# Solutions to Assignment 11

**Due: 11:59pm on Thursday, November 17, 2011**

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**8.5.** **IDENTIFY:** For each object, $\vec{p} = m\vec{v}$ and $K = \frac{1}{2}mv^2$. The total momentum is the vector sum of the momenta of each object. The total kinetic energy is the scalar sum of the kinetic energies of each object.

**SET UP:** Let object $A$ be the 110 kg lineman and object $B$ the 125 kg lineman. Let $+x$ be to the right, so $v_{Ax} = +2.75$ m/s and $v_{Bx} = -2.60$ m/s.

**EXECUTE:** **(a)** $P_x = m_A v_{Ax} + m_B v_{Bx} = (110\text{ kg})(2.75\text{ m/s}) + (125\text{ kg})(-2.60\text{ m/s}) = -22.5\text{ kg}\cdot\text{m/s}$. The net momentum has magnitude $22.5\text{ kg}\cdot\text{m/s}$ and is directed to the left.

**(b)** $K = \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2 = \frac{1}{2}(110\text{ kg})(2.75\text{ m/s})^2 + \frac{1}{2}(125\text{ kg})(2.60\text{ m/s})^2 = 838\text{ J}$

**EVALUATE:** The kinetic energy of an object is a scalar and is never negative. It depends only on the magnitude of the velocity of the object, not on its direction. The momentum of an object is a vector and has both magnitude and direction. When two objects are in motion, their total kinetic energy is greater than the kinetic energy of either one. But if they are moving in opposite directions, the net momentum of the system has a smaller magnitude than the magnitude of the momentum of either object.

**8.6.** **IDENTIFY:** We know the contact time of the ball with the racket, the change in velocity of the ball, and the mass of the ball. From this information we can use the fact that the impulse is equal to the change in momentum to find the force exerted on the ball by the racket.

**SET UP:** $J_x = \Delta p_x$ and $J_x = F_x \Delta t$. In part (a), take the $+x$ direction to be along the final direction of motion of the ball. The initial speed of the ball is zero. In part (b), take the $+x$ direction to be in the direction the ball is traveling before it is hit by the opponent's racket.

**EXECUTE:** **(a)** $J_x = mv_{2x} - mv_{1x} = (57\times10^{-3}\text{kg})(73.14\text{ m/s} - 0) = 4.2\text{ kg}\cdot\text{m/s}$. Using $J_x = F_x\Delta t$ gives

$$F_x = \frac{J_x}{\Delta t} = \frac{4.2\text{ kg}\cdot\text{m/s}}{30.0\times10^{-3}\text{s}} = 140\text{ N}.$$

**(b)** $J_x = mv_{2x} - mv_{1x} = (57\times10^{-3}\text{kg})(-55\text{ m/s} - 73.14\text{ m/s}) = -7.3\text{ kg}\cdot\text{m/s}$. $F_x = \dfrac{J_x}{\Delta t} = \dfrac{-7.3\text{ kg}\cdot\text{m/s}}{30.0\times10^{-3}\text{s}} = -240\text{ N}.$

**EVALUATE:** The signs of $J_x$ and $F_x$ show their direction. $140\text{ N} = 31\text{ lb}$. This very attainable force has a large effect on the light ball. 140 N is 250 times the weight of the ball

**8.12.** **IDENTIFY:** Apply Eq. 8.9 to relate the change in momentum to the components of the average force on it.

**SET UP:** Let $+x$ be to the right and $+y$ be upward.

**EXECUTE:** $J_x = \Delta p_x = mv_{2x} - mv_{1x} = (0.145\text{ kg})(-[65.0\text{ m/s}]\cos30° - 50.0\text{ m/s}) = -15.4\text{ kg}\cdot\text{m/s}$.

$$J_y = \Delta p_y = mv_{2y} - mv_{1y} = (0.145\text{ kg})([65.0\text{ m/s}]\sin30° - 0) = 4.71\text{ kg}\cdot\text{m/s}$$

The horizontal component is $15.4\text{ kg}\cdot\text{m/s}$, to the left and the vertical component is $4.71\text{ kg}\cdot\text{m/s}$, upward.

$$F_{\text{av-}x} = \frac{J_x}{\Delta t} = \frac{-15.4\text{ kg}\cdot\text{m/s}}{1.75\times10^{-3}\text{ s}} = -8800\text{ N}. \quad F_{\text{av-}y} = \frac{J_y}{\Delta t} = \frac{4.71\text{ kg}\cdot\text{m/s}}{1.75\times10^{-3}\text{ s}} = 2690\text{ N}.$$

The horizontal component is 8800 N, to the left, and the vertical component is 2690 N, upward.

