CHAPTERS 25 AND 26 NOTES

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Contents

25 Current, Resistance, and Electromotive Force

This chapter involves electric charges *in motion* rather than static as before An *electric current* consists of charges in motion from one region to another. If the charges follow a conduct- ing path that forms a closed loop, the path is called an *electric circuit.*

25.1 Current.

Definition 1. Current (I): Any motion of charge from one region to another and is induced by the ability of electrons to freely move. Current is zero everywhere in electrostatics. Current can be defined as

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

where Q is Coulombs and its unit is Amperes(1 A = 1 C/s). Because Current is a scalar it must be accompanied by a statement of direction: "25 Amps in the clockwise direction"

Remark. We define the current, denoted by I, to be in the direction in which there is a flow of positive charge and describe currents as though

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they consisted entirely of positive charge flow, even in cases in which we know that the actual current is due to electrons.

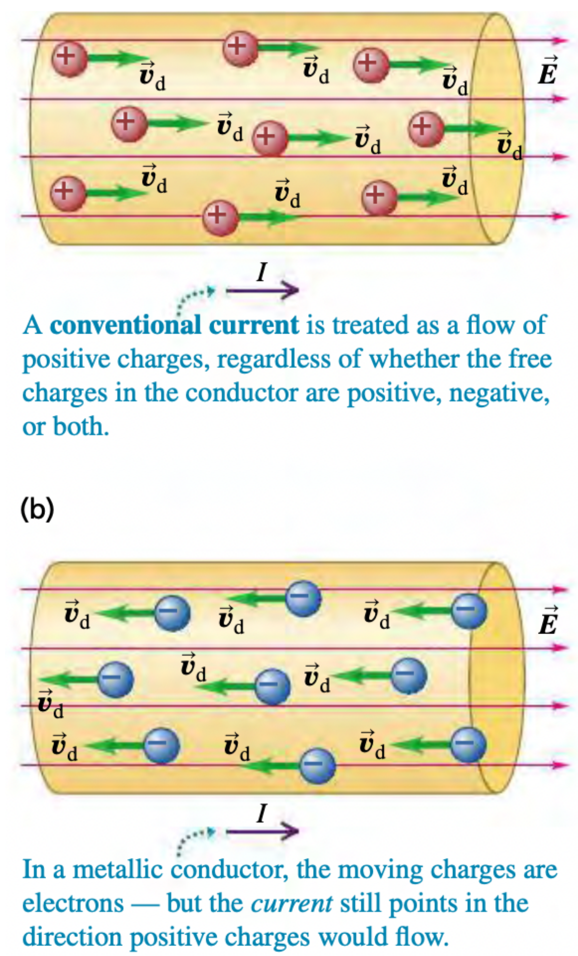

FIGURE 1. Current Flow Diagram

Definition 2. Drift Velocity (v_d): The average velocity of charged particles moving in the direction of the electric force $\vec{F} = q\vec{E}$, though individual charge path is random. This value gives us an alternate calculation of I of

$$I = nqv_dA$$

where n is concentration of particles, q is unit charge and A is area.

25.1.1 Direction of Current Flow.

Remark. Different current-carrying materials may have differently charged moving particles In metals the moving charges are always electrons, while in an ionized gas (plasma) or an ionic solution the moving charges may include both electrons and positively charged ions. In a semiconductor conduction is partly by electrons and partly by motion of *vacancies*, also known as holes; these are sites of missing electrons and act like positive charges.

25.1.2 Current Density.

Definition 3. Current Density (J):
The current per unit cross-section area or

$$J = I/A = nqv_d$$

where n is charge concentration, q is the charge per particle and v_d is the drift velocity.

25.2 Resistivity.

Theorem 1. Ohm's Law: A relationship in an idealized model that states that the ratio of the electric field and the current density is constant in metals at a given temperature, and this is known as Resistivity.

Definition 4. Resistivity (ρ): The permitivity of electrons to move freely in a material, linked with resistance. Resistivity is defined as

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

where E is the magnitude of the electric field and J is the current density. unit is ohm-meters($1\ \Omega \cdot m = V \cdot m/A$) Good insulators have high resistivity and conductors have low Resistivity.

Resistivity can also be calculated as a function of Temperature:

$$\rho(T) = \rho_0[1 + \alpha(T - T_0)]$$

where α is a temperature coefficient of resistivity and ρ_0 being the Resistivity at a reference temperature T_0

Definition 5. Conductivity: The recipprocal of resistivity whose units are $(\Omega \cdot m)^{-1}$ Good conductors obviously have high Conductivity.

Definition 6. Semiconductor: Materials with propertis intermediate of metals and insulators, whose resistivity is likewise between these two groups.

Remark. A material that obeys Ohm's law reasonably well is called an *ohmic conductor* or a *linear conductor*, those that dont are *nonohmic*, or *nonlinear*. In the latter materials, J depends on E in a more complicated manner.

