CHAPTER 18

1. The charge that passes through the battery is
   Æ$Q = I$ Æt = (5.7 A)(7.0 h)(3600 s/h) = 1.4×10^5 C.

2. The rate at which electrons pass any point in the wire is the current:
   I = 1.00 A = (1.00 C/s)/(1.60×10^{-19} C/electron) = 6.25×10^{18} electron/s.

3. We find the current from
   I = ÆQ/Æt = (1000 ions)(1.60×10^{-19} C/ion)/(6.5×10^{-6} s) = 2.5×10^{-11} A.

4. We find the voltage from
   $V = IR$ = (0.25 A)(3000 Ω) = 7.5×10^2 V.

5. We find the resistance from
   $V = IR$;
   110 V = (3.1 A)R, which gives R = 35 Ω.

6. For the device we have $V = IR$.
   (*a*) If we assume constant resistance and divide expressions for the two conditions, we get
   $V_2/V_1 = I_2/I_1$;
   0.90 = I_2/(5.50 A), which gives I_2 = 4.95 A.
   (*b*) With the voltage constant, if we divide expressions for the two conditions, we get
   $I_2/I_1 = R_1/R_2$;
   I_2/(5.50 A) = 1/0.90, which gives I_2 = 6.11 A.

7. The rate at which electrons leave the battery is the current:
   $I = V/R$ = [(9.0 V)/(1.6 Ω)](60 s/min)/(1.60×10^{-19} C/electron) = 2.1×10^{21} electron/min.

8. (*a*) We find the resistance from
   $V = IR$;
   120 V = (9.0 A)R, which gives R = 13 Ω.
   (*b*) The charge that passes through the hair dryer is
   Æ$Q = I$ Æt = (9.0 A)(15 min)(60 s/min) = 8.1×10^3 C.

9. We find the resistance from
   $V = IR$;
   12 V = (0.50 A)R, which gives R = 24 Ω.
   The energy taken out of the battery is
   E = $Pt = IVt$ = (0.50 A)(12 V)(1 min)(60 s/min) = 3.6×10^2 J.

10. We find the voltage across the bird's feet from
    $V = IR$ = (2500 A)(2.5×10^{-5} Ω/m)(4.0×10^{-2} m) = 2.5×10^{-3} V.

11. We find the resistance from

$R = \rho L/A = \rho L/\left({}^1 d^2\right.$

$= (1.68 \times 10^{-8}\ \Omega \cdot \text{m})(3.0\ \text{m})/\left(\pi(1.5 \times 10^{-3}\ \text{m})^2\right. =$ 0.029 Ω.

12. We find the radius from

$R = \rho L/A = \rho L/{}^1 r^2;$

$0.22\ \Omega = (5.6 \times 10^{-8}\ \Omega \cdot \text{m})(1.00\ \text{m})/{}^1 r^2$, which gives $r = 2.85 \times 10^{-4}$ m,

so the diameter is 5.7×10^{-4} m = 0.57 mm.

13. From the expression for the resistance, $R = \rho L/A$, we form the ratio

$R_{Al}/R_{Cu} = (\rho_{Al}/\rho_{Cu})(L_{Al}/L_{Cu})(A_{Cu}/A_{Al}) = (\rho_{Al}/\rho_{Cu})(L_{Al}/L_{Cu})(d_{Cu}/d_{Al})^2$

$= [(2.65 \times 10^{-8}\ \Omega \cdot \text{m})/(1.68 \times 10^{-8}\ \Omega \cdot \text{m})][(10.0\ \text{m})/(15.0\ \text{m})][(2.5\ \text{mm})/(2.0\ \text{mm})]^2$

$= 1.6$, or $R_{Al} = 1.6 R_{Cu}$.

14. Yes, if we select the appropriate diameter. From the expression for the resistance, $R = \rho L/A$, we form the ratio

$R_T/R_{Cu} = (\rho_T/\rho_{Cu})(L_T/L_{Cu})(A_{Cu}/A_T) = (\rho_T/\rho_{Cu})(d_{Cu}/d_T)^2;$

$1 = [(5.6 \times 10^{-8}\ \Omega \cdot \text{m})/(1.68 \times 10^{-8}\ \Omega \cdot \text{m})][(2.5\ \text{mm})/d_T]^2$, which gives $d_T =$ 4.6 mm.

15. Because the material and area of the two pieces are the same, from the expression for the resistance, $R = \rho L/A$, we see that the resistance is proportional to the length:

$R_1/R_2 = L_1/L_2 = 7.$

Because $L_1 + L_2 = L$, we have

$7L_2 + L_2 = L$, or $L_2 = L/8$, and $L_1 = 7L/8$, so the wire should be cut at 1/8 the length.