**EVALUATE:** The ball gains momentum to the left and upward and the force components are in these directions.

**8.20.** **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. $m_A = 0.400$ kg (ball). $m_B = 70.0$ 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 $v_2 = 0.0568$ 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 $v_{B2} = 0.103$ m/s.

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

**8.40.** **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 8.40. Use the coordinates shown.

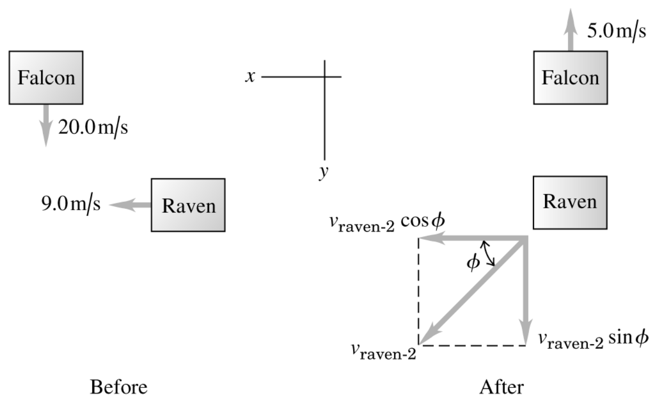


**Figure 8.40**

**EXECUTE:** **(a)** 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 $v_{\text{raven-2}}\cos\phi = 9.0$ 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 $v_{\text{raven-2}}\sin\phi = 10.0$ m/s.

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

**(b)** $\boldsymbol{v_{\text{raven-2}} = 13.5}$ **m/s**

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

**8.43.** **IDENTIFY:** Apply conservation of momentum to the collision and conservation of energy to the motion after the collision. After the collision the kinetic energy of the combined object is converted to gravitational potential energy.

**SET UP:** Immediately after the collision the combined object has speed $V$. Let $h$ be the vertical height through which the pendulum rises.

**EXECUTE:** **(a)** Conservation of momentum applied to the collision gives

$(12.0\times10^{-3} \text{ kg})(380 \text{ m/s}) = (6.00 \text{ kg} + 12.0\times10^{-3} \text{ kg})V$ and $V = 0.758$ m/s.

Conservation of energy applied to the motion after the collision gives $\frac{1}{2}m_{\text{tot}}V^2 = m_{\text{tot}}gh$ and

$$h = \frac{V^2}{2g} = \frac{(0.758\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = 0.0293\text{ m} = 2.93\text{ cm}.$$

**(b)** $K = \frac{1}{2}m_{\text{b}}v_{\text{b}}^2 = \frac{1}{2}(12.0\times10^{-3}\text{ kg})(380\text{ m/s})^2 = 866\text{ J}.$

**(c)** $K = \frac{1}{2}m_{\text{tot}}V^2 = \frac{1}{2}(6.00\text{ kg} + 12.0\times10^{-3}\text{ kg})(0.758\text{ m/s})^2 = 1.73\text{ J}.$

**EVALUATE:** Most of the initial kinetic energy of the bullet is dissipated in the collision.

**8.44.** **IDENTIFY:** During the collision, momentum is conserved. After the collision, mechanical energy is conserved.
**SET UP:** The collision occurs over a short time interval and the block moves very little during the collision, so the spring force during the collision can be neglected. Use coordinates where $+x$ is to the right. During the collision, momentum conservation gives $P_{1x} = P_{2x}$. After the collision, $\frac{1}{2}mv^2 = \frac{1}{2}kx^2$.

**EXECUTE:** *Collision*: There is no external horizontal force during the collision and $P_{1x} = P_{2x}$, so $(3.00\text{ kg})(8.00\text{ m/s}) = (15.0\text{ kg})v_{\text{block, 2}} - (3.00\text{ kg})(2.00\text{ m/s})$ and $v_{\text{block, 2}} = 2.00\text{ m/s}.$

*Motion after the collision*: When the spring has been compressed the maximum amount, all the initial kinetic energy of the block has been converted into potential energy $\frac{1}{2}kx^2$ that is stored in the compressed spring.

Conservation of energy gives $\frac{1}{2}(15.0\text{ kg})(2.00\text{ m/s})^2 = \frac{1}{2}(500.0\text{ kg})x^2$, so $x = 0.346\text{ m}.$

**EVALUATE:** We cannot say that the momentum was converted to potential energy, because momentum and energy are different types of quantities.

**8.50.** **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 $K_1 = K_2$.