



INTEGRATED

# **i**SCIENCE

GLENCOE



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SAMPLER

GRADE 6



# Louisiana Student Standards for Science

## Correlated to Grade 6

Student Performance Expectations [PE]	Chapter and Lesson References
<b>Matter and Its Interactions</b>	
<b>6-MS-PS1-1</b> Develop models to describe the atomic composition of simple molecules and extended structures.* [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include carbon dioxide and water. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3-D models, or computer representations showing different molecules with different types of atoms.]	<b>Chapter 14</b> Project-Based Learning Activity <i>Model Molecules</i> (online at ConnectED)
<b>Motion and Stability: Forces and Interactions</b>	
<b>6-MS-PS2-1</b> Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects. [Clarification Statement: Examples of practical problems could include reducing the effects of impact of two objects such as two cars hitting each other, an object hitting a stationary object, or a meteor hitting a spacecraft.]	<b>Chapter 2</b> Project-Based Learning Activity <i>Cracking Up</i> (online at ConnectED)
<b>6-MS-PS2-2</b> Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law) in one dimension to a given frame of reference, or specification of units.]	<b>Chapter 2</b> Project-Based Learning Activity <i>Putting the Shot in Motion</i> (online at ConnectED)
<b>6-MS-PS2-3</b> Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. [Clarification Statement: Questions about data might require quantitative answers related to proportional reasoning and algebraic thinking. Examples of devices that use electric and magnetic forces could include electromagnets. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.]	<b>Chapter 6</b> Project-Based Learning Activity <i>The Great Metal Pick-Up Machine</i> (online at ConnectED)
<b>6-MS-PS2-4</b> Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools and charts displaying mass, strength of interaction, distance from the Sun, or orbital periods of objects within the solar system, not necessarily including Newton's Law of Gravitation or Kepler's Laws.]	<b>Chapters 2, 11</b> Project-Based Learning Activity <i>Gravity: It's Attractive!</i> (online at ConnectED)
<b>6-MS-PS2-5</b> Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, or electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations designed to provide qualitative evidence for the existence of fields.]	<b>Chapter 6</b> Project-Based Learning Activity <i>Hands Off!</i> (online at ConnectED)
<b>Energy</b>	
<b>6-MS-PS3-1</b> Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass as well as kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different masses of rocks downhill, or the impact of a wiffle ball versus a tennis ball.]	<b>Chapters 2, 3</b> Project-Based Learning Activity <i>Energy in Motion</i> (online at ConnectED)

# Louisiana Student Standards for Science

## Correlated to Grade 6



Student Performance Expectations [PE]	Chapter and Lesson References
<p><b>6-MS-PS3-2</b> Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, or a balloon with static electrical charge being brought closer to a classmate’s hair. Examples of models could include representations, diagrams, pictures, or written descriptions of systems.]</p>	<p><b>Chapter 3</b></p> <p>Project-Based Learning Activity <i>Physics Day at the Amusement Park</i> (online at ConnectED)</p>
<b>Waves and Their Applications In Technologies For Information Transfer</b>	
<p><b>6-MS-PS4-1</b> Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave and how the frequency and wavelength change the expression of the wave. [Clarification Statement: Emphasis is on describing mechanical waves with both qualitative and quantitative thinking.]</p>	<p><b>Chapter 4</b></p> <p>Project-Based Learning Activity <i>Don’t Make Waves!</i> (online at ConnectED)</p>
<p><b>6-MS-PS4-2</b> Develop and use a model to describe that waves are refracted, reflected, absorbed, transmitted, or scattered through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves interacting with various objects such as light striking a mirror or a water wave striking a jetty. Examples of models could include drawings, simulations, or written descriptions.]</p>	<p><b>Chapters 4, 5</b></p> <p>Project-Based Learning Activity <i>Build a Better Room</i> (online at ConnectED)</p>
<b>Earth’S Place In The Universe</b>	
<p><b>6-MS-ESS1-1</b> Develop and use a model of the Earth-sun-moon system to describe the reoccurring patterns of lunar phases, eclipses of the sun and moon, and seasons. [Clarification Statement: Earth’s rotation relative to the positions of the moon and sun describes the occurrence of tides; the revolution of Earth around the sun explains the annual cycle of the apparent movement of the constellations in the night sky; the moon’s revolution around Earth explains the cycle of spring/neap tides and the occurrence of eclipses; the moon’s elliptical orbit mostly explains the occurrence of total and annular eclipses. Examples of models can be physical, graphical, or conceptual.]</p>	<p><b>Chapter 11</b></p> <p>Project-Based Learning Activity <i>Patterns in the Sky</i> (online at ConnectED)</p>
<p><b>6-MS-ESS1-2</b> Use a model to describe the role of gravity in the motions within galaxies and the solar system. [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as their school or state).]</p>	<p><b>Chapters 11, 12, 13</b></p> <p>Project-Based Learning Activity <i>Gravity Glue</i> (online at ConnectED)</p>
<p><b>6-MS-ESS1-3</b> Analyze and interpret data to determine scale properties of objects in the solar system. [Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object’s layers (such as crust and atmosphere), atmospheric composition, surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.]</p>	<p><b>Chapter 11</b></p> <p>Project-Based Learning Activity <i>PBI: Planetary Bureau of Investigations</i> (online at ConnectED)</p>



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Student Performance Expectations [PE]	Chapter and Lesson References
<b>Earth and Human Activity</b>	
<b>6-MS-ESS3-4</b> Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions.]	<b>Chapters 3, 9</b>  Project-Based Learning Activity <i>7 Billion and Counting</i> (online at ConnectED)
<b>From Molecules To Organisms: Structures and Processes</b>	
<b>6-MS-LS1-1</b> Conduct an investigation to provide evidence that living things are made of cells, either one or many different numbers and types.* [Clarification Statement: Emphasis is on developing evidence that living things are made of cells, distinguishing between living and nonliving things, and understanding that living things may be made of one or many cells, including specialized cells. Examples could include animal cells (blood, muscle, skin, nerve, bone, or reproductive) or plant cells (root, leaf, or reproductive).]	<b>Chapter 16</b>  Project-Based Learning Activity <i>It's Alive! Or is it?</i> (online at ConnectED)
<b>6-MS-LS1-2</b> Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. [Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, such as the nucleus, chloroplasts, mitochondria, cell membrane, or cell wall.]	Project-Based Learning Activity <i>Engineering a Cell</i> (online at ConnectED)
<b>Ecosystems: Interactions, Energy, and Dynamics</b>	
<b>6-MS-LS2-1</b> Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant or scarce resources.]	<b>Chapters 17, 18</b>  Project-Based Learning Activity <i>The Fox and the Hare</i> (online at ConnectED)
<b>6-MS-LS2-2</b> Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. [Clarification Statement: Emphasis is on (1) predicting consistent patterns of interactions in different ecosystems and (2) relationships among and between biotic and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, mutually beneficial, or other symbiotic relationships.]	<b>Chapters 17, 18</b>  Project-Based Learning Activity <i>The Hungry Games: Eat or Be Eaten</i> (online at ConnectED)
<b>6-MS-LS2-3</b> Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.]	<b>Chapters 17</b>  Project-Based Learning Activity <i>Web of Life</i> (online at ConnectED)



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# Chapter 2



6-MS-PS2-1, 6-MS-PS2-2,  
6-MS-PS2-4, 6-MS-PS3-1

# The Laws of Motion



How do forces change the motion of objects?

**Inquiry**

## Why move around?

Imagine the sensations these riders experience as they swing around. The force of gravity pulls the riders downward. Instead of falling, however, they move around in circles.

- What causes the riders to move around?
- What prevents the riders from falling?
- How do forces change the motion of the riders?



## Get Ready to Read

### What do you think?

Before you read, decide if you agree or disagree with each of these statements. As you read this chapter, see if you change your mind about any of the statements.

- 1 You pull on objects around you with the force of gravity.
- 2 Friction can act between two unmoving, touching surfaces.
- 3 Forces acting on an object cannot be added.
- 4 A moving object will stop if no forces act on it.
- 5 When an object's speed increases, the object accelerates.
- 6 If an object's mass increases, its acceleration also increases if the net force acting on the object stays the same.
- 7 If objects collide, the object with more mass applies more force.
- 8 Momentum is a measure of how hard it is to stop a moving object.



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# Lesson 1

# Gravity and Friction

## Reading Guide

### Key Concepts

#### ESSENTIAL QUESTIONS

- What are some contact forces and some noncontact forces?
- What is the law of universal gravitation?
- How does friction affect the motion of two objects sliding past each other?

### Vocabulary

**force** p. 45

**contact force** p. 45

**noncontact force** p. 46

**gravity** p. 47

**mass** p. 47

**weight** p. 48

**friction** p. 49

 **Multilingual eGlossary**

 **What's Science Got to do With It?**



## Inquiry

### Why doesn't he fall?

This astronaut is on an aircraft that flies at steep angles and provides a sense of weightlessness. Why doesn't he fall? He does! Earth's gravity pulls the astronaut down, but the aircraft moves downward at the same speed.

NASA






### Can you make a ball move without touching it?

You can make a ball move by kicking it or throwing it. Is it possible to make the ball move even when nothing is touching the ball?

- 1 Read and complete a lab safety form.
- 2 Roll a **tennis ball** across the floor. Think about what makes the ball move.
- 3 Toss the ball into the air. Watch as it moves up and then falls back to your hand.
- 4 Drop the ball onto the floor. Let it bounce once, and then catch it.



### Think About This

1. What made the ball move when you rolled, tossed, and dropped it? What made it stop?
2.  **Key Concept** Did something that was touching the ball or not touching the ball cause it to move in each case?

## Types of Forces

Think about all the things you pushed or pulled today. You might have pushed toothpaste out of a tube. Maybe you pulled out a chair to sit down. *A push or a pull on an object is called a **force**.* An object or a person can apply a force to another object or person. Some forces are applied only when objects touch. Other forces are applied even when objects do not touch.

### Contact Forces

The hand of the karate expert in **Figure 1** applied a force to the stack of boards and broke them. You have probably also seen a musician strike the keys of a piano and an athlete hit a ball with a bat. In each case, a person or an object applied a force to an object that it touched. A **contact force** is a push or a pull on one object by another that is touching it.

Contact forces can be weak, like when you press the keys on a computer keyboard. They also can be strong, such as when large sections of underground rock suddenly move, resulting in an earthquake. The large sections of Earth's crust called plates also apply strong contact forces against each other. Over long periods of time, these forces can create mountain ranges if one plate pushes another plate upward.

### WORD ORIGIN

**force**

from Latin *fortis*, means "strong"

**Figure 1** The man's hand applies a contact force to the boards.





## FOLDABLES<sup>®</sup>

Make a vertical two-tab book from a sheet of paper. Label it as shown. Use it to organize your notes on gravity and friction.



▲ **Figure 2** A noncontact force causes the girl's hair to stand on end.

### Noncontact Forces

Lift a pencil and then release it. What happens? The pencil falls toward the floor. A parachutist falls toward Earth even though nothing is touching him. A *force that one object can apply to another object without touching it is a noncontact force*. Gravity, which pulled on your pencil and the parachutist, is a noncontact force. The magnetic force, which attracts certain metals to magnets, is also a noncontact force. In **Figure 2**, another noncontact force, called the electric force, causes the girl's hair to stand on end.



**Key Concept Check** What are some contact forces and some noncontact forces?

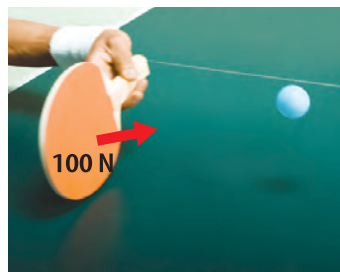
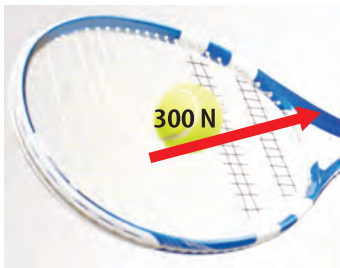
### Strength and Direction of Forces

Forces have both strength and direction. If you push your textbook away from you, it probably slides across your desk. What happens if you push down on your book? It probably does not move. You can use the same strength of force in both cases. Different things happen because the direction of the applied force is different.

