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Solutions to Practice Problems Chapter 8

Responses to Questions

Q8.4 Kinetic energy depends only on speed but momentum is a vector and has the same direction as the velocity. The momentum of the car is different in the two cases.

Q8.6 (a) Momentum conservation requires that the magnitude of the momentum change of the truck equals that of the car. It is the same for both. (b) Since $\Delta p = m\,\Delta v$ and the momentum changes for the two vehicles have the same magnitude, the car has a greater change in velocity than the truck. Therefore, the acceleration of the occupants of the small car is greater than for the occupants of the truck and the net force on the occupants of the small car is greater.

Q8.9 The final kinetic energy would be zero if the final speed of the combined object is zero. This will be the case whenever the initial momentum of the system is zero, when $m_A\vec{v}_{A1} + m_B\vec{v}_{B1} = 0.$ The initial kinetic energy is $K_1 = K_{A1} + K_{B1} = \frac{1}{2}m_A v_{A1}^2 + \frac{1}{2}m_B v_{B1}^2$ and cannot be zero. In the inelastic collision, momentum is conserved but kinetic energy is not.

Solutions to Problem

P8.1. **IDENTIFY** and **SET UP:** $p = mv.$ $K = \frac{1}{2}mv^2.$

EXECUTE: (a) $p = (10{,}000\text{ kg})(12.0\text{ m/s}) = 1.20\times10^5\text{ kg}\cdot\text{m/s}$

(b) (i) $v = \dfrac{p}{m} = \dfrac{1.20\times10^5\text{ kg}\cdot\text{m/s}}{2000\text{ kg}} = 60.0\text{ m/s}.$ (ii) $\frac{1}{2}m_{\text{T}}v_{\text{T}}^2 = \frac{1}{2}m_{\text{SUV}}v_{\text{SUV}}^2$, so

$$v_{\text{SUV}} = \sqrt{\frac{m_{\text{T}}}{m_{\text{SUV}}}}v_{\text{T}} = \sqrt{\frac{10{,}000\text{ kg}}{2000\text{ kg}}}(12.0\text{ m/s}) = 26.8\text{ m/s}$$

EVALUATE: The SUV must have less speed to have the same kinetic energy as the truck than to have the same momentum as the truck.

P8.3. **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 $\frac{p_c^2}{2m_c} = \frac{p_b^2}{2m_b}$. $p_b = \sqrt{\frac{m_b}{m_c}}p_c = \sqrt{\frac{0.145\text{ kg}}{0.040\text{ kg}}}p_c = 1.90p_c$.

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.

P8.6. **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) $J_x = mv_{2x} - mv_{1x} = (57\times10^{-3}\text{kg})(-55\text{ m/s} - 73.14\text{ m/s}) = -7.3\text{ kg}\cdot\text{m/s}$. $F_x = \frac{J_x}{\Delta t} = \frac{-7.3\text{ kg}\cdot\text{m/s}}{30.0\times10^{-3}\text{s}} = -240\text{ N}$.

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.

P8.13. **IDENTIFY:** The force is constant during the 1.0 ms interval that it acts, so $\vec{J} = \vec{F}\Delta t$. $\vec{J} = \vec{p}_2 - \vec{p}_1 = m(\vec{v}_2 - \vec{v}_1)$.

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 $J = F\Delta t = (2.50\times10^3\text{ N})(1.00\times10^{-3}\text{ s}) = 2.50\text{ N}\cdot\text{s}$. The direction of the impulse is the direction of the force.

(b) (i) $v_{2x} = \frac{J_x}{m} + v_{1x}$. $J_x = +2.50\text{ N}\cdot\text{s}$. $v_{2x} = \frac{+2.50\text{ N}\cdot\text{s}}{2.00\text{ kg}} + 5.00\text{ m/s} = 6.25\text{ m/s}$. 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 $v_{2x} = \frac{-2.50\text{ N}\cdot\text{s}}{2.00\text{ kg}} + 5.00\text{ m/s} = 3.75\text{ m/s}$. 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.

P8.20. **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. $m_A = 0.400\text{ kg}$ (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.

P8.33. **IDENTIFY:** Since drag effects are neglected there is no net external force on the system of two fish and the momentum of the system is conserved. The mechanical energy equals the kinetic energy, which is $K = \frac{1}{2}mv^2$ for each object.