We find the resistance of each piece from

$R_1 = (L_1/L)R = (7/8)(10.0\ \Omega) =$ 8.75 Ω;

$R_2 = (L_2/L)R = (1/8)(10.0\ \Omega) =$ 1.25 Ω.

16. We find the temperature change from

$R = R_0(1 + \alpha\,\Delta T)$, or ÆR $= R_0 \alpha\,\Delta T;$

$0.20R_0 = R_0[0.0068\ (\text{C}°)^{-1}]$ ÆT, which gives ÆT = 29 C°.

17. For the wire we have $R = V/I$. We find the temperature from

$R = R_0(1 + \alpha\,\Delta T);$

$(V/I) = (V/I_0)(1 + \alpha\,\Delta T);$

$(10.00\ \text{V}/0.3618\ \text{A}) = (10.00\ \text{V}/0.4212\ \text{A})\{1 + [0.00429\ (\text{C}°)^{-1}](T - 20.0°\text{C})\}$, which gives $T =$ 58.3°C.

18. We find the temperature from

$\rho_{0,T} = \rho_{Cu} = \rho_{0,Cu}(1 + \alpha_{Cu}\,\Delta T);$

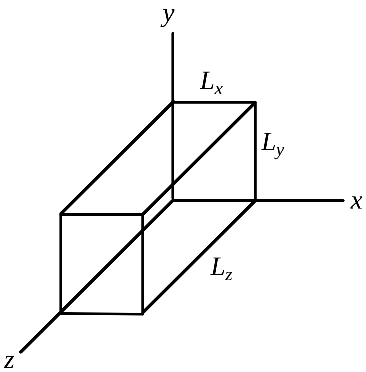
$5.6 \times 10^{-8}\ \Omega \cdot \text{m} = (1.68 \times 10^{-8}\ \Omega \cdot \text{m})\{1 + [0.0068\ (\text{C}°)^{-1}](T - 20.0°\text{C})\}$, which gives $T =$ 363°C.

19. We find the temperature from

$R = R_0(1 + \alpha_{\mathrm{Cu}}\,\Delta T)$;

$140\ \Omega = (12\ \Omega)\{1 + [0.0060\ (\mathrm{C}°)^{-1}](T - 20.0°\mathrm{C})\}$, which gives $T =$ $1.8 \times 10^3\ °\mathrm{C}$.

20. For each direction through the solid, the length and area will be constant, so we have $R = \rho L/A$.



(*a*) In the x-direction, we have

$R_x = \rho L_x/L_yL_z$
$= (3.0 \times 10^{-8}\ \Omega\cdot\text{m})(0.010\ \text{m})/(0.020\ \text{m})(0.040\ \text{m})$
$= \quad 3.8 \times 10^{-4}\ \Omega.$

(*b*) In the y-direction, we have

$R_y = \rho L_y/L_xL_z$
$= (3.0 \times 10^{-8}\ \Omega\cdot\text{m})(0.020\ \text{m})/(0.010\ \text{m})(0.040\ \text{m})$
$= \quad 1.5 \times 10^{-3}\ \Omega.$

(*c*) In the z-direction, we have

$R_z = \rho L_z/L_xL_y$
$= (3.0 \times 10^{-8}\ \Omega\cdot\text{m})(0.040\ \text{m})/(0.010\ \text{m})(0.020\ \text{m})$
$= \quad 6.0 \times 10^{-3}\ \Omega.$

21. (*a*) For the resistance of each wire we have

$R_{Cu} = \rho_{Cu}L_{Cu}/A = (1.68 \times 10^{-8}\ \Omega\cdot\text{m})(5.0\ \text{m})/{}^{1}(0.50 \times 10^{-3}\ \text{m})^2 = 0.107\ \Omega.$
$R_{Al} = \rho_{Al}L_{Al}/A = (2.65 \times 10^{-8}\ \Omega\cdot\text{m})(5.0\ \text{m})/{}^{1}(0.50 \times 10^{-3}\ \text{m})^2 = 0.169\ \Omega.$

Thus the total resistance is

$R = R_{Cu} + R_{Al} = 0.107\ \Omega + 0.169\ \Omega = \quad 0.28\ \Omega.$

(*b*) We find the current from

$V = IR;$
$80\ \text{V} = I(0.28\ \Omega)$, which gives $I = \quad 2.9 \times 10^2\ \text{A}.$

