Chapter 11

Energy in Thermal Processes

Quick Quizzes

1. (a) Water, glass, iron. Because it has the highest specific heat $(4186\ \text{J/kg}\cdot{}^\circ\text{C})$, water has the smallest change in temperature. Glass is next $(837\ \text{J/kg}\cdot{}^\circ\text{C})$, and iron $(448\ \text{J/kg}\cdot{}^\circ\text{C})$ is last. (b) Iron, glass, water. For a given temperature increase, the energy transfer by heat is proportional to the specific heat.

2. (b). The slopes are proportional to the reciprocal of the specific heat, so larger specific heat results in a smaller slope, meaning more energy to achieve a given change in temperature.

3. (c). The blanket acts as a thermal insulator, slowing the transfer of energy by heat from the air into the cube.

4. (b). The rate of energy transfer by conduction through a rod is proportional to the difference in the temperatures of the ends of the rod. When the rods are in parallel, each rod experiences the full difference in the temperatures of the two regions. If the rods are connected in series, neither rod will experience the full temperature difference between the two regions, and hence neither will conduct energy as rapidly as it did in the parallel connection.

5. **(a)** 4. The From Stefan's law, the power radiated from an object at absolute temperature T is proportional to the surface area of that object. Star A has twice the radius and four times the surface area of star B. **(b)** 16. From Stefan's law, the power radiated from an object having surface area A is proportional to the fourth power of the absolute temperature. Thus, $\mathcal{P}_\text{A} = \sigma Ae(2T_\text{B})^4 = 2^4\left(\sigma AeT_\text{B}^4\right) = 16\mathcal{P}_\text{B}$. **(c)** 64. When star A has both twice the radius and twice the absolute temperature of star B, the ratio of the radiated powers is

$$\frac{\mathcal{P}_\text{A}}{\mathcal{P}_\text{B}} = \frac{\sigma A_\text{A} eT_\text{A}^4}{\sigma A_\text{B} eT_\text{B}^4} = \frac{\sigma\left(4\pi R_\text{A}^2\right)(1)T_\text{A}^4}{\sigma\left(4\pi R_\text{B}^2\right)(1)T_\text{B}^4} = \frac{(2R_\text{B})^2(2T_\text{B})^4}{R_\text{B}^2 T_\text{B}^4} = \left(2^2\right)\left(2^4\right) = 64$$

Answers to Even Numbered Conceptual Questions

2. In winter the produce is protected from freezing. The specific heat of Earth is so high that soil freezes only to a depth of a few inches in temperate regions. Throughout the year the temperature will stay nearly constant day and night. Factors to be considered are the insulating properties of the soil, the absence of a path for energy to be radiated away from or to the vegetables, and the hindrance of the formation of convection currents in the small, enclosed space.

4. The high thermal capacity of the barrel of water and its high heat of fusion mean that a large amount of energy would have to leak out of the cellar before the water and produce froze solid. Evaporation of the water keeps the relative humidity high to protect foodstuffs from drying out.

6. Yes, if you know the specific heat of zinc and copper, you can determine the relative fraction of each by heating a known weight of pennies to a specific initial temperature, say 100° C, then dump them into a known quantity of water, at say 20° C. The equation for conservation of energy will be

$$m_{pennies}\left[x \cdot c_{\mathrm{Cu}} + (1-x)c_{\mathrm{Zn}}\right](100°\mathrm{C} - T) = m_{water}c_{water}(T - 20°\mathrm{C})$$

The equilibrium temperature, T, and the masses will be measured. The specific heats are known, so the fraction of metal that is copper, x, can be computed.

8. Convection is the dominant energy transfer process involved in the cooling of the bridge surface. Air currents can flow freely around all parts of the bridge, making convection particularly effective.

10. The black car absorbs more of the incoming energy from the Sun than does the white car, making it more likely to cook the egg.

12. Keep them dry. The air pockets in the pad conduct energy slowly. Wet pads absorb some energy in warming up themselves, but the pot would still be hot and the water would quickly conduct a lot of energy to your hand.

14. Write $m_{water}c_{water}(1°\mathrm{C}) = (\rho_{air}V)c_{air}(1°\mathrm{C})$, to find

$$V = \frac{m_{water}c_{water}}{\rho_{air}c_{air}} = \frac{(1000\ \mathrm{kg})(4186\ \mathrm{J/kg\cdot°C})}{(1.3\ \mathrm{kg/m^3})(1000\ \mathrm{J/kg\cdot°C})} = 3.2\times10^{3}\ \mathrm{m^3}$$

16. (c). The ice and the liquid water have the same mass and both undergo a 5°C rise in temperature, but the ice requires less energy to accomplish this. Thus, the specific heat, $c = Q/m(\Delta T)$, of ice is less than that of the liquid water.

Answers to Even Numbered Problems

2. 166 °C

4. 0.152 mm

6. 1.17 calories

8. 0.105°C

10. **(a)** 9.9×10^{-3} °C
(b) The remaining energy is absorbed by the surface on which the block slides.

12. 467 pellets

14. copper wins, 89.7°C to 89.8°C

16. 1.7 kg

18. 47°C

20. 49 kJ

22. 0.12 MJ

24. 11.1 W

26. 0.33kg of water evaporated, 0.066 or 6.6%

28. $403 \text{ cm}^3/\text{hr}$

30. **(a)** 0°C, with 24 g of ice left **(b)** 8.2°C

32. $39 \text{ m}^3/\text{d}$

34. **(a)** 0.50 kW into the house **(b)** 1.7 kW out of the house

36. 2.22×10^{-2} W/m · °C

38. **(a)** 52 W **(b)** 1.9 kW, 37 times greater

40. 7.2×10^{-2} W/m · °C

42. 3.77×10^{26} W

44. 1.8×10^{3} °C

46. 91°C

48. 1.83 h

50. 14.1 h

52. approximately 0.9 kg or 1 L

54. 45°C

56. **(a)** 75.0°C **(b)** 36 kJ

58. **(a)** 25.8°C **(b)** No, the mass cancels.

60. **(a)** 2.0 kW **(b)** 4.5°C

62. 28 L

64. 28°C

66. **(a)** 2.03 kW **(b)** $7.78\ \text{ft}^2 \cdot \text{h/Btu}$

68. **(a)** 0.457 kg or more
(b) The test samples and the inner surface of the insulation can be preheated to 37.0°Ç as the box is assembled. Then, nothing changes in temperature during the test period and the masses of the test samples and insulation make no difference.

Problem Solutions

11.1 We assume that all the gravitational potential energy given up by the water is converted into internal energy and goes into raising the temperature of the water. Then,

$$\left|\Delta PE_g\right| = Q = mc(\Delta T) \quad \text{or} \qquad T = T_0 + Q/mc = T_0 + \cancel{m}gh/\cancel{m}c = T_0 + gh/c$$

gives $T = 10.0°\text{C} + \dfrac{(9.80\ \text{m/s}^2)(50.0\ \text{m})}{(4\,186\ \text{J/kg}\cdot°\text{C})} = \boxed{10.1°\text{C}}$

11.2 From $Q = mc(\Delta T)$, the final temperature is

$$T = T_0 + \Delta T = T_0 + \frac{Q}{mc} = 20°\text{C} + \frac{(400\ \text{cal})(4.186\ \text{J/1 cal})}{(50.0\times10^{-3}\ \text{kg})(230\ \text{J/kg}\cdot°\text{C})} = \boxed{166°\text{C}}$$

11.3 The mass of water involved is

$$m = \rho V = \left(10^3\ \frac{\text{kg}}{\text{m}^3}\right)(4.00\times10^{11}\ \text{m}^3) = 4.00\times10^{14}\ \text{kg}$$

(a) $Q = mc(\Delta T) = (4.00\times10^{14}\ \text{kg})(4\,186\ \text{J/kg}\cdot°\text{C})(1.00°\text{C}) = \boxed{1.67\times10^{18}\ \text{J}}$

(b) The power input is $\mathcal{P} = 1\,000\ \text{MW} = 1.00\times10^{9}\ \text{J/s}$,

so, $t = \dfrac{Q}{\mathcal{P}} = \dfrac{1.67\times10^{18}\ \text{J}}{1.00\times10^{9}\ \text{J/s}}\left(\dfrac{1\ \text{yr}}{3.156\times10^{7}\ \text{s}}\right) = \boxed{53.1\ \text{yr}}$

11.4 The change in temperature of the rod is

$$\Delta T = \frac{Q}{mc} = \frac{1.00\times10^{4}\ \text{J}}{(0.350\ \text{kg})(900\ \text{J/kg°C})} = 31.7°\text{C}$$

and the change in the length is

$$\Delta L = \alpha L_0(\Delta T)$$

$$= \left[24\times10^{-6}\ (°\text{C})^{-1}\right](20.0\ \text{cm})(31.7°\text{C}) = 1.52\times10^{-2}\ \text{cm} = \boxed{0.152\ \text{mm}}$$

11.5 $Q = mc(\Delta T) = (0.100\text{ kg})(129\text{ J/kg}\cdot{}^\circ\text{C})(100^\circ\text{C} - 20.0^\circ\text{C}) = \boxed{1.03\times 10^{3}\text{ J}}$

11.6 The internal energy converted to mechanical energy in one ascent of the rope is $Q = \Delta PE_g = mgh$. Since $1\text{ Calorie} = 1\,000\text{ calories} = 4\,186\text{ Joules}$,

$$Q = (50.0\text{ kg})(9.80\text{ m/s}^2)(10.0\text{ m})\left(\frac{1\text{ Calorie}}{4\,186\text{ J}}\right) = \boxed{1.17\text{ Calorie}}$$

