chapter 2

Forces

lesson 3 Unbalanced Forces and Acceleration

Grade Eight Science Content Standard. 2.e. Students know that when the forces on an object are unbalanced, the object will change its velocity (that is, it will speed up, slow down, or change direction). **Also covers:** 2.a, 2.b, 2.c, 2.d, 2.f.

Before You Read

If someone told you that a car was accelerating, what would that mean to you? Write your response on the lines below. Then read the lesson to learn about the forces causing acceleration.

MAIN Idea

Unbalanced forces cause accelerations.

What You'll Learn

- how unbalanced forces cause changes in velocity
- how net force affects acceleration
- how mass affects acceleration

Read to Learn

Unbalanced Forces and Velocity

An unbalanced force changes an object's speed or direction of motion. How do unbalanced forces affect objects that are either not moving or already moving?

When an unbalanced force acts on an object at rest, the object will increase in speed in the direction of the unbalanced force. When an unbalanced force acts on an object that is already moving, it can cause the object to speed up or slow down. The change in speed depends on two things:

- the direction of the unbalanced force, and
- the direction in which the object was moving.

A net force applied in the same direction as a moving object makes an object speed up. A net force applied in the opposite direction of a moving object makes an object slow down. In the figure at the top of the next page, the net force is made up of gravity and sliding friction. The net force is in the same direction as the sled's velocity. The sled speeds up and its velocity increases. When the boy puts his feet in the snow, the net force is the combination of gravity and the sliding friction, which increases as the boy drags his feet. This causes the sled to slow down. ☑

Study Coach

Outline As you read the lesson, make an outline using each heading from the text. Under each heading, write the main points or ideas that you read.

Reading Check

1. **Explain** What is the result of net force applied in the same direction as a moving object?

Picture This

2. Label In the figure, label the appropriate arrow "Force due to friction" and the other arrow "Direction of motion."

How do unbalanced forces affect the direction of motion?

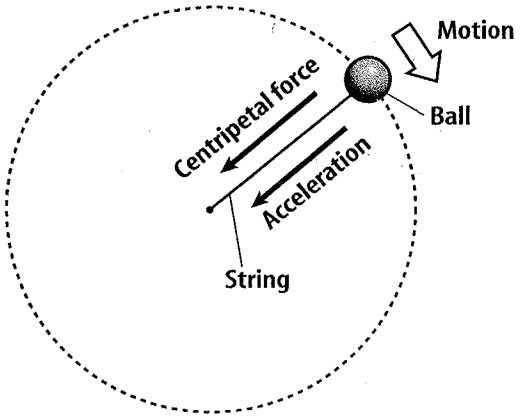
Unbalanced forces also can change the direction of an object's motion. A ball bouncing off a tree, as shown below, is an example of an object whose direction of motion changes.

Straight Line of Motion Before a ball hits the tree, the ball travels in a straight line at a constant speed. The tree then exerts an unbalanced force on the ball, causing the motion of the ball to change. After hitting the tree, the ball travels in another direction in a straight line at a constant speed.

Picture This

3. Identify Draw arrows in the second figure showing the direction of the ball.

Circular Motion The figure below shows a ball tied to a string and swung in a horizontal circle. This type of motion is called circular motion. The speed of the ball is constant. But the velocity of the ball is changing because the direction of its motion is changing. The unbalanced force acting on the ball is the tension force exerted by the string. This force is called the centripetal (sen TRIH put ul) force. In circular motion, **centripetal force** is the force that acts perpendicular to the velocity and toward the center of the circle.



Picture This

4. Locate Highlight the direction of centripetal force in the figure.

Newton's Second Law of Motion

Unbalanced forces can cause an object to speed up, slow down, or change direction. When an object changes speed or direction, its velocity changes and the object is accelerating. Unbalanced forces cause an object to accelerate. According to Newton's second law of motion, the acceleration of an object equals the net force divided by the object's mass. The direction is the same for the net force.

Newton's Second Law Equation Isaac Newton determined that acceleration depends on both the net force acting on an object and the mass of the object. Newton's second law of motion can be written as this equation:

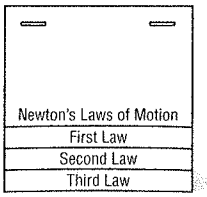
$$\text{acceleration (in m/s}^2\text{)} = \frac{\text{net force (in N)}}{\text{mass (in kg)}}$$

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

Force is measured in newtons (N) and mass is measured in kilograms. One N is equal to 1 kg $\times$ m/s^2. Acceleration is measured in meters per second squared (m/s^2).

FOLDABLES™

C Explain Make a layered Foldable. Label the tabs as illustrated and record what you learn about Newton's second and third laws of motion, and review what you learned in Lesson 1 about Newton's first law of motion.



