Section 4

The Outer Planets

Objectives

After this lesson, students will be able to

J.3.4.1 Describe characteristics that the gas giants have in common.

J.3.4.2 Identify characteristics that distinguish each outer planet.

Target Reading Skill

Identifying Main Ideas Explain that identifying main ideas and details helps students sort the facts into groups.

Answers

Possible answers include the following:

Detail: Structure—they do not have a solid surface

Detail: Atmosphere—thick and made up mainly of hydrogen and helium

Detail: Rings—each is surrounded by a set of rings

Detail: Size and mass—each is very large and massive

All in One Teaching Resources

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Preteach

Build Background Knowledge L2

Knowledge About Outer Planets

Divide the class into groups of five. Give each student in a group an index card with the name of a different outer planet written on it. Have each student write three things that he or she believes to be true about the planet. When students have finished, they can share their cards within each group. Collect the cards and use them to review the material when students have finished the section.

Section 4

The Outer Planets

Reading Preview

Key Concepts

- What characteristics do the gas giants have in common?
- What characteristics distinguish each of the outer planets?

Key Terms

- gas giant
- ring

Target Reading Skill

Identifying Main Ideas As you read the *Gas Giants and Pluto* section, write the main idea—the biggest or most important idea—in a graphic organizer like the one below. Then write three supporting details that further explain the main idea.

Main Idea

The four gas giants are similar in . . .

Detail **Detail** **Detail**

Lab zone Discover Activity

How Big Are the Planets?

The table shows the diameters of the outer planets compared to Earth. For example, Jupiter's diameter is about 11 times Earth's diameter.

Planet	Diameter (Earth = 1)
Earth	1.0
Jupiter	11.2
Saturn	9.4
Uranus	4.0
Neptune	3.9
Pluto	0.2

1. Measure the diameter of a quarter in millimeters. Trace the quarter to represent Earth.
2. If Earth were the size of a quarter, calculate how large Jupiter would be. Now draw a circle to represent Jupiter.
3. Repeat Step 2 for each of the other planets in the table.

Think It Over

Classifying List the outer planets in order from largest to smallest. What is the largest outer planet? Which outer planet is much smaller than Earth?

Imagine you are in a spaceship approaching Jupiter. You'll quickly discover that Jupiter is very different from the terrestrial planets. The most obvious difference is Jupiter's great size. Jupiter is so large that more than 1,300 Earths could fit within it!

As your spaceship enters Jupiter's atmosphere, you encounter thick, colorful bands of clouds. Next, you sink into a denser and denser mixture of hydrogen and helium gas. Eventually, if the enormous pressure of the atmosphere does not crush your ship, you'll reach an incredibly deep "ocean" of liquid hydrogen and helium. But where exactly is Jupiter's surface? Surprisingly, there isn't a solid surface. Like the other giant planets, Jupiter has no real surface, just a solid core buried deep within the planet.

◀ **An illustration of the space probe *Galileo* approaching the cloud-covered atmosphere of Jupiter.**

Lab zone Discover Activity

Skills Focus classifying L2

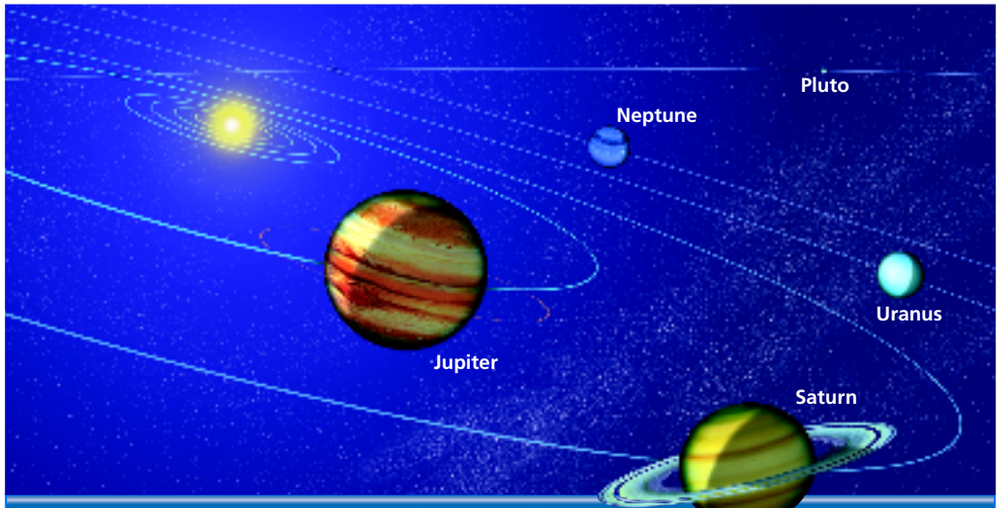
Materials quarter, metric ruler, lined paper, butcher paper or poster board, compass, pushpin, string

Time 15 minutes

Tips **CAUTION:** *Compasses have sharp points and can cause injury.* A quarter has a diameter of 24 mm. Jupiter and Saturn will be too large to draw with a compass, so use a pin and string for them. Have students locate the center of each circle in the same place. They will need to use large paper to fit the larger circles onto one sheet.

