CHAPTER 7

Using Forces

The Big Idea

How do forces move objects?

Vocabulary

velocity the speed and the direction of a moving object

momentum the mass of an object multiplied by its velocity

force any push or pull by one object on another

work the use of force to move an object a certain distance

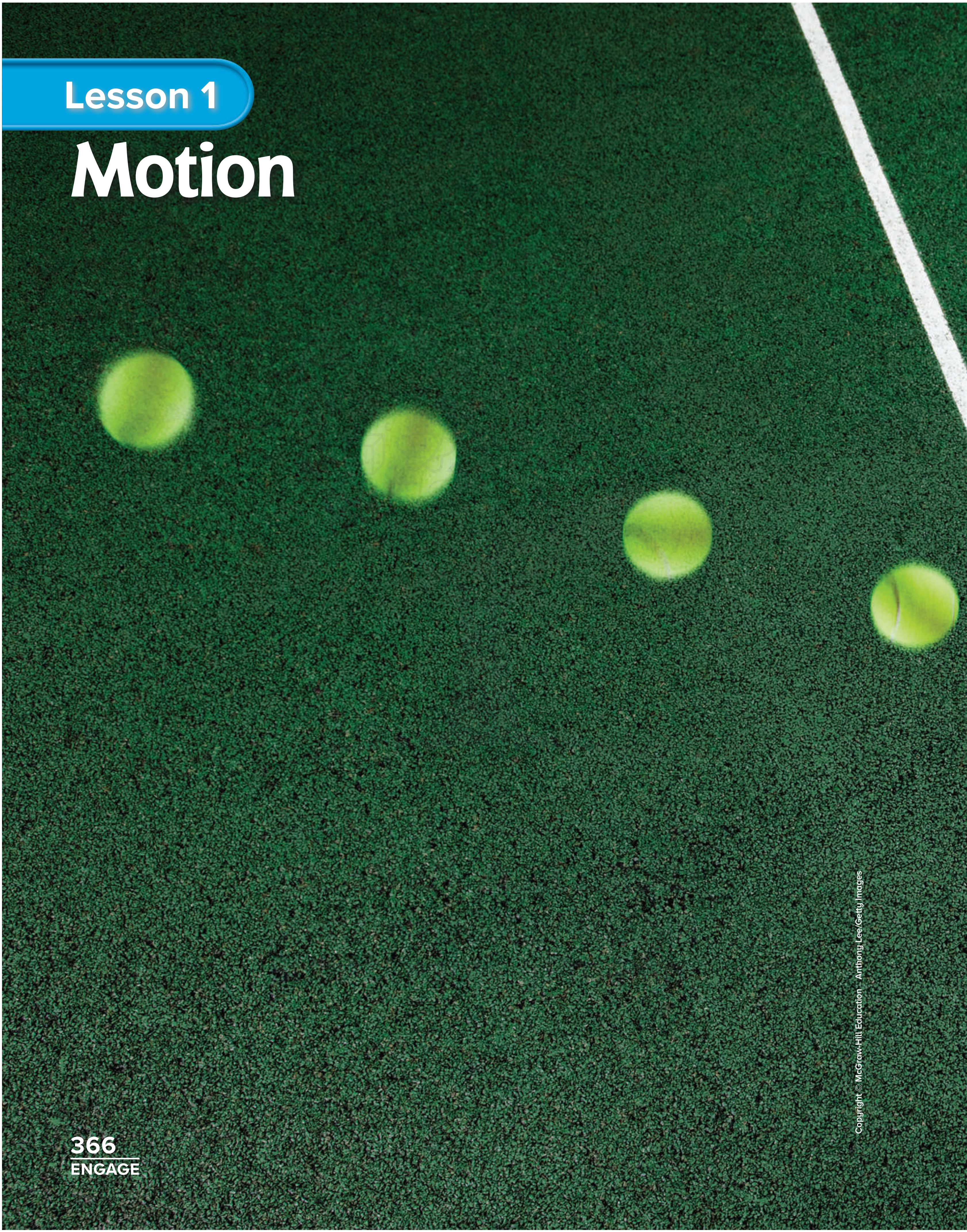
energy the ability to perform work or change an object

Before reading this chapter, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this chapter, write down what you learned in the third column.

Using Forces		
What We **K**now	What We **W**ant to Know	What We **L**earned

Lesson 1

Motion



Look and Wonder

Are these images happening in slow motion? In a way, yes. A flashing light helps record movement over time. How could you measure how fast the tennis ball is moving?

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Essential Question How is motion measured?

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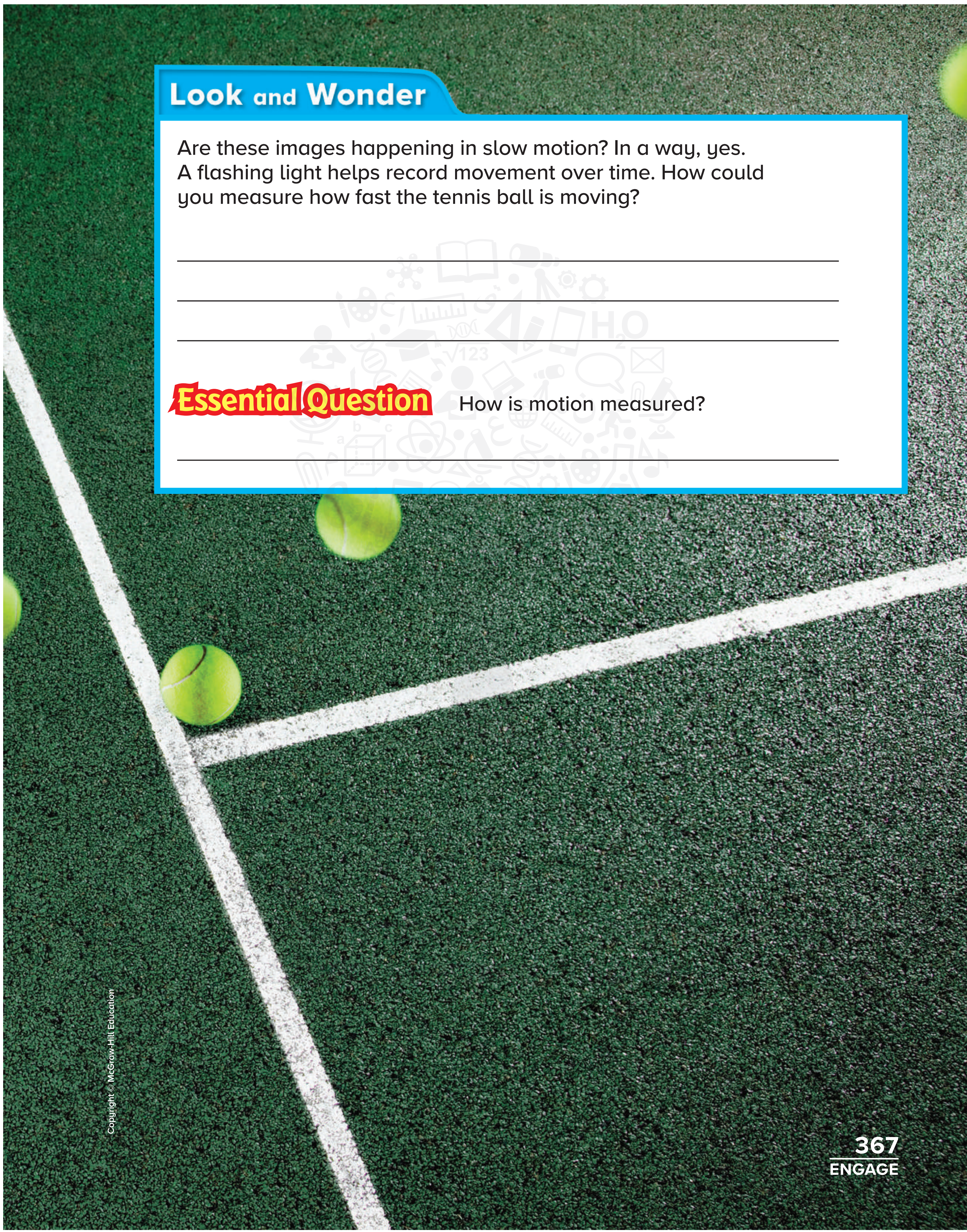

Explore

How is speed measured?

Form a Hypothesis

How do you think speed depends on the distance an object travels? Write your answer in the form "If the distance a marble travels increases, then..."

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Test Your Hypothesis

1. Make a marble launcher out of an index card. Use the pattern provided. Place the launcher on a long, flat, and smooth surface.

2. Place a piece of tape in front of the launcher—this is your starting point. Use a meterstick to place a piece of tape 1 m from your starting point. This is your "finish line" and your independent variable.

3. **Measure** Roll a marble down the launcher.

   Use a stopwatch to time it as it travels from the starting point to the finish line. Repeat twice more and calculate an average time—this is your dependent variable.

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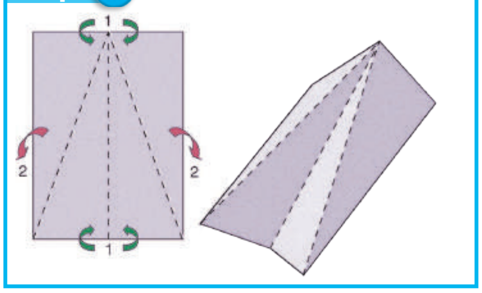
4. Repeat step 3 for finish lines at 2 m and 3 m.

Materials

- index card
- masking tape
- meterstick
- marble
- stopwatch

Step 1



Step 3

Draw Conclusions

5 **Use Numbers** Divide each distance by its average time. This value is the average speed of the marble over that distance.

Explore More

What would be the marble's speed if it traveled on a curved path? Would it move faster or slower than on a straight path? Write a hypothesis and design an experiment to test it.

Open Inquiry

How does the slope of the launcher affect the speed of a launched marble?

Read and Respond

What is motion?

Where are you? Are you in a state, in a city, in a classroom? Are you a certain number of steps from a door? Is the door to the left or right? To answer these questions you need to know your position. A **position** is the location of an object. It answers the question, "Where is the object?"

Positions of objects can be described by a grid. In a grid, you describe a position using points on each axis, or axes. When an object changes its position on the grid, you can draw an arrow between the old position and the new position. This arrow represents the motion of the object. **Motion** is a change in position over time.

Motion has two parts: distance and direction. Distance is the length of the arrow on the grid, and it can be measured with a ruler. We use units such as meters (m) or kilometers (km) describe distance.

Direction is where the arrow is pointing. On a map, we use words such as north, east, south, and west. To measure direction you can use a compass or protractor, and units of degrees.

Motion has 2 parts.

