The Laws of Motion

Gravity and Friction

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

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

Read to Learn

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

You have probably seen a musician strike the keys of a piano or an athlete hit a ball with a bat. In these cases, the person or object applies a force to an object that it touches. *A* **contact force** *is a push or a pull on one object by another that is touching it*.

Contact forces can be weak. When you press the keys on a computer keyboard, the contact force is weak. Contact forces can also be strong. The plates, or rock slabs, that make up Earth's crust can apply strong contact forces against each other. Over long periods of time, these forces can be strong enough to form mountain ranges if one plate pushes another plate upward.

Key Concepts

- 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?

Mark the Text

Building Vocabulary As you read this lesson, underline each key term about the laws of motion. Then highlight information about each term to help you review the lesson later.

Think it Over

1. Describe Give an example of a force.

Noncontact Forces

When you drop an object, it falls toward the floor. This downward force occurs even though nothing is touching the object. *A force that one object can apply to another object without touching it is a* **noncontact force.** Gravity, which pulls on objects, is a noncontact force. The magnetic force, which attracts certain metals to magnets, is also a noncontact force. The electric force is another noncontact force.

Key Concept Check

2. Identify What are some contact forces and some noncontact forces?

Strength and Direction of Forces

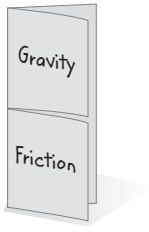
Forces have both strength and direction. If you push your textbook away from you, it probably slides across the desk. What happens if you push down on your book? It probably does not move. You can use the same strength of force in both cases. Different things happen each time because the direction of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

Arrows can be used to show forces. The length of an arrow shows the strength of the force. A longer arrow indicates a stronger force than a shorter arrow. The direction that an arrow points shows the direction in which the force was applied.

Force is measured in newtons (N). When you lift a stick of butter, you apply about 1 N of force. When you lift a 2-L bottle of water, you apply about 20 N of force. If you use arrows to show these forces, the water's arrow would be 20 times longer than the butter's arrow.

FOLDABLES®

Use a two-tab book to organize your notes on gravity and friction.



What is gravity?

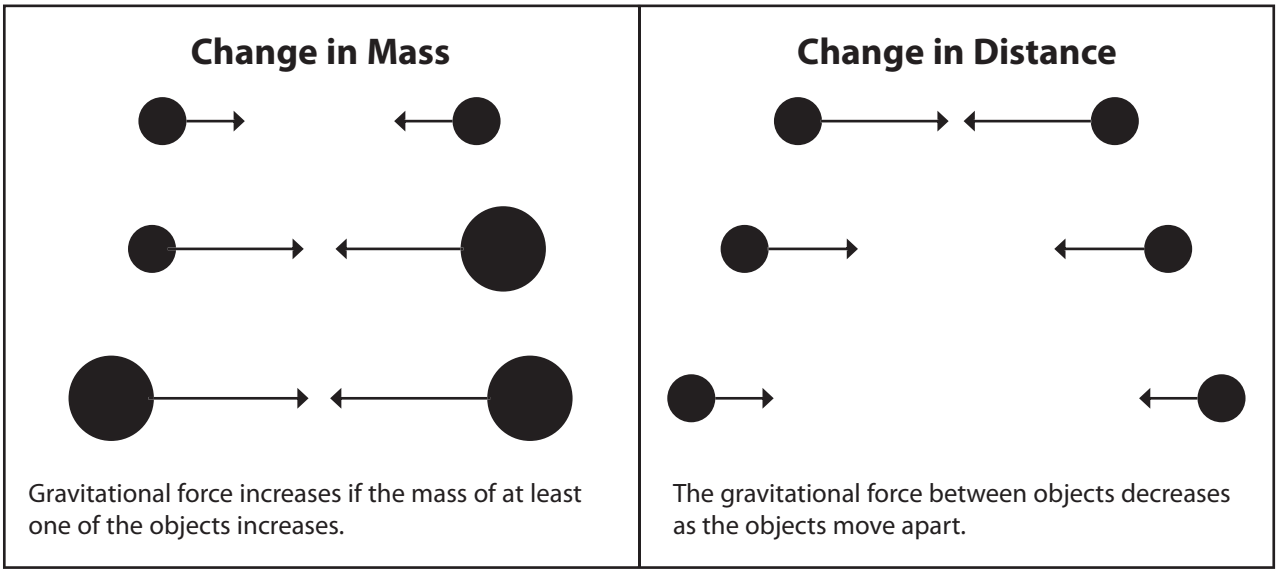
Objects fall to the ground because Earth exerts an attractive force on them. You also exert an attractive force on objects. **Gravity** *is an attractive force that exists between all objects that have mass*. **Mass** *is the amount of matter in an object*. Mass is often measured in kilograms (kg).

