6.3 Newton's Third Law and Momentum

Newton's first and second laws apply to the motion of an *individual* object. Newton's third law applies to forces between interacting objects. Think about throwing a basketball (Figure 6.10). You feel the ball push back against your hand as you throw it. You apply a force to the ball to make it move. Where does the force against your hand come from? Can you predict your hand's motion and the basketball's motion after the throw?

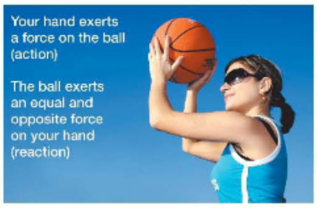
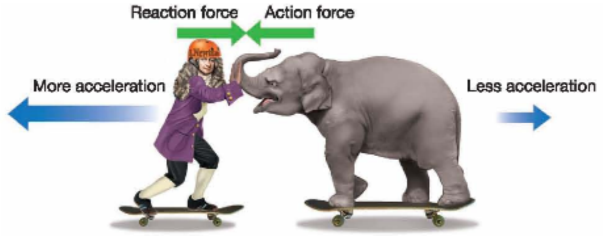


Figure 6.10: *You experience Newton's third law (action–reaction) whenever you apply force to any object, such as a basketball.*

Forces always come in matched pairs

An imaginary skateboard contest Imagine a skateboard contest between Isaac Newton and an elephant. They can push against each other, but not against the ground. The one whose skateboard moves the fastest wins. The elephant is much stronger and pushes off Newton with a huge force thinking he will surely win. But will he?



The winner Newton flies away with a great speed and the puzzled elephant moves backward with a much smaller speed. Newton wins—and will always win this contest against the elephant. No matter how hard the elephant pushes, Newton will always move away faster. Why?

Forces always come in pairs It takes force to make both Newton and the elephant move. Newton wins because *forces always come in pairs*. The elephant pushes against Newton and that *action* force pushes Newton away. The elephant's force against Newton creates a *reaction* force against the elephant. The action and reaction forces are equal in strength. Newton has much less mass so he has much more acceleration, therefore his speed is always greater.

JOURNAL

Think of three examples of action–reaction pairs that you experienced before class today. Write each one down and identify the action and reaction forces. Also write down what object each force acted on. Hint: The action and reaction forces never act on the same object.

The third law: Action and reaction

The first and second laws The first two laws of motion apply to individual objects. The first law says an object will remain at rest or in motion at a constant velocity unless acted upon by a net force. The second law states that acceleration equals the force on an object divided by the mass of the object.

The third law The third law of motion deals with pairs of objects. This is because *all forces come in pairs*. **Newton's third law** states that every action force creates a reaction force that is equal in strength and opposite in direction.

Every action force creates a reaction force that is equal in strength and opposite in direction.

Force pairs There can never be a single force acting alone, without its action–reaction partner. Forces *only* come in action–reaction pairs. In the skateboard contest, the net force is the difference between the force created by the elephant in one direction and the force created by Newton in the opposite direction. The *action* of this force acts on Newton and moves Newton. The *reaction* of the same force acts on the elephant and moves the elephant. The combined strength of Newton and the elephant create two equal and opposite forces, an action and a reaction.

The labels *action* and *reaction* The words *action* and *reaction* are just labels. It does not matter which force is called action and which is called reaction. You simply choose one to call the action and then call the other one the reaction (Figure 6.11).

Why action and reaction forces do not cancel each other out Why don't action and reaction forces cancel each other out? The reason is *action and reaction forces act on different objects*. For example, think again about throwing a ball. When you throw a ball, you apply the action force to the ball, creating the ball's acceleration. The reaction is the ball pushing back against your hand. The action acts on the ball and the reaction acts on your hand. The forces do not cancel each other out because they act on different objects. You can only cancel out forces acting on the same object (Figure 6.12).

VOCABULARY

Newton's third law - a law of motion that states that for every action force there is a reaction force equal in strength and opposite in direction.