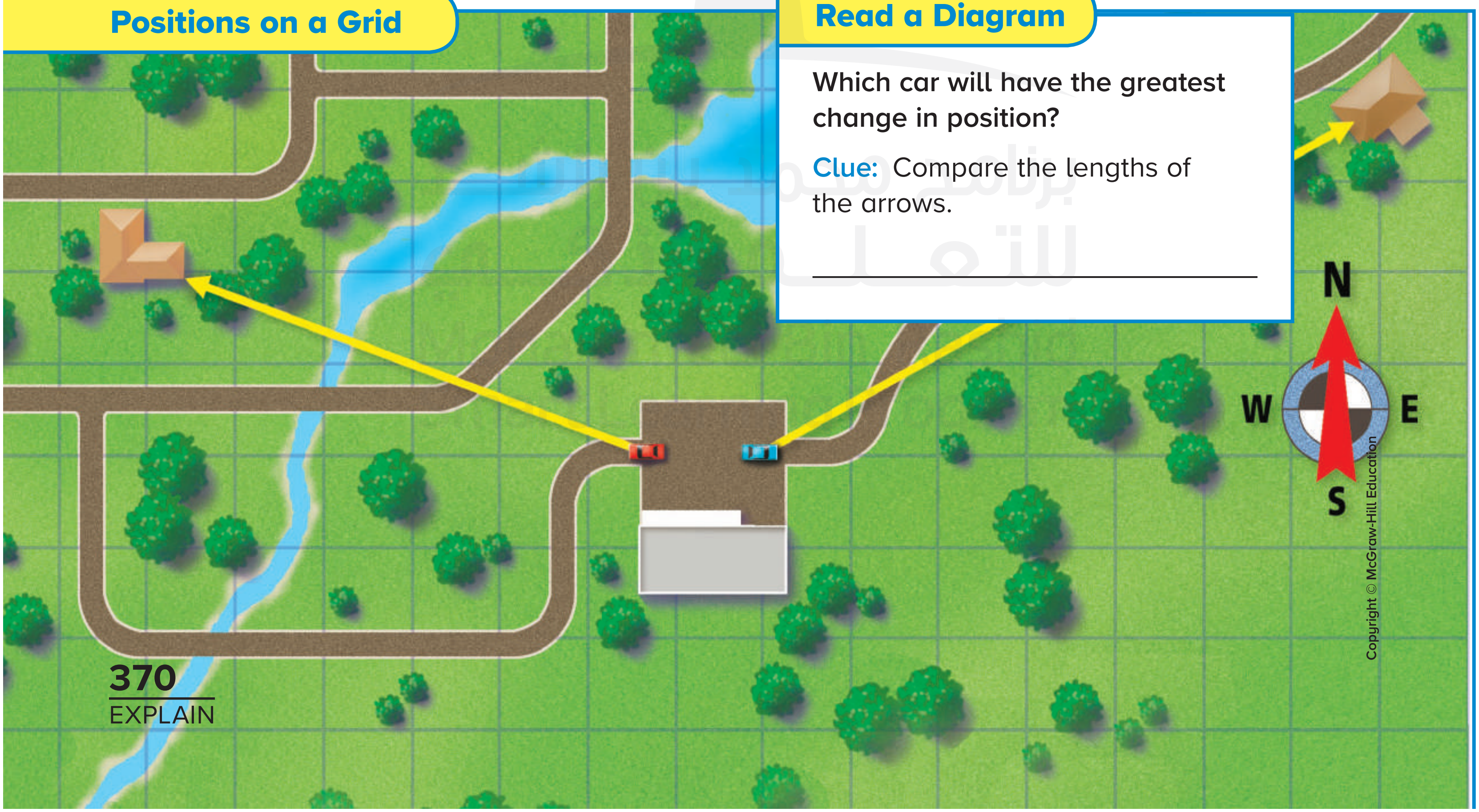
A. distance and position

B. distance and direction

C. position and distance

D. direction and position

Positions on a Grid



Read a Diagram

Which car will have the greatest change in position?

Clue: Compare the lengths of the arrows.

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Frame of Reference

Suppose your friend tells you he is north. Do you think you know where he is? You need to ask him, "North of what?" Positions and motions only make sense if you have a frame of reference.

A **frame of reference** is a group of objects from which you can measure a position or the motion. Your classroom and the objects inside are a frame of reference. If your friend told you he was moving three meters north of his desk, then you could find him easily.

Almost anything can be a frame of reference: a baseball field, a fish tank, or the solar system. It is easiest to describe positions and motions when the frame of reference is a grid. This is why maps often have grids placed on top of them.

Frames of reference can move. For example, the inside of a moving car is a frame of reference. If you move in a car, other passengers inside that car see you moving normally. In your frame of reference, the car's motion does not seem to affect you at all.

Different frames of reference see things differently, however. To anyone outside the car, you appear to be moving very fast. Why? They see the motion of the car added to your motion. The same thing occurs when you look out the car window. The ground seems to be moving very fast, even though you know it's really not moving at all. You add the motion of the car to all the objects outside your frame of reference.

In the frame of reference of a car, outside objects seem to be moving quickly.

In the frame of reference of the ground, the car is moving quickly.

Quick Check

1. How can you measure the distance an object has moved?

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What is speed?

You're at the starting line of a 100-meter dash. The race starts, and you spring from the starting blocks. What is your goal? To cover the 100-m distance in the shortest time possible! Whoever travels fastest wins the race.

"Fastest" in a race means running with the greatest speed. **Speed** is how fast an object's position changes over time. To calculate speed, you divide the distance traveled by the time spent traveling. Units of speed are units of distance per unit of time, such as meters per second (m/s), kilometers per hour (km/h), or miles per hour (mph).

The speed of a moving object can change. A runner in a longer race, for example, might go fast at first, slow down in the middle, and then go fast again at the end.

We determine the runner's average speed by dividing the total distance by the total time. Over short distances, such as 100 m, the fastest human can run at an average speed of about 10 m/s. Over longer distances, such as 50 km, the fastest human can run at an average speed of about 5.6 m/s.

Calculating Speed

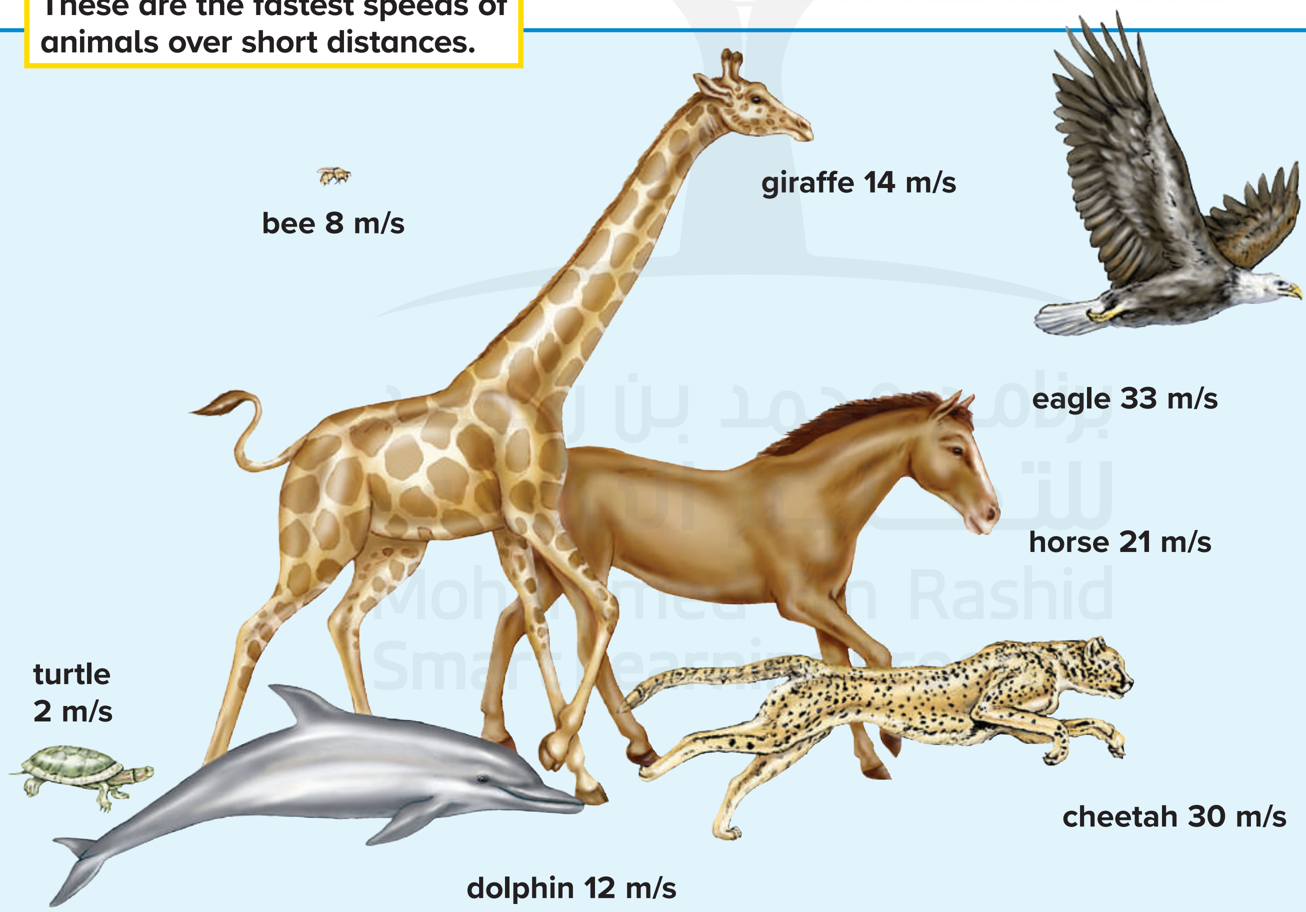
data: distance = 100 m, time = 10 s

speed = distance ÷ time

= 100 m ÷ 10 s

= 10 m/s

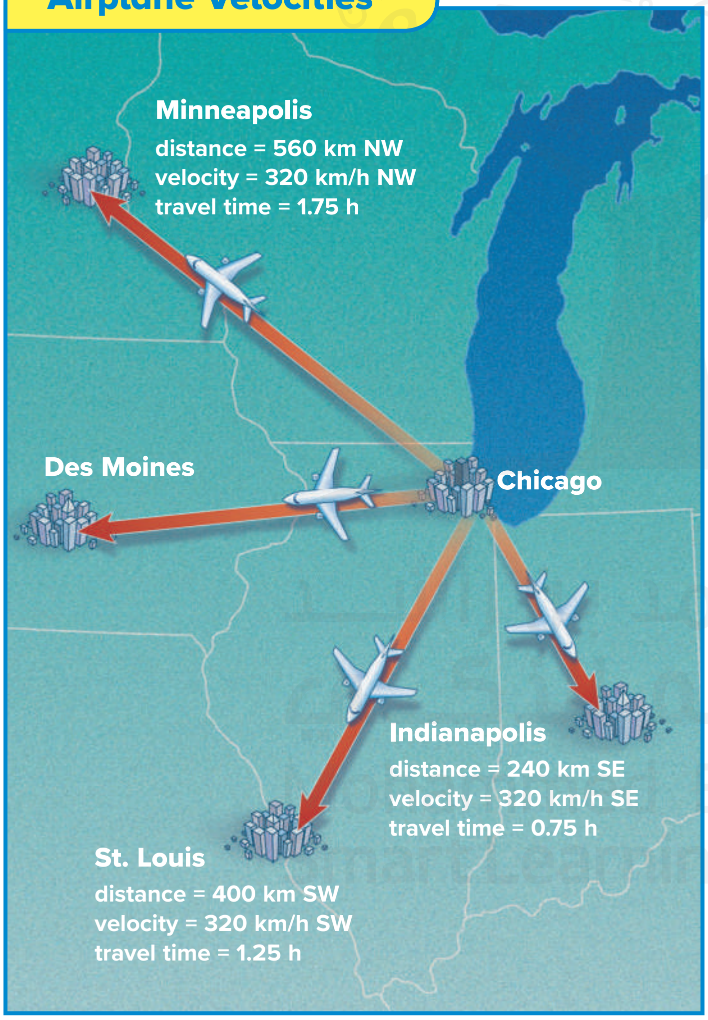
These are the fastest speeds of animals over short distances.



Speed with Direction

If you were a pilot flying a plane, you would want to know how fast your plane could fly and how far the trip would be. With this data, you could calculate how long your trip would take. You would also need to know in what direction to fly, or you would miss your destination. **Velocity** (vuh•LAH•suh•tee) is the measurement that combines both the speed and the direction of a moving object. As a pilot, you would want to know the velocity of the plane as you traveled.

Airplane Velocities



Quick Check

2. How do you calculate average speed?

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3. What is the difference between speed and velocity? Give an example.

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Read a Diagram

The distance from Dubai to Abu Dhabi is 150 kilometers. What should your velocity be to fly in 1.5 hours?

Clue: Be sure to state a direction of travel.

