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:

\[ p_{1,x} = (4 \text{ kg})(1.1 \text{ m/s}) = 4.4 \text{ kg-m/s} \]
\[ p_{1,y} = (4 \text{ kg})(0 \text{ m/s}) = 0 \text{ kg-m/s} \]
\[ p_{2,x} = 0 \text{ kg-m/s} \]
\[ p_{2,y} = (4 \text{ kg})(-1.1 \text{ m/s}) = -4.4 \text{ kg-m/s} \]
\[ p_{3,x} = 0 \text{ kg-m/s} \]
\[ p_{3,y} = (9 \text{ kg})(1.3 \text{ m/s}) = 11.7 \text{ kg-m/s} \]

Add the x and y components separately:

\[ p_{\text{total},x} = +4.4 \text{ kg-m/s} \]
\[ p_{\text{total},y} = +7.3 \text{ kg-m/s} \]

magnitude via Pythagorean thm:

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

angle using \( \tan \theta = p_y / p_x \)

\[ \theta = 59^\circ \text{ above +x axis} \]

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?

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

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

\[ p_{\text{final}} = m \cdot v_{\text{final}} \rightarrow v_{\text{final}} = 15.7 \text{ m/s} \]

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)

\[ p_{\text{final}} = 0 = p_b + p_{\text{stick}} \]

\[ 0 = m_b \cdot v_b + m_{\text{stick}} \cdot v_{\text{stick}} \]

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

\[ v_b = 0.38 \text{ m/s} \]
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) Is the collision between the stone and the block elastic?

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:

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

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

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 the block’s 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:

$K_{f}=1600\text{J}$

$K_{i}=24\text{J}$ (KE is NOT conserved)