Section 3: Newton's Third Law

Make your predictions here.

What happens when an object exerts a force on another object?

How do you calculate the momentum of an object?

What is the total momentum after objects collide?

Why It Matters

Newton's third law explains how rockets lift off the ground and maintain acceleration in space.

When you kick a soccer ball, as shown in **Figure 1,** you notice the effect of the force exerted by your foot on the ball. The ball experiences a change in motion. Is the force that moves the ball the only force present? Do you feel a force acting on your foot?

Figure 1 According to Newton's third law, the foot and the soccer ball exert equal and opposite forces on each other.

Using figure 1 as a guide, how is an action force different from a reaction force?

Action and Reaction Forces

The moment that you kick the ball, the ball exerts an equal and opposite force on your foot. The force exerted on the ball by your foot is called the *action force,* and the force exerted on your foot by the ball is called the *reaction force.* This pair of forces gives an example of Newton's third law of motion, also called the *law of action and reaction.*

Newton's third law: For every action force, there is an equal and opposite reaction force.

What is Newton's third law in your own words?

When one object exerts a force on a second object, the second object exerts a force equal in size and opposite in direction on the first object.

Forces always occur in pairs.
Action and reaction forces are applied to different objects. These forces are equal and opposite. The action force acts on the ball, and the reaction force acts on the foot. Action and reaction force pairs are present even when there is no motion. For example, when you sit on a chair, your weight pushes down on the chair. The force of your weight is the action force. The chair pushing back up with a force equal to your weight is the reaction force.

What is an action/reaction force pair you are experiencing right now?

Forces in a force pair do not act on the same object.
Newton's third law states that forces happen in pairs. In other words, every force is part of a force pair made up of an action force and a reaction force. Although the forces are equal and opposite, they do not cancel each other because they act on different objects. In the example shown in Figure 2, the swimmer's hands and feet exert the action force on the water. The water exerts the reaction force on the swimmer's hands and feet. Note that action and reaction forces occur at the same time. But the action and reaction forces never act on the same object.

Why don't force pairs act on the same object?

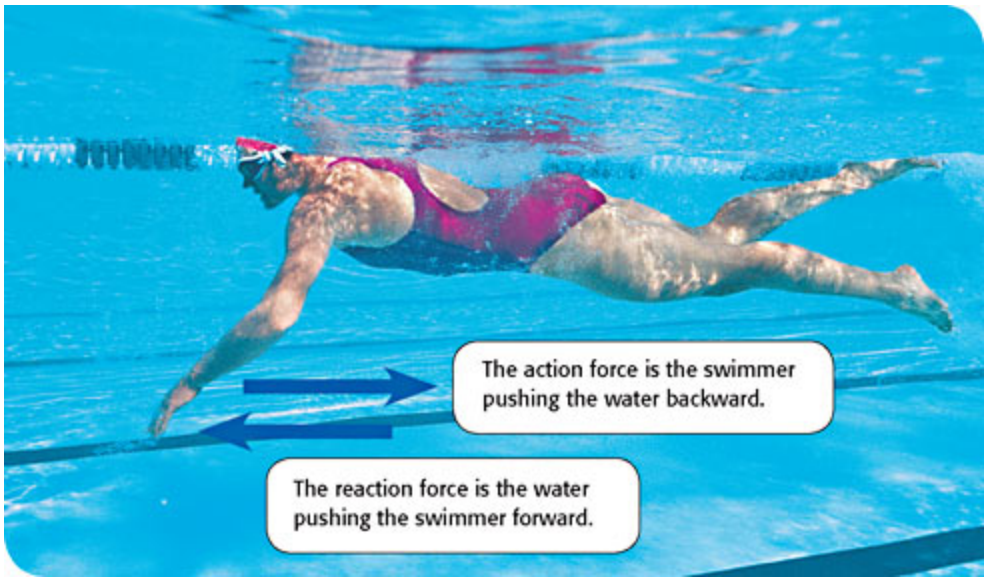

Figure 2 The two forces in a force pair act on different objects. In this example, the action force acts on the water, and the reaction force acts on the swimmer

Equal forces don't always have equal effects.
Another example of an action-reaction force pair is shown in **Figure 3.** If you drop a ball, the force of gravity pulls the ball toward Earth. This force is the action force exerted by Earth on the ball. But the same force of gravity also pulls Earth toward the ball. That force is the reaction force exerted by the ball on Earth.

