Q27.3 Geometry and resistivity. In turn, the resistivity of the material depends on the temperature.

Q27.4 Resistance is a physical property of the conductor based on the material of which it is made and its size and shape, including the locations where current is put in and taken out. Resistivity is a physical property only of the material of which the resistor is made.

Q27.7 A conductor is not in electrostatic equilibrium when it is carrying a current, duh! If charges are placed on an isolated conductor, the electric fields established in the conductor by the charges will cause the charges to move until they are in positions such that there is zero electric field throughout the conductor. A conductor carrying a steady current is not an isolated conductor—its ends must be connected to a source of emf, such as a battery. The battery maintains a potential difference across the conductor and, therefore, an electric field in the conductor. The steady current is due to the response of the electrons in the conductor due to this constant electric field.

corresponds to difference in height between the ends of a pipe or the ports of a water pump.

Q27.11 The amplitude of atomic vibrations increases with temperature. Atoms can then scatter electrons more efficiently.

Q27.14 A current will continue to exist in a superconductor without voltage because there is no resistance loss.

Q27.20 The 25 W bulb has a higher resistance. The 100 W bulb carries more current.

Q27.21 One ampere–hour is 3 600 coulombs. The ampere–hour rating is the quantity of charge that the

P27.1 $I = \dfrac{\Delta Q}{\Delta t}$ $\Delta Q = I\Delta t = \left(30.0\times10^{-6}\text{ A}\right)(40.0\text{ s}) = 1.20\times10^{-3}\text{ C}$

$$N = \frac{Q}{e} = \frac{1.20\times10^{-3}\text{ C}}{1.60\times10^{-19}\text{ C/electron}} = \boxed{7.50\times10^{15}\text{ electrons}}$$

P27.7 $I = \dfrac{dq}{dt}$

$$q = \int dq = \int I dt = \int_0^{1/240\text{ s}} (100\text{ A}) \sin\left(\frac{120\pi t}{\text{s}}\right) dt$$

$$q = \frac{-100\text{ C}}{120\pi}\left[\cos\left(\frac{\pi}{2}\right) - \cos 0\right] = \frac{+100\text{ C}}{120\pi} = \boxed{0.265\text{ C}}$$

P27.8 (a) $$J = \frac{I}{A} = \frac{5.00\text{ A}}{\pi\left(4.00\times10^{-3}\text{ m}\right)^2} = \boxed{99.5\text{ kA/m}^2}$$

(b) $$J_2 = \frac{1}{4}J_1\,;\ \frac{I}{A_2} = \frac{1}{4}\frac{I}{A_1}$$

$$A_1 = \frac{1}{4}A_2 \text{ so } \pi\left(4.00\times10^{-3}\right)^2 = \frac{1}{4}\pi r_2^2$$

$$r_2 = 2\left(4.00\times10^{-3}\right) = 8.00\times10^{-3}\text{ m} = \boxed{8.00\text{ mm}}$$

*P27.12 $J = \sigma E = \frac{E}{\rho} = \frac{0.740 \text{ V/m}}{2.44 \times 10^{-8} \ \Omega \cdot \text{m}} \left(\frac{1 \ \Omega \cdot \text{A}}{1 \text{ V}} \right) = \boxed{3.03 \times 10^{7} \ \text{A/m}^2}$

*P27.18 The volume of the gram of gold is given by $\rho = \frac{m}{V}$

$$V = \frac{m}{\rho} = \frac{10^{-3}\ \text{kg}}{19.3 \times 10^{3}\ \text{kg/m}^{3}} = 5.18 \times 10^{-8}\ \text{m}^{3} = A\left(2.40 \times 10^{3}\ \text{m}\right)$$

$$A = 2.16 \times 10^{-11}\ \text{m}^{2}$$

$$R = \frac{\rho \ell}{A} = \frac{2.44 \times 10^{-8}\ \Omega \cdot \text{m}\left(2.4 \times 10^{3}\ \text{m}\right)}{2.16 \times 10^{-11}\ \text{m}^{2}} = \boxed{2.71 \times 10^{6}\ \Omega}$$

P27.20 The distance between opposite faces of the cube is $\ell = \left(\frac{90.0\text{ g}}{10.5\text{ g/cm}^3}\right)^{1/3} = 2.05\text{ cm}$.

(a) $$R = \frac{\rho\ell}{A} = \frac{\rho\ell}{\ell^2} = \frac{\rho}{\ell} = \frac{1.59\times10^{-8}\ \Omega\cdot\text{m}}{2.05\times10^{-2}\text{ m}} = 7.77\times10^{-7}\ \Omega = \boxed{777\text{ n}\Omega}$$

(b) $$I = \frac{\Delta V}{R} = \frac{1.00\times10^{-5}\text{ V}}{7.77\times10^{-7}\ \Omega} = 12.9\text{ A}$$

$$n = \frac{10.5\text{ g/cm}^3}{107.87\text{ g/mol}}\left(6.02\times10^{23}\text{ electrons/mol}\right)$$

$$n = \left(5.86\times10^{22}\text{ electrons/cm}^3\right)\left(\frac{1.00\times10^6\text{ cm}^3}{1.00\text{ m}^3}\right) = 5.86\times10^{28}/\text{m}^3$$

$$I = nqvA \text{ and } v = \frac{I}{nqA} = \frac{12.9\text{ C/s}}{\left(5.86\times10^{28}/\text{m}^3\right)\left(1.60\times10^{-19}\text{ C}\right)\left(0.020\,5\text{ m}\right)^2} = \boxed{3.28\ \mu\text{m/s}}$$

P27.29 $R = R_0[1 + \alpha(\Delta T)]$ gives $140\ \Omega = (19.0\ \Omega)\left[1 + \left(4.50 \times 10^{-3}/°\text{C}\right)\Delta T\right]$.

