Section 5

Rockets and Satellites

Objectives

After this lesson, students will be able to

M.2.5.1 Explain how a rocket lifts off the ground.

M.2.5.2 Describe the forces that keep a satellite in orbit.

Target Reading Skill

Identifying Main Ideas Explain that identifying main ideas and details helps students sort the facts from the information into groups. Each group can have a main topic, subtopic, and details.

Answers

Sample answers:

Main Idea: A satellite stays in orbit due to

Detail: its inertia

Detail: Earth's gravity

Detail: Earth's shape

All in One Teaching Resources

- Transparency M20

Preteach

Build Background Knowledge L2

Describing Forces in a Rocket Launch

Ask: **Have you ever seen a space shuttle launch on television?** *(Some students will say yes.)* Ask volunteers to describe the launch. Call students' attention to Figure 19, and have them describe the action-reaction force pair that produces lift.

Rockets and Satellites

Reading Preview

Key Concepts

- How does a rocket lift off the ground?
- What keeps a satellite in orbit?

Key Terms

- satellite
- centripetal force

Target Reading Skill

Identifying Main Ideas As you read the What Is a Satellite? section, write the main idea in a graphic organizer like the one below. Then write three supporting details that further explain the main idea.

Main Idea

A satellite stays in orbit due to . . .

Detail **Detail** **Detail**

Lab zone Discover Activity

What Makes an Object Move in a Circle?

1. Tie a small mass, such as an empty thread spool, to the end of a string no more than one meter long.
2. Swing the object rapidly around in a circle that is perpendicular to the floor. Make sure no one is near the swinging object, and don't let it go!
3. Predict what will happen if you decrease the speed of the object. Test your prediction.
4. Predict how the length of the string affects the object's motion. Test your prediction.

Think It Over

Forming Operational Definitions Describe the object's motion. How do you know that the string exerts a force?

In October 1957, 14-year-old Homer Hickam looked upward and saw a speck of light move across the sky. It was the Russian satellite *Sputnik*, the first artificial satellite. It was propelled into space by a powerful rocket. This sight inspired Homer and his friends. They spent the next three years designing, building, and launching rockets in their hometown of Coalwood, West Virginia. Many of their first attempts failed, but they did not give up. Eventually, they built a rocket that soared to a height of almost ten kilometers. Their hard work paid off. In 1960, they won first place in the National Science Fair. Since then, rocket launches have become more familiar, but they are still an awesome sight.

◄ **Homer Hickam holds a rocket that he and his friends designed.**

Lab zone Discover Activity

Skills Focus Forming operational definitions L2

Materials length of string not more than 1 meter long, safety goggles, small object such as an empty thread spool

Time 10 minutes

Tips Caution students not to swing the object near another person. Have students wear safety goggles during the procedure.

Expected Outcome In Step 3 students might predict that the spool will move more slowly or that it won't make it over the top.

Think It Over The object moves in a circle; therefore it is constantly accelerating. What causes the acceleration is the pulling force, or tension, of the string.

How Do Rockets Lift Off?

A space shuttle like the one in Figure 19 has a mass of more than 2 million kilograms when loaded with fuel. To push the shuttle away from the pull of Earth's gravity and into space requires an incredible amount of force. How is this force generated? Rockets and space shuttles lift into space using Newton's third law of motion. As they lift off, they burn fuel and push the exhaust gases downward at a high velocity. In turn, the gases push upward on the rocket with an equal but opposite force. **A rocket can rise into the air because the gases it expels with a downward action force exert an equal but opposite reaction force on the rocket.** As long as this upward pushing force, called thrust, is greater than the downward pull of gravity, there is a net force in the upward direction. As a result, the rocket accelerates upward into space.

What Is a Satellite?

Rockets are often used to carry satellites into space. A **satellite** is any object that orbits another object in space. An artificial satellite is a device that is launched into orbit. Artificial satellites are designed for many purposes, such as communications, military intelligence, weather analysis, and geographical surveys. The International Space Station is an example of an artificial satellite. It was designed for scientific research.

