Questions and Example Problems from Chapter 9

Question 1

To win a prize at the county fair, you' re trying to knock down a heavy bowling pin by hitting it with a thrown object. Should you choose to throw a rubber ball or a beanbag of equal size and weight? Explain.

You should choose to throw a $\boxed{\text{rubber ball}}$. This is because the rubber ball will bounce off the bowling pin and experience a greater change in momentum than the beanbag which will keep moving in the same direction. The rubber ball will therefore experience the greater impulse and the impulse on the bowling pin is negative the impulse on the rubber ball.

Question 2

Two ice skaters, Megan and Jason, push off from each other on frictionless ice. Jason's mass is twice that of Megan. (a) Which skater, if either, experiences the greater impulse during the push? Explain. (b) Which skater, if either, has the greater speed after the push off? Explain.

(a) The impulse is the $\boxed{\text{same on each}}$ because by Newton's 3rd law, the magnitude of the force on each is the same. (b) $\boxed{\text{Megan}}$ will have a greater speed from Newton's 2nd law: $\vec{a} = \sum \vec{F}/m$ because her mass is smaller.

Question 3

An ice boat is coasting along a frozen lake. Friction between the ice and the boat is negligible, and so is air resistance. Nothing is propelling the boat. From a bridge, someone jumps straight down and lands in the boat, which continues to coast straight ahead. (a) Does the horizontal momentum of the boat change? (b) Does the speed of the boat increase, decrease, or remain the same? Explain your answers.

(a) $\boxed{\text{no}}$, since $\sum \vec{F}_{ext,x} = 0$, $\Delta \vec{P}_x = 0$

(b) the speed of the boat $\boxed{\text{decreases}}$; $\vec{P}_x$ remains constant but mass increases so velocity must decrease.

Question 4

Two particles collide, one of which was initially moving and the other initially at rest.
(a) Is it possible for *both* particles to be at rest after the collision? Give an example in which this happens, or explain why it can't happen. (b) Is it possible for *one* particle to be at rest after the collision? Give an example in which this happens, or explain why it can't happen.

(a) $\boxed{\text{no}}$, this would violate conservation of momentum

(b) $\boxed{\text{yes}}$, if both masses are the same, the initially moving particle can come to rest and the initially at rest particle can move at the initial speed of the first particle

Problem 1

A sled and rider, gliding over horizontal, frictionless ice at 4.0 m/s, have a combined mass of 80.0 kg. The sled then slides over a rough spot in the ice, slowing down to 3.0 m/s. (a) What impulse was delivered to the sled by the friction force from the rough spot? (b) If the sled was in contact with the rough spot is 1.50 s, what was the average force exerted by friction?

$m = 80.0\,Kg$

$\vec{V}_i = 4.0\,m/s$

$\vec{V}_f = 3.0\,m/s$

$\vec{J} = ?$

(a) $\vec{J} = \Delta\vec{p} = m(\vec{V}_f - \vec{V}_i)$

$\vec{J} = (80.0\,Kg)(3.0\,m/s - 4.0\,m/s)$

$\vec{J} = -80.0\,Kg\,m/s$

$\boxed{\vec{J} = -80.0\,N\cdot s}$

note: the − sign indicates that the direction of the impulse is in the opposite direction of motion

(b) $\vec{J} = \vec{F}_{avg}\Delta t \longrightarrow \vec{F}_{avg} = \vec{J}/\Delta t = \dfrac{-80.0\,N\cdot s}{1.50\,s}$

$\vec{F}_{avg} = -53.3\,N \longrightarrow \boxed{\vec{F}_{avg} = -53\,N}$

Problem 2

A truck of mass 10^4 kg is initially traveling at 35 m/s when it hits the brakes. If the brakes are applied for 2.0 s, what is the average force required to bring it to rest?

$m = 10^4\,Kg$

$\vec{V}_i = 35\,m/s$

$\vec{V}_f = 0\,m/s$

$\Delta t = 2.0\,s$

$\vec{J} = \vec{F}_{ave}\Delta t = \vec{P}_f - \vec{P}_i$

$\vec{F}_{ave}\Delta t = m(\vec{V}_f - \vec{V}_i)$

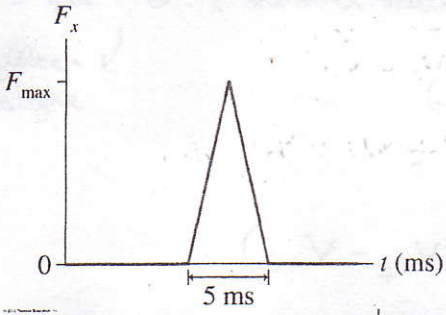
$\vec{F}_{ave} = \dfrac{m(\vec{V}_f - \vec{V}_i)}{\Delta t}$

$\vec{F}_{ave} = \dfrac{(10^4\,Kg)(0 - 35\,m/s)}{(2.0\,s)} \longrightarrow \boxed{\vec{F}_{ave} = -1.75\times10^5\,N}$

the − sign indicates that the force is in the opposite direction of the velocity

Problem 3

A 200.0 g ball is dropped from a height of 2.00 m, bounces on a hard floor, and rebounds to a height of 1.50 m. The figure below shows the impulse received from the floor. What maximum force does the floor exert on the ball?