The Law of Universal Gravitation

In the late 1600s, an English scientist and mathematician, Sir Isaac Newton, developed the law of universal gravitation. The law of universal gravitation 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

3. Identify What is the law of universal gravitation?



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

Gravitational Force and Distance The effect of distance on gravity is shown above on the right. 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.

Weight—A Gravitational Force

Earth has more mass than any object near you. As a result, the gravitational force that 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.

Visual Check

4. Interpret How does the gravitational force between objects change if one object increases in mass but the other does not increase?

Reading Check

5. Explain What effect does distance have on gravity?

Reading Check

6. Describe What is the relationship between mass and weight?

ACADEMIC VOCABULARY
significant
(adjective) important, momentous

Weight and Mass High Above Earth Astronauts in orbit around Earth are not weightless. Their weight is about 90 percent of what it is on Earth. 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 before the gravitational force will change much. The distance between the astronaut and Earth is small compared to the size of Earth.

Reading Check

7. Explain Why is the gravitational force that a friend exerts on you less than the gravitational force exerted on you by Earth?

Friction

Friction *is a force that resists the motion of two surfaces that are touching*. There are several types of friction.

Static Friction

Static friction prevents surfaces from sliding past each other. The box on the left below does not move because the strength of the static friction is equal to the force a person is applying to the box. Up to a limit, the strength of static friction changes to match the applied force. If the person increases the applied force, the static friction will also increase. The box still will not move.

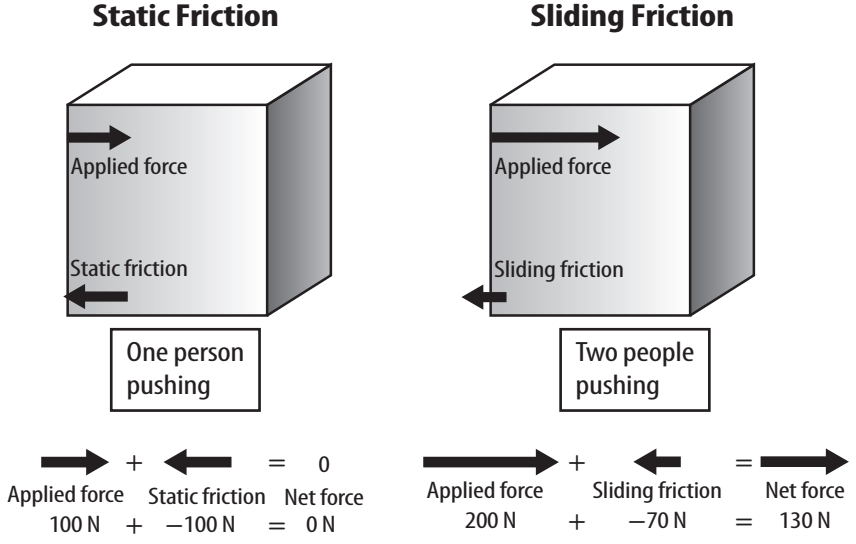
When static friction reaches its limit between the surfaces, the box will move. The box on the right below moves because the two people are pushing with greater force than the static friction between the box and the floor.

Sliding Friction

Sliding friction opposes the motion of surfaces sliding past each other. As long as the box is sliding, the sliding friction does not change. If the pushing force increases, the box will slide faster. If the two people stop pushing, sliding friction will cause the box to slow down and stop.