Circular Motion Artificial satellites travel around Earth in an almost circular path. Recall that an object traveling in a circle is accelerating because it constantly changes direction. If an object is accelerating, a force must be acting on it. Any force that causes an object to move in a circular path is a **centripetal force** (sen TRIP ih tul). The word *centripetal* means "center-seeking."

In the Discovery Activity, the string supplies the centripetal force. The string acts to pull the object toward the center, and thereby keeps it moving in a circular path. For a satellite, the centripetal force is the gravitational force that pulls the satellite toward the center of Earth.

Reading Checkpoint **What force causes an object to move in a circular path?**

FIGURE 19
A Rocket Launch
The action force pushes the rocket's exhaust gases downward. The reaction force of the gases sends the rocket into space. **Predicting** *As the rocket ascends, how will its mass change?*

Differentiated Instruction

Gifted and Talented L3
Researching Have students research the requirements for a rocket launch site and prepare a short report to share with the class. Have students find out why ideal launch sites are close to the equator. **learning modality: verbal**

Less Proficient Readers L1
Using Visuals Have students review the figures in Section 5. Help students read the caption of each figure. Then have students explain in their own words what is shown in each figure. **learning modality: visual**

Instruct

How Do Rockets Lift Off?

Teach Key Concepts L2

Newton's Third Law and Rockets

Focus Remind students of Newton's third law: If one object exerts a force on another object, then the second object exerts an equal and opposite force on the first object.

Teach Direct students' attention to Figure 19. Remind students that during the launch, the upward force must be greater than the downward pull of gravity.

Apply Ask: **Is there a net force acting on the rocket in Figure 19?** *(Yes)* **How can you tell?** *(The rocket is accelerating.)* **learning modality: visual**

What Is a Satellite?

Teach Key Concepts L2

Gravity Affects Satellite Motion

Focus Ask: **What happens when you throw a baseball as hard as you can in an empty field?** *(It travels through the air and eventually falls to Earth.)* Point out that the baseball travels in a curved path. Tell students that satellites also travel in a curved path.

Teach Direct students' attention to Figure 20. Ask: **What force makes the ball fall toward Earth?** *(Gravity)* Explain that satellites stay in orbit due to inertia and the force of gravity.

Apply Ask: **Does a satellite require fuel once it is in orbit? Why?** *(No, inertia and the force of gravity keep the satellite in orbit.)* **learning modality: visual**

Independent Practice L2

All in One Teaching Resources

- Guided Reading and Study Worksheet: *Rockets and Satellites*

Student Edition on Audio CD

Monitor Progress L2

Answers

Figure 19 Its mass will decrease as the rocket burns fuel.

Reading Checkpoint a centripetal force, gravity

Lab zone Teacher Demo

Observing a Rocket Launch L1

Materials hand air pump, plastic water rocket, safety goggles

Time 15 minutes plus time for rocket assembly

Focus Ask: **What are some forces that affect a rocket launch?** *(Sample answer: Gravity, force of the gas expelled by the rocket)*

Teach This demonstration uses a plastic water rocket and must be done outdoors. Water rockets can be purchased from science supply companies. The rocket uses compressed air to expel a mixture of water and air from the rocket nozzle. **CAUTION:** *These water rockets are safe, but manufacturer's instructions must be followed exactly.* Students should wear goggles and stand at a safe distance. After the launch, challenge students to identify the action and reaction forces that acted as the rocket lifted off the ground.

Apply Ask: **As the rocket launches, are the forces acting on it balanced or unbalanced? How do you know?** *(Unbalanced, because the rocket is accelerating)* **learning modality: visual**

Help Students Read L1

Outlining Have students create an outline of the section, Rockets and Satellites. Outlines should use the headings in the section as main ideas. Check that students have included the key terms and boldface sentences under the appropriate headings.