SET UP: Let object *A* be the 15.0 kg fish and *B* be the 4.50 kg fish. Let $+x$ be the direction the large fish is moving initially, so $v_{A1x} = 1.10\text{ m/s}$ and $v_{B1x} = 0$. After the collision the two objects are combined and move with velocity $\vec{v}_2$. Solve for v_{2x}.

EXECUTE: **(a)** $P_{1x} = P_{2x}$. $m_A v_{A1x} + m_B v_{B1x} = (m_A + m_B)v_{2x}$.

$$v_{2x} = \frac{m_A v_{A1x} + m_B v_{B1x}}{m_A + m_B} = \frac{(15.0\text{ kg})(1.10\text{ m/s}) + 0}{15.0\text{ kg} + 4.50\text{ kg}} = 0.846\text{ m/s}.$$

(b) $K_1 = \frac{1}{2}m_A v_{A1}^2 + \frac{1}{2}m_B v_{B1}^2 = \frac{1}{2}(15.0\text{ kg})(1.10\text{ m/s})^2 = 9.08\text{ J}$.

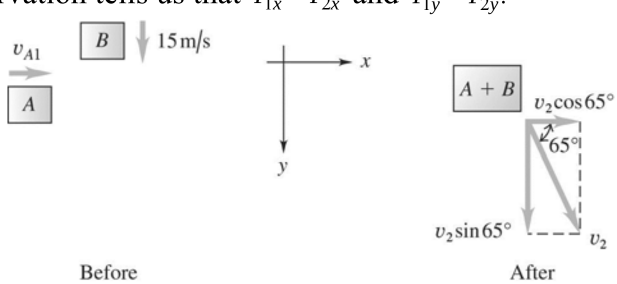
$K_2 = \frac{1}{2}(m_A + m_B)v_2^2 = \frac{1}{2}(19.5\text{ kg})(0.846\text{ m/s})^2 = 6.98\text{ J}$.

$\Delta K = K_2 - K_1 = 2\ 2.10\text{ J}$. 2.10 J of mechanical energy is dissipated.

EVALUATE: The total kinetic energy always decreases in a collision where the two objects become combined.

P8.38. **IDENTIFY:** The momentum is conserved during the collision. Since the motions involved are in two dimensions, we must consider the components separately.

SET UP: Use coordinates where □*x* is east and □*y* is south. The system of two cars before and after the collision is sketched in Figure 8.38. Neglect friction from the road during the collision. The enmeshed cars have a total mass of $2000\text{ kg} + 1500\text{ kg} = 3500\text{ kg}$. Momentum conservation tells us that $P_{1x} = P_{2x}$ and $P_{1y} = P_{2y}$.



EXECUTE: There are no external horizontal forces during the collision, so $P_{1x} = P_{2x}$ and $P_{1y} = P_{2y}$.

(a) $P_{1x} = P_{2x}$ gives $(1500\text{ kg})(15\text{ m/s}) = (3500\text{ kg})v_2\sin 65°$ and $v_2 = 7.1\text{ m/s}$.

(b) $P_{1y} = P_{2y}$ gives $(2000\text{ kg})v_{A1} = (3500\text{ kg})v_2\cos 65°$. And then using $v_2 = 7.1\text{ m/s}$, we have $v_{A1} = 5.2\text{ m/s}$.

EVALUATE: Momentum is a vector so we must treat each component separately.

P8.44. 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.

P8.46. IDENTIFY: No net external horizontal force so P_x is conserved. Elastic collision so $K_1 = K_2$ and can use Eq. 8.27.

SET UP:

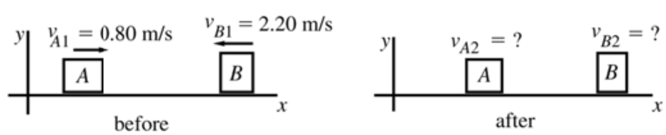


Figure 8.46

EXECUTE: From conservation of *x*-component of momentum:

$$m_A v_{A1x} + m_B v_{B1x} = m_A v_{A2x} + m_B v_{B2x}$$

$$m_A v_{A1} - m_B v_{B1} = m_A v_{A2x} + m_B v_{B2x}$$

$$(0.150\text{ kg})(0.80\text{ m/s}) - (0.300\text{ kg})(2.20\text{ m/s}) = (0.150\text{ kg})v_{A2x} + (0.300\text{ kg})v_{B2x}$$

