

Observing the Solar System

Objectives

After this lesson, students will be able to

J.3.1.1 Identify the geocentric and heliocentric systems.

J.3.1.2 Recognize how scientists such as Copernicus, Galileo, and Kepler contributed to acceptance of the heliocentric system.

J.3.1.3 Identify the objects that make up the solar system.

Target Reading Skill

Previewing Visuals Explain that looking at visuals before they read helps students activate prior knowledge and predict what they are about to read.

Answers

Possible Answers

Q: What is a geocentric model?

A: A model that shows Earth at the center of the revolving planets and stars

Q: What is a heliocentric system?

A: A model that shows Earth and the other planets revolving around the sun

All in One Teaching Resources

- [Transparency J22](#)

Preteach

Build Background Knowledge

L2

Night Sky

Let students examine a photograph of the night sky that shows stars and the moon. Ask them to identify the objects they see. Then ask: **Where was the sun when this picture was taken?** (*The sun could not be seen from the spot where the picture was taken because it was on the other side of Earth.*) Reinforce the idea that the objects in our solar system are moving.

Observing the Solar System

Reading Preview

Key Concepts

- What are the geocentric and heliocentric systems?
- How did Copernicus, Galileo, and Kepler contribute to our knowledge of the solar system?
- What objects make up the solar system?

Key Terms

- geocentric
- heliocentric
- ellipse

Target Reading Skill

Previewing Visuals

Preview Figure 2 and Figure 3. Then write two questions that you have about the diagrams in a graphic organizer. As you read, answer your questions.

Models of the Universe

Q. What is a geocentric model?

A.

Q.



FIGURE 1
Star Trails

This photo was made by exposing the camera film for several hours. Each star appears as part of a circle, and all the stars seem to revolve around the North Star.

Lab
zone

Discover Activity

What Is at the Center?

1. Stand about 2 meters from a partner who is holding a flashlight. Have your partner shine the flashlight in your direction. Tell your partner not to move the flashlight.
2. Continue facing your partner, but move sideways in a circle, staying about 2 meters away from your partner.
3. Record your observations about your ability to see the light.
4. Repeat the activity, but this time remain stationary and continually face one direction. Have your partner continue to hold the flashlight toward you and move sideways around you, remaining about 2 meters from you.
5. Record your observations about your ability to see the light.

Think It Over

Drawing Conclusions Compare your two sets of observations. If you represent Earth and your partner represents the sun, is it possible, just from your observations, to tell whether Earth or the sun is in the center of the solar system?

Have you ever gazed up at the sky on a starry night? If you watch for several hours, the stars seem to move across the sky. The sky seems to be rotating right over your head. In fact, from the Northern Hemisphere, the sky appears to rotate completely around the North Star once every 24 hours.

Now think about what you see every day. During the day, the sun appears to move across the sky. From here on Earth, it seems as if Earth is stationary and that the sun, moon, and stars are moving around Earth. But is the sky really moving above you? Centuries ago, before there were space shuttles or even telescopes, there was no easy way to find out.

Lab
zone

Discover Activity

Skills Focus drawing conclusions

Materials flashlight

Time 10 minutes

Tips Darken the room before students conduct the activity. Let students take turns representing the sun and Earth.

L2 Expected Outcome The student who represents Earth will find it difficult to see the light when moving behind the student who represents the sun. The same student will find it difficult to see the light when the “sun” moves behind him or her.

Think It Over It would be difficult if not impossible to tell whether Earth or the sun were the center of the solar system.

Earth at the Center

When the ancient Greeks watched the stars move across the sky, they noticed that the patterns of the stars didn't change. Although the stars seemed to move, they stayed in the same position relative to one another. These patterns of stars, called constellations, kept the same shapes from night to night and from year to year.

Greek Observations As the Greeks observed the sky, they noticed something surprising. Several points of light seemed to wander slowly among the stars. The Greeks called these objects *planets*, from the Greek word meaning “wanderers.” The Greeks made careful observations of the motions of the planets that they could see. You know these planets by the names the ancient Romans later gave them: Mercury, Venus, Mars, Jupiter, and Saturn.