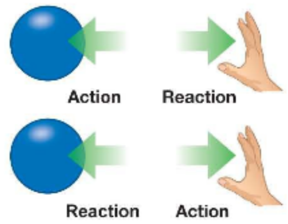


Figure 6.11: *It doesn't matter which force you call the action and which you call the reaction.*

Figure 6.12: *Action and reaction forces do not cancel each other out. One force acts on the ball, and the other force acts on the hand.*

Action and reaction forces

A skateboard example Think carefully about propelling a skateboard with your foot. Your foot presses backward against the ground (Figure 6.13). The force acts *on* the ground. However, *you* move, so a force must act on you, too. Why do you move? What force acts on you? You move because the action force of your foot against the ground creates a reaction force of the ground against your foot. You "feel" the ground because you sense the reaction force pressing on your foot. The reaction force is what makes you move because it acts on *you*.

Draw diagrams When sorting out action and reaction forces, it is helpful to draw diagrams. Draw each object apart from the other. Represent each force as an arrow in the appropriate direction. The illustration in Figure 6.13 is a good example of a diagram that shows a pair of action and reaction forces. The Solve It! box in the sidebar gives you an opportunity to think of your own example and draw a diagram.

Action and reaction guidelines Below are some guidelines to help you sort out action and reaction forces.

Guidelines for Action–Reaction Forces	Examples
Both forces are always there whenever any force occurs.	Your foot pushes (action) and the ground pushes back (reaction).
They always have the exact same strength.	The force arrows are the same length.
They always act in opposite directions.	The force arrows point in opposite directions.
They always act on different objects.	Your foot and the ground.
Both are real forces and can cause changes in motion.	You move forward on your skateboard.

Figure 6.13: *You move forward because of the reaction force of the ground on your foot.*

SOLVE IT!

Think of an action–reaction pair situation. Then, draw a diagram illustrating the action–reaction pair. Use the tips in the text for drawing your diagram.

Solving Problems: Action and Reaction

A woman with a weight of 600 newtons is sitting on a chair (Figure 6.14). Describe one action-reaction pair of forces in this situation.

1. Looking for: You are asked for a pair of action and reaction forces.

2. Given: You are given an action force—the woman's force on the chair. Her force is 600 N.

3. Relationships: Action-reaction forces are equal and opposite and act on different objects.

4. Solution: The downward force of 600 N exerted by the woman on the chair is an action. Therefore, the chair acting on the woman provides an upward force of 600 N and is a reaction.

Your turn...

a. A dog jumps up and sits on the lap of the woman who is sitting in the chair in Figure 6.14. The dog's weight is 40 newtons. What is the reaction force provided by the chair now?

b. A strong man now picks up the chair with the woman and the dog and holds them all above his head. If the upward force from the strong man is 700 newtons, what is the weight of the chair in newtons? Describe the different action-reaction pairs in this scenario.

c. A baseball player hits a ball with a bat. Describe an action-reaction pair of forces in this situation.

Figure 6.14: *An action is sitting on a chair.*

SOLVE FIRST LOOK LATER

a. 640 N

b. The weight of the chair is 60 N. Action-reaction pairs include the dog-woman's lap, the woman-chair, the chair-strongman, and the strongman-ground.

c. The force of the bat on the ball (action) accelerates the ball. The force of the ball on the bat (reaction) slows down the swinging bat.

Collisions and momentum

The effect of forces

Newton's third law tells us that when two objects collide, they exert equal and opposite forces on each other. However, the *effect* of the force is not always the same. Imagine two hockey players moving at the same speed toward each other, one with twice the mass of the other. The force on each during the collision is the same strength, but they do not have the same change in motion during the collision.

Momentum

When studying motion related to collisions, we can predict how two colliding objects might move using Newton's third law of motion and *momentum*. **Momentum** is the mass of a object times its velocity. The units for momentum are kilogram-meter per second (kg · m/s).

