Essential Question

What Are Forces?

Engage Your Brain!

As you read the lesson, figure out the answers to the following questions. Write the answers here.

What forces are acting on this cyclist? Are all the forces balanced?

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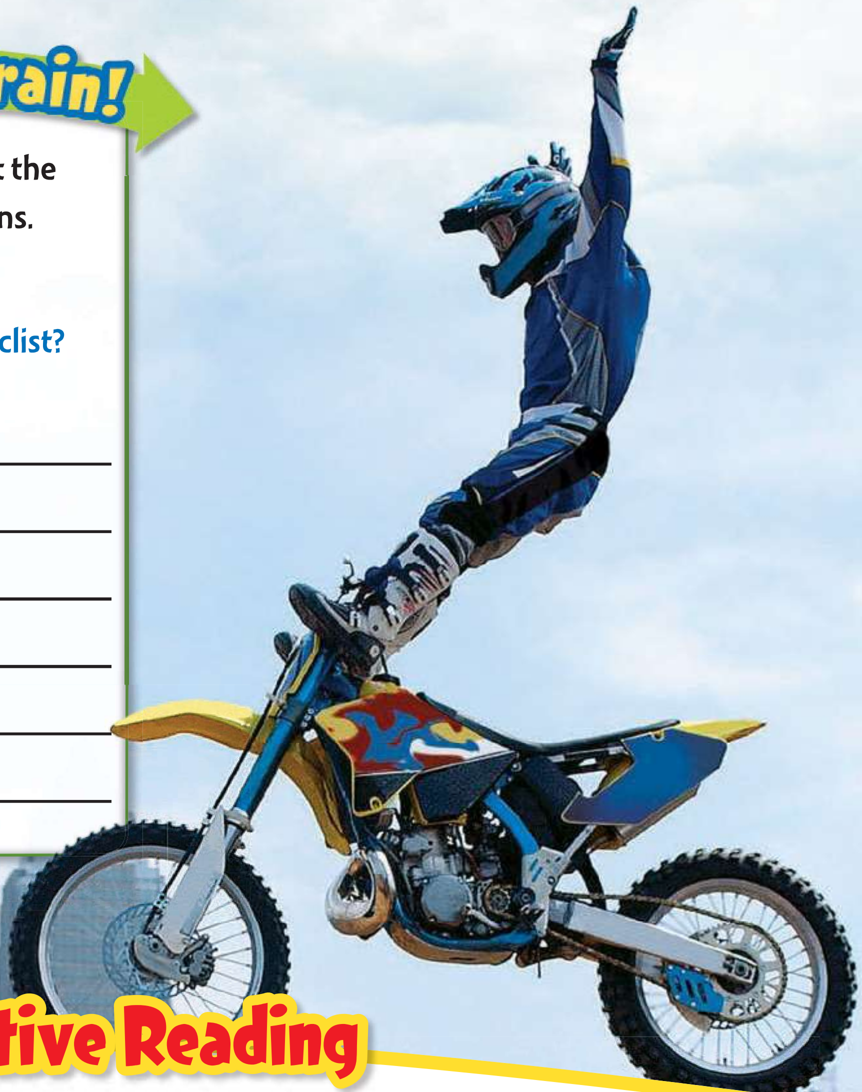

Active Reading

Lesson Vocabulary

List the terms. As you learn about each one, make notes in the Interactive Glossary.

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Cause and Effect

Some ideas in this lesson are connected by a cause-and-effect relationship. Why something happens is a cause. What happens as a result of something else is an effect. Active readers look for effects by asking themselves, What happened? They look for causes by asking, Why did it happen?

PUSHING and Pulling

You pull on a door to open it. You lift up a backpack. You push on the pedals of a bike to go faster. What is the relationship between force and motion?

