CHAPTER 14

1. The required heat flow is
   $\Delta Q = mc\,\Delta T = (20.0\text{ kg})(4186\text{ J/kg}\cdot\text{C}°)(95°\text{C} - 15°\text{C}) =$ 6.7×10^6 J.

2. For the work to equal the energy value of the food, we have
   $W = (750\text{ Cal})(4186\text{ J/Cal}) =$ 3.14×10^6 J.

3. We find the temperature from
   $W = \Delta Q = mc\,\Delta T$;
   $7700\text{ J} = (3.0\text{ kg})(4186\text{ J/kg}\cdot\text{C}°)(T - 10.0°\text{C})$, which gives $T =$ 10.6°C.

4. (*a*) We convert the units:
   $(2500\text{ Cal/day})(4186\text{ J/Cal}) =$ 1.05×10^7 J/day.
   (*b*) We convert the units:
   $(1.05 \times 10^7\text{ J/day})(1\text{ W}\cdot\text{s/J})/(3600\text{ s/h})(1000\text{ W/kW}) =$ 2.9 kWh/day.
   (*c*) Cost = (Rate)(Energy) = ($0.10/kWh)(2.9 kWh/day) = $0.29 /day.
   Difficult to feed yourself on 29 cents/day.

5. We convert the units:
   $\Delta Q = mc\,\Delta T$;
   $1\text{ Btu} = (1\text{ lb})(1.00\text{ kcal/kg}\cdot\text{C}°)(1\text{ F}°)(0.454\text{ kg/lb})(5\text{ C}°/9\text{ F}°) = 0.252\text{ kcal}$;
   $1\text{ Btu} = (0.252\text{ kcal})(4186\text{ J/kcal}) = 1055\text{ J}$.

6. We find the time from
   $\Delta Q = mc\,\Delta T$;
   $(350\text{ W})t = (250\text{ mL})(1.00\text{ g/mL})(10^{-3}\text{ kg/g})(4186\text{ J/kg}\cdot\text{C}°)(50°\text{C} - 20°\text{C})$, which gives $t =$ 90 s.

7. We find the mass per hour from
   $\Delta Q/t = (m/t)c\,\Delta T$;
   $7200\text{ kcal/h} = (m/t)(1.00\text{ kcal/kg}\cdot\text{C}°)(50°\text{C} - 15°\text{C})$, which gives $m/t =$ 2.1×10^2 kg/h.

8. The heat flow generated must equal the kinetic energy loss:
   $\Delta Q = !mv^2 = !(1000\text{ kg})[(100\text{ km/h})/(3.6\text{ ks/h})]^2(1\text{ kcal}/4186\text{ J}) =$ 92 kcal.

9. We find the specific heat from
   $\Delta Q = mc\,\Delta T$;
   $135 \times 10^3\text{ J} = (5.1\text{ kg})c\,(30°\text{C} - 20°\text{C})$, which gives $c =$ 2.6×10^3 J/kg·C°.

10. The required heat flow is
   $\Delta Q = mc\,\Delta T = (18\text{ L})(1.00\text{ kg/L})(4186\text{ J/kg}\cdot\text{C}°)(90°\text{C} - 20°\text{C}) =$ 5.3×10^6 J.

11. Because ΔQ and ΔT are the same, from $\Delta Q = mc\,\Delta T$ we see that $m \propto 1/c$:
    $m_{Cu} : m_{Al} : m_w = 1/c_{Cu} : 1/c_{Al} : 1/c_w$
    $= 1/390 : 1/900 : 1/4186 =$ 10.7 : 4.65 : 1.

12. We convert the units:
    $c = (4186 \text{ J/kg}\cdot\text{C°})(1 \text{ Btu}/1055 \text{ J})(5 \text{ C°}/9 \text{ F°})(0.454 \text{ kg/lb}) =$ 1.00 Btu/lb ·F°.

13. To be equivalent the water and lead must have the same mc:
    $m_{lead}c_{lead} = m_{water}c_{water}$;
    $(4.00 \text{ kg})(130 \text{ J/kg}\cdot\text{C°}) = m_{water}(4186 \text{ J/kg}\cdot\text{C°})$, which gives $m_{water} =$ 0.124 kg.

14. We find the temperature from
    heat lost = heat gained;
    $m_{water}c_{water}\,\Delta T_{water} = m_{glass}c_{glass}\,\Delta T_{glass}$;
    $(135 \text{ mL})(1.00 \text{ g/mL})(10^{-3} \text{ kg/g})(4186 \text{ J/kg}\cdot\text{C°})(T - 39.2\text{°C}) =$
    $(0.030 \text{ kg})(840 \text{ J/kg}\cdot\text{C°})(39.2\text{°C} - 21.6\text{°C})$,
    which gives $T =$ 40.0°C.

15. If all the kinetic energy in the hammer blows is absorbed by the nail, we have
    $\text{KE} = 10(!mv^2) = mc\,\Delta T$;
    $10[!(1.20 \text{ kg})(8.0 \text{ m/s})^2] = (0.014 \text{ kg})(450 \text{ J/kg}\cdot\text{C°})\,\Delta T$, which gives $\Delta T =$ 61 C°.

