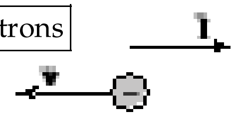
Chapter 17
Current and Resistance

Problem Solutions

17.1 The charge that moves past the cross section is $\Delta Q = I(\Delta t)$, and the number of electrons is

$$n = \frac{\Delta Q}{|e|} = \frac{I(\Delta t)}{|e|}$$

$$= \frac{(80.0\times 10^{-3}\ \text{C/s})[(10.0\ \text{min})(60.0\ \text{s/min})]}{1.60\times 10^{-19}\ \text{C}} = \boxed{3.00\times 10^{20}\ \text{electrons}}$$



The negatively charged electrons move in the direction opposite to the conventional current flow.

17.3 The current is $I = \frac{\Delta Q}{\Delta t} = \frac{\Delta V}{R}$. Thus, the change that passes is $\Delta Q = \left(\frac{\Delta V}{R}\right)(\Delta t)$, giving

$$\Delta Q = \left(\frac{1.00\ \text{V}}{10.0\ \Omega}\right)(\Delta t) = (0.100\ \text{A})(20.0\ \text{s}) = \boxed{2.00\ \text{C}}$$

17.8 Assuming that, on average, each aluminum atom contributes one electron, the density of charge carriers is the same as the number of atoms per cubic meter. This is

$$n = \frac{density}{mass\ per\ atom} = \frac{\rho}{M/N_A} = \frac{N_A \rho}{M},$$

or $$n = \frac{\left(6.02\times10^{23}/\text{mol}\right)\left[\left(2.7\ \text{g/cm}^3\right)\left(10^6\ \text{cm}^3/1\ \text{m}^3\right)\right]}{26.98\ \text{g/mol}} = 6.0\times10^{28}/\text{m}^3$$

The drift speed of the electrons in the wire is then

$$v_d = \frac{I}{n|e|A} = \frac{5.0\ \text{C/s}}{\left(6.0\times10^{28}/\text{m}^3\right)\left(1.60\times10^{-19}\ \text{C}\right)\left(4.0\times10^{-6}\ \text{m}^2\right)} = \boxed{1.3\times10^{-4}\ \text{m/s}}$$

17.9 (a) The carrier density is determined by the physical characteristics of the wire, not the current in the wire. Hence, n is $\boxed{\text{unaffected}}$.

(b) The drift velocity of the electrons is $v_d = I/nqA$. Thus, the drift velocity is $\boxed{\text{doubled}}$ when the current is doubled.

17.11 $(\Delta V)_{\text{max}} = I_{\text{max}} R = \left(80\times10^{-6}\ \text{A}\right) R$

Thus, if $R = 4.0\times10^5\ \Omega$, $(\Delta V)_{\text{max}} = \boxed{32\ \text{V}}$

and if $R = 2\,000\ \Omega$, $(\Delta V)_{\text{max}} = \boxed{0.16\ \text{V}}$

17.13 From $R = \dfrac{\rho L}{A}$, we obtain $A = \dfrac{\pi d^2}{4} = \dfrac{\rho L}{R}$, or

$$d = \sqrt{\frac{4\rho L}{\pi R}} = \sqrt{\frac{4\left(5.6\times10^{-8}\ \Omega\cdot\text{m}\right)\left(2.0\times10^{-2}\ \text{m}\right)}{\pi\left(0.050\ \Omega\right)}} = 1.7\times10^{-4}\ \text{m} = \boxed{0.17\ \text{mm}}$$

17.16 We assume that your hair dryer will use about 400 W of power for 10 minutes each day of the year. The estimate of the total energy used each year is

$$E = \mathcal{P}(\Delta t) = (0.400 \text{ kW})\left[\left(10\ \frac{\text{min}}{\text{d}}\right)\left(\frac{1 \text{ hr}}{60 \text{ min}}\right)(365 \text{ d})\right] = 24 \text{ kWh}$$

If your cost for electrical energy is approximately ten cents per kilowatt-hour, the cost of using the hair dryer for a year is on the order of

$$cost = E \times rate = (24 \text{ kWh})\left(0.10\ \frac{\$}{\text{kWh}}\right) = \$2.4 \quad \text{or} \quad \boxed{\sim\$1}$$

17.19 The volume of material, $V = AL_0 = \left(\pi r_0^2\right) L_0$, in the wire is constant. Thus, as the wire is stretched to decrease its radius, the length increases such that $\left(\pi r_f^2\right) L_f = \left(\pi r_0^2\right) L_0$ giving

$$L_f = \left(\frac{r_0}{r_f}\right)^2 L_0 = \left(\frac{r_0}{0.25 r_0}\right)^2 L_0 = (4.0)^2 L_0 = 16 L_0$$