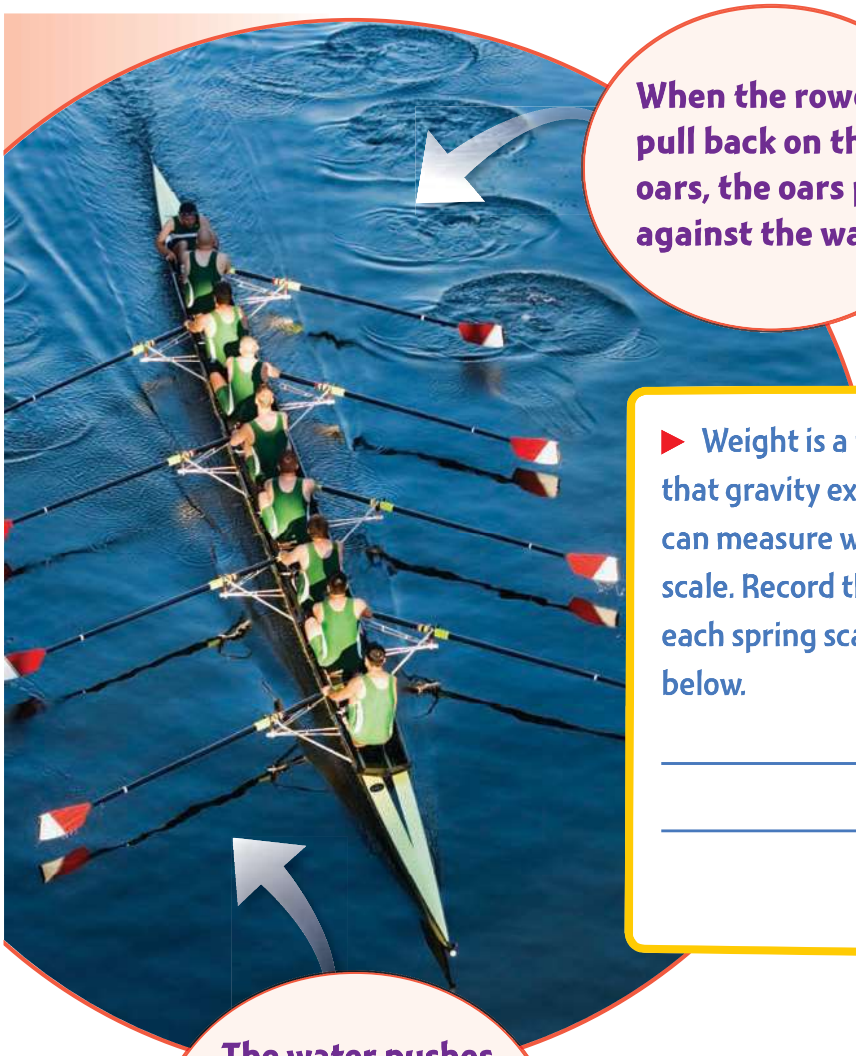
Active Reading As you read this page, underline the effects a force can have on an object.

The horse and the road it is on both exert a force on the cart.

▶ **Draw an arrow that shows the direction of the force applied to the cart by the horse.**

Changes in motion all have one thing in common. They require a **force**, which is a push or a pull. Forces can cause an object at rest to move. They can cause a moving object to speed up, slow down, change direction, or stop. Forces can also change an object's shape.

Forces are measured with a spring scale in units called newtons (N). The larger the force, the greater the change it can cause to the motion of an object. Smaller forces cause smaller changes. Sometimes more than one force can act together in a way that does not cause a change in motion.



When the rowers pull back on the oars, the oars push against the water.

▶ Weight is a measure of the force that gravity exerts on an object. You can measure weight with a spring scale. Record the weight shown on each spring scale in the spaces below.

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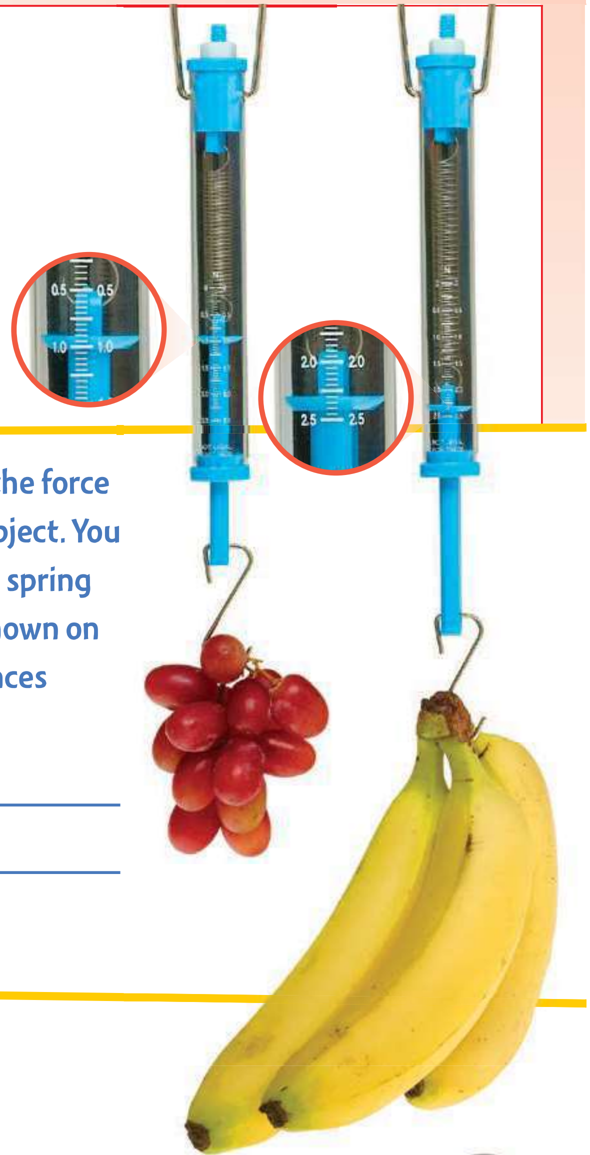
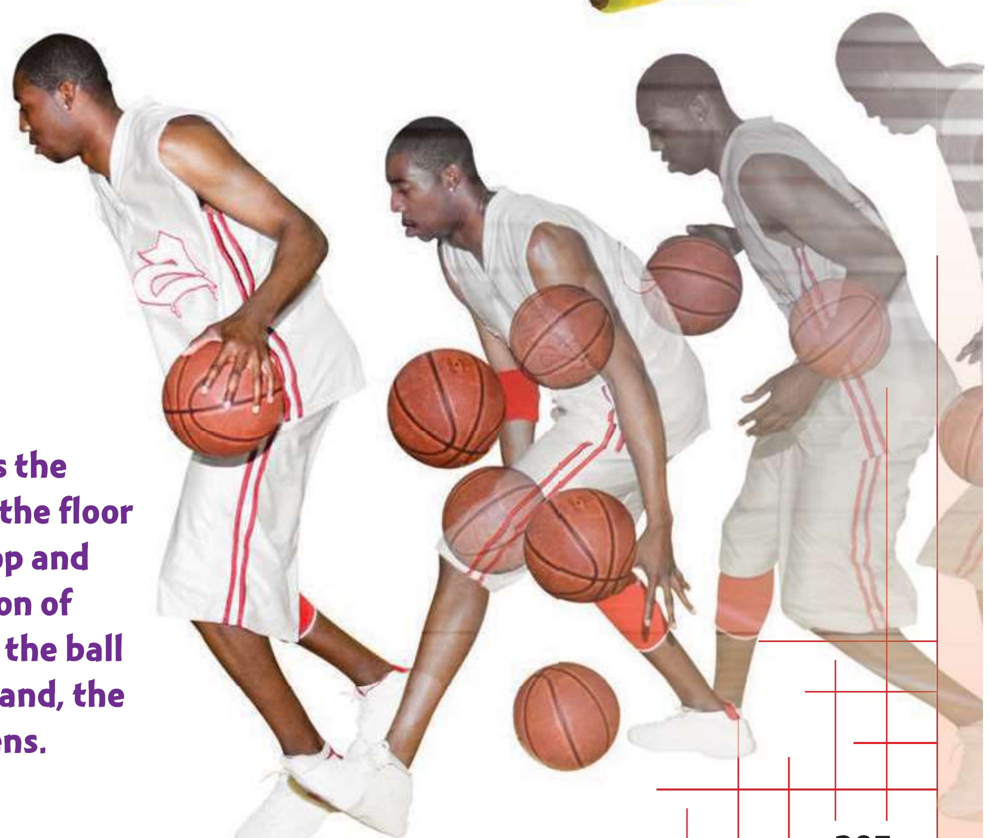