⇒ first use equations of constant acceleration to get $\vec{v}$ right before and right after the ball hits the floor

right before ball hits: $(V_y)_i = 0\,m/s$, $(V_y)_f = ?$, $\Delta y = -2.00\,m$, $a_y = -9.80\,m/s^2$

$$(V_y)_f^2 = \overset{=0}{(V_y)_i^2} + 2a_y\Delta y$$

$$(V_y)_f^2 = 2a_y\Delta y$$

$$(V_y)_f = \pm\sqrt{2a_y\Delta y} = \pm\sqrt{2(-9.80\,m/s^2)(-2.00\,m)}$$

$$(V_y)_f = -6.26\,m/s$$ (− sign because ball moving downward)

right after ball hits: $(V_y)_i = ?$ $(V_y)_f = 0\,m/s$, $\Delta y = -9.80\,m/s^2$ $\Delta y = 1.50\,m$

$$\overset{=0}{(V_y)_f^2} = (V_y)_i^2 + 2a_y\Delta y$$

$$(V_y)_i = \pm\sqrt{-2a_y\Delta y}$$

$$= \sqrt{-2(-9.80\,m/s^2)(1.50\,m)}$$

$$(V_y)_i = 5.42\,m/s$$

$\vec{v}_i$ $\vec{v}_f$

$$\vec{J} = \text{area under curve} = m(\vec{v}_f - \vec{v}_i)$$

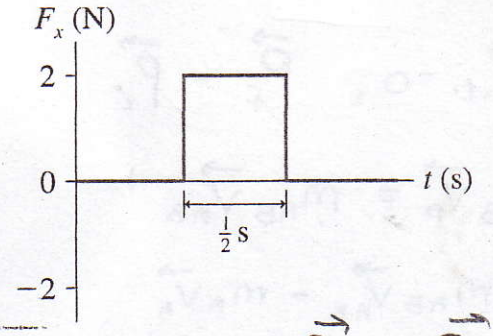
$$\tfrac{1}{2}(F_{max})(5\,ms) = m(\vec{v}_f - \vec{v}_i)$$

$$F_{max} = \frac{2m(\vec{v}_f - \vec{v}_i)}{5\,ms} = \frac{2(0.200\,kg)[(5.42\,m/s) - (-6.26\,m/s)]}{(5.00\times10^{-3}\,s)}$$

$$\boxed{F_{max} = 934\,N}$$

Problem 4

A 2.0 kg object is moving to the right with a speed of 1.0 m/s when it experiences the force shown in the figure below. What are the object's speed and direction after the force ends?



$m = 2.0\,kg$ $\vec{V}_i = 1.0\,m/s$ $\vec{V}_f = ?$

$$\vec{J} = \Delta\vec{p} = \vec{p}_f - \vec{p}_i$$

↓

area under curve of F vs t

$$\vec{p}_f = \vec{p}_i + \vec{J}$$

area under curve $= (2N)(\tfrac{1}{2}s) = 1.0\,Ns$

$$\vec{p}_f = (2.0\,kg)(1.0\,m/s) + (1.0\,Ns)$$

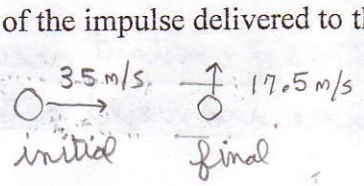
$$\vec{p}_f = 3.0\,kg\,m/s \qquad \vec{p}_f = m\vec{V}_f \longrightarrow \vec{V}_f = \vec{p}_f/m$$

$$\vec{V}_f = \frac{(3.0\,kg\,m/s)}{2.0\,kg} = 1.5\,m/s$$

$\boxed{\text{speed} = 1.5\,m/s \text{ and direction is to the right}}$

Problem 5

A 0.14 kg baseball moves horizontally with a speed of 35 m/s towards the bat. After striking the bat the ball moves vertically upward with half its initial speed. Find the direction and magnitude of the impulse delivered to the ball by the bat.



