3. When a flashlight is operated, what is being used up: battery current, battery voltage, battery energy, battery power, or battery resistance? Explain.

3. When a flashlight is operated, the battery energy is being used up.

4. One terminal of a car battery is said to be connected to "ground." Since it is not really connected to the ground, what is meant by this expression?

4. The terminal of the car battery connected to "ground" is actually connected to the metal frame of the car. This provides a large "sink" or "source" for charge. The metal frame serves as the common ground for all electrical devices in the car, and all voltages are measured with respect to the car's frame.

8. What happens when a lightbulb burns out?

8. When a lightbulb burns out, the filament breaks, creating a gap in the circuit so that no current flows.

12. Which draws more current, a 100-W lightbulb or a 75-W bulb? Which has the higher resistance?

12. When connected to the same potential difference, the 100-W bulb will draw more current ($P = IV$). The 75-W bulb has the higher resistance ($V = IR$ or $P = V^2/R$).

8. (II) A bird stands on a dc electric transmission line carrying 3100 A (Fig. 25–34). The line has $2.5 \times 10^{-5}\ \Omega$ resistance per meter, and the bird's feet are 4.0 cm apart. What is the potential difference between the bird's feet?

FIGURE 25–34 Problem 8.

8. Find the potential difference from the resistance and the current.

$$R = \left(2.5\times10^{-5}\ \Omega/\text{m}\right)\left(4.0\times10^{-2}\ \text{m}\right) = 1.0\times10^{-6}\ \Omega$$

$$V = IR = \left(3100\ \text{A}\right)\left(1.0\times10^{-6}\ \Omega\right) = \boxed{3.1\times10^{-3}\ \text{V}}$$

3. (I) What is the current in amperes if 1200 Na^+ ions flow across a cell membrane in 3.5 μs? The charge on the sodium is the same as on an electron, but positive.

3. Use the definition of current, Eq. 25-1a.

$$I = \frac{\Delta Q}{\Delta t} = \frac{(1200\ \text{ions})(1.60\times10^{-19}\ \text{C/ion})}{3.5\times10^{-6}\,\text{s}} = \boxed{5.5\times10^{-11}\,\text{A}}$$

10. (II) An electric device draws 6.50 A at 240 V. (*a*) If the voltage drops by 15%, what will be the current, assuming nothing else changes? (*b*) If the resistance of the device were reduced by 15%, what current would be drawn at 240 V?

10. (*a*) If the voltage drops by 15%, and the resistance stays the same, then by Eq. 25-2b, $V = IR$, the current will also drop by 15%.

$$I_{\text{final}} = 0.85 I_{\text{initial}} = 0.85(6.50\,\text{A}) = 5.525\,\text{A} \approx \boxed{5.5\,\text{A}}$$

(*b*) If the resistance drops by 15% (the same as being multiplied by 0.85), and the voltage stays the same, then by Eq. 25-2b, the current must be divided by 0.85.

$$I_{\text{final}} = \frac{I_{\text{initial}}}{0.85} = \frac{6.50\,\text{A}}{0.85} = 7.647\,\text{A} \approx \boxed{7.6\,\text{A}}$$

34. (I) (*a*) Determine the resistance of, and current through, a 75-W lightbulb connected to its proper source voltage of 110 V. (*b*) Repeat for a 440-W bulb.

34. Use Eq. 25-7b to find the resistance, and Eq. 25-6 to find the current.

(*a*) $$P = \frac{V^2}{R} \rightarrow R = \frac{V^2}{P} = \frac{(110\,\text{V})^2}{75\,\text{W}} = 161.3\,\Omega \approx \boxed{160\,\Omega}$$

$$P = IV \rightarrow I = \frac{P}{V} = \frac{75\,\text{W}}{110\,\text{V}} = 0.6818\,\text{A} \approx \boxed{0.68\,\text{A}}$$

(*b*) $$P = \frac{V^2}{R} \rightarrow R = \frac{V^2}{P} = \frac{(110\,\text{V})^2}{440\,\text{W}} = 27.5\,\Omega \approx \boxed{28\,\Omega}$$

$$P = IV \rightarrow I = \frac{P}{V} = \frac{440\,\text{W}}{110\,\text{V}} = \boxed{4.0\,\text{A}}$$

44. (II) An extension cord made of two wires of diameter 0.129 cm (no. 16 copper wire) and of length 2.7 m (9 ft) is connected to an electric heater which draws 15.0 A on a 120-V line. How much power is dissipated in the cord?