The water pushes back against the oars. This force causes the boat to move.



When the ball hits the floor, the force of the floor makes the ball stop and change its direction of movement. When the ball hits the player's hand, the same thing happens.

TWO COMMON Forces

What do the skydivers and some of the flower petals have in common? They are both falling! What causes this?

Active Reading As you read these pages, circle the sentence that describes a force that causes things to slow down.

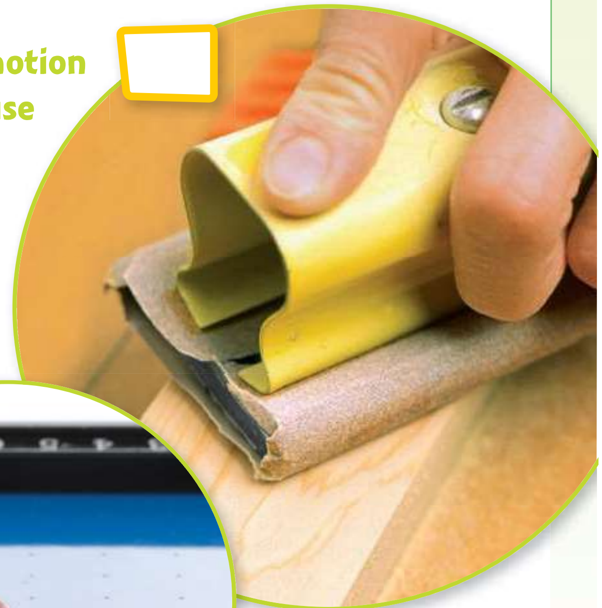
▶ Draw an arrow showing the direction of the gravitational force between Earth and the falling flower petals.

Gravity

Gravity is a force of attraction between two objects. The size of this force increases as the mass of the objects increases. It decreases as the distance between the objects increases. Gravity acts on objects even if they are not touching.

Large objects such as Earth cause smaller objects, such as the skydivers, to accelerate quickly. We expect to see things fall toward Earth. However, the force of attraction is the same on both objects. If you place two objects with the same mass in outer space, they will move toward one another. If one object is "above" the other, the bottom object will appear to "fall up" as the other "falls down"!

Friction changes the energy of motion into thermal energy. When you use sandpaper to smooth wood, you can feel the temperature rise.



Friction

Is it easier to ride your bike on a smooth road or on a muddy trail? Why?

Friction is a force that opposes motion. Friction acts between two objects that are touching, such as the bike tires and the road. Friction can also exist between air and a moving object. This is called air resistance.

It is easy to slide across smooth ice because it doesn't have much friction. Pulling something across rough sandpaper is a lot harder because there is lots of friction.

