CHAPTER 2
LESSON 4

The Laws of Motion

Newton's Third Law

Key Concepts

- What is Newton's third law of motion?
- Why don't the forces in a force pair cancel each other?
- What is the law of conservation of momentum?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	7. If objects collide, the object with more mass applies more force.	
	8. Momentum is a measure of how hard it is to stop a moving object.	

Study Coach

Outline Main Ideas As you read, make an outline to summarize the information in the lesson. Use the main headings in the lesson as the main headings in the outline. Complete the outline with the information under each heading. Review the outline to help you learn the material in this lesson.

Read to Learn

Opposite Forces

If you are wearing skates and push against a wall, you will move away from the wall. What force causes you to move? You might think that the force of your muscles moves you away from the wall. Think about the direction of your push. Your push is against the wall in the opposite direction from your movement. In fact, when you push against the wall, the wall pushes back in the opposite direction. The push of the wall causes you to accelerate away from the wall. When an object applies a force on another object, the second object applies a force of the same strength on the first object, but the force is in the opposite direction.

Newton's Third Law of Motion

Newton's first two laws of motion describe the effects of balanced and unbalanced forces on one object. Newton's third law relates forces between two objects. *According to* **Newton's third law of motion,** *when one object exerts a force on a second object, the second object exerts a force of the same size but in the opposite direction on the first object.* An example of forces described in Newton's third law of motion is a gymnast pushing against the floor during a flip. When the gymnast applies force against the floor, the floor applies force back.

Key Concept Check

1. Define What is Newton's third law of motion?

Force Pairs

The forces described by Newton's third law depend on each other. *A* **force pair** *is the forces two objects apply to each other.* Recall that you can add forces to calculate the net force. If the forces of a force pair always act in opposite directions and are always the same strength, why don't they cancel each other? The reason is that each force acts on a different object. Adding forces results in a net force of zero only if the forces act on the same object.

Action and Reaction

In a force pair, one force is the action force and the other is the reaction force. Swimmers diving from a boat apply an action force against the boat. The boat applies a reaction force on the swimmers. For every action force, there is a reaction force of equal strength but in the opposite direction.

Using Newton's Third Law of Motion

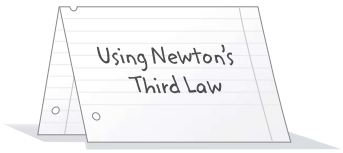
When you push against an object, the force you apply is the action force. The object then pushes back against you. The force applied by the object is the reaction force. According to Newton's second law, when the reaction force results in an unbalanced force, there is a net force, and the object accelerates. Newton's third law explains many common activities, such as those described in the table.

Key Concept Check

2. Explain Why don't the forces in a force pair cancel each other?

FOLDABLES®

Make a half-book to summarize how Newton's third law explains the motion of a variety of common activities.



Action and Reaction Forces		
Swimming When you push your arms against the water to swim, the water pushes back in the opposite (forward) direction. If you push with enough force, the water's reaction force becomes greater than the force of fluid friction. You accelerate in the direction of the net force and swim forward.	**Jumping** When you jump, you push down on the ground, and the ground pushes up on you. The upward force of the ground combines with the downward force of gravity to form the net force acting on you. If you push down hard enough, the upward force becomes greater than the downward force of gravity. The net force is upward, and you accelerate in the direction of the net force.	**Rocket Motion** The burning fuel in a rocket engine produces a hot gas. The engine pushes the hot gas out in a downward direction. The gas pushes upward on the engine. When the upward force of the gas pushing on the engine becomes greater than the downward force of gravity on the rocket, the net force is upward. The rocket then accelerates upward.

Momentum

Because action and reaction forces do not cancel each other, they can change the motion of objects. **Momentum** *is a measure of how hard it is to stop a moving object.* It is the product of an object's mass and velocity. The momentum equation appears on the top of the opposite page. An object's momentum is in the same direction as its velocity.

Interpreting Tables

3. Specify On what part of a swimmer's body does the water's reaction force push?

Math Skills

What is the momentum of a 12-kg bicycle moving at 5.5 m/s?

mass: $m = 12$ kg

velocity: $v = 5.5$ m/s

momentum: p

Use this formula:

$$p = m \times v$$

Substitute the values for m and v into the formula and multiply:

$$p = 12 \text{ kg} \times 5.5 \text{ m/s}$$
$$= 66 \text{ kg•m/s}$$

Momentum = 66 kg•m/s in the direction of the velocity.

4. Solve for Momentum What is the momentum of a 1.5-kg ball rolling at 3.0 m/s?

Momentum Equation

momentum (in kg•m/s) = mass (in kg) × velocity (in m/s)

$$p = m \times v$$

Momentum and Mass If a large truck and a car are moving at the same speed, the truck is harder to stop. Because the truck has more mass, it has more momentum. If cars of equal mass move at different speeds, the faster car has more momentum and is more difficult to stop.

Newton's Laws and Momentum According to Newton's first law, if the net force on an object is zero, its velocity does not change. This means its momentum does not change. Newton's second law states that the net force on an object is the product of its mass and its change in velocity. Because momentum is the product of mass and velocity, the force on an object equals its change in momentum.

Conservation of Momentum

In a game of billiards, when the moving cue ball hits a ball that is not moving, the motion of both balls changes. The cue ball has momentum because it has mass and is moving. When it hits the other ball, the cue ball's velocity and momentum decrease. The other ball starts moving. Because this ball then has mass and velocity, it also has momentum.

The Law of Conservation of Momentum

In any collision, momentum transfers from one object to another. The billiard ball gains the momentum lost by the cue ball. The total momentum, however, does not change. *According to the* **law of conservation of momentum,** *the total momentum of a group of objects stays the same unless outside forces act on the objects.* Outside forces include friction. Friction between the balls and the billiard table decreases their velocities, and they lose momentum.

Key Concept Check

5. Define What is the law of conservation of momentum?

Types of Collisions

Objects collide with each other in different ways. When colliding objects bounce off each other, an elastic collision occurs. If objects collide and stick together, such as when one football player tackles another, the collision is inelastic. No matter the type of collision, the total momentum will be the same before and after the collision.

Mini Glossary

force pair: the forces two objects apply to each other

law of conservation of momentum: the law that states that the total momentum of a group of objects stays the same unless outside forces act on the objects

momentum: a measure of how hard it is to stop a moving object

Newton's third law of motion: the law that states that when one object exerts a force on a second object, the second object exerts a force of the same size but in the opposite direction on the first object

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that summarizes Newton's third law of motion in your own words.

2. Circle the diagram below that shows an example of an inelastic collision.

3. If a tennis ball and a bowling ball are rolling at the same speed, which ball is harder to stop? Explain why.

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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END OF LESSON