11.7 The internal energy converted to mechanical energy in the climb is $Q = \Delta PE_g = mgh$. Thus, the required height is

$$h = \frac{Q}{mg} = \frac{(500\text{ Calories})(4\,186\text{ J/1 Calorie})}{(75.0\text{ kg})(9.80\text{ m/s}^2)} = 2.85\times 10^{3}\text{ m} = \boxed{2.85\text{ km}}$$

11.8 The internal energy added to the system equals the gravitational potential energy given up by the 2 falling blocks, or $Q = \Delta PE_g = 2m_b gh$. Thus,

$$\Delta T = \frac{Q}{m_w c_w} = \frac{2m_b gh}{m_w c_w} = \frac{2(1.50\text{ kg})(9.80\text{ m/s}^2)(3.00\text{ m})}{(0.200\text{ kg})(4\,186\text{ J/kg}\cdot{}^\circ\text{C})} = \boxed{0.105^\circ\text{C}}$$

11.9 The mechanical energy transformed into internal energy of the bullet is $Q = \frac{1}{2}(KE_i) = \frac{1}{2}\left(\frac{1}{2}mv_i^2\right) = \frac{1}{4}mv_i^2$. Thus, the change in temperature of the bullet is

$$\Delta T = \frac{Q}{mc} = \frac{\frac{1}{4}mv_i^2}{mc} = \frac{(300\text{ m/s})^2}{4(128\text{ J/kg}\cdot{}^\circ\text{C})} = \boxed{176^\circ\text{C}}$$

11.10 (a) The mechanical energy converted into internal energy of the block is $Q = 0.85(KE_i) = 0.85\left(\frac{1}{2}mv_i^2\right)$. The change in temperature of the block will be

$$\Delta T = \frac{Q}{mc} = \frac{0.85\left(\frac{1}{2}mv_i^2\right)}{mc} = \frac{0.85(3.0\text{ m/s})^2}{2(387\text{ J/kg}\cdot{}^\circ\text{C})} = \boxed{9.9\times 10^{-3}\,{}^\circ\text{C}}$$

(b) The remaining energy is $\boxed{\text{absorbed by the horizontal surface}}$ on which the block slides.

11.11 The quantity of energy transferred from the water-cup combination in a time interval of 1 minute is

$$Q = \left[(mc)_{water} + (mc)_{cup}\right](\Delta T)$$

$$= \left[(0.800\ \text{kg})\left(4\,186\ \frac{\text{J}}{\text{kg}\cdot{}^\circ\text{C}}\right) + (0.200\ \text{kg})\left(900\ \frac{\text{J}}{\text{kg}\cdot{}^\circ\text{C}}\right)\right](1.5^\circ\text{C}) = 5.3\times10^3\ \text{J}$$

The rate of energy transfer is $\mathcal{P} = \dfrac{Q}{\Delta t} = \dfrac{5.3\times10^3\ \text{J}}{60\ \text{s}} = 88\ \dfrac{\text{J}}{\text{s}} = \boxed{88\ \text{W}}$

11.12 If N pellets are use, the mass of the lead is Nm_{pellet}. Since the energy lost by the lead must equal the energy absorbed by the water,

$$\left|Nm_{pellet}c(\Delta T)\right|_{lead} = \left[mc(\Delta T)\right]_{water}$$

or the number of pellets required is

$$N = \frac{m_w c_w (\Delta T)_w}{m_{pellet} c_{lead} |\Delta T|_{lead}}$$

$$= \frac{(0.500\ \text{kg})(4\,186\ \text{J/kg}\cdot{}^\circ\text{C})(25.0^\circ\text{C} - 20.0^\circ\text{C})}{(1.00\times10^{-3}\ \text{kg})(128\ \text{J/kg}\cdot{}^\circ\text{C})(200^\circ\text{C} - 25.0^\circ\text{C})} = \boxed{467}$$

11.13 The energy absorbed by the water equals the energy given up by the gold bar, and the final temperature of both the water and bar is 45.0°C since they come to thermal equilibrium . Thus,

$$\left[mc(\Delta T)\right]_{water} = \left[mc|\Delta T|\right]_{gold}\ \text{, or}$$

$$m_{water} = \frac{(3.00\ \text{kg})(129\ \text{J/kg}\cdot{}^\circ\text{C})(100^\circ\text{C} - 45.0^\circ\text{C})}{(4\,186\ \text{J/kg}\cdot{}^\circ\text{C})(45.0^\circ\text{C} - 25.0^\circ\text{C})} = 0.254\ \text{kg} = \boxed{254\ \text{g}}$$

11.14 The mass of water is

$$m_w = \rho_w V_w = \left(1.00 \text{ g/cm}^3\right)\left(100 \text{ cm}^3\right) = 100 \text{ g} = 0.100 \text{ kg}$$

For each bullet, the energy absorbed by the bullet equals the energy given up by the water, so $m_b c_b \left(T - 20°\text{C}\right) = m_w c_w \left(90°\text{C} - T\right)$. Solving for the final temperature gives

$$T = \frac{m_w c_w \left(90°\text{C}\right) + m_b c_b \left(20°\text{C}\right)}{m_w c_w + m_b c_b}.$$

For the silver bullet, $m_b = 5.0 \times 10^{-3}$ kg and $c_b = 234$ J/kg·°C, giving

$$T_{silver} = \frac{(0.100)(4\,186)(90°\text{C}) + \left(5.0 \times 10^{-3}\right)(234)(20°\text{C})}{(0.100)(4\,186) + \left(5.0 \times 10^{-3}\right)(234)} = \boxed{89.8°\text{C}}$$

For the copper bullet, $m_b = 5.0 \times 10^{-3}$ kg and $c_b = 387$ J/kg·°C, which yields

$$T_{copper} = \frac{(0.100)(4\,186)(90°\text{C}) + \left(5.0 \times 10^{-3}\right)(387)(20°\text{C})}{(0.100)(4\,186) + \left(5.0 \times 10^{-3}\right)(387)} = \boxed{89.7°\text{C}}$$

Thus, $\boxed{\text{the copper bullet wins}}$ the showdown of the water cups.

11.15 The total energy absorbed by the cup, stirrer, and water equals the energy given up by the silver sample. Thus,

$$\left[m_c c_{\text{Al}} + m_s c_{\text{Cu}} + m_w c_w\right](\Delta T)_w = \left[mc|\Delta T|\right]_{\text{Ag}}$$

Solving for the mass of the cup gives

$$m_c = \frac{1}{c_{\text{Al}}}\left[\left(m_{\text{Ag}} c_{\text{Ag}}\right)\frac{|\Delta T|_{\text{Ag}}}{(\Delta T)_w} - m_s c_{\text{Cu}} - m_w c_w\right],$$

or $$m_c = \frac{1}{900}\left[(400 \text{ g})(234)\frac{(87-32)}{(32-27)} - (40 \text{ g})(387) - (225 \text{ g})(4\,186)\right] = \boxed{80 \text{ g}}$$

11.16 The energy absorbed by the water equals the energy given up by the iron and they come to thermal equilibrium at 100°F. Thus, considering cooling 1.00 kg of iron, we have

$$m_w c_w (\Delta T)_w = m_{\text{Fe}} c_{\text{Fe}} |\Delta T|_{\text{Fe}} \qquad \text{or} \qquad m_w = \frac{(1.00\text{ kg}) c_{\text{Fe}} |\Delta T|_{\text{Fe}}}{c_w (\Delta T)_w}$$

giving $$m_w = \frac{(1.00\text{ kg})(448\text{ J/kg}\cdot°\text{C})(500°\text{F} - 100°\text{F})\cancel{(1°\text{C}/\tfrac{9}{5}°\text{F})}}{(4\,186\text{ J/kg}\cdot°\text{C})(100°\text{F} - 75°\text{F})\cancel{(1°\text{C}/\tfrac{9}{5}°\text{F})}} = \boxed{1.7\text{ kg}}$$

11.17 The total energy given up by the copper and the unknown sample equals the total energy absorbed by the calorimeter and water. Hence,

$$m_{\text{Cu}} c_{\text{Cu}} |\Delta T|_{\text{Cu}} + m_{unk} c_{unk} |\Delta T|_{unk} = \left[m_c c_{\text{Al}} + m_w c_w\right](\Delta T)_w$$

Solving for the specific heat of the unknown material gives

$$c_{unk} = \frac{\left[m_c c_{\text{Al}} + m_w c_w\right](\Delta T)_w - m_{\text{Cu}} c_{\text{Cu}} |\Delta T|_{\text{Cu}}}{m_{unk} |\Delta T|_{unk}}, \text{ or}$$

$$c_{unk} = \frac{1}{(70\text{ g})(80°\text{C})}\Big\{\big[(100\text{ g})(900\text{ J/kg}\cdot°\text{C}) + (250\text{ g})(4\,186\text{ J/kg}\cdot°\text{C})\big](10°\text{C})$$
$$-(50\text{ g})(387\text{ J/kg}\cdot°\text{C})(60°\text{C})\Big\} = \boxed{1.8\times 10^3\text{ J/kg}\cdot°\text{C}}$$

11.18 The kinetic energy given up by the car is absorbed as internal energy by the four brake drums (a total mass of 32 kg of iron). Thus, $\Delta KE = Q = m_{drums} c_{\text{Fe}} (\Delta T)$ or

$$\Delta T = \frac{\frac{1}{2} m_{car} v_i^2}{m_{drums} c_{\text{Fe}}} = \frac{\frac{1}{2}(1\,500\text{ kg})(30\text{ m/s})^2}{(32\text{ kg})(448\text{ J/kg}\cdot°\text{C})} = \boxed{47°\text{C}}$$

