PS for Chapter 7 Momentum

Example 7-5

EXAMPLE 7–5 **Rifle recoil.** Calculate the recoil velocity of a 5.0-kg rifle that shoots a 0.020-kg bullet at a speed of 620 m/s, Fig. 7–7.

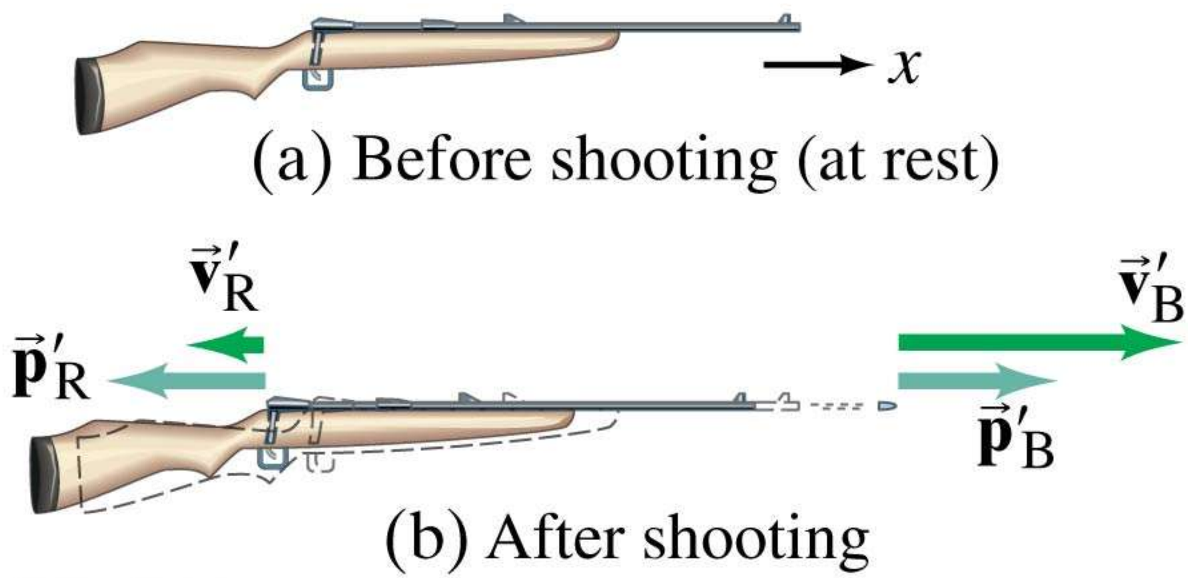

FIGURE 7–7 Example 7–5.

Solution 7-5

SOLUTION Let subscript B represent the bullet and R the rifle; the final velocities are indicated by primes. Then momentum conservation in the x direction gives

$$
\begin{aligned}
\text{momentum before} &= \text{momentum after} \\
m_B v_B + m_R v_R &= m_B v'_B + m_R v'_R \\
0 \quad + \quad 0 &= m_B v'_B + m_R v'_R .
\end{aligned}
$$

We solve for the unknown v'_R, and find

$$
v'_R = -\frac{m_B v'_B}{m_R} = -\frac{(0.020\,\mathrm{kg})(620\,\mathrm{m/s})}{(5.0\,\mathrm{kg})} = -2.5\,\mathrm{m/s}.
$$

Since the rifle has a much larger mass, its (recoil) velocity is much less than that of the bullet. The minus sign indicates that the velocity (and momentum) of the rifle is in the negative x direction, opposite to that of the bullet.

Example 7-6

EXAMPLE 7–6 ESTIMATE **Karate blow.** Estimate the impulse and the average force delivered by a karate blow that breaks a board (Fig. 7–11). Assume the hand moves at roughly 10 m/s when it hits the board.

FIGURE 7–11 Example 7–6.

Solution 7-6

EXAMPLE 7–6 ESTIMATE **Karate blow.** Estimate the impulse and the average force delivered by a karate blow that breaks a board (Fig. 7–11). Assume the hand moves at roughly 10 m/s when it hits the board.

APPROACH We use the momentum-impulse relation, Eq. 7–4. The hand's speed changes from 10 m/s to zero over a distance of perhaps one cm (roughly how much your hand and the board compress before your hand comes to a stop, and the board begins to give way). The hand's mass should probably include part of the arm, and we take it to be roughly $m \approx 1$ kg.