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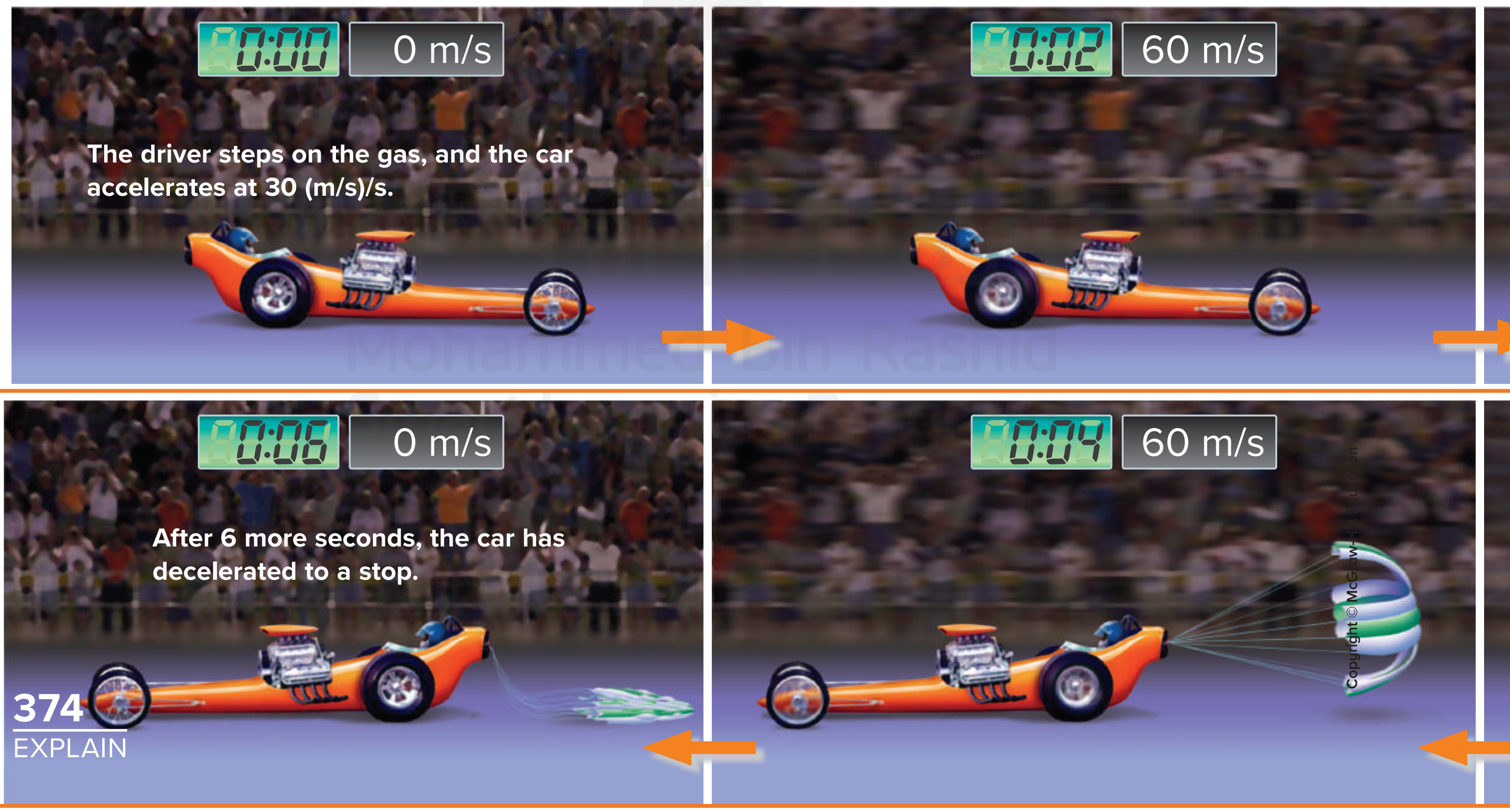
What is acceleration?

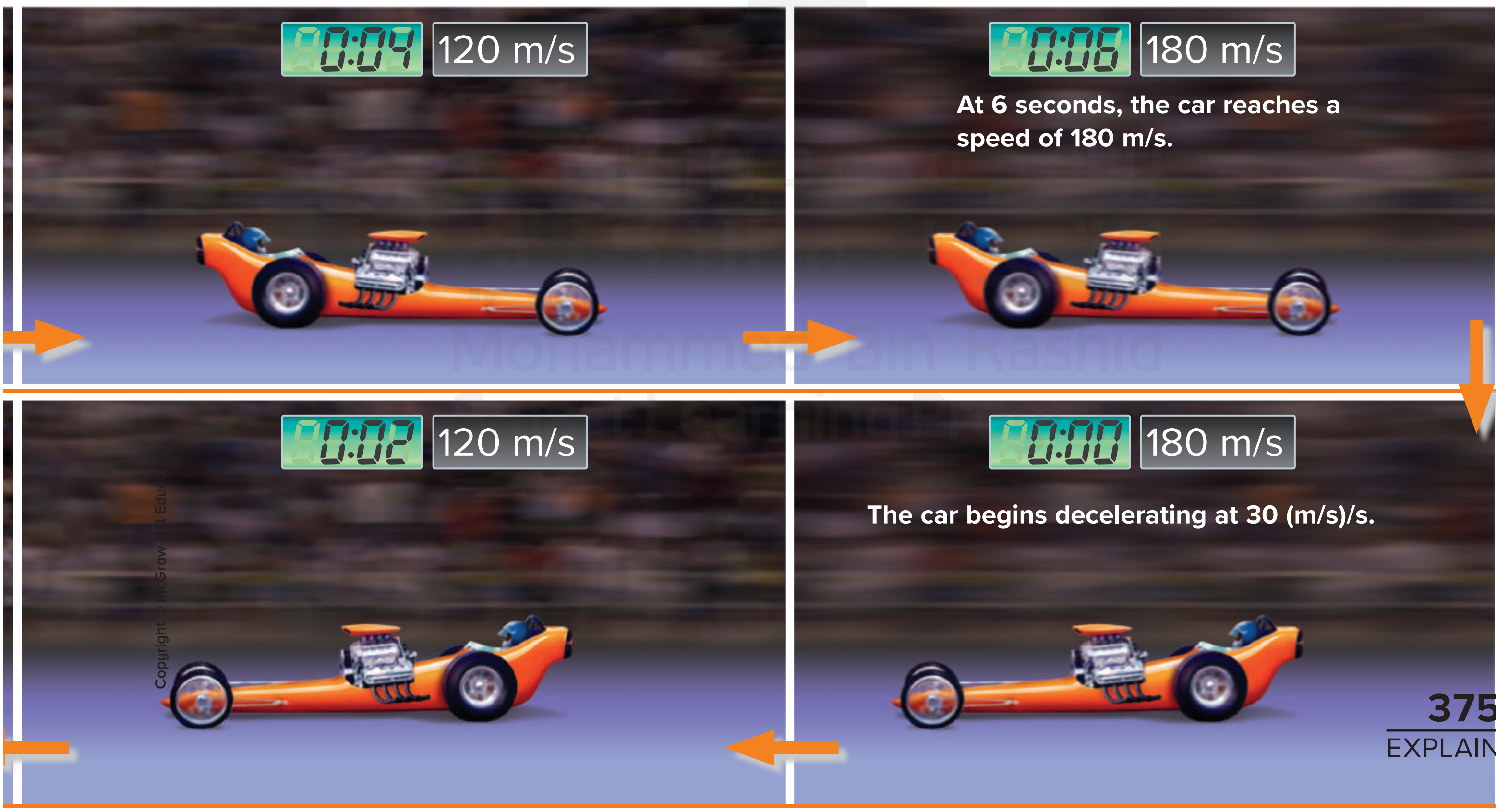
Suppose you are in a race car at the starting line facing north. The light changes from red to green, and the driver steps on the gas. When you reach 180 m/s the driver lets off the gas, and the car travels at a constant speed. On your watch, you note that it took 6 seconds for the car to go from rest (0 m/s) to 180 m/s.

When the position of an object changes, it is in motion and it has a velocity. When the velocity of an object changes, it is accelerating. **Acceleration** (ik•se•luh•RAY•shun) is the change in velocity over time for an object. Units of acceleration are units of velocity divided by units of time: meters per second per second ((m/s)/s). Just like motions and velocity, accelerations have a direction. So you might say the race car accelerates at 30 (m/s)/s north when the driver steps on the gas.



In the example of the race car, the value of the acceleration is 30 (m/s)/s. What does “(m/s)/s” really mean? Each time a second passes, the car gains 30 m/s of speed. After 6 seconds, the car has reached a final speed of 180 m/s. After the driver lets off the gas, the car is traveling at a constant velocity, so it is no longer accelerating.

A car also accelerates when it slows down. An example would be a car stopping at a red light. Acceleration for decreasing speed is given as a negative number. For example, a stopping car might accelerate at –30 (m/s)/s. We could also say that the car decelerates (dee•SEL•uh•rayts) at 30 (m/s)/s.



What is momentum?

Have you ever gone bowling? In this game, there are many pins at the end of a lane. A player knocks pins over with a large bowling ball. How could you knock over the most pins? You could use a heavier ball, you could roll your ball faster, or you could aim it in a different direction.

When you change mass or velocity, you also change momentum (moh•MEN•tum). **Momentum** is the product of mass multiplied by velocity. The more momentum an object has, the easier it is for that object to move other objects. Units of momentum are equal to units of mass times units of velocity, most velocity, most often kilogram meters per second (kg m/s) or gram meters per second (g m/s).

When you want to change an object's velocity, you have to overcome its inertia. **Inertia** is the tendency of any object to resist a change in motion or of a moving object to keep moving in a straight line. The more mass an object has, the more inertia it will have. The more inertia an object has, the harder it is to change its momentum. A very heavy bowling ball is hard to get rolling because of its inertia. Once rolling, it also has a lot of momentum. When it hits the pins, the bowling ball's momentum will overcome the inertia of the pins and knock them over.

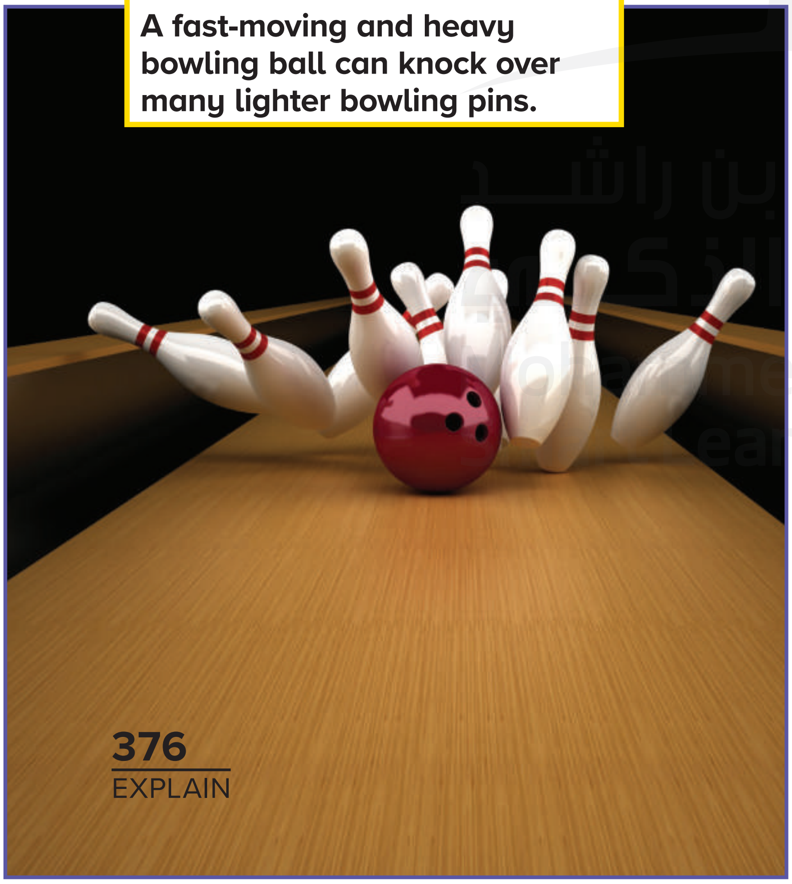
Calculating Momentum

data: mass = 4 kg, velocity = 5 m/s up the lane

momentum = mass × velocity

= 4 kg × 5 m/s

= 20 kg m/s



A fast-moving and heavy bowling ball can knock over many lighter bowling pins.

4. Who would be harder to stop—a professional hockey player skating at 4 m/s or a fifth-grader skating at 4 m/s? Why?

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5. What changes the momentum of an object?

