16.22 (a) $Q = C(\Delta V) = (4.00\times10^{-6}\text{ F})(12.0\text{ V}) = 48.0\times10^{-6}\text{ C} = \boxed{48.0\ \mu\text{C}}$

(b) $Q = C(\Delta V) = (4.00\times10^{-6}\text{ F})(1.50\text{ V}) = 6.00\times10^{-6}\text{ C} = \boxed{6.00\ \mu\text{C}}$

16.27 (a) $\Delta V = \dfrac{Q}{C} = \dfrac{Q}{\epsilon_0 A/d} = \dfrac{Qd}{\epsilon_0 A} = \dfrac{(400\times10^{-12}\text{ C})(1.00\times10^{-3}\text{ m})}{(8.85\times10^{-12}\text{ C}^2/\text{N}\cdot\text{m}^2)(5.00\times10^{-4}\text{ m}^2)} = \boxed{90.4\text{ V}}$

(b) $E = \dfrac{|\Delta V|}{d} = \dfrac{90.4\text{ V}}{1.00\times10^{-3}\text{ m}} = \boxed{9.04\times10^{4}\text{ V/m}}$

16.30 (a) For parallel connection,

$$C_{eq} = C_1 + C_2 + C_3 = (5.00 + 4.00 + 9.00)\ \mu\text{F} = \boxed{18.0\ \mu\text{F}}$$

(b) For series connection, $\dfrac{1}{C_{eq}} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$

$\dfrac{1}{C_{eq}} = \dfrac{1}{5.00\ \mu\text{F}} + \dfrac{1}{4.00\ \mu\text{F}} + \dfrac{1}{9.00\ \mu\text{F}}$, giving $C_{eq} = \boxed{1.78\ \mu\text{F}}$

16.34 (a) The combination reduces to an equivalent capacitance of $\boxed{12.0\ \mu\text{F}}$ in stages as shown below.

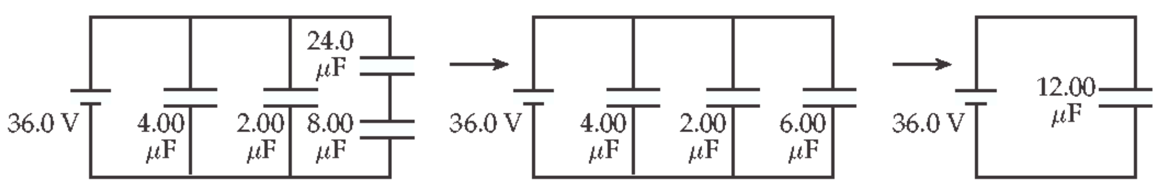


Figure 1 **Figure 2** **Figure 3**

(b) From Figure 2, $Q_4 = (4.00\ \mu\text{F})(36.0\text{ V}) = \boxed{144\ \mu\text{C}}$

$Q_2 = (2.00\ \mu\text{F})(36.0\text{ V}) = \boxed{72.0\ \mu\text{C}}$

and $Q_6 = (6.00\ \mu\text{F})(36.0\text{ V}) = 216\ \mu\text{C}$

Then, from Figure 1, $Q_{24} = Q_8 = Q_6 = \boxed{216\ \mu\text{C}}$

16.43 The capacitance is

$$C = \frac{\epsilon_0 A}{d} = \frac{\left(8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2\right)\left(2.00\times10^{-4}\ \text{m}^2\right)}{5.00\times10^{-3}\ \text{m}} = 3.54\times10^{-13}\ \text{F}$$

and the stored energy is

$$W = \frac{1}{2}C(\Delta V)^2 = \frac{1}{2}\left(3.54\times10^{-13}\ \text{F}\right)(12.0\ \text{V})^2 = \boxed{2.55\times10^{-11}\ \text{J}}$$

16.44 (a) When connected in parallel, the energy stored is

$$W = \frac{1}{2}C_1(\Delta V)^2 + \frac{1}{2}C_2(\Delta V)^2 = \frac{1}{2}(C_1 + C_2)(\Delta V)^2$$

$$= \frac{1}{2}\left[(25.0 + 5.00)\times10^{-6}\ \text{F}\right](100\ \text{V})^2 = \boxed{0.150\ \text{J}}$$

(b) When connected in series, the equivalent capacitance is

$$C_{eq} = \left(\frac{1}{25.0} + \frac{1}{5.00}\right)^{-1}\ \mu\text{F} = 4.17\ \mu\text{F}$$

From $W = \frac{1}{2}C_{eq}(\Delta V)^2$, the potential difference required to store the same energy as in part (a) above is

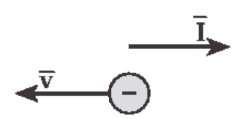
$$\Delta V = \sqrt{\frac{2W}{C_{eq}}} = \sqrt{\frac{2(0.150\ \text{J})}{4.17\times10^{-6}\ \text{F}}} = \boxed{268\ \text{V}}$$

