Name: _____ Date: _____

PRACTICE 112m = 4 sec 3.1

Momentum Conservation

READ

Just like the third law of motion says that forces are equal and opposite, changes in momentum are equal and opposite. This is because when objects exert forces on each other, their motion is affected.

The law of momentum conservation states that if interacting objects in a system are not acted on by outside forces, the total amount of momentum in the system cannot change.

The formula below can be used to find the new velocities of objects if both keep moving after the collision.

$$\text{the momentum of a system before} = \text{the total momentum of a system after}$$

$$m_1 v_{1(\text{initial})} + m_2 v_{2(\text{initial})} = m_1 v_{3(\text{final})} + m_2 v_{4(\text{final})}$$

If two objects are initially at rest, the total momentum of the system is zero.

$$\text{the momentum of a system before a collision} = 0$$

For the final momentum to be zero, the objects must have equal momenta in opposite directions.

$$0 = \text{the momentum of a system after a collision}$$

$$0 = m_1 v_3 + m_2 v_4$$

$$m_1 v_3 = -(m_2 v_4)$$

EXAMPLES

Example 1: What is the momentum of a 0.2-kilogram steel ball that is rolling at a velocity of 3.0 m/sec?

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

Example 2: You and a friend stand facing each other on ice skates. Your mass is 50 kilograms and your friend's mass is 60 kilograms. As the two of you push off each other, you move with a velocity of 4 m/sec to the right. What is your friend's velocity?

Looking for	**Solution**
Your friend's velocity to the left.	$m_1 v_3 = -(m_2 v_4)$
Given	$(50 \text{ kg})(4 \text{ m/sec}) = -(60 \text{ kg})(v_4)$
Your mass of 50 kg.	$\frac{200 \text{ kg-m/sec}}{-(60 \text{ kg})} = v_4$
Your friend's mass of 60 kg.	$-3.33 \text{ m/sec} = v_4$
Your velocity of 4 m/sec to the right.	
Relationship	Your friends velocity to the left is 3.33 m/sec.
$m_1 v_3 = -(m_2 v_4)$	

PRACTICE

1. 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?

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

3. Tiger Woods hits 45.0-gram golf ball, giving it a speed of 75.0 m/sec. What momentum has Tiger given to the golf ball?

4. A 400-kilogram cannon fires a 10-kilogram cannonball at 20 m/sec. If the cannon is on wheels, at what velocity does it move backward? (This backward motion is called recoil velocity.)

5. "Big" Al stands on a skateboard at rest and throws a 0.5-kilogram rock at a velocity of 10.0 m/sec. "Big" Al moves back at 0.05 m/sec. What is the combined mass of "Big" Al and the skateboard?

6. As the boat in which he is riding approaches a dock at 3.0 m/sec, Jasper stands up in the boat and jumps toward the dock. Jasper applies an average force of 800 newtons on the boat for 0.30 seconds as he jumps.
   a. How much momentum does Jasper's 80-kilogram body have as it lands on the dock?
   b. What is Jasper's speed on the dock?

7. Daryl the delivery guy gets out of his pizza delivery truck forgetting to set the parking brake. The 2,000 kilogram truck rolls down hill reaching a speed of 30 m/sec just before hitting a large oak tree. The vehicle stops 0.72 seconds after first making contact with the tree.
   a. How much momentum does the truck have just before hitting the tree?
   b. What is the average force applied by the tree?

8. Two billion people jump up in the air at the same time with an average velocity of 7.0 m/sec. If the mass of an average person is 60 kilograms and the mass of Earth is 5.98×10^{24} kilograms:
   a. What is the total momentum of the two billion people?
   b. What is the effect of their action on Earth?

9. Tammy, a lifeguard, spots a swimmer struggling in the surf and jumps from her lifeguard chair to the sand beach. She makes contact with the sand at a speed of 6.00 m/sec leaving an indentation in the sand 0.10 meters deep.
   a. If Tammy's mass is 60. kilograms, what is momentum as she first touches the sand?
   b. What is the average force applied on Tammy by the sand beach?

10. When a gun is fired, the shooter describes the sensation of the gun kicking. Explain this in terms of momentum conservation.

11. What does it mean to say that momentum is conserved?

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PRACTICE 112m = 4 sec 3.3

Collisions and Conservation of Momentum

READ

- There are two main types of collisions: elastic and inelastic.
- As long as there are no outside forces (such as friction), momentum is conserved in both elastic and inelastic collisions.
- Conservation of momentum makes it possible to determine the motion of objects before and after colliding.
- The steps from the text for using momentum to solve collision problems are provided in the graphic below. Use these problem-solving steps and the problem-solving table to complete this skill sheet. Keep in mind that bounces have greater momentum change.