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My Notes

Visual Summary

Complete the lesson summary in your own words.

Motion ______________________

Velocity ______________________

Acceleration ______________________

Think, Talk, and Write

1. **Vocabulary** The property of a moving object that is equal to its mass times its velocity is its ________________.

2. **Main Idea and Details** How could an object accelerate while still traveling at a constant speed?

Main Idea	Details

3. **Critical Thinking** Earth spins on its axis at about 1,600 km/h. How can you be going so fast and not sense it?

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4. **Test Prep** **Which unit would properly label an object's acceleration?**
A m **C** (m/s)/s
B m/s **D** kg m/s

5. **Test Prep** **Which describes how objects tend to resist changes in motion?**
A distance **C** time
B speed **D** inertia

Essential Question How is motion measured?

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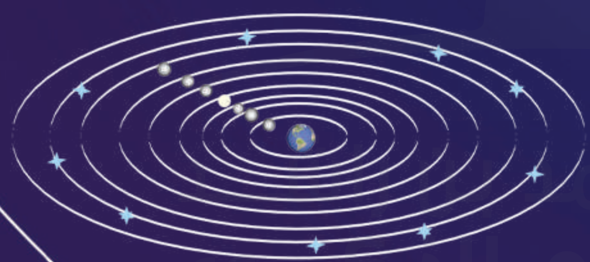
The Positions of EARTH and the SUN

Look at the sky, and you'll see the universe in motion. The Sun and the Moon move in patterns, and the stars change with the seasons. Long ago, people thought Earth was the center of the universe and that everything revolved around it. After all, the Sun does seem to move across the sky. Today we know that Earth's rotation makes it appear this way. We see the Sun move because we are in Earth's frame of reference. How did people discover that Earth revolves around the Sun?

384–322 BCE Aristotle

This Greek philosopher thought that Earth was the center of the universe. His model had stars and planets attached to hollow spheres, or shells, that moved around Earth.

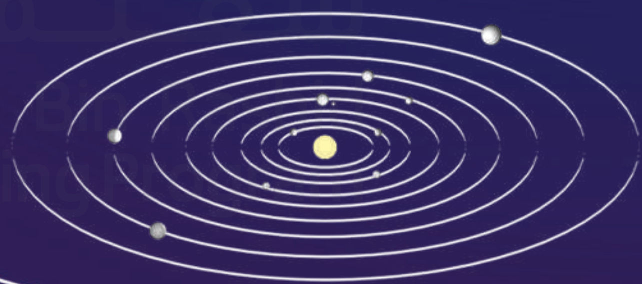


100–178 CE Ptolemy

This Greek astronomer followed Aristotle's Earth-centered model. He made careful observations of the positions of planets and stars. Then he used geometry to accurately predict the way the Sun, the Moon, and the planets would move in the sky.

1473–1543 CE Copernicus

This Polish astronomer challenged Ptolemy's view. He proposed that the Sun was at the center of the solar system and that Earth and other planets revolved around it. He claimed that Earth's rotation and revolution around the Sun explained how the stars and planets appeared to move. His idea was not accepted for many years.



Today, with the help of new technology, astrophysicists such as Margaret Geller continue to develop our understanding of the universe. She started the field of precision cosmology with the first 3-D map of the universe.

Today

1879–1955 CE **Einstein**

By the time this German physicist was born, it was common knowledge that Earth revolves around the Sun. He used physics and mathematics to explain how gravity puts objects in motion. His theories helped astrophysicists answer important questions about the movement of planets, stars, galaxies, and the universe.

1879

1564–1642 CE **Galileo**

This Italian physicist and astronomer built a telescope and discovered Jupiter's moons and Saturn's rings. His observations supported Copernicus's theory. The view that the Sun is the center of the solar system became more widely accepted.

1564

1473

Write About It

Summarize

1. What is the main idea of the selection?

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2. Give one detail that supports the main idea.

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Lesson 2

Forces and Motion

Look and Wonder

This skydiver falling could reach speeds of more than 183 km/h before opening a parachute. Why might some skydivers fall faster than others?

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Essential Question How do forces affect motion?

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Explore

Do heavier objects fall faster?

Materials

- balance with set of masses
- golf ball
- tennis ball
- cotton ball

Form a Hypothesis

In the late 1500s, Galileo argued that mass does not affect how fast something falls. Do you agree? Write your answer in the form "If the mass of an object increases, then..."

Test Your Hypothesis

1. **Observe** Use a balance and standard masses to determine the mass of each object. Order the objects from lightest to heaviest and write down your list.

2. **Experiment** Hold two of the objects at the same height in front of you. Drop them at exactly the same time. Record which object hits first or if they hit at the same time. Repeat two more times to verify your result.

3. Repeat step 2 until you've tested all possible pairs of objects.

Draw Conclusions

4 **Interpret Data** Was your hypothesis correct? Write a brief explanation of your answer.

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5 **Infer** In your experiment, the objects were falling through air. However, there is no air on the Moon. How would the falling rate of a tennis ball and a cotton ball compare on the Moon? Why?

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Explore More

How would the results of this experiment change if you dropped objects with the same mass but different densities? Write a hypothesis. Then use balloons at different levels of inflation to test your hypothesis. Write a summary of your results.

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Read and Respond

What are forces?

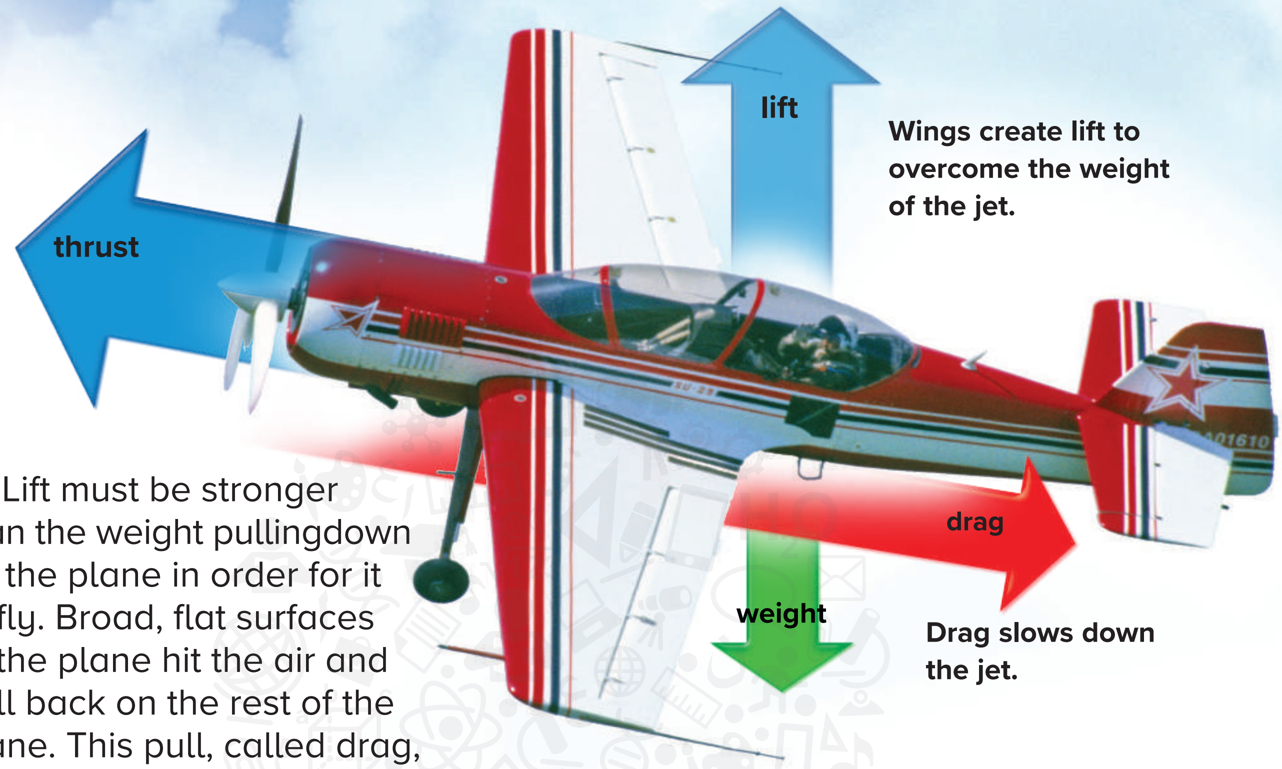
Draw a circle around the units of force.

Have you ever been in a tug-of-war? You push with your feet against the ground, and you pull as hard as you can. Pushes, pulls, and lifts are all known as forces. A **force** is any push or pull from one object to another. Units of force are the newton (N) . When we draw diagrams of forces, we often use arrows to represent the direction and the strength of a force.

Many forces occur as one object touches another, such as the pull of a tow truck on a broken car. Other forces, though, may act without objects touching. Think about a compass needle. It swings to point north because it is pulled by the magnetic force of Earth. There is nothing actually touching the needle, but it still feels a force.

You know about buoyancy, which is a lifting force caused by a difference in densities. Buoyancy lifts lighter substances out of denser substances.

An airplane has special names for its forces. The engines push or pull the plane forward. This is known as thrust. As the plane moves forward, air moves around the wings and creates a force that raises the plane into the air. This force is called lift.



Lift must be stronger than the weight pullingdown on the plane in order for it to fly. Broad, flat surfaces of the plane hit the air and pull back on the rest of the plane. This pull, called drag, slows down the plane.

You use forces in many different ways. Forces can crush, stretch, or twist objects and deform them. For example, you can crush an aluminum can if you squeeze it hard with your hands. The harder a substance is, the more force it takes to change its shape.

Most often, though, we use forces to move objects. A force can cause an object to start moving, speed up, change direction, slow down, or stop. Do you notice anything about all of these motions? They all involve accelerations. Forces accelerate objects when they affect their motion.

A force that acts over a short period of time can still have a large effect.

Some forces, such as a bat hitting a ball, act for a very short time. You know that the bat still accelerates objects, however, because the ball flies away quickly. Other forces act continuously. A cyclist pedaling steadily and a balloon rising slowly are examples of continuous forces.

Quick Check

1. Give an example of a force that changes both an object's shape and motion.

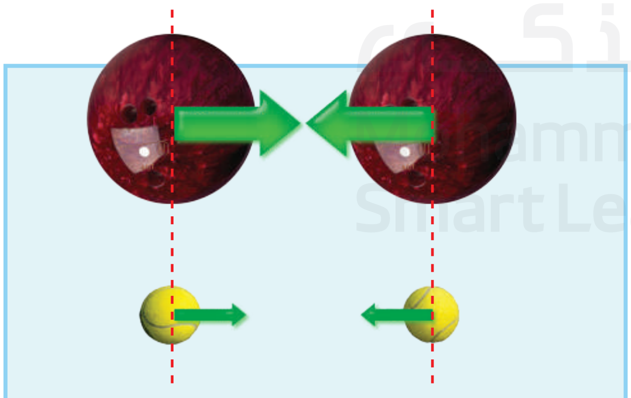
The drag force on a parachute is almost as strong as gravity.

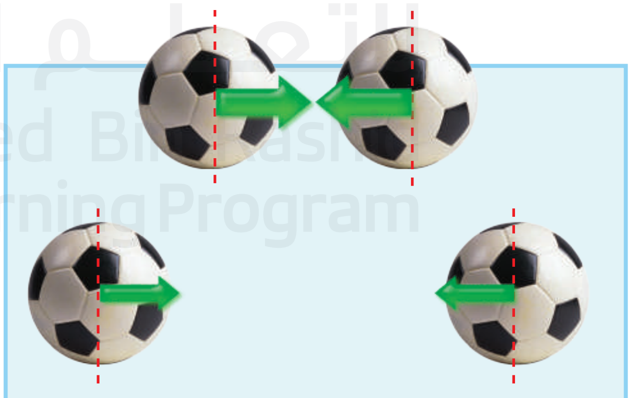
What are gravity and friction?

Has anyone ever said to you, “What goes up, must come down”? If so, he or she may have been talking about gravity, the force that attracts all matter together. If you throw a ball up, the gravity between it and Earth will make it fall back to the ground. Without gravity, the ball would fly off Earth.