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How does Newton's second law apply to balanced forces and unbalanced forces?

According to Newton's second law of motion, the acceleration of an object depends on two things:

- the object's mass, and
- the net force acting on the object.

When the forces on an object are balanced, the net force is zero. According to the second law of motion, when the net force on an object is zero, the acceleration of an object is zero. That means the velocity of the object is constant and its motion doesn't change.

If the forces on an object are unbalanced, then the net force is not zero. According to the second law of motion, the acceleration is also not zero, and the velocity of the object changes. Only unbalanced forces cause the motion of objects to change. ☑

Reading Check

5. Identify What causes the motion of an object to change?

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How does Newton's second law apply to centripetal force?

The planets, including Earth, move around the Sun in nearly circular paths. This means that the planets are accelerating because their direction of motion is always changing. According to the second law of motion, there must be an unbalanced force acting on Earth and the other planets. Isaac Newton realized that the unbalanced force involved was the gravitational force exerted by the Sun.

Recall that the centripetal force keeps an object moving in a circle. The gravitational force exerted by the Sun is the centripetal force that keeps planets moving around the Sun.

Academic Vocabulary
involve (ihn VOHLV) (verb) to include in an action; to be part of something happening

Newton's Third Law of Motion

Think about the forces involved when you jump. Because you are accelerating, an unbalanced force is acting on you. This force is partly caused by the upward push of your feet. But there is more to it than that.

According to the **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. When you jump, your feet exert a force on the ground. The ground also pushes upward on your feet and you accelerate upward. ☑

Reading Check

6. Determine Which of the following diagrams best explains the third law of motion? (Circle your answer.)

a. →|←

b. →|→

What are force pairs?

The forces two objects exert on each other are called force pairs. In a force pair, forces are equal and act in opposite directions. Force pairs don't cancel each other because the forces are acting on different objects. When you jump, one force in the force pair acts on the ground. The other force acts on you. The net force is not zero because the forces act on different objects. To have a net force of zero, equal and opposite forces must act on the same object. ☑

Reading Check

7. Explain Why don't force pairs cancel each other out?

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What are action and reaction forces?

According to the third law of motion, forces always act in pairs called action and reaction forces. For example, when you push on a wall, the wall pushes back on you. The action force is the force you exert on the wall. The reaction force is the force exerted by the wall on you. For every action force, there is a reaction force that is equal in size, but opposite in direction.

Applying Newton's Laws

Newton's laws of motion describe how forces affect the motion of any object. For example, when you jump, you push down on the ground. Newton's third law of motion says that the ground pushes up on you. This force combines with the downward force of gravity to form the net force acting on you. If you push down hard enough, the direction of the net force becomes upward. According to the second law of motion, you accelerate upward.

Once you've jumped and are in the air, the downward force due to gravity is in the direction opposite to your motion. This causes you to slow down until you reach the top of your jump. Then as you start moving downward, gravity is in the same direction as you are moving, so you speed up as you fall. ☑

Reading Check

8. Decide Why do you speed up as you fall?

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When you hit the ground, the upward force exerted on you by the ground brings you to a stop. Then the forces on you are balanced, and you remain at rest. The table at the top of the next page provides more examples of how Newton's laws of motion explain objects' motion.

Picture This

9. Identify Circle the statement of law that is an equation.

Newton's Laws of Motion		
Law	**Statement of Law**	**Example**
Newton's first law of motion	An object at rest will remain at rest unless acted on by an unbalanced force. An object in motion will continue moving at a constant velocity unless acted on by an unbalanced force.	The forces acting on a book at rest on a table are balanced, so the book's motion does not change. The forces acting on a skydiver with an open parachute are balanced, so the skydiver falls in a straight line at a constant speed.
Newton's second law of motion	The size of the acceleration of an object is equal to the net force on the object divided by its mass. The acceleration is in the same direction as the net force.	A skydiver jumping out of a plane accelerates toward the ground as gravity pulls her down.
Newton's third law of motion	When one object exerts a force on another object, the second object exerts a force on the first object that is equal in size but opposite in direction.	When you push on a wall with a force of 100 N, the wall pushes back on you with a force of 100 N.

What have you learned?

In Lesson 1 you read that unbalanced forces cause the motion of an object to change. In this lesson you learned how forces cause motion to change. An object accelerates when it changes speed or direction. According to Newton's second law of motion, the acceleration of an object equals the net force divided by the object's mass. The acceleration is in the same direction as the net force. The third law of motion says that forces are always exerted in pairs. This means that when you push on a door, the door pushes on you with a force of the same size in the opposite direction. ☑

Reading Check

10. State Which of the laws of motion refers to pairs of forces?

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