy in the deterimanion of null point

(a) Increases (b) decreases (c) remain same
(d) NoN of these.

Sol:- (a) Inerases.

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Date ___/___/___

Q The instrument for accurate measurement of the e.m.f of a cell is →

(a) Voltmeter (b) M. meter (c) potentiometer (d) A slide wire bridge.

Sol :- (c) potentiometer.

Q The heater element in a ~~iron~~ electric iron is made of
(a) nichrome (b) iron (c) Constantan (d) ∓.

Sol (a) nichrome

Q The heating element of an electric heater should be made with a material which should have

(a) higher resistivity and high ~~temp~~ melting point.
(b) high resistivity and low melting point
(c) low resistivity and high melting point
(d) low resistivity and low melting point.

Sol :- (a) High resistivity and high melting point.

Q A fuse is used an electric circuit to
(a) Indicate the Consumption
(b) break the circuit when the power is off
(c) mentain Constant Current.
(d) act as switch during emergency.

Sol (d) act as switch during emergency.

Guru Ji

Date / /

Q:- Temp. of electric heater become constant temp. after some time because

(a) heat stop genrating after some time
(b) Rise of curren become steady after some time.
(c) temp. of heater is equal to the atmosphere.
(d) Rate of heat genration become equal to the rate of heat lossed to the atmosphere

Sol:- (d) Rate of heat genration become equal to the rate of heat lossed to the atmosphere.

Formula :-

① Electrostatic Potential :-

$V = \frac{\text{work}}{\text{charge}}$ $\left(V = \frac{W}{q}\right)$

$\left[ML^{2}T^{-3}A^{-1}\right]$
unit (volts)

② Electrostatic Potential Due to Point charge

$$\boxed{V = \frac{q}{4\pi\varepsilon_0 r}}$$

Due to system of charges :-

$$\boxed{V = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_i}}$$

③ Electric Potential due to Electric dipole :-

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$$

(i) on the axis :- $(\theta = 0)$

$$\therefore \quad V = \pm\frac{p}{4\pi\varepsilon_0 r^2}$$

(11) In the equatorial plane, $\theta = \frac{\pi}{2}$

$$\left[\cos\frac{\pi}{2} = 0\right]$$

$$V = \frac{1}{4\pi\varepsilon_0}(0)$$

$$\boxed{V = 0}$$

(4) Electrostatic Potential Energy of a System of two Point charges :-

$$U = W = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_{AB}}\right)$$

(5) Potential Energy of a dipole in an External field :-

$$U = W = -\vec{p}\cdot\vec{E} = -pE\cos\theta.$$

(6) Dielectric Constant (K)

$$K = \frac{E_0}{E}$$

(7) Polarisation (P)

$$\boxed{P = \alpha \varepsilon_0 E_0}$$

(8) Electric Susceptibility :

$$\boxed{P = \chi \varepsilon_0 E}$$

(9) Capacitor and Capacitance

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

$[M^{-1}L^{-2}T^{4}A^{2}]$

$$\boxed{C = 4\pi\varepsilon_0 r}$$

Unit :- Farad

(10) Parallel plate Capacitor :-

$$\boxed{C = \frac{\varepsilon_0 A}{d}}$$

Effect of dielectric in it :-

$$C' = \frac{K\varepsilon_0 A}{d} \Rightarrow C' = KC$$

Capacitance, $C = \dfrac{\varepsilon_0 A}{d - t + \frac{t}{K}}$

(11) <u>Capacitors in series</u> :-

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$$

(12) <u>Capacitors in parallel</u> :-

$$\underline{C = C_1 + C_2 + \cdots + C_n}$$

(13) <u>Energy stored in a Capacitor</u> :-

$$\boxed{U = \frac{1}{2}\varepsilon_0 E^2} \text{ or } \boxed{U = \frac{1}{2} C V^2}$$