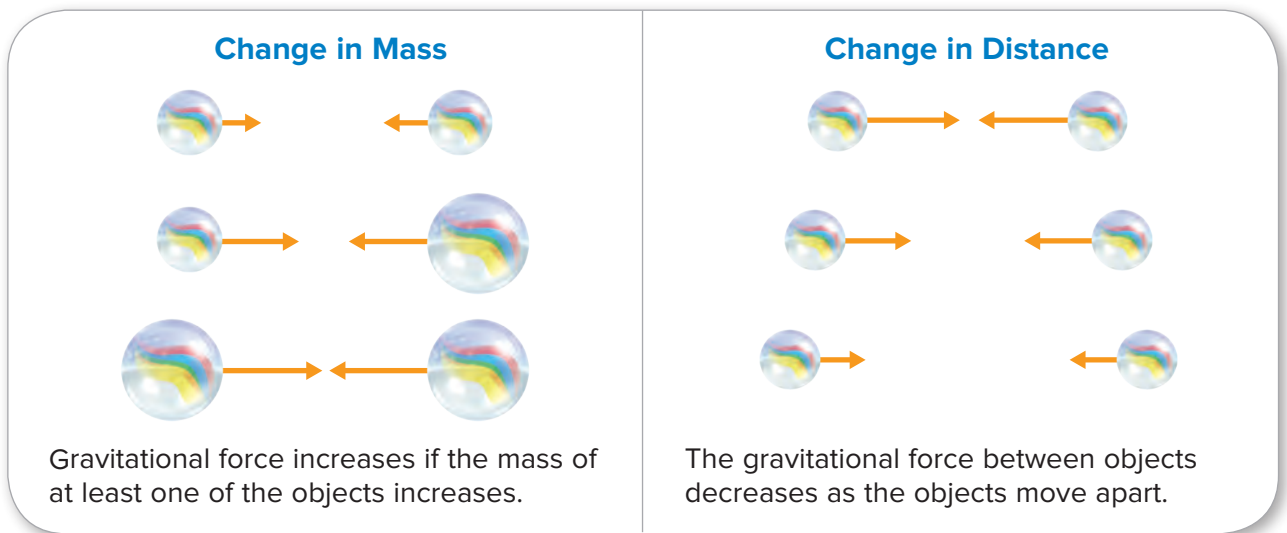
As shown in **Figure 3**, arrows can be used to show forces. The length of an arrow shows the strength of the force. Notice in the figure that the force applied by the tennis racquet is stronger than the force applied by the table-tennis paddle. As a result, the arrow showing the force of the tennis racquet is longer. The direction that an arrow points shows the direction in which force was applied.

The SI unit for force is the newton (N). You apply a force of about 1 N when lifting a stick of butter. You use a force of about 20 N when lifting a 2-L bottle of water. If you use arrows to show these forces, the water's arrow would be 20 times longer.

**Figure 3** Arrows can indicate the strength and direction of a force. ▼



✓ **Visual Check** How are the lengths of the arrows related to the different forces on the two balls?



## What is gravity?

Objects fall to the ground because Earth exerts an attractive force on them. Did you know that you also exert an attractive force on objects? **Gravity** is an attractive force that exists between all objects that have mass. **Mass** is the amount of matter in an object. Mass is often measured in kilograms (kg).

### The Law of Universal Gravitation


In the late 1600s, an English scientist and mathematician, Sir Isaac Newton, developed the law of universal gravitation. This law states that all objects are attracted to each other by a gravitational force. The strength of the force depends on the mass of each object and the distance between them.

 **Key Concept Check** What is the law of universal gravitation?

**Gravitational Force and Mass** The way in which the mass of objects affects gravity is shown in **Figure 4**. When the mass of one or both objects increases, the gravitational force between them also increases. Notice that the force arrows for each pair of marbles are the same size even when one object has less mass. Each object exerts the same attraction on the other object.

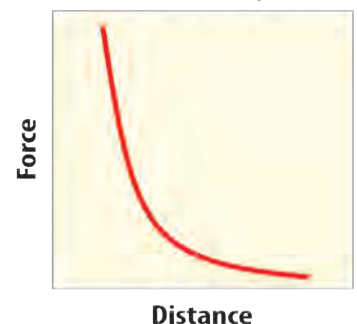
**Gravitational Force and Distance** The effect that distance has on gravity is also shown in **Figure 4**. The attraction between objects decreases as the distance between the objects increases. For example, if your mass is 45 kg, the gravitational force between you and Earth is about 440 N. On the Moon, about 384,000 km away, the gravitational force between you and Earth would only be about 0.12 N. The relationship between gravitational force and distance is shown in the graph in **Figure 5**.

 **Reading Check** What effect does distance have on gravity?

**Figure 4**  The gravitational force between objects depends on the mass of the objects and the distance between them.

 **Personal Tutor**

### Effect of Distance on Gravity




**Figure 5** The gravitational force between objects decreases as the distance between the objects increases.




## Weight—A Gravitational Force

Earth has more mass than any object near you. As a result, the gravitational force Earth exerts on you is greater than the force exerted by any other object. **Weight** is the gravitational force exerted on an object. Near Earth's surface, an object's weight is the gravitational force exerted on the object by Earth. Because weight is a force, it is measured in newtons.

**The Relationship Between Weight and Mass** An object's weight is proportional to its mass. For example, if one object has twice the mass of another object, it also has twice the weight. Near Earth's surface, the weight of an object in newtons is about ten times its mass in kilograms.

 **Reading Check** What is the relationship between mass and weight?

**Weight and Mass High Above Earth** You might think that astronauts in orbit around Earth are weightless. Their weight is about 90 percent of what it is on Earth. The mass of the astronaut in **Figure 6** is about 55 kg. Her weight is about 540 N on Earth and about 500 N on the space station 350 km above Earth's surface. Why is there no **significant** change in weight when the distance increases so much? Earth is so large that an astronaut must be much farther away for the gravitational force to change much. The distance between the astronaut and Earth is small compared to the size of Earth.

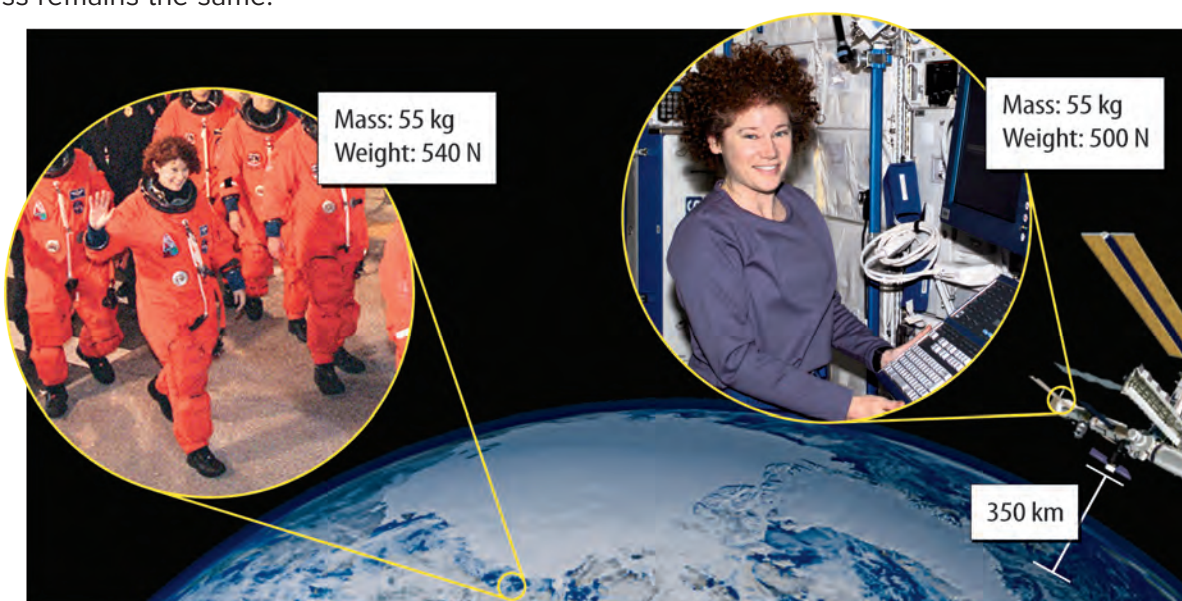
 **Reading Check** Why is the gravitational force that a friend exerts on you less than the gravitational force exerted on you by Earth?


### ACADEMIC VOCABULARY

**significant**

(*adjective*) important, momentous

**Figure 6** As she travels from Earth to the space station, the astronaut's weight changes, but her mass remains the same.

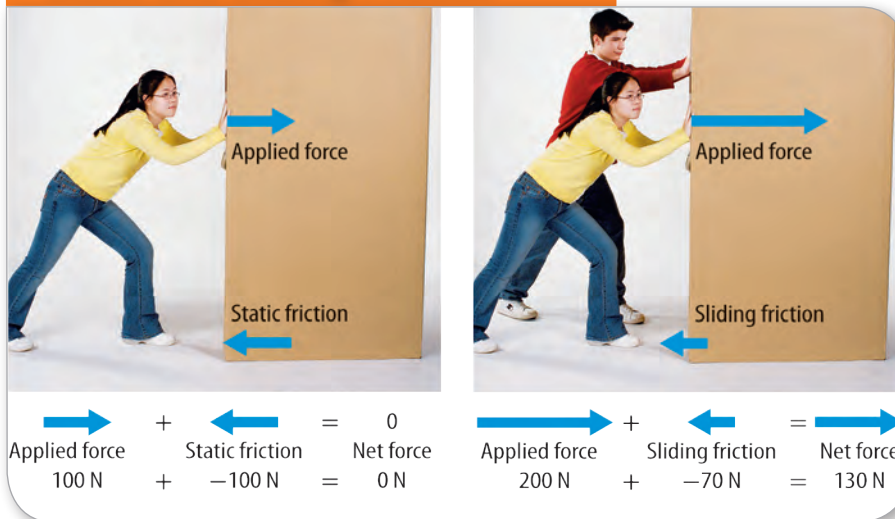


 **Visual Check** What would be the weight of a 110-kg object on Earth? On the space station?

NASA



## Static and Sliding Friction



◀ **Figure 7** Static friction prevents the box on the left from moving. Sliding friction slows the motion of the box on the right.

## Friction

If you slide across a smooth floor in your socks, you move quickly at first and then stop. The force that slows you is friction. **Friction** is a force that resists the motion of two surface that are touching. There are several types of friction.

### Static Friction

The box on the left in **Figure 7** does not move because the girl's applied force is balanced by **static** friction. Static friction prevents surfaces from sliding past each other. Up to a limit, the strength of static friction changes to match the applied force. If the girl increases the applied force, the box still will not move because the static friction also increases.

### Sliding Friction

When static friction reaches its limit between surfaces, the box will move. As shown in **Figure 7**, the force of two students pushing is greater than the static friction between the box and the floor. Sliding friction opposes the motion of surfaces sliding past each other. As long as the box is sliding, the sliding friction does not change. Increasing the applied force makes the box slide faster. If the students stop pushing, the box will slow and stop because of sliding friction.

### Fluid Friction

Friction between a surface and a fluid—any material, such as water or air, that flows—is fluid friction. Fluid friction between a surface and air is air resistance. Suppose an object is moving through a fluid. Decreasing the surface area toward the oncoming fluid decreases the air resistance against the object. The crumpled paper in **Figure 8** falls faster than the flat paper because it has less surface area and less air resistance.

### SCIENCE USE V. COMMON USE

#### static

*Science Use* at rest or having no motion

*Common Use* noise produced in a radio or a television

**Figure 8** Air resistance is greater on the flat paper.







## MiniLab

10 minutes

### How does friction affect motion?



Friction affects the motion of an object sliding across a surface.



- 1 Read and complete a lab safety form.
- 2 Use **tape** to fasten **sandpaper** to a table. Attach a **spring scale** to a **wooden block** with an **eyehook** in it.
- 3 Record in your Science Journal the force required to gently pull the block at a constant speed on the sandpaper and then on the table.

### Analyze and Conclude

1. **Compare** the forces required to pull the block across the two surfaces.
2. **Key Concept** How did reducing friction affect the motion of the block?

## What causes friction?

Rub your hands together. What do you feel? If your hands were soapy, you could slide them past each other easily. You feel more friction when you rub your dry hands together than when you rub your soapy hands together.

What causes friction between surfaces? Look at the close-up view of surfaces in **Figure 9**. Microscopic dips and bumps cover all surfaces. When surfaces slide past each other, the dips and bumps on one surface catch on the dips and bumps on the other surface. This microscopic roughness slows sliding and is a source of friction.



**Key Concept Check** How does friction affect the motion of two objects sliding past each other?

In addition, small particles—atoms and molecules—make up all surfaces. These particles contain weak electrical charges. When a positive charge on one surface slides by a negative charge on the other surface, an attraction occurs between the particles. This attraction slows sliding and is another source of friction between the surfaces.

