31.46. Solve: **(a)** A current of 1.8 pA for the potassium ions means that a charge of 1.8 pC flows through the potassium ion channel per second. The number of potassium ions that pass through the ion channel per second is

$$\frac{1.8\times10^{-12}\ \text{C/s}}{1.6\times10^{-19}\ \text{C}}=1.125\times10^{7}\ \text{s}^{-1}$$

Since the channel opens only for 1.0 ms, the total number of potassium ions that pass through the channel is $(1.125\times10^{7}\ \text{s}^{-1})(1.0\times10^{-3}\ \text{s})=1.13\times10^{4}$ atoms.

(b) The current density in the ion channel is

$$J=\frac{I}{A}=\frac{1.8\ \text{pA}}{\pi(0.30\ \text{nm}/2)^2}=\frac{1.8\times10^{-12}\ \text{A}}{\pi(0.15\times10^{-9}\ \text{m})^2}=2.5\times10^{7}\ \text{A/m}^2$$

31.61. Model: Assume the battery is ideal.

Solve: **(a)** The electric field inside the wire is $E=\Delta V_{\text{wire}}/L$. Attaching the wire to the battery makes $\Delta V_{\text{wire}} = \Delta V_{\text{bat}}=1.5\ \text{V}$. Thus,

$$E=\frac{1.5\ \text{V}}{0.15\ \text{m}}=10\ \text{V/m}$$

(b) Using Table 31.2, the current density is

$$J=\sigma E=\frac{E}{\rho}=\frac{10\ \text{V/m}}{1.5\times10^{-6}\ \Omega\text{m}}=6.7\times10^{6}\ \text{A/m}^2$$

(c) The current in a wire is related to the potential difference by $I=\Delta V_{\text{wire}}/R$. Thus,

$$R=\frac{\Delta V_{\text{wire}}}{I}=\frac{1.5\ \text{V}}{2\ \text{A}}=0.75\ \Omega$$

The resistance is related to the wire's geometry by

$$R=\frac{\rho L}{A}=\frac{\rho L}{\pi r^2}\Rightarrow r=\sqrt{\frac{\rho L}{\pi R}}=\sqrt{\frac{(1.5\times10^{-6}\ \Omega\ \text{m})(0.15\ \text{m})}{\pi(0.75\ \Omega)}}=3.1\times10^{-4}\ \text{m}\ =\ 0.31\ \text{mm}$$

Thus, the wire's diameter is $d = 2r = 0.62$ mm.

31.67. Model: The copper wire is uniform.

Solve: Equation 31.22 relates the current in a wire to the potential difference across it:

$$I=\frac{A}{\rho L}\Delta V\Rightarrow\Delta V=\frac{\rho LI}{A}=\frac{(1.7\times10^{-8}\ \Omega\text{m})(20\ \text{m})(8.0\ \text{A})}{\pi(1.0\times10^{-3}\ \text{m})^2}=0.87\ \text{V}$$

The resistivity ρ of copper is taken from Table 31.2.

Assess: While voltage drops in household wires are small compared to the applied voltage, voltage drops in transmission wires between homes and power plants could be quite large. The power company transports energy in a way that minimizes the voltage drop, as we will learn in Chapter 36.