Chapter 1

Currents, Resistance, and Electromotive Force

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Announcements:

1.1 Current

Definition 1 (Current)**.** *A current is any motion of charge form one region to another.* •

Quantifying Current

- Model a wire as a cylinder:
- $n = \frac{\text{\# of moving charges}}{\text{volume}}$
- Volume $= dxA$
- Volume $= (\overline{v}_d dt)A$
- Amount of charge that folows through cylinder:

$$dQ = q \cdot \text{ number of charges } = q \cdot n \cdot V$$

$$dQ = qn\overline{v}_d dtA$$

$$\frac{dQ}{dt} = I = qn\overline{v}_d A$$

$$\boxed{I = n|q|v_d A} \tag{1.1}$$

Current

I Current

q charge per particle

n # of moving Charges

v_d Drift velocity

A Cross sectional area of conductor

units Ampers, Amps, A

Scalar quantity, cw or ccw in a curcuit

$$\boxed{\overline{J} = \frac{I}{A} = |q|\, n\overline{v}_d} \tag{1.2}$$

Vector Current Density

I Current

A Cross sectional area

units $\frac{A}{m^2}$

1.1.1 Direction of Current Flow

- **Conventional Current** is treated as a flow of positive charges.
- I a metallic conductor, the charges moving are electrons, but the conventional current points in the opposite direction.
- The vector **Current Density** is always in the same direction as the electric field.

1.2 Resistivity

Definition 2 (Resistivity)**.** *The resistivity of a material is the ratio of the electric field in the material to the current density it causes. A measure of a materia's opposition to flow. Depends on material and temperature.* ***Conductivity*** *is the recipricol of resistivity* •

$$\boxed{\rho = \frac{E}{J}} \tag{1.3}$$

Resistivity

rho Resistivity

E Electric field

J Current densityCurrent density

$$\boxed{\rho(T)v = \rho_0[1 + \alpha(T - T_0)]} \tag{1.4}$$

Temperature dependence of resistivity

1.3 Resistance

1.3.1 Resistance and Ohm's Law

The **resistance** of a conductor is $R = \rho \frac{L}{A}$.

The potential across a conductor is given by Ohm's Law:

$$\boxed{V = IR} \tag{1.5}$$

Ohm's Law

$$\boxed{R = \frac{\rho L}{A}} \tag{1.6}$$

Resistance Equation

L Length of conductor

A Cross sectional area

1.4 Electromotive Froce and Circuits

Electromotive force (emf) makes current flow from low to high potential. A circuit that provides emf is called a **source of emf**. SI units of $1V = 1\frac{J}{C}$. A flashlight battery has an emf of 1.5V; it does 1.5 J of work on every coulomb of charge that passes through it. Use symbol $\mathcal{E}$ (cursive E) for emf.

When a battery is connected, electrons must reach the positive charge. When they do:

$$W_{net} = W_b - W_c = \Delta KE = 0(\text{ steady state })$$

$$W_b = W_e$$

$$q\mathcal{E} = qV_{ab}$$

$$\mathcal{E} = V_{ab}$$

$U_i \implies$ powering circuit elements. Rise in PE = loss in potential energy.

$$\mathcal{E} = V_{ab} = IR$$

This is energy balance, what ever emf is put in is used by the resistors.

1.4.1 Internal Resistance

Real sources contain some **internal resistance, r**.

$$\boxed{V_{ab} = \mathcal{E} - Ir} \tag{1.7}$$

Potential of source with internal resistance

V Terminal voltage, source with internal resistance.

$\mathcal{E}$ emf of source.

I Current through source.

r Internal resistance of source.

-Ir Loss of potential in battery.

1.5 Energy and Power in Electric Circuits

- A circuit element causes a net transfer of energy into or out of the circuit.
- the time rate of energy transfer is power, denoted by P

$$\boxed{P = V_{ab}I = I^2R = \frac{V_{ab}^2}{R}} \tag{1.8}$$

Power delivered to or extracted from a circuit element

V Voltage across circuit element.

I Current in circuit element.

Unit Watts, W