Expected Outcome Diameters of circles: Earth 24 mm, Jupiter 264 mm, Saturn 226 mm, Uranus 96 mm, Neptune 94 mm, Pluto 4 mm

Think It Over Jupiter, Saturn, Uranus, Neptune, Earth, Pluto; Jupiter; Pluto



The Outer Planets

Planet	Diameter (kilometers)	Period of Rotation (Earth days)	Average Distance From Sun (kilometers)	Period of Revolution (Earth years)	Number of Moons
Jupiter	143,000	0.41	779,000,000	12	60+
Saturn	120,500	0.45	1,434,000,000	29	31+
Uranus	51,100	0.72	2,873,000,000	84	25+
Neptune	49,500	0.67	4,495,000,000	164	13+
Pluto	2,400	6.4	5,870,000,000	248	1

Gas Giants and Pluto

Jupiter and the other planets farthest from the sun are called the outer planets. **The first four outer planets—Jupiter, Saturn, Uranus, and Neptune—are much larger and more massive than Earth, and they do not have solid surfaces.** Because these four planets are all so large, they are often called the **gas giants.** The fifth outer planet, Pluto, is small and rocky like the terrestrial planets. Figure 17 provides information about these planets.

Like the sun, the gas giants are composed mainly of hydrogen and helium. Because they are so massive, the gas giants exert a much stronger gravitational force than the terrestrial planets. Gravity keeps the giant planets' gases from escaping, so they have thick atmospheres. Despite the name "gas giant," much of the hydrogen and helium is actually in liquid form because of the enormous pressure inside the planets. The outer layers of the gas giants are extremely cold because of their great distance from the sun. Temperatures increase greatly within the planets.

All the gas giants have many moons. In addition, each of the gas giants is surrounded by a set of rings. A **ring** is a thin disk of small particles of ice and rock.

FIGURE 17
The outer planets are much farther apart than the inner planets. Note that planet sizes and distances are not drawn to scale.
Observing *Which outer planet has the most moons?*

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For: More on the planets
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Students can review the planets in an online interactivity.

Instruct

Gas Giants and Pluto

Teach Key Concepts L2

Characteristics of Outer Planets

Focus Tell students to imagine that a space probe is exploring a gas giant.

Teach Ask students to describe what the probe would encounter as it approached the visible surface. *(There is no solid surface; the atmosphere just gets thicker. Eventually, the combination of heat and pressure would probably cause the probe to fail.)*

Apply Ask: **Could the probe penetrate to the solid part of the planet?** *(Not likely; the solid core is buried deep inside the planet.)* **learning modality: logical/mathematical**

Use Visuals: Figure 17 L2

Focus Have students use their fingers to trace the orbit of each planet.

Teach Ask: **Which planet has an orbit that crosses the orbit of another?** *(Pluto crosses the orbit of Neptune.)* Refer students to the data table. Ask: **Which planet is about twice as far from the sun as Jupiter?** *(Saturn)* **About six times as far from the sun as Jupiter?** *(Neptune)*

Apply Have students use the data table to identify additional differences among the outer planets. **learning modality: visual**

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Independent Practice L2

All in One Teaching Resources
- Guided Reading and Study Worksheet: *The Outer Planets*

Monitor Progress L2

Skills Check Have students compare and contrast Earth to the outer planets.

Answer
Figure 17 Jupiter

Differentiated Instruction

English Learners/Beginning L1
Comprehension: Key Concept On the board, rewrite the boldface sentence as three sentences, for example: **The first four outer planets are Jupiter, Saturn, Uranus, and Neptune. These planets are much larger and more massive than Earth. None of these planets has a solid surface.** Discuss each sentence, and then help students organize the information in the text in a graphic organizer that lists main ideas and supporting details. **learning modality: verbal**

English Learners/Intermediate L2
Comprehension: Key Concept Have pairs of students rewrite the boldface sentence as three sentences and then organize the information in the text in a graphic organizer. **learning modality: verbal**

Jupiter

Teach Key Concepts L3

Characteristics of Jupiter

Focus Remind students that Jupiter is the largest planet.

Teach Ask: **Why is it somewhat misleading to call Jupiter a "gas" giant?** *(Much of the planet is mainly liquid.)* Remind students that hydrogen and helium occur naturally as gases on Earth. Ask: **Why are much of the hydrogen and helium on Jupiter in the liquid state?** *(The force of gravity on Jupiter is immense because Jupiter is so massive. Therefore, the hydrogen and helium are under a great pressure, which causes them to be compressed into the liquid state as their molecules slow down and are forced into a smaller volume.)*

Apply Ask: **In addition to Jupiter and other gas giants, what object or objects in our solar system are made up mainly of hydrogen and helium?** *(The sun)* **learning modality: logical/mathematical**

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Help Students Read

Active Comprehension Before students read about Jupiter, ask them what they would like to know about this planet. Write a few of their questions on the board, such as "What is the Great Red Spot?" and "How do astronomers know what Jupiter is made of?" After students finish reading the selection, ask them to answer the questions.

Jupiter

Jupiter is the largest and most massive planet. Jupiter's enormous mass dwarfs the other planets. In fact, its mass is about $2\frac{1}{2}$ times that of all the other planets combined!

Jupiter's Atmosphere Like all of the gas giants, Jupiter has a thick atmosphere made up mainly of hydrogen and helium. An especially interesting feature of Jupiter's atmosphere is its Great Red Spot, a storm that is larger than Earth! The storm's swirling winds blow hundreds of kilometers per hour, similar to a hurricane. But hurricanes on Earth weaken quickly as they pass over land. On Jupiter, there is no land to weaken the huge storm. The Great Red Spot, which was first observed in the mid-1600s, shows no signs of going away soon.