16. We find the temperature from
    heat lost = heat gained;
    $m_{Cu}c_{Cu}\,\Delta T_{Cu} = (m_{Al}c_{Al} + m_{water}c_{water})\,\Delta T_{Al}$;
    $(0.270 \text{ kg})(390 \text{ J/kg}\cdot\text{C°})(300\text{°C} - T) =$
    $[(0.150 \text{ kg})(900 \text{ J/kg}\cdot\text{C°}) + (0.820 \text{ kg})(4186 \text{ J/kg}\cdot\text{C°})](T - 12.0\text{°C})$, which gives $T =$ 20.2°C.

17. We find the temperature from
    heat lost = heat gained;
    $m_{poker}c_{poker}\,\Delta T_{poker} = m_{cider}c_{cider}\,\Delta T_{cider}$;
    $(0.55 \text{ kg})(450 \text{ J/kg}\cdot\text{C°})(700\text{°C} - T) = (0.50 \text{ L})(1.00 \text{ kg/L})(4186 \text{ J/kg}\cdot\text{C°})](T - 15\text{°C})$,
    which gives $T =$ 87°C.

18. We find the temperature from
    heat lost = heat gained;
    $m_{shoe}c_{shoe}\,\Delta T_{shoe} = (m_{pot}c_{pot} + m_{water}c_{water})\,\Delta T_{pot}$;
    $(0.40 \text{ kg})(450 \text{ J/kg}\cdot\text{C°})(T - 25\text{°C}) =$
    $[(0.30 \text{ kg})(450 \text{ J/kg}\cdot\text{C°}) + (1.60 \text{ L})(1.00 \text{ kg/L})(4186 \text{ J/kg}\cdot\text{C°})](25\text{°C} - 20\text{°C})$,
    which gives $T =$ 215°C.

19. We find the specific heat from
    heat lost = heat gained;
    $m_{Fe}c_{Fe}\,\Delta T_{Fe} = (m_{Al}c_{Al} + m_{glycerin}c_{glycerin})\,\Delta T_{glycerin}$;

(0.290 kg)(450 J/kg ·C°)(180°C – 38°C) = [(0.100 kg)(900 J/kg ·C°) + (0.250 kg)c_{glycerin}](38°C – 10°C),
which gives c_{glycerin} = 2.3×10^3 J/kg ·C°.

20. We find the specific heat from

heat lost = heat gained;

$m_x c_x \,\Delta T_x = (m_{Al}c_{Al} + m_{water}c_{water} + m_{glass}c_{glass})\,\Delta T_{water}$;

(0.195 kg)c_x (330°C – 35.0°C) =

[(0.100 kg)(900 J/kg ·C°) + (0.150 kg)(4186 J/kg ·C°) + (0.017 kg)(840 J/kg ·C°)](35.0°C – 12.5°C),

which gives c_x = 286 J/kg ·C°.

21. The water must be heated to the boiling temperature, 100°C. We find the time from

t = (heat gained)/P = [$(m_{Al}c_{Al} + m_{water}c_{water})\,\Delta T_{water}$]/$P$

= [(0.360 kg)(900 J/kg ·C°) + (0.60 L)(1.00 kg/L)(4186 J/kg ·C°)](100°C – 8.0C)/(750 W)

= 348 s = 5.8 min.

22. The silver must be heated to the melting temperature, 961°C, and then melted. We find the heat required from

$Q = m_{silver}c_{silver}\,\Delta T_{silver} + m_{silver}L_{silver}$

= (16.50 kg)(230 J/kg ·C°)(961°C – 20° C) + (16.50 kg)(0.88×10^5 J/kg) = 5.02×10^6 J.

23. If we assume that the heat is required just to evaporate the water, we have

$Q = m_{water}L_{water}$;

180 kcal = m_{water}(539 kcal/kg), which gives m_{water} = 0.334 kg (0.334 L).

24. The temperature of the liquid nitrogen will not change, so the ice will cool to 77 K. We find the amount of nitrogen that has evaporated from

heat lost = heat gained;

$m_{ice}c_{ice}\,\Delta T_{ice} = m_{nitrogen}L_{nitrogen}$;

(0.030 kg)(2100 J/kg ·C°)(273 K – 77 K) = $m_{nitrogen}$(200×10^3 J/kg), which gives $m_{nitrogen}$ = 0.062 kg.

Note that a change of 1 K is equal to a change of 1 C°.

25. The temperature of the ice will rise to 0°C, at which point melting will occur, and then the resulting water will rise to the final temperature. We find the mass of the ice cube from

heat lost = heat gained;

$(m_{Al}c_{Al} + m_{water}c_{water})\,\Delta T_{Al} = m_{ice}(c_{ice}\,\Delta T_{ice} + L_{ice} + c_{water}\,\Delta T_{water})$;

[(0.100 kg)(900 J/kg ·C°) + (0.300 kg)(4186 J/kg ·C°)](20°C – 17°C) =

m_{ice}{(2100 J/kg ·C°)[0°C – (– 8.5°C)] + (3.33×10^5 J/kg) + (4186 J/kg ·C°)(17°C – 0°C)},

which gives m_{ice} = 9.6×10^3 kg = 9.6 g.