Solving, $\Delta T = 1.42 \times 10^3\ °\text{C} = T - 20.0°\text{C}$.

And, the final temperature is $\boxed{T = 1.44 \times 10^3\ °\text{C}}$.

P27.34 Assuming linear change of resistance with temperature, $R = R_0(1+\alpha\Delta T)$

$$R_{77\text{ K}} = (1.00\ \Omega)\left[1+\left(3.92\times10^{-3}\right)(-216°\text{C})\right] = \boxed{0.153\ \Omega}.$$

P27.36 $I = \frac{\mathcal{P}}{\Delta V} = \frac{600 \text{ W}}{120 \text{ V}} = \boxed{5.00 \text{ A}}$

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

P27.41 $$\frac{\mathcal{P}}{\mathcal{P}_0} = \frac{(\Delta V)^2/R}{(\Delta V_0)^2/R} = \left(\frac{\Delta V}{\Delta V_0}\right)^2 = \left(\frac{140}{120}\right)^2 = 1.361$$

$$\Delta\% = \left(\frac{\mathcal{P} - \mathcal{P}_0}{\mathcal{P}_0}\right)(100\%) = \left(\frac{\mathcal{P}}{\mathcal{P}_0} - 1\right)(100\%) = (1.361 - 1)100\% = \boxed{36.1\%}$$

P27.44 (a) $$\Delta U = q(\Delta V) = It(\Delta V) = (55.0\ \text{A}\cdot\text{h})(12.0\ \text{V})\left(\frac{1\ \text{C}}{1\ \text{A}\cdot\text{s}}\right)\left(\frac{1\ \text{J}}{1\ \text{V}\cdot\text{C}}\right)\left(\frac{1\ \text{W}\cdot\text{s}}{1\ \text{J}}\right) = 660\ \text{W}\cdot\text{h} = \boxed{0.660\ \text{kWh}}$$

(b) $$\text{Cost} = 0.660\ \text{kWh}\left(\frac{\$0.060\,0}{1\ \text{kWh}}\right) = \boxed{3.96¢}$$

P27.54 (a) $I = \frac{\Delta V}{R}$ so $\mathcal{P} = I\Delta V = \frac{(\Delta V)^2}{R}$

$$R = \frac{(\Delta V)^2}{\mathcal{P}} = \frac{(120\text{ V})^2}{25.0\text{ W}} = \boxed{576\ \Omega} \quad \text{and} \quad R = \frac{(\Delta V)^2}{\mathcal{P}} = \frac{(120\text{ V})^2}{100\text{ W}} = \boxed{144\ \Omega}$$

(b) $I = \frac{\mathcal{P}}{\Delta V} = \frac{25.0\text{ W}}{120\text{ V}} = 0.208\text{ A} = \frac{Q}{\Delta t} = \frac{1.00\text{ C}}{\Delta t}$

$$\Delta t = \frac{1.00\text{ C}}{0.208\text{ A}} = \boxed{4.80\text{ s}}$$

The bulb takes in charge at high potential and puts out the same amount of charge at low potential.

(c) $\mathcal{P} = 25.0\text{ W} = \frac{\Delta U}{\Delta t} = \frac{1.00\text{ J}}{\Delta t}$ $\quad \Delta t = \frac{1.00\text{ J}}{25.0\text{ W}} = \boxed{0.040\,0\text{ s}}$

The bulb takes in energy by electrical transmission and puts out the same amount of energy by heat and light.

(d) $\Delta U = \mathcal{P}\Delta t = (25.0\ \text{J/s})(86\,400\ \text{s/d})(30.0\text{ d}) = 64.8 \times 10^8\text{ J}$

The electric company sells $\boxed{\text{energy}}$.

$$\text{Cost} = 64.8 \times 10^6\text{ J}\left(\frac{\$0.070\,0}{\text{kWh}}\right)\left(\frac{\text{k}}{1\,000}\right)\left(\frac{\text{W}\cdot\text{s}}{\text{J}}\right)\left(\frac{\text{h}}{3\,600\text{ s}}\right) = \boxed{\$1.26}$$

$$\text{Cost per joule} = \frac{\$0.070\,0}{\text{kWh}}\left(\frac{\text{kWh}}{3.60 \times 10^6\text{ J}}\right) = \boxed{\$1.94 \times 10^{-8}/\text{J}}$$