MOMENTUM

$$p = mv$$

Momentum (kg · m/s), Mass (kg), Velocity (m/s)

The law of conservation of momentum

Using this information, we can determine the momentum of each player in the example above. The **law of conservation of momentum** states that as long as the interacting objects are not influenced by outside forces (like friction) the total amount of momentum is constant (does not change). This means that the total amount of momentum for the colliding hockey players before the collision equals the total amount of momentum afterward. Also, any momentum lost by one player is gained by the other one.

VOCABULARY

momentum - the mass of an object times its velocity.

law of conservation of momentum - a law that states that as long as interacting objects are not influenced by outside forces, the total amount of momentum is constant.

SOLVE IT!

Calculate: Use the momentum formula to find the momentum of each hockey player before they collide.

Player #1: m = 80 kg; v = 2 m/s

Player #2: m = 40 kg; v = 3 m/s

Predict: Let's say the motion of Player #1 is in the positive direction and the motion of Player #2 is in the negative direction. Based on your momentum calculations, in which direction do you think the two combined players will move after the collision?

Understanding the law of conservation of momentum

Positive and negative momentum The forces on any two interacting objects are always equal and opposite. Similarly, the momentum of two interacting objects is equal and opposite. Therefore, it makes sense to use positive and negative values to tell the direction of motion (Figure 6.15). Momentum can be positive (moving to the right) or negative (moving to the left) (Figure 6.15).

A ball example Let's say a skateboarder is standing on a skateboard and is holding a ball. Before he throws the ball, his velocity (and the ball's) is zero. Since momentum is mass times velocity, the total momentum is also zero. The law of conservation of momentum says that after the ball is thrown, the total momentum still has to be zero. Here's where positive and negative values help us.

Conservation of momentum If the ball has a mass of 1 kilogram and the skateboarder throws it at a velocity of –20 m/s to the left, the ball takes away –20 kg · m/s of momentum. To make the total momentum zero, the skateboarder must take away +20 kg · m/s of momentum. If his mass is 40 kilogram and you ignore friction, then his speed is +0.5 m/s to the right (Figure 6.16).

More mass results in less acceleration Because of his greater mass, the skateboarder will have a slower speed. The ball, which has less mass, has the greater speed. *They each have equal and opposite momentum after the throw.* The two objects, the skateboarder and the ball, have different speeds because they have different masses, *not because the forces are different!*

Jet planes and rockets Rockets and jet planes use the law of conservation of momentum to move. In a process called jet propulsion, a jet moves forward when the engine pushes exhaust air at very high speed out of the back of the engine. The momentum lost by the air going backward is compensated for by the momentum gained by the jet moving forward. Similarly, a rocket accelerates in space because it pushes mass at high speed out the end of the engine in the form of exhaust gases from burning fuel. The forward momentum of a rocket is equal to, but in the opposite direction from, the momentum of the escaping mass ejected from the end of the engine.

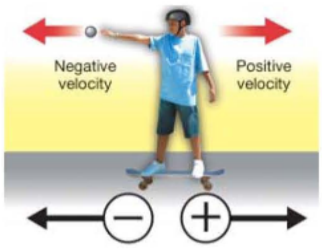


Figure 6.15: *The direction is important when using the law of conservation of momentum. We use positive and negative numbers to represent opposite directions.*

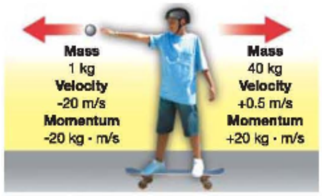


Figure 6.16: *The result of a skateboarder throwing a 1-kg ball at a velocity of –20 m/s is that he and the skateboard with a total mass of 40 kg move backward at a velocity of +0.5 m/s if you ignore friction. If you account for friction, would the calculation for velocity of the skateboarder on the skateboard end up being less or more than 0.5 m/s?*

Solving Problems: Conservation of Momentum

An astronaut in space throws a 2-kilogram wrench away from her at a velocity of –10 m/s. If the astronaut's mass is 100 kilograms, at what velocity does the astronaut move backward after throwing the wrench?