All in One Teaching Resources

- Transparency M21

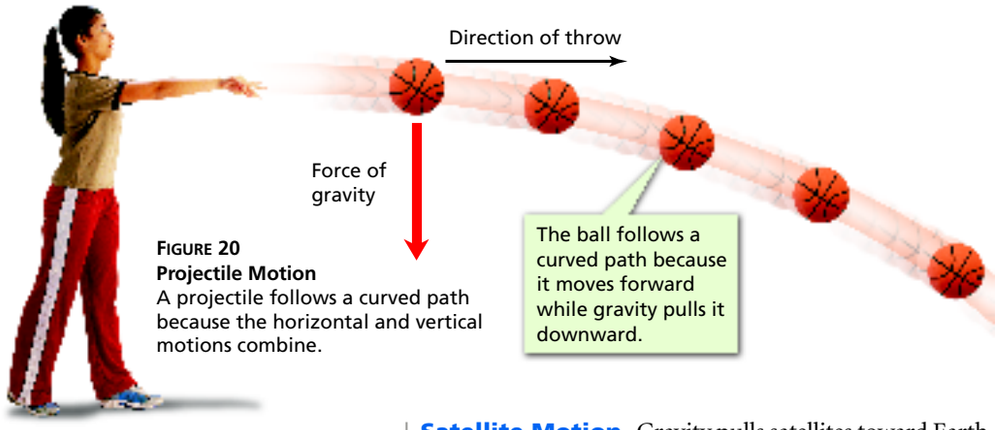

FIGURE 20
Projectile Motion
A projectile follows a curved path because the horizontal and vertical motions combine.

Satellite Motion Gravity pulls satellites toward Earth. So why don't satellites fall, as a ball thrown into the air would? The answer is that satellites do not travel straight up into the air. Instead they move around Earth.

If you throw a ball horizontally, as shown in Figure 20, the ball will move away from you at the same time that it is pulled to the ground because of gravity. The horizontal and vertical motions combine, and the ball follows a curved path toward the ground. If you throw the ball faster, it will land even farther in front of you. The faster you throw a projectile, the farther it travels before it lands.

Now suppose, as Isaac Newton did, what would happen if you were on a high mountain and could throw a ball as fast as you wanted. The faster you threw it, the farther away it would land. But, at a certain speed, the path of the ball would match the curve of Earth. Although the ball would keep falling due to gravity, Earth's surface would curve away from the ball at the same rate. Thus the ball would circle Earth, as shown in Figure 21.

Satellites in orbit around Earth continuously fall toward Earth, but because Earth is curved they travel around it. In other words, a satellite is a falling projectile that keeps missing the ground! It falls around Earth rather than into it. A satellite does not need fuel because it continues to move ahead due to its inertia. At the same time, gravity continuously changes the satellite's direction. The speed with which an object must be thrown in order to orbit Earth turns out to be about 7,900 m/s! This speed is about 200 times faster than a pitcher can throw a baseball.

FIGURE 21
Satellite Motion
The faster a projectile is thrown, the farther it travels before it hits the ground. A projectile with enough velocity moves in a circular orbit. **Interpreting Diagrams** *How does the direction of gravity compare to the direction of the orbiting projectile's motion at any point?*

Satellite Location Some satellites, such as mapping and observation satellites, are put into low orbits of less than 1,000 kilometers. In a low orbit, satellites complete a trip around Earth in less than two hours. Other satellites are sent into higher orbits. At those distances, a satellite travels more slowly, taking longer to circle Earth. For example, communications satellites travel about 36,000 kilometers above Earth's surface. At that height, they circle Earth once every 24 hours. Because Earth rotates once every 24 hours, a satellite above the equator always stays at the same point above Earth as it orbits.