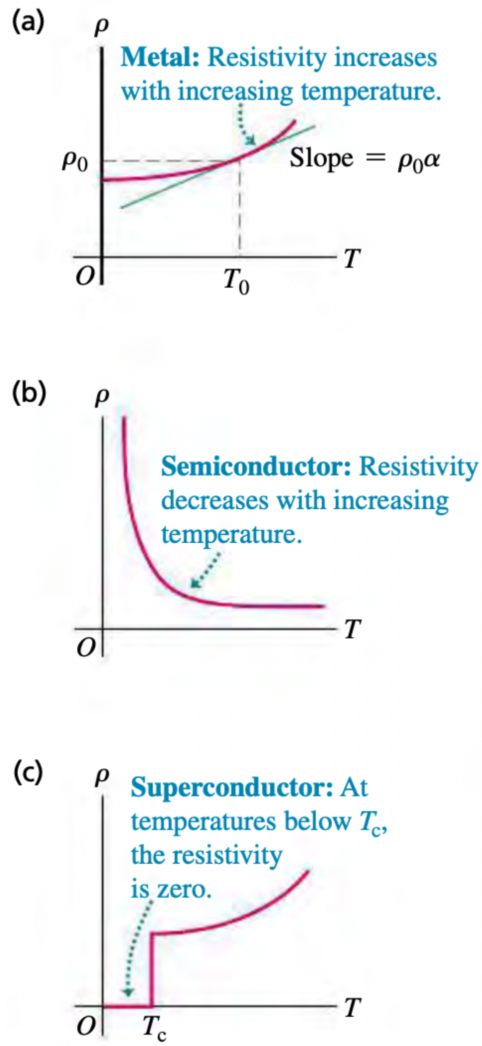

FIGURE 2. Resistivity Across Material Types

25.3 Resistance.

Definition 7. Resistance (R): The ratio of Potential Difference V to Current I for a particular conductor. Resistance measures the opposition to current flow in an electrical circuit. The resistance of a conductor can be calculated by the equation

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

and its unit is Ohm ($1\ \Omega = 1V/A$) and similar to resistivity can be ade a function of Temperature:

$$R(T) = R_0[1 + \alpha(T - T_0)]$$

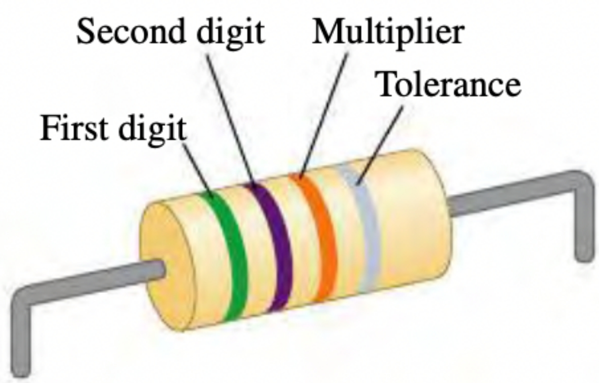

FIGURE 3. Labeling Guide for Resistors

25.4 Electromotive Force and Circuits.

Definition 8. Electromotive Force ($\mathcal{E}$): In an electric circuit there must be a device somewhere in the loop that acts like the water pump in a water fountain. This pumping action is called Electromotive Force or emf and the device is called a source of emf. This is not actually a force but a energy-per-unit-charge and thus has the unit Volt (1 V = 1 J/C).

Emf can be calculated in multiple ways:

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

for ideal sources and where V_{ab} is the Terminal Voltage or

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

for when there is internal resistance (r).

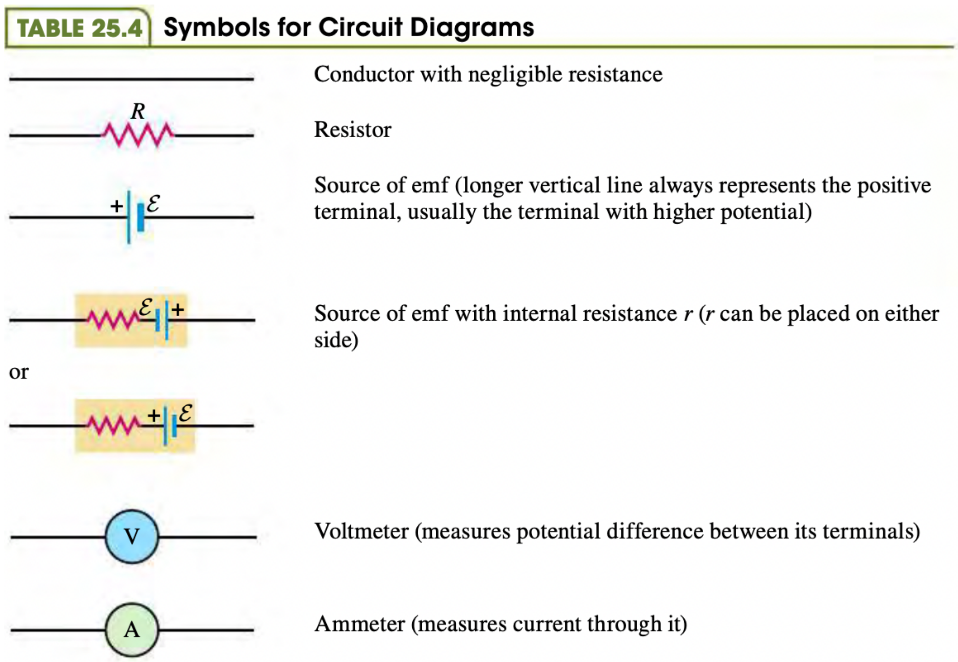

FIGURE 4. Table of Circuit Labels

25.5 Energy and Power in Electric Circuits.

Definition 9. Power (P): the rate, per unit time, at which electrical energy is transferred in or out of an electric element. Power can be found by the following equations:

$$P = V_{ab}I = I^2R = \frac{V_{ab}^2}{R} = \mathcal{E}I - I^2r$$

The SI unit of power is the watt(1 W = 1 J/s)

Remark. The moving charges in flowing current collide with atoms in the resistor and transfer some of their energy, increasing the *internal energy* of the material. Either the temperature of the resistor increases or there is a flow of heat out of it, or both. Every resistor has a power rating, the maximum power the device can dissipate without becoming overheated and damaged.

26 Direct-Current Circuits