Sir Isaac Newton, after whom the unit of force is named, researched gravity in the 1600s. He believed that every object in the universe was pulling on every other object. This theory is called Newton’s law of universal gravitation. Newton said that gravity depends on the masses of the objects and the distance between them. Increasing the mass increases the force, and increasing the distance decreases the force.

Gravity pulls all objects together, big or small. The gravity between small objects, though, is weak. Two bowling balls an inch apart will never roll together because of gravity. Their masses are too small. The huge masses of moons, planets, and stars, however, make their gravity powerful. The force of gravity between Earth and the Moon is 200 billion billion newtons!


Gravity decreases as mass decreases.


Gravity decreases as distance increases.

Friction

You've probably slid down a slide at a playground. For the slide to be fast, the surface must be very slippery. Friction (FRIK•shun) makes it difficult to slide on rough surfaces. **Friction** is a force that opposes the motion of one object moving past another.

Friction depends on the surfaces of two objects and how hard the objects are pushed together. Smooth surfaces usually have less friction than rough surfaces. Friction increases when surfaces are pressed together with greater force. Friction also increases with the weight of an object.

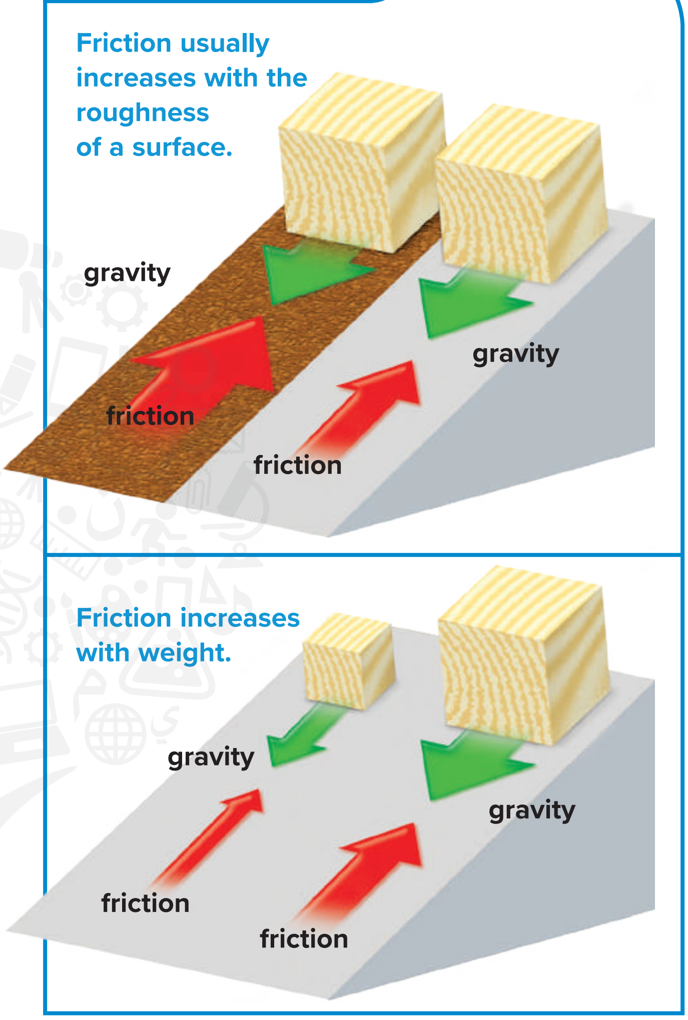
Have you ever rubbed your hands together to keep them warm? Friction between your hands slows them down and also generates heat. Heat is created whenever there is friction.

Air Resistance

When an object moves through air, the air hits the object and slows it down. This air resistance increases with velocity, but friction usually does not. Liquids also exert resistance. This is why water can slow down a boat.

Drag forces are a result of air resistance. Broad, flat surfaces have the most drag. This is why a feather falls slower than a pencil. Without air, the two would fall at the same rate. Drag is affected by the movement of liquids and gases. This is why it is harder to paddle upstream in a boat or to fly into the wind in an airplane.

Sliding Blocks



Read a Diagram

Which block experiences the strongest friction force?

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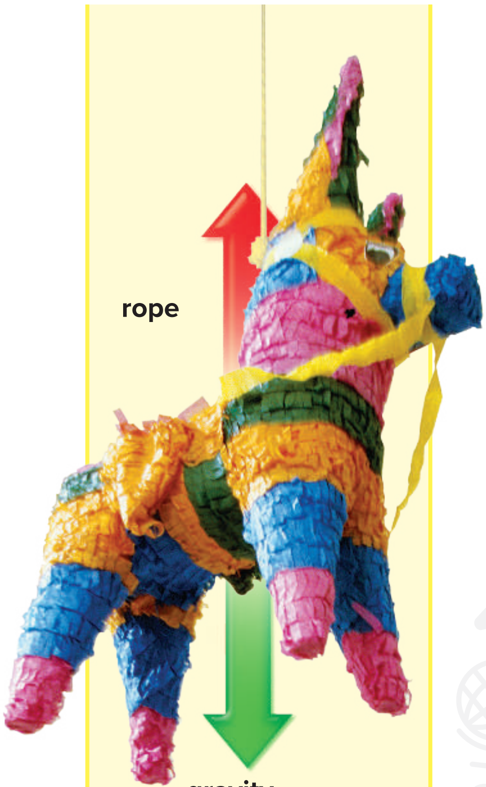


The forces acting on the doll are balanced, so it will not fall.

What is Newton's first law?

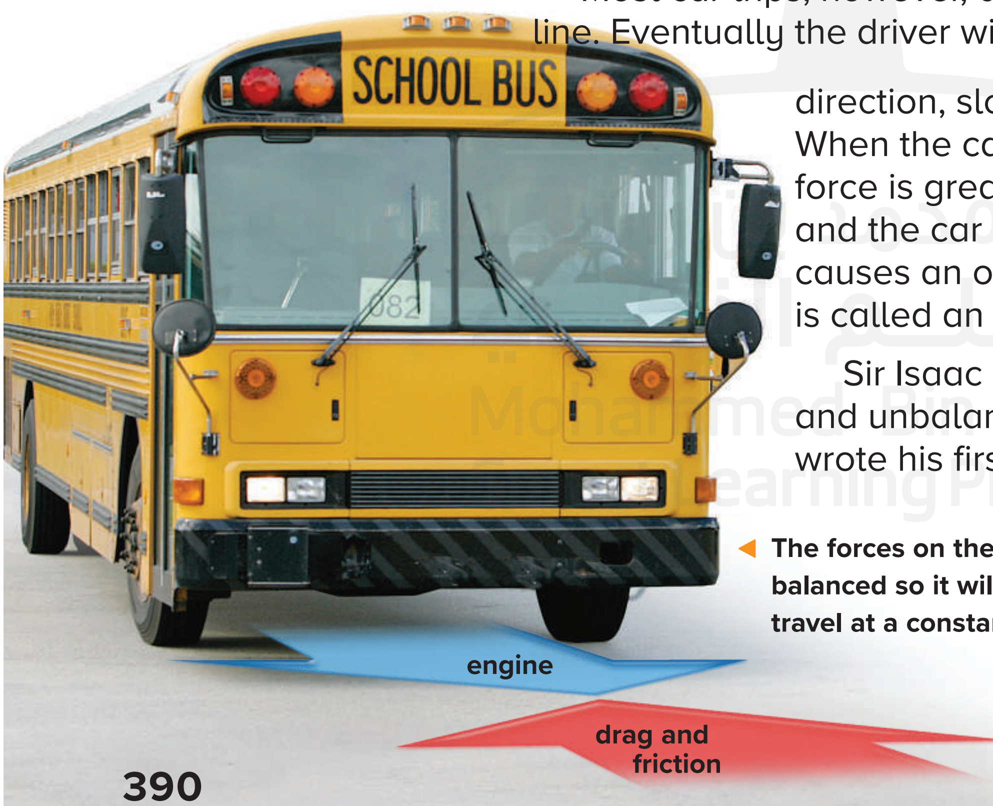
Suppose you want to hang a picture on the wall. The force of gravity is pulling the picture down, but you do not want the picture to fall down. What can you do? Use a piece of string to hold up the picture. The force of the string pulling up on the picture is equal to the force of gravity pulling it down, but in the opposite direction.

When forces act on an object without changing its motion, they are called **balanced forces**. Balanced forces often point in opposite directions, and they always add up to zero. There may be more than one pair of balanced forces acting on an object.

The forces acting on stationary objects are always balanced. However, balanced forces can act on moving objects, too. Think of a bus moving at a constant speed down a straight road. The force of the engine pushing the bus forward is balanced by the force of drag and the friction of the tires. Although the bus is moving, its velocity is not changing, so the forces acting on it are balanced. As long as those forces remain balanced, the bus will continue at the same speed and travel in a straight line.

Most car trips, however, do not follow a straight line. Eventually the driver will have to change direction, slow down, or speed up. When the car speeds up, the forward force is greater than the friction force and the car accelerates. A force that causes an object to change its motion is called an **unbalanced force**.

Sir Isaac Newton studied balanced and unbalanced forces. He then wrote his first law of motion.



The forces on the bus are balanced so it will continue to travel at a constant velocity.

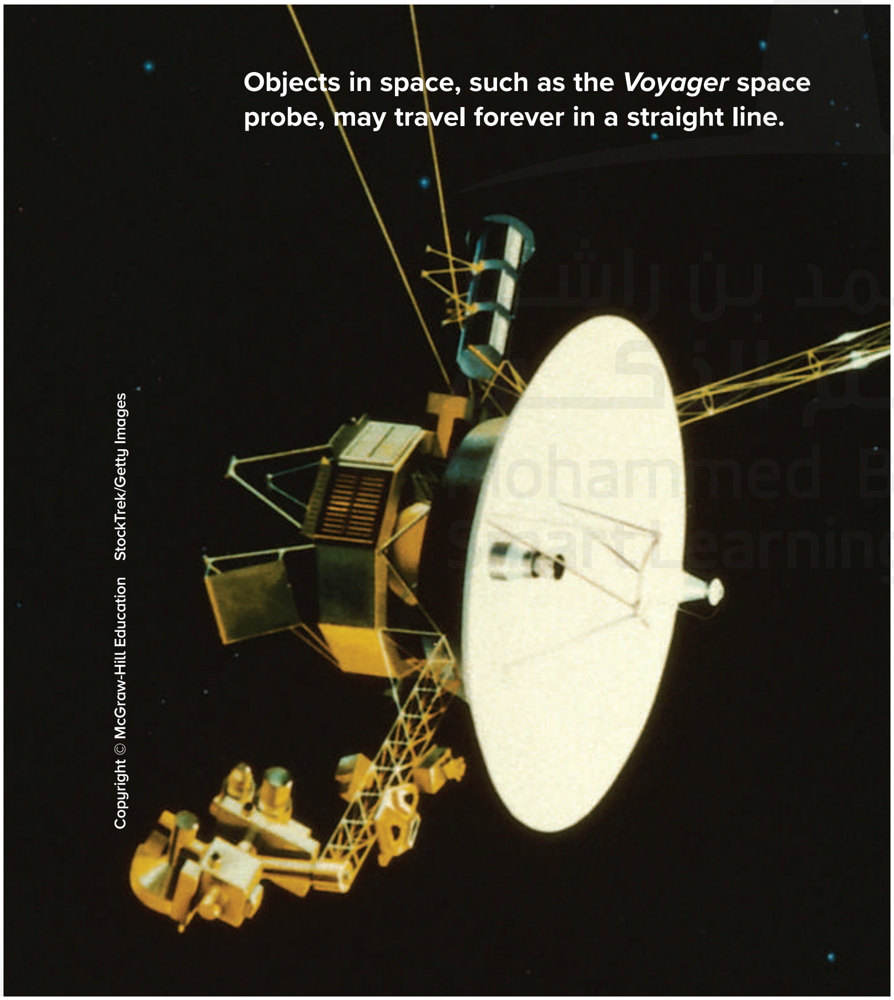
FACT Moving objects will not stop until acted upon by an unbalanced force.

