Chapter 26 Current and Resistance

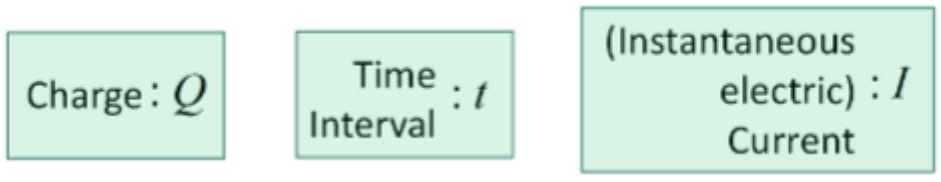
Electric Current

- **Electric current** (I) is the **rate of flow of electric charge** through a surface.
- The SI unit of current is the **ampere (A)**:

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

  where dQ is the change in charge over time dt.
- **1 ampere (A)** means 1 coulomb (C) of charge flows through a conductor per second.

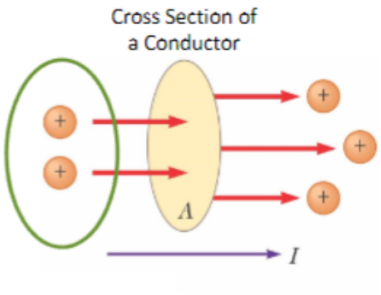
Average Current

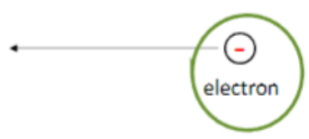


- If ΔQ is the charge passing through an area in time Δt:

$$I_{\text{avg}} = \frac{\Delta Q}{\Delta t}$$

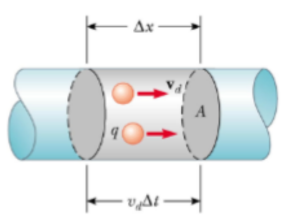
Direction of Current





- By convention, **current direction** is the direction a **positive charge** would flow.
- The **actual flow of electrons** is opposite to this convention.

Current and Drift Speed



- **Drift speed** (v_d) is the average velocity of charge carriers due to an electric field.
- If n is the number of charge carriers per unit volume and q is the charge per carrier:

$$I = nqv_dA$$

  where:
  - A is the cross-sectional area of the conductor.

Ohm's Law

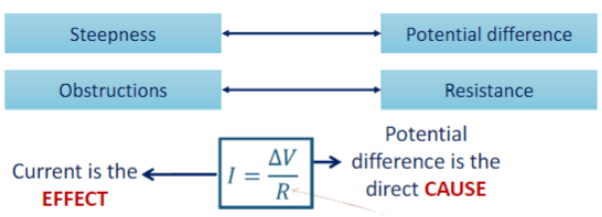
> **Analogy**: Resistance of water flow in a river

- **Ohm's Law** describes the relationship between **voltage (ΔV)**, **current (I)**, and **resistance (R)**:

$$\Delta V = IR$$

  - Resistance R is constant for **ohmic materials** over a range of voltages and currents.

Definition of Resistance

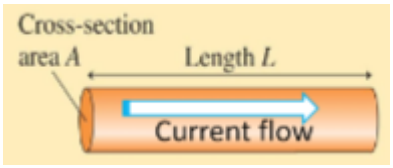


- **Resistance (R)** of a conductor depends on material, length L, and cross-sectional area A:

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

- ρ: **Resistivity** of the material, unique for each material.

Factors Affecting Resistance



- **Length** (L): Resistance increases with length.
- **Cross-sectional Area** (A): Resistance decreases with larger area.
- **Temperature**: Resistance of most metals increases with temperature.

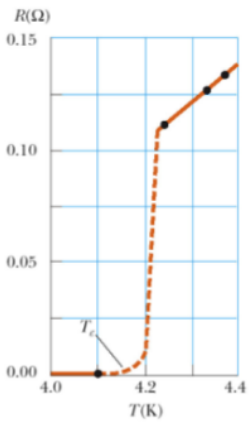
Resistivity and Temperature

- **Temperature dependence** of resistivity for most metals:

$$\rho = \rho_0 \left(1 + \alpha(T - T_0)\right)$$

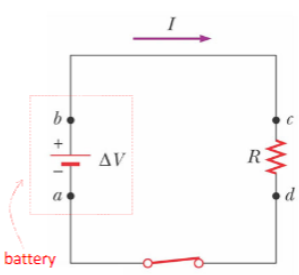
  - α: Temperature coefficient of resistivity.
  - T: Temperature, T_0 is a reference temperature (usually 20°C).

Superconductors



- **Superconductors** are materials that exhibit **zero resistance** below a critical temperature T_C.
- Current in a superconductor can flow indefinitely without energy loss.

Electrical Power



- **Electric power (P)** is the rate at which electrical energy is converted to other forms:

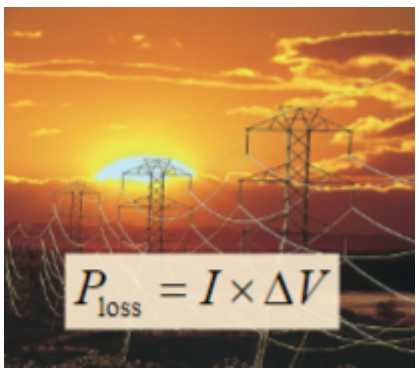
$$P = IV$$

  - Applying Ohm's Law, power can also be expressed as:

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

  - Unit of power: **watt (W)**, where $1\,\mathrm{W} = 1\,\mathrm{J/s}$.

Power Transmission



- **Power losses** during transmission are minimized by using **high voltage and low current**:

$$P_{\text{loss}} = I^2R$$

  - High voltage reduces current for a given power, minimizing power loss due to resistance.
  - Since $I_{transmit} \downarrow$, $I_{source} \downarrow$