(*c*) The current must be the same for the two wires, so we have

$V_{Cu} = IR_{Cu} = (2.9 \times 10^2\ \text{A})(0.107\ \Omega) = \quad 31\ \text{V}.$
$V_{Al} = IR_{Al} = (2.9 \times 10^2\ \text{A})(0.169\ \Omega) = \quad 49\ \text{V}.$

22. We use the temperature coefficients at 20°C. For the total resistance we have

$R = R_C + R_N = R_{C0}(1 + \alpha_C\,\Delta T) + R_{N0}(1 + \alpha_N\,\Delta T) = R_{C0} + R_{N0} + R_{C0}\alpha_C\,\Delta T + R_{N0}\alpha_N\,\Delta T.$

If the total resistance does not change, we have

$R_C + R_N = R_{C0} + R_{N0}$, or
$R_{C0}\alpha_C\,\Delta T = -\,R_{N0}\alpha_N\,\Delta T;$
$R_{C0}[-\,0.0005\ (\text{C}°)^{-1}] = -\,R_{N0}[0.0004\ (\text{C}°)^{-1}]$, which gives $R_{C0} = 0.8R_{N0}$.

For the total resistance we have

$4.70\ \text{k}\Omega = R_{C0} + R_{N0} = 0.8R_{N0} + R_{N0}$, which gives $\quad R_{N0} = 2.61\ \text{k}\Omega$, and $\quad R_{C0} = 2.09\ \text{k}\Omega.$

23. For an ohmic resistor, we have

$P = IV = V^2/R$, or $R = V^2/P = (240\ \text{V})^2/(3.3 \times 10^3\ \text{W}) = \quad 17\ \Omega.$

24. We find the power from

$P = IV = (0.350\ \text{A})(9.0\ \text{V}) = \quad 3.2\ \text{W}.$

25. From $P = V^2/R$, we see that the maximum voltage will produce the maximum power, so we have

(W $= V_{max}^2/(2.7 \times 10^3\ \Omega)$), which gives $V_{max} = \quad 26\ \text{V}.$

26. (*a*) From $P = V^2/R$, we see that the lower power setting, 600 W, must have the higher resistance.

    (*b*) At the lower setting, we have

    $P_1 = V^2/R_1$;

    $600\text{ W} = (120\text{ V})^2/R_1$, which gives $R_1 =$ 24 Ω.

    (*c*) At the higher setting, we have

    $P_2 = V^2/R_2$;

    $1200\text{ W} = (120\text{ V})^2/R_2$, which gives $R_2 =$ 12 Ω.

27. (*a*) We find the resistance from

    $P_1 = V^2/R_1$;

    $60\text{ W} = (120\text{ V})^2/R_1$, which gives $R_1 =$ 240 Ω.

    The current is

    $I_1 = V/R_1 = (120\text{ V})/(240\ \Omega) =$ 0.50 A.

    (*b*) We find the resistance from

    $P_2 = V^2/R_2$;

    $440\text{ W} = (120\text{ V})^2/R_2$, which gives $R_2 =$ 32.7 Ω.

    The current is

    $I_2 = V/R_2 = (120\text{ V})/(32.7\ \Omega) =$ 3.67 A.

28. We find the operating resistance from

    $P = V^2/R$;

    $60\text{ W} = (240\text{ V})^2/R$, which gives $R = 9.6 \times 10^2\ \Omega$.

    If we assume that the resistance stays the same, for the lower voltage we have

    $P = V^2/R = (120\text{ V})^2/(9.6 \times 10^2\ \Omega) =$ 15 W.

    At one-quarter the power, the bulb will be much dimmer.

29. We find the energy used by the toaster from

    $E = Pt = (0.550\text{ kW})(10\text{ min})/(60\text{ min/h}) =$ 0.092 kWh.

    The cost for a month would be

    Cost = E(rate) = (0.092 kWh/day)(4 days/wk)(4 wk/month)(12¢/kWh) = 18¢/month.

30. The cost for a year would be

    Cost = E(rate) = Pt(rate)

    = $(40 \times 10^{-3}$ kW)(1 yr)(365 days/yr)(24 h/day)($0.110/kWh) = $38.50.

31. (*a*) We find the resistance from

    $V = IR$;

    $2(1.5\text{ V}) = (0.350\text{ A})/R$, which gives $R =$ 8.6 Ω.

    The power dissipated is

    $P = IV = (0.350\text{ A})(3.0\text{ V}) =$ 1.1 W.