Most early Greek astronomers believed the universe to be perfect, with Earth at the center. The Greeks thought that Earth is inside a rotating dome they called the celestial sphere. Since *geo* is the Greek word for “Earth,” an Earth-centered model is known as a **geocentric** (jee oh SEN trik) system. **In a geocentric system, Earth is at the center of the revolving planets and stars.**

Ptolemy's Model About A.D. 140, the Greek astronomer Ptolemy (TAHL uh mee) further developed the geocentric model. Like the earlier Greeks, Ptolemy thought that Earth is at the center of a system of planets and stars. In Ptolemy's model, however, the planets move on small circles that move on bigger circles.

Even though Ptolemy's geocentric model was incorrect, it explained the motions observed in the sky fairly accurately. As a result, the geocentric model of the universe was widely accepted for nearly 1,500 years after Ptolemy.

Reading Checkpoint What is a geocentric system?

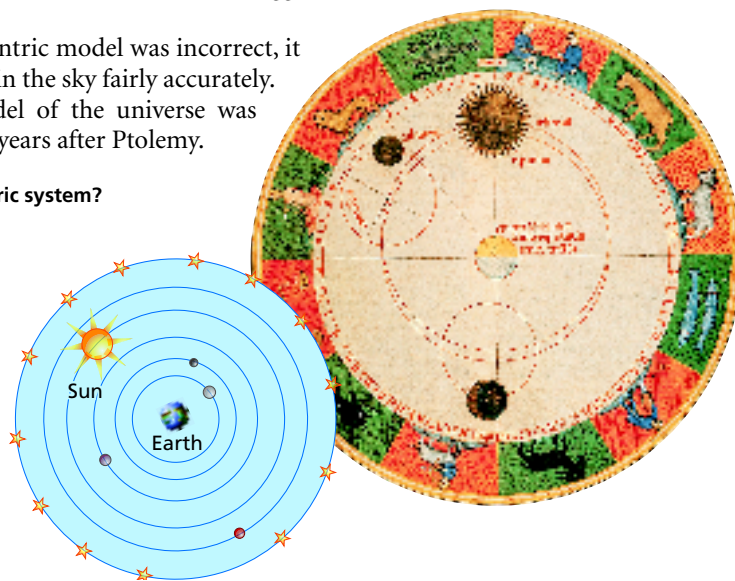


FIGURE 2
Geocentric System

In a geocentric system, the planets and stars are thought to revolve around a stationary Earth. In the 1500s, an astronomy book published the illustration of Ptolemy's geocentric system shown below.

Interpreting Diagrams Where is Earth located in each illustration?

Instruct

Earth at the Center

Teach Key Concepts

L2

Geocentric Model of the Solar System

Focus Ask: **Why could the ancient Greeks see only five planets in the sky?** (*They did not have telescopes and could not see the other planets because those planets are too dim because they are so far away.*)

Teach Ask students to describe the movement of Earth and the other planets in the geocentric system. (*Earth is stationary; the other planets revolve around Earth.*)

Apply Tell students they will learn how scientists eventually concluded that Earth and the other planets revolved around the sun. **learning modality: visual**

Independent Practice

L2

All in One Teaching Resources

- [Guided Reading and Study Worksheet: Observing the Solar System](#)

Student Edition on Audio CD

Differentiated Instruction

English Learners/Beginning

L1

Vocabulary: Link to Visual Make copies of Figure 2, and distribute them to students. Give students a list of words related to the diagram, such as *geocentric*, *planet*, *moon*, *celestial sphere*, and *stationary center*. Have students label the illustration using these words. Model the activity first by writing the word *geocentric* as a title.

learning modality: visual

English Learners/Intermediate

L2

Vocabulary: Link to Visual Make copies of the diagram described for beginning learners and distribute them to students. Have them label the illustration using words from the text. **learning modality: visual**

Monitor Progress

L2

Drawing Have students draw and label a diagram of a geocentric system. The diagram should include the sun, Earth, and at least one other planet. Students can place their drawings in their portfolios.



