Work-Energy versus Energy Conservation

The work-energy principle and the law of conservation of energy are basically equivalent. The difference between them is in how you use them, and in particular on your *choice of the system* under study. If you choose as your system one or more objects on which external forces do work, then you must use the work-energy principle: the work done by the external forces on your system equals the total change in energy of your chosen system.

On the other hand, if you choose a system on which no external forces do work, then you can apply conservation of energy to that system.

Consider, for example, a spring connected to a block on a frictionless table (Fig. 6–26). If you choose the block as your system, then the work done on the block by the spring equals the change in kinetic energy of the block: the work-energy principle. (Energy conservation does not apply to this system—the block's energy changes.) If instead you choose the block plus the spring as your system, no external forces do work (since the spring is part of the chosen system). To this system you can apply conservation of energy: if you compress the spring and then release it, the spring still exerts a force on the block, but the subsequent motion can be discussed in terms of kinetic energy $\left(\frac{1}{2}mv^2\right)$ plus potential energy $\left(\frac{1}{2}kx^2\right)$, whose total remains constant.

Conservation of energy applies to any system on which no work is done by external forces.

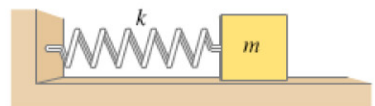

FIGURE 6–26 A spring connected to a block on a frictionless table. If you choose your system to be the block plus spring, then

$$E = \tfrac{1}{2}mv^2 + \tfrac{1}{2}kx^2$$

is conserved.

PROBLEM SOLVING Conservation of Energy

1. **Draw a picture** of the physical situation.
2. Determine **the system** for which energy will be conserved: the object or objects and the forces acting.
3. Ask yourself what quantity you are looking for, and decide what are **the initial** (point 1) **and final** (point 2) **positions**.
4. If the object under investigation changes its height during the problem, then **choose a reference frame** with a convenient $y = 0$ level for gravitational potential energy; the lowest point in the problem is often a good choice.

   If springs are involved, choose the unstretched spring position to be x (or y) $= 0$.
5. **Apply conservation of energy.** If no friction or other nonconservative forces act, then conservation of mechanical energy holds:

   $$\text{KE}_1 + \text{PE}_1 = \text{KE}_2 + \text{PE}_2.$$

   If friction or other nonconservative forces are present, then an additional term (W_{NC}) will be needed:

   $$W_{NC} = \Delta\text{KE} + \Delta\text{PE}.$$

   To be sure which sign to give W_{NC}, you can use your intuition: is the total mechanical energy increased or decreased in the process?
6. Use the equation(s) you develop to **solve** for the unknown quantity.

EXAMPLE 6–13 **Friction on the roller coaster.** The roller-coaster car in Example 6–9 reaches a vertical height of only 25 m on the second hill before coming to a momentary stop (Fig. 6–27). It traveled a total distance of 400 m. Estimate the average friction force (assume constant) on the car, whose mass is 1000 kg.

APPROACH We explicitly follow the Problem Solving Box step by step.

SOLUTION **1. Draw a Picture.** See Fig. 6–27.

2. **The system.** The system is the roller-coaster car (and the Earth since it exerts the gravitational force). The forces acting on the car are gravity and friction. (The normal force also acts on the car, but does no work, so it does not affect the energy.)
3. **Choose initial and final positions.** We take point 1 to be the instant when the car started coasting (at the top of the first hill), and point 2 to be the instant it stopped 25 m up the second hill.
4. **Choose a reference frame.** We choose the lowest point in the motion to be $y = 0$ for the gravitational potential energy.
5. **Apply conservation of energy.** There is friction acting on the car, so we use conservation of energy in the form of Eq. 6–15, with $v_1 = 0$, $y_1 = 40$ m, $v_2 = 0$, $y_2 = 25$ m, and $d = 400$ m. Thus

$$0 + (1000\,\text{kg})(9.8\,\text{m/s}^2)(40\,\text{m}) = 0 + (1000\,\text{kg})(9.8\,\text{m/s}^2)(25\,\text{m}) + F_{fr}(400\,\text{m}).$$

6. **Solve.** We can solve this equation for F_{fr}: $F_{fr} = 370$ N.

FIGURE 6–27 Example 6–13. Because of friction, a roller coaster car does not reach the original height on the second hill.