

1. **REASONING AND SOLUTION** Convection is the process in which heat is carried from one place to another by the bulk movement of the medium. In liquids and gases, the molecules are free to move; hence, convection occurs as a result of bulk molecular motion. In solids, however, the molecules are generally bound to specific locations (lattice sites). While the molecules in a solid can vibrate about their equilibrium locations, they are not free to move from place to place within the solid. Therefore, convection does not generally occur in solids.

4. **REASONING AND SOLUTION** A road surface is exposed to the air on its upper surface and to the earth on its lower surface. Even when the air temperature is at the freezing point, the road surface may be above this temperature as heat flows through the road from the earth. In order for a road to freeze, sufficient heat must be lost from the earth by conduction through the road surface. The temperature of the earth under the road must be reduced at least to the freezing point. A bridge is exposed to the air on both its upper and lower surfaces. It will, therefore, lose heat from both surfaces and reach thermal equilibrium with the air much more quickly than an ordinary roadbed. It is reasonable, then, that the bridge surface will usually freeze before the road surface.

6. ***REASONING AND SOLUTION*** When heat is transferred from place to place inside the human body by the flow of blood, the main method of heat transfer is forced convection, similar to that illustrated for the radiator fluid in Figure 13.7. The heart is analogous to the water pump in the figure.

8. **REASONING AND SOLUTION** A poker used in a fireplace is held at one end, while the other end is in the fire. Such pokers are made of iron rather than copper because the thermal conductivity of iron is roughly smaller by a factor of five than the thermal conductivity of copper. Therefore, the transfer of heat along the poker by conduction is considerably reduced by using iron. Hence, one end of the poker can be placed in the fire, and the other end will remain cool enough to be comfortably handled.

15. **REASONING AND SOLUTION** The radiant energy Q emitted in a time t by an object that has a Kelvin temperature T , a surface area A , and an emissivity e , is given by Equation 13.2, $Q = e\sigma T^4 At$, where σ is the Stefan-Boltzmann constant.

We now consider two objects that have the same size and shape. Object A has an emissivity of 0.3, and object B has an emissivity of 0.6. Since each object radiates the same power, $e_A \sigma T_A^4 A_A = e_B \sigma T_B^4 A_B$. The Stefan-Boltzmann constant is a universal constant, and since the objects have the same size and shape, $A_A = A_B$; therefore, $e_A T_A^4 = e_B T_B^4$, or $T_A / T_B = \sqrt[4]{e_B / e_A} = \sqrt[4]{2}$. Hence, the Kelvin temperature of A is $\sqrt[4]{2}$ or 1.19 times the Kelvin temperature of B, not twice the temperature of B.

3. **REASONING AND SOLUTION** Since 1 kWh of energy costs \$ 0.10, we know that $Q = 10.0 \times 10^3 \text{ W}\cdot\text{h}$ of energy can be purchased with \$ 1.00. Using Equation 13.1, we find that the time required is

$$t = \frac{QL}{kA\Delta T} = \frac{(10.0 \times 10^3 \text{ W}\cdot\text{h})(0.10 \text{ m})}{[1.1 \text{ J}/(\text{s}\cdot\text{m}\cdot\text{C}^\circ)](9.0 \text{ m}^2)(20.0 \text{ C}^\circ - 12.8 \text{ C}^\circ)} = \boxed{14 \text{ h}}$$

6. **REASONING AND SOLUTION** The heat lost in each case is given by $Q = (kA\Delta T)t/L$. For the goose down jacket

$$Q_g = \frac{[0.025 \text{ J}/(\text{s}\cdot\text{m}\cdot\text{C}^\circ)]A\Delta Tt}{1.5 \times 10^{-2} \text{ m}}$$

For the wool jacket

$$Q_w = \frac{[0.040 \text{ J}/(\text{s}\cdot\text{m}\cdot\text{C}^\circ)]A\Delta Tt}{5.0 \times 10^{-3} \text{ m}}$$

