8.3 **IDENTIFY** and **SET UP:** $p = mv$. $K = \frac{1}{2}mv^2$.

EXECUTE: **(a)** $v = \dfrac{p}{m}$ and $K = \frac{1}{2}m\left(\dfrac{p}{m}\right)^2 = \dfrac{p^2}{2m}$.

(b) $K_c = K_b$ and the result from part (a) gives $\dfrac{p_c^2}{2m_c} = \dfrac{p_b^2}{2m_b}$. $p_b = \sqrt{\dfrac{m_b}{m_c}}p_c = \sqrt{\dfrac{0.145\text{ kg}}{0.040\text{ kg}}}p_c = 1.90p_c$. The baseball has the greater magnitude of momentum. $p_c / p_b = 0.526$.

(c) $p^2 = 2mK$ so $p_m = p_w$ gives $2m_m K_m = 2m_w K_w$. $w = mg$, so $w_m K_m = w_w K_w$.

$$K_w = \left(\frac{w_m}{w_w}\right)K_m = \left(\frac{700\text{ N}}{450\text{ N}}\right)K_m = 1.56K_m.$$

The woman has greater kinetic energy. $K_m / K_w = 0.641$.

EVALUATE: For equal kinetic energy, the more massive object has the greater momentum. For equal momenta, the less massive object has the greater kinetic energy.

8.7 **IDENTIFY:** The average force on an object and the object's change in momentum are related by Eq. 8.9. The weight of the ball is $w = mg$.

SET UP: Let $+x$ be in the direction of the final velocity of the ball, so $v_{1x} = 0$ and $v_{2x} = 25.0\text{ m/s}$.

EXECUTE: $(F_{av})_x(t_2 - t_1) = mv_{2x} - mv_{1x}$ gives $(F_{av})_x = \dfrac{mv_{2x} - mv_{1x}}{t_2 - t_1} = \dfrac{(0.0450\text{ kg})(25.0\text{ m/s})}{2.00\times 10^{-3}\text{ s}} = 562\text{ N}$.

$w = (0.0450\text{ kg})(9.80\text{ m/s}^2) = 0.441\text{ N}$. The force exerted by the club is much greater than the weight of the ball, so the effect of the weight of the ball during the time of contact is not significant.

EVALUATE: Forces exerted during collisions typically are very large but act for a short time.

8.13 **IDENTIFY:** The force is constant during the 1.0 ms interval that it acts, so $\vec{J} = \vec{F}\Delta t$. $\vec{J}\ 5\ \vec{p}_2\ 2\ \vec{p}_1\ 5\ m(\vec{v}_2\ 2\ \vec{v}_1)$.

SET UP: Let $+x$ be to the right, so $v_{1x} = +5.00\text{ m/s}$. Only the x component of $\vec{J}$ is nonzero, and $J_x = m(v_{2x} - v_{1x})$.

EXECUTE: **(a)** The magnitude of the impulse is $J = F\Delta t = (2.50\times 10^3\text{ N})(1.00\times 10^{-3}\text{ s}) = 2.50\text{ N}\cdot\text{s}$. The direction of the impulse is the direction of the force.

(b) (i) $v_{2x} = \dfrac{J_x}{m} + v_{1x}$. $J_x = +2.50\text{ N}\cdot\text{s}$. $v_{2x} = \dfrac{+2.50\text{ N}\cdot\text{s}}{2.00\text{ kg}} + 5.00\text{ m/s} = 6.25\text{ m/s}$. The stone's velocity has magnitude 6.25 m/s and is directed to the right. (ii) Now $J_x = -2.50\text{ N}\cdot\text{s}$ and $v_{2x} = \dfrac{-2.50\text{ N}\cdot\text{s}}{2.00\text{ kg}} + 5.00\text{ m/s} = 3.75\text{ m/s}$. The stone's velocity has magnitude 3.75 m/s and is directed to the right.

EVALUATE: When the force and initial velocity are in the same direction the speed increases and when they are in opposite directions the speed decreases.

