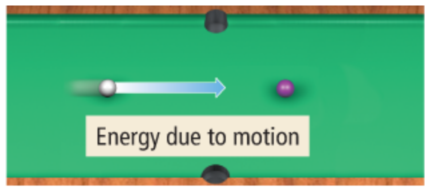
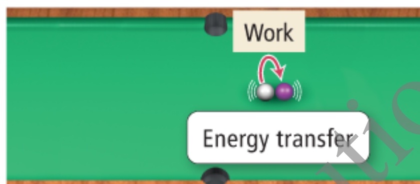
9.2: The Nature of Energy: Key Definitions

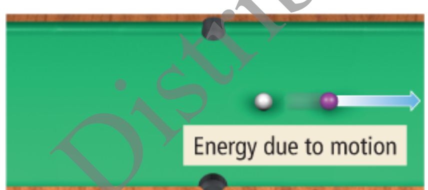
Recall from our discussion of energy in Section E.6 that **energy** is the capacity to do work and **work** is the result of a force acting through a distance. You do work, for example, when you push a box across the floor. Another example of work is the collision between a rolling billiard ball and a stationary one. The rolling ball has *energy* due to its motion. When it collides with another ball it does *work*, resulting in the *transfer* of energy from one ball to the other. The second billiard ball absorbs the energy and begins to roll across the table.



(a)



(b)



(c)

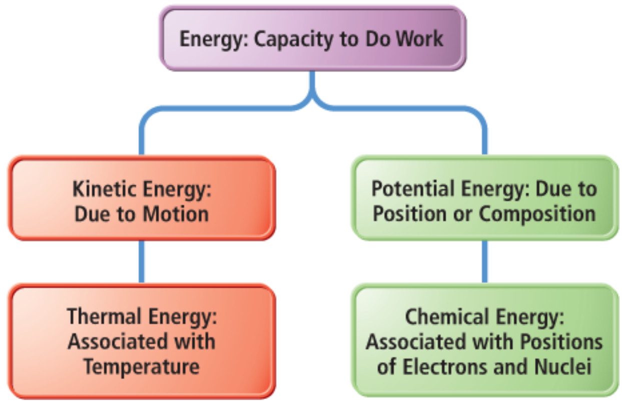
(a) A rolling billiard ball has energy due to its motion. **(b)** When the ball collides with a second ball it does work, transferring energy to the second ball. **(c)** The second ball now has energy as it rolls away from the collision.

Energy can also be transferred through **heat (q)**, the flow of energy caused by a temperature difference. For example, if you hold a cup of coffee in your hand, energy is transferred, in the form of heat, from the hot coffee to your cooler hand. Think of *energy* as something that an object or set of objects possesses. Think of *heat* and *work* as ways that objects or sets of objects *exchange* energy.

The energy contained in a rolling billiard ball is an example of **kinetic energy**, the energy associated with the *motion* of an object. The energy contained in a hot cup of coffee is **thermal energy**, the energy associated with the *temperature* of an object. Thermal energy is actually a type of kinetic energy because it arises from the motions of atoms or molecules within a substance.

If you raise a billiard ball off the table, you increase its **potential energy**, the energy associated with the *position* or *composition* of an object. The potential energy of the billiard ball, for example, is a result of its position in Earth's gravitational field. Raising the ball off the table, against Earth's gravitational pull, gives it more potential energy. Another example of potential energy is the energy contained in a compressed spring. When you compress a spring, you push against the forces that tend to maintain the spring's uncompressed shape, storing energy as potential energy. **Chemical energy**, the energy associated with the relative positions of electrons and nuclei in atoms and molecules, is also a form of potential energy. Some chemical compounds, such as the methane in natural gas or the ethanol in the burning ice cube, also contain potential energy, and chemical reactions can release that potential energy. Figure 9.1 summarizes these different kinds of energy.

Figure 9.1 The Different Manifestations of Energy



As we discussed in Section E.6, the SI unit of energy is the $\text{Kg} \cdot \text{m}^2/\text{s}^2$, defined as the joule (J). A second common unit of energy is the calorie (cal); $1 \text{ cal} = 4.184 \text{ J}$ (exact). A related energy unit is the nutritional, or uppercase "C" Calorie (Cal), equivalent to 1000 lowercase "c" calories. The Calorie is the same as a kilocalorie (kcal): $1 \text{ Cal} = 1 \text{ kcal} = 1000 \text{ cal}$.

Recall also from Section E.6 that the **law of conservation of energy** states that *energy can be neither created nor destroyed*. However, energy can be transferred from one object to another, and it can assume different forms. For example, if you drop a raised billiard ball, some of its potential energy becomes kinetic energy as the ball falls toward the table, as shown in Figure 9.2. If you release a compressed spring, the potential energy becomes kinetic energy as the spring expands outward, as shown in Figure 9.3. When you burn natural gas in an oven, the chemical energy of the natural gas and oxygen becomes thermal energy that increases the temperature of the air in the oven.