26. (*a*) We find the heat required to reach the boiling point from

$Q_1 = (m_{\text{Fe}}c_{\text{Fe}} + m_{\text{water}}c_{\text{water}})\Delta T$

$= [(230\text{ kg})(450\text{ J/kg}\cdot\text{C°}) + (830\text{ kg})(4186\text{ J/kg}\cdot\text{C°})](100°\text{C} - 20°\text{ C}) = 2.86 \times 10^8\text{ J}.$

We find the time from

$t_1 = Q_1/P = (2.86 \times 10^8\text{ J})/(52{,}000 \times 10^3\text{ J/h}) =$ 5.5 h.

(*b*) There is no change in the temperature, so the additional heat required to change the water into steam is

$Q_2 = m_{\text{water}}L_{\text{steam}}$

$= (830\text{ kg})(22.6 \times 10^5\text{ J/kg}) = 1.88 \times 10^9\text{ J}.$

We find the additional time from

$t_2 = Q_2/P = (1.88 \times 10^9\text{ J})/(52{,}000 \times 10^3\text{ J/h}) = 36.1\text{ h}.$

Thus the total time required is

$t = t_1 + t_2 = 5.5\text{ h} + 36.1\text{ h} =$ 41.6 h.

27. We use the heat of vaporization at body temperature: 585 kcal/kg.
If all of the energy supplied by the bicyclist evaporates the water, we have

$Q = m_{\text{water}}L_{\text{water}}$

$= (8.0\text{ L})(1.00\text{ kg/L})(585\text{ kcal/kg}) =$ 4.7×10^3 kcal.

28. The steam will condense at 100°C, and then the resulting water will cool to the final temperature. The ice will melt at 0°C, and then the resulting water will rise to the final temperature. We find the mass of the steam required from

heat lost = heat gained;

$m_{\text{steam}}(L_{\text{steam}} + c_{\text{water}}\,\Delta T_1) = m_{\text{ice}}(L_{\text{ice}} + c_{\text{water}}\,\Delta T_2);$

$m_{\text{steam}}[(22.6 \times 10^5\text{ J/kg}) + (4186\text{ J/kg}\cdot\text{C°})](100°\text{C} - 20°\text{C}) =$

$(1.00\text{ kg})[(3.33 \times 10^5\text{ J/kg}) + (4186\text{ J/kg}\cdot\text{C°})(20°\text{C} - 0°\text{C})],$

which gives $m_{\text{steam}} =$ 0.16 kg.

29. We find the latent heat of fusion from

heat lost = heat gained;

$(m_{\text{Al}}c_{\text{Al}} + m_{\text{water}}c_{\text{water}})\,\Delta T_{\text{water}} = m_{\text{Hg}}(L_{\text{Hg}} + c_{\text{Hg}}\,\Delta T_{\text{Hg}})$

$[(0.620\text{ kg})(900\text{ J/kg}\cdot\text{C°}) + (0.400\text{ kg})(4186\text{ J/kg}\cdot\text{C°})](12.80°\text{C} - 5.06°\text{C}) =$

$(1.00\text{ kg})\{L_{\text{Hg}} + (138\text{ J/kg}\cdot\text{C°})[5.06°\text{C} - (-39.0°\text{C})]\},$

which gives $L_{\text{Hg}} =$ 1.12×10^4 J/kg.

30. We assume that the water created by the melting of the ice stays at 0°C. Because the work done by friction, which decreases the kinetic energy, generates the heat flow, we have

$Q = !(\Delta\text{KE});$

$m_{\text{ice}}L_{\text{ice}} = !(!mv^2);$

$m_{\text{ice}}(3.33 \times 10^5\text{ J/kg}) = ((54.0\text{ kg})(6.4\text{ m/s})^2$, which gives $m_{\text{ice}} = 1.7 \times 10^{-3}\text{ kg} =$ 1.7 g.

31. The work done by friction, which decreases the kinetic energy, generates the heat flow. In general a fraction of the heat flow is used to raise the temperature of the lead bullet and then melt the lead bullet. The larger this fraction is, the smaller the bullet velocity needed. We determine the minimum muzzle velocity by assuming that this fraction is 1:

$Q = \Delta\text{KE};$

$m_{\text{lead}}(c_{\text{lead}}\ \Delta T + L_{\text{lead}})$ = !$m_{\text{lead}}v^2$;
[(130 J/kg ·C°)(327°C – 20°C) + 0.25 × 10^5 J/kg] = !v^2, which gives v = 360 m/s.

32. The strong gusty winds will provide heat convection, so the temperature at the outside of the window will be the external air temperature. We find the rate of heat flow from

$\Delta Q/\Delta t = kA(\Delta T/L)$

$= (0.84\ \text{J/s}\cdot\text{m}\cdot\text{C°})(3.0\ \text{m}^2)[15°\text{C} - (-5°\text{C})]/(3.2\times10^{-3}\ \text{m}) =$ 1.6×10^4 W.

