

2.1

KEY CONCEPT

Forces change motion.

BEFORE, you learned

- The velocity of an object is its change in position over time
- The acceleration of an object is its change in velocity over time

NOW, you will learn

- What a force is
- How unbalanced forces change an object's motion
- How Newton's first law allows you to predict motion

VOCABULARY

force p. 41

net force p. 43

Newton's first law p. 45

inertia p. 46

EXPLORE Changing Motion

How can you change an object's motion?

PROCEDURE

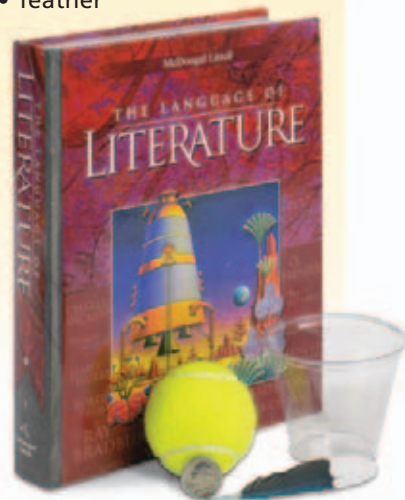
- 1 Choose an object from the materials list and change its motion in several ways, from
 - not moving to moving
 - moving to not moving
 - moving to moving faster
 - moving to moving in a different direction
- 2 Describe the actions used to change the motion.
- 3 Experiment again with another object. First, decide what you will do; then predict how the motion of the object will change.

WHAT DO YOU THINK?

In step 3, how were you able to predict the motion of the object?

MATERIALS

- quarter
- book
- tennis ball
- cup
- feather



A force is a push or a pull.

Think about what happens during an exciting moment at the ballpark. The pitcher throws the ball across the plate, and the batter hits it high up into the stands. A fan in the stands catches the home-run ball. In this example, the pitcher sets the ball in motion, the batter changes the direction of the ball's motion, and the fan stops the ball's motion. To do so, each must use a **force**, or a push or a pull.

You use forces all day long to change the motion of objects in your world. You use a force to pick up your backpack, to open or close a car door, and even to move a pencil across your desktop. Any time you change the motion of an object, you use a force.

REMINDER

Motion is a change in position over time.

Types of Forces

A variety of forces are always affecting the motion of objects around you. For example, take a look at how three kinds of forces affect the skater in the photograph on the left.



- 1 Contact Force** When one object pushes or pulls another object by touching it, the first object is applying a contact force to the second. The skater applies a contact force as she pushes against the ground. The ground applies a contact force that pushes the skater forward.
- 2 Gravity** Gravity is the force of attraction between two masses. Earth's gravity is pulling on the skater, holding her to the ground. The strength of the gravitational force between two objects depends on their masses. For example, the pull between you and Earth is much greater than the pull between you and a book.
- 3 Friction** Friction is a force that resists motion between two surfaces that are pressed together. Friction between the surface of the ground and the wheels of the skates exerts a force that resists the skater's forward motion.

You will learn more about gravity and friction in Chapter 3. In this chapter, most of the examples involve contact forces. You use contact forces constantly. Turning a page, pulling a chair, using a pencil to write, pushing your hair away from your eyes—all involve contact forces.



CHECK YOUR READING

What is a contact force? Give an example of a contact force.

Size and Direction of Forces

Like velocity, force is a vector. That means that force has both size and direction. For example, think about what happens when you try to make a shot in basketball. To get the ball through the hoop, you must apply the right amount of force to the ball and aim the force in the right direction. If you use too little force, the ball will not reach the basket. If you use too much force, the ball may bounce off the backboard and into your opponent's hands.

In the illustrations in this book, red arrows represent forces. The direction of an arrow shows the direction of the force, and the length of the arrow indicates the amount, or size, of the force. A blue box represents mass.

READING TIP

Red arrows are used to show force.



Blue boxes show mass.



Balanced and Unbalanced Forces

Considering the size and the direction of all the forces acting on an object allows you to predict changes in the object's motion. The overall force acting on an object when all the forces are combined is called the **net force**.

If the net force on an object is zero, the forces acting on the object are balanced. Balanced forces have the same effect as no force at all. That is, the motion of the object does not change. For example, think about the forces on the basketball when one player attempts a shot and another blocks it. In the photograph below on the left, the players are pushing on the ball with equal force but from opposite directions. The forces on the ball are balanced, and so the ball does not move.

Only an unbalanced force can change the motion of an object. If one of the basketball players pushes with greater force than the other player, the ball will move in the direction that player is pushing. The motion of the ball changes because the forces on the ball become unbalanced.

It does not matter whether the ball started at rest or was already moving. Only an unbalanced force will change the ball's motion.