NEWTON'S FIRST LAW

An object at rest tends to stay at rest, and an object in constant motion tends to stay in motion, unless acted upon by an unbalanced force.

Newton's first law is sometimes called the law of inertia. This is because the law describes inertia: Objects do not change their motion unless forced to do so.

If there were no forces, such as friction or drag, an object in motion could travel forever in a straight line. Objects in space, such as the Voyager space probe, are doing just that. On Earth, however, friction and drag often act as unbalanced forces to bring objects to rest.



Objects in space, such as the *Voyager* space probe, may travel forever in a straight line.

Quick Check

2. How could you keep a balloon from rising or falling in air?

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3. Other than clothing, what could plastic soda bottles be used for?

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What is Newton's third law?

You are ice skating with a friend. You give her a small push to help her go faster. As you push her forward, you find yourself moving backward. Why are you moving? Wasn't your friend the object being pushed?

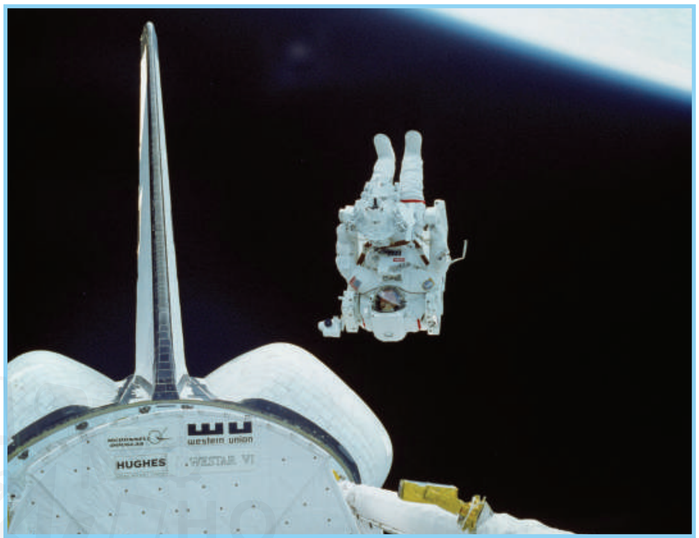
Actually, you received a push, too. When one object pushes on a second object, the second pushes back on the first with the same strength. Commonly, the push of the first object on the second is called the **action force**. The push of the second object back on the first is called the **reaction force**.

Newton summarized this idea in his third law of motion.

More commonly, people say, "For every action there is an equal but opposite reaction." It is important to remember that action and reaction forces are not balanced forces. This is because action and reaction forces always act on separate objects.

> **NEWTON'S THIRD LAW**
> *All forces occur in pairs, and these two forces are equal in strength and opposite in direction.*

When one skater pushes or pulls on the other, they each feel an equal but opposite force acting on them.



This astronaut feels "weightless" because there is nothing in space to create a reaction force.

When you sit in a chair, your weight is pushing down on the chair. A reaction force from the chair pushes back up on you. This reaction force is what you feel as your weight. When you are falling (or when astronauts are in space), the force of gravity is still acting upon you. You do not feel gravity, however, because there is nothing providing a reaction force. This is why you feel "weightless" when you are in free fall.

Quick Check

4. What are the action and reaction forces acting on your body when you walk?

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My Notes

Visual Summary

Complete the lesson summary in your own words.

Forces ______________________________

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Balanced and Unbalanced Forces ______________________________

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Think, Talk, and Write

1 Vocabulary One force that opposes motion is ____________.

2 Problem and Solution How could you decrease the drag on an airplane?

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3 Critical Thinking How could working underwater help astronauts practice being in space?

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4 Test Prep **If an unbalanced force acting on an object is increased, the object will**

A accelerate more.
B remain at constant velocity.
C remain at constant speed.
D remain still.

5 Test Prep **Which is a unit of force?**

A gram
B (m/s)/s
C newton
D m/s

Essential Question How do forces affect motion?

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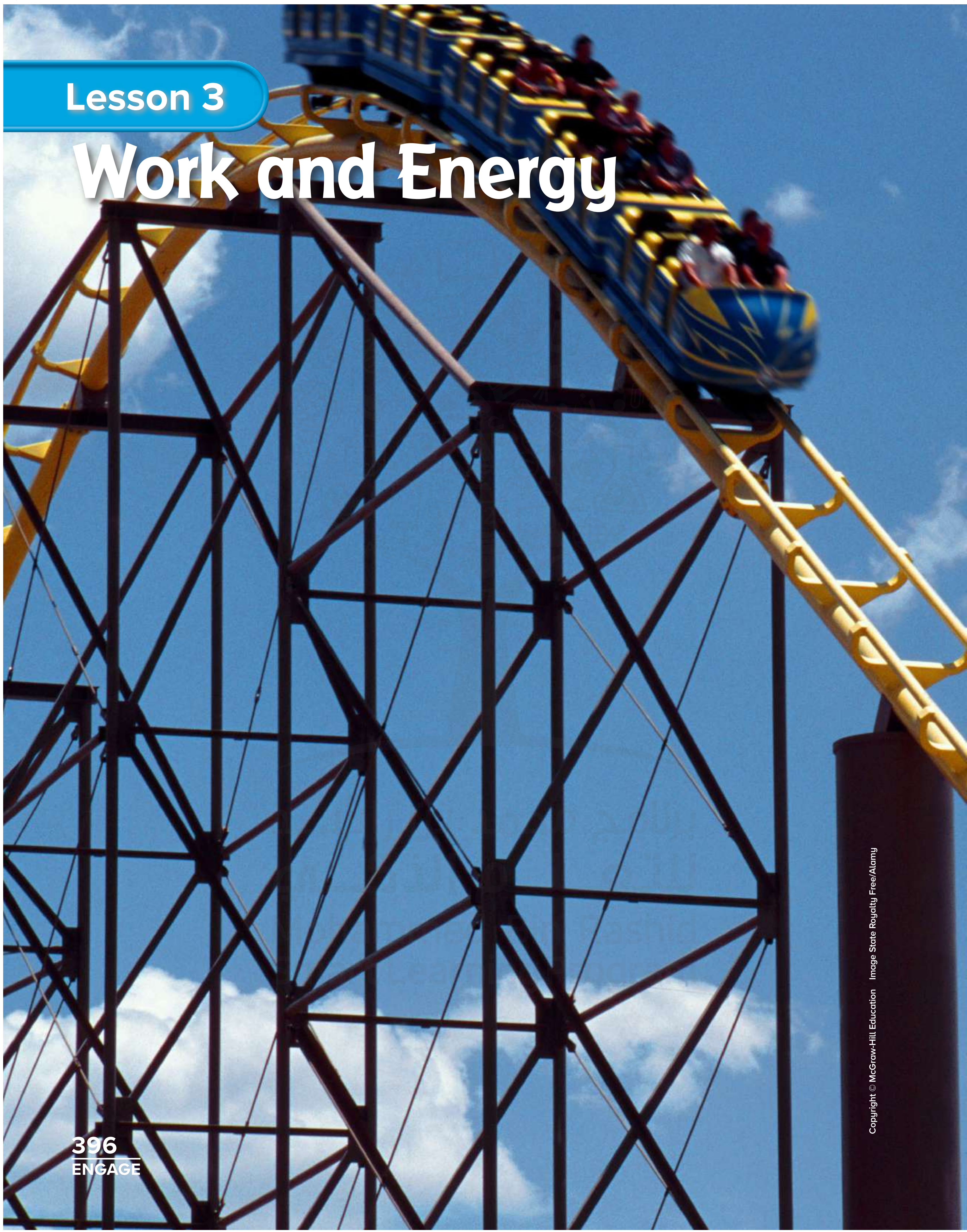
Lesson 3

Work and Energy



Look and Wonder

Passengers on a roller coaster may feel forces twice as strong as gravity. Where does the energy come from to take the roller coaster through the ride?

Essential Question How are work and energy related?

Explore

What happens to energy?

Form a Hypothesis

The energy of an object changes as it is pulled by gravity. What will happen if you let a marble roll in a bicycle tire? Write your answer in the form "If you increase the height a marble is released from, then..."

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Materials

- section of old bicycle tire (or piece of split garden hose)
- masking tape
- golf ball or marble

Test Your Hypothesis

1. Work in a group. One member of your group should hold the section of tire firmly on a tabletop. Use a piece of masking
tape to mark a starting point on one side of the tire.

2. **Observe** Release the marble at the starting point and let it roll in the tire. Observe what the marble does until it comes to a stop. The marble's actions are your dependent variable. Repeat several times to verify your observations.

3. Repeat steps 1 and 2 for two more starting points. They should be at different heights. The height of the marble is your independent variable.

Draw Conclusions

4. **Interpret Data** Did your observations support your hypothesis? Explain.

5. **Infer** When did the marble move the fastest? Did it have more or less energy there than when it began? How do you know?

Explore More

Why did the marble eventually stop? What effect did the texture of the inside of the bicycle tire have? Write a hypothesis and design an experiment to test it.

Read and Respond

What is work?

Underline the measurement of the energy used to perform a task.

Placing boxes on a shelf can be tiring work. You have to lift the boxes up from the ground to the shelf. Lighter boxes require less force to move, so it is less work to put them on a shelf. The lowest shelf is closest to the ground, so it is less work to place boxes there than on higher shelves. But what do we actually mean when we say *work?*

Work is the measurement of the energy used to perform a task. When work is done on an object, the amount of energy it has changes. Work is equal to the force used multiplied by the distance the force was applied. If the force and the distance are in the same direction, the work is positive. If the force and the distance are in opposite directions, the work is negative. Lifting a box is positive work; lowering a box is negative work.

The units of work are the units of force times the unit of distance: newton meters (N.m). If you lift a box that weighs 10 N onto a shelf that is 1 m high, you are performing 10 N m of work. Newton meters are also known as joules (J).

Read a Diagram

Which boxes took the most work to place on the shelves?

Clue: Look at the size of the boxes and the height of the shelves.

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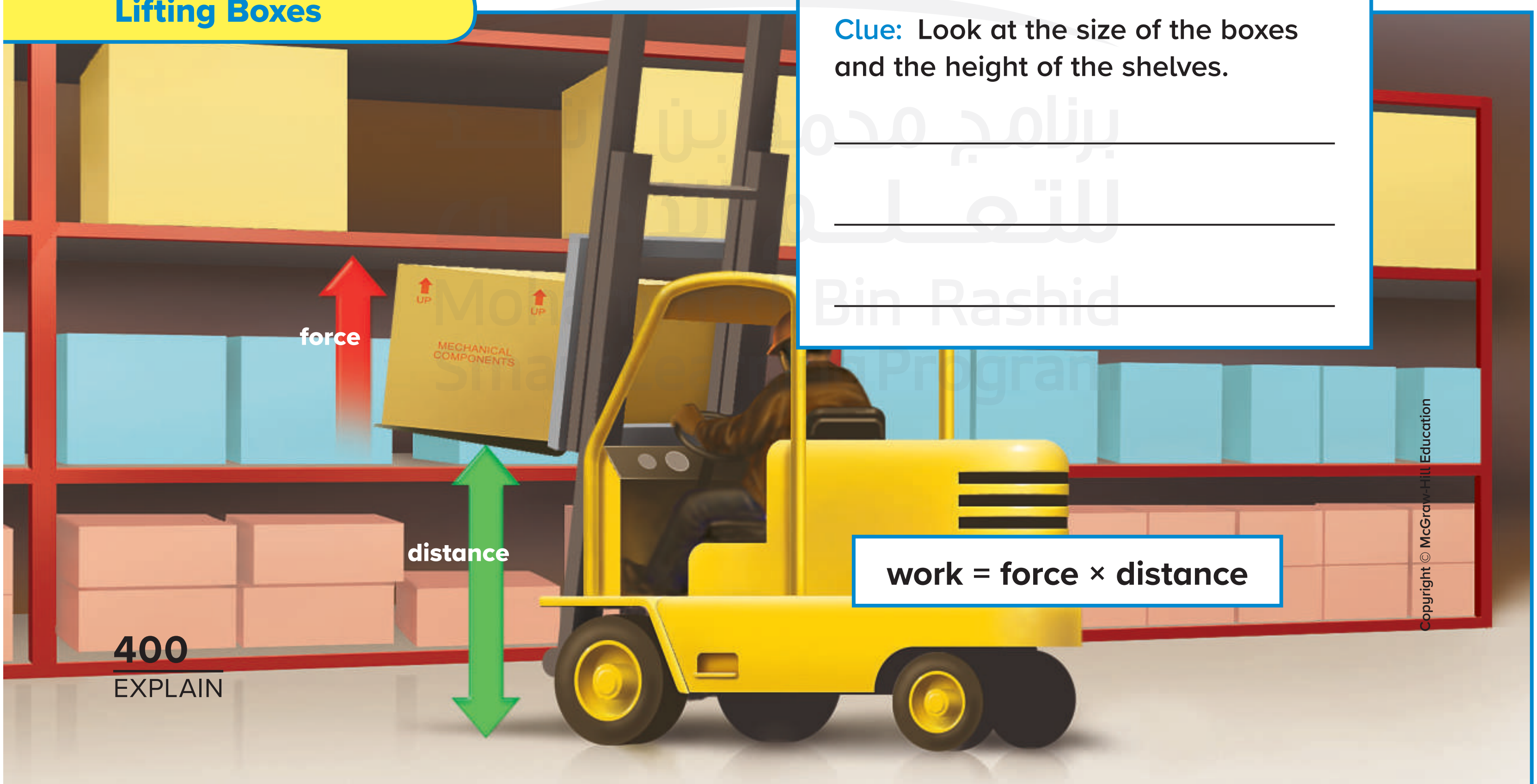
Lifting Boxes