Jupiter's Structure Astronomers think that Jupiter, like the other giant planets, probably has a dense core of rock and iron at its center. As shown in Figure 18, a thick mantle of liquid hydrogen and helium surrounds this core. Because of the crushing weight of Jupiter's atmosphere, the pressure at Jupiter's core is estimated to be about 30 million times greater than the pressure at Earth's surface.

Jupiter's Moons Recall that Galileo discovered Jupiter's four largest moons. These moons, which are highlighted in Figure 19, are named Io (EYE oh), Europa, Ganymede, and Callisto. All four are larger than Earth's own moon. However, they are very different from one another. Since Galileo's time, astronomers have discovered dozens of additional moons orbiting Jupiter. Many of these are small moons that have been found in the last few years thanks to improved technology.

Reading Checkpoint What is Jupiter's atmosphere composed of?

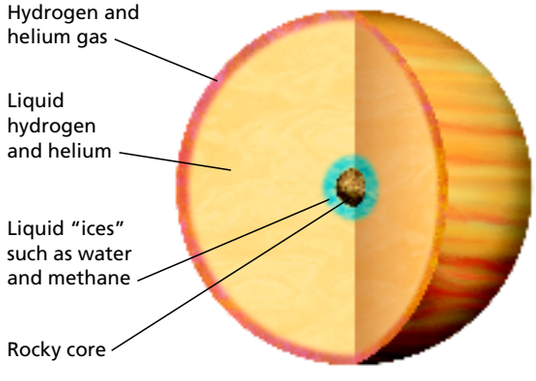


FIGURE 18
Jupiter's Structure
Jupiter is composed mainly of the elements hydrogen and helium. Although Jupiter is often called a "gas giant," much of it is actually liquid.
Comparing and Contrasting *How does the structure of Jupiter differ from that of a terrestrial planet?*

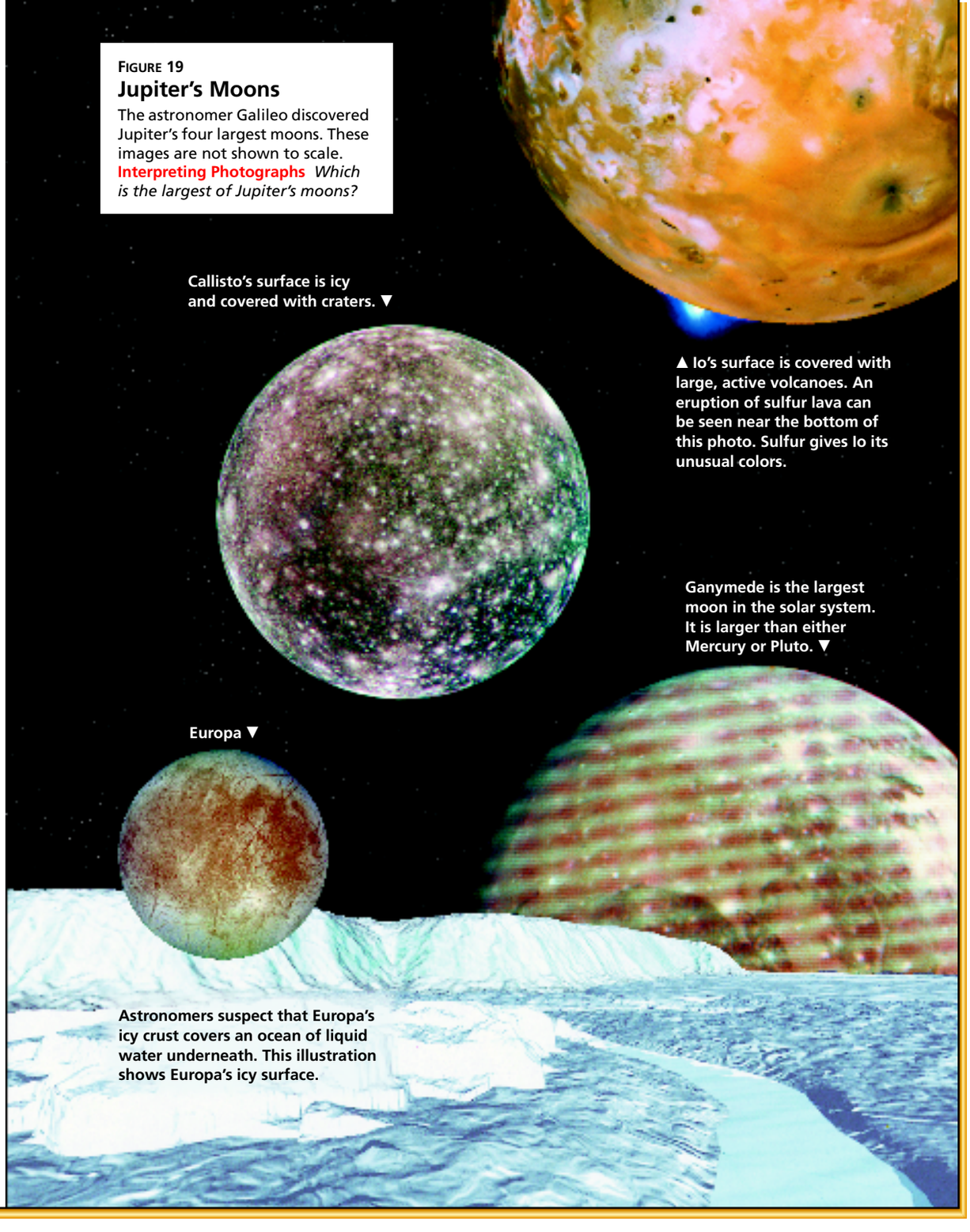


FIGURE 19
Jupiter's Moons
The astronomer Galileo discovered Jupiter's four largest moons. These images are not shown to scale.
Interpreting Photographs *Which is the largest of Jupiter's moons?*

Lab zone Teacher Demo

Modeling the Great Red Spot L1

Materials water, pepper, funnel or spoon, clear plastic 1-L bottle with lid

Time 10 minutes

Focus Point out the resemblance between the Great Red Spot and a hurricane on Earth. If necessary, show students images of hurricanes taken by satellites orbiting above Earth.

