1) At a city park, a person throws some bread into a duck pond. Two 4.00 kg ducks and a 9.00 kg goose paddle rapidly toward the bread, as shown in the sketch. If the ducks swim at 1.10 m/s, and the goose swims 1.30 m/s, find the magnitude and direction of the total momentum of the three birds.

Find x and y components of momentum for each bird:

- For duck 1:
  \[ p_{1,x} = (4\text{ kg})(1.1\text{ m/s}) = +4.4 \text{ kg-m/s} \]
  \[ p_{1,y} = (4\text{ kg})(0\text{ m/s}) = 0 \text{ kg-m/s} \]

- For duck 2:
  \[ p_{2,x} = 0 \text{ kg-m/s} \]
  \[ p_{2,y} = (4\text{ kg})(-1.1\text{ m/s}) = -4.4 \text{ kg-m/s} \]

- For goose 3:
  \[ p_{3,x} = 0 \text{ kg-m/s} \]
  \[ p_{3,y} = (9\text{ kg})(1.3\text{ m/s}) = +11.7 \text{ kg-m/s} \]

Add the x and y components separately:

- Total momentum in the x-direction:
  \[ p_{\text{total,x}} = +4.4 \text{ kg-m/s} \]

- Total momentum in the y-direction:
  \[ p_{\text{total,y}} = +7.3 \text{ kg-m/s} \]

Magnitude via Pythagorean theorem:

- Total momentum:
  \[ p_{\text{total}} = \sqrt{(4.4^2 + 7.3^2)} \approx 8.5 \text{ kg-m/s} \]

Angle using \( \tan \theta = \frac{p_y}{p_x} \):

- \( \theta = 59^\circ \) above +x axis

2) A 0.144 kg baseball is moving toward home plate with a speed of 43.0 m/s when it is bunted (hit softly). The bat exerts an average force of 6.50 \times 10^3 \text{ N} on the ball for 1.30 ms. The average force is directed toward the pitcher, which we take to be the positive x direction. What is the final speed of the ball?

Initial momentum of system:

- Initial momentum of the ball:
  \[ p_{\text{initial}} = (0.144\text{ kg})(-43 \text{ m/s}) = -6.2 \text{ kg-m/s} \]

Impulse:

- Impulse = \( \Delta p = F_{\text{avg}} \Delta t = (6.5 \times 10^3 \text{ N})(1.3 \times 10^{-3}\text{ s}) = 8.5 \text{ kg-m/s} \)

Final momentum:

- \( p_{\text{final}} = p_{\text{initial}} + \Delta p = +2.3 \text{ kg-m/s} \)

Final speed of the ball:

- Final speed:
  \[ v_{\text{final}} = \frac{p_{\text{final}}}{m} = \frac{2.3 \text{ kg-m/s}}{0.144 \text{ kg}} \approx 15.7 \text{ m/s} \]

3) A honeybee with a mass of 0.150 g lands on one end of a floating 4.75 g popsicle stick. After sitting at rest for a moment, it runs toward the other end with a velocity \( v_b \) relative to the still water. The stick moves in the opposite direction with a speed of 1.20 cm/s. What is the velocity of the bee? Let the direction of the bee’s motion be the positive x direction.

Use conservation of momentum for this one.

Initial momentum of system is zero (no motion):

- Initial momentum:
  \[ p_{\text{initial}} = 0 = p_b + p_{\text{stick}} \]

Conservation of momentum:

- \( p_{\text{final}} = 0 = m_b \cdot v_b + m_{\text{stick}} \cdot v_{\text{stick}} \)

Solve for \( v_b \):

- \( 0 = (0.15 \cdot 10^{-3}\text{ kg})v_b + (4.75 \cdot 10^{-3}\text{ kg})(-0.012 \text{ m/s}) \)

- \( v_b = 0.38 \text{ m/s} \)
4) A 15 kg block is attached to a very light horizontal spring of force constant 350 N/m and is resting on a smooth horizontal table (in figure). It is struck suddenly by a 3.00 kg stone traveling horizontally at 8.00 m/s to the right, whereupon the stone rebounds at 2.00 m/s horizontally to the left.

(a) Find the maximum distance that the block will compress the spring after the collision. (Hint: Break this problem into two parts - the collision and the behavior after the collision - then apply the appropriate conservation laws.)

(b) Find the initial and final kinetic energies of the system.

Before the collision only the ball has momentum – \( p_{\text{initial}} = (3 \text{kg})(8 \text{ m/s}) = 24 \text{ kgm/s} \)

After the collision both the ball and the block have momentum, but the total should not change.

We can now calculate the speed of the block just after the collision:

\[
24 \text{ kgm/s} = (3 \text{kg})(-2 \text{ m/s}) + (15 \text{kg})(v_{\text{block}})
\]

\[ v_{\text{block}} = \frac{2 \text{ m/s}}{}
\]

Now we can find the kinetic energy of the block:

\[ K_{\text{block}} = \frac{1}{2}(15 \text{kg})(2 \text{ m/s})^2 = 30 \text{J} \]

All of this kinetic energy will be converted into elastic potential energy as the spring is compressed, so we can find the maximum compression of the spring:

\[ 30 \text{J} = \frac{1}{2}kx^2 = \frac{1}{2}(350 \text{ N/m})(x^2) \Rightarrow x = 0.41 \text{m} = 41 \text{cm} \]

5) On a touchdown attempt, a 95.0-kg running back runs toward the end zone at 3.75m/s. Brian Urlacher, the 111-kg linebacker for the Chicago Bears, is moving at 4.10m/s and destroys the running back in a head-on collision. If the two players stick together, (a) Find their velocity immediately after the collision and (b) What are the initial and final kinetic energies of the system?

This is a completely inelastic collision. Total momentum will be conserved.

\[ p_i = (95 \text{kg})(3.75 \text{ m/s}) + (111 \text{kg})(-4.1 \text{ m/s}) = -98.9 \text{ kgm/s} \]

\[ p_f = (206 \text{kg})(v_f) = -98.9 \text{ kgm/s} \]

\[ v_f = -0.48 \text{ m/s} \]

Kinetic energy is a basic calculation:

\[ K_i = 1600 \text{J} \]

\[ K_f = 24 \text{J} \text{ (KE is NOT conserved)} \]