SECTION 1

# Work

## SECTION OBJECTIVES

- **Recognize the difference between the scientific and ordinary definitions of *work*.**
- **Define *work* by relating it to force and displacement.**
- **Identify where work is being performed in a variety of situations.**
- **Calculate the net work done when many forces are applied to an object.**

## DEFINITION OF WORK

Many of the terms you have encountered so far in this book have meanings in physics that are similar to their meanings in everyday life. In its everyday sense, the term *work* means to do something that takes physical or mental effort. But in physics, work has a distinctly different meaning. Consider the following situations:

- A student holds a heavy chair at arm's length for several minutes.
- A student carries a bucket of water along a horizontal path while walking at constant velocity.

It might surprise you to know that as the term work is used in physics, there is no work done on the chair or the bucket, even though effort is required in both cases. We will return to these examples later.

### Work is done on an object when a force causes a displacement of the object

**work**

*the product of the component of a force along the direction of displacement and the magnitude of the displacement*

Imagine that your car, like the car shown in **Figure 1,** has run out of gas and you have to push it down the road to the gas station. If you push the car with a constant horizontal force, the **work** you do on the car is equal to the magnitude of the force, $F$, times the magnitude of the displacement of the car. Using the symbol $d$ instead of $\Delta x$ for displacement, we define work for a constant force as:

$$W = Fd$$

**Figure 1**
This person exerts a constant force on the car and displaces it to the left. The work done on the car by the person is equal to the force the person exerts times the displacement of the car.

Work is not done on an object unless the object is moved with the action of a force. The application of a force alone does not constitute work. For this reason, no work is done on the chair when a student holds the chair at arm's length. Even though the student exerts a force to support the chair, the chair does not move. The student's tired arms suggest that work is being done, which is indeed true. The quivering muscles in the student's arms go through many small displacements and do work within the student's body. However, work is not done on the chair.

### Work is done only when components of a force are parallel to a displacement

When the force on an object and the object's displacement are in different directions, only the component of the force that is parallel to the object's displacement does work. Components of the force perpendicular to a displacement do not do work.