Name:

Skill Sheet 3-C — Momentum

This skill sheet will help you practice solving problems that involve momentum. The momentum of an object is equal to its mass times its velocity. When two objects collide, their momentum before the collision is equal to their momentum after the collision. This statement is called the law of conservation of momentum.

1. What is momentum?

A baseball bat and a ball are a pair of objects that collide with each other. Because of Newton's third law of motion, we know that the force the bat has on a baseball is equal to, but opposite in direction to the force of the the ball on the bat. The bat and the baseball illustrate that action and reaction forces come in pairs.

Similarly, the momentum of the bat before it hits the ball will affect how much momentum the ball has after the bat and ball collide. Likewise, the momentum of the ball coming toward the bat, determines how much force you must use when swinging the bat to get a home run. What is *momentum*?

The momentum (kg-m/sec) of an object is its mass (kg) multiplied by its velocity (m/sec). The equation for momentum where p equals momentum, m equals mass, and v equals velocity, is:

$$p = mv$$

p = mass in kilograms × speed in meters/sec

2. The law of conservation of momentum

The *law of conservation of momentum* states that the momentum of a system is conserved. Two or more objects interacting may be called a system. The bat and ball are a system. This means that the momentum of the bat and ball is conserved. In other words, the momentum of the bat and ball before their collision is equal to the momentum of the bat and ball after their collision. A formula which summarizes this law and helps you complete the skill sheet is written below:

Momentum of the system before a collision = Momentum of the system after a collision

Momentum before Momentum after

$$m_1 v_1 - m_2 v_2 = m_1 v_1 - m_2 v_2$$

For example:

$$(\text{mass}_{\text{ball}})(\text{velocity}_{\text{ball}}) + (\text{mass}_{\text{bat}})(\text{velocity}_{\text{bat}}) = (\text{mass}_{\text{ball}})(\text{velocity}_{\text{ball}}) + (\text{mass}_{\text{bat}})(\text{velocity}_{\text{bat}})$$

As you solve the momentum problems that follow, REMEMBER that a positive velocity is in the opposite direction to a negative velocity.

3. Solving momentum problems

Find the momentum of the following objects. The first two problems have been done for you.

1. A 0.2-kg steel ball that is rolling at a velocity of 3.0 m/sec.

$$\text{momentum} = m \times v = 0.2\ \text{kg} \times \frac{3\ \text{m}}{\text{sec}} = 0.6\ \text{kg} \cdot \frac{\text{m}}{\text{sec}}$$

2. A 0.005-kg bullet with a velocity of 500 m/sec.

$$\text{momentum} = m \times v = 0.005\ \text{kg} \times \frac{500\ \text{m}}{\text{sec}} = 2.5\ \text{kg} \cdot \frac{\text{m}}{\text{sec}}$$

3. A 100-kg football player, a fullback, moving at a velocity of 3.5 m/sec.

4. A 75-kg football player, a defensive back, running at a velocity of 5 m/sec.

5. If a ball is rolling at a velocity of 1.5 m/sec and has a momentum of 10.0 kg-m/sec, what is the mass of the ball?

6. What is the velocity of an object that has a mass of 2.5 kg, and a momentum of 1,000 kg-m/sec?

4. Problems involving the law of conservation of momentum

Use the law of conservation of momentum formula below to answer the following problems. The first problem has been done for you.

$$\underset{\text{Momentum before}}{m_1 v_1 - m_2 v_2} = \underset{\text{Momentum after}}{m_1 v_1 - m_2 v_2}$$

1. A 0.5-kg ball with a velocity of 2.0 m/sec hits another ball that is at rest and has a mass of 1.0 kg. If the first ball stops moving after it hits the second ball, what is the velocity of the second ball after the collision?

$$(0.5\text{ kg})\left(\frac{2.0\text{ m}}{\text{sec}}\right) - (0.5\text{ kg})\left(\frac{0.0\text{ m}}{\text{sec}}\right) = (0.5\text{ kg})\left(\frac{0.0\text{ m}}{\text{sec}}\right) + (1.0\text{ kg})(v_2)$$

$$\frac{(0.5\text{ kg})\left(\frac{2.0\text{ m}}{\text{sec}}\right)}{1.0\text{ kg}} = \frac{1.0\text{ m}}{\text{sec}} = v_2$$

2. A 1.0-kg ball with a velocity of 5 m/sec hits another 1.0-kg ball that is stationary. What is the momentum of each ball before the collision?

3. In question 2 above, what is the total momentum before and after the collision?

4. A 20-kg cart rolling to the right with a velocity of 20 m/sec collides with a 25-kg cart moving to the left with a velocity of 10 m/sec. What is momentum of each cart **before** the collision?

5. In question 4 above, what is the total momentum before and after the collision?

6. In question 5 above, the 20-kg cart rebounds to the left after the collision with a speed of 12.5 m/sec. What is the speed of the 25-kg cart after the collision?

7. In question 6 above, in which direction does the 25-kg cart move?