Teach Half fill a clear plastic bottle with water. Using a funnel or spoon, pour in a spoonful of pepper. Seal the bottle and swirl the water forcefully. Ask: **What happens to the pepper grains?** *(They spin in a large swirl.)*

Apply Have students compare the appearance of the spinning pepper grains to the images of the Great Red Spot. Ask: **What forces are causing the Great Red Spot to swirl?** *(Possible answer: Differences in pressure in Jupiter's atmosphere)* **What kind of data would you need to test your inferences?** *(Possible answer: Data that show the pressure of the atmosphere around the Great Red Spot)* **learning modality: visual**

Differentiated Instruction

Less Proficient Readers L1

Interpreting Visuals Refer students to Figure 19 and its captions. Help them interpret the visual by asking: How do the images relate to the captions? How do the captions help me understand the images? What do I already know about the information in the images and captions? What else do I want to learn about the subjects of these images? **learning modality: visual**

Monitor Progress L2

Oral Presentation Have students describe what they would see if they stood on the surfaces of Jupiter's four largest moons.

Answers

Figure 18 The terrestrial planets are small and rocky. Jupiter is large and mainly liquid with a solid core.

Figure 19 Ganymede

Reading Checkpoint Mainly hydrogen and helium

Saturn

Teach Key Concepts L2

Saturn's Rings

Focus Ask: **In your view, what is the most distinguishing characteristic of Saturn?** *(Possible answer: The rings)*

Teach Ask: **What are the rings made of?** *(Chunks of ice and rock)* **How do the rings appear from Earth?** *(It looks as if Saturn has only a few rings.)* **How do the rings look up close?** *(The obvious rings are divided into many smaller rings that are broad and thin.)*

Apply Tell students that the particles of Saturn's rings create an image of a solid surface when viewed from a distance, similar to the *pointillist* style of art or some computer graphics. Obtain and show an example of a pointillist painting or computer graphics with tiny dots showing an image. **learning modality: visual**

Lab zone Build Inquiry L2

Comparing and Contrasting Planets

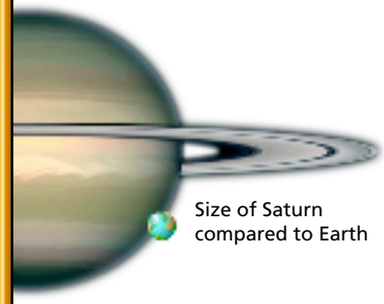
Materials none

Time 15 minutes

Focus Ask students to note similarities and differences between Saturn and Jupiter as they read about Saturn.

Teach Have students make a table comparing and contrasting Saturn and Jupiter. The table should include size, density, appearance, composition, and any other features students wish to include.

Apply Have students write a paragraph describing the similarities and differences between Jupiter and Saturn. **learning modality: verbal**



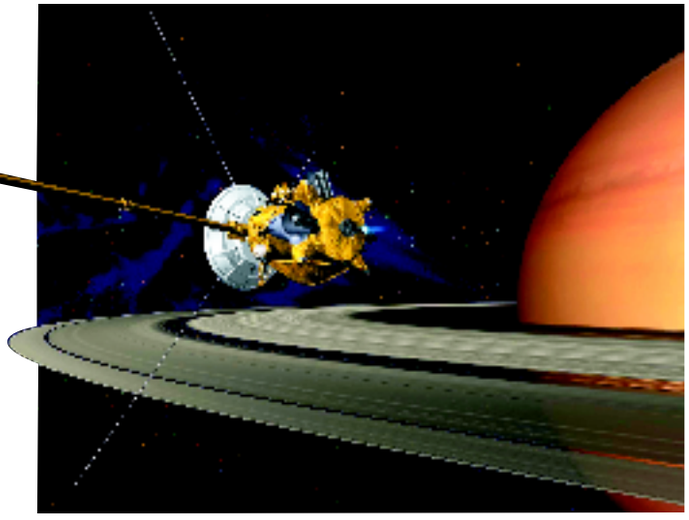


FIGURE 20
Exploring Saturn
The *Cassini* probe is exploring Saturn and its moons.
Observing *Why might it be hard to see Saturn's rings when their edges are facing Earth?*

Lab zone Skills Activity

Making Models

1. Use a plastic foam sphere 8 cm in diameter to represent Saturn.
2. Use an overhead transparency to represent Saturn's rings. Cut a circle 18 cm in diameter out of the transparency. Cut a hole 9 cm in diameter out of the center of the circle.
3. Stick five toothpicks into Saturn, spaced equally around its equator. Put the transparency on the toothpicks and tape it to them. Sprinkle baking soda on the transparency.
4. Use a peppercorn to represent Titan. Place the peppercorn 72 cm away from Saturn on the same plane as the rings.
5. What do the particles of baking soda represent?

