

## Section Summary

### 20.1 Current

- Electric current  $I$  is the rate at which charge flows, given by
- $I = \frac{\Delta Q}{\Delta t}$ ,  
where  $\Delta Q$  is the amount of charge passing through an area in time  $\Delta t$ .
- The direction of conventional current is taken as the direction in which positive charge moves.
- The SI unit for current is the ampere (A), where  $1 \text{ A} = 1 \text{ C/s}$ .
- Current is the flow of free charges, such as electrons and ions.
- Drift velocity  $v_d$  is the average speed at which these charges move.
- Current  $I$  is proportional to drift velocity  $v_d$ , as expressed in the relationship  $I = nqAv_d$ . Here,  $I$  is the current through a wire of cross-sectional area  $A$ . The wire's material has a free-charge density  $n$ , and each carrier has charge  $q$  and a drift velocity  $v_d$ .
- Electrical signals travel at speeds about  $10^{12}$  times greater than the drift velocity of free electrons.

### 20.2 Ohm's Law: Resistance and Simple Circuits

- A simple circuit *is* one in which there is a single voltage source and a single resistance.
- One statement of Ohm's law gives the relationship between current  $I$ , voltage  $V$ , and resistance  $R$  in a simple circuit to be  $I = \frac{V}{R}$ .
- Resistance has units of ohms ( $\Omega$ ), related to volts and amperes by  $1 \Omega = 1 \text{ V/A}$ .
- There is a voltage or IR drop across a resistor, caused by the current flowing through it, given by  $V = IR$ .

### 20.3 Resistance and Resistivity

- The resistance  $R$  of a cylinder of length  $L$  and cross-sectional area  $A$  is  $R = \frac{\rho L}{A}$ , where  $\rho$  is the resistivity of the material.
- Values of  $\rho$  in Table 20.1 show that materials fall into three groups—*conductors*, *semiconductors*, and *insulators*.
- Temperature affects resistivity; for relatively small temperature changes  $\Delta T$ , resistivity is  $\rho = \rho_0(1 + \alpha\Delta T)$ , where  $\rho_0$  is the original resistivity and  $\alpha$  is the temperature coefficient of resistivity.
- Table 20.2 gives values for  $\alpha$ , the temperature coefficient of resistivity.
- The resistance  $R$  of an object also varies with temperature:  $R = R_0(1 + \alpha\Delta T)$ , where  $R_0$  is the original resistance, and  $R$  is the resistance after the temperature change.

## 20.4 Electric Power and Energy

- Electric power  $P$  is the rate (in watts) that energy is supplied by a source or dissipated by a device.
- Three expressions for electrical power are
  - $P = IV$ ,
  - $P = \frac{V^2}{R}$ ,
  - and
  - $P = I^2 R$ .
- The energy used by a device with a power  $P$  over a time  $t$  is  $E = Pt$ .

## 20.5 Alternating Current versus Direct Current

- Direct current (DC) is the flow of electric current in only one direction. It refers to systems where the source voltage is constant.
- The voltage source of an alternating current (AC) system puts out  $V = V_0 \sin 2\pi ft$ , where  $V$  is the voltage at time  $t$ ,  $V_0$  is the peak voltage, and  $f$  is the frequency in hertz.
- In a simple circuit,  $I = V/R$  and AC current is  $I = I_0 \sin 2\pi ft$ , where  $I$  is the current at time  $t$ , and  $I_0 = V_0/R$  is the peak current.
- The average AC power is  $P_{\text{ave}} = \frac{1}{2} I_0 V_0$ .
- Average (rms) current  $I_{\text{rms}}$  and average (rms) voltage  $V_{\text{rms}}$  are  $I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$  and  $V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$ , where rms stands for root mean square.
- Thus,  $P_{\text{ave}} = I_{\text{rms}} V_{\text{rms}}$ .
- Ohm's law for AC is  $I_{\text{rms}} = \frac{V_{\text{rms}}}{R}$ .
- Expressions for the average power of an AC circuit are  $P_{\text{ave}} = I_{\text{rms}} V_{\text{rms}}$ ,  $P_{\text{ave}} = \frac{V_{\text{rms}}^2}{R}$ , and  $P_{\text{ave}} = I_{\text{rms}}^2 R$ , analogous to the expressions for DC circuits.

## 20.6 Electric Hazards and the Human Body

- The two types of electric hazards are thermal (excessive power) and shock (current through a person).
- Shock severity is determined by current, path, duration, and AC frequency.
- Table 20.3 lists shock hazards as a function of current.
- Figure 20.22 graphs the threshold current for two hazards as a function of frequency.

## 20.7 Nerve Conduction—Electrocardiograms

- Electric potentials in neurons and other cells are created by ionic concentration differences across semipermeable membranes.

- Stimuli change the permeability and create action potentials that propagate along neurons.
- Myelin sheaths speed this process and reduce the needed energy input.
- This process in the heart can be measured with an electrocardiogram (ECG).