SOLUTION The impulse $F\,\Delta t$ equals the change in momentum

$$\bar{F}\,\Delta t = \Delta p = m\,\Delta v \approx (1\,\mathrm{kg})(10\,\mathrm{m/s} - 0) = 10\,\mathrm{kg\cdot m/s}.$$

We can obtain the force if we know Δt. The hand is brought to rest over the distance of roughly a centimeter: $\Delta x \approx 1$ cm. The average speed during the impact is $\bar{v} = (10\,\mathrm{m/s} + 0)/2 = 5\,\mathrm{m/s}$ and equals $\Delta x/\Delta t$. Thus $\Delta t = \Delta x/\bar{v} \approx (10^{-2}\,\mathrm{m})/(5\,\mathrm{m/s}) = 2 \times 10^{-3}\,\mathrm{s}$ or 2 ms. The average force is thus (Eq. 7–4) about

$$\bar{F} = \frac{\Delta p}{\Delta t} = \frac{10\,\mathrm{kg\cdot m/s}}{2 \times 10^{-3}\,\mathrm{s}} \approx 5000\,\mathrm{N} = 5\,\mathrm{kN}.$$

Example 7-7

EXAMPLE 7–7 **Equal masses.** Billiard ball A of mass m moving with speed v_A collides head-on with ball B of equal mass. What are the speeds of the two balls after the collision, assuming it is elastic? Assume (*a*) both balls are moving initially (v_A and v_B), (*b*) ball B is initially at rest $(v_B = 0)$.

Solution 7-7

SOLUTION (*a*) The masses are equal $(m_A = m_B = m)$ so conservation of momentum gives

$$v_A + v_B = v'_A + v'_B.$$

We need a second equation, because there are two unknowns. We could use the conservation of kinetic energy equation, or the simpler Eq. 7–7 derived from it:

$$v_A - v_B = v'_B - v'_A.$$

We add these two equations and obtain

$$v'_B = v_A$$

and then subtract the two equations to obtain

$$v'_A = v_B.$$

That is, the balls exchange velocities as a result of the collision: ball B acquires the velocity that ball A had before the collision, and vice versa.

(*b*) If ball B is at rest initially, so that $v_B = 0$, we have

$$v'_B = v_A$$

and

$$v'_A = 0.$$

That is, ball A is brought to rest by the collision, whereas ball B acquires the original velocity of ball A. See Fig. 7–14.

Example 7-12

EXAMPLE 7–12 CM of three guys on a raft. On a lightweight (air-filled) "banana boat," three people of roughly equal mass m sit along the x axis at positions $x_A = 1.0\text{ m}$, $x_B = 5.0\text{ m}$, and $x_C = 6.0\text{ m}$, measured from the left-hand end as shown in Fig. 7–23. Find the position of the CM. Ignore the mass of the boat.

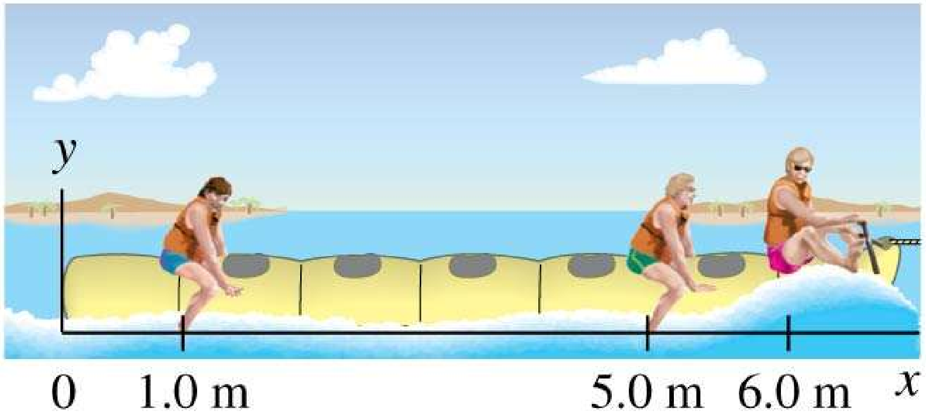

FIGURE 7–23 Example 7–12.

Solution 7-12

EXAMPLE 7–12 **CM of three guys on a raft.** On a lightweight (air-filled) "banana boat," three people of roughly equal mass m sit along the x axis at positions $x_A = 1.0\text{ m}$, $x_B = 5.0\text{ m}$, and $x_C = 6.0\text{ m}$, measured from the left-hand end as shown in Fig. 7–23. Find the position of the CM. Ignore the mass of the boat.

APPROACH We are given the mass and location of the three people, so we use three terms in Eq. 7–9a. We approximate each person as a point particle. Equivalently, the location of each person is the position of that person's own CM.

SOLUTION We use Eq. 7–9a with three terms:

$$x_{CM} = \frac{mx_A + mx_B + mx_C}{m + m + m} = \frac{m(x_A + x_B + x_C)}{3m}$$

$$= \frac{(1.0\text{ m} + 5.0\text{ m} + 6.0\text{ m})}{3} = \frac{12.0\text{ m}}{3} = 4.0\text{ m}.$$

The CM is 4.0 m from the left-hand end of the boat.