Name: Chandra Shekhar
College: IIT Gandhinagar
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CURRENT ELECTRICITY

Electric Current

Electric current represents the rate at which charge flows through a conductor. If a small amount of charge dq flows in time dt, then:

$$I = \frac{dq}{dt}$$

Direction of current is taken as the flow of positive charge (opposite to electron flow). Current is a scalar quantity and its SI unit is ampere (A).

Ohm's Law

Ohm's law states that for a conductor at constant temperature, the current through it is directly proportional to the voltage across its ends:

$$V = IR$$

R is the resistance, characteristic of the conductor.

Resistance

Resistance depends on material, length L, and cross-sectional area A:

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

Where ρ is resistivity. Unit: Ohm (Ω).

Current Density

Current density J is defined as the current per unit cross-sectional area:

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

It is a vector quantity. SI unit: $\mathrm{A/m^2}$.

Drift Velocity

Drift velocity v_d is the average velocity of electrons under an electric field:

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

Relation between current and v_d:

$$I = neAv_d$$

Mobility

Mobility μ is drift velocity per unit electric field:

$$\mu = \frac{v_d}{E} = \frac{e\tau}{m}$$

SI unit: $\mathrm{m^2/Vs}$.

Electrical Power and Energy

Power consumed in a resistor:

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

Energy consumed:

$$W = P \times t = VIt = I^2Rt = \frac{V^2}{R}t$$

SI unit: Joule. Commercial unit: kWh.

Kirchhoff's Laws

- **KCL:** At any junction, sum of incoming currents equals sum of outgoing currents.

$$\sum I = 0$$

- **KVL:** Sum of potential differences in any closed loop is zero.

$$\sum V = 0$$

Cell, EMF and Internal Resistance

- EMF (E): Potential difference when no current flows.
- Terminal voltage (V): When current I flows.
- Internal resistance (r):

$$V = E - Ir$$
$$r = \frac{E - V}{I} = \left(\frac{E}{V} - 1\right) R$$

Cell Combinations

- **Series:** $E_{total} = nE$, $r_{total} = nr$, $I = \frac{nE}{R+nr}$
- **Parallel:** $E_{total} = E$, $r_{total} = \frac{r}{n}$, $I = \frac{E}{R+r/n}$

Wheatstone Bridge

A circuit used to measure unknown resistance:

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

Potentiometer

Used to measure EMF and compare voltages based on the principle of potential drop across uniform wire:

- Comparing EMFs:

$$\frac{E_1}{E_2} = \frac{L_1}{L_2}$$

- Internal resistance:

$$r = \left(\frac{L_1}{L_2} - 1\right) R$$

Metre Bridge

Based on Wheatstone principle. For unknown resistance R and standard S:

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

Galvanometer and Its Conversions

- **To Ammeter:** Add shunt S in parallel:

$$S = \frac{I_g G}{I - I_g}$$

- **To Voltmeter:** Add resistance R in series:

$$R = \frac{V}{I_g} - G$$