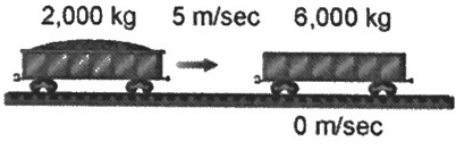
Problem Solving Steps

1. Draw a diagram
2. Decide whether the collision is elastic or inelastic
3. Assign variables to represent the masses and velocities of the objects before and after the collision.
4. Use momentum conservation to write an equation stating that the total momentum before the collision equals the total after. Then solve it.

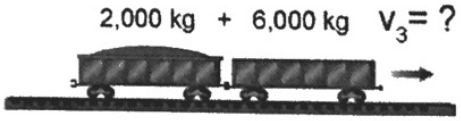
EXAMPLE

A 2,000-kilogram railroad car moving at 5 m/sec collides with a 6,000-kilogram railroad car at rest. If the cars coupled together, what is their velocity after the is inelastic collision?

Before collision



After collision



Looking for

m_3 = the velocity of the combined railroad cars after an inelastic collision

Given

Initial speed and mass of both cars:

$m_1 = 2{,}000$ kg, $v_1 = 5$ m/sec

$m_2 = 6{,}000$ kg, $v_2 = 0$ m/sec

Combined mass of the two cars:

$m_1 + m_2 = 8{,}000$ kg

Relationship

$m_1v_1 + m_2v_2 = (m_1 + m_2)m_3$

Solution

$$(2000 \text{ kg})(5 \text{ m/sec}) + (6000 \text{ kg})(0 \text{ m/sec}) = (2000 \text{ kg} + 6000 \text{ kg})v_3$$

$$10{,}000 \text{ kg-m/sec} = (8000 \text{ kg})v_3$$

$$\frac{10{,}000 \text{ kg-m/sec}}{8000 \text{ kg}} = v_3$$

$$10 \text{ m/sec} = v_3$$

The velocity of the two combined cars after the collision is 10 m/sec.

PRACTICE 112m = 4 sec 3.3

PRACTICE

1. What is the momentum of a 100-kilogram fullback carrying a football on a play at a velocity of 3.5 m/sec.
2. What is the momentum of a 75.0-kilogram defensive back chasing the fullback at a velocity of 5.00 m/sec.
3. A 2,000-kilogram railroad car moving at 5 m/sec to the east collides with a 6,000-kilogram railroad car moving at 3 m/sec to the west. If the cars couple together, what is their velocity after the collision?
4. A 4-kilogram ball moving at 8 m/sec to the right collides with a 1-kilogram ball at rest. After the collision, the 4-kilogram ball moves at 4.8 m/sec to the right. What is the velocity of the 1-kilogram ball?
5. A 0.0010-kg pellet is fired at a speed of 50.0m/s at a motionless 0.35-kg piece of balsa wood. When the pellet hits the wood, it sticks in the wood and they slide off together. With what speed do they slide?
6. Terry, a 70-kilogram tailback, runs through his offensive line at a speed of 7.0 m/sec. Jared, a 100-kilogram linebacker, running in the opposite direction at 6.0m/s, meets Jared head-on and "wraps him up." What is the result of this tackle?
7. Snowboarding cautiously down a steep slope at a speed of 7.0 m/sec, Sarah, whose mass is 50. kilograms, is afraid she won't have enough speed to travel up a slight uphill grade ahead of her. She extends her hand as her friend Trevor, having a mass of 100. kilograms is about to pass her traveling at 16 m/sec. If Trevor grabs her hand, calculate the speed at which the friends will be sliding.
8. Tex, an 85.0 kilogram rodeo bull rider is thrown from the bull after a short ride. The 520. kilogram bull chases after Tex at 13.0 m/sec. While running away at 3.00 m/sec, Tex jumps onto the back of the bull to avoid being trampled. How fast does the bull run with Tex aboard?
9. Identical twins Kate and Karen are rowing their boat on a hot Summer afternoon when they decide to go for a swim. Kate, whose mass is 45 kilograms, jumps off the front of the boat at a speed of 3.00 m/sec. Karen jumps off the back at a speed of 4.00 m/sec. If the 70-kilogram rowboat is moving at 1.00m/s when the girls jump, what is the speed of the rowboat after the girls jump?
10. A 0.10-kilogram piece of modeling clay is tossed at a motionless 0.10-kilogram block of wood and sticks. The block slides across a frictionless table at 15 m/sec.
    a. At what speed was the clay tossed?
    b. The clay is replaced with a "bouncy" ball tossed with the same speed. The bouncy ball rebounds from the wooden block at a speed of 10 meters per second. What effect does this have on the wooden block? Why?