1. Looking for: You are asked for the astronaut's speed. Since the astronaut is in space, we can ignore friction.

2. Given: You are given the mass and velocity of the wrench and the mass of the astronaut.

3. Relationships: This is enough information to apply the law of conservation of momentum. The momentum of the wrench (m_1v_1) and the momentum of the astronaut (m_2v_2) add up to zero BEFORE the wrench is thrown.
$m_1 v_1 + m_2 v_2 = 0$

Photo courtesy NASA

4. Solution: The momentum of the wrench and the astronaut also add up to zero AFTER the wrench is thrown.
$[2 \text{ kg} \times (-10 \text{ m/s})] + [(100 \text{ kg}) \times v_2] = 0;\ v_2 = +20 \div 100 = +0.2 \text{ m/s}$

The astronaut moves backward at a velocity of +0.2 m/s to the right.

Your turn...

a. Two hockey players have a total momentum of +200 kg·m/s before a collision (+ is to the right). After their collision, they move together. In what direction do they move and what is their momentum?

b. When a large truck hits a small car, the forces are equal (Figure 6.17). However, the small car experiences a much greater change in velocity than the big truck. Explain why.

Figure 6.17: *Your turn... Question b.*

SOLVE FIRST LOOK LATER

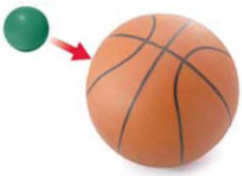
a. The two hockey players move in the positive direction (or to the right). Their momentum after the collision is +200 kg·m/s.

b. The car has less mass and therefore less inertia, so it accelerates more (and may become more damaged) than the truck in this collision.

Section 6.3 Review

1. Emilio tries to jump to a nearby dock from a canoe that is floating in the water. Instead of landing on the dock, he falls into the water beside the canoe. Use Newton's third law to explain why this happened. Hint: First identify the action–reaction pair in this example.
2. You push backward against the ground to move a skateboard forward. The force you make acts against the ground. What force acts against you to move you forward?
3. Explain why action–reaction forces do NOT cancel each other out, resulting in zero net force.
4. The momentum of an object depends on what two factors?
5. The engine of a jet airplane pushes exhaust gases from burning fuel backward. What pushes the jet forward?

6. A small rubber ball is thrown at a heavier, larger basketball that is not moving. The small ball bounces off the basketball. Assume there are no outside forces acting on the balls.
   a. How does the force on the small ball compare to the force on the basketball?
   b. Compare the total momentum of the two balls before and after the collision.
   c. The mass of the basketball is 600 grams and its velocity before the small ball hits is 0 m/s. The mass of the small ball is 100 grams and its velocity is +5 m/s before the collision and –4 m/s afterward. What is the velocity of the basketball after the collision?



SCIENCE FACT

Squid Science

Airplanes are not the only things that use jet propulsion. Several animals have adapted jet propulsion in order to get around. A squid takes water into its body chamber and rapidly pushes it out of a backward-facing tube. The water squirts backward and the squid jets forward. What are the action–reaction forces in this example? Draw a diagram to illustrate your answer.

Most species of squid are small, but *Architeuthis*, the giant squid, is not! In September 2004, Japanese scientists took over 500 photos of a giant squid. The animal was nearly 25 feet long! This was the first record of a live giant squid in the wild. Conduct an Internet search using the key phrase "giant squid" to find more information and photos.

Chapter 6 Assessment

Vocabulary

Select the correct term to complete the sentences.

Newton's first law	unbalanced forces	inertia
momentum	Newton's second law	Newton's third law

Section 6.1

1. ____ says that objects continue the motion they already have unless they are acted on by an unbalanced force.
2. If the net force acting on an object is not zero, then the forces acting on the object are ____.
3. Objects with more mass have more ____.