8.16 **IDENTIFY:** Apply conservation of momentum to the system of you and the ball. In part (a) both objects have the same final velocity.

SET UP: Let $+x$ be in the direction the ball is traveling initially. $m_A = 0.400\text{ kg}$ (ball). $m_B = 70.0\text{ kg}$ (you).

EXECUTE: **(a)** $P_{1x} = P_{2x}$ gives $(0.400\text{ kg})(10.0\text{ m/s}) = (0.400\text{ kg} + 70.0\text{ kg})v_2$ and $v_2 = 0.0568\text{ m/s}$.

(b) $P_{1x} = P_{2x}$ gives $(0.400\text{ kg})(10.0\text{ m/s}) = (0.400\text{ kg})(-8.00\text{ m/s}) + (70.0\text{ kg})v_{B2}$ and $v_{B2} = 0.103\text{ m/s}$.

EVALUATE: When the ball bounces off it has a greater change in momentum and you acquire a greater final speed.

8.23 **IDENTIFY:** Apply conservation of momentum to the nucleus and its fragments. The initial momentum is zero. The ^{214}Po nucleus has mass $214(1.67\times 10^{-27}\text{ kg}) = 3.57\times 10^{-25}\text{ kg}$, where $1.67\times 10^{-27}\text{ kg}$ is the mass of a nucleon (proton or neutron). $K = \frac{1}{2}mv^2$.

SET UP: Let $+x$ be the direction in which the alpha particle is emitted. The nucleus that is left after the decay has mass $m_n = 3.75\times 10^{-25}\text{ kg} - m_\alpha = 3.57\times 10^{-25}\text{ kg} - 6.65\times 10^{-27}\text{ kg} = 3.50\times 10^{-25}\text{ kg}$.

EXECUTE: $P_{2x} = P_{1x} = 0$ gives $m_\alpha v_\alpha + m_n v_n = 0$. $v_n = \frac{m_\alpha}{m_n} v_\alpha$. $v_\alpha = \sqrt{\frac{2K_\alpha}{m_\alpha}} = \sqrt{\frac{2(1.23\times10^{-12}\ \text{J})}{6.65\times10^{-27}\ \text{kg}}} = 1.92\times10^{7}\ \text{m/s}$.

$v_n = \left(\frac{6.65\times10^{-27}\ \text{kg}}{3.50\times10^{-25}\ \text{kg}}\right)(1.92\times10^{7}\ \text{m/s}) = 3.65\times10^{5}\ \text{m/s}$.

EVALUATE: The recoil velocity of the more massive nucleus is much less than the speed of the emitted alpha particle.

8.28 **IDENTIFY:** The *x* and *y* components of the momentum of the system of the two asteroids are separately conserved.
SET UP: The before and after diagrams are given in Figure 8.28 and the choice of coordinates is indicated. Each asteroid has mass *m*.
EXECUTE: **(a)** $P_{1x} = P_{2x}$ gives $mv_{A1} = mv_{A2}\cos 30.0° + mv_{B2}\cos 45.0°$. $40.0\ \text{m/s} = 0.866v_{A2} + 0.707v_{B2}$ and $0.707v_{B2} = 40.0\ \text{m/s} - 0.866v_{A2}$.

$$P_{2y} = P_{2y} \text{ gives } 0 = mv_{A2}\sin 30.0° - mv_{B2}\sin 45.0° \text{ and } 0.500v_{A2} = 0.707v_{B2}.$$

Combining these two equations gives $0.500v_{A2} = 40.0\ \text{m/s} - 0.866v_{A2}$ and $v_{A2} = 29.3\ \text{m/s}$. Then

$$v_{B2} = \left(\frac{0.500}{0.707}\right)(29.3\ \text{m/s}) = 20.7\ \text{m/s}.$$

(b) $K_1 = \tfrac{1}{2}mv_{A1}^2$. $K_2 = \tfrac{1}{2}mv_{A2}^2 + \tfrac{1}{2}mv_{B2}^2$. $\frac{K_2}{K_1} = \frac{v_{A2}^2 + v_{B2}^2}{v_{A1}^2} = \frac{(29.3\ \text{m/s})^2 + (20.7\ \text{m/s})^2}{(40.0\ \text{m/s})^2} = 0.804$.

$$\frac{\Delta K}{K_1} = \frac{K_2 - K_1}{K_1} = \frac{K_2}{K_1} - 1 = -0.196.$$

19.6% of the original kinetic energy is dissipated during the collision.
EVALUATE: We could use any directions we wish for the *x* and *y* coordinate directions, but the particular choice we have made is especially convenient.