Visual Check

8. Visualize Do frictional forces act in the same direction or in the opposite direction to the applied force?



Fluid Friction

Fluid friction is friction between a surface and a fluid. A fluid is any material that flows. For example, water and air are fluids. Fluid friction between air and a surface is air resistance.

The amount of fluid friction on an object depends on the amount of surface area that faces the oncoming fluid. The greater the facing surface area, the greater the fluid friction is on the object. Imagine that you drop a crumpled paper and a flat paper. The crumpled paper will fall faster than the flat paper because the crumpled paper has less surface area facing the oncoming air. The crumpled paper has less air resistance than the flat paper.

What causes friction?

If you rub your hands together when they are soapy, they will slide past each other easily. If you rub your hands together when they are dry, you will feel more friction. Your dry hands will not slide past each other as easily as when they are soapy.

What causes friction between surfaces? Microscopic dips and bumps cover all surfaces. The dips and bumps on one surface catch on the dips and bumps on the other surface when they slide past each other. This microscopic roughness slows sliding and is a source of friction.

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, there is attraction between the particles. This attraction slows sliding and is another source of friction between the surfaces.

Reducing Friction

Soap acts as a lubricant. When you rub soapy hands together, the soapy water slightly separates the surfaces of your hands. This creates less contact between the microscopic dips and bumps and between the electrical charges of your hands. Friction decreases with less contact.

Like soap on your hands, motor oil also acts as a lubricant. It reduces friction between the moving parts of a car's engine. With less friction, surfaces can slide past each other more easily. Reducing an object's surface area also reduces the fluid friction between the object and the fluid.

Think it Over

9. Specify How can fluid friction be decreased?

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Key Concept Check

10. Describe How does friction affect the motion of two objects sliding past each other?

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Reading Check

11. Identify What are two causes of friction?

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Mini Glossary

contact force: a push or a pull on one object by another that is touching it

force: a push or a pull on an object

friction: a force that resists the motion of two surfaces that are touching

gravity: an attractive force that exists between all objects that have mass

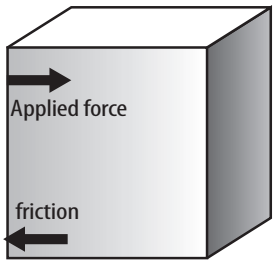
mass: the amount of matter in an object

noncontact force: a force that one object can apply to another object without touching it

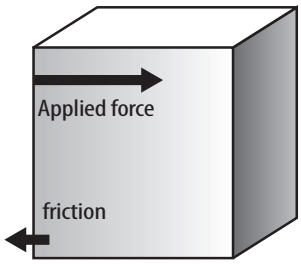
weight: the gravitational force exerted on an object

1. Review the terms and their definitions in the Mini Glossary. Write a sentence comparing contact forces and noncontact forces.

2. Label each of the diagrams below with the type of friction that is represented.



One person pushing



Two people pushing

3. Give an example of something you could do to reduce friction.

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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END OF LESSON

The Laws of Motion

Newton's First Law

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

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

Read to Learn

Identifying Forces

Imagine a bird of prey that lives near a lake. It dives through the air at a high speed toward a fish swimming in the water. It moves its legs forward to grab the fish with its talons. It then uses its wings to climb high into the air. The bird then slows its speed and lands softly on the edge of the nest, near the young birds waiting for it.

Forces helped the bird change speed and direction. Recall that a force is a push or a pull. Some forces are contact forces, such as air resistance. Other forces are noncontact forces, such as gravity. When an object moves, it often has several different forces acting on it at the same time. 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.

Combining Forces—The Net Force

Imagine that you are trying to move a piece of heavy furniture. If you push on it by yourself, you will have to push hard to get it to move. But 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 direction of the forces applied to the object.

Key Concepts

- 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?

Mark the Text

Underline Main Ideas As you read, underline the main ideas under each heading. After you finish reading, review the main ideas that you have underlined.

Think it Over

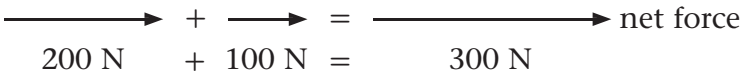
1. Analyze When a soccer ball is in flight, what forces are acting on it?