44. Find the power dissipated in the cord by Eq. 25-7a, using Eq. 25-3 for the resistance.

$$P = I^2R = I^2\rho\frac{\ell}{A} = I^2\rho\frac{\ell}{\pi d^2/4} = I^2\rho\frac{4\ell}{\pi d^2} = (15.0\,\text{A})^2\left(1.68\times10^{-8}\,\Omega\text{•m}\right)\frac{4(5.4\,\text{m})}{\pi\left(0.129\times10^{-2}\,\text{m}\right)^2}$$

$$= 15.62\,\text{W} \approx \boxed{16\,\text{W}}$$

38. (II) You buy a 75-W lightbulb in Europe, where electricity is delivered to homes at 240 V. If you use the lightbulb in the United States at 120 V (assume its resistance does not change), how bright will it be relative to 75-W 120-V bulbs? [*Hint*: Assume roughly that brightness is proportional to power consumed.]

38. The power (and thus the brightness) of the bulb is proportional to the square of the voltage, according to Eq. 25-7b, $P = \frac{V^2}{R}$. Since the resistance is assumed to be constant, if the voltage is cut in half from 240 V to 120V, the power will be reduced by a factor of 4. Thus the bulb will appear only about $\boxed{\text{1/4 as bright}}$ in the United States as in Europe.

* **60.** (I) What is the magnitude of the electric field across an axon membrane 1.0×10^{-8} m thick if the resting potential is −70 mV?

60. The magnitude of the electric field is the voltage change per unit meter.

$$|E| = \frac{\Delta V}{\Delta x} = \frac{70\times10^{-3}\,\text{V}}{1.0\times10^{-8}\,\text{m}} = \boxed{7.0\times10^{6}\,\text{V/m}}$$

59. (II) At a point high in the Earth's atmosphere, He^{2+} ions in a concentration of $2.8 \times 10^{12}/m^3$ are moving due north at a speed of 2.0×10^6 m/s. Also, a $7.0 \times 10^{11}/m^3$ concentration of O_2^- ions is moving due south at a speed of 6.2×10^6 m/s. Determine the magnitude and direction of the current density $\vec{\mathbf{j}}$ at this point.

59. We are given a charge density and a speed (like the drift speed) for both types of ions. From that we can use Eq. 25-13 (without the negative sign) to determine the current per unit area. Both currents are in the same direction in terms of conventional current – positive charge moving north has the same effect as negative charge moving south – and so they can be added.

$$I = neAv_d \quad \rightarrow$$

$$\frac{I}{A} = (nev_d)_{He} + (nev_d)_O = \left[(2.8\times10^{12}\ \text{ions/m}^3)2(1.60\times10^{-19}\ \text{C/ion})(2.0\times10^6\ \text{m/s})\right] + \left[(7.0\times10^{11}\ \text{ions/m}^3)(1.60\times10^{-19}\ \text{C/ion})(6.2\times10^6\ \text{m/s})\right]$$

$$= 2.486\ \text{A/m}^2 \approx \boxed{2.5\ \text{A/m}^2\text{, North}}$$

73. Determine the resistance of the tungsten filament in a 75-W 120-V incandescent lightbulb (*a*) at its operating temperature of about 3000 K, (*b*) at room temperature.