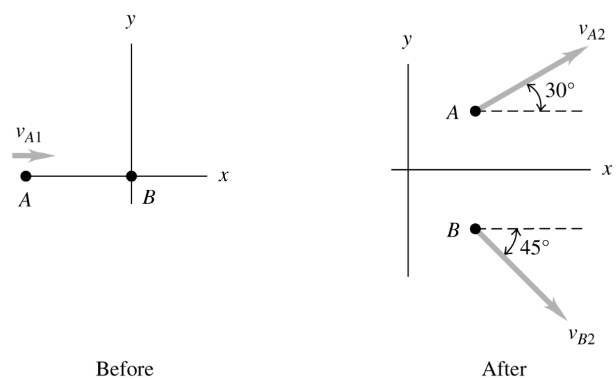

Figure 8.28

8.36 **IDENTIFY:** The collision forces are large so gravity can be neglected during the collision. Therefore, the horizontal and vertical components of the momentum of the system of the two birds are conserved.
SET UP: The system before and after the collision is sketched in Figure 8.36. Use the coordinates shown.

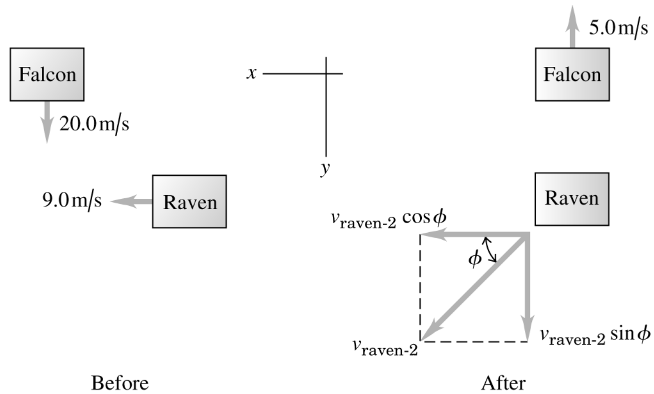

Figure 8.36

EXECUTE: There is no external force on the system so $P_{1x} = P_{2x}$ and $P_{1y} = P_{2y}$.

$P_{1x} = P_{2x}$ gives $(1.5\text{ kg})(9.0\text{ m/s}) = (1.5\text{ kg})v_{\text{raven-2}}\cos\phi$ and $v_{\text{raven-2}}\cos\phi = 9.0\text{ m/s}$.

$P_{1y} = P_{2y}$ gives $(0.600\text{ kg})(20.0\text{ m/s}) = (0.600\text{ kg})(-5.0\text{ m/s}) + (1.5\text{ kg})v_{\text{raven-2}}\sin\phi$ and $v_{\text{raven-2}}\sin\phi = 10.0\text{ m/s}$.

Combining these two equations gives $\tan\phi = \dfrac{10.0\text{ m/s}}{9.0\text{ m/s}}$ and $\phi = 48°$.

EVALUATE: Due to its large initial speed the lighter falcon was able to produce a large change in the raven's direction of motion.

8.37 **IDENTIFY:** Since friction forces from the road are ignored, the *x* and *y* components of momentum are conserved.
SET UP: Let object *A* be the subcompact and object *B* be the truck. After the collision the two objects move together with velocity $\vec{v}_2$. Use the *x* and *y* coordinates given in the problem. $v_{A1y} = v_{B1x} = 0$.

