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CURRENT, RESISTANCE, AND ELECTROMOTIVE FORCE

25.1. **IDENTIFY:** $I = Q/t$.

SET UP: $1.0 \text{ h} = 3600 \text{ s}$

EXECUTE: $Q = It = (3.6 \text{ A})(3.0)(3600 \text{ s}) = 3.89 \times 10^4 \text{ C}$.

EVALUATE: Compared to typical charges of objects in electrostatics, this is a huge amount of charge.

25.4. **(a) IDENTIFY:** By definition, $J = I/A$ and radius is one-half the diameter.

SET UP: Solve for the current: $I = JA = J\pi(D/2)^2$

EXECUTE: $I = (1.50 \times 10^6 \text{ A/m}^2)(\pi)[(0.00102 \text{ m})/2]^2 = 1.23 \text{ A}$

EVALUATE: This is a realistic current.

(b) IDENTIFY: The current density is $J = nqv_d$

SET UP: Solve for the drift velocity: $v_d = J/nq$

EXECUTE: Since most laboratory wire is copper, we use the value of n for copper, giving

$v_d = (1.50 \times 10^6 \text{ A/m}^2)/[(8.5 \times 10^{28} \text{ el/m}^3)(1.60 \times 10^{-19} \text{ C}) = 1.1 \times 10^{-4} \text{ m/s} = 0.11 \text{ mm/s}$

EVALUATE: This is a typical drift velocity for ordinary currents and wires.

25.12. **IDENTIFY:** $E = \rho J$, where $J = I/A$. The drift velocity is given by $I = n|q|v_d A$.

SET UP: For copper, $\rho = 1.72 \times 10^{-8} \ \Omega \cdot \text{m}$. $n = 8.5 \times 10^{28}/\text{m}^3$.

EXECUTE: **(a)** $J = \dfrac{I}{A} = \dfrac{3.6 \text{ A}}{(2.3 \times 10^{-3} \text{ m})^2} = 6.81 \times 10^5 \text{ A/m}^2$.

(b) $E = \rho J = (1.72 \times 10^{-8} \ \Omega \cdot \text{m})(6.81 \times 10^5 \text{ A/m}^2) = 0.012 \text{ V/m}$.

25.16. **IDENTIFY:** Apply $R = \dfrac{\rho L}{A}$ and solve for L.

SET UP: $A = \pi D^2/4$, where $D = 0.462 \text{ mm}$.

EXECUTE: $L = \dfrac{RA}{\rho} = \dfrac{(1.00 \ \Omega)(\pi/4)(0.462 \times 10^{-3} \text{ m})^2}{1.72 \times 10^{-8} \ \Omega \cdot \text{m}} = 9.75 \text{ m}$.

EVALUATE: The resistance is proportional to the length of the wire.

25.24. **IDENTIFY:** Apply $R = \dfrac{\rho L}{A}$ and $V = IR$.

SET UP: $A = \pi r^2$

EXECUTE: $\rho = \dfrac{RA}{L} = \dfrac{VA}{IL} = \dfrac{(4.50 \text{ V})\pi(6.54 \times 10^{-4} \text{ m})^2}{(17.6 \text{ A})(2.50 \text{ m})} = 1.37 \times 10^{-7} \ \Omega \cdot \text{m}$.

EVALUATE: Our result for ρ shows that the wire is made of a metal with resistivity greater than that of good metallic conductors such as copper and aluminum.

25.31. **IDENTIFY:** Use $R = \dfrac{\rho L}{A}$ to calculate R and then apply $V = IR$. $P = VI$ and energy $= Pt$

SET UP: For copper, $\rho = 1.72 \times 10^{-8} \ \Omega \cdot \text{m}$. $A = \pi r^2$, where $r = 0.050 \text{ m}$.

EXECUTE: **(a)** $R = \dfrac{\rho L}{A} = \dfrac{(1.72 \times 10^{-8} \ \Omega \cdot \text{m})(100 \times 10^3 \text{ m})}{\pi(0.050 \text{ m})^2} = 0.219 \ \Omega$. $V = IR = (125 \text{ A})(0.219 \ \Omega) = 27.4 \text{ V}$.

(b) $P = VI = (27.4 \text{ V})(125 \text{ A}) = 3422 \text{ W} = 3422 \text{ J/s}$ and energy $= Pt = (3422 \text{ J/s})(3600 \text{ s}) = 1.23 \times 10^7 \text{ J}$.

EVALUATE: The rate of electrical energy loss in the cable is large, over 3 kW.

25.72. **IDENTIFY:** The cost of operating an appliance is proportional to the amount of energy consumed. The energy depends on the power the item consumes and the length of time for which it is operated.

SET UP: At a constant power, the energy is equal to *Pt*, and the total cost is the cost per kilowatt-hour (kWh) times the time the energy (in kWh).

EXECUTE: **(a)** Use the fact that 1.00 kWh = (1000 J/s)(3600 s) = 3.60×10^6 J, and one year contains 3.156×10^7 s.

$$75\text{ J/s}\left(\frac{3.156\times10^7\text{ s}}{1\text{ yr}}\right)\left(\frac{\$0.120}{3.60\times10^6\text{ J}}\right) = \$78.90$$

(b) At 8 h/day, the refrigerator runs for 1/3 of a year. Using the same procedure as above gives

$$400\text{ J/s}\left(\frac{1}{3}\right)\left(\frac{3.156\times10^7\text{ s}}{1\text{ yr}}\right)\left(\frac{\$0.120}{3.60\times10^6\text{ J}}\right) = \$140.27$$

EVALUATE: Electric lights can be a substantial part of the cost of electricity in the home if they are left on for a long time!