Now

$$Q_w / Q_g = \boxed{4.8}$$

9. **REASONING AND SOLUTION** The rate of heat transfer is the same for all three materials so

$$Q/t = k_p A \Delta T_p / L = k_b A \Delta T_b / L = k_w A \Delta T_w / L$$

Let T_i be the inside temperature, T_1 be the temperature at the plasterboard-brick interface, T_2 be the temperature at the brick-wood interface, and T_o be the outside temperature. Then

$$k_p T_i - k_p T_1 = k_b T_1 - k_b T_2 \quad (1)$$

and

$$k_b T_1 - k_b T_2 = k_w T_2 - k_w T_o \quad (2)$$

Solving (1) for T_2 gives

$$T_2 = (k_p + k_b) T_1 / k_b - (k_p / k_b) T_i$$

- a. Substituting this into (2) and solving for T_1 yields

$$T_1 = \frac{(k_p / k_b)(1 + k_w / k_b) T_i + (k_w / k_b) T_o}{(1 + k_w / k_b)(1 + k_p / k_b) - 1} = \boxed{21^\circ \text{C}}$$

- b. Using this value in (1) yields

$$\boxed{T_2 = 18^\circ \text{C}}$$

12. **REASONING** The heat Q required to melt ice at $0\text{ }^\circ\text{C}$ into water at $0\text{ }^\circ\text{C}$ is given by the relation $Q = mL_f$ (Equation 12.5), where m is the mass of the ice and L_f is the latent heat of fusion. We divide both sides of this equation by the time t and solve for the mass of ice per second (m/t) that melts:

$$\frac{m}{t} = \frac{\left(\frac{Q}{t}\right)}{L_f} \quad (1)$$

The heat needed to melt the ice is conducted through the copper bar, from the hot end to the cool end. The amount of heat conducted in a time t is given by $Q = \frac{(kA\Delta T)t}{L}$ (Equation 13.1), where k is the thermal conductivity of the bar, A and L are its cross-sectional area and length, and ΔT is the temperature difference between the ends. We will use these two relations to find the mass of ice per second that melts.

SOLUTION Solving Equation 13.1 for Q/t and substituting the result into Equation (1) gives

$$\frac{m}{t} = \frac{\frac{kA\Delta T}{L}}{L_f} = \frac{kA\Delta T}{LL_f}$$

The thermal conductivity of copper can be found in Table 13.1, and the latent heat of fusion for water can be found in Table 12.3. The temperature difference between the ends of the rod is $\Delta T = 100\text{ }^\circ\text{C}$, since the hot end is in boiling water ($100\text{ }^\circ\text{C}$) and the cool end is in ice ($0\text{ }^\circ\text{C}$). Thus,

$$\frac{m}{t} = \frac{kA\Delta T}{LL_f} = \frac{[390\text{ J}/(\text{s}\cdot\text{m}\cdot\text{C}^\circ)](4.0\times 10^{-4}\text{ m}^2)(100\text{ }^\circ\text{C})}{(1.5\text{ m})(33.5\times 10^4\text{ J/kg})} = \boxed{3.1\times 10^{-5}\text{ kg/s}}$$

17. **SSM** **WWW** **REASONING AND SOLUTION** Solving the Stefan-Boltzmann law, Equation 13.2, for the time t , and using the fact that $Q_{\text{blackbody}} = Q_{\text{bulb}}$, we have

$$t_{\text{blackbody}} = \frac{Q_{\text{blackbody}}}{\sigma T^4 A} = \frac{Q_{\text{bulb}}}{\sigma T^4 A} = \frac{P_{\text{bulb}} t_{\text{bulb}}}{\sigma T^4 A}$$

where P_{bulb} is the power rating of the light bulb. Therefore,

$$t_{\text{blackbody}} = \frac{(100.0 \text{ J/s})(3600 \text{ s})}{\left[5.67 \times 10^{-8} \text{ J}/(\text{s} \cdot \text{m}^2 \cdot \text{K}^4)\right] (303 \text{ K})^4 \left[(6 \text{ sides})(0.0100 \text{ m})^2 / \text{side}\right]} \times \left(\frac{1 \text{ h}}{3600 \text{ s}}\right) \left(\frac{1 \text{ da}}{24 \text{ h}}\right) = \boxed{14.5 \text{ da}}$$