33. (*a*) We find the radiated power from

$\Delta Q/\Delta t = e\sigma AT^4$

$= (0.35)(5.67\times10^{-8}\ \text{W/m}^2\cdot\text{K}^4)4\pi(0.22\ \text{m})^2(298\ \text{K})^4 =$ 95 W.

(*b*) We find the net flow rate from

$\Delta Q/\Delta t = e\sigma A(T_2^4 - T_1^4)$

$= (0.35)(5.67\times10^{-8}\ \text{W/m}^2\cdot\text{K}^4)4\pi(0.22\ \text{m})^2[(298\ \text{K})^4 - (268\ \text{K})^4] =$ 33 W.

34. We find the distance for the conduction from

$\Delta Q/\Delta t = kA(\Delta T/L)$

$200\ \text{W} = (0.2\ \text{J/s}\cdot\text{m}\cdot\text{C°})(1.5\ \text{m}^2)(0.50\ \text{C°})/L$, which gives $L = 7.5\times10^{-4}$ m = 0.75 mm.

35. We find the radiated power from

$\Delta Q/\Delta t = e_{\text{Betelgeuse}}\sigma A_{\text{Betelgeuse}}T_{\text{Betelgeuse}}^4 = e_{\text{Betelgeuse}}\sigma 4\pi r_{\text{Betelgeuse}}^2 T_{\text{Betelgeuse}}^4$.

$= (1.0)(5.67\times10^{-8}\ \text{W/m}^2\cdot\text{K}^4)4\pi(3.1\times10^{11}\ \text{m})^2(2800\ \text{K})^4 =$ 4.2×10^{30} W.

If we form the ratio for Betelgeuse and the Sun, we have

$P_{\text{Betelgeuse}}/P_{\text{Sun}} = (r_{\text{Betelgeuse}}/r_{\text{Sun}})^2(T_{\text{Betelgeuse}}/T_{\text{Sun}})^4$, or

$P_{\text{Betelgeuse}} = (3.1\times10^{11}\ \text{m}/7.0\times10^{8}\ \text{m})^2(!)^4 P_{\text{Sun}} =$ $1.2\times10^4\ P_{\text{Sun}}$.

36. (*a*) The cross-sectional area of the beam that falls on an area A is $A\cos\theta$. Thus the rate at which energy is absorbed is

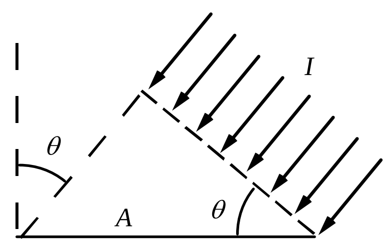
$P = IeA\cos\theta = (1000\ \text{W/m}^2)(0.75)(225\times10^{-4}\ \text{m}^2)\cos 40°$

$=$ 13 W.

(*b*) With the new emissivity we have

$P = IeA\cos\theta = (1000\ \text{W/m}^2)(0.20)(225\times10^{-4}\ \text{m}^2)\cos 40°$

$=$ 3.4 W.



37. We find the rate of heat flow through the wall from

$\Delta Q/\Delta t = kA(\Delta T/L)$

$= (0.84\ \text{J/s}\cdot\text{m}\cdot\text{C°})(4.0\ \text{m})(4.0\ \text{m})(30°\text{C} - 10°\text{C})/(0.12\ \text{m}) = 2.24\times10^3$ W.

We find the number of bulbs required to provide this heat flow from

$N = (\Delta Q/\Delta t)/P = (2.24\times10^3\ \text{W})/(100\ \text{W}) = 22.4 =$ 22 bulbs.

38. The cross-sectional area of the beam that falls on an area A is $A\cos\theta$. Thus the rate at which energy is absorbed is

$P = IeA\cos\theta$.

There is no change in temperature of the ice. We find the time to provide the energy to melt the ice from

$Q = mL = \rho AhL = Pt = (IeA\cos\theta)t$;

$(917\ \text{kg/m}^3)(0.010\ \text{m})(3.33\times10^5\ \text{J/kg}) = (1000\ \text{W/m}^2)(0.050)(\cos 30°)t$, which gives $t = 7.1$ s = 20 h.

Note that the result is independent of the area.

39. In the steady state, the intermediate temperature does not change, so the heat flow must be the same through the two rods:

$\Delta Q/\Delta t = k_{Cu}A_{Cu}(T_{hot} - T)/L_{Cu} = k_{Al}A_{Al}(T_{hot} - T)/L_{Al}$.

The rods have the same area and length, so we have

$k_{Cu}(T_{hot} - T) = k_{Al}(T_{hot} - T)$;

(380 J/s ·m ·C°)(250°C – T) = (200 J/s ·m ·C°)(T – 0.0°C), which gives T = 164°C.