    (*b*) We assume that the resistance does not change, so we have

    $P_2/P_1 = (V_2/V_1)^2 = (6.0\text{ V}/3.0\text{ V})^2 =$ 4×.

    The increased power would last for a short time, until the increased temperature of the filament would burn out the bulb.

32. 90 A ·h is the total charge that passed through the battery when it was charged.
We find the energy from
$E = Pt = VIt = VQ = (12\ \text{V})(90\ \text{A}\cdot\text{h})(10^{-3}\ \text{kW/W}) =$ 1.1 kWh $= 3.9 \times 10^{6}$ J.

33. (*a*) We find the maximum power output from
$P_{max} = I_{max}V = (0.025\ \text{A})(9.0\ \text{V}) =$ 0.23 W.
(*b*) The power output eventually becomes thermal energy. The circuit is designed to allow the dissipation of the maximum power, which we assume is the same. Thus we have
$P_{max} = I_{max}V = I_{max}'V'$;
$0.225\ \text{W} = I_{max}'(7.0\ \text{V})$, which gives $I_{max}' = 0.032\ \text{A} =$ 32 mA.

34. The total power will be the sum, so we have
$P_{total} = I_{total}V$;
$N(100\ \text{W}) = (2.5\ \text{A})(120\ \text{V})$, which gives $N =$ 3.

35. The power rating is the mechanical power output, so we have
efficiency $=$ output/input $= P_{mechanical}/P_{electrical}$
$= (0.50\ \text{hp})(746\ \text{W/hp})/(4.4\ \text{A})(120\ \text{V}) = 0.706 =$ 71%.

36. The required current to deliver the power is $I = P/V$, and the wasted power (thermal losses in the wires) is $P_{loss} = I^2R$. For the two conditions we have
$I_1 = (520\ \text{kW})/(12\ \text{kV}) = 43.3\ \text{A}$; $P_{loss1} = (43.3\ \text{A})^2(3.0\ \Omega)(10^{-3}\ \text{kW/W}) = 5.63\ \text{kW}$;
$I_2 = (520\ \text{kW})/(50\ \text{kV}) = 10.4\ \text{A}$; $P_{loss2} = (10.4\ \text{A})^2(3.0\ \Omega)(10^{-3}\ \text{kW/W}) = 0.324\ \text{kW}$.
Thus the decrease in power loss is
Æ$P_{loss} = P_{loss1} - P_{loss2} = 5.63\ \text{kW} - 0.324\ \text{kW} =$ 5.3 kW.

37. (*a*) We find the resistance from
$P = V^2/R$;
$2200\ \text{W} = (240\ \text{V})^2/R$, which gives $R =$ 26.2 Ω.
(*b*) If 80% of the electrical energy is used to heat the water to the boiling point, we have
$0.80E_{elec} = 0.80\ P_{elec}t = mc$ ÆT;
$(0.80)(2200\ \text{W})t = (100\ \text{mL})(1\ \text{g/mL})(10^{-3}\ \text{kg/g})(4186\ \text{J/kg}\cdot\text{C°})(100\text{°C} - 20\text{°C})$,
which gives $t =$ 19 s.
(*c*) We find the cost from
Cost $= E(\text{rate}) = P_{elec}t\ (\text{rate})$
$= [(2.20\ \text{kW})(19\ \text{s})/(3600\ \text{s/h})](10¢/\text{kWh}) =$ 0.12¢.

38. For the water to remove the thermal energy produced, we have
$P = IV = (m/t)c$ ÆT;
$(14.5\ \text{A})(240\ \text{V}) = (m/t)(4186\ \text{J/kg}\cdot\text{C°})(7.50\ \text{C°})$, which gives $m/t =$ 0.111 kg/s.

39. If 60% of the electrical energy is used to heat the water, we have
$0.60E_{elec} = 0.60\ IVt = mc$ ÆT;
$(0.60)I(12\ \text{V})(5.0\ \text{min})(60\ \text{s/min}) = (150\ \text{mL})(1\ \text{g/mL})(10^{-3}\ \text{kg/g})(4186\ \text{J/kg}\cdot\text{C°})(95\text{°C} - 5\text{°C})$,
which gives $I =$ 26 A.

The resistance of the heating coil is

$R = V/I = (12\text{ V})/(26\text{ A}) = 0.46\ \Omega.$

40. We find the peak current from the peak voltage:
    $V_0 = \text{Ã}2\ V_{\text{rms}} = I_0R$;
    $\text{Ã}2(120\ \text{V}) = I_0(2.2 \times 10^3\ \Omega)$, which gives $I_0 =$ $0.077\ \text{A}$.