An air hockey table blows air upward. This layer of air reduces the surface friction, so the pieces move quickly.

▶ In the pictures on this page, circle the places where there is friction between two objects. In the small boxes, write *Inc* if the object is designed to increase friction and *Dec* if the object is designed to decrease friction.

The tires on this bike are designed to keep the rider from slipping. You have to pedal harder on a rough surface to overcome the force of friction.

BALANCED or Unbalanced?

The tug-of-war teams are both applying forces. So why isn't anyone moving?

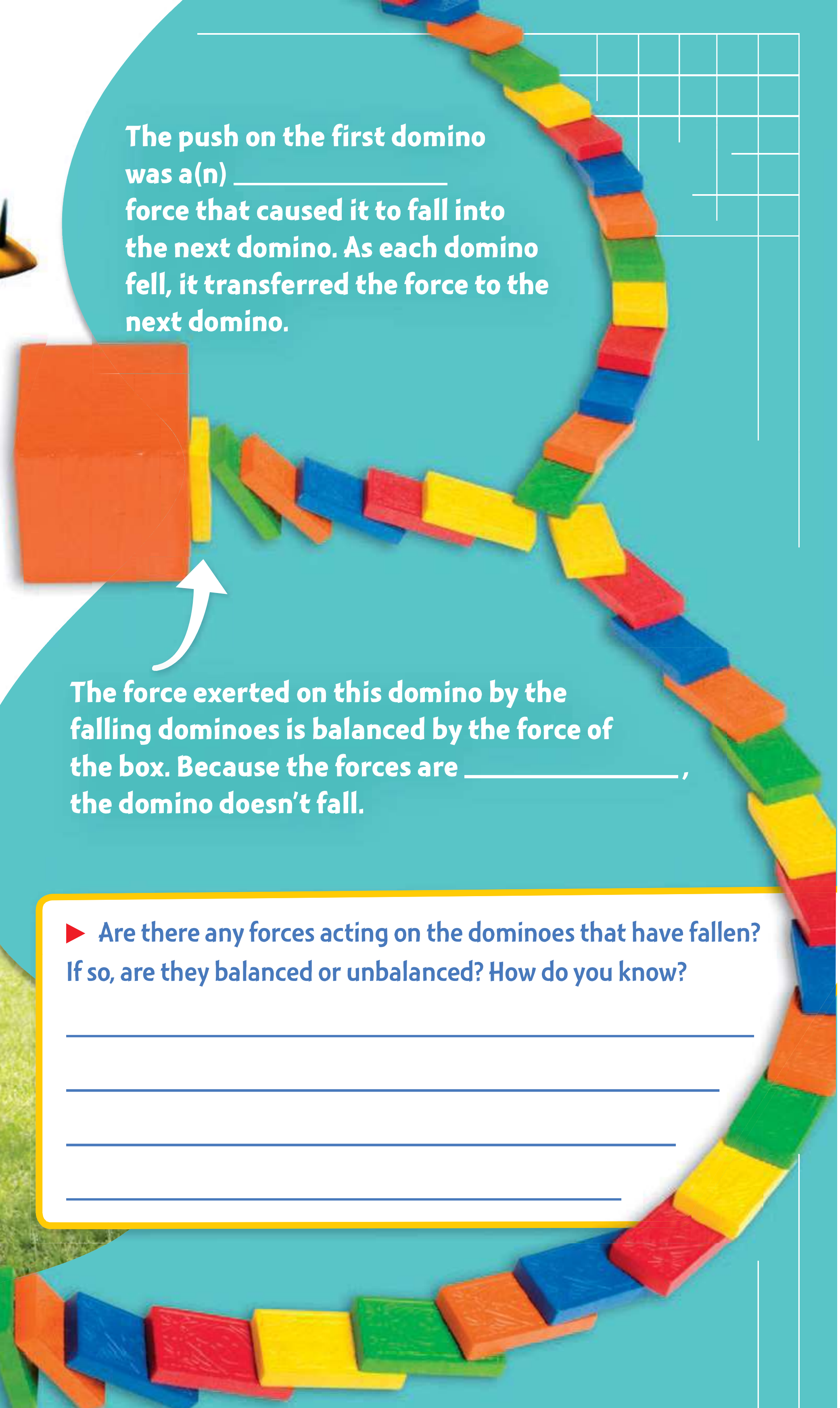
Active Reading Draw a circle around a sentence that explains why objects don't always move when a force is applied.

When you sit on a chair, the force of gravity pulls you down. The chair pushes you up. You stay in one place because the forces on you are balanced. **Balanced forces** are forces on an object that are equal in size and opposite in direction. They cancel each other out.

The tug-of-war teams in the picture don't move because the forces are balanced. Friction keeps them from sliding. They won't move until one side exerts a larger force. Then, the forces are no longer balanced. **Unbalanced forces** are forces that cause a change in motion. A force must also overcome the force of friction before an object will move.

When a plane flies at a constant velocity, all the forces on the plane are balanced. If they weren't, the plane would speed up, slow down, or gain or lose altitude.