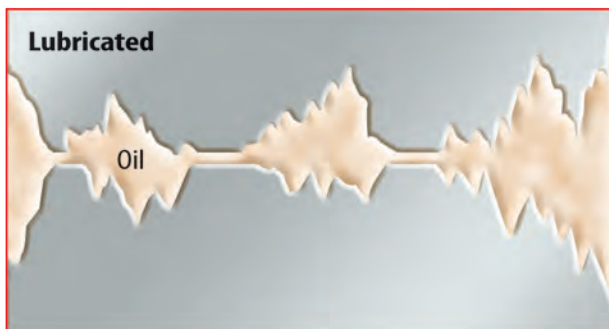
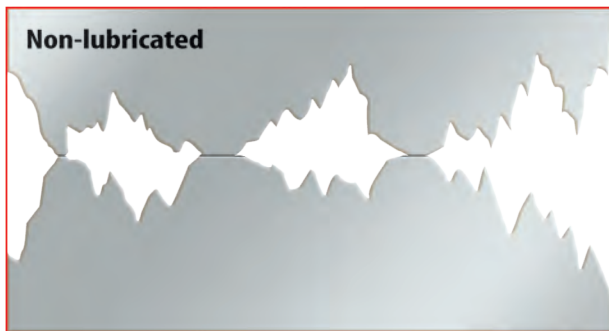


**Reading Check** What are two causes of friction?

## Reducing Friction

When you rub soapy hands together, the soapy water slightly separates the surfaces of your hands. There is less contact between the microscopic dips and bumps and between the electrical charges of your hands. Soap acts as a lubricant and decreases friction. With less friction, it is easier for surfaces to slide past each other, as shown in **Figure 9**. Motor oil is a lubricant that reduces friction between moving parts of a car's engine.

Look again at the effect of air resistance on the falling paper in **Figure 8**. Reducing the paper's surface area reduces the fluid friction between it and the air.



**Figure 9** Lubricants such as oil decrease friction caused by microscopic roughness.

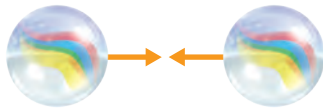


## Visual Summary



Forces can be either contact, such as a karate chop, or noncontact, such as gravity. Each type is described by its strength and direction.

Gravity is an attractive force that acts between any two objects that have mass. The attraction is stronger for objects with greater mass.



Friction can reduce the speed of objects sliding past each other. Air resistance is a type of fluid friction that slows the speed of a falling object.



Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

## What do you think NOW?

You first read the statements below at the beginning of the chapter.

1. You pull on objects around you with the force of gravity.
2. Friction can act between two unmoving, touching surfaces.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

## Use Vocabulary

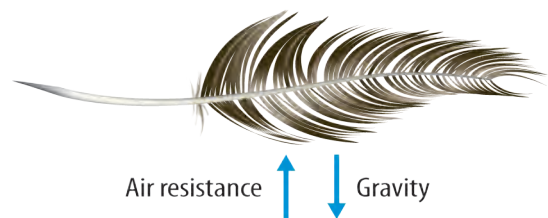
- 1 Define *friction* in your own words.
- 2 Distinguish between weight and mass.

## Understand Key Concepts

- 3 Explain the difference between a contact force and a noncontact force.
- 4 You push a book sitting on a desk with a force of 5 N, but the book does not move. What is the static friction?
  - A. 0 N
  - B. 5 N
  - C. between 0 N and 5 N
  - D. greater than 5 N
- 5 Apply According to the law of universal gravitation, is there a stronger gravitational force between you and Earth or an elephant and Earth? Why?

## Interpret Graphics

- 6 Interpret Look at the forces on the feather.



In terms of these forces, explain why the feather falls slowly rather than fast.

- 7 Organize Information Copy and fill in the table below to describe forces mentioned in this lesson. Add as many rows as you need.

Force	Description

## Critical Thinking

- 3 Decide Is it possible for the gravitational force between two 50-kg objects to be less than the gravitational force between a 50-kg object and a 5-kg object? Explain.





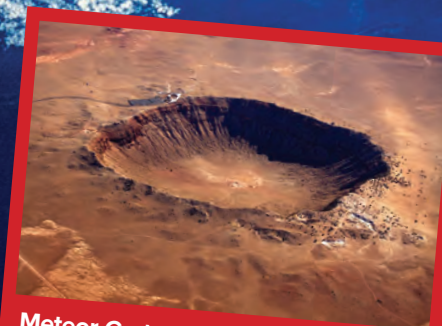
# Avoiding an Asteroid Collision



The force of gravity can change the path of an asteroid moving through the solar system.



The Spacewatch telescope in Arizona scans the sky for near-Earth asteroids. Other U.S. telescopes with this mission are in Hawaii, California, and New Mexico.



Meteor Crater in Arizona was created when an asteroid about 50 m wide collided with Earth about 50,000 years ago.

## Gravity to the rescue!

Everything in the universe—from asteroids to planets to stars—exerts gravity on every other object. This force keeps the Moon in orbit around Earth and Earth in orbit around the Sun. Gravity can also send objects on a collision course—a problem when those objects are Earth and an asteroid. Asteroids are rocky bodies found mostly in the asteroid belt between Mars and Jupiter. Jupiter’s strong gravity can change the orbits of asteroids over time, occasionally sending them dangerously close to Earth.

Astronomers use powerful telescopes to track asteroids near Earth. More than a thousand asteroids are large enough to cause serious damage if they collide with Earth. If an asteroid were heading our way, how could we prevent the collision? One idea is to launch a spacecraft into the asteroid. The impact could slow it down enough to cause it to miss Earth. But if the asteroid broke apart, the pieces could rain down onto Earth!

Scientists have another idea. They propose launching a massive spacecraft into an orbit close to the asteroid. The spacecraft’s gravity would exert a small tug on the asteroid. Over time, the asteroid’s path would be altered enough to pass by Earth. Astronomers track objects now that are many years away from crossing paths with Earth. This gives them enough time to set a plan in motion if one of the objects appears to be on a collision course with Earth.

## It's Your Turn

**PROBLEM SOLVING** With a group, come up with a plan for avoiding an asteroid’s collision with Earth. Present your plan to the class. Include diagrams and details that explain exactly how your plan will work.

(a)NASA/Goddard Space Flight Center Scientific Visualization Studio, (c)Digital Vision/Alamy, (b)Chris Sault/Getty Images, (d)gdjStockTrek/Getty Images





# Lesson 2

## Reading Guide

### Key Concepts

#### ESSENTIAL QUESTIONS

- What is Newton's first law of motion?
- How is motion related to balanced and unbalanced forces?
- What effect does inertia have on the motion of an object?

#### Vocabulary

**net force** p. 55

**balanced forces** p. 56

**unbalanced forces** p. 56

**Newton's first law of motion** p. 57

**inertia** p. 58



**Multilingual eGlossary**



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# Newton's First Law



## Inquiry

### How does it balance?

You probably would be uneasy standing under Balanced Rock near Buhl, Idaho. Yet this unusual rock stays in place year after year. The rock has forces acting on it. Why doesn't it fall over? The forces acting on the rock combine, and the rock does not move.








### Can you balance magnetic forces?

Magnets exert forces on each other. Depending on how you hold them, magnets either attract or repel each other. Can you balance these magnetic forces?

- 1 Read and complete a lab safety form.
- 2 Have your lab partner hold a **ring magnet** vertically on a **pencil**, as shown in the picture.
- 3 Place **another magnet** on the pencil, and use it to push the first magnet along the pencil.
- 4 Place a **third magnet** on the same pencil so that the outer magnets push against the middle one. Does the middle magnet still move along the pencil?



### Think About This

1. Describe the forces that the other magnets exert on the first magnet in steps 3 and 4.
2.  **Key Concept** Describe how the motion of the first magnet seemed to depend on whether each force on the magnet was balanced by another force.

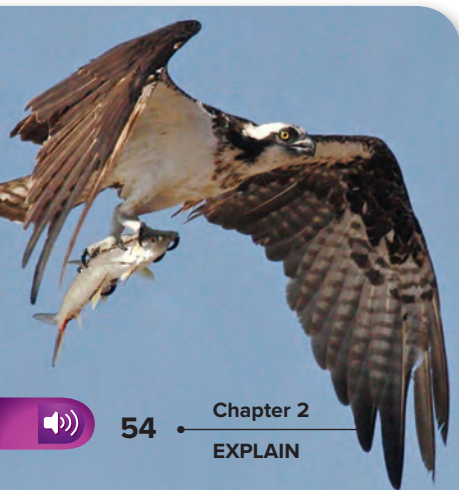
## Identifying Forces

Ospreys are birds of prey that live near bodies of water. Perhaps several minutes ago, the mother osprey in **Figure 10** was in the air in a high-speed dive. It might have plunged toward a nearby lake after seeing a fish in the water. As it neared the water, it moved its legs forward to grab the fish with its talons. It then stretched out its wings and used them to climb high into the air. Before the osprey comes to rest on its nest, it will slow its speed and land softly on the nest's edge, near the young birds waiting for food.

Forces helped the mother osprey change the speed and direction of its motion. Recall that a force is a push or a pull. Some of the forces were contact forces, such as air resistance. When soaring, the osprey spread its wings, increasing air resistance. In a dive, it held its wings close to its body, changing its shape, decreasing its surface area and air resistance. Gravity also pulled the osprey toward the ground.

To understand the motion of an object, you need to identify the forces acting on it. In this lesson you will read how forces change the motion of objects.

**Figure 10** Forces change the motion of this osprey.



(t)Hutchings Photography/Digital Light Source, (b)Robert Burton/USFWS




## Combining Forces—The Net Force

Suppose you try to move a piece of heavy furniture, such as the dresser in **Figure 11**. If you push on the dresser by yourself, you have to push hard on the dresser to overcome the static friction and move it. If you ask a friend to push with you, you do not have to push as hard. When two or more forces act on an object, the forces combine. *The combination of all the forces acting on an object is the **net force**.* The way in which forces combine depends on the directions of the forces applied to an object.

### Combining Forces in the Same Direction

When the forces applied to an object act in the same direction, the net force is the sum of the individual forces. In this case, the direction of the net force is the same as the direction of the individual forces.

Because forces have direction, you have to specify a **reference direction** when you combine forces. In **Figure 11**, for example, you would probably choose “to the right” as the positive reference direction. Both forces then would be positive. The net force on the dresser is the sum of the two forces pushing in the same direction. One person pushes on the dresser with a force of 200 N to the right. The other person pushes with a force of 100 N to the right. The net force on the dresser is  $200\text{ N} + 100\text{ N} = 300\text{ N}$  to the right. The force applied to the dresser is the same as if one person pushed on the dresser with a force of 300 N to the right.

 **Reading Check** How do you calculate the net force on an object if two forces are acting on it in the same direction?


### REVIEW VOCABULARY

#### reference direction

a direction that you choose from a starting point to describe an object's position


### Personal Tutor


**Figure 11** When forces in the same direction combine, the net force is also in the same direction. The strength of the net force is the sum of the forces.

 **Visual Check** What would the net force be if one boy pushed with 250 N and the other boy pushed in the same direction with 180 N?



**Figure 12** When two forces acting on an object in opposite directions combine, the net force is in the same direction as the larger force. The strength of the net force is the sum of the positive and negative forces. ▶

**Unbalanced Forces** 



$\begin{matrix} \text{→} & + & \text{←} & = & \text{→} & \text{Net force} \\ 200 \text{ N} & + & -100 \text{ N} & = & 100 \text{ N} \end{matrix}$


### Combining Forces in Opposite Directions


When forces act in opposite directions on an object, the net force is still the sum of the forces. Suppose you choose “to the right” again as the reference direction in **Figure 12**. A force in that direction is positive, and a force in the opposite direction is negative. The net force is the sum of the positive and negative forces. The net force on the dresser is 100 N to the right.


### Balanced and Unbalanced Forces

When equal forces act on an object in opposite directions, as in **Figure 13**, the net force on the object is zero. The effect is the same as if there were no forces acting on the object. *Forces acting on an object that combine and form a net force of zero are **balanced forces**.* Balanced forces do not change the motion of an object. However, the net force on the dresser in **Figure 12** is not zero. There is a net force to the right. *Forces acting on an object that combine and form a net force that is not zero are **unbalanced forces**.*

**Figure 13** When two forces acting on an object in opposite directions are the same strength, the forces are balanced. ▶

 **Visual Check** How are the force arrows for the balanced forces in the figure alike? How are they different?


**Balanced Forces** 



$\begin{matrix} \text{→} & + & \text{←} & = & \text{→} & \text{0 Net force} \\ 200 \text{ N} & + & -200 \text{ N} & = & 0 \text{ N} \end{matrix}$


## Newton's First Law of Motion

Sir Isaac Newton studied how forces affect the motion of objects. He developed three rules known as Newton's laws of motion. According to **Newton's first law of motion**, if the net force on an object is zero, the motion of the object does not change. As a result, balanced forces and unbalanced forces have different results when they act on an object.