Section 6.2

4. The relationship between the force on an object, the mass of the object, and its acceleration is described by ____.

Section 6.3

5. ____ states that every action force creates a reaction force that is equal in strength and opposite in direction.
6. The law of conservation of ____ can be used to predict motion of interacting objects after they collide.

Concepts

Section 6.1

1. Newton's first law states that no force is required to maintain motion in a straight line at constant speed. If Newton's first law is true, why must you continue to pedal a bicycle on a level surface in order to keep moving?
2. Two identical-looking, large, round balls are placed in front of you. One is filled with feathers and the other is filled with sand. Without lifting the balls, how could you use Newton's first law to distinguish between them?
3. Which motion is possible for an object that has no unbalanced forces?
   a. being stopped
   b. moving with constant direction
   c. moving with changing speed
   d. moving with constant velocity

Section 6.2

4. What is a newton?
   a. the time it takes to move 1 kilogram
   b. the force it takes to change the speed of 1 kilogram by 1 m/s in 1 second
   c. the speed it takes to move a 1 kilogram mass in 1 hour
5. If you are applying the brakes on your bicycle, and you are slowing down, are you accelerating? Why or why not?
6. What is the formula that summarizes Newton's second law?

Section 6.3

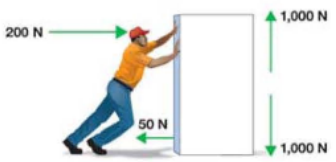
7. Identify each statement as correct or incorrect. If incorrect, rewrite the sentence so that it is correct.
   a. In an action–reaction pair, the forces work on the same object.
   b. Every action force creates a reaction force and the two forces are different in strength but act in the same direction.
8. Give an example of the law of conservation of momentum from everyday life.

9. When a bug traveling west collides with the windshield of a car traveling east, which statement about the collision is true?
   a. The bug feels a stronger force than the car.
   b. The bug and the car feel the same size force.
   c. The car accelerates more than the bug.
   d. The bug does not accelerate due to the force.

Problems

Section 6.1

1. While an object is moving at a constant 20 m/s, a 5 N force pushes the object to the left. At the same time, a 5 N force is pushing the object to the right. What will the object's velocity be after 10 seconds?
2. A bowling ball has a mass of 6 kilograms. A tennis ball has a mass of 0.06 kilogram. How much inertia does the bowling ball have compared to the tennis ball?
3. What is the net force on the refrigerator shown below?



4. Make a free-body diagram of someone pushing a refrigerator that shows:
   a. A net force of 100 N with the refrigerator being pushed to the right.
   b. The refrigerator in equilibrium.

Section 6.2

5. What force is needed to accelerate a 1,000-kg car from a stop to 5 m/s^2?
6. What is the acceleration of a truck with a mass of 2,000 kg when its brakes apply a force of 10,000 N?
7. Gina is pushing a 10-kg box with 50 N of force toward the east. Dani is pushing the same box at the same time with 100 N of force toward the west. Assuming there is no friction, what is the acceleration of the box?
8. A car speeds up from 5 m/s to 29 m/s over 4 seconds.
   a. What is the car's acceleration?
   b. If the car had started at 29 m/s and ended at 5 m/s after 4 seconds, what would its acceleration be? How is this different from the answer above?

Section 6.3

9. Jane has a mass of 40 kg. She pushes on a 50-kg rock with a force of 100 N. What force does the rock exert on Jane?
10. Look at the picture below.
    a. Identify at least three action–reaction pairs.
    b. Why might it be hard for the firefighter to hold the hose steady when the water gushes out of the hose? Think about the law of conservation of momentum.

11. A 3,000-kg car bumps into a stationary, 5,000-kg truck. The velocity of the car before the collision was +4 m/s and –1 m/s after the collision. What is the velocity of the truck after the collision?

