Name: _____ Date: _____ Skill and Practice

4D Momentum Conservation

Read:

Just as forces are equal and opposite (according to Newton's third law), changes in momentum are also 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.

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

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

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.

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

$$0 = m_1 v_3 + m_2 v_4$$

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

Example:

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

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

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 4.0 m/s to the right. What is your friend's velocity?

Looking for Your friend's velocity to the left.	**Solution** $m_1 v_3 = -(m_2 v_4)$ $(50\ \text{kg})(4.0\ \text{m/s}) = -(60\ \text{kg})(v_4)$ $\frac{200\ \text{kg-m/s}}{-(60\ \text{kg})} = v_4$ $-3.3\ \text{m/s} = v_4$ Your friend's velocity to the left is 3.3 m/s.
Given Your mass of 50 kg. Your friend's mass of 60 kg. Your velocity of 4.0 m/s to the right.	
Relationship $m_1 v_3 = -(m_2 v_4)$	

Skill and Practice

Practice:

1. If a ball is rolling at a velocity of 1.5 m/s and has a momentum of 10.0 kg·m/s, what is the mass of the ball?

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

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3. A pro golfer hits 45.0-gram golf ball, giving it a speed of 75.0 m/s. What momentum has the golfer given to the ball?

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

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5. Eli stands on a skateboard at rest and throws a 0.5-kg rock at a velocity of 10.0 m/s. Eli moves back at 0.05 m/s. What is the combined mass of Eli and the skateboard?

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6. As the boat in which he is riding approaches a dock at 3.0 m/s, 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?

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   b. What is Jasper's speed on the dock?

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7. Daryl the delivery guy gets out of his pizza delivery truck but forgets to set the parking brake. The 2,000-kilogram truck rolls down hill reaching a speed of 30 m/s just before hitting a large oak tree. The vehicle stops 0.72 s after first making contact with the tree.

   a. How much momentum does the truck have just before hitting the tree?

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   b. What is the average force applied by the tree?

Skill and Practice

8. Two billion people jump up in the air at the same time with an average velocity of 7.0 m/s. 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/s, leaving an indentation in the sand 0.10 m deep.

   a. If Tammy's mass is 60. kilograms, what is the 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?