Combining Forces in the Same Direction

When the forces acting on an object are in the same direction, the net force is the sum of the individual forces. The direction of the net force is the same direction as the forces you add together.

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

Because forces have direction, you have to specify a reference direction when you combine forces. For example, if two people are pushing on a dresser from the left side, you would probably choose "to the right" as the reference direction. Both forces would then be positive. One person pushes the dresser with a force of 200 N to the right. The other person pushes with a force of 100 N to the right. To calculate the net force, add the two forces together, as shown below. The net force is 300 N to the right.



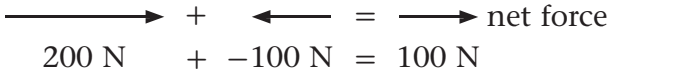
The force exerted on the dresser is the same as if one person pushed on the dresser with a force of 300 N to the right.

Reading Check

2. Describe How do you calculate the net force on an object if two forces are acting on it in the same direction?

Combining Forces in Opposite Directions

When forces act in opposite directions on an object, the net force is still the sum of the forces. Imagine that two people push on a dresser in opposite directions. One pushes with a force of 200 N to the right. The other person pushes with a force of 100 N to the left. You choose "to the right" as the reference direction. A force in that direction, then, is positive. A force in the opposite direction is negative. The net force is the sum of the positive and negative forces, as shown below. The net force is 100 N to the right.

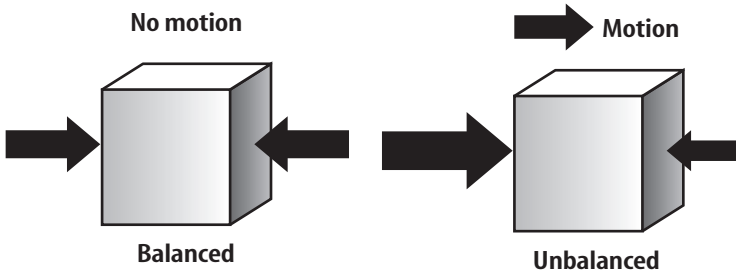


Balanced and Unbalanced Forces

If two people push in opposite directions, but with the same amount of force, the net force on the object is zero. The effect is the same as if there were no forces at all acting on the object. *Forces acting on an object that combine and form a net force of zero are* **balanced forces.** As shown in the figure on the opposite page, balanced forces do not change the motion of an object. *Forces acting on an object that combine and form a net force that is not zero are* **unbalanced forces.**

Think it Over

3. Interpret What does a negative number in the net-force equation mean?



100 N + −100 N = 0 N 200 N + −100 N = 100 N

Newton's First Law of Motion

Sir Isaac Newton studied how forces affect the motion of objects. He developed three rules that are 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.

Balanced Forces and Motion

According to Newton's first law of motion, balanced forces cause no change in the motion of an object. This is true when an object is at rest or in motion. A dresser is at rest before anyone pushes on it. It remains at rest when balanced forces are applied.

Both gravity and air resistance act on the motion of a parachutist. Gravity pulls the parachutist toward the ground. Air resistance against the parachute slows the fall. When the air resistance and gravity on the parachutist are balanced, the parachutist moves downward with a constant velocity known as terminal velocity. Recall that velocity is the speed and the direction of motion. Terminal velocity is the constant velocity reached when air resistance equals the force of gravity on a falling object.

Unbalanced Forces and Motion

Newton's first law of motion applies only to balanced forces acting on an object. When unbalanced forces act on an object, the object's velocity changes. If an object is at rest, unbalanced forces cause it to start moving. If an object is already moving, unbalanced forces cause its velocity to change.

Visual Check

4. Evaluate Why doesn't the box on the left move?

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Key Concept Check

5. Define What is Newton's first law of motion?

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_____

Key Concept Check

6. Explain How is motion related to balanced and unbalanced forces?

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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 a crash-test dummy. Before a crash, the car and the dummy move with constant velocity. If no other force acts on them, the car and the dummy continue to move with constant velocity because of inertia. The car crashing into a wall results in an unbalanced force on the car, and the car stops. The dummy continues moving forward because of its inertia.

