CURRENT ELECTRICITY

ELECTRIC CURRENT

Rate of flow of Charge $I = \frac{dq}{dt}$

S.I. Unit Ampere (A) Coulomb/ Second

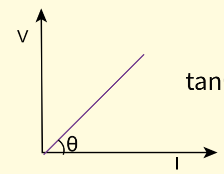
Instantaneous, $I_{ins} = \frac{dq}{dt}$

Average, $I_{av} = \frac{q}{t}$

Ohm's Law

- At constant temperature current passing through metals or conductors is directly proportional to the potential difference applied across them.
- $I \propto V \Rightarrow V = IR$;(R-electric resistance)
- Substances which Obey Ohm's law called Ohmic and that do not obey called non-ohmic substances.

The slope of V-I plot for Ohmic substance



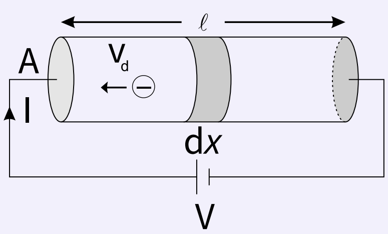
$\tan\theta = \frac{V}{I} = R$

Drift Velocity

Drift velocity is defined as the velocity with which the free electrons get drifted towards the positive terminal under the effect of the applied external electric field.

$$V_d = \frac{qE}{m}\tau$$

Relation between Drift velocity and current



$$i = neAV_d = \frac{ne^2 A\tau E}{m}$$

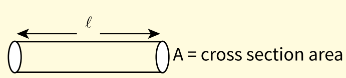
$$= neA\mu_e E = neA\mu_e \frac{V}{\ell}$$

Current density (J)

Current per unit cross-section area perpendicular to current flow.

$$J = \frac{I}{A} = \frac{E}{\rho}$$

Resistance



The property due to which body opposes the flow of current through it, is known as resistance.

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

S.I unit of Resistivity: ohm (Ω)

Factors affecting resistivity:

- Nature of material
- Temperature.

Relation between resistivity and temprature

$$\rho_f = \rho_i\,[1+\alpha(t_f - t_i)]$$

Conductance

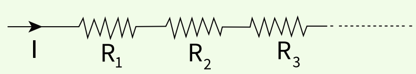
$$C = \frac{1}{\text{Resistance}} = \frac{1}{R}$$

Unit is mho (Ω^{-1})

Grouping of Resistance

Series grouping of resistance

- Equivalent resistance, $R_s = R_1+R_2+R_3.....$

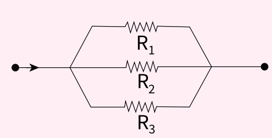


- Current flow through each resistance is same.
- Potential difference, $V \propto R$

Parallel grouping of resistance

- Equivalent resistance,

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



- Potential difference across each resistance same current distribution, in each resistance, $I \propto \frac{1}{R}$

Some Important Formula

- After stretching length of wire increases by n times then resistance will increase by n^2 times i.e.,
- If radius be reduced $\frac{1}{n}$ to times then area of cross-section decreases $\frac{1}{n^2}$ time so the resistance become n^4 times i.e., $R_2 = n^4 R_1$

Conductivity (σ)

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

$$\text{Unit} = \frac{1}{\Omega m} = \frac{1}{\text{ohm} \times \text{m}} \text{ or } \frac{\text{mho}}{\text{m}}$$

Electric Energy and Power

Heat energy developed across resistor

$H = I^2RT$

Power, $= VI = I^2R = \frac{V^2}{R}$

In parallel, $P = P_1 + P_2$

In series, $P = \frac{P_1P_2}{P_1 + P_2}$

Grouping of cells

Cells in series

Current in the circuits, $I = \frac{n\varepsilon}{R + nr}$

Cells in parallel

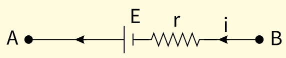
Current in the circuit, $I = \frac{\varepsilon}{R + \frac{r}{m}}$

Cells in mixed grouping

The current in the circuit,

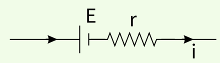
$$I = \frac{n\varepsilon}{\frac{nr}{m} + R}$$

When cell is discharging



$\Delta V = E - ir$

When cell charging



$\Delta V = E + ir$

When cell is in an open circuit

$R = \infty$

$I = \frac{E}{R+r} = 0$ and $V = E$

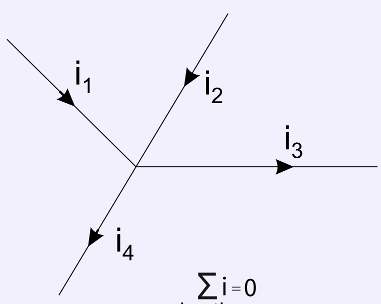
When cell is short circuited

$R = 0$ and $I = \frac{-E}{R+r}$ and $V = IR = 0$

Kirchhoff's laws

1st law/ Junction law

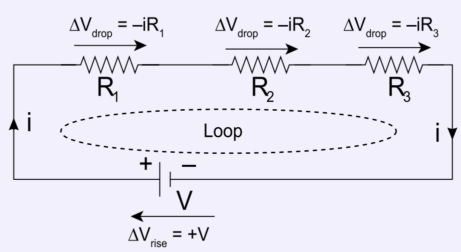
- Sum of the incoming currents is equal to sum of the outgoing currents at any junction.
- Based on law of conservation of charge.



$$\sum_{\text{junction}} i = 0$$

2nd law/loop rule

- The algebraic sum of the potential differences in any loop (including those associated with emf's and those of resistive elements), must equal zero.
- Based on law of conservation of energy.

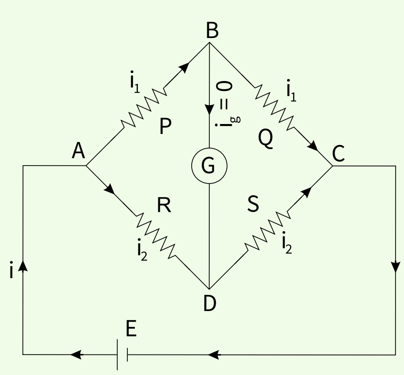


$$\sum_{\text{Closedloop}} \Delta V = 0$$

Wheatstone Bridge

Balanced Condition of Wheatstone bridge

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



Metre bridge

Based on Wheatstone bridge

$$\frac{P}{Q} = \frac{R}{S} = \frac{\ell}{100 - \ell}$$