The push on the first domino was a(n) _______________ force that caused it to fall into the next domino. As each domino fell, it transferred the force to the next domino.



The force exerted on this domino by the falling dominoes is balanced by the force of the box. Because the forces are _______________, the domino doesn't fall.

▶ Are there any forces acting on the dominoes that have fallen? If so, are they balanced or unbalanced? How do you know?

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The forces on the dominoes are _______________ when they are standing upright. When a falling domino hits them, the forces become _______________ and they fall.

PULL (or Push) Harder!

Would you expect a bunt in baseball to go out of the park? Why or why not?

Active Reading As you read, circle the sentences that explain the relationship between the size of a force and motion.

▶ Use forces to explain why the boy can't ring the bell.

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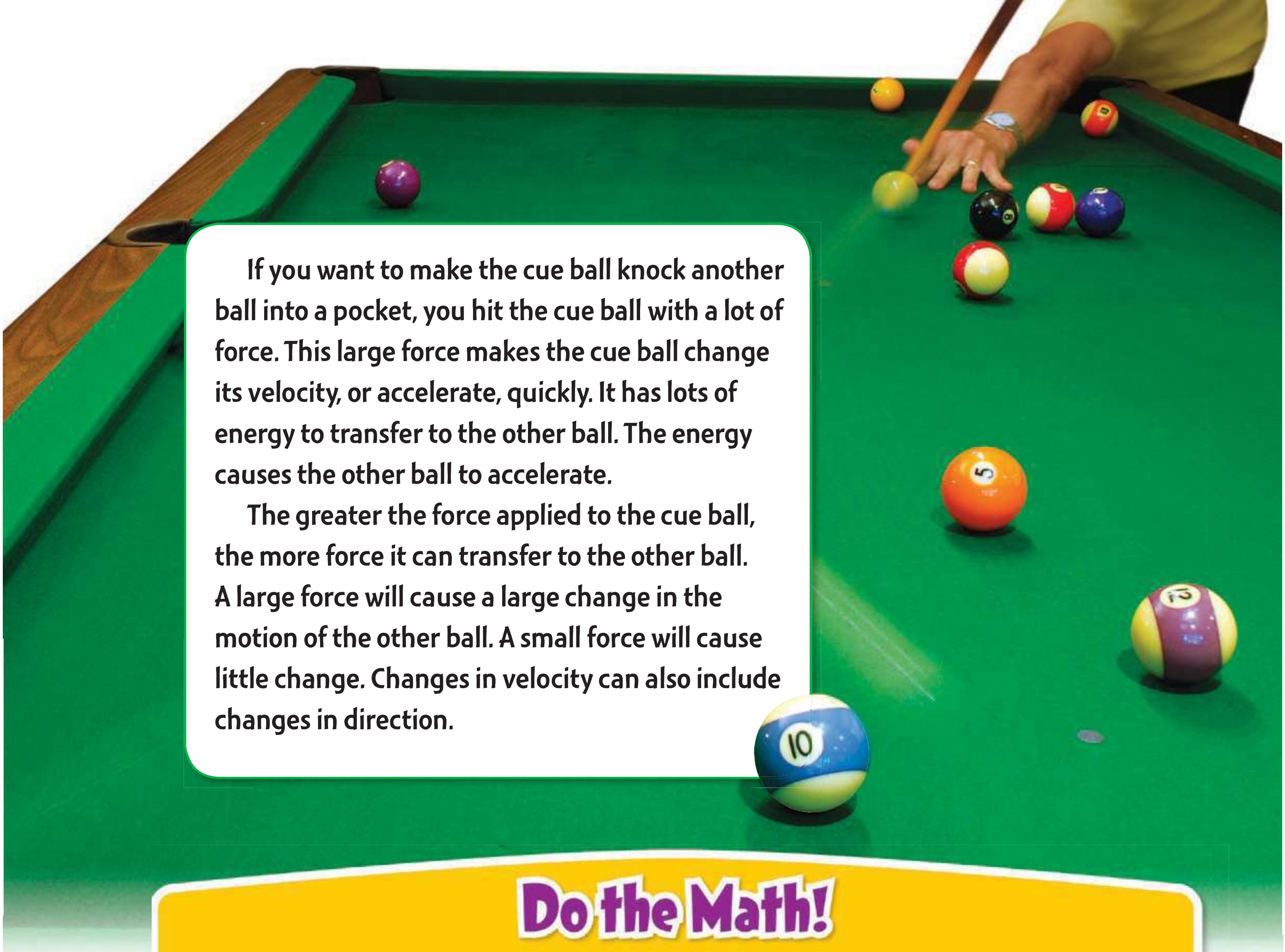
When the man swings the hammer, he exerts a force on a plate. The plate transfers the force to a piece of metal that rises up the column and rings the bell.

The boy swings the same kind of hammer at the same kind of machine. Why doesn't the metal hit the bell?



If you want to make the cue ball knock another ball into a pocket, you hit the cue ball with a lot of force. This large force makes the cue ball change its velocity, or accelerate, quickly. It has lots of energy to transfer to the other ball. The energy causes the other ball to accelerate.