41. We find the peak current from the peak voltage:
    $V_0 = I_0R$;
    $180\ \text{V} = I_0(330\ \Omega)$, which gives $I_0 =$ $0.545\ \text{A}$.
    The rms current is
    $I_{\text{rms}} = I_0/\text{Ã}2 = (0.545\ \text{A})/\text{Ã}2 =$ $0.386\ \text{A}$.

42. (*a*) Because the total resistance is
    $R_{\text{total}} = V/I$, when $I = 0$, the resistance is infinite.
    (*b*) With one lightbulb on, we have
    $P = I_{\text{rms}}V_{\text{rms}} = V_{\text{rms}}^2/R$;
    $75\ \text{W} = (120\ \text{V})^2/R$, which gives $R =$ $1.9 \times 10^2\ \Omega$.

43. We find the rms voltage from
    $P = I_{\text{rms}}V_{\text{rms}}$;
    $1500\ \text{W} = [(4.0\ \text{A})/\text{Ã}2]V_{\text{rms}}$, which gives $V_{\text{rms}} =$ $5.3 \times 10^2\ \text{V}$.

44. The peak voltage is
    $V_0 = \text{Ã}2\ V_{\text{rms}} = \text{Ã}2(450\ \text{V}) =$ $636\ \text{V}$.
    We find the peak current from
    $P = I_{\text{rms}}V_{\text{rms}} = (I_0/\text{Ã}2)V_{\text{rms}}$;
    $1800\ \text{W} = (I_0/\text{Ã}2)(450\ \text{V})$, which gives $I_0 =$ $5.66\ \text{A}$.

45. The maximum instantaneous power is
    $P_0 = I_0V_0 = (\text{Ã}2\ I_{\text{rms}})(\text{Ã}2\ V_{\text{rms}}) = 2P = 2(3.0\ \text{hp}) =$ $6.0\ \text{hp}$ $(4.5\ \text{kW})$.
    For the maximum current, we have
    $P = I_{\text{rms}}V_{\text{rms}} = (I_0/\text{Ã}2)V_{\text{rms}}$;
    $(3.0\ \text{hp})(746\ \text{W/hp}) = (I_0/\text{Ã}2)(240\ \text{V})$, which gives $I_0 =$ $13\ \text{A}$.

46. For the average power, we have
    $P = I_{\text{rms}}V_{\text{rms}} = V_{\text{rms}}^2/R = (240\ \text{V})2/(34\ \text{W}) = 1.7 \times 10^3\ \text{W} =$ $1.7\ \text{kW}$.
    The maximum power is
    $P_0 = I_0V_0 = (\text{Ã}2\ I_{\text{rms}})(\text{Ã}2\ V_{\text{rms}}) = 2P = 2(1.7\ \text{kW}) =$ $3.4\ \text{kW}$.
    Because the power is always positive, the minimum power is zero.

47. From Example 18–14 we know that the density of free electrons in copper is
    $n = 8.4 \times 10^{28}\ \text{m}^{-3}$.
    We find the drift speed from
    $I = neAv_{\text{d}} = ne((^1D^2)v_{\text{d}}$;
    $2.5 \times 10^{-6}\ \text{A} = (8.4 \times 10^{28}\ \text{m}^{-3})(1.60 \times 10^{-19}\ \text{C})[(^1(0.55 \times 10^{-3}\ \text{m})^2]v_{\text{d}}$,
    which gives $v_{\text{d}} =$ $7.8 \times 10^{-10}\ \text{m/s}$.

48. (*a*) We find the resistance from

$R = V/I = (22.0\text{ mV})/(750\text{ mA}) =$ $0.0293\ \Omega$.

(*b*) We find the resistivity from

$R = \rho L/A$;

$0.0293\ \Omega = \rho(5.00\text{ m})/$¹$(1.0\text{x}10^3\text{ m})^2$, which gives $\rho =$ $1.8 \times 10^{-8}\ \Omega\cdot\text{m}$.

(*c*) We find the density of free electrons from the drift speed:

$I = neAv_{\text{d}} = ne($¹$r^2)v_{\text{d}}$;

$750\text{ mA} = n(1.60 \times 10^{-19}\text{ C})$¹$(1.0 \times 10^{-3}\text{ m})^2](1.7 \times 10^{-5}\text{ m/s})$, which gives $n =$ $8.8 \times 10^{28}\text{ m}^{-3}$.