40. We find the temperature from the power radiated into space:

$\Delta Q/\Delta t = e\sigma AT^4$, or $(\Delta Q/\Delta t)/A = e\sigma T^4$;

430 W/m² = (1.0)(5.67 × 10⁻⁸ W/m² ·K⁴)T^4, which gives T = 295 K (22°C).

41. We find the temperature difference from conduction through the glass:

$\Delta Q/\Delta t = kA(\Delta T/L)$;

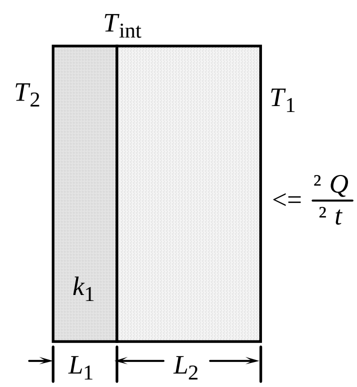
95 W = (0.84 J/s ·m ·C°)4π(0.030 m)² ΔT/(1.0 × 10⁻³ m), which gives ΔT = 10 C°.

42. The total rate of thermal energy loss through the wall and windows must be the power output of the stove:

$P = \Delta Q/\Delta t = (\Delta Q/\Delta t)_{wall} + (\Delta Q/\Delta t)_{windows}$

$= (k_1A_1\,\Delta T/L_1) + (k_2A_2\,\Delta T/L_2) = [(k_1A_1/L_1) + (k_2A_2/L_2)]\Delta T$.

43. The rate of thermal energy flow is the same for the brick and the insulation:



$\Delta Q/\Delta t = A(T_1 - T_2)/R_{eff} = A(T_1 - T_{int})/R_2 = A(T_{int} - T_2)/R_1$,

where T_{int} is the temperature at the brick-insulation interface.

By equating the first term to each of the others, we have

$R_{eff}(T_1 - T_{int}) = R_2(T_1 - T_2)$, and $R_{eff}(T_{int} - T_2) = R_1(T_1 - T_2)$.

If we add these two equations, we get

$R_{eff}(T_1 - T_2) = R_1(T_1 - T_2) + R_2(T_1 - T_2)$, which gives

$R_{eff} = R_1 + R_2$.

This shows the usefulness of the R-value.

For the R-value of the brick we have

$R_1 = L_1/k_1$

= [(4.0 in)/(12 in/ft)](3.28 ft/m)/(0.84 J/s ·m ·C°)(1 Btu/1055 J)(1 h/3600 s)(5 C°/9 F°)

= 0.69 ft² ·h ·F°/Btu.

Thus the total R-value of the wall is

$R_{eff} = R_1 + R_2$ = 0.69 ft² ·h ·F°/Btu + 19 ft² ·h ·F°/Btu = 19.7 ft² ·h ·F°/Btu.

The rate of heat loss is

$\Delta Q/\Delta t = A(T_1 - T_2)/R_{eff}$

= [(240 ft²)(10 F°)/(19.7 ft² ·h ·F°/Btu)](1055 J/Btu)/(3600 s/h) = 36 W.

44. (*a*) We call the temperatures at the interfaces T_a and T_b, as shown. In the steady state, the rate of heat flow is the same for each layer:

$\Delta Q/\Delta t = k_1A(T_2 - T_a)/\neg_1 = k_2A(T_a - T_b)/\neg_2 = k_3A(T_b - T_1)/\neg_3$.

We treat this as three equations:

$T_2 - T_a = [(\Delta Q/\Delta t)/A]\neg_1/k_1$;

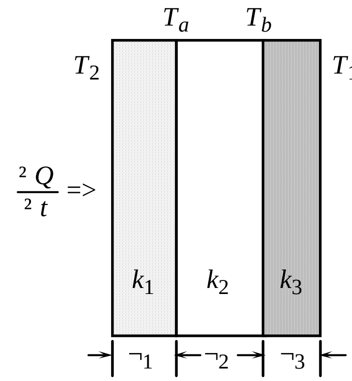
$T_a - T_b = [(\Delta Q/\Delta t)/A]\neg_2/k_2$;

$T_b - T_1 = [(\Delta Q/\Delta t)/A]\neg_3/k_3$.

If we add these equations, we get

$T_2 - T_1 = [(\Delta Q/\Delta t)/A][(\neg_1/k_1) + (\neg_2/k_2) + (\neg_3/k_3)]$, which gives

$\Delta Q/\Delta t = A(T_2 - T_1)/[(\neg_1/k_1) + (\neg_2/k_2) + (\neg_3/k_3)]$.



(*b*) We can generalize this by recognizing that more layers will mean more equations, similar to the three that we had. When we eliminate the intermediate temperatures by adding all the equations, we get

$\Delta Q/\Delta t = A(T_2 - T_1)/\sum(\neg_i/k_i)$.

45. The total area of the six sides of the icebox is

$A = 2[(0.25\text{ m})(0.35\text{ m}) + (0.25\text{ m})(0.50\text{ m}) + (0.35\text{ m})(0.50\text{ m})] = 0.775\text{ m}^2$.