The greater the force applied to the cue ball, the more force it can transfer to the other ball. A large force will cause a large change in the motion of the other ball. A small force will cause little change. Changes in velocity can also include changes in direction.

Do the Math!

Display Data in a Graph

Use the data in the table to make a graph that shows the relationship between the force applied to an object and its acceleration.

Force (N)	Acceleration (m/sec^2)
1	0.5
2	1.0
5	2.5
8	4.0
10	5.0

I'M NOT Moving!

It's easy to lift your empty backpack off the ground. Could you use the same force to lift it when it's full of books?

Active Reading As you read these pages, circle cause-and-effect signal words, such as *because*, *so*, or *therefore*.

The springs in the pictures all exert the same force on the balls, causing them to roll across the page. The ball with the least mass accelerates the fastest. Therefore, it travels the farthest. The same force has a greater effect on an object with a small mass than an object with a larger mass.

▶ Rank the balls by writing *greatest, middle,* or *least* in the six blanks.

Foam Ball

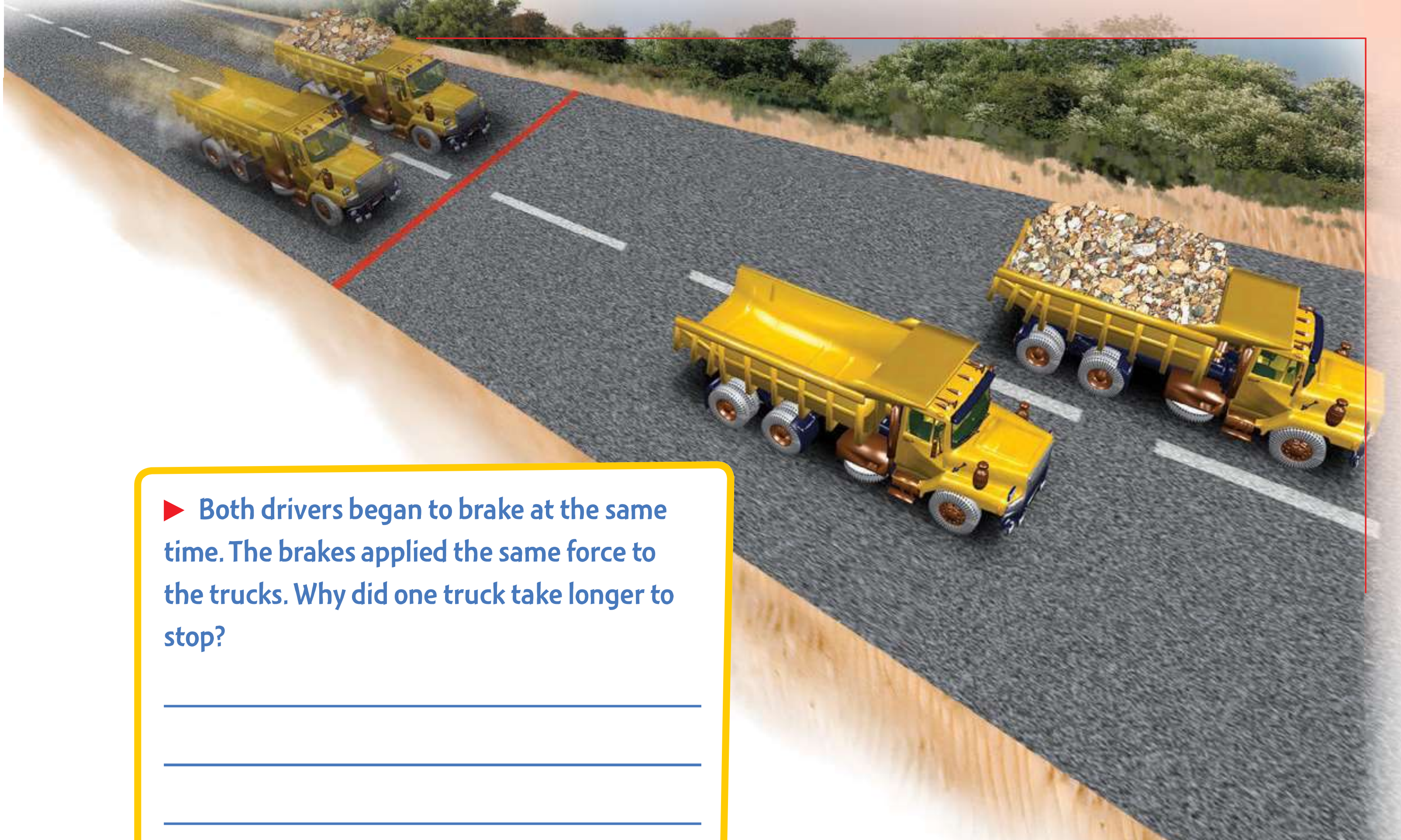
mass: ________

acceleration: ________

Baseball

mass: ________

acceleration: ________



▶ Both drivers began to brake at the same time. The brakes applied the same force to the trucks. Why did one truck take longer to stop?