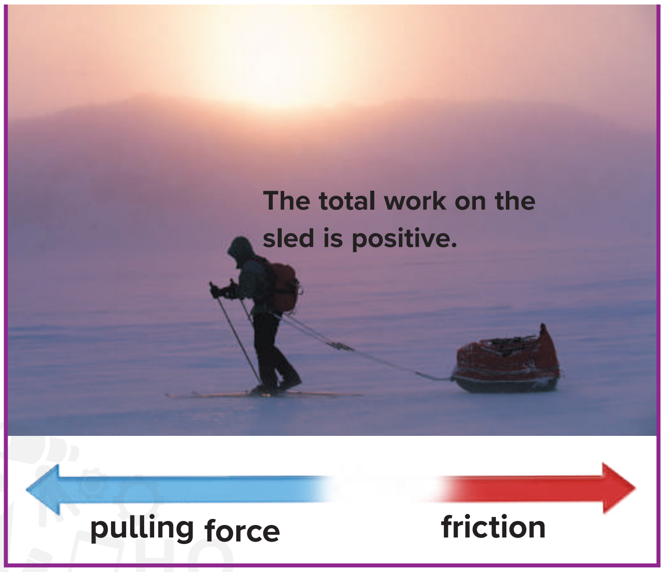
There are many things that seem like work but are not. For instance, do you think it is work to hold a ball over your head? Lifting it there is definitely work, but just holding it there is not. Why? A force must be applied over a distance in order to qualify as work. When you lift the ball, you are applying a force over a distance. When you are holding the ball, you are still applying a force, but the ball is not moving, so the distance equals zero.

You may notice that each example of work involves an unbalanced force. Unbalanced forces cause acceleration and motion. Motion is a necessary part of work, so you will always see work when there is an unbalanced force.

Consider a toy car that you and your friend push from opposite directions. If you both push with the same force, the car will not move.

Work is not being done. What if you push harder than your friend? The car starts to move, and work is done.

FACT Not everything that makes you tired is work.



Your work on the car is positive because it is in the direction of motion. Your friend's work is negative because it is against the direction of motion. The total work is the sum of the positive and negative work. When we talk about work, we may talk about the total work or the work of individual forces, like you and your friend.

Friction often performs negative work on objects as you move them. When a car is traveling at a constant velocity, the engine, friction, and air resistance may all be performing work on the car, but the total work is zero.

Quick Check

1. How does friction affect the work it takes to push a box across the floor?

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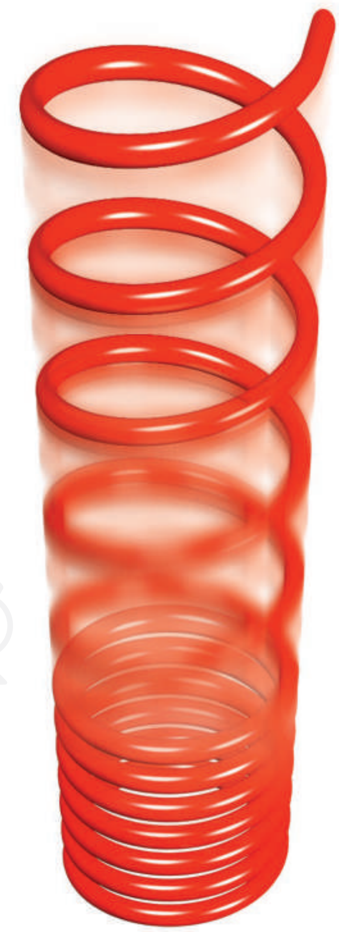
What is energy?

When you feel tired you may say, "I don't have any energy." **Energy** is the ability to perform work or to change an object. The units of energy are the same as the units of work—joules (J). When you are low on energy, you probably cannot do much work.

Objects can also have energy. When you stretch a spring, it pulls back on your hand. If you release it, the spring does work by pulling itself back to its original length.

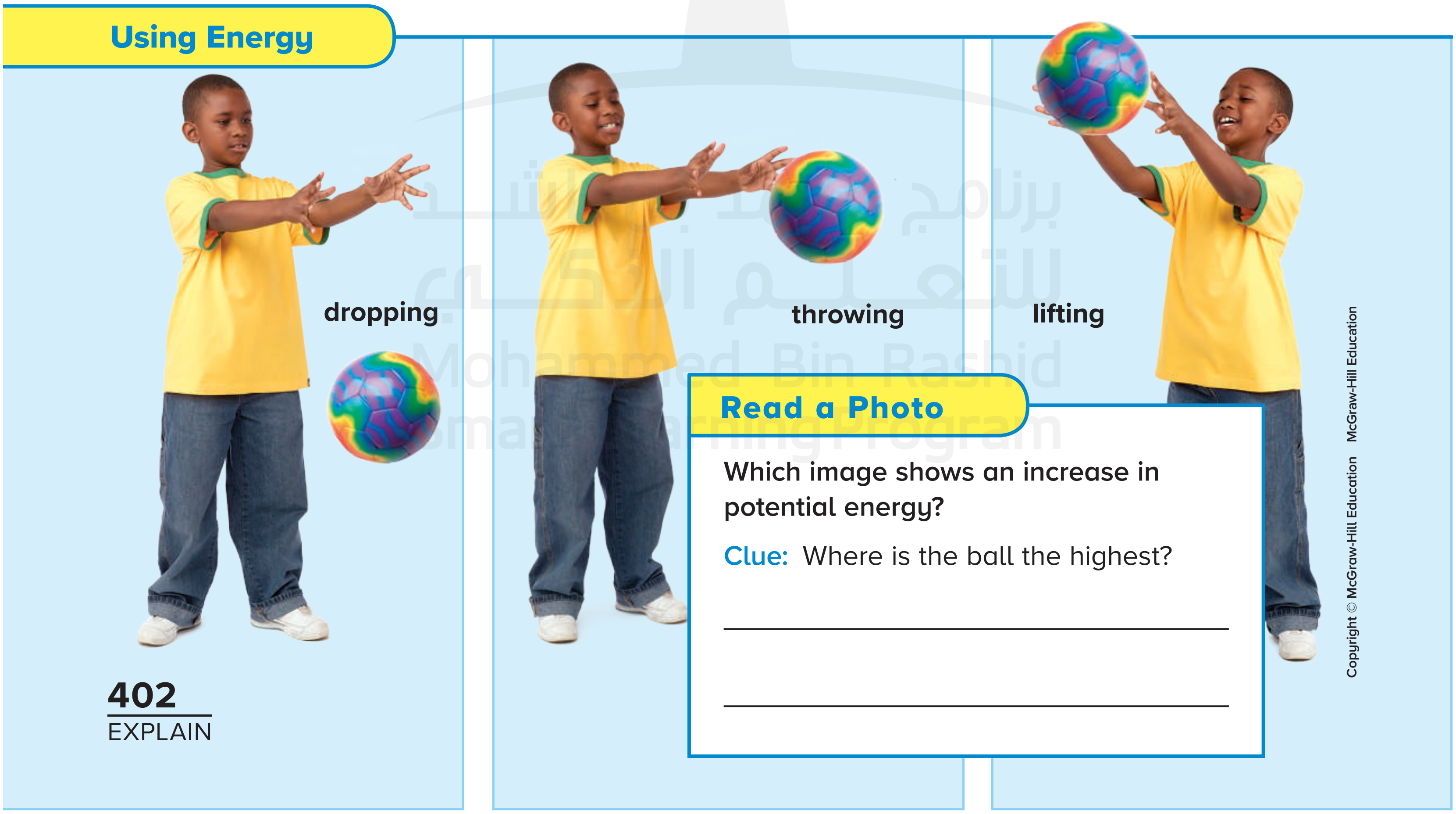
When the spring is stretched, it has energy, but it is not moving. It has the potential (puh•TEN•shul) to do work. **Potential energy** is energy that is stored in the position, or structure, of an object. When you release the spring, it moves. **Kinetic** (kuh•NE•tik) **energy** is the energy of a moving object. Vibrating like a spring is called *periodic motion*. In periodic motion, energy changes back and forth from potential to kinetic.

When you do positive work, you add energy to an object. If you throw a ball, you increase its velocity and add to its kinetic energy. If you lift a ball, you increase the distance gravity can pull it and add to its potential energy. If you drop a ball, gravity does work and changes the ball's potential energy into kinetic energy.



When you release a spring, potential energy becomes kinetic energy.

Using Energy



Read a Photo

Which image shows an increase in potential energy?

Clue: Where is the ball the highest?

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Forms of Energy

There are many forms that potential and kinetic energy can take. There is potential energy in the links between atoms and molecules. This is chemical energy. Nuclear energy is potential energy stored in the links between the protons and the neutrons in an atom. Magnetic energy is another form of potential energy. It acts like gravity and pulls objects together, but it can also push some objects apart. Electrical energy can be potential energy when particles of different electrical charges are attracted to one another.

Kinetic energy can take many forms as well. Heat is the kinetic energy in the vibrations of particles. Electricity is related to the kinetic energy of electrons. Sound is the kinetic energy of particles as they move in waves. Light is also kinetic energy that moves in the form of waves.

All forms of energy have one thing in common—they can perform work! Some forms of energy change the structure of objects rather than move them, but this is still work. You know that heat can melt or boil substances. You also know that chemical reactions change one type of substance into another. These are examples of work.

Quick Check

2. Which can do more work—a joule of heat energy or a joule of sound energy?

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How can energy change?

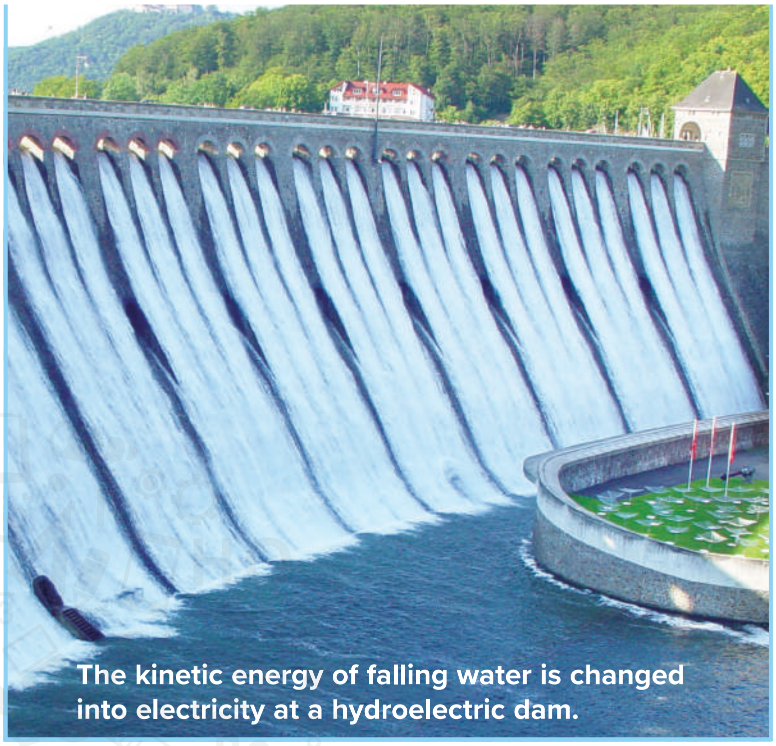
Scientists believe that energy cannot be created or destroyed, it can only change form. This theory has been observed so many times that it is called the law of conservation of energy. A roller coaster, for example, cannot gain kinetic energy without losing potential energy.