 **Key Concept Check** What is Newton's first law of motion?


### Balanced Forces and Motion

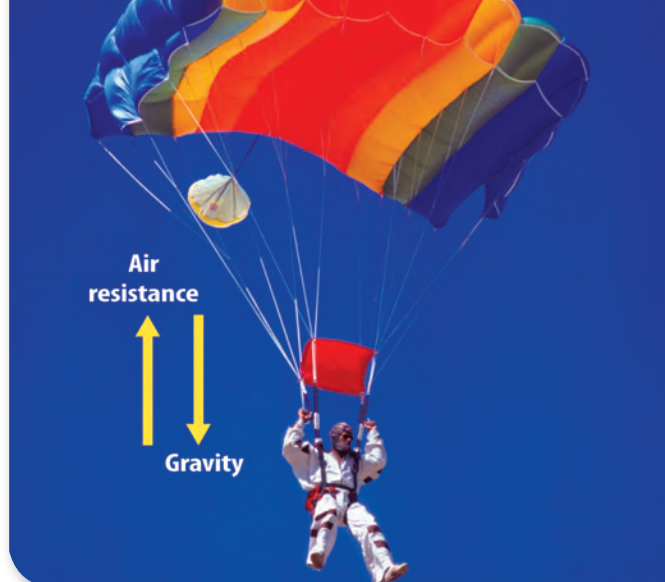
According to Newton's first law of motion, balanced forces cause no change in an object's velocity (speed in a certain direction). This is true when an object is at rest or in motion. Look again at **Figure 13**. The dresser is at rest before the boys push on it. It remains at rest when they apply balanced forces. Similarly, because the forces in **Figure 14**—air resistance and gravity—are balanced, the parachutist moves downward at his terminal velocity. Terminal velocity is the constant velocity reached when air resistance equals the force of gravity acting on a falling object.

 **Reading Check** What happens to the velocity of a moving car if the forces on it are balanced?

### Unbalanced Forces and Motion

Newton's first law of motion only applies to balanced forces acting on an object. When unbalanced forces act on an object at rest, the object starts moving. When unbalanced forces act on an already moving object, the object's speed, direction of motion, or both change. You will read more about how unbalanced forces affect an object's motion in the next lesson.

 **Key Concept Check** How is motion related to balanced and unbalanced forces?



**Figure 14** Balanced forces acting on an object do not change the object's speed and direction.



## MiniLab

15 minutes

### How do forces affect motion?




The motion of an object depends on whether balanced or unbalanced forces act on it.




- 1 Read and complete a lab safety form.
- 2 Attach **spring scales** to opposite sides of a **wooden block** with **eyehooks**.
- 3 With a partner, gently pull the scales so that the block moves toward one of you. Sketch the setup in your Science Journal, including the force readings on each scale.
- 4 Repeat step 3, pulling on the block so that it does not move.

### Analyze and Conclude


1. **Explain** Use Newton's first law of motion to explain what occurred in steps 3 and 4.
2.  **Key Concept** How was the block's motion related to balanced and unbalanced forces?






**Figure 15**  Inertia causes the crash-test dummy to keep moving forward after the car stops.



 **Visual Check** What effect would a shoulder belt and a lap belt have on the inertia of the crash-test dummy?

## Inertia

According to Newton’s first law, the motion of an object will not change if balanced forces act on it. *The tendency of an object to resist a change in its motion is called **inertia*** (ihn UR shuh). Inertia explains the motion of the crash-test dummy in **Figure 15**. Before the crash, the car and dummy moved with constant velocity. If no other force had acted on them, the car and dummy would have continued moving with constant velocity because of inertia. The impact with the barrier results in an unbalanced force on the car, and the car stops. The dummy continues moving forward because of its inertia.

 **Key Concept Check** What effect does inertia have on the motion of an object?

## WORD ORIGIN

### inertia

from Latin *iners*, means “without skill, inactive”

## FOLDABLES

Make a chart with six columns and six rows. Use your chart to define and show how this lesson’s vocabulary terms are related. Afterward, fold your chart in half and label the outside *Newton’s First Law*.

	Net force	Balanced forces	Unbalanced forces	Newton’s First Law	Inertia
Net force					
Balanced forces					
Unbalanced forces					
Newton’s First Law					
Inertia					

## Why do objects stop moving?

Think about how friction and inertia together affect an object’s movement. A book sitting on a table, for example, stays in place because of inertia. When you push the book, the force you apply to the book is greater than static friction between the book and the table. The book moves in the direction of the greater force. If you stop pushing, friction stops the book.

What would happen if there were no friction between the book and the table? Inertia would keep the book moving. According to Newton’s first law, the book would continue to move at the same speed in the same direction as your push.

On Earth, friction can be reduced but not totally removed. For an object to start moving, a force greater than static friction must be applied to it. To keep the object in motion, a force at least as strong as friction must be applied continuously. Objects stop moving because friction or another force acts on them.

## Visual Summary



Unbalanced forces cause an object to move.



According to Newton's first law of motion, if the net force on an object is zero, the object's motion does not change.



Inertia is a property that resists a change in the motion of an object.

### FOLDABLES®

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

## What do you think NOW?

You first read the statements below at the beginning of the chapter.

3. Forces acting on an object cannot be added.
4. A moving object will stop if no forces act on it.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

## Use Vocabulary

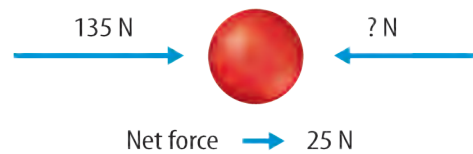
- 1 **Define** *net force* in your own words.
- 2 **Distinguish** between balanced forces and unbalanced forces.

## Understand Key Concepts

- 3 Which causes an object in motion to remain in motion?
  - A. friction
  - B. gravity
  - C. inertia
  - D. velocity
- 4 **Apply** You push a coin across a table. The coin stops. How does this motion relate to balanced and unbalanced forces?
- 5 **Explain** Use Newton's first law to explain why a book on a desk does not move.

## Interpret Graphics

- 6 **Analyze** What is the missing force?



- 7 **Organize Information** Copy and fill in the graphic organizer below to explain Newton's first law of motion in each case.

Object at rest	
Object in motion	

## Critical Thinking

- 8 **Extend** Three people push a piano on wheels with forces of 130 N to the right, 150 N to the left, and 165 N to the right. What are the strength and direction of the net force on the piano?
- 9 **Assess** A child pushes down on a box lid with a force of 25 N. At the same time, her friend pushes down on the lid with a force of 30 N. The spring on the box lid pushes upward with a force of 60 N. Can the children close the box? Why or why not?



## How can you model Newton's first law of motion?

### Materials



markers  
(red, blue,  
black, green)

According to Newton's first law of motion, balanced forces do not change an object's motion. Unbalanced forces change the motion of objects at rest or in motion. You can model different forces and their effects on the motion of an object.


### Learn It

When you **model** a concept in science, you act it out, or imitate it. You can model the effect of balanced and unbalanced forces on motion by using movements on a line.

### Try It

- 1 Draw a line across a sheet of lined notebook paper lengthwise. Place an X at the center. Each space to the right of the X will model a force of 1 N east, and each space to the left will model 1 N west.
- 2 Suppose a force of 3 N east and a force of 11 N west act on a moving object. Model these forces by starting at X and drawing a red arrow three spaces to the right. Then, start at that point and draw a blue arrow 11 spaces to the left. The net force is modeled by how far this point is from X, 8 N west.
- 3 Are the forces you modeled balanced or unbalanced? Will the forces change the object's motion?

### Apply It

- 4 Suppose a force of 8 N east, a force of 12 N west, and a force of 4 N east act on a moving object. Use different colors of markers to model the forces on the object.
- 5 What is the net force on the object? Are the forces you modeled balanced or unbalanced? Will the forces change the object's motion?
- 6 **Model** other examples of balanced and unbalanced forces acting on an object. In each case, decide which forces will act on the object.
- 7  **Key Concept** For each of the forces you modeled, determine the net force, and decide if the forces are balanced or unbalanced. Then, decide if the forces will change the object's motion.





# Lesson 3

## Reading Guide

### Key Concepts

#### ESSENTIAL QUESTIONS

- What is Newton's second law of motion?
- How does centripetal force affect circular motion?

#### Vocabulary

**Newton's second law of motion** p. 65

**circular motion** p. 66

**centripetal force** p. 66



**Multilingual eGlossary**

# Newton's Second Law

**PBL**

Go to the resource tab in ConnectED to find the PBL *Putting the Shot in Motion*.

**Inquiry**

## What makes it go?

The archer pulls back the string and takes aim. When she releases the string, the arrow soars through the air. To reach the target, the arrow must quickly reach a high speed. How is it able to move so fast? The force from the string determines the arrow's speed.







### What forces affect motion along a curved path?

When traveling in a car or riding on a roller coaster, you can feel different forces acting on you as you move along a curved path. What are these forces? How do they affect your motion?


- 1 Read and complete a lab safety form.
- 2 Attach a piece of **string** about 1 m long to a rolled-up **sock**.

**WARNING:** Find a spot away from your classmates for the next steps.

- 3 While holding the end of the string, swing the sock around in a circle above your head. Notice the force tugging on the string.
- 4 Repeat step 3 with two socks rolled together. In your Science Journal, compare the force of swinging one sock to the force of swinging two socks.



### Think About This

- 1. Describe the forces acting along the string while you were swinging it. Classify each force as balanced or unbalanced.
- 2.  **Key Concept** How does the force from the string seem to affect the sock's motion?

## How do forces change motion?

Think about different ways that forces can change an object's motion. For example, how do forces change the motion of someone riding a bicycle? The forces of the person's feet on the pedals cause the wheels of the bicycle to turn faster and the bicycle's speed to increase. The speed of a skater slowly sliding across ice gradually decreases because of friction between the skates and the ice. Suppose you are pushing a wheelbarrow across a yard. You can change its speed by pushing with more or less force. You can change its direction by pushing it in the direction you want to move. Forces change an object's motion by changing its speed, its direction, or both its speed and its direction.

### Unbalanced Forces and Velocity

Velocity is speed in a certain direction. Only unbalanced forces change an object's velocity. A bicycle's speed will not increase unless the forces of the person's feet on the pedals is greater than friction that slows the wheels. A skater's speed will not decrease if the skater pushes back against the ice with a force greater than the friction against the skates. If someone pushes the wheelbarrow with the same force but in the opposite direction that you are pushing, the wheelbarrow's direction will not change.

In the previous lesson, you read about Newton's first law of motion—balanced forces do not change an object's velocity. In this lesson you will read about how unbalanced forces affect the velocity of an object.

## Unbalanced Forces on an Object at Rest


An example of how unbalanced forces affect an object at rest is shown in **Figure 16**. At first the ball is not moving. The hand holds the ball up against the downward pull of gravity. Because the forces on the ball are balanced, the ball remains at rest. When the hand moves out of the way, the ball falls downward. You know that the forces on the ball are now unbalanced because the ball's motion changed. The ball moves in the direction of the net force. When unbalanced forces act on an object at rest, the object begins moving in the direction of the net force.

## Unbalanced Forces on an Object in Motion

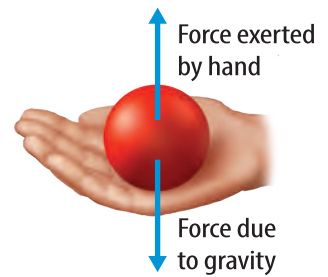
Unbalanced forces change the velocity of a moving object. Recall that one way to change an object's velocity is to change its speed.

**Speeding Up** If the net force acting on a moving object is in the direction that the object is moving, the object will speed up. For example, a net force acts on the sled in **Figure 17**. Because the net force is in the direction of motion, the sled's speed increases.

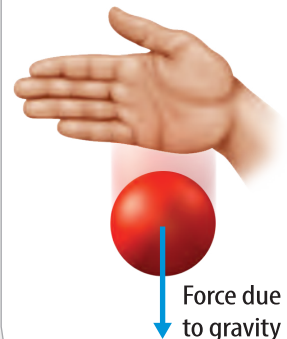
**Slowing Down** Think about what happens if the direction of the net force on an object is opposite to the direction the object moves. The object slows down. When the boy sliding on the sled in **Figure 17** pushes his foot against the snow, friction acts in the direction opposite to his motion. Because the net force is in the direction opposite to the sled's motion, the sled's speed decreases.

 **Reading Check** What happens to the speed of a wagon rolling to the right if a net force to the right acts on it?

### Balanced Forces



### Unbalanced Forces



▲ **Figure 16** When unbalanced forces act on a ball at rest, it moves in the direction of the net force.