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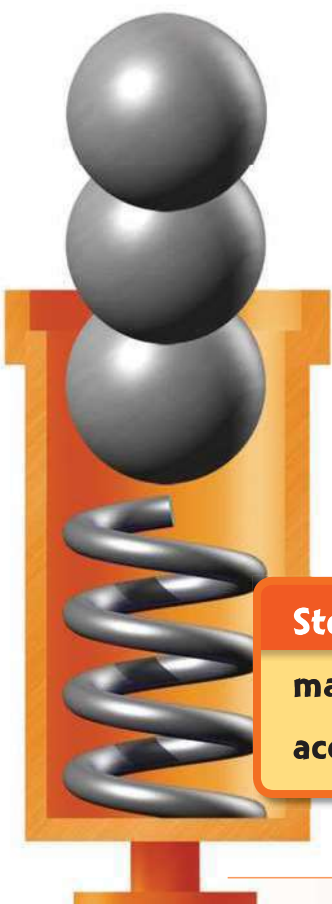
An object's acceleration depends on the object's mass and the force applied to it. The larger the force, the greater is the acceleration. Suppose you push a wagon gently. The wagon speeds up slowly. If you use more strength to push, then the wagon's speed changes quickly.

The less an object's mass is, the less force is needed to change its motion. It's easier to push an empty shopping cart than a full one. Light cars are used in drag races because a car with less mass speeds up faster than a car with more mass.

If you want to slide a heavy box across the floor faster, you have two options. You could take some items out of the box, which decreases its mass. Or you could have a friend help you, which increases the force you apply.