73. (*a*) The resistance at the operating temperature can be calculated directly from Eq. 25-7.

$$P = \frac{V^2}{R} \quad \rightarrow \quad R = \frac{V^2}{P} = \frac{(120\ \text{V})^2}{75\ \text{W}} = \boxed{190\,\Omega}$$

(*b*) The resistance at room temperature is found by converting Eq. 25-5 into an equation for resistances and solving for R_0.

$$R = R_0\left[1 + \alpha(T - T_0)\right]$$

$$R_0 = \frac{R}{\left[1 + \alpha(T - T_0)\right]} = \frac{192\,\Omega}{\left[1 + (0.0045\ \text{K}^{-1})(3000\ \text{K} - 293\ \text{K})\right]} = \boxed{15\,\Omega}$$

80. A proposed electric vehicle makes use of storage batteries as its source of energy. Its mass is 1560 kg and it is powered by 24 batteries, each 12 V, 95 A·h. Assume that the car is driven on level roads at an average speed of 45 km/h, and the average friction force is 240 N. Assume 100% efficiency and neglect energy used for acceleration. No energy is consumed when the vehicle is stopped, since the engine doesn't need to idle. (*a*) Determine the horsepower required. (*b*) After approximately how many kilometers must the batteries be recharged?

86. Lightbulb A is rated at 120 V and 40 W for household applications. Lightbulb B is rated at 12 V and 40 W for automotive applications. (*a*) What is the current through each bulb? (*b*) What is the resistance of each bulb? (*c*) In one hour, how much charge passes through each bulb? (*d*) In one hour, how much energy does each bulb use? (*e*) Which bulb requires larger diameter wires to connect its power source and the bulb?

80. (*a*) The horsepower required is the power dissipated by the frictional force, since we are neglecting the energy used for acceleration.

$$P = Fv = (240\,\text{N})(45\,\text{km/hr})\left(\frac{1\,\text{m/s}}{3.6\,\text{km/hr}}\right) = 3000\,\text{W}\left(\frac{1\,\text{hp}}{746\,\text{W}}\right) = \boxed{4.0\,\text{hp}}$$

(*b*) The charge available by each battery is $Q = 95\text{A}\bullet\text{h} = 95\,\text{C/s}\bullet 3600\,\text{s} = 3.42\times10^5\,\text{C}$, and so the total charge available is 24 times that. The potential energy of that charge is the charge times the voltage. That energy must be delivered (batteries discharged) in a certain amount of time to produce the 3000 W necessary. The speed of the car times the discharge time is the range of the car between recharges.

$$P = \frac{U}{t} = \frac{QV}{t} \quad \rightarrow \quad t = \frac{QV}{P} = \frac{d}{v} \quad \rightarrow$$

$$d = vt = v\frac{QV}{P} = v\frac{QV}{Fv} = \frac{QV}{F} = \frac{24(3.42\times10^5\,\text{C})(12\,\text{V})}{240\,\text{N}} = \boxed{410\,\text{km}}$$

86. (*a*) The current can be found from Eq. 25-6.

$$I = P/V \qquad I_A = P_A/V_A = 40\text{W}/120\,\text{V} = \boxed{0.33\,\text{A}} \qquad I_B = P_B/V_B = 40\text{W}/12\,\text{V} = \boxed{3.3\,\text{A}}$$

(*b*) The resistance can be found from Eq. 25-7b.

$$R = \frac{V^2}{P} \qquad R_A = \frac{V_A^2}{P_A} = \frac{(120\,\text{V})^2}{40\,\text{W}} = \boxed{360\,\Omega} \qquad R_B = \frac{V_B^2}{P_B} = \frac{(12\,\text{V})^2}{40\,\text{W}} = \boxed{3.6\,\Omega}$$

(*c*) The charge is the current times the time.

$$Q = It \qquad Q_A = I_A t = (0.33\,\text{A})(3600\,\text{s}) = \boxed{1200\,\text{C}}$$

$$Q_B = I_B t = (3.3\,\text{A})(3600\,\text{s}) = \boxed{12{,}000\,\text{C}}$$

(*d*) The energy is the power times the time, and the power is the same for both bulbs.

$$E = Pt \qquad E_A = E_B = (40\,\text{W})(3600\,\text{s}) = \boxed{1.4\times10^5\,\text{J}}$$

(*e*) $\boxed{\text{Bulb B}}$ requires a larger current, and so should have larger diameter connecting wires to avoid overheating the connecting wires.