SECTION 1

Relationships Between Heat and Work

SECTION OBJECTIVES

- **Recognize that a system can absorb or release energy as heat in order for work to be done on or by the system and that work done on or by a system can result in the transfer of energy as heat.**
- **Compute the amount of work done during a thermodynamic process.**
- **Distinguish between isovolumetric, isothermal, and adiabatic thermodynamic processes.**

HEAT, WORK, AND INTERNAL ENERGY

Pulling a nail from a piece of wood causes the temperature of the nail and the wood to increase. Work is done by the frictional forces between the nail and the wood fibers. This work increases the internal energy of the iron atoms in the nail and the molecules in the wood.

The increase in internal energy of the nail corresponds to an increase in the nail's temperature, which is higher than the temperature of the surrounding air. As a result, energy is transferred as heat from the nail to the surrounding air. When the nail and surrounding air are at the same temperature, this energy transfer ceases.

Internal energy can be used to do work

The example of the hammer and nail illustrates that work can increase the internal energy of a substance. This internal energy can then decrease through the transfer of energy as heat. The reverse is also possible. Energy can be transferred to a substance as heat, and this internal energy can then be used to do work.

Consider a flask of water. A balloon is placed over the mouth of the flask, and the flask is heated until the water boils. Energy transferred as heat from the flame of the gas burner to the water increases the internal energy of the water. When the water's temperature reaches the boiling point, the water changes phase and becomes steam. At this constant temperature, the volume of the steam increases. This expansion provides a force that pushes the balloon outward and does work on the atmosphere, as shown in **Figure 1.** Thus, the steam does work, and the steam's internal energy decreases as predicted by the principle of energy conservation.

Figure 1
Energy transferred as heat turns water into steam. Energy from the steam does work on the air outside the balloon.

Heat and work are energy transferred to or from a system

On a microscopic scale, heat and work are similar. In this textbook, both are defined as energy that is transferred to or from a substance. This changes the substance's internal energy (and thus its temperature or phase). In other words, the terms *heat* and *work* always refer to energy in transit. An object never has "heat" or "work" in it; it has only internal energy.

In the previous examples, the internal energy of a substance or combination of substances has been treated as a single quantity to which energy is added or from which energy is taken away. Such a substance or combination of substances is called a **system.**

system

a set of particles or interacting components considered to be a distinct physical entity for the purpose of study