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

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

$$= \frac{\left(80.0\times10^{-3}\ \text{C/s}\right)\left[(10.0\ \text{min})(60.0\ \text{s/min})\right]}{1.60\times10^{-19}\ \text{C}} = \boxed{3.00\times10^{20}\ \text{electrons}}$$

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



17.7 The drift speed of electrons in the line is $v_d = \dfrac{I}{nqA} = \dfrac{I}{n|e|\left(\pi d^2/4\right)}$, or

$$v_d = \frac{4(1\,000\text{ A})}{\left(8.5\times10^{28}/\text{m}^3\right)\left(1.60\times10^{-19}\text{ C}\right)\pi(0.020\text{ m})^2} = 2.3\times10^{-4}\text{ m/s}$$

The time to travel the length of the 200-km line is then

$$\Delta t = \frac{L}{v_d} = \frac{200\times10^3\text{ m}}{2.34\times10^{-4}\text{ m/s}}\left(\frac{1\text{ yr}}{3.156\times10^7\text{ s}}\right) = \boxed{27\text{ yr}}$$

17.14 $R = \dfrac{\rho L}{A} = \dfrac{\rho L}{\pi d^2/4} = \dfrac{4\left(1.7\times10^{-8}\ \Omega\cdot\text{m}\right)(15\text{ m})}{\pi\left(1.024\times10^{-3}\text{ m}\right)^2} = \boxed{0.31\ \Omega}$

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

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

The new resistance is then

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

17.23 At 80°C,

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

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

17.32 (a) The energy used by a 100-W bulb in 24 h is

$$E = \mathcal{P}\cdot\Delta t = (100\text{ W})(24\text{ h}) = (0.100\text{ kW})(24\text{ h}) = 2.4\text{ kWh}$$

and the cost of this energy, at a rate of \$0.12 per kilowatt-hour is

$$cost = E\cdot rate = (2.4\text{ kWh})(\$0.12/\text{kWh}) = \boxed{\$0.29}$$

(b) The energy used by the oven in 5.0 h is

$$E = \mathcal{P} \cdot \Delta t = \left[I(\Delta V) \right] \cdot \Delta t = \left[(20.0 \text{ C/s})(220 \text{ J/C}) \left(\frac{1 \text{ kW}}{10^3 \text{ J/s}} \right) \right] (5.0 \text{ h}) = 22 \text{ kWh}$$

and the cost of this energy, at a rate of \$0.12 per kilowatt-hour is

$$cost = E \cdot rate = (22 \text{ kWh})(\$0.12/\text{kWh}) = \boxed{\$2.6}$$

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

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

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

17.38 (a) At the operating temperature,

$$\mathcal{P} = (\Delta V) I = (120 \text{ V})(1.53 \text{ A}) = \boxed{184 \text{ W}}$$

(b) From $R = R_0 \left[1 + \alpha (T - T_0) \right]$, the temperature T is given by $T = T_0 + \dfrac{R - R_0}{\alpha R_0}$. The resistances are given by Ohm's law as

$$R = \frac{(\Delta V)}{I} = \frac{120 \text{ V}}{1.53 \text{ A}}, \text{ and } R_0 = \frac{(\Delta V)_0}{I_0} = \frac{120 \text{ V}}{1.80 \text{ A}}$$

Therefore, the operating temperature is

$$T = 20.0°\text{C} + \frac{(120/1.53) - (120/1.80)}{\left(0.400 \times 10^{-3} \ (°\text{C})^{-1}\right)(120/1.80)} = \boxed{461°\text{C}}$$

17.44 The energy used was $E = \dfrac{cost}{rate} = \dfrac{\$200}{\$0.080/\text{kWh}} = 2.50 \times 10^3 \text{ kWh}$

The total time the furnace operated was $t = \dfrac{E}{\mathcal{P}} = \dfrac{2.50 \times 10^3 \text{ kWh}}{24.0 \text{ kW}} = 104 \text{ h}$, and since January has 31 days, the average time per day was

$$average\ daily\ operation = \frac{104 \text{ h}}{31.0 \text{ d}} = \boxed{3.36 \text{ h/d}}$$

17.55 (a) From $\mathcal{P} = (\Delta V)I$, the current is $I = \frac{\mathcal{P}}{\Delta V} = \frac{8.00 \times 10^3 \text{ W}}{12.0 \text{ V}} = \boxed{667 \text{ A}}$

(b) The time before the stored energy is depleted is

$$t = \frac{E_{storage}}{\mathcal{P}} = \frac{2.00 \times 10^7 \text{ J}}{8.00 \times 10^3 \text{ J/s}} = 2.50 \times 10^3 \text{ s}$$

Thus, the distance traveled is

$$d = v \cdot t = (20.0 \text{ m/s})(2.50 \times 10^3 \text{ s}) = 5.00 \times 10^4 \text{ m} = \boxed{50.0 \text{ km}}$$