Applying Your Knowledge

Section 6.1

1. You are watching a magic show. During one trick, the magician rolls a ball down a hill. Suddenly, the ball stops moving down the hill. It is as if the ball is defying gravity! Come up with an explanation for how the magician might have accomplished his trick. Hint: Think of all the forces that might be acting on the ball.
2. Answer the following motion questions for a hot air balloon.
   a. List all the forces that are acting on a hot air balloon to keep it on the ground.
   b. List all the forces that act on a hot air balloon when it is in the sky.
   c. Sketch a free-body diagram for a hot air balloon that is rising straight off the ground. Indicate the magnitude of forces with the length of the force vectors.
   d. Sketch a free-body diagram for a hot air balloon that is in a neutral position in the sky (neither rising nor sinking) but being blown eastward by the wind. Indicate the magnitude of forces with the length of the force vectors. What force might be opposing the wind?

Section 6.2

3. The text stated that anyone who does anything involving motion needs to understand Newton's second law. Think of a job or career that might involve using and understanding motion and answer the following.
   a. Name the job or career. Describe the types of motion-related tasks that are involved in this job or career.
   b. Pick one task listed in your answer above and explain how understanding Newton's laws of motion might help accomplish the task better.
4. Describe the design features you would incorporate into a battery-operated motor for a robot mail cart for the following situations. The design features to consider include the mass of the motor, rate of acceleration, and speed.
   a. A robot mail cart is needed to collect mail from offices located in a large warehouse. The warehouse has a lot of open space.
   b. A robot mail cart is needed in a small office space that has many offices that are close together.
   c. A robot mail cart is needed in an elementary school that has long hallways and many offices. However, many children are often in the hallways.

Section 6.3

5. At the beginning of the chapter, you read about astronauts investigating how toys work in space. Describe how you think the following toys would work in space based on what you have learned in this chapter.
   a. A ball that can be thrown through a hoop
   b. Building blocks
   c. A board game with game pieces for each player
   d. A deck of cards
6. Auto manufacturers design cars to withstand collisions. Research design features that allow a car and the people inside the car to survive a crash. Write a paragraph about one design feature that interests you.
7. If you push a very large object, such as a building, it doesn't move before or after the interaction. Explain why.

Lesson 6.3: Newton's Third Law and Momentum

This lesson is about action–reaction forces, which are explained by Newton's third law. Students evaluate the guidelines for action–reaction forces and consider examples of each criterion. They also learn about collisions and study applications of the law of conservation of momentum.

Start the lesson

Connect to Prior Knowledge: Forces and Cartoons

Obtain a copy of action cartoon shorts from your school or local library. Those featuring the coyote and the roadrunner are excellent for this activity. Say to students, "Imagine that the school principal asks you to be a member of a team whose job is to hire a new science teacher." Ask students to discuss the desired qualifications of their new science teacher. Then tell students that you want to show them an audition video sent in by a prospective teacher. Immediately begin the cartoon short. Once it is completed, ask students to rate the coyote's potential as a physical science teacher. Ask students to describe how their observations influenced their decisions. Did students observe any evidence of Newton's laws at work? Were any of these laws violated? Encourage students to share examples with the class. Create a list of student responses on the board.

Remind students that they have already learned about Newton's first and second laws of motion. Ask students, "What do the first and second laws state?" Then, state the third law, with emphasis on the these words: *action*, *reaction*, *equal*, and *opposite*. Show the cartoon again, this time asking students to keep Newton's third law in mind as they watch. Pause the video periodically to play up examples which demonstrate action–reaction forces and violations of the third law.

Motivate: Design a Catapult

Assign students to work in small groups. Their task is to build a device that will launch a ping-pong ball at least 10 feet. Have students to use the Internet or other resources to gather ideas about constructing basic catapults; but encourage them not to limit their design options to examples they find. Encourage students to improve on existing design or to create their own.