from impulse momentum theorem: $\vec{J} = \Delta\vec{p} = m\Delta\vec{v}$

↳ really 2 equations

$$J_x = m\,\Delta V_x$$

$$J_y = m\,\Delta V_y$$

$m = 0.14\ Kg$

$(V_x)_i = 35\ m/s$

$(V_x)_f = 0\ m/s$

$(V_y)_i = 0\ m/s$

$(V_y)_f = 17.5\ m/s$

$$J_x = m\,\Delta V_x = m(V_{xf} - V_{xi})$$

$$= (0.14\ Kg)(0 - 35\ m/s) = -4.90\ Ns$$

$$J_y = m\,\Delta V_y = m(V_{yf} - V_{yi})$$

$$= (0.14\ Kg)(17.5\ m/s - 0) = 2.45\ Ns$$

$$J = \sqrt{J_x^2 + J_y^2} = \sqrt{(-4.90\ Ns)^2 + (2.45\ Ns)^2} = \boxed{5.5\ Ns}$$

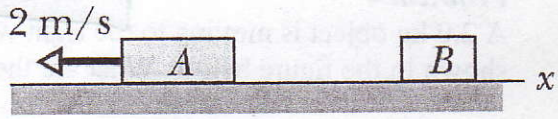
$$\theta = \tan^{-1}\left(\frac{J_y}{J_x}\right) = \tan^{-1}\left(\frac{2.45\ N\cdot s}{-4.90\ N\cdot s}\right) = -26.6^\circ$$

→ wrong quadrant

$$\boxed{\theta = 153^\circ}$$

Problem 6

A 10 kg block is sliding with a velocity of 5.0 m/s to the right on a frictionless surface when it explodes into two pieces. After the explosion, piece A, with a mass of 7.0 kg, is traveling 2 m/s to the left as shown in the figure below. Find the velocity of piece B assuming that no mass is lost in the explosion.



⇒ if no mass is lost in the explosion, then $m_B = 3.0\ Kg$

$m_{AB} = 10\ Kg$

$\vec{V}_{AB} = 5.0\ m/s$

$m_A = 7.0\ Kg$

$\vec{V}_A = -2.0\ m/s$

$m_B = 3.0\ Kg$

$\vec{V}_B = ?$

since $\sum \vec{F}_{ext} = 0$, $\vec{P}_f = \vec{P}_i$

$$m_A\vec{V}_A + m_B\vec{V}_B = m_{AB}\vec{V}_{AB}$$

$$m_B\vec{V}_B = m_{AB}\vec{V}_{AB} - m_A\vec{V}_A$$

$$\vec{V}_B = \frac{(m_{AB}\vec{V}_{AB} - m_A\vec{V}_A)}{m_B}$$

$$\vec{V}_B = \frac{(10\ Kg)(5.0\ m/s) - (7.0\ Kg)(-2.0\ m/s)}{(3.0\ Kg)}$$

$$\boxed{\vec{V}_B = 21.3\ m/s}$$

Problem 7

A 0.150 kg projectile is fired with a velocity of +715 m/s at a 2.00 kg wooden block that rests on a frictionless table. The velocity of the block, immediately after the projectile passes through it, is +40.0 m/s. Find the velocity with which the projectile exits from the block.

1 → projectile
2 → block

$m_1 = 0.150\,Kg$

$m_2 = 2.00\,Kg$

$V_{1i} = 715\,m/s$

$V_{2i} = 0\,m/s$

$V_{1f} = ?$

$V_{2f} = 40.0\,m/s$

$$\sum \vec{F}_{ext} = 0 \longrightarrow \vec{P}_f = \vec{P}_i$$

$$m_1\vec{V}_{1f} + m_2\vec{V}_{2f} = m_1\vec{V}_{1i} + m_2\overset{=0}{\vec{V}_{2i}}$$

$$m_1\vec{V}_{1f} = m_1\vec{V}_{1i} - m_2\vec{V}_{2f}$$

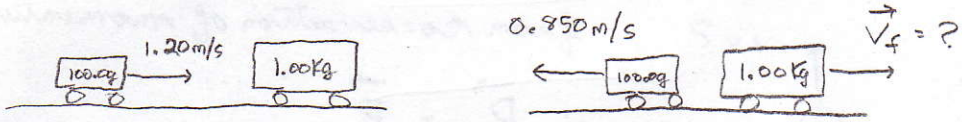
$$\vec{V}_{1f} = \frac{m_1\vec{V}_{1i} - m_2\vec{V}_{2f}}{m_1}$$

$$\vec{V}_{1f} = \frac{(0.150\,Kg)(715\,m/s) - (2.00\,Kg)(40.0\,m/s)}{(0.150\,Kg)}$$

$$\boxed{\vec{V}_{1f} = 182\,m/s}$$

Problem 8

A small, 100.0 g cart is moving at 1.20 m/s on an air track when it collides with a larger, 1.00 kg cart at rest. After the collision, the small cart recoils at 0.850 m/s. What is the speed of the large cart after the collision?