Answers

Figure 2 Earth is at the center.

Reading Checkpoint A geocentric system is one in which Earth is at the center of a system of revolving planets.

Sun at the Center

Teach Key Concepts

Scientific Contributions

Focus Ask: How do Earth and the other planets move in the heliocentric system? (They revolve around the sun.)

Teach Ask: Describe Copernicus's contribution to the heliocentric system. (Copernicus worked out the arrangement of the known planets and many details of how they moved around the sun.)

Apply Have students examine the top model in Figure 3.

Ask: Does this diagram reflect Kepler's contribution to the heliocentric system?

How do you know? (It reflects Kepler's contribution to the heliocentric system because the orbits of the planets are ellipses rather than circles.) **learning modality: visual**

L2

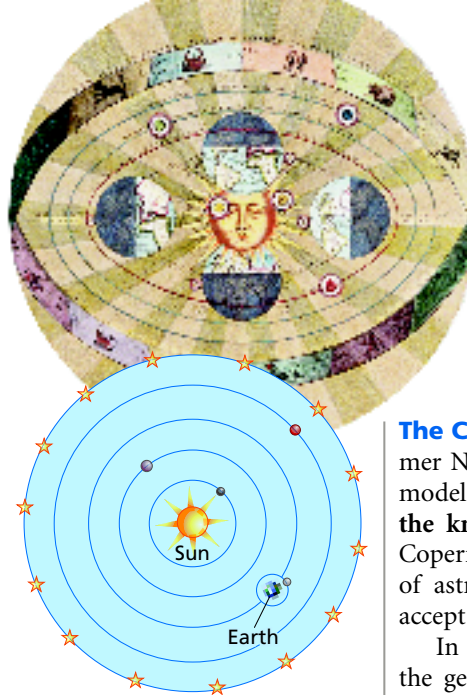


FIGURE 3
Heliocentric System

In a heliocentric system, Earth and the other planets revolve around the sun. The illustration by Andreas Cellarius (top) was made in the 1660s.

Interpreting Diagrams In a heliocentric model, what revolves around Earth?

Sun at the Center

Not everybody believed in the geocentric system. An ancient Greek scientist developed another explanation for the motion of the planets. This sun-centered model is called a **heliocentric** (hee lee oh SEN trik) system. *Helios* is Greek for “sun.” In a **heliocentric system**, Earth and the other planets revolve around the sun. This model was not well received in ancient times, however, because people could not accept that Earth is not at the center of the universe.

The Copernican Revolution In 1543, the Polish astronomer Nicolaus Copernicus further developed the heliocentric model. Copernicus was able to work out the arrangement of the known planets and how they move around the sun. Copernicus's theory would eventually revolutionize the science of astronomy. But at first, many people were unwilling to accept his theory. They needed more evidence to be convinced.

In the 1500s and early 1600s, most people still believed in the geocentric model. However, evidence collected by the Italian scientist Galileo Galilei gradually convinced others that the heliocentric model was correct.

Galileo's Evidence Galileo used the newly invented telescope to make discoveries that supported the heliocentric model. For example, in 1610, Galileo used a telescope to discover four moons revolving around Jupiter. The motion of these moons proved that not everything in the sky revolves around Earth.

L1

Lab zone Build Inquiry

Modeling the Movements of the Inner Planets

Materials chalk, metric ruler

Time 15 minutes

Focus Place students in groups of four. Have each group use chalk to draw concentric circles in a playground or a parking lot of radii 3.5 m, 5.0 m, and 7.5 m. Tell students they will represent the sun, Venus, Earth, and Mars, respectively.

Teach Ask: Where will the sun stand? (In the center) Where will the other planets stand? (Inner circle: Venus; middle circle: Earth; outer circle: Mars) Have students model the movements of the planets by walking around the “sun.”