### Speeding up



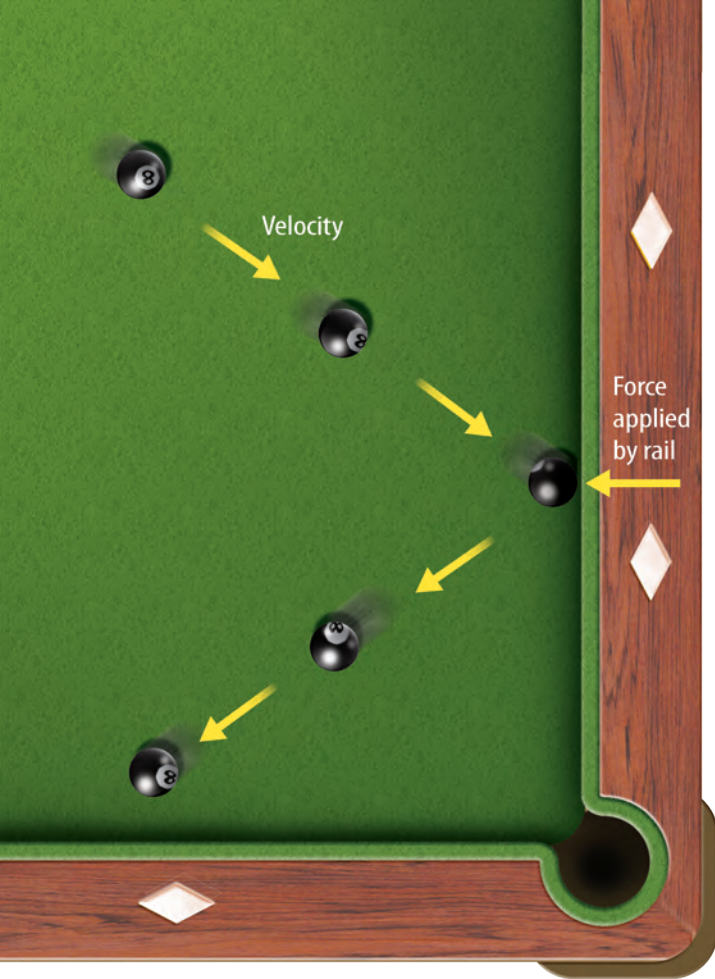
### Slowing down



◀ **Figure 17** Unbalanced forces can cause an object to speed up or slow down.

 **Visual Check** How would the net force and velocity arrows in the left photo change if the girl pushed harder?





**Figure 18** Unbalanced forces act on the billiard ball, causing its direction to change.

## Changes in Direction of Motion

Another way that unbalanced forces can change an object's velocity is to change its direction. The ball in **Figure 18** moved at a constant velocity until it hit the rail of the billiard table. The force applied by the rail changed the ball's direction. Likewise, unbalanced forces change the direction of Earth's crust. Recall that the crust is broken into moving pieces called plates. The direction of one plate changes when another plate pushes against it with an unbalanced force.

## Unbalanced Forces and Acceleration

You have read how unbalanced forces can change an object's velocity by changing its speed, its direction, or both its speed and its direction. Another name for a change in velocity over time is acceleration. When the girl in **Figure 17** pushed the sled, the sled accelerated because its speed changed. When the billiard ball in **Figure 18** hit the side of the table, the ball accelerated because its direction changed. Unbalanced forces can make an object accelerate by changing its speed, its direction, or both.



**Reading Check** How do unbalanced forces affect an object at rest or in motion?



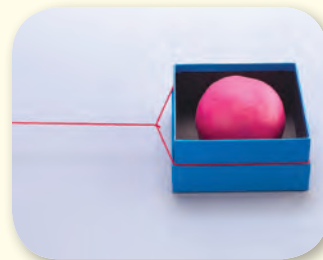
## MiniLab

10 minutes


### How are force and mass related?

Unbalanced forces cause an object to accelerate. If the mass of the object increases, how does the force required to accelerate the object change?

- 1 Read and complete a lab safety form.
- 2 Tie a **string** to a **small box**. Pull the box about 2 m across the floor. Notice the force required to cause the box to accelerate.
- 3 Put **clay** in the box to increase its mass. Pull the box so that its acceleration is about the same as before. Notice the force required.



### Analyze and Conclude

1. **Compare** the strength of the force needed to accelerate the box each time.
2.  **Key Concept** How did the mass affect the force needed to accelerate the box?



## Newton's Second Law of Motion

Isaac Newton also described the relationship between an object's acceleration (change in velocity over time) and the net force that acts on an object. According to **Newton's second law of motion**, the acceleration of an object is equal to the net force acting on the object divided by the object's mass. The direction of acceleration is the same as the direction of the net force.



**Key Concept Check** What is Newton's second law of motion?

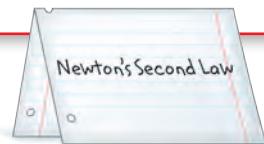
### Newton's Second Law Equation

$$\text{acceleration (in m/s}^2\text{)} = \frac{\text{net force (in N)}}{\text{mass (in kg)}}$$
$$a = \frac{F}{m}$$

Notice that the equation for Newton's second law has SI units. Acceleration is expressed in meters per second squared ( $\text{m/s}^2$ ), mass in kilograms (kg), and force in newtons (N). From this equation, it follows that a newton is the same as  $\text{kg}\cdot\text{m/s}^2$ .

### FOLDABLES®

Make a half-book from a sheet of notebook paper. Use it to organize your notes on Newton's second law.



### Math Skills



### Newton's Second Law Equation

**Solve for Acceleration** You throw a 0.5-kg basketball with a force of 10 N. What is the acceleration of the ball?

- This is what you know:**  
mass:  $m = 0.5 \text{ kg}$   
force:  $F = 10 \text{ N}$  or  $10 \text{ kg}\cdot\text{m/s}^2$
- This is what you need to find:** acceleration:  $a$
- Use this formula:**  
 $a = \frac{F}{m}$
- Substitute:**  
the values for  $F$  and  $m$   
into the formula and divide.  
 $a = \frac{10 \text{ N}}{0.5 \text{ kg}} = 20 \frac{\text{kg}\cdot\text{m/s}^2}{\text{kg}} = 20 \text{ m/s}^2$

**Answer:** The acceleration of the ball is  $20 \text{ m/s}^2$ .



Math Practice



Personal Tutor

### Practice

- A 24-N net force acts on an 8-kg rock. What is the acceleration of the rock?
- A 30-N net force on a skater produces an acceleration of  $0.6 \text{ m/s}^2$ . What is the mass of the skater?
- What net force acting on a 14-kg wagon produces an acceleration of  $1.5 \text{ m/s}^2$ ?




## Circular Motion

Newton's second law of motion describes the relationship between an object's change in velocity over time, or acceleration, and unbalanced forces acting on the object. You already read how this relationship applies to motion along a line. It also applies to circular motion. **Circular motion** is any motion in which an object is moving along a curved path.

### Centripetal Force

The ball in **Figure 19** is in circular motion. The velocity arrows show that the ball has a tendency to move along a straight path. Inertia—not a force—causes this motion. The ball's path is curved because the string pulls the ball inward. *In circular motion, a force that acts perpendicular to the direction of motion, toward the center of the curve, is **centripetal** (sen TRIH puh tuhl) **force**.* The figure also shows that the ball accelerates in the direction of the centripetal force.

 **Key Concept Check** How does centripetal force affect circular motion?

### The Motion of Satellites and Planets


Another object that experiences centripetal force is a satellite. A satellite is any object in space that orbits a larger object. Like the ball in **Figure 19**, a satellite tends to move along a straight path because of inertia. But just as the string pulls the ball inward, gravity pulls a satellite inward. Gravity is the centripetal force that keeps a satellite in orbit by changing its direction. The Moon is a satellite of Earth. As shown in **Figure 19**, Earth's gravity changes the Moon's direction. Similarly, the Sun's gravity changes the direction of its satellites, including Earth.

### WORD ORIGIN

#### centripetal

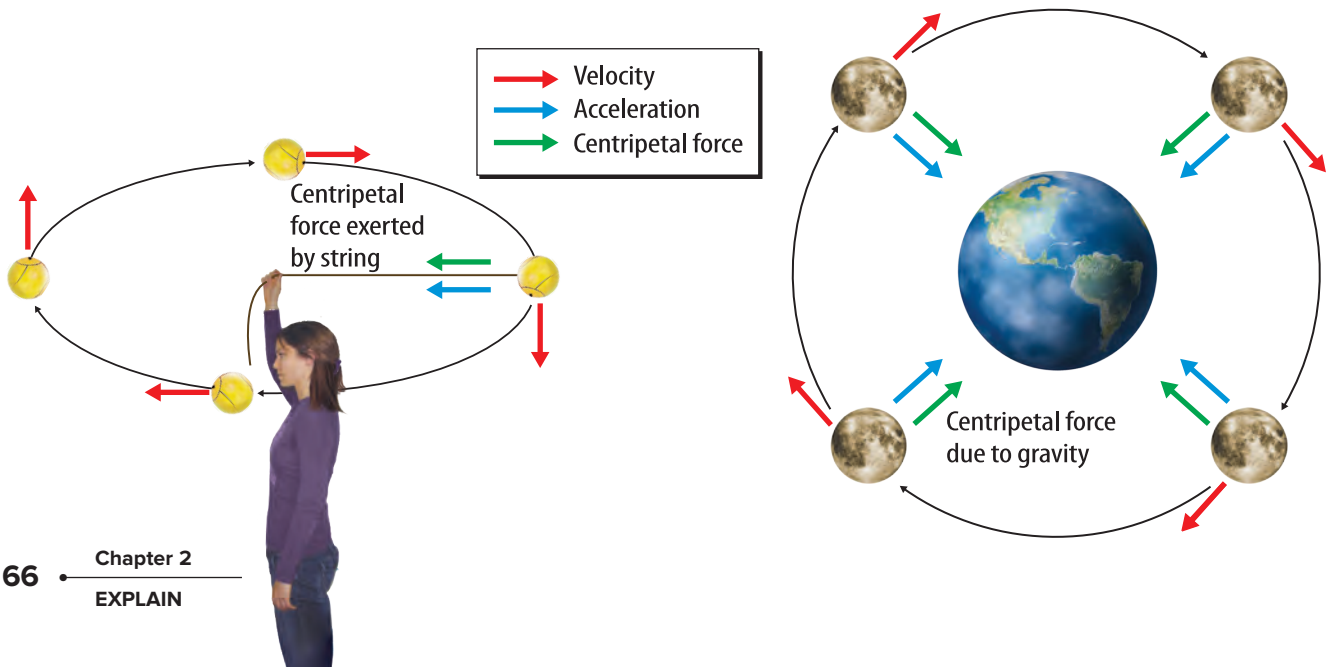
from Latin *centripetus*, means "toward the center"

**Figure 19** Inertia of the moving object and the centripetal force acting on the object produce the circular motion of the ball and the Moon.

 **Visual Check** How does the direction of the velocity of a satellite differ from the direction of its acceleration?

## Circular Motion

 **Animation**



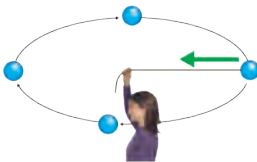
## Visual Summary



Unbalanced forces cause an object to speed up, slow down, or change direction.



Newton's second law of motion relates an object's acceleration to its mass and the net force on the object.



Any motion in which an object is moving along a curved path is circular motion.



Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

## What do you think NOW?

You first read the statements below at the beginning of the chapter.

- When an object's speed increases, the object accelerates.
- If an object's mass increases, its acceleration also increases if the net force acting on the object stays the same.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

## Use Vocabulary

- Explain** Newton's second law of motion in your own words.
- Use the term** *circular motion* in a sentence.

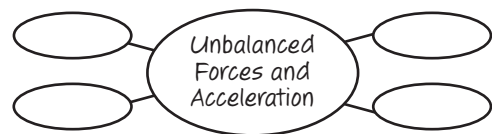
## Understand Key Concepts

- A cat pushes a 0.25-kg toy with a net force of 8 N. According to Newton's second law what is the acceleration of the ball?
 

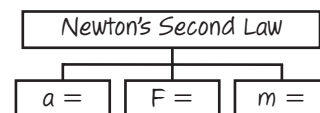
A. $2 \text{ m/s}^2$	C. $16 \text{ m/s}^2$
B. $4 \text{ m/s}^2$	D. $32 \text{ m/s}^2$
- Describe** how centripetal force affects circular motion.

## Interpret Graphics

- Apply** Copy and fill in the graphic organizer below. Give examples of unbalanced forces on an object that could cause an object to accelerate.



- Complete** Copy the graphic organizer below and complete each equation according to Newton's second law.



## Critical Thinking

- Design** You need to lift up a 45-N object. Draw an illustration that explains the strength and direction of the force used to lift the object.

## Math Skills

## Math Practice

- The force of Earth's gravity is about 10 N downward. What is the acceleration of a 15-kg backpack if lifted with a 15-N force?





