

SOLUTION (a) The car's acceleration is $a = \frac{1}{2}g = \frac{1}{2}(9.8 \text{ m/s}^2) \approx 5 \text{ m/s}^2$. We use Newton's second law to get the net force needed to achieve this acceleration:

$$\Sigma F = ma \approx (1000 \text{ kg})(5 \text{ m/s}^2) = 5000 \text{ N.}$$

(If you are used to British units, to get an idea of what a 5000-N force is, you can divide by 4.45 N/lb and get a force of about 1000 lb.)

(b) For the apple, $m = 200 \text{ g} = 0.200 \text{ kg}$, so

$$\Sigma F = ma \approx (0.200 \text{ kg})(5 \text{ m/s}^2) = 1 \text{ N.}$$

EXAMPLE 4-3 Force to stop a car. What average net force is required to bring a 1500-kg car to rest from a speed of 100 km/h within a distance of 55 m?

APPROACH We can use Newton's second law, $\Sigma F = ma$, to determine the force if we know the mass and acceleration of the car. We are given the mass, but we will have to calculate the acceleration a . We assume the acceleration is constant, so we can use the kinematic equations, Eqs. 2-11, to calculate it.



FIGURE 4-6 Example 4-3.

SOLUTION We assume the motion is along the $+x$ axis (Fig. 4-6). We are given the initial velocity $v_0 = 100 \text{ km/h} = 28 \text{ m/s}$ (Section 1-6), the final velocity $v = 0$, and the distance traveled $x - x_0 = 55 \text{ m}$. From Eq. 2-11c, we have

$$v^2 = v_0^2 + 2a(x - x_0),$$

so

$$a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{0 - (28 \text{ m/s})^2}{2(55 \text{ m})} = -7.1 \text{ m/s}^2.$$

The net force required is then

$$\Sigma F = ma = (1500 \text{ kg})(-7.1 \text{ m/s}^2) = -1.1 \times 10^4 \text{ N.}$$

The force must be exerted in the direction *opposite* to the initial velocity, which is what the negative sign means.

NOTE When we assume the acceleration is constant, even though it may not be precisely true, we are determining an “average” acceleration and we obtain an “average” net force (or vice versa).

Newton's second law, like the first law, is valid only in inertial reference frames (Section 4-2). In the noninertial reference frame of an accelerating car, for example, a cup on the dashboard starts sliding—it accelerates—even though the net force on it is zero; thus $\Sigma \vec{F} = m\vec{a}$ doesn't work in such an accelerating reference frame.

4-5 Newton's Third Law of Motion

Newton's second law of motion describes quantitatively how forces affect motion. But where, we may ask, do forces come from? Observations suggest that a force applied to any object is always applied *by another object*. A horse pulls a wagon, a person pushes a grocery cart, a hammer pushes on a nail, a magnet attracts a paper clip. In each of these examples, a force is exerted *on* one object, and that force is exerted *by* another object. For example, the force exerted *on* the nail is exerted *by* the hammer.

A force is exerted on an object and is exerted by another object