Apply Ask: If everyone moved at a constant speed, which planet circled the sun the fastest? (Venus) The slowest? (Mars) **learning modality: kinesthetic**



Nicolaus Copernicus
1473–1543



Galileo Galilei
1564–1642

▼ A reconstruction of Galileo's telescope



FIGURE 4
Major Figures in the History of Astronomy

Galileo's observations of Venus also supported the heliocentric system. Galileo knew that Venus is always seen near the sun. He discovered that Venus goes through a series of phases similar to those of Earth's moon. But Venus would not have a full set of phases if it circled around Earth. Therefore, Galileo reasoned, the geocentric model must be incorrect.

Tycho Brahe's Observations Copernicus correctly placed the sun at the center of the planets. But he incorrectly assumed that the planets travel in orbits that are perfect circles. Copernicus had based his ideas on observations made by the ancient Greeks.

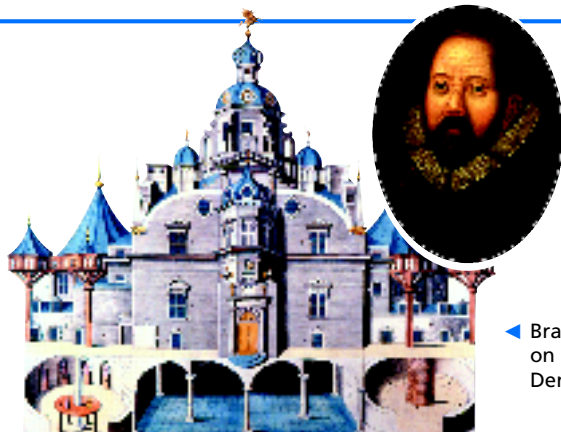
In the late 1500s, the Danish astronomer Tycho Brahe (TEE koh BRAH uh) and his assistants made much more accurate observations. For more than 20 years, they carefully observed and recorded the positions of the planets. Surprisingly, these observations were made without using a telescope. Telescopes had not yet been invented!

Kepler's Calculations Tycho Brahe died in 1601. His assistant, Johannes Kepler, went to work analyzing the observations. Kepler began by trying to figure out the shape of Mars's orbit. At first, he assumed that the orbit was circular. But his calculations did not fit the observations. Kepler eventually found that Mars's orbit was a slightly flattened circle, or ellipse. An **ellipse** is an oval shape, which may be elongated or nearly circular.

After years of detailed calculations, Kepler reached a remarkable conclusion about the motion of the planets. **Kepler found that the orbit of each planet is an ellipse.** Kepler had used the evidence gathered by Tycho Brahe to disprove the long-held belief that the planets move in perfect circles.



What is an ellipse?



Tycho Brahe
1546–1601

Johannes Kepler
1571–1630



◀ Brahe's observatory on an island between Denmark and Sweden

Lab zone Try This Activity

A Loopy Ellipse

You can draw an ellipse.

1. Carefully stick two pushpins about 10 cm apart through a sheet of white paper on top of corrugated cardboard. One pushpin represents the sun.
2. Tie the ends of a 30-cm piece of string together. Place the string around the pushpins.
3. Keeping the string tight, move a pencil around inside the string.
4. Now place the pushpins 5 cm apart. Repeat Step 3.

Predicting How does changing the distance between the pushpins affect the ellipse's shape? What shape would you draw if you used only one pushpin? Is the "sun" at the center of the ellipse?

Lab zone Teacher Demo

L1

Elliptical Orbits

Materials chalk

Time 15 minutes

Focus To help students understand elliptical orbits, diagram Mars, its orbit, and the sun on the board. The sun should be slightly offset from the center of the orbit. The orbit itself should be slightly flattened.

Teach Ask: **In an elliptical orbit, what happens to the distance between a planet and the sun?** (*It changes as the planet revolves.*)

Apply Ask: **What would it be like to live on a planet that had an extremely elliptical orbit?** (*The temperature would likely vary more extremely than on Earth, seasons would be very different.*) **learning modality: visual**

Lab zone Try This Activity

Skills Focus predicting

Materials white paper, corrugated cardboard, 30-cm string, 2 pushpins, ruler, pencil

Time 15 minutes

Tips Provide students with pieces of cardboard the same size as a sheet of paper. Remind students to keep the string taut when drawing their lines.