$v_{2x} = (16.0\text{ m/s})\sin 24.0° = 6.5\text{ m/s}$; $v_{2y} = (16.0\text{ m/s})\cos 24.0° = 14.6\text{ m/s}$.

EXECUTE: $P_{1x} = P_{2x}$ gives $m_A v_{A1x} = (m_A + m_B)v_{2x}$.

$$v_{A1x} = \left(\frac{m_A + m_B}{m_A}\right)v_{2x} = \left(\frac{950\text{ kg} + 1900\text{ kg}}{950\text{ kg}}\right)(6.5\text{ m/s}) = 19.5\text{ m/s}.$$

$P_{1y} = P_{2y}$ gives $m_A v_{B1y} = (m_A + m_B)v_{2y}$.

$$v_{B1y} = \left(\frac{m_A + m_B}{m_A}\right)v_{2y} = \left(\frac{950\text{ kg} + 1900\text{ kg}}{1900\text{ kg}}\right)(14.6\text{ m/s}) = 21.9\text{ m/s}.$$

Before the collision the subcompact car has speed 19.5 m/s and the truck has speed 21.9 m/s.
EVALUATE: Each component of momentum is independently conserved.

8.45 **IDENTIFY:** Eqs. 8.24 and 8.25 apply, with object *A* being the neutron.
SET UP: Let +*x* be the direction of the initial momentum of the neutron. The mass of a neutron is $m_n = 1.0\text{ u}$.

EXECUTE: **(a)** $v_{A2x} = \left(\dfrac{m_A - m_B}{m_A + m_B}\right)v_{A1x} = \dfrac{1.0\text{ u} - 2.0\text{ u}}{1.0\text{ u} + 2.0\text{ u}}v_{A1x} = -v_{A1x}/3.0$. The speed of the neutron after the collision is one-third its initial speed.

(b) $K_2 = \frac{1}{2}m_n v_n^2 = \frac{1}{2}m_n(v_{A1}/3.0)^2 = \dfrac{1}{9.0}K_1$.

(c) After *n* collisions, $v_{A2} = \left(\dfrac{1}{3.0}\right)^n v_{A1}$. $\left(\dfrac{1}{3.0}\right)^n = \dfrac{1}{59{,}000}$, so $3.0^n = 59{,}000$. $n\log 3.0 = \log 59{,}000$ and $n = 10$.

EVALUATE: Since the collision is elastic, in each collision the kinetic energy lost by the neutron equals the kinetic energy gained by the deuteron.

8.46 **IDENTIFY:** Elastic collision. Solve for mass and speed of target nucleus.
SET UP: (a) Let *A* be the proton and *B* be the target nucleus. The collision is elastic, all velocities lie along a line, and *B* is at rest before the collision. Hence the results of Eqs. 8.24 and 8.25 apply.

EXECUTE: Eq. 8.24: $m_B(v_x + v_{Ax}) = m_A(v_x - v_{Ax})$, where v_x is the velocity component of *A* before the collision and v_{Ax} is the velocity component of *A* after the collision. Here, $v_x = 1.50\times10^7$ m/s (take direction of incident beam to be positive) and $v_{Ax} = -1.20\times10^7$ m/s (negative since traveling in direction opposite to incident beam).

$$m_B = m_A\left(\frac{v_x - v_{Ax}}{v_x + v_{Ax}}\right) = m\left(\frac{1.50\times10^7\ \text{m/s} + 1.20\times10^7\ \text{m/s}}{1.50\times10^7\ \text{m/s} - 1.20\times10^7\ \text{m/s}}\right) = m\left(\frac{2.70}{0.30}\right) = 9.00m.$$

(b) Eq. 8.25: $v_{Bx} = \left(\frac{2m_A}{m_A + m_B}\right)v = \left(\frac{2m}{m + 9.00m}\right)(1.50\times10^7\ \text{m/s}) = 3.00\times10^6\ \text{m/s}.$

EVALUATE: Can use our calculated v_{Bx} and m_B to show that P_x is constant and that $K_1 = K_2$.