## How does a change in mass or force affect acceleration?

### Materials



baseball



foam ball



meterstick

### Safety



Force, mass, and acceleration are all related variables. In this activity, you will use these variables to study Newton's second law of motion.


### Learn It

*Vary* means "to change." A **variable** is a quantity that can be changed. For example, the variables related to Newton's second law of motion are force, mass, and acceleration. You can find the relationship between any two of these variables by changing one of them and keeping the third variable the same.

### Try It

- 1 Read and complete a lab safety form.
- 2 Hold a baseball in one hand and a foam ball in your other hand. Compare the masses of the two balls.
- 3 Lay both balls on a flat surface. Push a meterstick against the balls at the same time with the same force. Compare the accelerations of the ball.
- 4 Using only the baseball and the meterstick, lightly push the ball and observe its acceleration. Again observe the acceleration as you push the baseball with a stronger push. Compare the accelerations of the ball when you used a weak force and when you used a strong force.

### Apply It

- 5 Answer the following questions for both step 3 and step 4. What variable did you change? What variable changed as a result? What variable did you keep the same?
- 6 Using your results, state the relationship between acceleration and mass if the net force on an object does not change. Then, state the relationship between acceleration and force if mass does not change.
- 7  **Key Concept** How do your results support Newton's second law of motion?



# Lesson 4

## Reading Guide

### Key Concepts

#### ESSENTIAL QUESTIONS

- What is Newton's third law of motion?
- Why don't the forces in a force pair cancel each other?
- What is the law of conservation of momentum?

#### Vocabulary

**Newton's third law of motion** p. 71

**force pair** p. 71

**momentum** p. 73

**law of conservation of momentum** p. 74



**Multilingual eGlossary**

# Newton's Third Law



## Inquiry

### Why move up?

To reach the height she needs for her dive, this diver must move up into the air. Does she just jump up? No, she doesn't. She pushes down on the diving board and the diving board propels her into the air. How does pushing down cause the diver to move up?



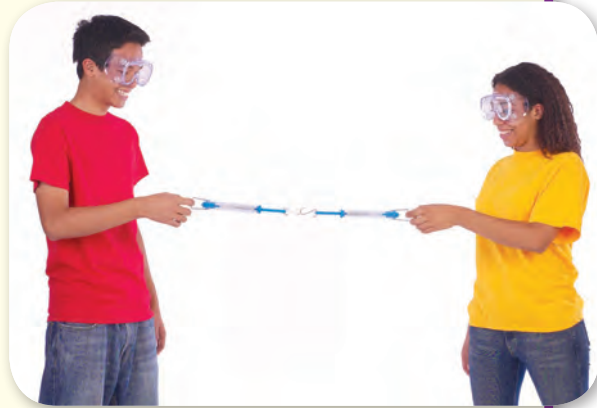





### How do opposite forces compare?

If you think about forces you encounter every day, you might notice forces that occur in pairs. For example, if you drop a rubber ball, the falling ball pushes against the floor. The ball bounces because the floor pushes with an opposite force against the ball. How do these opposite forces compare?

- 1 Read and complete a lab safety form.
- 2 Stand so that you face your lab partner, about half a meter away. Each of you should hold a **spring scale**.
- 3 Hook the two scales together, and gently pull them away from each other. Notice the force reading on each scale.
- 4 Pull harder on the scales, and again notice the force readings on the scales.
- 5 Continue to pull on both scales, but let the scales slowly move toward your lab partner and then toward you at a constant speed.



### Think About This

1. Identify the directions of the forces on each scale. Record this information in your Science Journal.
2.  **Key Concept** Describe the relationship you noticed between the force readings on the two scales.



**Figure 20** When the skater pushes against the wall, the wall applies a force to the skater that pushes him away from the wall.

## Opposite Forces

Have you ever been on in-line skates and pushed against a wall? When you pushed against the wall, like the boy is doing in **Figure 20**, you started moving away from it. What force caused you to move?

You might think the force of the muscles in your hands moved you away from the wall. But think about the direction of your push. You pushed against the wall in the opposite direction from your movement. It might be hard to imagine, but when you pushed against the wall, the wall pushed back in the opposite direction. The push of the wall caused you to accelerate away from the wall. When an object applies a force on another object, the second object applies a force of the same strength on the first object, but the force is in the opposite direction.




**Reading Check** When you are standing, you push on the floor, and the floor pushes on you. How do the directions and strengths of these forces compare?




## Newton's Third Law of Motion

Newton's first two laws of motion describe the effects of balanced and unbalanced forces on one object. Newton's third law relates forces between two objects. According to **Newton's third law of motion**, when one object exerts a force on a second object, the second object exerts an equal force in the opposite direction on the first object. An example of forces described by Newton's third law is shown in **Figure 21**. When the gymnast pushes against the vault, the vault pushes back against the gymnast. Notice that the lengths of the force arrows are the same, but the directions are opposite.

 **Key Concept Check** What is Newton's third law of motion?

### Force Pairs

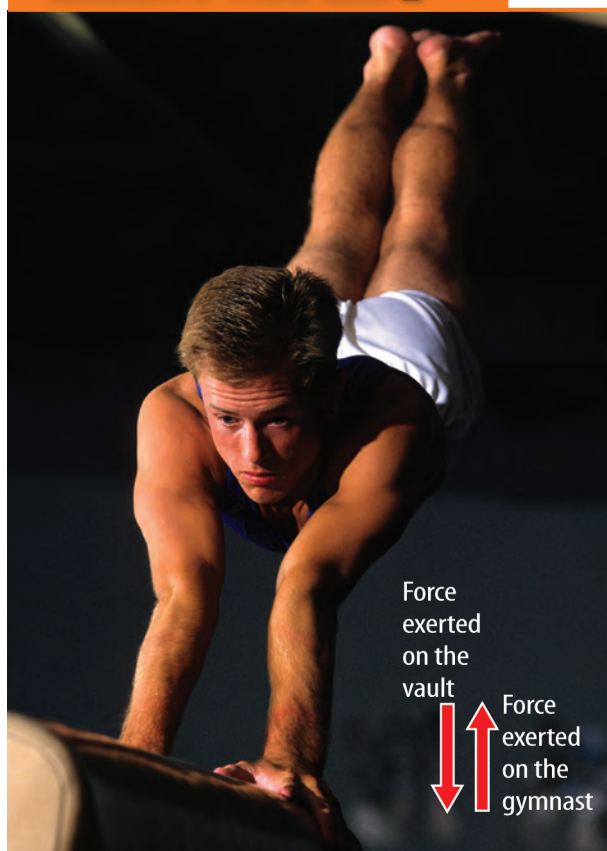
The forces described by Newton's third law depend on each other. A **force pair** is the forces two objects apply to each other. Recall that you can add forces to calculate the net force. If the forces of a force pair always act in opposite directions and are always the same strength, why don't they cancel each other? The answer is that each force acts on a different object. In **Figure 22**, the girl's feet act on the boat. The force of the boat acts on the girl's feet. The forces do not result in a net force of zero because they act on different objects. Adding forces can only result in a net force of zero if the forces act on the same object.

 **Key Concept Check** Why don't the forces in a force pair cancel each other?

### Action and Reaction

In a force pair, one force is called the action force. The other force is called the reaction force. The girl in **Figure 22** applies an action force against the boat. The reaction force is the force that the boat applies to the girl. For every action force, there is a reaction force that is equal in strength but opposite in direction.

## Newton's Third Law




▲ **Figure 21** The force of the vault propels the gymnast upward.

## Force Pairs



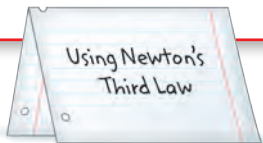
▲ **Figure 22** The force pair is the force the girl applies to the boat and the force that the boat applies to the girl.

 **Visual Check** How can you tell that the forces don't cancel each other?



## FOLDABLES®

Make a half-book from a sheet of notebook paper. Use it to summarize how Newton's third law explains the motion of a variety of common activities.



## Using Newton's Third Law of Motion

When you push against an object, the force you apply is called the action force. The object then pushes back against you. The force applied by the object is called the reaction force. According to Newton's second law of motion, when the reaction force results in an unbalanced force, there is a net force, and the object accelerates. As shown in **Figure 23**, Newton's third law explains how you can swim and jump. It also explains how rockets can be launched into space.



**Reading Check** How does Newton's third law apply to the motion of a bouncing ball?

## Action and Reaction Forces

**Figure 23** Every action force has a reaction force in the opposite direction.



◀ **Swimming** When you swim, you push your arms against the water in the pool. The water in the pool pushes back on you in the opposite (forward) direction. If your arms push the water back with enough force, the reaction force of the water on your body is greater than the force of fluid friction. The net force is forward. You accelerate in the direction of the net force and swim forward through the water.

▶ **Jumping** When you jump, you push down on the ground, and the ground pushes up on you. The upward force of the ground combines with the downward force of gravity to form the net force acting on you. If you push down hard enough, the upward reaction force is greater than the downward force of gravity. The net force is upward. According to Newton's second law, your acceleration is in the same direction as the net force, so you accelerate upward.



◀ **Rocket Motion** The burning fuel in a rocket engine produces a hot gas. The engine pushes the hot gas out in a downward direction. The gas pushes upward on the engine. When the upward force of the gas pushing on the engine becomes greater than the downward force of gravity on the rocket, the net force is in the upward direction. The rocket then accelerates upward.



**Visual Check** On what part of the swimmer's body does the water's reaction force push?



## Momentum

Because action and reaction forces do not cancel each other, they can change the motion of objects. A useful way to describe changes in velocity is by describing momentum. **Momentum** is a measure of how hard it is to stop a moving object. It is the product of an object's mass and velocity. An object's momentum is in the same direction as its velocity.

### Momentum Equation

**momentum** (in kg·m/s) = **mass** (in kg) × **velocity** (in m/s)

$$p = m \times v$$

If a large truck and a car move at the same speed, the truck is harder to stop. Because it has more mass, it has more momentum. If cars of equal mass move at different speeds, the faster car has more momentum and is harder to stop.

Newton's first two laws relate to momentum. According to Newton's first law, if the net force on an object is zero, its velocity does not change. This means its momentum does not change. Newton's second law states that the net force on an object is the product of its mass and its change in velocity. Because momentum is the product of mass and velocity, the force on an object equals its change in momentum.

### WORD ORIGIN

**momentum**

from Latin *momentum*, means "movement, impulse"

### Math Skills



### Finding Momentum

**Solve for Momentum** What is the momentum of a 12-kg bicycle moving at 5.5 m/s?

- This is what you know:**  
mass:  $m = 12 \text{ kg}$   
velocity:  $v = 5.5 \text{ m/s}$
- This is what you need to find:** momentum:  $p$
- Use this formula:**  $p = m \times v$
- Substitute:**  $p = 12 \text{ kg} \times 5.5 \text{ m/s} = 66 \text{ kg}\cdot\text{m/s}$   
the values for  $m$  and  $v$   
into the formula and multiply.

**Answer:** The momentum of the bicycle is 66 kg·m/s in the direction of the velocity.

### Practice

- What is the momentum of a 1.5-kg ball rolling at 3.0 m/s?
- A 55-kg woman has a momentum of 220 kg·m/s. What is her velocity?



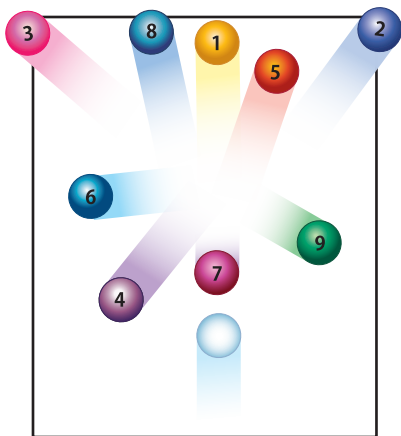
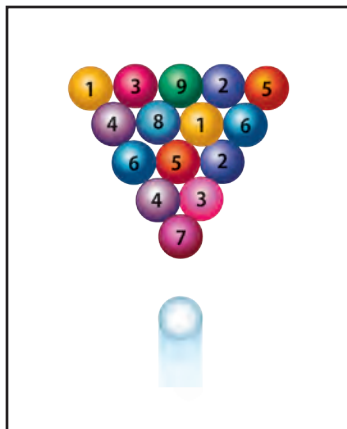
Math Practice



Personal Tutor







**Figure 24** The total momentum of all the balls is the same before and after the collision.

## Conservation of Momentum

You might have noticed that if a moving ball hits another ball that is not moving, the motion of both balls changes. The cue ball in **Figure 24** has momentum because it has mass and is moving. When it hits the other balls, the cue ball's velocity and momentum decrease. Now the other balls start moving. Because these balls have mass and velocity, they also have momentum.