L2 Expected Outcome Moving the pushpins closer together makes the ellipse more round. If students used only one pushpin, they would draw a circle.

Extend Challenge students to predict the shape of ellipses formed with pushpins 2.5 cm and 7.5 cm apart. Encourage them to test their predictions. **learning modality: kinesthetic**

Monitor Progress L2

Writing Have students write a paragraph explaining in their own words the contributions made to the heliocentric model by Copernicus, Galileo, Tycho, and Kepler.

Answers

Figure 3 The moon



An oval shape, which may be elongated or nearly circular

Modern Discoveries

Teach Key Concepts

L2

Observing the Solar System

Focus Remind students that early astronomers knew of only six planets.

Teach Ask: **Which planets have been discovered since Galileo's time?** (*Uranus, Neptune, and Pluto*) **What other objects in the solar system have been discovered since that time?** (*Asteroids and many moons orbiting other planets*)

Apply Ask: **What kinds of technology do modern scientists use to study space?** (*Possible answer: Space and Earth-based telescopes and space probes*) **learning modality: logical/mathematical**

Math Analyzing Data

Math Skill Making and interpreting graphs

Focus Remind students that a line graph shows the relationship between two sets of data. In this graph, the data shown are the average speeds of planets and their average distances from the sun.

Teach Ask: **What data are shown on the y-axis?** (*Speed*) **What data are shown on the x-axis?** (*Average distance from the sun*)

Answers

1. About 30 km/s
2. Mercury; Mercury
3. Planets that are closer to the sun move faster.
4. Uranus's speed is less than that of Jupiter because Uranus is farther from the sun than Jupiter.



FIGURE 5

The Sun and Planets

This illustration shows the average distances of the nine planets from the sun. These distances are drawn to scale, but the sizes of the planets are not drawn to the same scale. **Observing** Which planet is closest to the sun?

Modern Discoveries

Today, people talk about the “solar system” rather than the “Earth system.” This shows that people accept the idea that Earth and the other planets revolve around the sun.

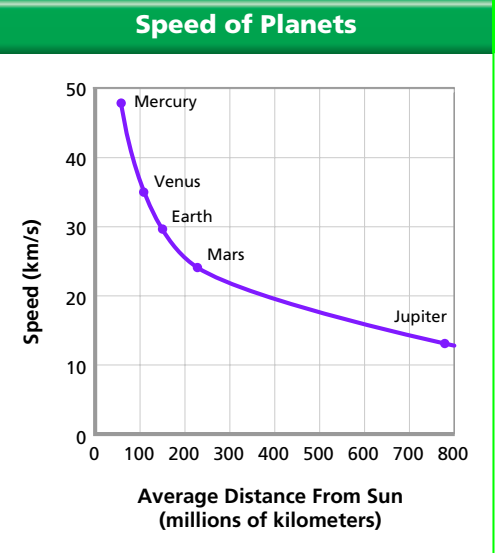
Since Galileo's time, our knowledge of the solar system has increased dramatically. Galileo knew the same planets that the ancient Greeks had known—Mercury, Venus, Earth, Mars, Jupiter, and Saturn. Since Galileo's time, astronomers have discovered three more planets—Uranus, Neptune, and Pluto. Astronomers have also identified many other objects in the solar system, such as comets and asteroids. **Today we know that the solar system consists of the sun, nine planets and their moons, and several kinds of smaller objects that revolve around the sun.**

Math Analyzing Data

Planet Speed Versus Distance

Johannes Kepler discovered a relationship between the speed of a planet and its distance from the sun. Use the graph to help discover what Kepler learned.