The new resistance is then

$$R_f = \rho \frac{L_f}{A_f} = \rho \frac{L_f}{\pi r_f^2} = \rho \frac{16 L_0}{\pi (r_0/4)^2} = 16(4)^2 \left(\rho \frac{L_0}{\pi r_0^2}\right) = 256 R_0 = 256(1.00\,\Omega) = \boxed{256\,\Omega}$$

17.20 Solving $R = R_0\left[1 + \alpha(T - T_0)\right]$ for the final temperature gives

$$T = T_0 + \frac{R - R_0}{\alpha R_0} = 20°\text{C} + \frac{140\ \Omega - 19\ \Omega}{\left[4.5\times10^{-3}\ (°\text{C})^{-1}\right](19\ \Omega)} = \boxed{1.4\times10^3\ °\text{C}}$$

17.23 At 80°C,

$$I = \frac{\Delta V}{R} = \frac{\Delta V}{R_0\left[1 + \alpha(T - T_0)\right]} = \frac{5.0 \text{ V}}{(200\ \Omega)\left[1 + \left(-0.5\times10^{-3}\ °\text{C}^{-1}\right)(80°\text{C} - 20°\text{C})\right]}$$

or $\quad I = 2.6\times10^{-2}\ \text{A} = \boxed{26 \text{ mA}}$

17.31 $I = \dfrac{P}{\Delta V} = \dfrac{600\text{ W}}{120\text{ V}} = \boxed{5.00\text{ A}}$

and $R = \dfrac{\Delta V}{I} = \dfrac{120\text{ V}}{5.00\text{ A}} = \boxed{24.0\ \Omega}$

17.33 The maximum power that can be dissipated in the circuit is

$$P_{\max} = (\Delta V) I_{\max} = (120\text{ V})(15\text{ A}) = 1.8\times 10^{3}\text{ W}$$

Thus, one can operate at most $\boxed{18\text{ bulbs}}$ rated at 100 W per bulb.

17.39 The resistance per unit length of the cable is

$$\frac{R}{L} = \frac{P/I^2}{L} = \frac{P/L}{I^2} = \frac{2.00\text{ W/m}}{(300\text{ A})^2} = 2.22\times 10^{-5}\ \Omega/\text{m}$$

From $R = \rho L/A$, the resistance per unit length is also given by $R/L = \rho/A$. Hence, the cross-sectional area is $\pi r^2 = A = \dfrac{\rho}{R/L}$, and the required radius is

$$r = \sqrt{\frac{\rho}{\pi(R/L)}} = \sqrt{\frac{1.7\times 10^{-8}\ \Omega\cdot\text{m}}{\pi(2.22\times 10^{-5}\ \Omega/\text{m})}} = 0.016\text{ m} = \boxed{1.6\text{ cm}}$$

17.45 The energy saved is

$$\Delta E = \left(P_{high} - P_{low}\right)\cdot t = (40\text{ W} - 11\text{ W})(100\text{ h}) = 2.9\times 10^{3}\text{ Wh} = 2.9\text{ kWh}$$

and the monetary savings is

$$savings = \Delta E \cdot rate = (2.9\text{ kWh})(\$0.080/\text{kWh}) = \$0.23 = \boxed{23\text{ cents}}$$

17.52 The resistance of the 4.0 cm length of wire between the feet is

$$R = \frac{\rho L}{A} = \frac{\left(1.7\times10^{-8}\ \Omega\cdot\text{m}\right)\left(0.040\ \text{m}\right)}{\pi\left(0.011\ \text{m}\right)^2} = 1.79\times10^{-6}\ \Omega\,,$$

so the potential difference is

$$\Delta V = IR = \left(50\ \text{A}\right)\left(1.79\times10^{-6}\ \Omega\right) = 8.9\times10^{-5}\ \text{V} = \boxed{89\ \mu\text{V}}$$

17.60 Each speaker has a resistance of $R = 4.00\ \Omega$ and can handle 60.0 W of power. From $\mathcal{P} = I^2R$, the maximum safe current is

$$I_{\text{max}} = \sqrt{\frac{\mathcal{P}}{R}} = \sqrt{\frac{60.0\ \text{W}}{4.00\,\Omega}} = 3.87\ \text{A}$$

Thus, the system $\boxed{\text{is not adequately protected}}$ by a 4.00 A fuse.