40. (II) (*a*) Using the solar constant, estimate the rate at which the whole Earth receives energy from the Sun. (*b*) Assume the Earth radiates an equal amount back into space (that is, the Earth is in equilibrium). Then, assuming the Earth is a perfect emitter ($e = 1.0$), estimate its average surface temperature.

41. (II) A 100-W lightbulb generates 95 W of heat, which is dissipated through a glass bulb that has a radius of 3.0 cm and is 1.0 mm thick. What is the difference in temperature between the inner and outer surfaces of the glass?

42. (III) Suppose the insulating qualities of the wall of a house come mainly from a 4.0-in. layer of brick and an *R*-19 layer of insulation, as shown in Fig. 14–19. What is the total rate of heat loss through such a wall, if its total area is $240\ \mathrm{ft}^2$ and the temperature difference across it is 12 F°?

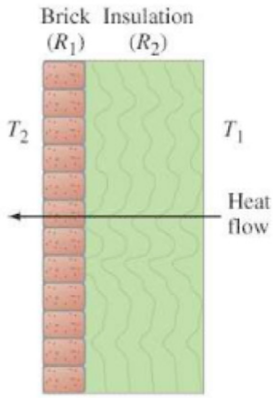

FIGURE 14–19 Two layers insulating a wall. Problem 42.

43. (III) A double-glazed window has two panes of glass separated by an air space, Fig. 14–20. (*a*) Show that the rate of heat flow through such a window by conduction is given by

$$\frac{Q}{t} = \frac{A(T_2 - T_1)}{l_1/k_1 + l_2/k_2 + l_3/k_3},$$

where k_1, k_2, and k_3 are the thermal conductivities for glass, air, and glass, respectively. (*b*) Generalize this expression for any number of materials placed next to one another.

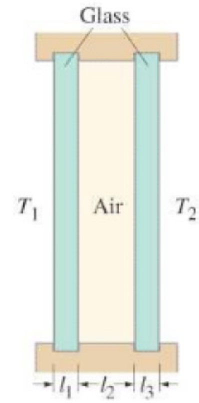

FIGURE 14–20 Problem 43.

44. (III) Approximately how long should it take 11.0 kg of ice at 0°C to melt when it is placed in a carefully sealed Styrofoam ice chest of dimensions 25 cm × 35 cm × 55 cm whose walls are 1.5 cm thick? Assume that the conductivity of Styrofoam is double that of air and that the outside temperature is 32°C.

General Problems

45. A soft-drink can contains about 0.20 kg of liquid at 5°C. Drinking this liquid can actually consume some of the fat in the body, since energy is needed to warm the water to body temperature (37°C). How many food Calories should the drink have so that it is in perfect balance with the heat needed to warm the liquid?

46. If coal gives off 30 MJ/kg when it is burned, how much coal would be needed to heat a house that requires 2.0×10^5 MJ for the whole winter? Assume that 30% of the heat is lost up the chimney.

47. To get an idea of how much thermal energy is contained in the world's oceans, estimate the heat liberated when a cube of ocean water, 1 km on each side, is cooled by 1 K. (Approximate the ocean water as pure water for this estimate.)

48. A 15-g lead bullet is tested by firing it into a fixed block of wood with a mass of 1.05 kg. The block and imbedded bullet together absorb all the heat generated. After thermal equilibrium has been reached, the system has a temperature rise measured as 0.020 C°. Estimate the entering speed of the bullet.

49. (*a*) Find the total power radiated into space by the Sun, assuming it to be a perfect emitter at $T = 5500$ K. The Sun's radius is 7.0×10^8 m. (*b*) From this, determine the power per unit area arriving at the Earth, 1.5×10^{11} m away (Fig. 14–21).

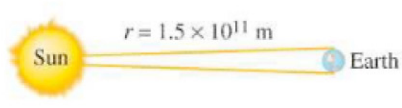

FIGURE 14–21 Problem 49.

50. During light activity, a 70-kg person may generate 200 kcal/h. Assuming that 20% of this goes into useful work and the other 80% is converted to heat, calculate the temperature rise of the body after 1.00 h if none of this heat were transferred to the environment.

51. A 340-kg marble boulder rolls off the top of a cliff and falls a vertical height of 140 m before striking the ground. Estimate the temperature rise of the rock if 50% of the heat generated remains in the rock.

52. A 2.3-kg lead ball is dropped into a 2.5-L insulated pail of water initially at 20.0°C. If the final temperature of the water–lead combination is 28.0°C, what was the initial temperature of the lead ball?

53. A mountain climber wears a goose down jacket 3.5 cm thick with total surface area $1.2\ \mathrm{m}^2$. The temperature at the surface of the clothing is −20°C and at the skin is 34°C. Determine the rate of heat flow by conduction through the jacket (*a*) assuming it is dry and the thermal conductivity *k* is that of down, and (*b*) assuming the jacket is wet, so *k* is that of water and the jacket has matted to 0.50 cm thickness.

54. A marathon runner has an average metabolism rate of about 950 kcal/h during a race. If the runner has a mass of 55 kg, estimate how much water she would lose to evaporation from the skin for a race that lasts 2.5 h.

55. Estimate the rate at which heat can be conducted from the interior of the body to the surface. Assume that the thickness of tissue is 4.0 cm, that the skin is at 34°C and the interior at 37°C, and that the surface area is $1.5\ \mathrm{m}^2$. Compare this to the measured value of about 230 W that must be dissipated by a person working lightly. This clearly shows the necessity of convective cooling by the blood.