You might think that a roller coaster destroys energy. After all, the roller coaster steadily slows down. The "lost" energy, however, is not destroyed. It has become heat and sound through the work of friction.

Whenever energy is used to do work, that energy changes. The kinetic energy of water does work by moving the arms of a water turbine. The arms of the turbine do work and generate electricity. Electricity does work in an oven by moving particles around and changes into heat. Heat does work on a loaf of bread and changes into chemical energy.

Chemical energy in the bread does work and changes into kinetic energy in your muscles. Your muscles can do work when they build another turbine!

Energy can sometimes do undesirable work. This often happens when there is friction. For example, friction inside a turbine causes some kinetic energy to change into heat, not electricity. Although some energy is changed into heat, the energy is not lost. However, the heat in this situation is much less useful. It also harms the turbine.



The kinetic energy of falling water is changed into electricity at a hydroelectric dam.

Kinetic energy is changed into heat energy through the work of friction.

Quick Check

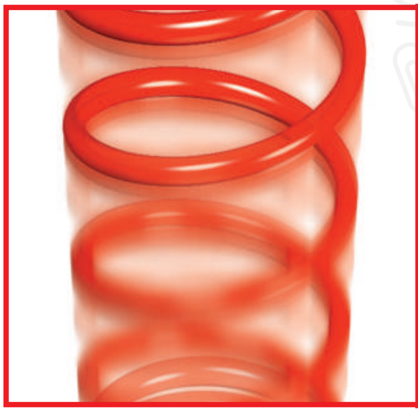
3. A dropped ball doesn't bounce back to its starting height. How does this situation fit the law of conservation of energy?

My Notes

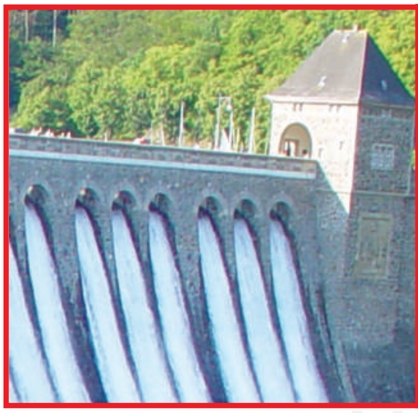
Visual Summary

Complete the lesson summary in your own words.

Work ______________________________



Energy ______________________________



Changing Energy ______________________________

Think, Talk, and Write

1 **Vocabulary** Energy stored in the position or the structure of an object is ____________________.

2 **Infer** When might kinetic energy turn into sound energy?

Clues	What I Know	What I Infer

3 **Critical Thinking** A pendulum is a weight swinging back and forth on a cord. What energy changes occur as a pendulum swings?

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4 **Test Prep** **If a car accelerates on a level road, it gains**

A chemical energy.
B kinetic energy
C light energy.
D potential energy.

5 **Test Prep** **Which is a unit of work or energy?**

A joule
B watt
C newton
D meter

Essential Question How are work and energy related?

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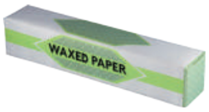
Be a Scientist

Materials



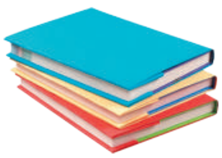
wax paper

aluminum foil

clear plastic wrap


masking tape


cardboard


4 books


ruler


wooden block

Structured Inquiry

What affects potential and kinetic energy?

Form a Hypothesis

Potential energy is the amount of energy stored in an object. Kinetic energy is the energy that an object has due to its motion. Gravity converts potential energy into kinetic energy as an object falls. Friction can decrease an object's kinetic energy.

Picture sliding a block down a smooth ramp. How would friction affect this block as it slides? Write your answer in the form "If friction is increased, then the amount of potential energy that becomes kinetic energy..."

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Test Your Hypothesis

1. **Observe** Examine the wax paper, aluminum foil, and plastic wrap. Which do you think would create more friction? Why?

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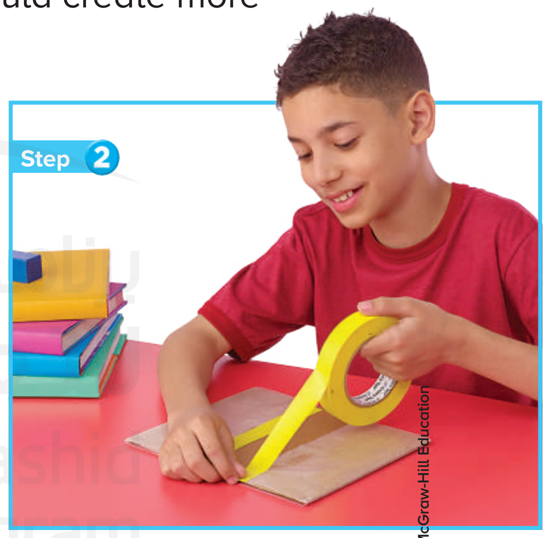

2. Tape a piece of wax paper to one side of a piece of cardboard. The material on the ramp is your independent variable.

3. Use four books to create a ramp with the wax paper on the cardboard facing up.

4. **Measure** Record the height of the books. Using tape, mark where the cardboard rests on the table. These are variables you want to keep the same every time.

5. **Experiment** Place the wooden block at the top of the ramp and release it. Record how far the block slides. Repeat two more times and take an average. This is your dependent variable.

6. Repeat the experiment with aluminum foil and plastic wrap.

Draw Conclusions

7. Did your results support your hypothesis?
Explain why or why not.

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8. **Infer** What material caused the wooden block to lose the most kinetic energy? Where do you think this energy went?

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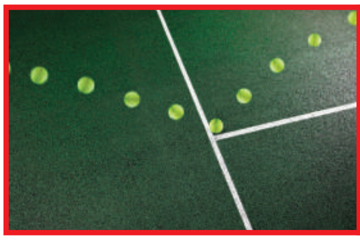
CHAPTER 7 Review

Visual Summary

Summarize each lesson in your own words



Motion ________________________________

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Forces and Motion ________________________________

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Work and Energy ________________________________

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Vocabulary

Fill each blank with the best term from the list.

acceleration	kinetic energy
balanced forces	momentum
energy	motion
Inertia	velocity
force	work

1. A push, pull, or lift from one object to another is a(n) ________________

2. A change in the position of an object over time is ________________.

3. The use of force to move an object a certain distance is called ________________ .

4. The tendency of any object to resist a change in motion is ________________.

5. The ability to perform work or to change an object ________________.

6. When you drop a ball, gravity changes potential energy into ________________ .

7. The mass of an object multiplied by its velocity is called its ________________ .

8. An object's motion will not change if you only apply ________________ .

9. The speed and direction of a moving object are its ________________ .

10. The rate at which velocity changes is ________________.

CHAPTER 7 Review

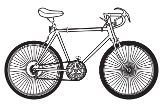
Skills and Concepts

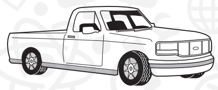
Answer each of the following.

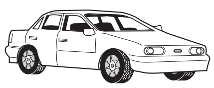
11. A fast-moving and heavy ball could knock over many lighter objects. This illustrates the principle of

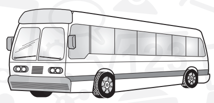
A deceleration.
B friction.
C momentum.
D balanced forces.

12. If the same force is applied to each object, which will have the greatest acceleration?

A 

B 

C 

D 

13. Which demonstrates balanced forces?

A a bicycle leaning against a building
B a kite falling to the ground
C a bus accelerating around a curve
D wind slowing down a runner

14. **True or False** *A rock sitting at the top of a hill does not have energy.* Is this statement true or false? Explain.

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15. **Main Idea and Details** Friction is a force that opposes motion. Provide two details that help explain how friction works.

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16. **Use Numbers** How much work is done when a student who weighs 360 N climbs a 3 m ladder?

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17. **Infer** Describe what is happening in the image below. How would it look different to someone standing outside the car?

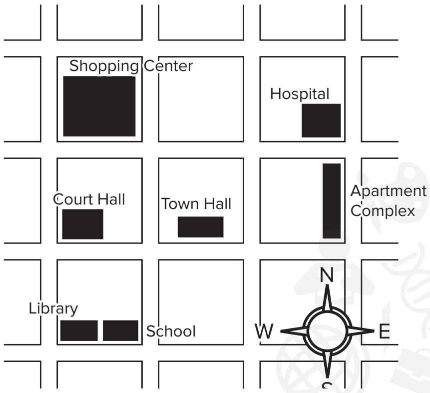
18. **Critical Thinking** If you are designing a model car for a race, how can you make it travel as fast as possible?

19. **Explanatory Writing** Write a detailed caption for a display on the law of conservation of energy. Use a roller coaster as an example.

20. **Explanatory Writing** How do forces move objects?

Test Preparation

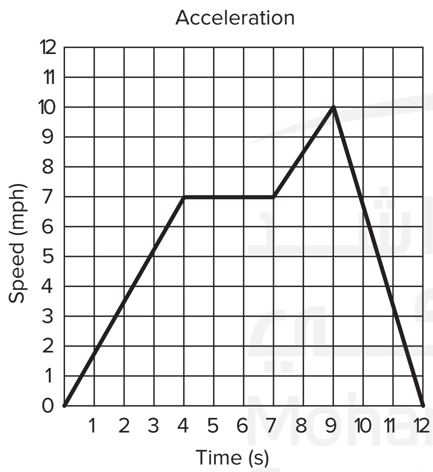
1. Study the map below.



Which is the position of the hospital?

A southwest of the town hall
B directly east of the town hall
C northeast of the town hall
D directly north of the town hall

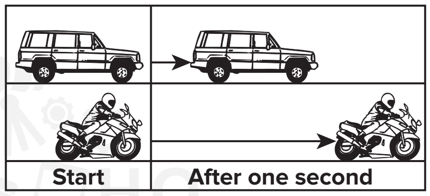
2. The graph below shows the speed of an object over a 12-second period.



At which time interval is the object's acceleration zero?

A 0–4 s
B 4–7 s
C 7–9 s
D 9–12 s

3. Which statement can you conclude from the photo below?



A The car had the greatest acceleration.
B The motorcycle had the greatest acceleration.
C Both the car and the motorcycle had the same acceleration.
D Both the car and the motorcycle had the same speed.

4. What will happen if a feather and a ball are released from the same height at the same time?

A The feather will hit the ground first.
B The ball will hit the ground first.
C Both objects will hit the ground at the same time.
D Both objects will hit the ground with equal force.

5. Study the picture below.

Which would increase the boat's acceleration?

A Have both people row.
B Add more bags to the boat.
C Flatten the front of the boat.
D Have the person stop rowing.

6. What can be done to reduced the force of attraction between Earth and a body?

A Reduce the distance between body and ground.
B Increase the body mass.
C Increase the distance between the body and ground.
D Increase the air temperature and humidity in the ground.

7. A carpenter rubs sandpaper along a piece of wood. Why does the wood become warm? Explain why energy is not lost as she sands the wood.

8. Study the picture below.
What effect does the wind have on the speed of the biker? Explain why the biker's jacket slows her down. What can the biker do to keep moving at the same speed if the wind speed increases?

My Notes