Key Concept Check

7. Summarize What effect does inertia have on the motion of an object?

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.

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 continuously applied. Objects stop moving because friction or another force acts on them.

Think it Over

8. Apply Why does a rolling ball eventually stop rolling?

FOLDABLES®

Make a chart with six columns and six rows to define and show how this lesson's vocabulary words are related.

Mini Glossary

balanced forces: forces acting on an object that combine and form a net force of zero

inertia (ihn UR shuh): the tendency of an object to resist a change in its motion

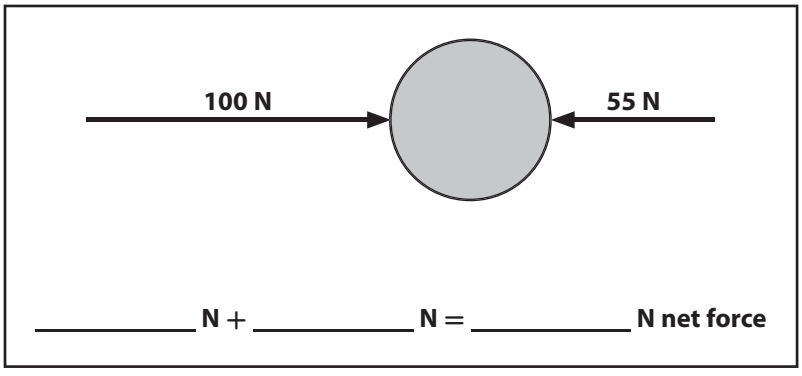
net force: the combination of all the forces acting on an object

Newton's first law of motion: the law that states that if the net force on an object is zero, the motion of the object does not change

unbalanced forces: forces acting on an object that combine and form a net force that is not zero

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains how balanced forces affect an object at rest.

2. Use the information in the diagram to complete the equation and determine the net force on the object. The reference direction is "to the right."



3. How did underlining the main ideas help you review Newton's first law of motion?

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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END OF LESSON

The Laws of Motion

Newton's Second Law

Key Concepts

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

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	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.	

Study Coach

Create a Quiz As you read this lesson, write quiz questions based on what you have read under each heading. After you finish reading, answer the quiz questions.

Read to Learn

How do forces change motion?

Forces can change an object's motion in different ways. When you pedal a bicycle, the force of your foot on the pedal causes the wheels of the bicycle to turn. Increasing the force causes the wheels to turn faster and increases the speed of the bicycle. Imagine that you are pushing a wheelbarrow. You can change the wheelbarrow's direction by pushing it in the direction you want it to move. Forces change an object's motion by changing its speed of motion, its direction of motion, or both its speed and its direction of motion.

Unbalanced Forces and Velocity

Velocity is the speed of an object in a certain direction. Only unbalanced forces change an object's velocity. A bicycle's speed will not increase unless the force of the person's foot on the pedal is greater than friction that slows the wheels. 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 this lesson, you will read about how unbalanced forces affect the velocity of an object.

Think it Over

1. Identify Name three ways that forces can change the motion of an object.

Unbalanced Forces on an Object at Rest

Unbalanced forces affect an object at rest. If you hold a ball in your hand, the ball does not move. Your hand holds the ball up against the downward pull of gravity. The forces acting on the ball are balanced. When your hand moves out of the way, the ball falls. 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

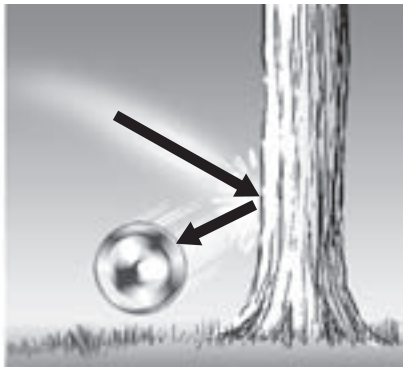
Unbalanced forces change the velocity of an object that is moving. Recall that one way to change an object's velocity is to change its speed.