11.19 Since the temperature of the water and the steel container is unchanged, and neither substance undergoes a phase change, the internal energy of these materials is constant. Thus, all the energy given up by the copper is absorbed by the aluminum, giving $m_{\text{Al}} c_{\text{Al}} (\Delta T)_{\text{Al}} = m_{\text{Cu}} c_{\text{Cu}} |\Delta T|_{\text{Cu}}$, or

$$m_{\text{Al}} = \left(\frac{c_{\text{Cu}}}{c_{\text{Al}}}\right)\left[\frac{|\Delta T|_{\text{Cu}}}{(\Delta T)_{\text{Al}}}\right] m_{\text{Cu}}$$

$$= \left(\frac{387}{900}\right)\left(\frac{85°\text{C} - 25°\text{C}}{25°\text{C} - 5.0°\text{C}}\right)(200\text{ g}) = 2.6\times 10^2\text{ g} = \boxed{0.26\text{ kg}}$$

11.20 The total energy input required is

$$Q = (\text{energy to melt 50 g of ice}) + (\text{energy to warm 50 g of water to }100°\text{C}) + (\text{energy to vaporize 5.0 g water})$$

$$= (50\text{ g})L_f + (50\text{ g})c_{water}(100°\text{C-}0°\text{C}) + (5.0\text{ g})L_v$$

Thus, $Q = (0.050\text{ kg})\left(3.33\times10^5\ \dfrac{\text{J}}{\text{kg}}\right) + (0.050\text{ kg})\left(4\,186\ \dfrac{\text{J}}{\text{kg}\cdot°\text{C}}\right)(100°\text{C-}0°\text{C}) + \left(5.0\times10^{-3}\text{ kg}\right)\left(2.26\times10^6\ \dfrac{\text{J}}{\text{kg}}\right)$

which gives $Q = 4.9\times10^4\text{ J} = \boxed{49\text{ kJ}}$

11.21 The conservation of energy equation for this process is

$(\text{energy to melt ice}) + (\text{energy to warm melted ice to } T) = (\text{energy to cool water to } T)$

or $m_{ice}L_f + m_{ice}c_w(T - 0°\text{C}) = m_w c_w(80°\text{C} - T)$

This yields $T = \dfrac{m_w c_w(80°\text{C}) - m_{ice}L_f}{(m_{ice} + m_w)c_w}$, so

$$T = \frac{(1.0\text{ kg})(4\,186\text{ J/kg}\cdot°\text{C})(80°\text{C}) - (0.100\text{ kg})\left(3.33\times10^5\text{ J/kg}\right)}{(1.1\text{ kg})(4\,186\text{ J/kg}\cdot°\text{C})} = \boxed{65°\text{C}}$$

11.22 The energy required is the following sum of terms:

$$Q = (\text{energy to reach melting point}) + (\text{energy to melt}) + (\text{energy to reach boiling point}) + (\text{energy to vaporize}) + (\text{energy to reach } 110°\text{C})$$

Mathematically,

$$Q = m\left[c_{ice}\left[0°\text{C-}(\text{-}10°\text{C})\right] + L_f + c_w(100°\text{C-}0°\text{C}) + L_v + c_{steam}(110°\text{C-}100°\text{C})\right]$$

This yields

$$Q = (40 \times 10^{-3}\ \text{kg})\left[\left(2\,090\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}\right)(10°\text{C}) + \left(3.33 \times 10^5\ \frac{\text{J}}{\text{kg}}\right) + \left(4\,186\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}\right)(100°\text{C}) + \left(2.26 \times 10^6\ \frac{\text{J}}{\text{kg}}\right) + \left(2\,010\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}\right)(10°\text{C})\right]$$

or $Q = 1.2 \times 10^5\ \text{J} = \boxed{0.12\ \text{MJ}}$

11.23 In order to come to equilibrium at 50°C, the steam must: cool to 100°C, condense, and then cool (as condensed water) to 50°C. Thus, the conservation of energy equation is

$$m_{steam}\left[c_{steam}(120°\text{C} - 100°\text{C}) + L_v + c_w(100°\text{C} - 50°\text{C})\right] = (m_w c_w + m_{cup} c_{\text{Al}})(50°\text{C-}20°\text{C})$$

or $$m_{steam} = \frac{(m_w c_w + m_{cup} c_{\text{Al}})(30°\text{C})}{c_{steam}(20°\text{C}) + L_v + c_w(50°\text{C})}.$$

This gives

$$m_{steam} = \frac{\left[(0.350\ \text{kg})(4\,186\ \text{J/kg}\cdot°\text{C}) + (0.300\ \text{kg})(900\ \text{J/kg}\cdot°\text{C})\right](30°\text{C})}{(2\,010\ \text{J/kg}\cdot°\text{C})(20°\text{C}) + (2.26 \times 10^6\ \text{J/kg}) + (4\,186\ \text{J/kg}\cdot°\text{C})(50°\text{C})},$$

and $m_{steam} = 2.1 \times 10^{-2}\ \text{kg} = \boxed{21\ \text{g}}$

11.24 First, we use the ideal gas law (with $T = 37.0°\text{C} = 310\ \text{K}$) to determine the quantity of water vapor in each exhaled breath:

$$PV = nRT \;\Rightarrow\; n = \frac{PV}{RT} = \frac{\left(3.20\times10^{3}\ \text{Pa}\right)\left(0.600\times10^{-3}\ \text{m}^3\right)}{\left(8.31\ \text{J/mol}\cdot\text{K}\right)\left(310\ \text{K}\right)} = 7.45\times10^{-4}\ \text{mol}$$

or $$m = nM_{water} = \left(7.45\times10^{-4}\ \text{mol}\right)\left(18.0\times10^{-3}\ \text{kg/mol}\right) = 1.34\times10^{-5}\ \text{kg}$$

The energy required to vaporize this much water, and hence the energy carried from the body with each breath is

$$Q = mL_v = \left(1.34\times10^{-5}\ \text{kg}\right)\left(2.26\times10^{6}\ \text{J/kg}\right) = 30.3\ \text{J}$$

The rate of losing energy by exhaling humid air is then

$$\mathcal{P} = \text{Q}\cdot\left(\textit{respiration rate}\right) = \left(30.3\ \frac{\text{J}}{\text{breath}}\right)\left(22.0\ \frac{\text{breaths}}{\text{min}}\right)\left(\frac{1\ \text{min}}{60\ \text{s}}\right) = \boxed{11.1\ \text{W}}$$

11.25 Assuming all work done against friction is used to melt snow, the energy balance equation is $f\cdot s = m_{snow}L_f$. Since $f = \mu_k\left(m_{skier}g\right)$, the distance traveled is

$$s = \frac{m_{snow}L_f}{\mu_k\left(m_{skier}g\right)} = \frac{\left(1.0\ \text{kg}\right)\left(3.33\times10^{5}\ \text{J/kg}\right)}{0.20\left(75\ \text{kg}\right)\left(9.80\ \text{m/s}^2\right)} = 2.3\times10^{3}\ \text{m} = \boxed{2.3\ \text{km}}$$

11.26 At a rate of $400\ \text{kcal/h}$, the excess internal energy that must be eliminated in a half-hour run is

$$Q = \left(400\times10^{3}\ \frac{\text{cal}}{\text{h}}\right)\left(\frac{4.186\ \text{J}}{1\ \text{cal}}\right)\left(0.500\ \text{h}\right) = 8.37\times10^{5}\ \text{J}$$

The mass of water that will be evaporated by this amount of excess energy is

$$m_{evaporated} = \frac{Q}{L_v} = \frac{8.37\times10^{5}\ \text{J}}{2.5\times10^{6}\ \text{J/kg}} = \boxed{0.33\ \text{kg}}$$

The mass of fat burned (and thus, the mass of water produced at a rate of 1 gram of water per gram of fat burned) is

$$m_{produced} = \frac{(400 \text{ kcal/h})(0.500 \text{ h})}{9.0 \text{ kcal/gram of fat}} = 22 \text{ g} = 22 \times 10^{-3} \text{ kg}$$

so the fraction of water needs provided by burning fat is

$$f = \frac{m_{produced}}{m_{evaporated}} = \frac{22 \times 10^{-3} \text{ kg}}{0.33 \text{ kg}} = \boxed{0.066 \text{ or } 6.6\%}$$

11.27 Assume that all the ice melts. If this yields a result $T > 0$, the assumption is valid, otherwise the problem must be solved again based on a different premise. If all ice melts, energy conservation yields

$$m_{ice}\left[c_{ice}\left[0°\text{C-}(\text{-}78°\text{C})\right] + L_f + c_w(T - 0°\text{C})\right] = \left(m_w c_w + m_{cup} c_{\text{Cu}}\right)(25°\text{C} - T)$$

or $$T = \frac{\left(m_w c_w + m_{cup} c_{\text{Cu}}\right)(25°\text{C}) - m_{ice}\left[c_{ice}(78°\text{C}) + L_f\right]}{\left(m_w + m_{ice}\right)c_w + m_{cup} c_{\text{Cu}}}$$

With $m_w = 560$ g, $m_{cup} = 80$ g, $m_{ice} = 40$ g, $c_w = 4\,186 \text{ J/kg} \cdot °\text{C}$

$c_{\text{Cu}} = 387 \text{ J/kg} \cdot °\text{C}$, $c_{ice} = 2\,090 \text{ J/kg} \cdot °\text{C}$, and $L_{\text{f}} = 3.33 \times 10^5 \text{ J/kg}$

this gives $T = \boxed{16\,°\text{C}}$ and the assumption that all ice melts is seen to be valid.