49. For the total current we have

$I = n_+(+e)Av_{\text{d}+} + n_-(-2e)Av_{\text{d}-} = 0$;

$(5.00\text{ mol/m}^3)(5.00 \times 10^{-4}\text{ m/s}) - 2n_-(-2.00 \times 10^{-4}\text{ m/s}) = 0$, which gives $n_- =$ 6.25 mol/m^3.

50. For the net current density we have

$I/A = n_+(+2e)v_{\text{d}+} + n_-(-e)v_{\text{d}-}$

$= (2.8 \times 10^{12}\text{ m}^{-3})(2)(1.60 \times 10^{-19}\text{ C})(2.0 \times 10^6\text{ m/s}) +$

$(8.0 \times 10^{11}\text{ m}^{-3})(-1.60 \times 10^{-19}\text{ C})(-7.2 \times 10^6\text{ m/s}) =$ 2.7 A/m^2 north.

51. We find the magnitude of the electric field from

$E = V/d = (70 \times 10^{-3}\text{ V})/(1.0 \times 10^{-8}\text{ m}) =$ $7.0 \times 10^6\text{ V/m}$.

Note that the direction of the field will be into the cell.

52. We find the speed of the pulse from

$v =$ Æ$x/$Æ$t = (7.20\text{ cm} - 3.40\text{ cm})/(100\text{ cm/m})(0.0063\text{ s} - 0.0052\text{ s}) =$ 35 m/s.

Two measurements are necessary to eliminate uncertainty over the exact location of the stimulation and the effects of the initial creation of the stimulation, including any initial delay in producing the change in concentrations.

53. From the data of Example 18–15, we can find the required energy from the energy stored in the capacitor during a pulse:

$U =$!$CV^2 =$!$(10^{-8}\text{ F})(0.10\text{ V})^2 =$ $5 \times 10^{-11}\text{ J}$.

If the time between pulses is

$t = 1/(100\text{ pulses/s}) = 0.010\text{ s}$,

for N neurons the average power is

$P_{\text{av}} = NU/t = (10^4)(5 \times 10^{-11}\text{ J})/(0.010\text{ s}) =$ $5 \times 10^{-5}\text{ W}$.

54. Because each ion carries the electron charge, the effective current of the Na^+ ions through the surface of the axon is

$I = jN_{\text{A}}e($¹$dL)$

$= (3 \times 10^{-7}\text{ mol/m}^2\cdot\text{s})(6.02 \times 10^{23}\text{ ion/mol})(1.60 \times 10^{-19}\text{ C/ion})$¹$(20 \times 10^{-6}\text{ m})(0.10\text{ m})$

$= 1.8 \times 10^{-7}\text{ A}$.

The power required to move these charges through the potential difference is

$P = IV = (1.8 \times 10^{-7}\text{ A})(30 \times 10^{-3}\text{ V}) =$ $5.4 \times 10^{-9}\text{ W}$.

55. The charge is

Æ*Q* = *I* Æ*t* = (1.00 A ·h)(3600 s/h) = 3.60×10^{3} C.

56. We find the current from
$P = IV$;
(1.0 hp)(746 W/hp) = I(120 V), which gives I = 6.2 A.

57. We find the current when the lights are on from
$P = IV$;
(92 W) = I(12 V), which gives I = 7.67 A.
90 A ·h is the total charge that passes through the battery when it is completely discharged. Thus the time for complete discharge is
$t = Q/I$ = (90 A ·h)/(7.67 A) = 12 h.

58. We find the resistance of the heating element from
$P = IV = V^2/R$;
1500 W = (110 V)$^2/R$, which gives R = 8.07 Ω.
We find the diameter from
$R = \rho L/A = \rho L/($¹$D^2 = 4\rho L/$¹D^2;
8.07 Ω = 4(9.71 × 10^{-8} Ω ·m)(5.4 m)/¹D^2, which gives $D = 2.9 \times 10^{-4}$ m = 0.29 mm.

59. We find the conductance from
$G = 1/R = I/V$ = (0.700 A)/(3.0 V) = 0.23 S.

60. (*a*) The daily energy use is
E = (1.8 kW)(3.0 h/day) + 4(0.10 kW)(6.0 h/day) + (3.0 kW)(1.4 h/day) + 2.0 kWh/day
= 14 kWh/day.
The cost for a month is
Cost = E(rate) = (4 kWh/day)(30 days/month)($0.105/kWh) = $44.
(*b*) For a 35-percent efficient power plant, we find the amount of coal from
0.35m(7000 kcal/kg)(4186 J/kcal) = (14 kWh/day)(365 days/yr)(10^3 W/kW)(3600 s/yr),
which gives m = 1.8×10^3 kg.