1. **Reading Graphs** According to the graph, what is Earth's average speed?
2. **Interpreting Data** Which is closer to the sun, Mercury or Mars? Which moves faster?
3. **Drawing Conclusions** What is the general relationship between a planet's speed and its average distance from the sun?
4. **Predicting** The planet Uranus is about 2,900 million km from the sun. Predict whether its speed is greater or less than Jupiter's speed. Explain your answer.



Uranus
2,873,000,000 km

Neptune
4,495,000,000 km

Pluto
5,870,000,000 km

Galileo used a telescope to observe the solar system from Earth's surface. Astronomers today still use telescopes located on Earth, but they have also placed telescopes in space to gain a better view of the universe beyond Earth. Scientists have also sent astronauts to the moon and launched numerous space probes to explore the far reaches of the solar system. Our understanding of the solar system continues to grow every day. Who knows what new discoveries will be made in your lifetime!

 **Reading Checkpoint** Which six planets were known to the ancient Greeks?

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For: Solar System activity
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Students can interact with the art of the solar system online.

Monitor Progress L1

Answers

Figure 5 Mercury

 **Reading Checkpoint** Mercury, Venus, Earth, Mars, Jupiter, Saturn

Assess

Reviewing Key Concepts

- a.** Geocentric: Earth is at the center of the solar system. Heliocentric: the sun is at the center. **b.** Ptolemy thought that the planets, moon, and sun revolved around Earth. Copernicus thought that the sun was in the middle and that the planets revolved around the sun. **c.** Moons revolving around Jupiter and the phases of Venus **d.** No; Earth is rotating from west to east. This causes the sun to appear to move across the sky.
- a.** To describe the motion of the planets **b.** They are elliptical. **c.** Brahe observed and recorded his observations. Kepler used the evidence gathered by Brahe to form a hypothesis about planetary orbits. Then he made predictions and confirmed or revised his hypothesis on the basis of his observations.
- a.** The sun, nine planets and their moons, and other smaller objects **b.** Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto **c.** Venus

Reteach L1

Use a mnemonic device to help students remember the planets in order from the sun. Example: Many Very Eager Monkeys Jump Skyward Until Night Passes.

All in One Teaching Resources L2

- [Section Summary: Observing the Solar System](#)
- [Review and Reinforce: Observing the Solar System](#)
- [Enrich: Observing the Solar System](#)

Section 1 Assessment

Target Reading Skill **Previewing Visuals**

Refer to your questions and answers about Figure 2 and Figure 3 to help you answer Question 1 below.

Reviewing Key Concepts

- a. Explaining** What are the geocentric and heliocentric systems?
b. Comparing and Contrasting How was Copernicus's model of the universe different from Ptolemy's model?
c. Drawing Conclusions What discoveries by Galileo support the heliocentric model?
d. Applying Concepts People often say the sun rises in the east, crosses the sky, and sets in the west. Is this literally true? Explain.
- a. Interpreting Data** How did Kepler use Tycho Brahe's data?
b. Describing What did Kepler discover about the orbits of the planets?
c. Inferring How did Tycho Brahe and Kepler employ the scientific method?

- a. Describing** What objects make up the solar system?
b. Listing What are the nine planets, in order of increasing distance from the sun?
c. Interpreting Diagrams Use Figure 5 to find the planet with the closest orbit to Earth.

Writing in Science

Dialogue Write an imaginary conversation between Ptolemy and Galileo about the merits of the geocentric and heliocentric systems. Which system would each scientist favor? What evidence could each offer to support his view? Do you think that one scientist could convince the other to change his mind? Use quotation marks around the comments of each scientist.

Lab Zone Chapter Project

Keep Students on Track Have students begin by making a table that shows the distances of the planets from the sun. They should then decide on a scale for their model. If students have difficulty developing a scale, suggest that they try 1: 10,000,000. Also, suggest that they use lined paper to keep their calculations neat and easy to follow.

Writing in Science

Writing Skill Description

Scoring Rubric

- 4 Exceeds criteria, includes the system favored by each scientist and supporting evidence is lively and entertaining
- 3 Meets all criteria but does not go beyond requirements
- 2 Meets only some criteria
- 1 Is inaccurate and incomplete