11.28 In one hour, the energy dissipated by the runner is

$$\Delta E = \mathcal{P} \cdot t = (300 \text{ J/s})(3\,600 \text{ s}) = 1.08 \times 10^6 \text{ J}$$

Ninety percent, or $Q = 0.900\left(1.08 \times 10^6 \text{ J}\right) = 9.72 \times 10^5 \text{ J}$, of this is used to evaporate bodily fluids. The mass of fluid evaporated is

$$m = \frac{Q}{L_v} = \frac{9.72 \times 10^5 \text{ J}}{2.41 \times 10^6 \text{ J/kg}} = 0.403 \text{ kg}$$

Assuming the fluid is primarily water, the volume of fluid evaporated in one hour is

$$V = \frac{m}{\rho} = \frac{0.403 \text{ kg}}{1\,000 \text{ kg/m}^3} = \left(4.03 \times 10^{-4} \text{ m}^3\right)\left(\frac{10^6 \text{ cm}^3}{1 \text{ m}^3}\right) = \boxed{403 \text{ cm}^3}$$

11.29 The mass of 2.0 liters of water is $m_w = \rho V = \left(10^3 \text{ kg/m}^3\right)\left(2.0\times 10^{-3} \text{ m}^3\right) = 2.0 \text{ kg}$

The energy required to raise the temperature of the water (and pot) up to the boiling point of water is

$$Q_{boil} = \left(m_w c_w + m_{\text{Al}} c_{\text{Al}}\right)(\Delta T)$$

or
$$Q_{boil} = \left[(2.0 \text{ kg})\left(4\,186 \ \frac{\text{J}}{\text{kg}}\right) + (0.25 \text{ kg})\left(900 \ \frac{\text{J}}{\text{kg}}\right)\right](100°\text{C} - 20°\text{C}) = 6.9\times 10^5 \text{ J}$$

The time required for the $14\,000 \text{ Btu/h}$ burner to produce this much energy is

$$t_{boil} = \frac{Q_{boil}}{14\,000 \text{ Btu/h}} = \frac{6.9\times 10^5 \text{ J}}{14\,000 \text{ Btu/h}}\left(\frac{1 \text{ Btu}}{1.054\times 10^3 \text{ J}}\right) = 4.7\times 10^{-2} \text{ h} = \boxed{2.8 \text{ min}}$$

Once the boiling temperature is reached, the additional energy required to evaporate all of the water is

$$Q_{evaporate} = m_w L_v = (2.0 \text{ kg})\left(2.26\times 10^6 \text{ J/kg}\right) = 4.5\times 10^6 \text{ J}$$

and the time required for the burner to produce this energy is

$$t_{boil} = \frac{Q_{evaporate}}{14\,000 \text{ Btu/h}} = \frac{4.5\times 10^6 \text{ J}}{14\,000 \text{ Btu/h}}\left(\frac{1 \text{ Btu}}{1.054\times 10^3 \text{ J}}\right) = 0.31 \text{ h} = \boxed{18 \text{ min}}$$

11.30 The energy that must be absorbed to cool the water and cup to 0°C is

$$Q_1 = \left(m_w c_w + m_{cup} c_{\text{Al}}\right)(\Delta T)$$

$$= \left[(0.180 \text{ kg})(4\,186 \text{ J/kg}\cdot°\text{C}) + (0.100 \text{ kg})(900 \text{ J/kg}\cdot°\text{C})\right](30.0°\text{C}) = 2.53\times 10^4 \text{ J}$$

(a) The amount of ice, at 0°C, that must melt to absorb energy equal to Q_1 is

$$m = \frac{Q_1}{L_f} = \frac{2.53\times 10^4 \text{ J}}{3.33\times 10^5 \text{ J/kg}} = 7.6\times 10^{-2} \text{ kg} = 76 \text{ g}$$

Hence, if 100 g of ice is used, not all of it will melt. Rather, the final temperature is $\boxed{0°\text{C} \text{ with 24 g of ice left over}}$.

(b) If 50 g of ice is used, all of the ice will melt and the conservation of energy equation is

$$m_{ice}\left[L_f + c_w\left(T - 0°\text{C}\right)\right] = \left(m_w c_w + m_{cup} c_{\text{Al}}\right)\left(30°\text{C} - T\right)$$

Thus,

$$\left(50\text{ g}\right)\left[\left(3.33\times 10^5\ \frac{\text{J}}{\text{kg}}\right) + \left(4\,186\ \frac{\text{J}}{\text{kg}\cdot\text{C}}\right)T\right] =$$
$$\left[\left(180\text{ g}\right)\left(4\,186\ \frac{\text{J}}{\text{kg}\cdot\text{C}}\right) + \left(100\text{ g}\right)\left(900\ \frac{\text{J}}{\text{kg}\cdot\text{C}}\right)\right]\left(30°\text{C} - T\right)$$

This yields a final temperature of $T = \boxed{8.2°\text{C}}$

11.31 The energy required to melt 50 g of ice is

$$Q_1 = m_{ice} L_f = \left(0.050\text{ kg}\right)\left(333\ \text{kJ/kg}\right) = 16.7\ \text{kJ}$$

The energy needed to warm 50 g of melted ice from 0°C to 100°C is

$$Q_2 = m_{ice} c_w\left(\Delta T\right) = \left(0.050\text{ kg}\right)\left(4.186\ \text{kJ/kg}\cdot°\text{C}\right)\left(100°\text{C}\right) = 20.9\ \text{kJ}$$

(a) If 10 g of steam is used, the energy it will give up as it condenses is

$$Q_3 = m_s L_v = \left(0.010\text{ kg}\right)\left(2\,260\ \text{kJ/kg}\right) = 22.6\ \text{kJ}$$

Since $Q_3 > Q_1$, all of the ice will melt . However, $Q_3 < Q_1 + Q_2$, so the final temperature is less than 100°C. From conservation of energy, we find

$$m_{ice}\left[L_f + c_w\left(T - 0°\text{C}\right)\right] = m_{steam}\left[L_v + c_w\left(100°\text{C} - T\right)\right],\text{ or}$$

$$T = \frac{m_{steam}\left[L_v + c_w\left(100°\text{C}\right)\right] - m_{ice}L_f}{\left(m_{ice} + m_{steam}\right)c_w},$$

giving $$T = \frac{\left(10\text{ g}\right)\left[2.26\times 10^6 + \left(4\,186\right)\left(100\right)\right] - \left(50\text{ g}\right)\left(3.33\times 10^5\right)}{\left(50\text{ g} + 10\text{ g}\right)\left(4\,186\right)} = \boxed{40°\text{C}}$$

(b) If only 1.0 g of steam is used, then $Q_3' = m_s L_v = 2.26$ kJ. The energy 1.0 g of condensed steam can give up as it cools from 100°C to 0°C is

$$Q_4 = m_s c_w (\Delta T) = (1.0\times10^{-3}\ \text{kg})(4.186\ \text{kJ/kg}\cdot{}^\circ\text{C})(100^\circ\text{C}) = 0.419\ \text{kJ}$$

Since $Q_3' + Q_4$ is less than Q_1, not all of the 50 g of ice will melt, so the final temperature will be $\boxed{0^\circ\text{C}}$. The mass of ice which melts as the steam condenses and the condensate cools to 0°C is

$$m = \frac{Q_3' + Q_4}{L_f} = \frac{(2.26+0.419)\ \text{kJ}}{333\ \text{kJ/kg}} = 8.0\times10^{-3}\ \text{kg} = \boxed{8.0\ \text{g}}$$

11.32 The total surface area of the house is

$$A = A_{\text{side walls}} + A_{\text{end walls}} + A_{\text{gables}} + A_{\text{roof}}$$

where $A_{\text{side walls}} = 2\left[(5.00\ \text{m})\times(10.0\ \text{m})\right] = 100\ \text{m}^2$

$A_{\text{end walls}} = 2\left[(5.00\ \text{m})\times(8.00\ \text{m})\right] = 80.0\ \text{m}^2$

$A_{\text{gables}} = 2\left[\frac{1}{2}(base)\times(altitude)\right] = 2\left[\frac{1}{2}(8.00\ \text{m})\times(4.00\ \text{m})\tan 37.0^\circ\right] = 24.1\ \text{m}^2$

$A_{roof} = 2\left[(10.0\ \text{m})\times(4.00\ \text{m}/\cos 37.0^\circ)\right] = 100\ \text{m}^2$

Thus, $A = 100\ \text{m}^2 + 80.0\ \text{m}^2 + 24.1\ \text{m}^2 + 100\ \text{m}^2 = 304\ \text{m}^2$

With an average thickness of 0.210 m, average thermal conductivity of $4.8\times10^{-4}\ \text{kW/m}\cdot{}^\circ\text{C}$, and a 25.0°C difference between inside and outside temperatures, the energy transfer from the house to the outside air each day is

$$E = \mathcal{P}(\Delta t) = \left[\frac{kA(\Delta T)}{L}\right](\Delta t) = \left[\frac{(4.8\times10^{-4}\ \text{kW/m}\cdot{}^\circ\text{C})(304\ \text{m}^2)(25.0^\circ\text{C})}{0.210\ \text{m}}\right](86\,400\ \text{s})$$

or $E = 1.5\times10^6\ \text{kJ} = 1.5\times10^9\ \text{J}$

The volume of gas that must be burned to replace this energy is

$$V = \frac{E}{heat\ of\ combustion} = \frac{1.5\times10^9\ \text{J}}{(9\,300\ \text{kcal/m}^3)(4\,186\ \text{J/kcal})} = \boxed{39\ \text{m}^3}$$

11.33 The rate of energy transfer through a block of the given dimensions is

$$\mathcal{P} = \frac{\Delta Q}{\Delta t} = kA\left(\frac{\Delta T}{L}\right) = k\left(15\times 10^{-4}\ \text{m}^2\right)\left(\frac{30°\text{C}}{0.080\ \text{m}}\right) = k\left(0.56\ \text{m}\cdot°\text{C}\right)$$

where k is the thermal conductivity of the material.