### The Law of Conservation of Momentum

In any collision, one object transfers momentum to another object. The billiard balls in **Figure 24** gain the momentum lost by the cue ball. The total momentum, however, does not change. According to the **law of conservation of momentum**, the total momentum of a group of objects stays the same unless outside forces act on the objects. Outside forces include friction. Friction between the balls and the billiard table decreases their velocities, and they lose momentum.



**Key Concept Check** What is the law of conservation of momentum?

### Types of Collisions

Objects collide with each other in different ways. When colliding objects bounce off each other, it is an elastic collision. If objects collide and stick together, such as when one football player tackles another, the collision is inelastic. No matter the type of collision, the total momentum will be the same before and after the collision.



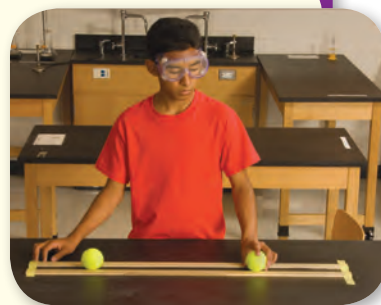
## MiniLab

15 minutes

### Is momentum conserved during a collision?



- 1 Read and complete a lab safety form.
- 2 Make a track by using **masking tape** to secure two **metersticks** side by side on a table, about 4 cm apart.
- 3 Place two **tennis balls** on the track. Roll one ball against the other. Then, roll the balls at about the same speed toward each other.
- 4 Place the balls so that they touch. Observe the collision as you gently roll **another ball** against them.



### Analyze and Conclude

1. **Explain** how you know that momentum was transferred from one ball to another.
2. **Key Concept** What could you measure to show that momentum is conserved?

# Lesson 4 Review

 Online Quiz

 Virtual Lab

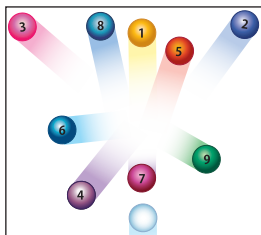
## Visual Summary



Newton's third law of motion describes the force pair between two objects.



For every action force, there is a reaction force that is equal in strength but opposite in direction.



In any collision, momentum is transferred from one object to another.

**FOLDABLES**

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

## What do you think **NOW?**

You first read the statements below at the beginning of the chapter.

- If objects collide, the object with more mass applies more force.
- Momentum is a measure of how hard it is to stop a moving object.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

## Use Vocabulary

- Define *momentum* in your own words.
- The force of a bat on a ball and the force of a ball on a bat are a(n) \_\_\_\_\_.

## Understand Key Concepts

- State Newton's third law of motion.
- A ball with momentum  $16 \text{ kg}\cdot\text{m/s}$  strikes a ball at rest. What is the total momentum of both balls after the collision?
  - $-16 \text{ kg}\cdot\text{m/s}$
  - $-8 \text{ kg}\cdot\text{m/s}$
  - $8 \text{ kg}\cdot\text{m/s}$
  - $16 \text{ kg}\cdot\text{m/s}$
- Identify A child jumps on a trampoline. The trampoline bounces her up. Why don't the forces cancel each other?

## Interpret Graphics

- Predict what will happen to the velocity and momentum of each ball when the small ball hits the heavier large ball?



- Organize Copy and fill in the table.

Event	Action Force	Reaction Force
A girl kicks a soccer ball.		
A book sits on a table.		

## Critical Thinking

- Decide How is it possible for a bicycle to have more momentum than a truck?

**Math Skills** 

 **Math Practice**

- A  $2.0\text{-kg}$  ball rolls to the right at  $3.0 \text{ m/s}$ . A  $4.0\text{-kg}$  ball rolls to the left at  $2.0 \text{ m/s}$ . What is the momentum of the system after a head-on collision of the two balls?

# Modeling Newton's Laws of Motion



## Materials



plastic lid



golf ball



modeling clay



2.5-N spring scales (2)

## Safety



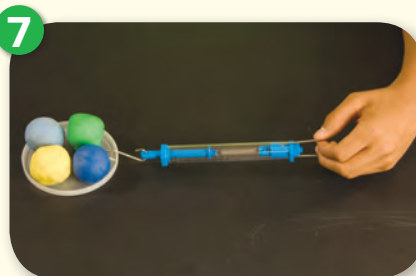
Newton's first and second laws of motion describe the relationship between unbalanced forces and motion. These laws relate to forces acting on one object. Newton's third law describes the strength and direction of force pairs. This law relates to forces on two different objects. You can learn about all three of Newton's laws of motion by modeling them.

## Question

How can you model Newton's laws of motion?

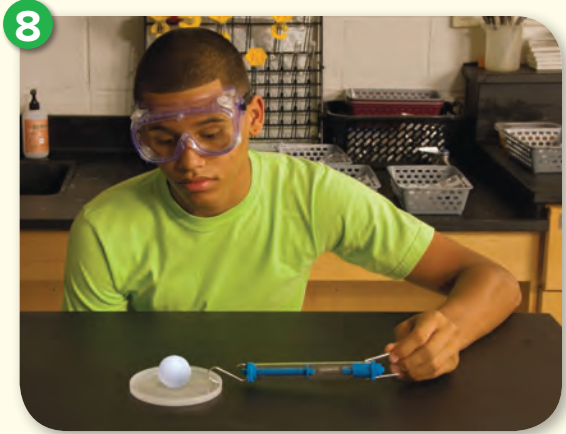
## Procedure

- 1 Read and complete a lab safety form.
- 2 Attach a spring scale to a plastic lid. Add mass to the lid by placing a ball of modeling clay on it.
- 3 Slowly pull the lid along a table with the spring scale. Record the force reading on the scale in your Science Journal.
- 4 Try to use the spring scale to pull the lid with constant force and constant speed.
- 5 Try pulling the lid with increasing force and constant speed.
- 6 Pull the lid so that it accelerates quickly.
- 7 Increase the mass of the lid by adding more modeling clay. Repeat steps 3–6.
- 8 Replace the modeling clay with a golf ball. Try pulling the lid slowly. Then, try pulling it from a standstill quickly. What happens to the ball in each case? Record your results.





- 9 To model Newton's first law of motion, design an activity using the lid and the spring scales that shows that a net force of zero does not change the motion of an object.
- 10 To model Newton's second law of motion, design an activity that shows that if the net force acting on an object is not zero, the object accelerates.
- 11 To model Newton's third law of motion, plan an activity that shows action and reaction forces on an object.
- 12 After your teacher approves your plan, perform the activities.



## Analyze and Conclude

- 13 **Identify** the variables in each of your models. Which variables changed and which remained constant?
- 14 **THE BIG IDEA** For each law of motion that you modeled, how did the force applied to the lid relate to the motion of the lid?

## Lab TIPS

- Use a smooth surface so that the lid moves easily.
- You might want to make a data table in which you can record your observations and the force readings.

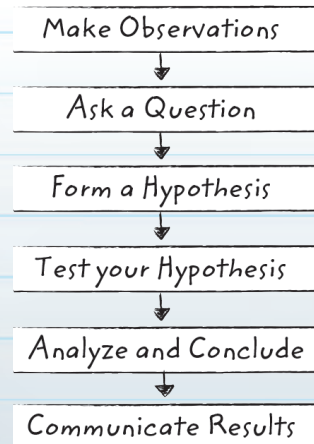
## Communicate Your Results

Choose one of the laws of motion, and model it for the class. Compare your model with the method of modeling used by other lab groups.

### Inquiry Extension

Describe another way you could model Newton's three laws of motion using materials other than those used in this lab. For example, for Newton's first law of motion, you could pedal a bicycle at a constant speed.

**Remember** to use scientific methods.





An object's motion changes if a net force acts on the object.

## Key Concepts Summary

### Lesson 1: Gravity and Friction

- Friction is a **contact force**. Magnetism is a **noncontact force**.
- The law of universal gravitation states that all objects are attracted to each other by **gravity**.
- **Friction** can stop or slow down objects sliding past each other.



## Vocabulary

**force** p. 45  
**contact force** p. 45  
**noncontact force** p. 46  
**gravity** p. 47  
**mass** p. 47  
**weight** p. 48  
**friction** p. 49

### Lesson 2: Newton's First Law

- An object's motion can only be changed by **unbalanced forces**.
- According to **Newton's first law of motion**, the motion of an object is not changed by **balanced forces** acting on it.
- **Inertia** is the tendency of an object to resist a change in its motion.



**net force** p. 55  
**balanced forces** p. 56  
**unbalanced forces** p. 56  
**Newton's first law of motion** p. 57  
**inertia** p. 58

### Lesson 3: Newton's Second Law

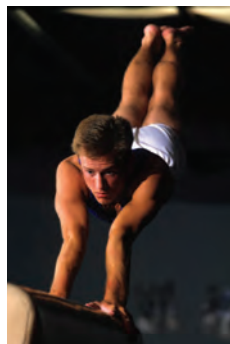
- According to **Newton's second law of motion**, an object's acceleration is the net force on the object divided by its mass.
- In **circular motion**, a **centripetal force** pulls an object toward the center of the curve.



**Newton's second law of motion** p. 65  
**circular motion** p. 66  
**centripetal force** p. 66

### Lesson 4: Newton's Third Law

- **Newton's third law of motion** states that when one object applies a force on another, the second object applies an equal force in the opposite direction on the first object.
- The forces of a **force pair** do not cancel because they act on different objects.
- According to the **law of conservation of momentum**, momentum is conserved during a collision unless an outside force acts on the colliding objects.



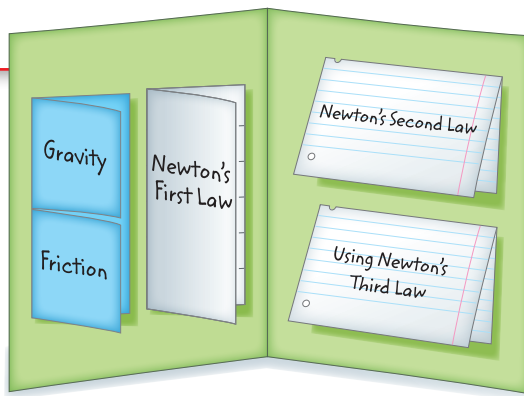
**Newton's third law of motion** p. 71  
**force pair** p. 71  
**momentum** p. 73  
**law of conservation of momentum** p. 74



## FOLDABLES®

### Chapter Project

Assemble your lesson Foldables as shown to make a Chapter Project. Use the project to review what you have learned in this chapter.



### Use Vocabulary

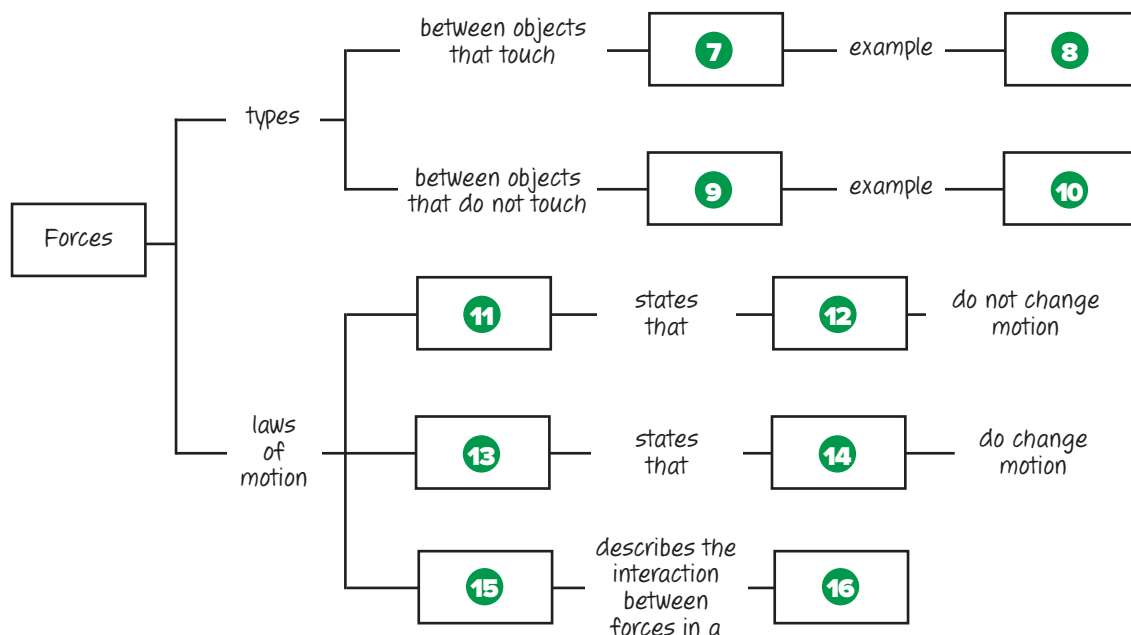
- 1 The kilogram is the SI unit for \_\_\_\_\_.
- 2 The force of gravity on an object is its \_\_\_\_\_.
- 3 The sum of all the forces on an object is the \_\_\_\_\_.
- 4 An object that has \_\_\_\_\_ acting on it acts as if there were no forces acting on it at all.
- 5 A car races around a circular track. Friction on the tires is the \_\_\_\_\_ that acts toward the center of the circle and keeps the car on the circular path.
- 6 A heavy train requires nearly a mile to come to a complete stop because it has a lot of \_\_\_\_\_.

