the Romans, even in houses in the remote province of Great Britain, made use of hot-water and steam conduits in the floor to heat their houses.

EXAMPLE 14–12 ESTIMATE Two teapots. A ceramic teapot ($e = 0.70$) and a shiny one ($e = 0.10$) each hold 0.75 L of tea at 95°C. (*a*) Estimate the rate of heat loss from each, and (*b*) estimate the temperature drop after 30 min for each. Consider only radiation, and assume the surroundings are at 20°C.

APPROACH We are given all the information necessary to calculate the heat loss due to radiation, except for the area. The teapot holds 0.75 L, and we can approximate it as a cube 10 cm on a side (volume = 1.0 L), with five sides exposed. To estimate the temperature drop in (*b*), we use the concept of specific heat and ignore the contribution of the pots compared to that of the water.

SOLUTION (*a*) The teapot, approximated by a cube 10 cm on a side with five sides exposed, has a surface area of about $5 \times (0.1\,\mathrm{m})^2 = 5 \times 10^{-2}\,\mathrm{m}^2$. The rate of heat loss would be about

$$\begin{aligned}\frac{\Delta Q}{\Delta t} &= e\sigma A\left(T_1^4 - T_2^4\right)\\ &= e\left(5.67 \times 10^{-8}\,\mathrm{W/m^2\cdot K^4}\right)\left(5 \times 10^{-2}\,\mathrm{m}^2\right)\left[(368\,\mathrm{K})^4 - (293\,\mathrm{K})^4\right]\\ &\approx e(30)\ \mathrm{W},\end{aligned}$$

or about 20 W for the ceramic pot ($e = 0.70$) and 3 W for the shiny one ($e = 0.10$).

(*b*) To estimate the temperature drop, we use the specific heat of water and ignore the contribution of the pots. The mass of 0.75 L of water is 0.75 kg. (Recall that $1.0\,\mathrm{L} = 1000\,\mathrm{cm}^3 = 1 \times 10^{-3}\,\mathrm{m}^3$ and $\rho = 1000\,\mathrm{kg/m^3}$.) Using Eq. 14–2 and Table 14–1, we get

$$\frac{\Delta Q}{\Delta t} = mc\,\frac{\Delta T}{\Delta t}.$$

Then

$$\frac{\Delta T}{\Delta t} = \frac{\Delta Q/\Delta t}{mc} \approx \frac{e(30)\ \mathrm{J/s}}{(0.75\,\mathrm{kg})\left(4.186 \times 10^3\,\mathrm{J/kg\cdot C^\circ}\right)} = e(0.01)\ \mathrm{C^\circ/s}.$$

After 30 min (1800 s), $\Delta T = e(0.01\,\mathrm{C^\circ/s})\Delta t = e(0.01\,\mathrm{C^\circ/s})(1800\,\mathrm{s}) = 18e\,\mathrm{C^\circ}$, or about 12 C° for the ceramic pot ($e = 0.70$) and about 2 C° for the shiny one ($e = 0.10$). The shiny one clearly has an advantage, at least as far as radiation is concerned.

NOTE Convection and conduction could play a greater role than radiation.

PHYSICS APPLIED
Radiation from the Sun

Heating of an object by radiation from the Sun cannot be calculated using Eq. 14–6 since this equation assumes a uniform temperature, T_2, of the environment surrounding the object, whereas the Sun is essentially a point source. Hence the Sun must be treated as a separate source of energy. Heating by the Sun is calculated using the fact that about 1350 J of energy strikes the atmosphere of the Earth from the Sun per second per square meter of area at right angles to the Sun's rays. This number, $1350\,\mathrm{W/m^2}$, is called the **solar constant**. The atmosphere may absorb as much as 70% of this energy before it reaches the ground, depending on the cloud cover. On a clear day, about $1000\,\mathrm{W/m^2}$ reaches the Earth's surface. An object of emissivity e with area A facing the Sun absorbs energy from the Sun at a rate, in watts, of about

Solar constant

$$\frac{\Delta Q}{\Delta t} = \left(1000\,\mathrm{W/m^2}\right)eA\cos\theta, \qquad \textbf{(14–7)}$$

where θ is the angle between the Sun's rays and a line perpendicular to the area A (Fig. 14–12). That is, $A\cos\theta$ is the "effective" area, at right angles to the Sun's rays.

FIGURE 14–12 Radiant energy striking a body at an angle θ.