As the ice melts, the inside temperature of the icebox remains at 0°C. The rate at which heat flows through the sides of the icebox is

$\Delta Q/\Delta t = m_{\text{ice}}L_{\text{ice}}/\Delta t = kA(\Delta T/L)$;

$(11.0\text{ kg})(3.33 \times 10^5\text{ J/kg})/\Delta t = (0.023\text{ J/s}\cdot\text{m}\cdot\text{C°})(0.775\text{ m}^2)(30\text{°C} - 0\text{°C})/(0.015\text{ m})$,

which gives $\Delta t = 5.14 \times 10^4\text{ s} =$ 14 h.

46. We assume that the rate of heat loss is proportional to the temperature difference, so the heat flow in a time t is

$Q = K(\Delta T)t$.

We assume that the constant K takes into account all forms of heat loss, but does not depend on the temperature difference, and thus is the same day and night. When the thermostat is turned down, we have

$Q_1 = K(\Delta T_{\text{day}})t_{\text{day}} + K(\Delta T_{\text{1night}})t_{\text{night}}$

$= K[(22\text{°C} - 8\text{°C})(17.0\text{ h}) + (12\text{°C} - 0\text{°C})(7.0\text{ h})] = (322\text{ h}\cdot\text{C°})K$.

When the thermostat is not turned down, we have

$Q_2 = K(\Delta T_{\text{day}})t_{\text{day}} + K(\Delta T_{\text{2night}})t_{\text{night}}$

$= K[(22\text{°C} - 8\text{°C})(17.0\text{ h}) + (22\text{°C} - 0\text{°C})(7.0\text{ h})] = (392\text{ h}\cdot\text{C°})K$.

For the percentage increase we have

$(\Delta Q/Q_1)(100) = \{[(392\text{ h}\cdot\text{C°})K - (322\text{ h}\cdot\text{C°})K]/[(322\text{ h}\cdot\text{C°})K]\}(100) =$ 22%.

47. Because 70% of the heat generated by burning the coal heats the house, we have

$0.70m_{\text{coal}}(7000\text{ kcal/kg}) = 4.8 \times 10^7\text{ kcal}$, which gives $m_{\text{coal}} =$ 9.8×10^3 kg.

48. The work done by friction, which decreases the kinetic energy, generates the heat flow. If all the heat flow is absorbed by the lead bullet and wooden block, we have

$Q = \Delta\text{KE}$;

$(m_{\text{lead}}c_{\text{lead}} + m_{\text{wood}}c_{\text{wood}})\Delta T = !m_{\text{lead}}v^2$;

$[(0.015\text{ kg})(130\text{ J/kg}\cdot\text{C°}) + (1.05\text{ kg})(1700\text{ J/kg}\cdot\text{C°})](0.020\text{ C°}) = !(0.015\text{ kg})v^2$,

which gives $v =$ 69 m/s.

49. (*a*) We find the power radiated from

$\Delta Q/\Delta t = e\sigma AT^4$

$= (1.0)(5.67 \times 10^{-8}\ \text{W/m}^2 \cdot \text{K}^4)4\pi(7.0 \times 10^8\ \text{m})^2(5500\ \text{K})^4 =$ $3.2 \times 10^{26}\ \text{W}$.

(*b*) Because this radiation passes through a sphere centered at the Sun, we have

$P/4\pi R^2 = (3.2 \times 10^{26}\ \text{W})/4\pi(1.5 \times 10^{11}\ \text{m})^2 =$ $1.1 \times 10^3\ \text{W/m}^2$.

50. We find the temperature rise from

$Q = mc\,\Delta T;$

$(0.70)(200\ \text{kcal/h})(1.00\ \text{h}) = (70\ \text{kg})(0.83\ \text{kcal/kg}\cdot\text{C°})\Delta T$, which gives $\Delta T =$ $2.8\ \text{C°}$.

51. The heat generated in stopping the fall equals the decrease in kinetic energy. From energy conservation for the fall, this must equal the change in potential energy. We find the temperature rise from

$Q = (0.50)mgh = mc\,\Delta T;$

$(0.50)(340\ \text{kg})(9.80\ \text{m/s}^2)(140\ \text{m}) = (340\ \text{kg})(860\ \text{J/kg}\cdot\text{C°})\Delta T$, which gives $\Delta T =$ $0.80\ \text{C°}$.

52. (*a*) We use the two expressions for Q:

$Q = mc\,\Delta T = C\,\Delta T$, which gives $C = mc$.

(*b*) For 1 kg we have

$C = mc = (1.00\ \text{kg})(4186\ \text{J/kg}\cdot\text{C°}) =$ $4186\ \text{J/C°}$.

(*c*) For 50 kg we have

$C = mc = (50.0\ \text{kg})(4186\ \text{J/kg}\cdot\text{C°}) =$ $2.09 \times 10^5\ \text{J/C°}$.

53. We find the temperature rise in the rod of length L from

$\Delta Q = mc\,\Delta T = \rho ALc\,\Delta T;$

$320 \times 10^3\ \text{J} = (3.64\ \text{kg/m}^3)\pi(0.0100\ \text{m})^2L(130\ \text{J/kg}\cdot\text{C°})\,\Delta T$, which gives $\Delta T = (676\ \text{C°}\cdot\text{m})/L$.