Speeding Up If a net force acts on a moving object in the direction that the object is moving, the object will speed up. For example, imagine that you are pushing someone on a sled. If you push in the direction that the sled is already moving, the sled will speed up.

Slowing Down If the direction of the net force on an object is opposite to the direction the object is moving, the object will slow down. If you are riding on a sled and push your foot against the ground, friction acts in the direction opposite to the motion of the sled. Because the net force is in the direction opposite to the sled's motion, the sled's speed decreases.

Changes in Direction of Motion

Unbalanced forces can also change an object's velocity by changing its direction. The ball shown in the figure moves at a constant velocity until it hits the tree. The tree exerts a force on the ball, which makes the ball change direction.



Think it Over

2. Predict What will happen to an object at rest if unbalanced forces act upon it?

Think it Over

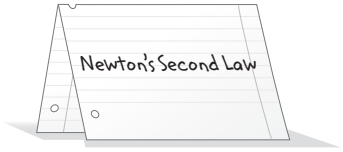
3. Apply What will happen to the speed of a wagon rolling to the right if a net force pushes it to the right?

Visual Check

4. Interpret Why does the velocity of the ball change when it hits the tree?

FOLDABLES®

Make a half-book to organize your notes on Newton's second law.



Key Concept Check

5. Define What is Newton's second law of motion?

Math Skills

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

mass: $m = 0.5$ kg

force: $F = 10$ N or 10 kg•m/s^2

acceleration: a

Use this formula: $a = \frac{F}{m}$

Substitute the values for F and m into the formula and divide:

$$a = \frac{10\text{ N}}{0.5\text{ kg}} = \frac{20\text{ kg•m/s}^2}{\text{kg}} = 20\text{ m/s}^2$$

Acceleration = 20 m/s^2

6. Solve for Force

A 24-N net force acts on an 8-kg rock. What is the acceleration of the rock?

Unbalanced Forces and Acceleration

You have read how unbalanced forces can change an object's velocity by changing its speed, its direction, or both. Recall that another name for a change in velocity over time is acceleration. When you push a sled forward, the sled accelerates because its speed changes. When the soccer ball in the figure hit the tree, the ball accelerated because its direction changed. Unbalanced forces can make an object accelerate by changing its speed, its direction, or both.

Newton's Second Law of Motion

Newton's second law of motion describes the relationship between an object's acceleration and the net force that acts on the 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.

Newton's Second Law Equation

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

$$a = \frac{F}{m}$$

SI units are included in the equation. Acceleration is expressed in meters per second squared (m/s^2), mass in kilograms (kg), and force in newtons (N). From this equation, it follows that a newton is the same as kg•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 learned how this relationship applies to motion along a line. **Circular motion** *is any motion in which an object is moving along a curved path.* Velocity and acceleration also apply to centripetal force.

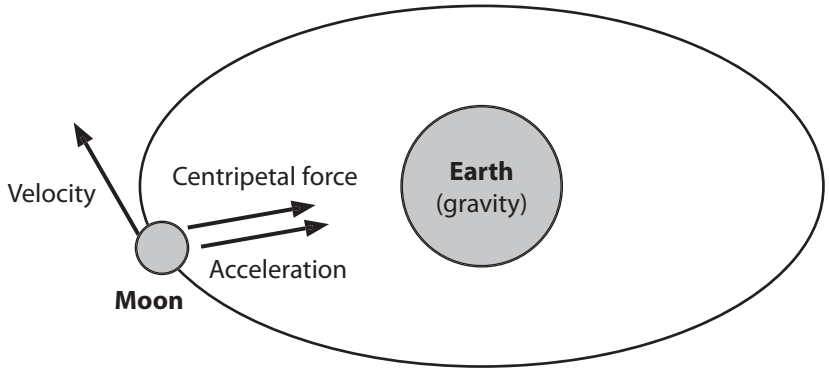
Centripetal Force

You can tie a string to a ball and swing it around above your head. The ball has a tendency to move along a straight path. Inertia—not a force—causes this motion. The ball's path is curved, however, 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 ball accelerates in the direction of the centripetal force.