61. The dependence of the resistance on the dimensions is $R = \rho L/A$. When we form the ratio for the two wires, we get
$R_2/R_1 = (L_2/L_1)(A_1/A_2)$ = (!)(!) = (, so R_2 = (R_1.

62. (*a*) The dependence of the power output on the voltage is $P = V^2/R$. When we form the ratio for the two conditions, we get
$P_2/P_1 = (V_2/V_1)^2$.
For the percentage change we have
$[(P_2 - P_1)/P_1](100) = [(V_2/V_1)^2 - 1](100) = [(105\text{ V}/117\text{ V})^2 - 1](100)$ = – 19.5%.
(*b*) The decreased power output would cause a decrease in the temperature, so the resistance would decrease. This means for the reduced voltage, the
percentage decrease in the power output would be less than calculated.

63. The maximum current will produce the maximum rate of heating. We can find the resistance per meter from

$P/L = I^2R/L$;

$1.6\ \mathrm{W/m} = (35\ \mathrm{A})^2(R/L)$, which gives $R/L = 1.31 \times 10^{-3}\ \Omega/\mathrm{m}$.

From the dependence of the resistance on the dimensions, $R = \rho L/A$, we get

$R/L = \rho/($¹$D^2 = 4\rho/$¹D^2;

$1.31 \times 10^{-3}\ \Omega/\mathrm{m} = 4(1.68 \times 10^{-8}\ \Omega\cdot\mathrm{m})/$¹$D^2$, which gives $D = 4.0 \times 10^{-3}\ \mathrm{m} =$ 4.0 mm.

64. (*a*) We find the frequency from the coefficient of t:

2¹$f = 210\ \mathrm{s}^{-1}$, which gives $f =$ 33.4 Hz.

(*b*) The maximum current is 1.80 A, so the rms current is

$I_{\mathrm{rms}} = I_0/$Ã2 = (1.80 A)/Ã2 = 1.27 A.

(*c*) For the voltage we have

$V = IR = (1.80\ \mathrm{A})(42.0\ \Omega)\sin(210\ \mathrm{s}^{-1})t =$ $(75.6\ \mathrm{V})\sin(210\ \mathrm{s}^{-1})t$.

65. The dependence of the power output on the voltage is $P = V^2/R$. When we form the ratio for the two conditions, we get

$P_2/P_1 = (V_2/V_1)^2$.

For the percentage change we have

(ÆP/P)(100) $= [(P_2 - P_1)/P_1](100) = [(V_2/V_1)^2 - 1](100)$

$= \{[(V +$ Æ$V)^2/V]^2 - 1\}(100) = \{[1 +$ (Æ$V/V)]^2 - 1\}(100)$.

If ÆV/V is small, we can use the approximation: $[1 +$ (Æ$V/V)]^2 \approx 1 + 2$ ÆV/V:

(ÆP/P)(100) $\approx$ (2 ÆV/V)(100), so the power drop is twice the voltage drop.

If we assume that the drop from 60 W to 50 W is small, we have

(ÆV/V)(100) = $![(50\ \mathrm{W} - 60\ \mathrm{W})/(60\ \mathrm{W})](100) = -8.4\%$.

Thus the required voltage drop is 8.4%.

66. (*a*) We find the input power from

$P_{\mathrm{output}} = (\mathrm{efficiency})P_{\mathrm{input}}$;

$900\ \mathrm{W} = (0.60)P_{\mathrm{input}}$, which gives $P_{\mathrm{input}} = 1500\ \mathrm{W} =$ 1.5 kW.

(*b*) We find the current from

$P = IV$;

$1500\ \mathrm{W} = I(120\ \mathrm{V})$, which gives $I =$ 12.5 A.

67. Because the volume is constant, we have

$AL = A'L'$, or $A'/A = L/L' = 1/3.00$.

The dependence of the resistance on the dimensions is $R = \rho L/A$. When we form the ratio for the two wires, we get

$R'/R = (L'/L)(A/A')$

$R'/(1.00\ \Omega) = (3.00)(3.00)$, which gives $R' =$ 9.00 Ω.

68. The dependence of the resistance on the dimensions is $R = \rho L/A$. When we form the ratio for the two wires, we get

$R_1/R_2 = (L_1/L_2)(A_2/A_1) = (L_1/L_2)(D_2/D_1)^2 = (2)(!)^2 = !$.

For a fixed voltage, the power dissipation is

$P = V^2/R$.

When we form the ratio for the two wires, we get

$P_1/P_2 = R_2/R_1 = 1/! = 2$.