Saturn

The second-largest planet in the solar system is Saturn. The *Voyager* probes showed that Saturn, like Jupiter, has a thick atmosphere made up mainly of hydrogen and helium. Saturn's atmosphere also contains clouds and storms, but they are less dramatic than those on Jupiter. Saturn is the only planet whose average density is less than that of water.

Saturn's Rings When Galileo first looked at Saturn with a telescope, he could see something sticking out on the sides. But he didn't know what it was. A few decades later, an astronomer using a better telescope discovered that Saturn had rings around it. These rings are made of chunks of ice and rock, each traveling in its own orbit around Saturn.

Saturn has the most spectacular rings of any planet. From Earth, it looks as though Saturn has only a few rings and that they are divided from each other by narrow, dark regions. The *Voyager* spacecraft discovered that each of these obvious rings is divided into many thinner rings. Saturn's rings are broad and thin, like a compact disc.

Saturn's Moons Saturn's largest moon, Titan, is larger than the planet Mercury. Titan was discovered in 1665 but was known only as a point of light until the *Voyager* probes flew by. The probes showed that Titan has an atmosphere so thick that little light can pass through it. Four other moons of Saturn are each over 1,000 kilometers in diameter.

Reading Checkpoint What are Saturn's rings made of?

Lab zone Skills Activity

Skills Focus making models L1

Materials 8-cm plastic foam sphere, clear plastic sheet, ruler, scissors, compass, 5 toothpicks, tape, baking soda, peppercorn, glue (optional)

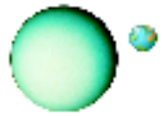
Time 20 minutes

Tips You may want to cut circles from the center of the transparencies yourself so that students do not need to use sharp scissors.

Expected Outcome The particles of baking soda represent the chunks of ice and rock that make up Saturn's rings.

Extend Have students use their model to demonstrate why the rings of Saturn are occasionally invisible from Earth. **learning modality: kinesthetic**

Size of Uranus compared to Earth



Uranus

Although the gas giant Uranus (YOOR uh nus) is about four times the diameter of Earth, it is still much smaller than Jupiter and Saturn. Uranus is twice as far from the sun as Saturn, so it is much colder. Uranus looks blue-green because of traces of methane in its atmosphere. Like the other gas giants, Uranus is surrounded by a group of thin, flat rings, although they are much darker than Saturn's rings.

Discovery of Uranus In 1781, Uranus became the first new planet discovered since ancient times. Astronomer William Herschel, in England, found a fuzzy object in the sky that did not look like a star. At first he thought it might be a comet, but it soon proved to be a planet beyond Saturn. The discovery made Herschel famous and started an era of active solar system study.

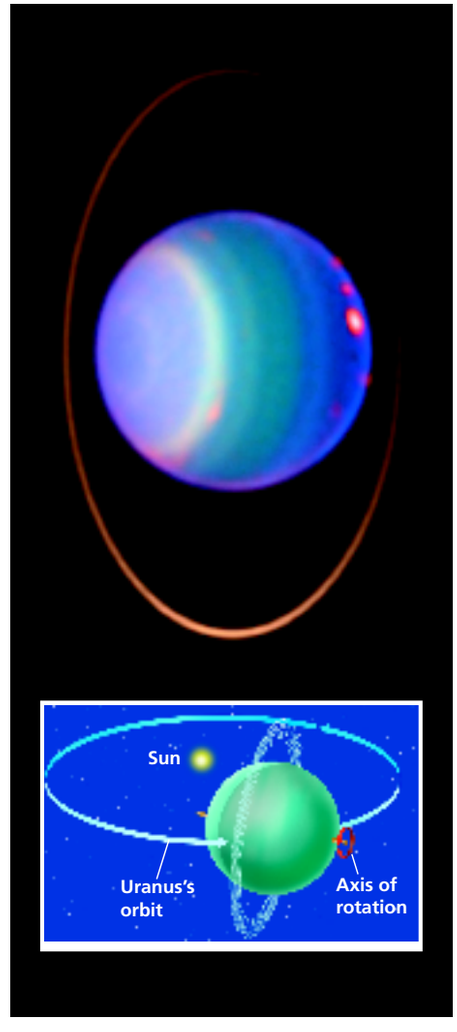
Exploring Uranus About 200 years after Herschel's discovery, *Voyager 2* arrived at Uranus and sent back close-up views of that planet. Images from *Voyager 2* show only a few clouds on Uranus's surface. But even these few clouds allowed astronomers to calculate that Uranus rotates in about 17 hours.

Uranus's axis of rotation is tilted at an angle of about 90 degrees from the vertical. Viewed from Earth, Uranus is rotating from top to bottom instead of from side to side, the way most of the other planets do. Uranus's rings and moons rotate around this tilted axis. Astronomers think that billions of years ago Uranus was hit by an object that knocked it on its side.

Uranus's Moons Photographs from *Voyager 2* show that Uranus's five largest moons have icy, cratered surfaces. The craters show that rocks from space have hit the moons. Uranus's moons also have lava flows on their surfaces, suggesting that material has erupted from inside each moon. *Voyager 2* images revealed 10 moons that had never been seen before. Recently, astronomers discovered several more moons, for a total of at least 25.