The Motion of Satellites and Planets

A satellite is another object that is acted on by centripetal force. A satellite is any object in space that orbits a larger object. Like the ball described above, a satellite tends to move in 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. Look at the figure of Earth and the Moon below. The Moon is a satellite of Earth. Earth's gravity changes the Moon's direction. The inertia of the Moon and Earth's gravity determine the circular motion of the Moon's orbit around Earth. Similarly, the Sun's gravity changes the direction of its satellites, including Earth.



Key Concept Check

7. Describe How does centripetal force affect circular motion?

Think it Over

8. Explain What prevents Earth from leaving its orbit and flying out into space?

Visual Check

9. Discover How does the direction of the velocity of a satellite differ from the direction of its acceleration?

Mini Glossary

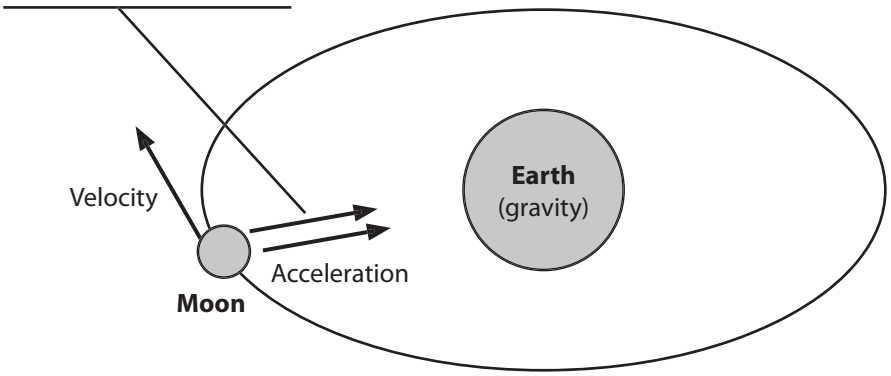
centripetal (sen TRIH puh tuhl) force: in circular motion, a force that acts perpendicular to the direction of motion, toward the center of the curve

circular motion: any motion in which an object is moving along a curved path

Newton's second law of motion: the law that states that the acceleration of an object is equal to the net force acting on the object divided by the object's mass

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes how centripetal force affects circular motion.

2. Identify the force that keeps the Moon in orbit around Earth.



3. The equation for Newton's second law of motion is $a = \frac{F}{m}$. What does each letter in this formula stand for?

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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END OF LESSON

The Laws of Motion

Newton's Third Law

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	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.	

Read to Learn

Opposite Forces

If you are wearing skates and push against a wall, you will move away from the wall. What force causes you to move? You might think that the force of your muscles moves you away from the wall. Think about the direction of your push. Your push is against the wall in the opposite direction from your movement. In fact, when you push against the wall, the wall pushes back in the opposite direction. The push of the wall causes 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.

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 a force of the same size but in the opposite direction on the first object.* An example of forces described in Newton's third law of motion is a gymnast pushing against the floor during a flip. When the gymnast applies force against the floor, the floor applies force back.

Key Concepts

- 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?

Study Coach

Outline Main Ideas As you read, make an outline to summarize the information in the lesson. Use the main headings in the lesson as the main headings in the outline. Complete the outline with the information under each heading. Review the outline to help you learn the material in this lesson.

Key Concept Check

1. Define 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 reason is that each force acts on a different object. Adding forces results in a net force of zero only if the forces act on the same object.

Key Concept Check

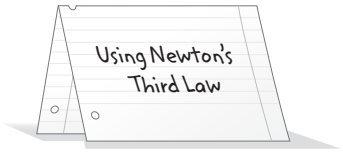
2. Explain Why don't the forces in a force pair cancel each other?

Action and Reaction

In a force pair, one force is the action force and the other is the reaction force. Swimmers diving from a boat apply an action force against the boat. The boat applies a reaction force on the swimmers. For every action force, there is a reaction force of equal strength but in the opposite direction.