69. Heat must be provided to replace the heat loss through the walls and to raise the temperature of the air brought in:

$P = P_{loss} + mc\,\Delta T = 850\text{ kcal/h} + 2(1.29\text{ kg/m}^3)(62\text{ m}^3)(0.17\text{ kcal/kg}\cdot\text{C°})(20\text{°C} - 5\text{°C})$
$= 1.26 \times 10^3\text{ kcal/h} = (1.26 \times 10^3\text{ kcal/h})(4186\text{ J/kcal})/(3600\text{ s/h}) = 1.46 \times 10^3\text{ W} =$ 1.5 kW.

70. (*a*) We find the average power required to provide the force to balance the average friction force from

$P = Fv = (240\text{ N})(40\text{ km/h})/(3.6\text{ ks/h})(746\text{ W/hp}) =$ 3.6 hp.

(*b*) We find the average current from

$P = IV$;

$(3.6\text{ hp})(746\text{ W/hp}) = I(12\text{ V})$, which gives $I = 222\text{ A}$.

52 A·h is the total charge that passes through the battery when it is completely discharged. Thus the time for complete discharge is

$t = Q/I = (26)(52\text{ A}\cdot\text{h})/(222\text{ A}) = 6.09\text{ h}$.

In this time the car can travel

$x = vt = (40\text{ km/h})(6.09\text{ h}) =$ 2.4×10^2 km.

71. For the resistance, we have

$R = \rho L/A = \rho L/(\frac{1}{4}\pi d^2)$;

$12.5\ \Omega = 4(1.68 \times 10^{-8}\ \Omega\cdot\text{m})L/\pi d^2$.

The mass of the wire is

$m = \rho_m AL$;

$0.0180\text{ kg} = (8.9 \times 10^3\text{ kg/m}^3)(\frac{1}{4}\pi d^2)L$.

This gives us two equations with two unknowns, L and d. When we solve them, we get

$d = 2.58 \times 10^{-4}\text{ m} =$ 0.258 mm, and $L =$ 38.8 m.

72. (*a*) We find the initial power consumption from

$P = V^2/R_0 = (120\text{ V})^2/(12\ \Omega) = 1.2 \times 10^3\text{ W} =$ 1.2 kW.

(*b*) The power consumption when the bulb is hot is

$P = V^2/R = (120\text{ V})^2/(140\ \Omega) =$ 100 W.

The designated power is the operating power.

73. The stored energy in the capacitor must provide the energy used during the lapse:

$U = \frac{1}{2}CV^2 = Pt$;

$\frac{1}{2}C(120\text{ V})^2 = (150\text{ W})(0.10\text{ s})$, which gives $C =$ 2.1×10^{-3} F.

74. The time for a proton to travel completely around the accelerator is

$t = L/v$.

In this time all the protons stored in the beam will pass a point, so the current is

$I = Ne/t = Nev/L$;

$11 \times 10^{-3}\text{ A} = N(1.60 \times 10^{-19}\text{ C})(3.0 \times 10^8\text{ m/s})/(6300\text{ m})$, which gives $N =$ 1.4×10^{12} protons.

75. From Example 18–14 we know that the density of free electrons in copper is

$n = 8.4 \times 10^{28}\ \mathrm{m^{-3}}$.

With the alternating current an electron will oscillate with SHM. We find the rms current from

$P = I_{\mathrm{rms}} V_{\mathrm{rms}}$;

300 W = I_{rms}(120 V), which gives I_{rms} = 2.50 A, so the peak current is

I_0 = Ã2 I_{rms} = Ã2(2.50 A) = 3.54 A.

The peak current corresponds to the maximum drift speed, which we find from

$I_0 = neAv_{\mathrm{dmax}} = ne$((¹$D^2$)$v_{\mathrm{dmax}}$;

3.54 A = $(8.4 \times 10^{28}\ \mathrm{m^{-3}})(1.60 \times 10^{-19}\ \mathrm{C})$[(¹$(1.8 \times 10^{-3}\ \mathrm{m})^2$]$v_{\mathrm{dmax}}$,

which gives $v_{\mathrm{dmax}} = 1.03 \times 10^{-4}$ m/s.

For SHM the maximum speed is related to the maximum displacement:

$v_{\mathrm{dmax}} = A\omega = A$(2¹$f$);

1.03×10^{-4} m/s = A[2¹(60 Hz)], which gives $A = 2.73 \times 10^{-7}$ m.

For SHM the electron will move from one extreme to the other, so the total distance covered is 2A:

5.5×10^{-7} m.