Reading Checkpoint **Who discovered Uranus?**

FIGURE 21
Uranus
The false color image of Uranus below was taken by the Hubble Space Telescope. Unlike most other planets, Uranus rotates from top to bottom rather than side to side.
Inferring *How must Uranus's seasons be unusual?*



Uranus

Teach Key Concepts L1

Uranus's Axis of Rotation

Focus Remind students that Earth rotates on its axis from west to east.

Teach Ask: **How is Uranus's rotation different from that of the other planets?** *(It rotates from top to bottom instead of from side to side.)* **What do astronomers think caused this?** *(Uranus was probably hit by a large object that knocked it on its side.)*

Apply Tell students to examine the bottom image in Figure 21. Have them lay a pencil over the axis of rotation and then trace the orbit of Uranus by moving the pencil. Ask: **In which direction does the pencil point?** *(The pencil always points to the left edge of the paper.)* **Does the axis of rotation of Uranus always point to the sun?** *(No)* **learning modality: kinesthetic**

All in One Teaching Resources

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Monitor Progress L2

Skills Check Have students create two fact sheets about Uranus. The first should include facts known about the planet before the *Voyager* missions. The second should include facts learned since the *Voyager* missions.

Answers

Figure 20 The rings are so thin that when their edges face Earth they are nearly invisible.

Figure 21 During spring and fall, all parts of the planet experience equal hours of sunlight and darkness. During winter and summer, one hemisphere is always in darkness while the other is always in sunlight.

Reading Checkpoint Chunks of ice and rock

Reading Checkpoint William Herschel

Differentiated Instruction

Gifted and Talented L3

Researching Planet Names The ancient Romans named the planets they knew after the gods they worshipped. Mercury was the fast, winged messenger of the gods. Venus was the goddess of beauty, and Mars was the god of war. The planets and moons discovered in the last 200 years have also been named after ancient gods. Have students research the origin of the names of Jupiter, Saturn, Uranus, Neptune, or Pluto. Students can make posters describing the character of the god. *(Jupiter was the king of the Roman gods. Saturn was the god of agriculture. Uranus was the Greek god who was the husband of Gaea, Earth. Neptune was the Roman god of the sea. Pluto was the Roman god of the underworld.)* **learning modality: verbal**

Neptune

Teach Key Concepts L2

Neptune's Moons

Focus Have a student volunteer read aloud "Neptune's Moons."

Teach Ask: **How many moons does Neptune have?** *(At least 13)* **What is the name of Neptune's largest moon?** *(Triton)* **What is unusual about a region near Triton's south pole?** *(It may be covered by nitrogen ice; dark material erupts from under the ice.)*

Apply Tell students that the eruptions on Triton may be caused by geysers. On Earth, geysers are linked to tectonic activity. On Triton, geysers may be caused by sunlight warming the nitrogen gas; the resulting vapor rises through cracks in the icy surface. **learning modality: verbal**

Math Skills

Math Skills Formulas and Equations

Focus Have students recall that circumference is the perimeter of a circle.

Teach Point out that π is a constant, which means that its value does not vary.

Answer
$2 \times 3.14 \times 60{,}250$ km = about 378,800 km

Pluto

Teach Key Concepts L1

Classifying Pluto

Focus Remind students that Pluto is unique among the planets.

Teach Ask: **What makes Pluto different from the outer planets? The inner planets?** *(Pluto is much smaller than the outer planets and less dense than the inner planets.)*

Apply Remind students that Pluto is only twice the size of its own moon, Charon. Point out that Pluto and Charon may be two of many similar objects waiting to be discovered in the Kuiper belt. Challenge students to write a paragraph about whether Pluto should be classified as a planet, a Kuiper belt object, or some other type of object. **learning modality: verbal**

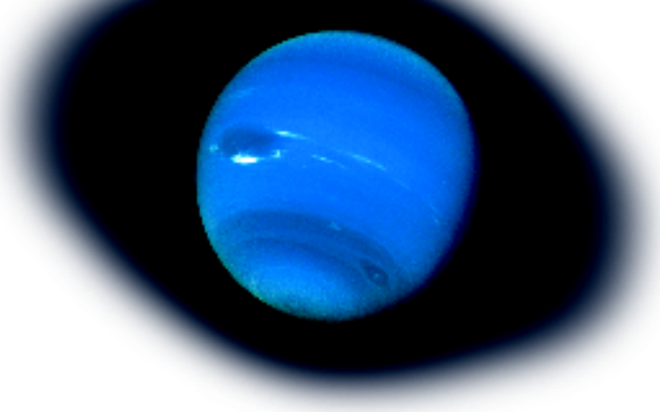

FIGURE 22
Neptune
The Great Dark Spot was a giant storm in Neptune's atmosphere. White clouds, probably made of methane ice crystals, can also be seen in the photo.

Size of Neptune compared to Earth

Math Skills

Circumference

To calculate the circumference of a circle, use this formula:

$$C = 2\pi r$$

In the formula, $\pi \approx 3.14$, and r is the circle's radius, which is the distance from the center of the circle to its edge. The same formula can be used to calculate the circumference of planets, which are nearly spherical.

Neptune's radius at its equator is about 24,800 km. Calculate its circumference.

$$C = 2\pi r$$
$$= 2.00 \times 3.14 \times 24{,}800 \text{ km}$$
$$= 156{,}000 \text{ km}$$

Practice Problem Saturn's radius is 60,250 km. What is its circumference?