(a) For a copper block, $k = 397\ \text{J/s}\cdot\text{m}\cdot°\text{C}$ and

$$\mathcal{P} = \left(397\ \frac{\text{J}}{\text{s}\cdot\text{m}\cdot°\text{C}}\right)\left(0.56\ \text{m}\cdot°\text{C}\right) = 0.22\ \frac{\text{kJ}}{\text{s}} = \boxed{0.22\ \text{kW}}$$

(b) For air, $\mathcal{P} = \left(0.0234\ \frac{\text{J}}{\text{s}\cdot\text{m}\cdot°\text{C}}\right)\left(0.56\ \text{m}\cdot°\text{C}\right) = 0.013\ \frac{\text{J}}{\text{s}} = \boxed{13\ \text{mW}}$

(c) For wood, $\mathcal{P} = \left(0.10\ \frac{\text{J}}{\text{s}\cdot\text{m}\cdot°\text{C}}\right)\left(0.56\ \text{m}\cdot°\text{C}\right) = 0.056\ \frac{\text{J}}{\text{s}} = \boxed{56\ \text{mW}}$

11.34 (a) With the outside temperature higher than that in the house, we have $\Delta T = T_h - T_c = 90°\text{F} - 70°\text{F} = 20°\text{F} = \frac{5}{9}(20°) = 11°\text{C}$ and the rate of energy transfer *into* the house is

$$\mathcal{P} = kA\left(\frac{\Delta T}{L}\right) = \left(0.84\ \frac{\text{J}}{\text{s}\cdot\text{m}\cdot°\text{C}}\right)\left(0.16\ \text{m}^2\right)\left(\frac{11°\text{C}}{3.0\times 10^{-3}\ \text{m}}\right) = 5.0\times 10^{2}\ \frac{\text{J}}{\text{s}}$$

or $\mathcal{P} = \boxed{0.50\ \text{kW into the house}}$

(b) With the interior warmer than the outside air, we have $\Delta T = T_h - T_c = 70°\text{F} - 0°\text{F} = 70°\text{F} = \frac{5}{9}(70°) = 39°\text{C}$ and the rate of energy transfer *out of* the house is

$$\mathcal{P} = kA\left(\frac{\Delta T}{L}\right) = \left(0.84\ \frac{\text{J}}{\text{s}\cdot\text{m}\cdot°\text{C}}\right)\left(0.16\ \text{m}^2\right)\left(\frac{39°\text{C}}{3.0\times 10^{-3}\ \text{m}}\right) = 1.7\times 10^{3}\ \frac{\text{J}}{\text{s}}$$

or $\mathcal{P} = \boxed{1.7\ \text{kW out of the house}}$

11.35 $\mathcal{P} = kA\left(\frac{\Delta T}{L}\right)$, with $k = 0.200\ \frac{\text{cal}}{\text{cm}\cdot{}^\circ\text{C}\cdot\text{s}}\left(\frac{10^2\ \text{cm}}{1\ \text{m}}\right)\left(\frac{4.186\ \text{J}}{1\ \text{cal}}\right) = 83.7\ \frac{\text{J}}{\text{s}\cdot\text{m}\cdot{}^\circ\text{C}}$

Thus, the energy transfer rate is

$$\mathcal{P} = \left(83.7\ \frac{\text{J}}{\text{s}\cdot\text{m}\cdot{}^\circ\text{C}}\right)\left[(8.00\ \text{m})(50.0\ \text{m})\right]\left(\frac{200^\circ\text{C} - 20.0^\circ\text{C}}{1.50\times 10^{-2}\ \text{m}}\right)$$

$$= 4.02\times 10^{8}\ \frac{\text{J}}{\text{s}} = \boxed{402\ \text{MW}}$$

11.36 Since the air temperature inside the box remains constant, the power input from the heater must equal the energy transfer to the exterior. Thus, $\mathcal{P} = kA\left(\frac{\Delta T}{L}\right)$, giving

$$k = \frac{\mathcal{P}}{A}\left(\frac{L}{\Delta T}\right) = \frac{(10.0\ \text{W})}{(1.20\ \text{m}^2)}\left(\frac{4.00\times 10^{-2}\ \text{m}}{15.0^\circ\text{C}}\right) = \boxed{2.22\times 10^{-2}\ \text{W/m}\cdot{}^\circ\text{C}}$$

11.37 $R = \Sigma R_i = R_{\substack{outside\\ air\ film}} + R_{shingles} + R_{sheathing} + R_{cellulose} + R_{dry\ wall} + R_{\substack{inside\\ air\ film}}$

$$R = \left[0.17 + 0.87 + 1.32 + 3(3.70) + 0.45 + 0.17\right]\ \frac{\text{ft}^2\cdot{}^\circ\text{F}}{\text{Btu/h}} = \boxed{14\ \frac{\text{ft}^2\cdot{}^\circ\text{F}}{\text{Btu/h}}}$$

11.38 The rate of energy transfer through a compound slab is

$$\mathcal{P} = \frac{A(\Delta T)}{R},\ \text{where}\ R = \Sigma\, L_i/k_i$$

(a) For the Thermopane, $R = R_{pane} + R_{trapped\ air} + R_{pane} = 2R_{pane} + R_{trapped\ air}$

Thus, $$R = 2\left(\frac{0.50\times 10^{-2}\ \text{m}}{0.84\ \text{W/m}\cdot{}^\circ\text{C}}\right) + \frac{1.0\times 10^{-2}\ \text{m}}{0.0234\ \text{W/m}\cdot{}^\circ\text{C}} = 0.44\ \frac{\text{m}^2\cdot{}^\circ\text{C}}{\text{W}}$$

and $$\mathcal{P} = \frac{(1.0\ \text{m}^2)(23^\circ\text{C})}{0.44\ \text{m}^2\cdot{}^\circ\text{C/W}} = \boxed{52\ \text{W}}$$

(b) For the 1.0 cm thick pane of glass:

$$R = \frac{1.0\times10^{-2}\text{ m}}{0.84\text{ W/m}\cdot{}^\circ\text{C}} = 1.2\times10^{-2}\ \frac{\text{m}^2\cdot{}^\circ\text{C}}{\text{W}}$$

so $\mathcal{P} = \dfrac{\left(1.0\text{ m}^2\right)\left(23^\circ\text{C}\right)}{1.2\times10^{-2}\text{ m}^2\cdot{}^\circ\text{C/W}} = 1.9\times10^3\text{ W} = \boxed{1.9\text{ kW}}$, 37 times greater

11.39 When the temperature of the junction stabilizes, the energy transfer rate must be the same for each of the rods, or $\mathcal{P}_{\text{Cu}} = \mathcal{P}_{\text{Al}}$. The cross-sectional areas of the rods are equal, and if the temperature of the junction is 50°C, the temperature difference is $\Delta T = 50^\circ\text{C}$ for each rod.

Thus, $\mathcal{P}_{\text{Cu}} = k_{\text{Cu}}A\left(\dfrac{\Delta T}{L_{\text{Cu}}}\right) = k_{\text{Al}}A\left(\dfrac{\Delta T}{L_{\text{Al}}}\right) = \mathcal{P}_{\text{Al}}$, which gives

$$L_{\text{Al}} = \left(\frac{k_{\text{Al}}}{k_{\text{Cu}}}\right)L_{\text{Cu}} = \left(\frac{238\text{ W/m}\cdot{}^\circ\text{C}}{397\text{ W/m}\cdot{}^\circ\text{C}}\right)(15\text{ cm}) = \boxed{9.0\text{ cm}}$$

11.40 The energy transfer rate is $\mathcal{P} = \dfrac{\Delta Q}{\Delta t} = \dfrac{m_{ice}L_f}{\Delta t} = \dfrac{(5.0\text{ kg})\left(3.33\times10^5\text{ J/kg}\right)}{(8.0\text{ h})(3\,600\text{ s/1 h})} = 58\text{ W}$

Thus, $\mathcal{P} = kA\left(\dfrac{\Delta T}{L}\right)$ gives the thermal conductivity as

$$k = \frac{\mathcal{P}\cdot L}{A(\Delta T)} = \frac{(58\text{ W})\left(2.0\times10^{-2}\text{ m}\right)}{\left(0.80\text{ m}^2\right)\left(25^\circ\text{C}-5.0^\circ\text{C}\right)} = \boxed{7.2\times10^{-2}\text{ W/m}\cdot{}^\circ\text{C}}$$