Figure 9.2 Energy Transformation: Potential and Kinetic Energy I

(**a**) A billiard ball held above the billiard table has gravitational potential energy. (**b**) When the ball is released, the potential energy is transformed into kinetic energy, the energy of motion.

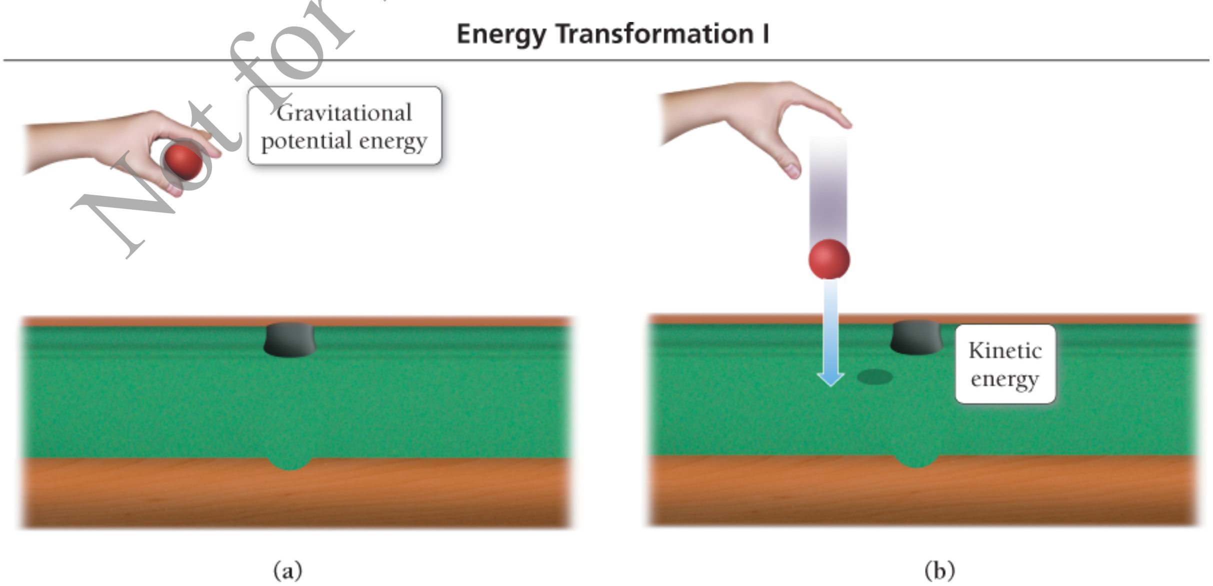
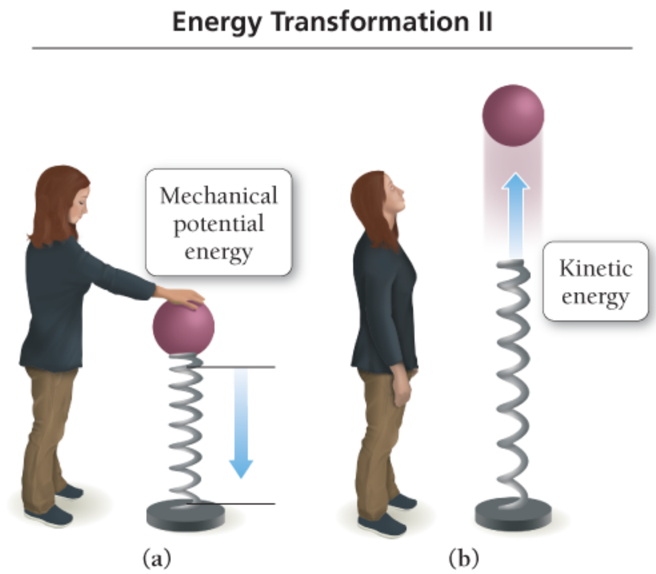


Figure 9.3 Energy Transformation: Potential and Kinetic Energy II

(**a**) A compressed spring has potential energy. (**b**) When the spring is released, the potential energy is transformed into kinetic energy.



When natural gas is burned, it combines with oxygen to form carbon dioxide and water, which have lower potential energy than the natural gas and the oxygen. The change in potential energy is the source of heat upon burning.

A good way to understand and track energy changes that we also discussed in Section E.6 is to define the **system** under investigation. For example, the system may be the chemicals in a beaker in an experiment. The system's **surroundings** are everything with which the system can exchange energy. For the chemicals in a beaker, the surroundings may include the water that the chemicals are dissolved in (for aqueous solutions), the beaker itself, the lab bench on which the beaker sits, the air in the room, and so on. In an energy exchange, energy is transferred between the system and the surroundings, as shown in Figure 9.4. If the system loses energy, the surroundings gain the same exact amount of energy, and vice versa.

Figure 9.4 Energy Transfer

If a system and surroundings had energy gauges (which would measure energy content in the way a fuel gauge measures fuel content), an energy transfer in which the system transfers energy to the surroundings would result in a decrease in the energy content of the system and an increase in the energy content of the surroundings. The total amount of energy, however, must be conserved.