Neptune

Neptune is even farther from the sun than Uranus. In some ways, Uranus and Neptune look like twins. They are similar in size and color. **Neptune is a cold, blue planet. Its atmosphere contains visible clouds.** Scientists think that Neptune, shown in Figure 22, is slowly shrinking, causing its interior to heat up. As this energy rises toward Neptune's surface, it produces clouds and storms in the planet's atmosphere.

Discovery of Neptune Neptune was discovered as a result of a mathematical prediction. Astronomers noted that Uranus was not quite following the orbit predicted for it. They hypothesized that the gravity of an unseen planet was affecting Uranus's orbit. By 1846, mathematicians in England and France had calculated the orbit of this unseen planet. Shortly thereafter, an observer saw an unknown object in the predicted area of the sky. It was the new planet, now called Neptune.

Exploring Neptune In 1989, *Voyager 2* flew by Neptune and photographed a Great Dark Spot about the size of Earth. Like the Great Red Spot on Jupiter, the Great Dark Spot was probably a giant storm. But the storm didn't last long. Images taken five years later showed that the Great Dark Spot was gone. Other, smaller spots and regions of clouds on Neptune also seem to come and go.

Neptune's Moons Astronomers have discovered at least 13 moons orbiting Neptune. The largest moon is Triton, which has a thin atmosphere. The *Voyager* images show that the region near Triton's south pole is covered by nitrogen ice.

Reading Checkpoint **Before they could see Neptune, what evidence led scientists to conclude that it existed?**

Size of Pluto compared to Earth

Pluto

Pluto is very different from the gas giants. **Pluto has a solid surface and is much smaller and denser than the other outer planets.** In fact, Pluto is smaller than Earth's moon.

Pluto has a single moon of its own, Charon. Since Charon is more than half the size of Pluto, some astronomers consider them to be a double planet instead of a planet and a moon.

Pluto's Orbit Pluto is so far from the sun that it revolves around the sun only once every 248 Earth years. Pluto's orbit is very elliptical, bringing it closer to the sun than Neptune on part of its orbit.

Is Pluto Really a Planet? Pluto is so small that many astronomers do not think it is worthy of being called a planet at all. Pluto may be merely the largest of tens of thousands of objects made of ice, rock, and dust that revolve around the sun beyond Neptune. If astronomers had found these other objects before they found Pluto, they might not have called Pluto a planet.

Reading Checkpoint **How long does it take Pluto to revolve around the sun?**

FIGURE 23
Pluto and Charon
The illustration above shows Pluto (lower right) and its moon Charon. **Inferring** *Why do astronomers often call Pluto and Charon a double planet?*

Section 4 Assessment

Target Reading Skill **Identifying Main Ideas** Use your graphic organizer about the structure of the gas giants to help you answer Question 1 below.

Reviewing Key Concepts

1. a. **Describing** How are the gas giants similar to one another?
   b. **Explaining** Why do all of the gas giants have thick atmospheres?
   c. **Listing** List the outer planets in order of size, from smallest to largest.
   d. **Comparing and Contrasting** Compare the structure of a typical terrestrial planet with that of a gas giant.
2. a. **Describing** Describe an important characteristic of each outer planet that helps to distinguish it from the other outer planets.
   b. **Comparing and Contrasting** How is Pluto different from the gas giants?
   c. **Classifying** Why do some astronomers think that Pluto should not be classified as a planet?

Math Practice

3. **Circumference** The radius of Jupiter at its equator is about 71,490 km. What is its circumference?

Monitor Progress L2

Answers

Figure 23 Pluto and Charon are similar in size and are close together.

Reading Checkpoint Uranus was not following the orbit that scientists predicted. Scientists believed that the gravity of a large object, probably a planet, was affecting Uranus's orbit.

Reading Checkpoint 248 Earth years

Assess

Reviewing Key Concepts

1. a. They are all much larger than Earth and do not have solid surfaces. **b.** Their strong gravitational pull keeps gases from escaping into space. **c.** Pluto, Neptune, Uranus, Saturn, Jupiter **d.** A typical terrestrial planet is small and rocky. A typical gas giant is large and mainly liquid with a solid core.

2. a. Possible answers: Jupiter—Great Red Spot; Saturn—spectacular rings; Uranus—axis of rotation; Neptune—Great Dark Spot; Pluto—small and dense **b.** It is much smaller, denser, and has a solid surface. **c.** It is too small.

3. Math Practice about 449,000 km

Reteach L1

Pass out the index cards that students completed in the "Preteach" activity at the beginning of this section. Have them discuss whether their statements are correct and, if not, make corrections.

Performance Assessment L2

Drawing Have students draw diagrams of the outer planets that show their relative sizes, their order, and at least one distinguishing characteristic of each.

All in One Teaching Resources

- Section Summary: *The Outer Planets*
- Review and Reinforce: *The Outer Planets*
- Enrich: *The Outer Planets*

Lab zone Chapter Project

Keep Students on Track By this time, students should have a model showing relative size and a model showing relative distance. Now they should attempt to design a model using the same scale for both size and distance. The larger the model, the more successful it will be in accurately representing the sizes of the planets.

Lab zone Design Your Own Lab

Speeding Around the Sun

L3

Prepare for Inquiry

Skills Objectives

After this lab, students will be able to

- Develop hypotheses concerning the revolution of a planet around the sun
- Make a model planet to test their hypotheses

Class Time 45 minutes

All in One Teaching Resources

- Lab Worksheet: *Speeding Around the Sun*

Alternative Materials

In place of a stopper, use a tennis ball with rubber bands around it. In place of the plastic tube, use a pen tube with smooth ends.