Because the rod is very long, the temperature rise will be small. We find the change in length from

$\Delta L = L\alpha\Delta T = L[29 \times 10^{-6}\ (\text{C°})^{-1}][(676\ \text{C°}\cdot\text{m})/L] = 1.96 \times 10^{-2}\ \text{m} =$ $1.96\ \text{cm}$.

If the rod is 2.0 cm long, the temperature rise will be

$\Delta T = (676\ \text{C°}\cdot\text{m})/L = (676\ \text{C°}\cdot\text{m})/(2.0 \times 10^{-2}\ \text{m}) = 3.4 \times 10^4\ \text{C°}$.

This is so much greater than the boiling point for lead, 1750°C, that the rod vaporizes.

54. (*a*) We find the rate of heat flow through the clothing from

$\Delta Q/\Delta t = kA(\Delta T/L)$

$= (0.025\ \text{J/s}\cdot\text{m}\cdot\text{C°})(1.7\ \text{m}^2)[34°\text{C} - (-20°\text{C})]/(0.035\ \text{m}) =$ $66\ \text{W}$.

(*b*) When the clothing is wet, we have

$\Delta Q/\Delta t = kA(\Delta T/L)$

$= (0.56\ \text{J/s}\cdot\text{m}\cdot\text{C°})(1.7\ \text{m}^2)[34°\text{C} - (-20°\text{C})]/(0.0050\ \text{m}) =$ $1.0 \times 10^4\ \text{W}$.

55. If we assume that all the energy evaporates the water, with the latent heat at 20° given in the text, we have

$Q = m_{\text{water}}L_{\text{water}}$

$(1000\ \text{kcal/h})(2.5\ \text{h}) = m_{\text{water}}(585\ \text{kcal/kg})$, which gives $m_{\text{water}} =$ $4.3\ \text{kg}$.

56. We find the rate of heat conduction from

$\Delta Q/\Delta t = kA(\Delta T/L)$

$= (0.2\ \mathrm{J/s\cdot m\cdot C°})(1.5\ \mathrm{m}^2)(37°\mathrm{C} - 34°\mathrm{C})/(0.040\ \mathrm{m}) =$ 23 W.

This is much less than the 230 W that must be dissipated, so the convection provided by the blood in carrying a heat flow to the skin is necessary.

57. The net heat flow rate from radiation, when the temperature difference is $\Delta T = T_1 - T_2$, is

$\Delta Q/\Delta t = e\sigma A(T_1^4 - T_2^4)$

$= e\sigma A[(T_2 + \Delta T)^4 - T_2^4] = e\sigma A\{T_2^4[1 + (\Delta T/T_2)]^4 - T_2^4\} = e\sigma A T_2^4\{[1 + (\Delta T/T_2)]^4 - 1\}.$

Because $\Delta T/T_2 \ll 1$, we use the binomial expansion for the first term:

$[1 + (\Delta T/T_2)]^4 \approx 1 + 4(\Delta T/T_2).$

When we substitute this, we get

$\Delta Q/\Delta t \approx e\sigma A T_2^4[1 + 4(\Delta T/T_2) - 1]$

$= 4e\sigma A T_2^4(\Delta T/T_2) = 4e\sigma A T_2^3\,\Delta T = 4e\sigma A T_2^3\,(T_1 - T_2) = \text{constant} \times (T_1 - T_2).$

58. (*a*) We find the rate of heat flow from

$\Delta Q/\Delta t = k_1A_1(\Delta T/L_1) + k_2A_2(\Delta T/L_2) + k_3A_3(\Delta T/L_3)$

$= [(k_1A_1/L_1) + (k_2A_2/L_2) + (k_3A_3/L_3)]\Delta T$

$= \{[(0.023\ \mathrm{J/s\cdot m\cdot C°})(410\ \mathrm{m}^2)/(0.175\ \mathrm{m})] + [(0.12\ \mathrm{J/s\cdot m\cdot C°})(280\ \mathrm{m}^2)/(0.065\ \mathrm{m})] +$

$[(0.84\ \mathrm{J/s\cdot m\cdot C°})(33\ \mathrm{m}^2)/(0.0065\ \mathrm{m})]\}[23°\mathrm{C} - (-\,10°\mathrm{C})] = 1.60 \times 10^5\ \mathrm{W}$

$=$ 160 kW.

(*b*) The heat flow needed to raise the temperature of the air is

$Q_{\mathrm{air}} = m_{\mathrm{air}}c_{\mathrm{air}}\,\Delta T = \rho_{\mathrm{air}}V_{\mathrm{air}}c_{\mathrm{air}}\,\Delta T$

$= (1.29\ \mathrm{kg/m^3})(750\ \mathrm{m^3})(0.24\ \mathrm{kcal/kg\cdot C°})(4186\ \mathrm{J/kcal})(23°\mathrm{C} - 10°\ \mathrm{C}) = 1.26 \times 10^7\ \mathrm{J}.$

During the 30 minutes there will be heat loss from conduction. We use the average temperature difference:

$\Delta T_{\mathrm{av}} =$!$(23°\mathrm{C} + 10°\mathrm{C}) - (-\,10°\mathrm{C}) = 26.5\ \mathrm{C°}.$

Because the conduction loss is proportional to the temperature difference, the loss during the 30 minutes is

$Q_{\mathrm{loss}} = [(1.60 \times 10^5\ \mathrm{W})/(33\ \mathrm{C°})](26.5\ \mathrm{C°})(30\ \mathrm{min})(60\ \mathrm{s/min}) = 2.30 \times 10^8\ \mathrm{J}.$

The total heat required is

$Q_{\mathrm{total}} = Q_{\mathrm{air}} + Q_{\mathrm{loss}} = 1.26 \times 10^7\ \mathrm{J} + 2.30 \times 10^8\ \mathrm{J} =$ 2.4×10^8 J.