Reading Checkpoint **How does gravity help keep satellites in orbit?**

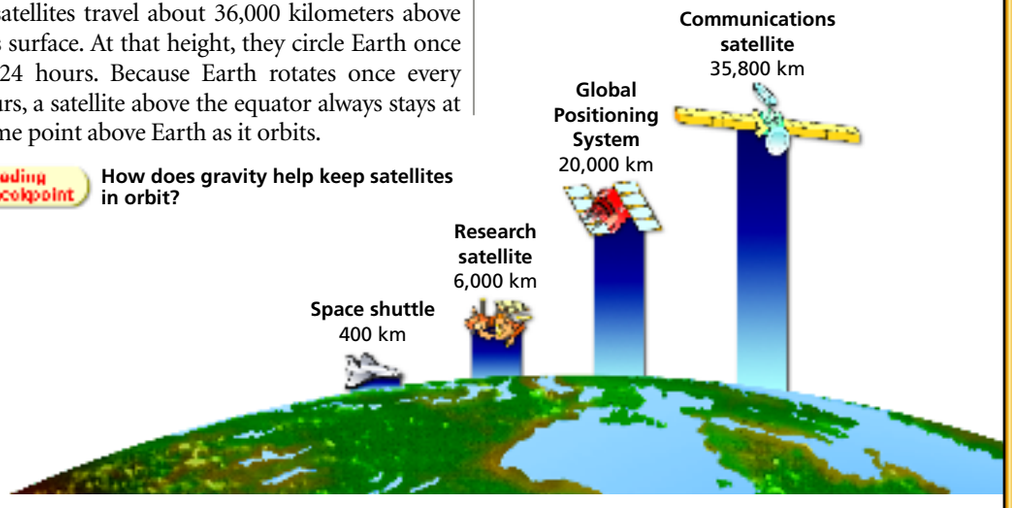

FIGURE 22
Satellite Locations
Depending on their uses, artificial satellites orbit at different heights.

Section 5 Assessment

Target Reading Skill **Identifying Main Ideas** Use your graphic organizer to help you answer Question 2 below.

Reviewing Key Concepts

1. a. **Identifying** Which of Newton's three laws of motion explains how a rocket lifts off?
   b. **Explaining** How do action-reaction pairs explain how a rocket lifts off?
   c. **Applying Concepts** As a rocket travels upward from Earth, air resistance decreases along with the force of gravity. The rocket's mass also decreases as its fuel is used up. If thrust remains the same, how do these factors affect the rocket's acceleration?
2. a. **Defining** What is a satellite?
   b. **Relating Cause and Effect** What causes satellites to stay in orbit rather than falling toward Earth?
   c. **Inferring** In Figure 21, a projectile is thrown with enough velocity to orbit Earth. What would happen if the projectile were thrown with a greater velocity?

Lab zone At-Home Activity

Swing the Bucket Fill a small plastic bucket halfway with water and take it outdoors. Challenge a family member to swing the bucket in a vertical circle. Explain that the water won't fall out at the top if the bucket is moving fast enough. Tell your family member that if the bucket falls as fast as the water, the water will stay in the bucket. Relate this activity to a satellite that also falls due to gravity, yet remains in orbit.

Monitor Progress L2

Answers

Figure 21 The direction of Earth's gravity is perpendicular to the direction of an orbiting projectile's motion.

Reading Checkpoint Earth's gravity provides the entire centripetal force needed to keep satellites in orbit. Gravity also continuously changes the satellite's direction.

Assess

Reviewing Key Concepts

1. a. Newton's third law explains how a rocket lifts off. **b.** Action force—rocket exerts a downward force on exhaust gases; reaction force—exhaust gases exert an equal and opposite force on the rocket, propelling it upward. **c.** All three factors increase the rocket's acceleration. Decreased air resistance and decreased force of gravity allow the rocket to accelerate faster because both result in less force opposing the rocket's acceleration. Decreased rocket mass increases acceleration because the same force acting on a smaller mass causes greater acceleration.

2. a. A satellite is any object that travels around another object in space. **b.** Satellites stay in orbit because Earth's surface curves away as Earth's gravity causes them to fall toward Earth. **c.** If the projectile were thrown with a greater velocity, it would escape Earth's gravity and move off into space.

Reteach L1

Have students review the boldface sentences in the section. Challenge students to state the key concepts using their own words.

Performance Assessment L2

Writing Have students write a letter explaining the motion of a communications satellite and why these satellites do not require fuel to stay in orbit.

All in One Teaching Resources

- Section Summary: *Rockets and Satellites*
- Review and Reinforce: *Rockets and Satellites*
- Enrich: *Rockets and Satellites*

Lab zone At-Home Activity

Swing the Bucket L2 Review the concept of satellites so students will be prepared to discuss this with their families. Remind students that just as Earth's gravity causes the water to fall toward Earth as fast as the bucket, Earth's gravity causes the satellite to fall around Earth so that it remains in orbit.