11.41 The absolute temperature of the sphere is $T = 473\text{ K}$ and that of the surroundings is $T_0 = 295\text{ K}$. For a perfect black-body radiator, the emissivity is $e = 1$. The net power radiated by the sphere is

$$\mathcal{P}_{net} = \sigma Ae\left(T^4 - T_0^4\right)$$

$$= \left(5.67\times10^{-8}\ \frac{\text{W}}{\text{m}^2\cdot\text{K}^4}\right)\left[4\pi(0.060\text{ m})^2\right]\left[(473\text{ K})^4 - (295\text{ K})^4\right]$$

or $\mathcal{P}_{net} = 1.1\times10^2\text{ W} = \boxed{0.11\text{ kW}}$

11.42 With an emissivity of $e = 0.965$, temperature of $T = 5\,800\text{ K}$, and radius of $r = 6.96 \times 10^8\text{ m}$, the total power radiated by the spherical Sun is

$$\mathcal{P} = \sigma A e T^4 = \left(5.67 \times 10^{-8}\ \frac{\text{W}}{\text{m}^2 \cdot \text{K}^4}\right)\left[4\pi\left(6.96 \times 10^8\text{ m}\right)^2\right](0.965)(5\,800\text{ K})^4$$

or $\mathcal{P} = \boxed{3.77 \times 10^{26}\text{ W}}$

11.43 The absolute temperature of the pizza is $T = 373\text{ K}$ and the total surface area of this cylindrical object is

$$A = \pi r^2 + 2\pi r L + \pi r^2 = 2\pi\left[(0.35\text{ m})^2 + (0.35\text{ m})(0.020\text{ m})\right] = 0.81\text{ m}^2$$

The power radiated into space (or the rate of energy loss) is

$$\mathcal{P} = \sigma A e T^4 = \left(5.67 \times 10^{-8}\ \frac{\text{W}}{\text{m}^2 \cdot \text{K}^4}\right)\left(0.81\text{ m}^2\right)(0.8)(373\text{ K})^4$$

$$= 7.1 \times 10^2\text{ W} \quad \boxed{\sim 10^3\text{ W}}$$

11.44 The net power radiated is $\mathcal{P}_{net} = \sigma A e\left(T^4 - T_0^4\right)$, so the temperature of the radiator is $T = \left[T_0^4 + \frac{\mathcal{P}_{net}}{\sigma A e}\right]^{\frac{1}{4}}$. If the temperature of the surroundings is $T_0 = 22°\text{C} = 295\text{ K}$,

$$T = \left[(295\text{ K})^4 + \frac{25\text{ W}}{\left(5.67 \times 10^{-8}\text{ W/m}^2 \cdot \text{K}^4\right)\left(2.5 \times 10^{-5}\text{ m}^2\right)(0.90)}\right]^{\frac{1}{4}}$$

$$= 2.1 \times 10^3\text{ K} = \boxed{1.8 \times 10^3\ °\text{C}}$$

11.45 The absolute temperatures of the two stars are $T_X = 6\,000\text{ K}$ and $T_Y = 12\,000\text{ K}$. Thus, the ratio of their radiated powers is

$$\frac{\mathcal{P}_Y}{\mathcal{P}_X} = \frac{\sigma A e T_Y^4}{\sigma A e T_X^4} = \left(\frac{T_Y}{T_X}\right)^4 = (2)^4 = \boxed{16}$$

11.46 Assume that the ground below the pavement is a very good insulator and that the emissivity of the blacktop is unity. Then, in steady state, the square meter of asphalt must radiate energy at the same rate as receiving it from the Sun. From $\mathcal{P} = \sigma A e T^4$, the temperature of the asphalt is

$$T = \left[\frac{\mathcal{P}}{\sigma A e}\right]^{\frac{1}{4}} = \left[\frac{1\,000\text{ W}}{\left(5.67\times10^{-8}\text{ W/m}^2\cdot\text{K}^4\right)\left(1.00\text{ m}^2\right)(1.00)}\right]^{\frac{1}{4}} = 364\text{ K} = \boxed{91°\text{C}}$$

11.47 At a pressure of 1 atm, water boils at 100°C. Thus, the temperature on the interior of the copper kettle is 100°C and the energy transfer rate through it is

$$\mathcal{P} = kA\left(\frac{\Delta T}{L}\right) = \left(397\ \frac{\text{W}}{\text{m}\cdot°\text{C}}\right)\left[\pi(0.10\text{ m})^2\right]\left(\frac{102°\text{C} - 100°\text{C}}{2.0\times10^{-3}\text{ m}}\right)$$

$$= 1.2\times10^4\text{ W} = \boxed{12\text{ kW}}$$

11.48 The mass of the water in the heater is

$$m = \rho V = \left(10^3\ \frac{\text{kg}}{\text{m}^3}\right)(50.0\text{ gal})\left(\frac{3.786\text{ L}}{1\text{ gal}}\right)\left(\frac{1\text{ m}^3}{10^3\text{ L}}\right) = 189\text{ kg}$$

The energy required to raise the temperature of the water from 20.0°C to 60.0°C is

$$Q = mc(\Delta T) = (189\text{ kg})(4\,186\text{ J/kg})(60.0°\text{C} - 20.0°\text{C}) = 3.17\times10^7\text{ J}$$

The time required for the water heater to transfer this energy is

$$t = \frac{Q}{\mathcal{P}} = \frac{3.17\times10^7\text{ J}}{4\,800\text{ J/s}}\left(\frac{1\text{ h}}{3\,600\text{ s}}\right) = \boxed{1.83\text{ h}}$$

11.49 At an average rate of 1000 W, the energy radiated between 4 PM and 8 AM is

$$Q = \mathcal{P}t = \left(1\,000\ \frac{\text{J}}{\text{s}}\right)(16.0\text{ h})\left(\frac{3\,600\text{ s}}{1\text{ h}}\right) = 5.76\times10^7\text{ J}$$

The mass of stone which can give up this quantity of energy as its temperature drops from 30°C to 18°C is

$$m = \frac{Q}{c(\Delta T)} = \frac{5.76\times10^7\text{ J}}{(800\text{ J/kg}\cdot°\text{C})(12°\text{C})} = \boxed{6.0\times10^3\text{ kg}}$$

11.50 The energy needed is

$$Q = mc(\Delta T) = (\rho V)c(\Delta T)$$

$$= \left[\left(10^3 \ \frac{\text{kg}}{\text{m}^3}\right)\left(1.00 \text{ m}^3\right)\right]\left(4\,186 \ \text{J/kg}\right)\left(40.0°\text{C}\right) = 1.67\times 10^8 \ \text{J}$$

The power input is $\mathcal{P} = \left(550 \ \text{W/m}^2\right)\left(6.00 \text{ m}^2\right) = 3.30\times 10^3 \ \text{J/s}$, so the time required is

$$t = \frac{Q}{\mathcal{P}} = \frac{1.67\times 10^8 \ \text{J}}{3.30\times 10^3 \ \text{J/s}}\left(\frac{1 \text{ h}}{3\,600 \text{ s}}\right) = \boxed{14.1 \text{ h}}$$

11.51 The energy conservation equation is

$$m_{\text{Pb}}c_{\text{Pb}}(98°\text{C} - 12°\text{C}) = m_{ice}L_f + \left[\left(m_{ice} + m_w\right)c_w + m_{cup}c_{\text{Cu}}\right](12°\text{C} - 0°\text{C})$$

This gives

$$m_{\text{Pb}}\left(128 \ \frac{\text{J}}{\text{kg}\cdot°\text{C}}\right)(86°\text{C}) = \left(0.040 \text{ kg}\right)\left(3.33\times 10^5 \ \text{J/kg}\right)$$
$$+\left[\left(0.24 \text{ kg}\right)\left(4\,186 \ \text{J/kg}\cdot°\text{C}\right) + \left(0.100 \text{ kg}\right)\left(357 \ \text{J/kg}\cdot°\text{C}\right)\right](12°\text{C})$$

or $\quad m_{\text{Pb}} = \boxed{2.3 \text{ kg}}$

11.52 We approximate the latent heat of vaporization of water on the skin (at 37°C) by asking how much energy would be needed to raise the temperature of 1.0 kg of water to the boiling point and evaporate it. The answer is

$$L_v^{37°\text{C}} \approx c_{water}\left(\Delta T\right) + L_v^{100°\text{C}} = \left(4\,186 \ \text{J/kg}\cdot°\text{C}\right)\left(100°\text{C} - 37°\text{C}\right) + 2.26\times 10^6 \ \text{J/kg}$$

or $\quad L_v^{37°\text{C}} \approx 2.5\times 10^6 \ \text{J/kg}$

Assuming that you are approximately 2.0 m tall and 0.30 m wide, you will cover an area of $A = (2.0 \text{ m})(0.30 \text{ m}) = 0.60 \text{ m}^2$ of the beach, and the energy you receive from the sunlight in one hour is

$$Q = IA(\Delta t) = \left(1\,000 \ \text{W/m}^2\right)\left(0.60 \text{ m}^2\right)\left(3\,600 \text{ s}\right) = 2.2\times 10^6 \ \text{J}$$

The quantity of water this much energy could evaporate from your body is

$$m = \frac{Q}{L_v^{37°\text{C}}} \approx \frac{2.2 \times 10^6 \text{ J}}{2.5 \times 10^6 \text{ J/kg}} = \boxed{0.9 \text{ kg}}$$

The volume of this quantity of water is $V = \dfrac{m}{\rho} = \dfrac{0.9 \text{ kg}}{10^3 \text{ kg/m}^3} \approx 10^{-3} \text{ m}^3 = 1 \text{ L}$

Thus, you will need to drink almost a liter of water each hour to stay hydrated. Note, of course, that any perspiration that drips off your body does not contribute to the cooling process, so drink up!