(*c*) We find the amount of gas required from

$0.90m_{\mathrm{gas}}(5.4 \times 10^7\ \mathrm{J/kg}) = (1.60 \times 10^5\ \mathrm{W})(24\ \mathrm{h/day})(30\ \mathrm{day/month})(3600\ \mathrm{s/h}),$

which gives $m_{\mathrm{gas}} = 8.48 \times 10^3$ kg/month.

We find the cost from

$\mathrm{Cost} = (\mathrm{rate})m_{\mathrm{gas}} = (\$0.080/\mathrm{kg})(8.48 \times 10^3\ \mathrm{kg/month}) =$ $\$6.8 \times 10^2$/month.

59. (*a*) The work done by friction, which decreases the kinetic energy, generates the heat flow. If 50% of the heat flow is absorbed by the lead bullet, we have

$Q =$!$\Delta\mathrm{KE};$

$m_{\mathrm{lead}}c_{\mathrm{lead}}\,\Delta T =$!(!$m_{\mathrm{lead}})(v_f^2 - v_i^2)$

$[(0.015\ \mathrm{kg})(130\ \mathrm{J/kg\cdot C°})\Delta T = (\!(0.015\ \mathrm{kg})[(220\ \mathrm{m/s})^2 - (160\ \mathrm{m/s})^2],$

which gives $\Delta T =$ 44 C°.

(*b*) With an ambient temperature of 20°C, we have $T_{\mathrm{lead}} = 20°\mathrm{C} + 44\ \mathrm{C°} = 64°\mathrm{C}$. Because this is less than the melting point of lead, 327°C, there will be no melting of the bullet.

60. (*a*) If we assume that all of the radiation is absorbed to raise the temperature of the leaf, we have

$P = IeA = m_{leaf}c_{leaf}\,(\Delta T/\Delta t)$;

$(1000\text{ W/m}^2)(0.85)(40 \times 10^{-4}\text{ m}^2) = (4.5 \times 10^{-4}\text{ kg})(0.80\text{ kcal/kg}\cdot\text{C°})(4186\text{ J/kcal})(\Delta T/\Delta t)$,

which gives $\Delta T/\Delta t =$ 2.3 C°/s.

(*b*) When the leaf reaches the temperature at which the absorbed energy is re-radiated to the surroundings from both sides of the leaf, we have

$IeA = e\sigma 2A(T_2^4 - T_1^4)$, or $I = 2\sigma(T_2^4 - T_1^4)$;

$(1000\text{ W/m}^2) = 2(5.67 \times 10^{-8}\text{ W/m}^2\cdot\text{K}^4)[T_2^4 - (293\text{ K})^4]$, which gives $T_2 = 357\text{ K} =$ 84°C.

(*c*) The major ways that heat can be dissipated are by convection from conduction to the air in contact with the leaf, and evaporation.

61. When we consider radiation from both sides of the leaf, the net absorbtion rate is

$P_{net} = IeA - e\sigma 2A(T_2^4 - T_1^4) = eA\,[I - 2\sigma(T_2^4 - T_1^4)]$.

To remove this energy by evaporation, we have

$eA\,[I - 2\sigma(T_2^4 - T_1^4)] = (m/t)L$;

$(0.85)(40 \times 10^{-4}\text{ m}^2)\{1000\text{ W/m}^2 - 2(5.67 \times 10^{-8}\text{ W/m}^2\cdot\text{K}^4)[(308\text{ K})^4 - (293)^4]\} =$
$(m/t)(585\text{ kcal/kg})(4186\text{ J/kcal})$,

which gives $m/t =$ 1.1×10^{-6} kg/s (4.1 g/h).

Note that we have used the latent heat at 20°C given in the text.

62. The work done by friction, which decreases the kinetic energy, generates the heat flow. In general, some of the heat flow will heat the air and some will be radiated, so a fraction of the heat flow is used to raise the temperature of the iron meteorite and then melt the iron meteorite. The larger this fraction is, the smaller the necessary velocity. We determine the minimum velocity by assuming that this fraction is 1:

$Q = \Delta\text{KE}$;

$m_{iron}(c_{iron}\,\Delta T + L_{iron}) = !m_{iron}v_{min}^2$;

$(450\text{ J/kg}\cdot\text{C°})[1808°\text{C} - (-125°\text{C})] + 2.89 \times 10^5\text{ J/kg} = !v_{min}^2$, which gives $v_{min} =$ 1.5×10^3 m/s.