$m_1 = 0.1000\,Kg$

$m_2 = 1.00\,Kg$

$\vec{V}_{1i} = 1.20\,m/s$

$\vec{V}_{2i} = 0\,m/s$

$\vec{V}_{1f} = -0.850\,m/s$

$\vec{V}_{2f} = ?$

note: $\vec{V}_{1f}$ is negative because cart is moving to the left

from conservation of momentum:

$$\vec{P}_f = \vec{P}_i \longrightarrow m_1\vec{V}_{1f} + m_2\vec{V}_{2f} = m_1\vec{V}_{1i} + m_2\overset{=0}{\vec{V}_{2i}}$$

$$m_2\vec{V}_{2f} = m_1\vec{V}_{1i} - m_1\vec{V}_{1f}$$

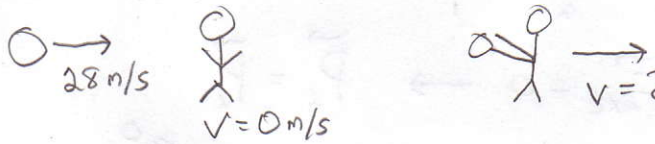
$$\vec{V}_{2f} = \frac{m_1(\vec{V}_{1i} - \vec{V}_{1f})}{m_2} = \frac{(0.1000\,Kg)\left[1.20\,m/s - (-0.850\,m/s)\right]}{1.00\,Kg}$$

$$\vec{V}_{2f} = 0.205\,m/s \rightarrow \boxed{\text{speed of large cart} = 0.205\,m/s}$$

Problem 9

A 71 kg baseball player jumps straight up to catch a line drive. If the 140 g ball is moving horizontally at 28 m/s. and the catch is made when the ballplayer is at the highest point of his leap, what is his speed immediately after stopping the ball?

note : at the highest point, the velocity of the ball player is zero



1 → baseball player
2 → ball

$m_1 = 71\,Kg$
$m_2 = 0.140\,Kg$
$V_{1i} = 0\,m/s$
$V_{2i} = 28\,m/s$
$V_f = ?$

from conservation of momentum : $\vec{P}_f = \vec{P}_i$

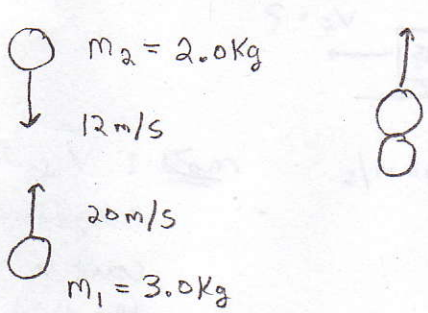
$$(m_1 + m_2)\vec{V}_f = m_1 \overset{=0}{\vec{V}_{1i}} + m_2 \vec{V}_{2i}$$

$$(m_1 + m_2)\vec{V}_f = m_2 \vec{V}_{2i}$$

$$\vec{V}_f = \frac{m_2 \vec{V}_{2i}}{(m_1 + m_2)} \rightarrow \vec{V}_f = \frac{(0.140\,Kg)(28\,m/s)}{(71\,Kg + 0.140\,Kg)} = \boxed{0.055\,m/s = 5.5\,cm/s}$$

Problem 10

A completely inelastic collision occurs between two balls of wet putty that move directly toward each other along a vertical axis. Just before the collision, one ball, of mass 3.0 kg, is moving upward at 20 m/s and the other ball, of mass 2.0 kg, is moving downward at 12 m/s. How high do the combined two balls of putty rise above the collision point?



from conservation of momentum :

$$\vec{P}_f = \vec{P}_i$$

$$(m_1 + m_2)\vec{V}_f = m_1 \vec{V}_{1i} + m_2 \vec{V}_{2i}$$

$$\vec{V}_f = \frac{m_1 \vec{V}_{1i} + m_2 \vec{V}_{2i}}{(m_1 + m_2)}$$

$$\vec{V}_f = \frac{(3.0\,Kg)(20\,m/s) + (2.0\,Kg)(-12\,m/s)}{(3.0\,Kg + 2.0\,Kg)}$$

$$\vec{V}_f = 7.2\,m/s$$

* now use equations of constant to get height

$(V_y)_i = 7.2\,m/s$
$(V_y)_f = 0\,m/s$
$y_i = 0\,m$
$y_f = ?$
$a_y = -9.80\,m/s^2$

$$(V_y)_f^2 = (V_y)_i^2 + 2a_y \Delta y$$

$$0 = (V_y)_i^2 + 2a_y \Delta y$$

$$\Delta y = -\frac{(V_y)_i^2}{2a_y}$$

$$\Delta y = -\frac{(7.2\,m/s)^2}{2(-9.80\,m/s^2)} = 2.6\,m$$

since $y_i = 0$, $\boxed{y_f = 2.6\,m}$