11.53 The conservation of energy equation is

$$\left(m_w c_w + m_{cup} c_{glass}\right)\left(T - 27°\text{C}\right) = m_{\text{Cu}} c_{\text{Cu}} \left(90°\text{C} - T\right)$$

This gives $\quad T = \dfrac{m_{\text{Cu}} c_{\text{Cu}} \left(90°\text{C}\right) + \left(m_w c_w + m_{cup} c_{glass}\right)\left(27°\text{C}\right)}{m_w c_w + m_{cup} c_{glass} + m_{\text{Cu}} c_{\text{Cu}}}$, or

$$T = \frac{(0.200)(387)(90°\text{C}) + \left[(0.400)(4\,186) + (0.300)(837)\right](27°\text{C})}{(0.400)(4\,186) + (0.300)(837) + (0.200)(387)} = \boxed{29°\text{C}}$$

11.54 The energy added to the air in one hour is

$$Q = \left(\mathcal{P}_{total}\right)t = \left[10(200 \text{ W})\right](3\,600 \text{ s}) = 7.20 \times 10^6 \text{ J}$$

and the mass of air in the room is

$$m = \rho V = \left(1.3 \text{ kg/m}^3\right)\left[(6.0 \text{ m})(15.0 \text{ m})(3.0 \text{ m})\right] = 3.5 \times 10^2 \text{ kg}$$

The change in temperature is $\Delta T = \dfrac{Q}{mc} = \dfrac{7.2 \times 10^6 \text{ J}}{\left(3.5 \times 10^2 \text{ kg}\right)\left(837 \text{ J/kg} \cdot °\text{C}\right)} = 25°\text{C}$

giving $T = T_0 + \Delta T = 20°\text{C} + 25°\text{C} = \boxed{45°\text{C}}$

11.55 The rate of energy transfer to the surface is

$$\mathcal{P} = kA\left(\frac{\Delta T}{L}\right) = \left(0.210\ \frac{\text{W}}{\text{m}\cdot{}^\circ\text{C}}\right)\left(1.40\ \text{m}^2\right)\left(\frac{37.0^\circ\text{C} - 34.0^\circ\text{C}}{0.025\,0\ \text{m}}\right)$$

which gives $\mathcal{P} = 35.3\ \dfrac{\text{J}}{\text{s}}\left(\dfrac{1\ \text{kcal}}{4\,186\ \text{J}}\right)\left(\dfrac{3\,600\ \text{s}}{1\ \text{h}}\right) = \boxed{30.3\ \text{kcal/h}}$

Since this is less than $240\ \text{kcal/h}$, blood flow is necessary for cooling.

11.56 (a) In steady state, the energy transfer rate is the same for each of the rods, or

$\mathcal{P}_{\text{Al}} = \mathcal{P}_{\text{Fe}}$. Thus, $k_{\text{Al}}A\left(\dfrac{100^\circ\text{C} - T}{L}\right) = k_{\text{Fe}}A\left(\dfrac{T - 0^\circ\text{C}}{L}\right)$

giving $T = \left(\dfrac{k_{\text{Al}}}{k_{\text{Al}} + k_{\text{Fe}}}\right)(100^\circ\text{C}) = \left(\dfrac{238}{238 + 79.5}\right)(100^\circ\text{C}) = \boxed{75.0^\circ\text{C}}$

(b) If $L = 15$ cm and $A = 5.0\ \text{cm}^2$, the energy conducted in 30 min is

$$Q = \mathcal{P}_{\text{Al}}\cdot t = \left[\left(238\ \frac{\text{W}}{\text{m}\cdot{}^\circ\text{C}}\right)\left(5.0\times10^{-4}\ \text{m}^2\right)\left(\frac{100^\circ\text{C} - 75.0^\circ\text{C}}{0.15\ \text{m}}\right)\right]\left(1\,800\ \text{s}\right)$$

$$= 3.6\times10^4\ \text{J} = \boxed{36\ \text{kJ}}$$

11.57 The rate at which energy must be added to the water is

$$\mathcal{P} = \frac{\Delta Q}{\Delta t} = \left(\frac{\Delta m}{\Delta t}\right)L_v = \left[\left(0.500\ \frac{\text{kg}}{\text{min}}\right)\left(\frac{1\ \text{min}}{60\ \text{s}}\right)\right]\left(2.26\times10^6\ \frac{\text{J}}{\text{kg}}\right) = 1.88\times10^4\ \text{W}$$

From $\mathcal{P} = kA\left(\dfrac{T - 100^\circ\text{C}}{L}\right)$, the temperature of the bottom surface is

$$T = 100^\circ\text{C} + \frac{\mathcal{P}\cdot L}{k\,A} = 100^\circ\text{C} + \frac{\left(1.88\times10^4\ \text{W}\right)\left(0.500\times10^{-2}\ \text{m}\right)}{\left(238\ \text{W/m}\cdot{}^\circ\text{C}\right)\left[\pi\left(0.120\ \text{m}\right)^2\right]} = \boxed{109^\circ\text{C}}$$

11.58 (a) $Q = mc(\Delta T) = (0.600)mgh$ gives $\Delta T = \dfrac{(0.600)gh}{c}$, or

$$T = T_0 + \Delta T = 25.0°\text{C} + \frac{(0.600)(9.80\ \text{m/s}^2)(50.0\ \text{m})}{387\ \text{J/kg}\cdot°\text{C}} = \boxed{25.8°\text{C}}$$

(b) $\boxed{\text{No}}$. As seen in the above calculation, the mass of the coin cancels.

11.59 In the steady state, $\mathcal{P}_{\text{Au}} = \mathcal{P}_{\text{Ag}}$, or $k_{\text{Au}}A\left(\dfrac{80.0°\text{C} - T}{L}\right) = k_{\text{Ag}}A\left(\dfrac{T - 30.0°\text{C}}{L}\right)$

This gives

$$T = \frac{k_{\text{Au}}(80.0°\text{C}) + k_{\text{Ag}}(30.0°\text{C})}{k_{\text{Au}} + k_{\text{Ag}}} = \frac{314(80.0°\text{C}) + 427(30.0°\text{C})}{314 + 427} = \boxed{51.2°\text{C}}$$

11.60 (a) The rate work is done against friction is

$$\mathcal{P} = f \cdot v = (50\ \text{N})(40\ \text{m/s}) = 2.0 \times 10^3\ \text{J/s} = \boxed{2.0\ \text{kW}}$$

(b) In a time interval of 10 s, the energy added to the 10-kg of iron is

$$Q = \mathcal{P} \cdot t = (2.0 \times 10^3\ \text{J/s})(10\ \text{s}) = 2.0 \times 10^4\ \text{J}$$

and the change in temperature is

$$\Delta T = \frac{Q}{mc} = \frac{2.0 \times 10^4\ \text{J}}{(10\ \text{kg})(448\ \text{J/kg}\cdot°\text{C})} = \boxed{4.5°\text{C}}$$

11.61 (a) The energy required to raise the temperature of the brakes to the melting point at 660°C is

$$Q = mc(\Delta T) = (6.0\ \text{kg})(900\,\text{J/kg}\cdot°\text{C})(660°\text{C} - 20°\text{C}) = 3.46 \times 10^6\ \text{J}$$

The internal energy added to the brakes on each stop is

$$Q_1 = \Delta KE = \frac{1}{2}m_{car}v_i^2 = \frac{1}{2}(1\,500\ \text{kg})(25\ \text{m/s})^2 = 4.69 \times 10^5\ \text{J}$$

The number of stops before reaching the melting point is

$$N = \frac{Q}{Q_1} = \frac{3.46 \times 10^6\ \text{J}}{4.69 \times 10^5\ \text{J}} = \boxed{7\ \text{stops}}$$

(b) This calculation assumes no energy loss to the surroundings and that all internal energy generated stays with the brakes. Neither of these will be true in a realistic case.

11.62 We assume that the time interval is so short that only the part of the rod immersed in the liquid helium undergoes a change in temperature. The mass of this half of the rod is

$$m_{\text{Al}} = \rho_{\text{Al}}\left[A(L/2)\right] = \left(2.70 \times 10^3\ \text{kg/m}^3\right)\left(2.0 \times 10^{-4}\ \text{m}^2\right)(0.50\ \text{m}) = 0.27\ \text{kg}$$

From conservation of energy, $m_{\text{He}}\left(L_v\right)_{\text{He}} = m_{\text{Al}}c_{\text{Al}}\left|\Delta T\right|$, or the mass of helium evaporated is

$$m_{\text{He}} = \frac{m_{\text{Al}}c_{\text{Al}}\left|\Delta T\right|}{\left(L_v\right)_{\text{He}}} = \frac{(0.27\ \text{kg})(900\ \text{J/kg}\cdot{}^\circ\text{C})(295.8^\circ\text{C})}{2.09 \times 10^4\ \text{J/kg}} = 3.4\ \text{kg}$$

The volume of liquid helium evaporated is then

$$V_{\text{He}} = \frac{m_{\text{He}}}{\rho_{\text{He}}} = \frac{3.4\ \text{kg}}{122\ \text{kg/m}^3}\left(\frac{10^3\ \text{L}}{1\ \text{m}^3}\right) = \boxed{28\ \text{L}}$$

11.63 (a) The internal energy ΔQ added to the volume ΔV of liquid that flows through the calorimeter in time Δt is $\Delta Q = (\Delta m)c(\Delta T) = \rho(\Delta V)c(\Delta T)$. Thus, the rate of adding energy is

$$\boxed{\frac{\Delta Q}{\Delta t} = \rho c(\Delta T)\left(\frac{\Delta V}{\Delta t}\right)}$$

where $\left(\frac{\Delta V}{\Delta t}\right)$ is the flow rate through the calorimeter.