Once students have completed their designs, choose a safe location for them to execute their launches. Have them identify the types of forces involved in operating their catapults and explain how their catapults demonstrate each of the three laws of motion. You may even have students calculate the speed and acceleration of the ping-pong balls and/or the force of their catapults.

vo·cab·u·lar·y

Newton's third law - a law of motion that states that for every action force there is a reaction force equal in strength and opposite in direction.

momentum - the mass of an object multiplied by its velocity. or·i·gin

law of conservation of momentum - a law that states that as long as interacting objects are not influenced by outside forces, the total amount of momentum is constant.

Addressing Misconceptions about Action–Reaction Forces

Teaching Tip

When students hear the words action–reaction forces, they often think that a reaction is in response to an action. For example, "Jimmy hit me and my reaction was to hit him back." While this example of human response may be correct in describing how our behavior is often reactionary, it is an incorrect assumption when speaking about forces and Newton's third law. This would imply that the action force happens first, then the reaction force follows.

Emphasize the fact that forces do not occur in isolation. Rather, forces happen in pairs. Students must also realize that no particular order exists for action–reaction forces. In other words, either force can be the action or reaction force because they happen at the same time. Ask students to consider what happens if a bird flies into a clear glass window of a skyscraper. Does the bird first exert a force on the window, with the window then reacting by exerting a force on the bird? Of course, this is not the case. The force of the bird hitting the window is equal in both size and timing to the force exerted by the window onto the bird. However, the forces are opposite in direction.

Present the content

Video Lesson: Newton's Laws

Use the video lesson to review the meaning of force and the first and second laws of motion. Then use the lesson to reinforce key concepts related to Newton's third law.

Check for understanding

Exit Slip

A 655-kg car traveling at 22.0 m/s collides with a parked bus that weighs 1,550 kg. When they collide, the two vehicles connect, forming a bus–car system. What is the velocity of the system?

	Before	After	
Car	14,410 kg · m/s	655 kg · v	655 kg · v + 1,550 kg · v = 14,410 kg · m/s
Bus	0	1,550 kg · v	2,205 kg · v = 14,410 kg · m/s
Total	14,410 kg · m/s	14,410 kg · m/s	v = 6.54 m/s in original direction of motion

Reteach

Write several scenarios which demonstrate Newton's laws on strips of paper or index cards. Fold the strips of paper in half and place them in a container. Have each student select one scenario, read it aloud, and then tell which law it best represents. Create a three-column table on the board so that students can record their answers. Sample scenarios are provided below.

First Law	Second Law	Third Law
– A wheelbarrow is harder to push as more dirt is added.	– Two objects are fired from a slingshot. One travels quicker than the other.	– You feel pain from stubbing your toe on the base of a table.
– A rolling ball slowly comes to a stop.	– A bicyclist pedals harder to go faster.	– A soccer player bounces a ball off her head.
– A passenger continues to move forward even when the driver applies the brakes.	– A person jumps off a diving board.	– A basketball player passes the ball to his teammate.

Applying Newton's Laws

Teaching Tip

Have students work in small groups and use Think-Pair-Share to solve these conceptual problems.

1. A landscaper decided to create a stone walkway. He drove to a home improvement store to pick up the stones he ordered. His speed was 45 miles per hour. As he returned home, the landscaper observed that it took a longer time to reach the same speed. What caused the difference in the time needed to reach the same speed on the way home from the store? What could the landscaper do to reach the 45 mph speed in the same amount of time?
2. Which airplane requires more force to take off: a small airplane or a large, 300-passenger jet? Why?
3. Two vehicles take off from rest at a stop light. One vehicle is a tiny sports car; the other a large SUV. Describe factors that affect each vehicle's acceleration. Which would you expect to have the greater force of impact in a collision? Explain your answer.
4. Paula enjoys weekend kick scooter races with her neighborhood friends. How do you ride a scooter? What must you do to start, speed up, slow down, or stop? Which of Newton's laws are involved in riding a scooter? Suppose you were taking a weekend scooter ride with Paula on a hilly street in her neighborhood. Would you be able to ride your scooter up the hill? Why or why not? How would the scooter ride change as you came down the hill? Describe your motion in terms of Newton's laws.