Safety

The stopper should be swung in an open space that is clear of all students and objects. Make sure that the object on the opposite end of the string from the stopper cannot be pulled through the tube. Check the strength of the string to make sure that it will not break. Tell students to wear eye protection throughout the lab. Review the safety guidelines in Appendix A.

Guide Inquiry

Invitation

Discuss the difference between a hypothesis and a scientific fact. A hypothesis is a possible explanation for a set of observations or an answer to a scientific question.

Lab zone Design Your Own Lab

Speeding Around the Sun

Problem

How does a planet's distance from the sun affect its period of revolution?

Skills Focus

making models, developing hypotheses, designing experiments

Materials

- string, 1.5 m
- plastic tube, 6 cm
- meter stick
- weight or several washers
- one-hole rubber stopper
- stopwatch or watch with second hand

Procedure

PART 1 Modeling Planetary Revolution

1. Copy the data table onto a sheet of paper.

Data Table				
Distance (cm)	Period of Revolution			
	Trial 1	Trial 2	Trial 3	Average
20				
40				
60				

2. Make a model of a planet orbiting the sun by threading the string through the rubber stopper hole. Tie the end of the string to the main part of the string. Pull tightly to make sure that the knot will not become untied.
3. Thread the other end of the string through the plastic tube and tie a weight to that end. Have your teacher check both knots.
4. Pull the string so the stopper is 20 cm away from the plastic tube. Hold the plastic tube in your hand above your head. Keeping the length of string constant, swing the rubber stopper in a circle above your head just fast enough to keep the stopper moving. The circle represents a planet's orbit, and the length of string from the rubber stopper to the plastic tube represents the distance from the sun. **CAUTION:** *Stand away from other students. Make sure the swinging stopper will not hit students or objects. Do not let go of the string.*
5. Have your lab partner time how long it takes for the rubber stopper to make ten complete revolutions. Determine the period for one revolution by dividing the measured time by ten. Record the time in the data table.
6. Repeat Step 5 two more times. Be sure to record each trial in a data table. After the third trial, calculate and record the average period of revolution.

Introduce the Procedure

- Have students think of the inward pull of the string as gravity.
- The activity should give students a "feel" for the effects of gravity and the increased speed of objects as their orbits get smaller.

Troubleshooting the Experiment

- Students may have to practice keeping the stopper moving at a constant speed.

PART 2 Designing an Experiment

7. Write your hypothesis for how a planet's period of revolution would be affected by changing its distance from the sun.
8. Design an experiment that will enable you to test your hypothesis. Write the steps you plan to follow to carry out your experiment. As you design your experiment, consider the following factors:
   - What different distances will you test?
   - What variables are involved in your experiment and how will you control them?
   - How many trials will you run for each distance?
9. Have your teacher review your step-by-step plan. After your teacher approves your plan, carry out your experiment.

Analyze and Conclude

1. **Making Models** In your experiment, what represents the planet and what represents the sun?
2. **Making Models** What force does the pull on the string represent?
3. **Interpreting Data** What happened to the period of revolution when you changed the distance in Part 2? Did your experiment prove or disprove your hypothesis?
4. **Drawing Conclusions** Which planets take less time to revolve around the sun—those closer to the sun or those farther away? Use the model to support your answer.
5. **Designing Experiments** As you were designing your experiment, which variable was the most difficult to control? How did you design your procedure to control that variable?
6. **Communicating** Write a brief summary of your experiment for a science magazine. Describe your hypothesis, procedure, and results in one or two paragraphs.

More to Explore

Develop a hypothesis for how a planet's mass might affect its period of revolution. Then, using a stopper with a different mass, modify the activity to test your hypothesis. Before you swing your stopper, have your teacher check your knots.

Sample Data Table				
Distance	Trial 1	Trial 2	Trial 3	Average
(cm)	(s)	(s)	(s)	(s)
20	0.4	0.5	0.4	0.43
40	0.6	0.6	0.7	0.63
60	0.8	0.8	0.8	0.8

Expected Outcome

- It takes longer for a single revolution when the string is longer.
- Tell students that as distance from the sun increases, the gravitational pull of the sun on a planet decreases. In addition, the circumference of the orbit increases as distance from the sun increases. This means that the planet is traveling more slowly over a greater distance.

Analyze and Conclude

1. The plastic tube represented the sun. The rubber stopper represented the planet.

2. The pull on the string represents the force of gravity.

3. The period of revolution should have increased as the length of string increased. This result may support or disprove students' hypotheses.

4. Planets closer to the sun revolve around the sun in less time. Students should support this conclusion by noting that when the string was short in the model, the period of revolution was also short.

5. Students may cite such variables as mass or angle of rotation. Make sure students designed their experiment to take into account a way to control that variable.

6. Check students' articles for accuracy. Make sure they included the requested information.

Extend Inquiry

More to Explore By adding additional rubber stoppers, the mass of the swinging object is increased. By repeating the swing of the increased mass in the same orbit, students will find that planets have the same period at the same distance. They may also notice that the inward pull of the string has to be greater with more stoppers. The force of gravity between the sun and a planet is related to the mass of the planet. The inertia of a planet is also related to its mass. Thus, the effect of increasing the mass is to increase both the pull of the sun's gravity and the ability of the planet to withstand that pull through inertia. The resulting speed of the planet is the same, regardless of mass.