(b) From the result of part (a), the specific heat is

$$c = \frac{\Delta Q/\Delta t}{\rho(\Delta T)(\Delta V/\Delta t)} = \frac{40\ \text{J/s}}{\left(0.72\ \text{g/cm}^3\right)(5.8^\circ\text{C})\left(3.5\ \text{cm}^3/\text{s}\right)}$$

$$= \left(2.7\ \frac{\text{J}}{\text{g}\cdot{}^\circ\text{C}}\right)\left(\frac{10^3\ \text{g}}{1\ \text{kg}}\right) = \boxed{2.7 \times 10^3\ \text{J/kg}\cdot{}^\circ\text{C}}$$

11.64 When liquids 1 and 2 are mixed, the conservation of energy equation is

$$mc_1(17°\text{C}-10°\text{C}) = mc_2(20°\text{C}-17°\text{C}), \text{ or } c_2 = \left(\frac{7}{3}\right)c_1$$

When liquids 2 and 3 are mixed, energy conservation yields

$$mc_3(30°\text{C}-28°\text{C}) = mc_2(28°\text{C}-20°\text{C}), \text{ or } c_3 = 4c_2 = \left(\frac{28}{3}\right)c_1$$

Then, mixing liquids 1 and 3 will give $mc_1(T-10°\text{C}) = mc_3(30°\text{C}-T)$

or $$T = \frac{c_1(10°\text{C})+c_3(30°\text{C})}{c_1+c_3} = \frac{10°\text{C}+(28/3)(30°\text{C})}{1+(28/3)} = \boxed{28°\text{C}}$$

11.65 During the first 50 minutes, the energy input is used converting m kilograms of ice at 0°C into liquid water at 0°C. The energy required is $Q_1 = mL_f = m(3.33\times10^5 \text{ J/kg})$, so the constant power input must be

$$\mathcal{P} = \frac{Q_1}{(\Delta t)_1} = \frac{m(3.33\times10^5 \text{ J/kg})}{50 \text{ min}}$$

During the last 10 minutes, the same constant power input raises the temperature of water having a total mass of $(m+10 \text{ kg})$ by 2.0°C. The power input needed to do this is

$$\mathcal{P} = \frac{Q_2}{(\Delta t)_2} = \frac{(m+10 \text{ kg})c(\Delta T)}{(\Delta t)_2} = \frac{(m+10 \text{ kg})(4\,186 \text{ J/kg}\cdot°\text{C})(2.0°\text{C})}{10 \text{ min}}$$

Since the power input is the same in the two periods, we have

$$\frac{m(3.33\times10^5 \text{ J/kg})}{50 \text{ min}} = \frac{(m+10 \text{ kg})(4\,186 \text{ J/kg}\cdot°\text{C})(2.0°\text{C})}{10 \text{ min}}$$

which simplifies to $(8.0)m = m + 10 \text{ kg}$ or $m = \dfrac{10 \text{ kg}}{7.0} = \boxed{1.4 \text{ kg}}$

11.66 (a) The surface area of the stove is $A_{stove} = A_{ends} + A_{\substack{cylindrical\\side}} = 2\left(\pi r^2\right) + \left(2\pi rh\right)$, or

$$A_{stove} = 2\pi\left(0.200\text{ m}\right)^2 + 2\pi\left(0.200\text{ m}\right)\left(0.500\text{ m}\right) = 0.880\text{ m}^2$$

The temperature of the stove is $T_s = \frac{5}{9}\left(400°\text{F} - 32.0°\text{F}\right) = 204°\text{C} = 477\text{ K}$ while that of the air in the room is $T_r = \frac{5}{9}\left(70.0°\text{F} - 32.0°\text{F}\right) = 21.1°\text{C} = 294\text{ K}$. If the emissivity of the stove is $e = 0.920$, the net power radiated to the room is

$$\mathcal{P} = \sigma A_{stove} e\left(T_s^4 - T_r^4\right)$$

$$= \left(5.67\times10^{-8}\text{ W/m}^2\cdot\text{K}^4\right)\left(0.880\text{ m}^2\right)\left(0.920\right)\left[\left(477\text{ K}\right)^4 - \left(294\text{ K}\right)^4\right]$$

or $\mathcal{P} = \boxed{2.03\times10^3\text{ W}}$

(b) The total surface area of the walls and ceiling of the room is

$$A = 4A_{wall} + A_{ceiling} = 4\left[\left(8.00\text{ ft}\right)\left(25.0\text{ ft}\right)\right] + \left(25.0\text{ ft}\right)^2 = 1.43\times10^3\text{ ft}^2$$

If the temperature of the room is constant, the power lost by conduction through the walls and ceiling must equal the power radiated by the stove. Thus, from thermal conduction equation, $\mathcal{P} = A\left(T_h - T_c\right)/\Sigma R_i$, the net R value needed in the walls and ceiling is

$$\Sigma R_i = \frac{A\left(T_h - T_c\right)}{\mathcal{P}} = \frac{\left(1.43\times10^3\text{ ft}^2\right)\left(70.0°\text{F} - 32.0°\text{F}\right)}{2.03\times10^3\text{ J/s}}\left(\frac{1\,054\text{ J}}{1\text{ Btu}}\right)\left(\frac{1\text{ h}}{3\,600\text{ s}}\right)$$

or $\Sigma R_i = \boxed{7.78\text{ ft}^2\cdot°\text{F}\cdot\text{h/Btu}}$

11.67 A volume 0f 1.0 L of water has a mass of $m = \rho V = \left(10^3 \text{ kg/m}^3\right)\left(1.0 \times 10^{-3} \text{ m}^3\right) = 1.0 \text{ kg}$

The energy required to raise the temperature of the water to 100°C and then completely evaporate it is $Q = mc(\Delta T) + mL_v$, or

$$Q = (1.0 \text{ kg})(4\,186 \text{ J/kg}\cdot{}^\circ\text{C})(100^\circ\text{C} - 20^\circ\text{C}) + (1.0 \text{ kg})\left(2.26 \times 10^6 \text{ J/kg}\right) = 2.59 \times 10^6 \text{ J}$$

The power input to the water from the solar cooker is

$$\mathcal{P} = (\textit{efficiency}) IA = (0.50)\left(600 \text{ W/m}^2\right)\left[\frac{\pi(0.50 \text{ m})^2}{4}\right] = 59 \text{ W}$$

so the time required to evaporate the water is

$$t = \frac{Q}{\mathcal{P}} = \frac{2.59 \times 10^6 \text{ J}}{59 \text{ J/s}} = \left(4.4 \times 10^4 \text{ s}\right)\left(\frac{1 \text{ h}}{3\,600 \text{ s}}\right) = \boxed{12 \text{ h}}$$

11.68 (a) From the thermal conductivity equation, $\mathcal{P} = kA\left[(T_h - T_c)/L\right]$, the total energy lost by conduction through the insulation during the 24-h period will be

$$Q = \mathcal{P}_1(12.0 \text{ h}) + \mathcal{P}_2(12.0 \text{ h}) = \frac{kA}{L}\left[(37.0^\circ\text{C} - 23.0^\circ\text{C}) + (37.0^\circ\text{C} - 16.0^\circ\text{C})\right](12.0 \text{ h})$$

or $$Q = \frac{(0.012\,0 \text{ J/s}\cdot\text{m}^\circ\text{C})\left(0.490 \text{ m}^2\right)}{0.095\,0 \text{ m}}\left[14.0^\circ\text{C} + 21.0^\circ\text{C}\right](12.0 \text{ h})\left(\frac{3\,600 \text{ s}}{1 \text{ h}}\right) = 9.36 \times 10^4 \text{ J}$$

The mass of molten wax which will give off this much energy as it solidifies (all at 37°C) is

$$m = \frac{Q}{L_f} = \frac{9.36 \times 10^4 \text{ J}}{205 \times 10^3 \text{ J/kg}} = \boxed{0.457 \text{ kg}}$$

(b) If the test samples and the inner surface of the insulation is preheated to 37.0°C during the assembly of the box, $\boxed{\text{nothing undergoes a temperature change}}$ during the test period. Thus, the masses of the samples and insulation do not enter into the calculation. Only the duration of the test, inside and outside temperatures, along with the surface area, thickness, and thermal conductivity of the insulation needs to be known.

11.69 The energy m kilograms of steam give up as it (i) cools to the boiling point of 100°C, (ii) condenses into a liquid, and (iii) cools on down to the final temperature of 50.0°C is

$$Q_m = mc_{steam}(\Delta T)_1 + mL_v + mc_{\substack{liquid\\water}}(\Delta T)_2$$

$$= m\left[\left(2.01\times 10^3\ \text{J/kg}\cdot{}^\circ\text{C}\right)\left(130^\circ\text{C}-100^\circ\text{C}\right)+2.26\times 10^6\ \text{J/kg}+\left(4\,186\ \text{J/kg}\cdot{}^\circ\text{C}\right)\left(100^\circ\text{C}-50.0^\circ\text{C}\right)\right]$$

$$= m\left(2.53\times 10^6\ \text{J/kg}\right)$$

The energy needed to raise the temperature of the 200-g of original water and the 100-g glass container from 20.0°C to 50.0°C is

$$Q_{needed} = \left(m_w c_w + m_g c_g\right)\Delta T = \left[\left(0.200\ \text{kg}\right)\left(4\,186\ \text{J/kg}\cdot{}^\circ\text{C}\right)+\left(0.100\ \text{kg}\right)\left(837\ \text{J/kg}\cdot{}^\circ\text{C}\right)\right]\left(30.0^\circ\text{C}\right)$$

$$= 2.76\times 10^4\ \text{J}$$

Equating the energy available from the steam to the energy required gives

$$m\left(2.53\times 10^6\ \text{J/kg}\right) = 2.76\times 10^4\ \text{J} \qquad \text{or} \qquad m = \frac{2.76\times 10^4\ \text{J}}{2.53\times 10^6\ \text{J/kg}} = 0.010\,9\ \text{kg} = \boxed{10.9\ \text{g}}$$