COMBINATION NOTES

Make an outline and draw a diagram about balanced and unbalanced forces.

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READING VISUALS

COMPARE Compare the net force on the balls in these two photographs. Which photograph shows a net force of zero?

Forces on Moving Objects



An object with forces acting on it can be moving at a constant velocity as long as those forces are balanced. For example, if you ride a bike straight ahead at a constant speed, the force moving the bike forward exactly balances the forces of friction that would slow the bike down. If you stop pedaling, the forces are no longer balanced, and frictional forces slow you down until you eventually stop.

Balanced forces cannot change an object's speed or its direction. An unbalanced force is needed to change an object's motion.

- To increase the speed of your bike, you may exert more forward force by pedaling harder or changing gears. The net force moves the bike ahead faster.
- To turn your bike, you apply an unbalanced force by leaning to one side and turning the handlebars.
- To stop the bike, you use the extra force of friction that your bike brakes provide.



What happens to a moving object if all the forces on it are balanced? Which sentence above tells you?

Newton's first law relates force and motion.

In the mid-1600s, the English scientist Sir Isaac Newton studied the effects of forces on objects. He formulated three laws of motion that are still helping people describe and predict the motions of objects today. Newton's ideas were built on those of other scientists, in particular the Italian scientist Galileo Galilei (gal-uh-LEE-oh gal-uh-LAY). Both Galileo and Newton overturned thinking that had been accepted since the times of the ancient Greek philosophers.

The ancient Greeks had concluded that it was necessary to apply a continuous force to keep an object in motion. For example, if you set a book on a table and give the book a quick push, the book slides a short way and then stops. To keep the book moving, you need to keep pushing it. The Greeks reasoned that the book stops moving because you stop pushing it.

Galileo's Thought Experiment

In the early 1600s, Galileo suggested a different way of interpreting such observations. He imagined a world without friction and conducted a thought experiment in this ideal world. He concluded that, in the absence of friction, a moving object will continue moving even if there is no force acting on it. In other words, it does not take a force to keep an object moving; it takes a force—friction—to stop an object that is already moving.

READING TIP

Contrast the last sentence of this paragraph with the last sentence of the previous paragraph.

Objects at rest and objects in motion both resist changes in motion. That is, objects at rest tend to stay at rest, and objects that are moving tend to continue moving unless a force acts on them. Galileo reasoned there was no real difference between an object that is moving at a constant velocity and an object that is standing still. An object at rest is simply an object with zero velocity.

CHECK YOUR READING How were Galileo's ideas about objects in motion different from the ideas of the ancient Greeks?

Newton's First Law

Newton restated Galileo's conclusions as his first law of motion.

Newton's first law states that objects at rest remain at rest, and objects in motion remain in motion with the same velocity, unless acted upon by an unbalanced force. You can easily observe the effects of unbalanced forces, both on the ball at rest and the ball in motion, in the pictures below.

Newton's First Law

Objects at rest remain at rest, and objects in motion remain in motion with the same velocity, unless acted upon by an unbalanced force.

An Object at Rest

An object at rest (**the ball**) remains at rest unless acted upon by an unbalanced force (**from the foot**).



 **unbalanced force (from the foot)**  **object at rest (ball)**

An Object in Motion

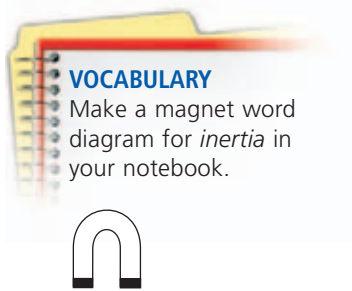
An object in motion (**the ball**) remains in motion with the same velocity, unless acted upon by an unbalanced force (**from the hand**).



 **object in motion (ball)**  **unbalanced force (from the hand)**

READING VISUALS What will happen to the ball's motion in each picture? Why?

You will find many examples of Newton's first law around you. For instance, if you throw a stick for a dog to catch, you are changing the motion of the stick. The dog changes the motion of the stick by catching it and by dropping it at your feet. You change the motion of a volleyball when you spike it, a tennis racket when you swing it, a paintbrush when you make a brush stroke, and an oboe when you pick it up to play or set it down after playing. In each of these examples, you apply a force that changes the motion of the object.



VOCABULARY

Make a magnet word diagram for *inertia* in your notebook.



Inertia

Inertia (ih-NUR-shuh) is the resistance of an object to a change in the speed or the direction of its motion. Newton's first law, which describes the tendency of objects to resist changes in motion, is also called the law of inertia. Inertia is closely related to mass. When you measure the mass of an object, you are also measuring its inertia. You know from experience that it is easier to push or pull an empty box than it is to push or pull the same box when it is full of books. Likewise, it is easier to stop or to turn an empty wagon than to stop or turn a wagon full of sand. In both of these cases, it is harder to change the motion of the object that has more mass.

