**heat pump** is usually reserved for a device that can heat a house in winter by using an electric motor that does work $W$ to take heat $Q_L$ from the outside at low temperature and delivers heat $Q_H$ to the warmer inside of the house; see Fig. 15–18. As in a refrigerator, there is an indoor and an outdoor heat exchanger (coils of the refrigerator) and an electric compressor motor. The operating principle is like that for a refrigerator or air conditioner; but the objective of a heat pump is to heat (deliver $Q_H$), rather than to cool (remove $Q_L$). Thus, the coefficient of performance of a heat pump is defined differently than for an air conditioner because it is the heat $Q_H$ delivered to the inside of the house that is important now:

$$\text{COP} = \frac{Q_H}{W}. \qquad \text{[Heat pump]} \quad \textbf{(15–7)}$$

The COP is necessarily greater than 1. Most heat pumps can be "turned around" and used as air conditioners in the summer.

PHYSICS APPLIED
*Heat pump*

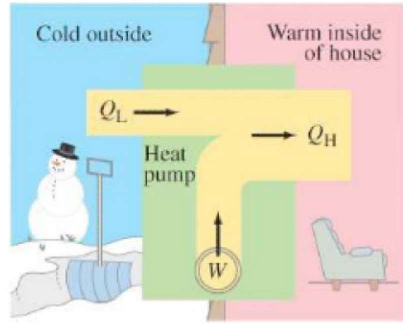


**FIGURE 15–18** A heat pump uses an electric motor to "pump" heat from the cold outside to the warm inside of a house.

**EXAMPLE 15–13** **Heat pump.** A heat pump has a coefficient of performance of 3.0 and is rated to do work at 1500 W. (*a*) How much heat can it add to a room per second? (*b*) If the heat pump were turned around to act as an air conditioner in the summer, what would you expect its coefficient of performance to be, assuming all else stays the same?

**APPROACH** We use the definitions of coefficient of performance, which are different for the two devices in (*a*) and (*b*).

**SOLUTION** (*a*) We use Eq. 15–7 for the heat pump, and, since our device does 1500 J of work per second, it can pour heat into the room at a rate of

$$Q_H = \text{COP} \times W = 3.0 \times 1500\,\text{J} = 4500\,\text{J}$$

per second, or at a rate of 4500 W.

(*b*) If our device is turned around in summer, it can take heat $Q_L$ from inside the house, doing 1500 J of work per second to then dump $Q_H = 4500\,\text{J}$ per second to the hot outside. Energy is conserved, so $Q_L + W = Q_H$ (see Fig. 15–18, but reverse the inside and outside of the house). Then

$$Q_L = Q_H - W = 4500\,\text{J} - 1500\,\text{J} = 3000\,\text{J}.$$

The coefficient of performance as an air conditioner would thus be (Eq. 15–6a)

$$\text{COP} = \frac{Q_L}{W} = \frac{3000\,\text{J}}{1500\,\text{J}} = 2.0.$$

**NOTE** The coefficients of performance are defined differently for heat pumps and air conditioners.

CAUTION
*Heat pumps and air conditioners have different COP definitions*

A good heat pump can sometimes be a money saver and an energy saver, depending on the cost of the unit and installation, etc. Compare, for example, our heat pump in Example 15–13 to, say, a 1500-W electric heater. We plug the latter into the wall, it draws 1500 W of electricity and delivers 1500 W of heat to the room. Our heat pump when plugged into the wall also draws 1500 W of electricity (which is what we pay for), but it delivers 4500 W of heat!

## * SEER Rating

Cooling devices such as refrigerators and air conditioners are often given a rating known as SEER (Seasonal Energy Efficiency Ratio), which is defined as

$$\text{SEER} = \frac{\text{(heat removed in Btu)}}{\text{(electrical input in watt-hours)}},$$

PHYSICS APPLIED
*SEER rating*

as measured by averaging over varying (seasonal) conditions. The definition of the SEER is basically the same as the COP except for the (unfortunate) mixed units. Given that $1\,\text{Btu} = 1055\,\text{J}$ (see Section 14–1 and Problem 4 in Chapter 14), then a $\text{SEER} = 1$ is a COP equal to $(1\,\text{Btu}/1\,\text{W}\cdot\text{h}) = (1055\,\text{J})/(1\,\text{J/s} \times 3600\,\text{s}) = 0.29$. A $\text{COP} = 1$ is a $\text{SEER} = 1/0.29 = 3.4$.