Any object not only emits energy by radiation but also absorbs energy radiated by other bodies. If an object of emissivity e and area A is at a temperature T_1, it radiates energy at a rate $e\sigma A T_1^4$. If the object is surrounded by an environment at temperature T_2, the rate at which the surroundings radiate energy is proportional to T_2^4, and the rate that energy is absorbed by the object is proportional to T_2^4. The *net* rate of radiant heat flow from the object is given by the equation

Net flow rate of heat radiation

$$\frac{\Delta Q}{\Delta t} = e\sigma A\left(T_1^4 - T_2^4\right), \qquad \textbf{(14–6)}$$

where A is the surface area of the object, T_1 its temperature and e its emissivity (at temperature T_1), and T_2 is the temperature of the surroundings. Notice in this equation that the rate of heat absorption by an object was taken to be $e\sigma A T_2^4$; that is, the proportionality constant is the same for both emission and absorption. This must be true to correspond with the experimental fact that equilibrium between the object and its surroundings is reached when they come to the same temperature. That is, $\Delta Q/\Delta t$ must equal zero when $T_1 = T_2$, so the coefficients of emission and absorption terms must be the same. This confirms the idea that a good emitter is a good absorber.

Because both the object and its surroundings radiate energy, there is a net transfer of energy from one to the other unless everything is at the same temperature. From Eq. 14–6 it is clear that if $T_1 > T_2$, the net flow of heat is from the object to the surroundings, so the object cools. But if $T_1 < T_2$, the net heat flow is from the surroundings into the object, and its temperature rises. If different parts of the surroundings are at different temperatures, Eq. 14–6 becomes more complicated.

PHYSICS APPLIED
The body's radiative heat loss

EXAMPLE 14–11 ESTIMATE **Cooling by radiation.** An athlete is sitting unclothed in a locker room whose dark walls are at a temperature of 15°C. Estimate the rate of heat loss by radiation, assuming a skin temperature of 34°C and $e = 0.70$. Take the surface area of the body not in contact with the chair to be $1.5\ \mathrm{m}^2$.

APPROACH We can make a rough estimate using the given assumptions and Eq. 14–6, for which we must use Kelvin temperatures.

SOLUTION We have

PROBLEM SOLVING
Must use the Kelvin temperature

$$\begin{aligned}\frac{\Delta Q}{\Delta t} &= e\sigma A\left(T_1^4 - T_2^4\right)\\ &= (0.70)\left(5.67\times10^{-8}\ \mathrm{W/m^2\cdot K^4}\right)\left(1.5\ \mathrm{m^2}\right)\left[(307\ \mathrm{K})^4 - (288\ \mathrm{K})^4\right]\\ &= 120\ \mathrm{W}.\end{aligned}$$

NOTE The "output" of this resting person is a bit more than what a 100-W lightbulb uses.

PHYSICS APPLIED
Room comfort

Temperature of walls and surroundings, not only the air, affects comfort

A resting person naturally produces heat internally at a rate of about 100 W (Chapter 15), less than the heat loss by radiation as calculated in this Example. Hence, the person's temperature would drop, causing considerable discomfort. The body responds to excessive heat loss by increasing its metabolic rate (Section 15–3), and shivering is one method by which the body increases its metabolism. Naturally, clothes help a lot. Example 14–11 illustrates that a person may be uncomfortable even if the temperature of the air is, say, 25°C, which is quite a warm room. If the walls or floor are cold, radiation to them occurs no matter how warm the air is. Indeed, it is estimated that radiation accounts for about 50% of the heat loss from a sedentary person in a normal room. Rooms are most comfortable when the walls and floor are warm and the air is not so warm. Floors and walls can be heated by means of hot-water conduits or electric heating elements. Such first-rate heating systems are becoming more common today, and it is interesting to note that 2000 years ago