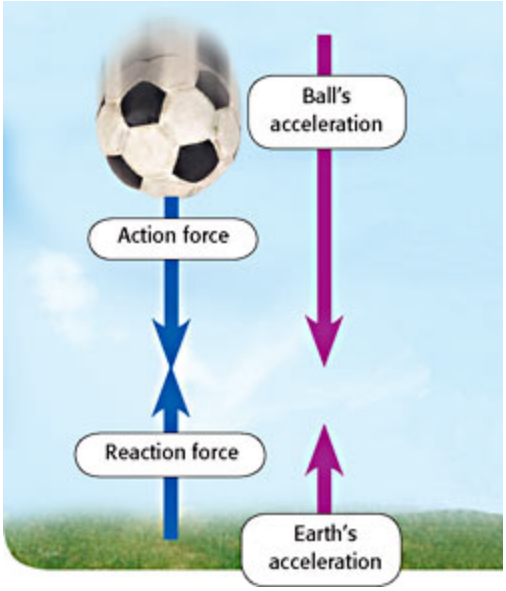

Figure 3 Earth accelerates toward the ball as the ball accelerates toward Earth. (The acceleration arrows are not drawn to scale.)

Why is Earth's acceleration so much smaller than the ball's?

It is easy to see the effect of the action force—the ball falls to Earth. Why don't you notice the effect of the reaction force—Earth is pulled upward? Remember Newton's second law: an object's acceleration is equal to the force applied to the object divided by the object's mass. The force applied to Earth is equal to the force applied to the ball. However, Earth's mass is much larger than the ball's mass. Thus, compared with the ball's acceleration, Earth's acceleration is almost undetectable.

Momentum

If a small car and a large truck are moving with the same velocity and the same braking force is applied to each vehicle, the truck takes more time to stop than the car does. Likewise, a fast-moving car takes more time to stop than a slow-moving car of the same mass does. The large truck and the fast-moving car have more **momentum** than the small car and the slow-moving car do. Momentum is a property of all moving objects. **For movement along a straight line, momentum is calculated by multiplying an object's mass and velocity.**

Momentum equation

$$momentum = mass \times velocity$$

$$p = mv$$

Why might the variable for momentum be a *p*?

In the SI, momentum is expressed in kilograms times meters per second (kg•m/s). Like velocity, momentum has direction. An object's momentum and velocity are in the same direction.

What is the unit of measurement for momentum?

Momentum increases as mass and velocity increase.

The momentum equation states that for a given velocity, the greater the mass of an object, the greater the momentum of the object. A tractor-trailer truck has much more momentum than a sports car moving at the same speed does. The momentum equation also states that the faster an object is moving, the greater the momentum of the object. If an object is not moving, its momentum is zero.
What would happen to momentum if velocity decreased?

Why It Matters: Real World

How Do Rockets Work?

Rockets are made in various sizes and designs, but the basic principle of each rocket is the same. The outward push of the hot gases through the nozzle is matched by an equal push in the opposite direction on the combustion chamber. This push accelerates the rocket forward.

Some people think that rockets work because flowing hot gases push against the atmosphere. If this were true, rockets could not travel through space. Write a few sentences to explain why.

Momentum is conserved in collisions.

When a moving object hits a second object, some or all of the momentum of the first object is transferred to the second object. Imagine hitting a billiard ball with a cue ball such that the billiard ball starts moving, as **Figure 5** shows. During a collision with a billiard ball, the cue ball transfers some of its momentum to the billiard ball. Anytime two or more objects interact, they may exchange momentum, but the total momentum of the system always stays the same.

Figure 5 Some of the cue ball's momentum is transferred to the billiard ball during a collision.

Newton's third law explains conservation of momentum. In a game of pool, the cue ball hits the billiard ball with a force—the action force. The equal but opposite force exerted by the billiard ball on the cue ball is the reaction force.

What does it mean when something is conserved?

What are two other examples when momentum is conserved?

Section review

Please indicate in the text where you got your answers.

1. State Newton's third law of motion, and give an example that shows how this law works.

2. Describe how momentum is calculated.

3. Explain what the law of conservation of momentum means, and give an example.

4. Evaluating Models Which of the following models explains why the action and reaction forces don't cancel each other when a soccer ball is kicked? Please give support why the model does or does not give an explanation.

a. The force of the player's foot on the ball is greater than the force of the ball on the player's foot.

b. The forces do not act on the same object.

c. The reaction force happens after the action force.

5. Identifying Examples List the action and reaction forces in three force pairs. Do not use examples from the chapter.

6. Applying Ideas The forces exerted by Earth and a skier become an action-reaction force pair when the skier pushes the ski poles against Earth. Explain why the skier accelerates while Earth does not seem to move at all. (Hint: Think about the math equation for Newton's second law of motion for each of the forces.)

7. Calculate the momentum of a 1 kg ball that is moving eastward at 12 m/s. Show your work.