INVESTIGATE Inertia

Which ball has more inertia?

Two balls have different masses and therefore different amounts of inertia. Use what you know about force and inertia to design an experiment that shows which ball has more inertia. Your procedure cannot include lifting the balls, weighing the balls, or touching the balls with your hands.

PROCEDURE

- 1 Figure out how to use the meter stick or other materials to compare the inertia of the two balls.
- 2 Write up your procedure.
- 3 Test your procedure.

WHAT DO YOU THINK?

- What were the results of your experiment? Did it work? Why or why not?
- What was the variable? What were the constants?
- How does your experiment demonstrate the property of inertia?

DESIGN
— YOUR OWN —
EXPERIMENT

SKILL FOCUS

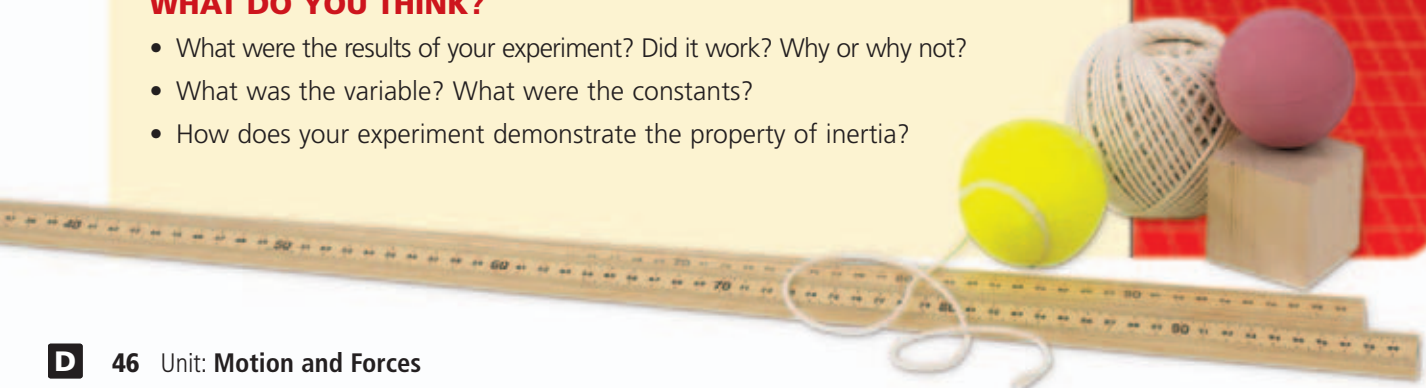
Designing experiments

MATERIALS

- 2 balls of unknown masses
- string
- block
- meter stick

TIME

30 minutes



Inertia is the reason that people in cars need to wear seat belts. A moving car has inertia, and so do the riders inside it. When the driver applies the brakes, an unbalanced force is applied to the car. Normally, the bottom of the seat applies an unbalanced force—friction—which slows the riders down as the car slows. If the driver stops the car suddenly, however, this force is not exerted over enough time to stop the motion of the riders. Instead, the riders continue moving forward with most of their original speed because of their inertia.



1 As a car moves forward, the driver—shown here as a crash-test dummy—moves forward with the same velocity as the car.



2 When the driver hits the brakes, the car stops. If the stop is sudden and the driver is not wearing a seat belt, the driver keeps moving forward.



3 Finally, the windshield applies an unbalanced force that stops the driver's forward motion.

If the driver is wearing a seat belt, the seat belt rather than the windshield applies the unbalanced force that stops the driver's forward motion. The force from the seat belt is applied over a longer time, so the force causes less damage. In a collision, seat belts alone are sometimes not enough to stop the motion of drivers or passengers. Air bags further cushion people from the effects of inertia in an accident.

CHECK YOUR READING If a car makes a sudden stop, what happens to a passenger riding in the back seat who is not wearing a seat belt?

2.1 Review

KEY CONCEPTS

1. Explain the difference between balanced and unbalanced forces.
2. What is the relationship between force and motion described by Newton's first law?
3. What is inertia? How is the inertia of an object related to its mass?

CRITICAL THINKING

4. **Infer** Once a baseball has been hit into the air, what forces are acting upon it? How can you tell that any forces are acting upon the ball?
5. **Predict** A ball is at rest on the floor of a car moving at a constant velocity. What will happen to the ball if the car swerves suddenly to the left?

CHALLENGE

6. **Synthesize** What can the changes in an object's position tell you about the forces acting on that object? Describe an example from everyday life that shows how forces affect the position of an object.