SECTION 1

Momentum and Impulse

SECTION OBJECTIVES

- Compare the momentum of different moving objects.
- Compare the momentum of the same object moving with different velocities.
- Identify examples of change in the momentum of an object.
- Describe changes in momentum in terms of force and time.

LINEAR MOMENTUM

When a soccer player heads a moving ball during a game, the ball's velocity changes rapidly. After the ball is struck, the ball's speed and the direction of the ball's motion change. The ball moves across the soccer field with a different speed than it had and in a different direction than it was traveling before the collision.

The quantities and kinematic equations describing one-dimensional motion predict the motion of the ball before and after the ball is struck. The concept of force and Newton's laws can be used to calculate how the motion of the ball changes when the ball is struck. In this chapter, we will examine how the force and the duration of the collision between the ball and the soccer player affect the motion of the ball.

Momentum is mass times velocity

momentum

a quantity defined as the product of the mass and velocity of an object

To address such issues, we need a new concept, **momentum.** *Momentum* is a word we use every day in a variety of situations. In physics this word has a specific meaning. The linear momentum of an object of mass m moving with a velocity $\mathbf{v}$ is defined as the product of the mass and the velocity. Momentum is represented by the symbol **p.**

MOMENTUM

$$\mathbf{p} = m\mathbf{v}$$

$$\textbf{momentum} = \textbf{mass} \times \textbf{velocity}$$

Figure 1
A bicycle rolling downhill has momentum. An increase in either mass or speed will increase the momentum.

As its definition shows, momentum is a vector quantity, with its direction matching that of the velocity. Momentum has dimensions mass × length/time, and its SI units are kilogram-meters per second (kg•m/s).

If you think about some examples of the way the word *momentum* is used in everyday speech, you will see that the physics definition conveys a similar meaning. Imagine coasting down a hill of uniform slope on your bike without pedaling or using the brakes. Because of the force of gravity, you will accelerate; that is, your velocity will increase with time. This idea is often expressed by saying that you are "picking up speed" or "gathering momentum." The faster you move, the more momentum you have and the more difficult it is to come to a stop.