FOLDABLES®

Make a half-book 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 the action force. The object then pushes back against you. The force applied by the object is the reaction force. According to Newton's second law, when the reaction force results in an unbalanced force, there is a net force, and the object accelerates. Newton's third law explains many common activities, such as those described in the table.

Action and Reaction Forces

Swimming When you push your arms against the water to swim, the water pushes back in the opposite (forward) direction. If you push with enough force, the water's reaction force becomes greater than the force of fluid friction. You accelerate in the direction of the net force and swim forward.	**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 force becomes greater than the downward force of gravity. The net force is upward, and you accelerate in the direction of the net force.	**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 upward. The rocket then accelerates upward.

Interpreting Tables

3. Specify On what part of a 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. **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. The momentum equation appears on the top of the opposite page. 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)

$$p = m \times v$$

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

Newton's Laws and 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.

Conservation of Momentum

In a game of billiards, when the moving cue ball hits a ball that is not moving, the motion of both balls changes. The cue ball has momentum because it has mass and is moving. When it hits the other ball, the cue ball's velocity and momentum decrease. The other ball starts moving. Because this ball then has mass and velocity, it also has momentum.

The Law of Conservation of Momentum

In any collision, momentum transfers from one object to another. The billiard ball gains 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.

Types of Collisions

Objects collide with each other in different ways. When colliding objects bounce off each other, an elastic collision occurs. 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.

Math Skills

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

mass: $m = 12$ kg

velocity: $v = 5.5$ m/s

momentum: p

Use this formula:

$$p = m \times v$$

Substitute the values for m and v into the formula and multiply:

$$p = 12 \text{ kg} \times 5.5 \text{ m/s}$$
$$= 66 \text{ kg•m/s}$$

Momentum = 66 kg•m/s in the direction of the velocity.

4. Solve for Momentum
What is the momentum of a 1.5-kg ball rolling at 3.0 m/s?

Key Concept Check

5. Define What is the law of conservation of momentum?

Mini Glossary

force pair: the forces two objects apply to each other

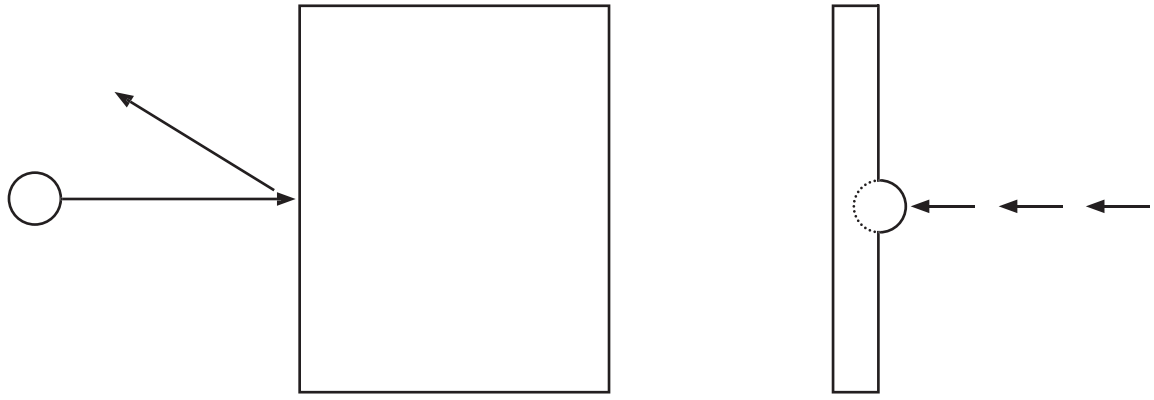
law of conservation of momentum: the law that states that the total momentum of a group of objects stays the same unless outside forces act on the objects

momentum: a measure of how hard it is to stop a moving object

Newton's third law of motion: the law that states that when one object exerts a force on a second object, the second object exerts a force of the same size but in the opposite direction on the first object

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that summarizes Newton's third law of motion in your own words.

2. Circle the diagram below that shows an example of an inelastic collision.



3. If a tennis ball and a bowling ball are rolling at the same speed, which ball is harder to stop? Explain why.

What do you think NOW?

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END OF LESSON