$$-3.60\text{ m/s} = v_{A2x} + 2v_{B2x}$$

From the relative velocity equation for an elastic collision Eq. 8.27:

$$v_{B2x} - v_{A2x} = -(v_{B1x} - v_{A1x}) = -(-2.20\text{ m/s} - 0.80\text{ m/s}) = +3.00\text{ m/s}$$

$$3.00\text{ m/s} = -v_{A2x} + v_{B2x}$$

Adding the two equations gives $-0.60\text{ m/s} = 3v_{B2x}$ and $v_{B2x} = -0.20\text{ m/s}.$ Then $v_{A2x} = v_{B2x} - 3.00\text{ m/s} = 2\ 3.20\text{ m/s}.$

The 0.150 kg glider (*A*) is moving to the left at 3.20 m/s and the 0.300 kg glider (*B*) is moving to the left at 0.20 m/s.

EVALUATE: We can use our v_{A2x} and v_{B2x} to show that P_x is constant and $K_1 = K_2$

P8.54. **IDENTIFY:** Apply Eqs. 8.28, 8.30 and 8.32. There is only one component of position and velocity.

SET UP: $m_A = 1200\text{ kg},$ $m_B = 1800\text{ kg}.$ $M = m_A + m_B = 3000\text{ kg}.$ Let $+x$ be to the right and let the origin be at the center of mass of the station wagon.

EXECUTE: **(a)** $x_{cm} = \dfrac{m_A x_A + m_B x_B}{m_A + m_B} = \dfrac{0 + (1800\text{ kg})(40.0\text{ m})}{1200\text{ kg} + 1800\text{ kg}} = 24.0\text{ m}.$

The center of mass is between the two cars, 24.0 m to the right of the station wagon and 16.0 m behind the lead car.

(b) $P_x = m_A v_{A,x} + m_B v_{B,x} = (1200\text{ kg})(12.0\text{ m/s}) + (1800\text{ kg})(20.0\text{ m/s}) = 5.04 \times 10^4\text{ kg}\cdot\text{m/s}.$

(c) $v_{cm,x} = \dfrac{m_A v_{A,x} + m_B v_{B,x}}{m_A + m_B} = \dfrac{(1200\text{ kg})(12.0\text{ m/s}) + (1800\text{ kg})(20.0\text{ m/s})}{1200\text{ kg} + 1800\text{ kg}} = 16.8\text{ m/s}.$

(d) $P_x = Mv_{cm-x} = (3000\text{ kg})(16.8\text{ m/s}) = 5.04 \times 10^4\text{ kg}\cdot\text{m/s},$ the same as in part (b).

EVALUATE: The total momentum can be calculated either as the vector sum of the momenta of the individual objects in the system, or as the total mass of the system times the velocity of the center of mass.

P8.58. **(a) IDENTIFY** and **SET UP:** Apply Eq. 8.28 and solve for m_1 and m_2.

EXECUTE: $y_{cm} = \dfrac{m_1 y_1 + m_2 y_2}{m_1 + m_2}$

$m_1 + m_2 = \dfrac{m_1 y_1 + m_2 y_2}{y_{cm}} = \dfrac{m_1(0) + (0.50\text{ kg})(6.0\text{ m})}{2.4\text{ m}} = 1.25\text{ kg}$ and $m_1 = 0.75\text{ kg}.$

EVALUATE: y_{cm} is closer to m_1 since $m_1 > m_2$.

(b) IDENTIFY and **SET UP:** Apply $\vec{a} = d\vec{v}/dt$ for the cm motion.

EXECUTE: $\vec{a}_{cm} = \dfrac{d\vec{v}_{cm}}{dt} = (1.5\text{ m/s}^3)t\hat{i}.$

(c) IDENTIFY and **SET UP:** Apply Eq. 8.34.

EXECUTE: $\Sigma\vec{F}_{ext} = M\vec{a}_{cm} = (1.25\text{ kg})(1.5\text{ m/s}^3)t\hat{i}.$

At $t = 3.0\text{ s},$ $\Sigma\vec{F}_{ext} = (1.25\text{ kg})(1.5\text{ m/s}^3)(3.0\text{ s})\hat{i} = (5.6\text{ N})\hat{i}.$

EVALUATE: $v_{cm\text{-}x}$ is positive and increasing so $a_{cm\text{-}x}$ is positive and $\vec{F}_{ext}$ is in the $+x$-direction. There is no motion and no force component in the y-direction.