The Laws of Motion

Newton's Second 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
	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.	

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.

Key Concepts

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

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.

Think it Over

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

Think it Over

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

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.

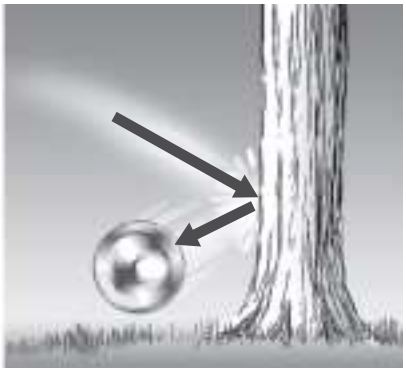
Slowing Down If the direction of the net force on an object is opposite to the direction the object is moving, the object will slow down. If you are riding on a sled and push your foot against the ground, friction acts in the direction opposite to the motion of the sled. Because the net force is in the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

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?

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.



Visual Check

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

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 $kg \cdot m/s^2$.

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.

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 $10\ kg \cdot m/s^2$

acceleration: a

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

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

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

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?

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.

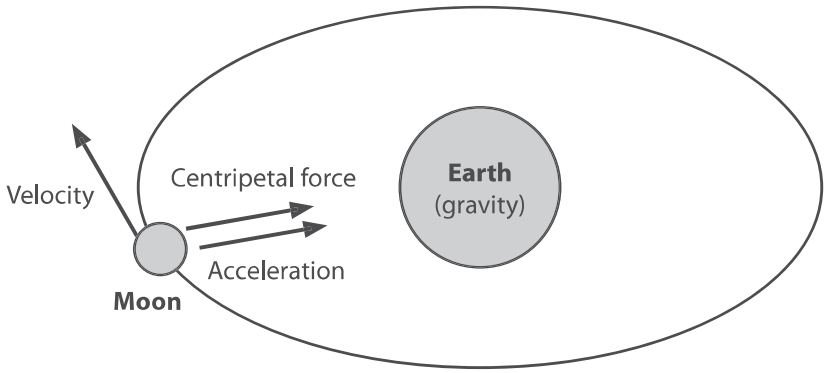
Key Concept Check

7. Describe How does centripetal force affect circular motion?

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.



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?

After You Read

Mini Glossary

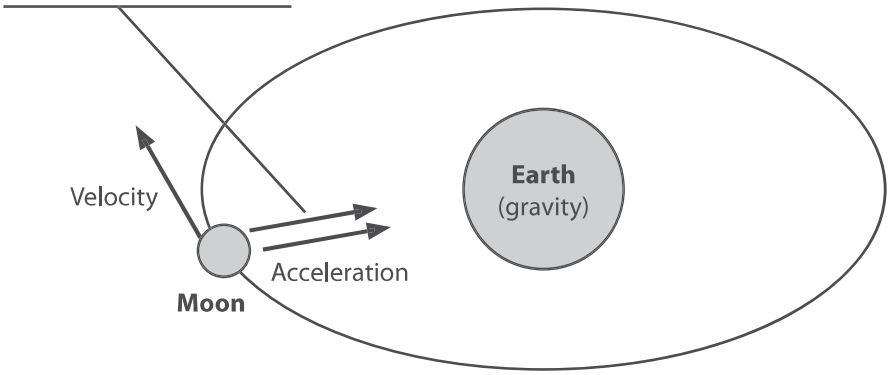
centripetal (sen TRIH puh tuhl) force: in circular motion, a force that acts perpendicular to the direction of motion, toward the center of the curve

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