Steel Ball

mass: ________

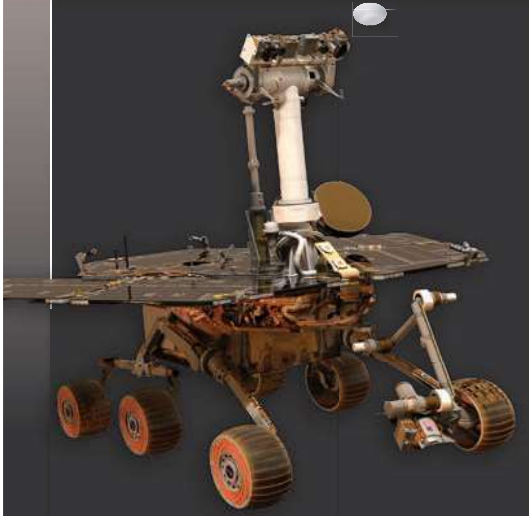
acceleration: ________

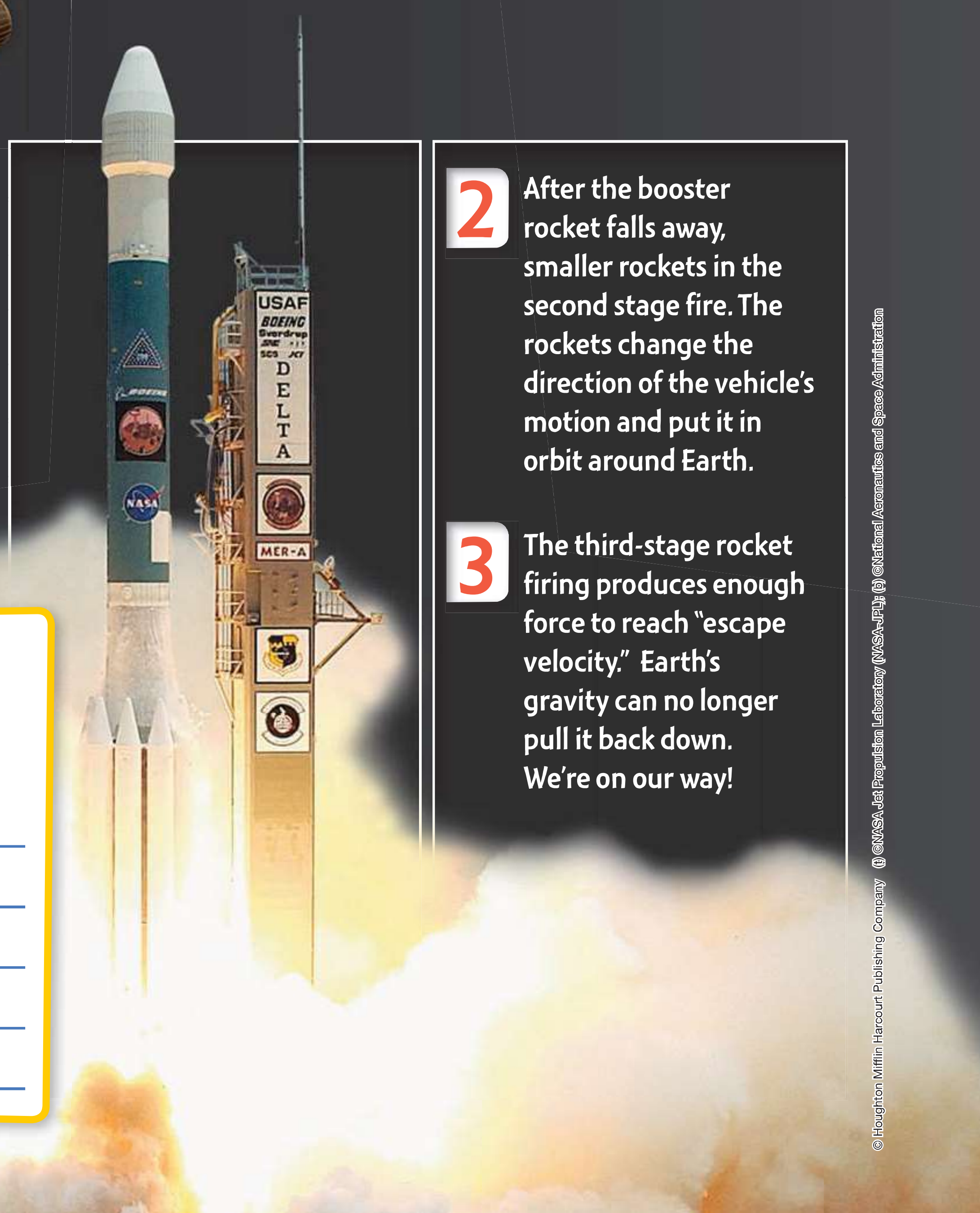
Why It Matters

How did I get to Mars?

LET'S GO to Mars!

How did an understanding of forces help to send a rover to Mars and safely land it there?





1 The first force you need is an unbalanced force to oppose Earth's gravity. A huge booster rocket produces nearly 900,000 N of force that accelerates the rocket upward.

2 After the booster rocket falls away, smaller rockets in the second stage fire. The rockets change the direction of the vehicle's motion and put it in orbit around Earth.

3 The third-stage rocket firing produces enough force to reach "escape velocity." Earth's gravity can no longer pull it back down. We're on our way!

▶ What forces act on the rocket while it's at rest on Earth's surface? Are they balanced or unbalanced?

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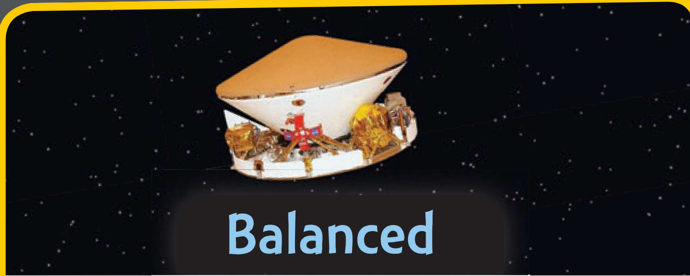
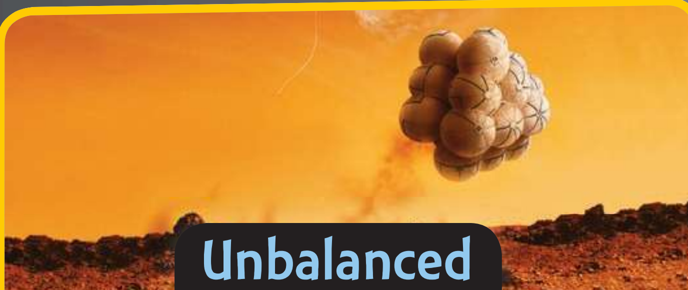


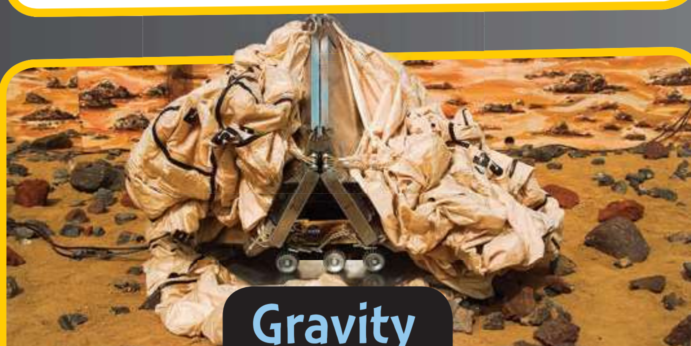
Balanced

▶ At what points during the Rover's trip to Mars are the forces on it balanced?



Unbalanced

▶ What unbalanced forces are acting on the Rover as it lands on Mars?



Gravity

▶ Use forces to explain why the Rover required a parachute and "air bags."

During much of the time it takes the spacecraft to travel to Mars, it travels at a constant velocity. The forces acting on the spacecraft are balanced, so its motion does not change.

Tiny rockets occasionally fire to keep the spacecraft on course. During these times, the forces are unbalanced.

As the spacecraft approaches Mars, gravitational attraction begins to accelerate it toward the surface. Like a person jumping from a plane, the Rover detaches from the spacecraft. Parachutes open to slow its fall. Then a big ball inflates around the Rover. When the Rover hits the surface of Mars, it bounces around until it comes safely to rest.

Mars Rover air bag testing