### Link Vocabulary and Key Concepts



### Interactive Concept Map

Copy this concept map, and then use vocabulary terms from the previous page to complete the concept map.

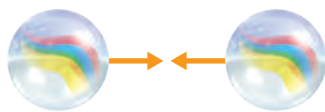




# Chapter 2 Review

## Understand Key Concepts

- 1 The arrows in the figure represent the gravitational force between marbles that have equal mass.



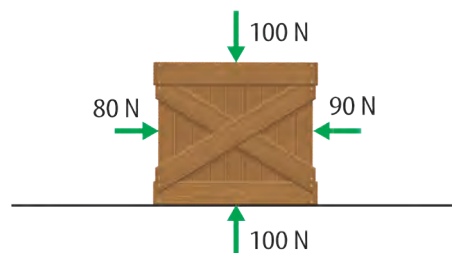
How should the force arrows look if a marble that has greater mass replaces one of these marbles?

- A. Both arrows should be drawn longer.
  - B. Both arrows should stay the same length.
  - C. The arrow from the marble with less mass should be longer than the other arrow.
  - D. The arrow from the marble with less mass should be shorter than the other arrow.
- 2 A person accelerates a box across a flat table with a force less than the weight of the box. Which force is weakest?
- A. the force of gravity on the box
  - B. the force of the table on the box
  - C. the applied force against the box
  - D. the sliding friction against the box
- 3 A train moves at a constant speed on a straight track. Which statement is true?
- A. No horizontal forces act on the train as it moves.
  - B. The train moves only because of its inertia.
  - C. The forces of the train's engine balances friction.
  - D. An unbalanced force keeps the train moving.
- 4 The Moon orbits Earth in a nearly circular orbit. What is the centripetal force?
- A. the push of the Moon on Earth
  - B. the outward force on the Moon
  - C. the Moon's inertia as it orbits Earth
  - D. Earth's gravitational pull on the Moon

- 5 A 30-kg television sits on a table. The acceleration due to gravity is  $10 \text{ m/s}^2$ . What force does the table exert on the television?

- A. 0.3 N
  - B. 3 N
  - C. 300 N
  - D. 600 N
- 6 Which does NOT describe a force pair?
- A. When you push on a bike's brakes, the friction between the tires and the road increases.
  - B. When a diver jumps off a diving board, the board pushes the diver up.
  - C. When an ice skater pushes off a wall, the wall pushes the skater away from the wall.
  - D. When a boy pulls a toy wagon, the wagon pulls back on the boy.

- 7 A box on a table has these forces acting on it.



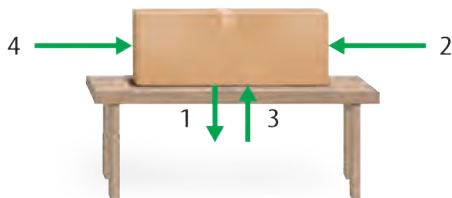
What is the static friction between the box and the table?

- A. 0 N
  - B. 10 N
  - C. greater than 10 N
  - D. between 0 and 10 N
- 8 A 4-kg goose swims with a velocity of  $1 \text{ m/s}$ . What is its momentum?
- A. 4 N
  - B.  $4 \text{ kg}\cdot\text{m/s}^2$
  - C.  $4 \text{ kg}\cdot\text{m/s}$
  - D.  $4 \text{ m/s}^2$



### Critical Thinking

- 9 Predict** If an astronaut moved away from Earth in the direction of the Moon, how would the gravitational force between Earth and the astronaut change? How would the gravitational force between the Moon and the astronaut change?
- 10 Analyze** A box is on a table. Two people push on the box from opposite sides. Which of the labeled forces make up a force pair? Explain your answer.



- 11 Conclude** A refrigerator has a maximum static friction force of 250 N. Sam can push the refrigerator with a force of 130 N. Amir and André can each push with a force of 65 N. How could they all move the refrigerator? Will the refrigerator move with constant velocity? Why or why not?
- 12 Give an example** of unbalanced forces acting on an object.
- 13 Infer** Two skaters stand on ice. One weighs 250 N, and the other weighs 500 N. They push against each other and move in opposite directions. Describe the momentum of each skater after they push away from each other.

### Writing in Science

- 14** Imagine that you are an auto designer. Your job is to design brakes for different automobiles. Write a four-sentence plan that explains what you need to consider about momentum when designing brakes for a heavy truck, a light truck, a small car, and a van.

### REVIEW



- 15** Explain how balanced and unbalanced forces affect objects that are not moving and those that are moving.
- 16** The photo below shows people on a carnival swing ride. How do forces change the motion of the riders?



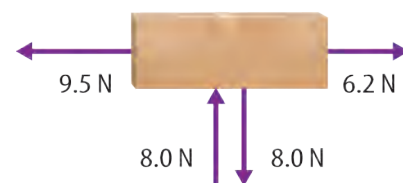
### Math Skills



### Math Practice

#### Solve One-Step Equations

- 17** A net force of 17 N is applied to an object, giving it an acceleration of  $2.5 \text{ m/s}^2$ . What is the mass of the object?
- 18** A tennis ball's mass is about 0.60 kg. Its velocity is 2.5 m/s. What is the momentum of the ball?
- 19** A box with a mass of 0.82 kg has these forces acting on it.



What is the strength and direction of the acceleration of the box?

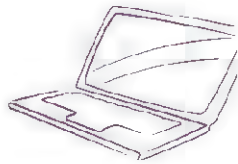
## Cracking Up

*Late one evening, your neighbor, Farmer Steve, calls you. He is completely frustrated about his chickens and their eggs. Steve explains that the eggs keep falling out of the nest and hitting the floor of the chicken coop. He's losing dozens of eggs a week!*

*He says that he decided to call you since you are an engineer and maybe you can design a solution to help with his problem.*

*The next day at work, you explain the problem to your team. The team decides that it's a simple matter of Newton's third law of motion. They agree to take on the challenge.*

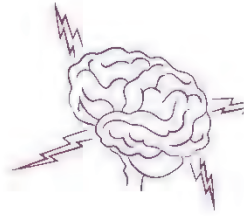
### Get Started!



- Review Newton's Third Law of motion. What aspects of the law do you need to account for with this design solution?
- Your design must conform to the following criteria and constraints.
  - Your design must keep at least three out of five eggs from breaking when dropped.
  - Your design cannot pad the eggs in any way.
  - You can use only two types of padding materials.
  - The area of the surface onto which you will drop the eggs will be 20 cm by 20 cm.
  - The height from which you will drop the eggs will be 1 m.
  - The impact-absorption materials cannot be more than 5 cm in thickness.



## Brainstorm Solutions!



- Examine the materials available to you. Which materials will you choose to meet your goal?
- You will be able to conduct one test to observe the effectiveness of your initial design. If needed, you can make modifications to complete your final design.
- Plan your design and how you will test it. Consider the points below as you work.
  - What variables must you consider in your design? Explain your reasoning.
  - In addition to the materials in your design, what other materials will you need to complete this task?
  - What data do you need to record?
  - How will you evaluate your results?

## Work Through It!



- Construct your design according to your plan.
- Line your work area with plastic and newspaper before you begin testing.

- Test your design with one of the raw eggs.
- Based on your results, make any changes to your design that you think are necessary.
- Once you have finalized your design, test five more raw eggs.
- Record your observations.

## Finish Up!



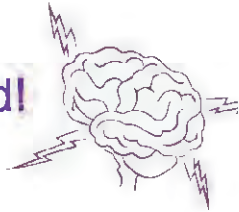
- Based on your test results, do you think your design would serve as a solution for Farmer Steve? Why or why not?
- How could you improve your design?
- Make a sketch of your final design for Farmer Steve. Be sure to include notes and details that explain the design and how it will keep eggs that fall onto the floor of the chicken coop from breaking.

# Putting the Shot in Motion

*The shot put is a track-and-field event. Athletes throw, or put, a heavy, round sphere called a shot. The athlete who puts the shot the greatest distance wins the event.*

*A new track-and-field coach has asked you to help him understand the science behind the shot put. He is coaching the women's and men's high-school teams at your school. To help him, your group must investigate how an object's motion depends on both the mass and the sum of the forces on an object.*

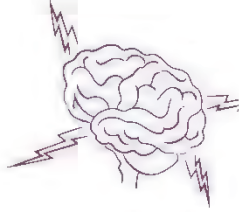
## Get Started!



- Begin your task by reviewing Newton's first and second laws of motion. As you begin to think about the investigation, identify the parts of the law of motions will you need to utilize.
- Research the shot put to learn the aspects of the event. A few topics to consider are listed below.
  - How far do a typical woman and a typical man put the shot?
  - What mass of shot does a high-school woman put?
  - What mass of shot does a high-school man put?
  - Where does a shot-put event take place?  
On grass? On a track?



## Brainstorm Solutions!



- Brainstorm with your group how you will plan your investigation.
- As you begin to plan your investigation, consider these points:
  - What will be your independent and dependent variables? What will act as your control?
  - Is there more than one factor to test? If so, how will you test each factor?
  - Will you use actual shots or will you use a model?
  - What tools are needed to gather data?
  - How will you measure your data?
  - How many data do you need to support your results?
- Write your investigation that will provide evidence about the factors that affect the motion of the shots.

## Work Through It!



- To help with your investigation, the coach has offered to allow his athletes to help you carry out your investigation.

- Instruct the athletes about your investigation's procedure. Be sure that they put the shot according to your plan.
- Collect and record your data.
- As the investigation occurs, do you notice changes that need to be made? If so, rewrite your plan and test again.

## Finish Up!



- Analyze your results collected from your investigation.
  - How does your investigation address changes in the shot's motion when the mass changes?
  - How does your investigation address changes in the shot's motion when the forces on the shot change?
- Write a report to submit to the coach to explain your findings. Be sure to relate your explanation to Newton's laws of motion.
  - Include an explanation of what happens to the shot if the force exerted is changed.
  - Include an explanation of how changing the mass of the shot affects the results.
  - Are there other factors the coach should consider related to shot put besides

force and mass? If so, explain how to account for these effects.

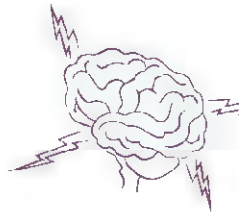


# Gravity: It's Attractive!

*Have you ever wondered why humans, elephants, and other objects on Earth don't float off into space? Sir Isaac Newton described an attractive force that exists between all objects—gravity. He concluded that the strength of gravity depends on the mass of each object and the distance between them.*

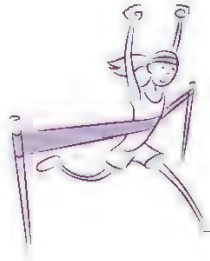
*Your team will be given two spheres and a distance. Each team will present to the class an argument on how the masses of and distance between the objects impact the strength of gravity.*

## Get Started!



- Review how mass and distance affect the strength of gravity between two objects.
- Each team will select two spheres of different masses from a “grab bag” and a distance from another “grab bag.”
- Your team will work together to produce an explanation describing the gravitational interactions between the objects.
- Repeat the process with either one new sphere or a new distance. Discuss the outcome produced by your change.
- Your team should construct two claims based on the evidence from your trials. One claim should explain how mass affects gravity. The other claim should explain how distance affects gravity.

## Finish Up!



- Prepare a 2- to 3-minute presentation of your argument to present your class. Some things to think about as you prepare your presentation:
  - How do you explain the effect of mass on the gravitational force between objects? The effect of distance on the gravitational force between objects?
  - Are your arguments supported by enough evidence? Explain.
- As you listen to your classmates' presentations, take notes on their arguments. Are there details of their arguments you agree or disagree with? Explain.

**GRADE 6**

- Unit 1 Motion and Energy
  - Unit 2 Exploring Earth
  - Unit 3 Exploring the Universe
  - Unit 4 Understanding Matter
  - Unit 5 Exploring Life
- 

**GRADE 7**

- Unit 1 Energy and Matter
  - Unit 2 Earth: A Dynamic Planet
  - Unit 3 Life: Structure and Function
  - Unit 4 Heredity and Changes Over Time
  - Unit 5 Exploring Ecology
- 

**GRADE 8**

- Unit 1 Interactions of Matter
  - Unit 2 Earth and Geological Changes
  - Unit 3 Water and Other Resources
  - Unit 4 Life: Changes and Interactions
- 

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