### Chapter 26: The Solar System

#### Instructional Sequence

1. Complete Chapter 26 Pretest.

#### Learning Goals

- Explain the significance of gravity in maintaining the solar system.
- Distinguish Sun-centered and Earth-centered models of the solar system.
- Explain the current model of the solar system.

#### National Science Standards

- INQ01.4
- ESS03.1
- PS04.2

#### Investigations and Materials

Investigation 26A: Phases of the Moon
- Materials (per group): Flashlight, 2- or 3-inch foam ball, Pencil or craft stick, 1 yellow sticker, 1 black sticker

Investigation 26B: Earth’s Seasons
- Materials (per group): Globe, Solar (PV) cell, Multimeter, Metric tape measure, Masking tape

Investigation 26C: Solar System
- Optional Activity
- Materials (per group): Access to a large space with a length of 100 meters (a soccer field is ideal), A metric tape measure or a trundle wheel, A variety of objects to represent the relative sizes of the planets (examples: softball, soccer ball, bowling ball, small plastic balls, inflatable beach balls), Blank paper for making signs
### Chapter 26 Resources

#### Assessment Tools

- **Chapter 26 Pretest**
- **Section 26.1 Review**
- **Section 26.2 Review**
- **Section 26.3 Review**

#### Program Resources

- **Skill and Practice Worksheets**
  - Astronomical Units, Gravity Problems, Universal Gravitation, Nicolaus Copernicus Biography, Galileo Galilei Biography, Johannes Kepler Biography, Measuring the Moon’s Diameter
  - Benjamin Banneker Biography
  - Touring the Solar System

- **Teaching Illustrations**
  - The Solar System
  - Sizes of Planets Relative to the Sun
  - Distance from Earth to the Sun
  - Moon Phases
  - Earth’s Rotation and Revolution

- **Graphic Organizers**
  - 26A The Solar System
  - 26B The Lunar Cycle

#### Technology Resources

- **Lesson Organizer**
- **CPO Website**—www.cposcience.com
  - Equipment Setup Videos
  - Science Content Videos
  - Simulations
  - Presentation Slides

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#### Literature Selections

- **Earth: Our Planet in Space** by Seymour Simon
  - Simon is a former teacher and an award-winning author of more than 200 books, including many others befitting the topics addressed throughout this unit. This book offers clear explanations of the relationships between Earth, the Sun, and the Moon and contains excellent color photographs.

- **NightWatch: A Practical Guide to Viewing the Universe** by Terence Dickson
  - NightWatch, the third edition is easily considered one of the best field guides for beginning astronomers. Includes discussions on light pollution, buying a telescope and binoculars, pronunciation of stars and constellations and photographs.

- **Exploring Our Solar System** by Sally Ride and Tam O’Shaughnessy
  - Another tour of the solar system, but this time it is navigated by astronaut Sally Ride and educator Tam O’Shaughnessy. This is a well-written book with straightforward language that is filled with facts and full colored photographs.
Investigation 26A: Phases of the Moon

Why does the Moon appear to change shape over the course of a month? In this investigation, students will model the lunar cycle and figure out if there really is a “dark side” of the Moon.

Key Question

What causes the lunar cycle?

Objectives

Students will:
- Describe the lunar cycle.
- Use a Sun-Moon-Earth model to explain the appearance of the Moon at different phases.
- Justify the description of the Moon’s far side.

Setup

1. One class period is needed to complete the investigation.
2. Students work in small groups of three to five.
3. A 1-watt LED flashlight with an adjustable beam works best in this investigation, but you can also get satisfactory results with a bell-shaped utility lamp with a 25-watt bulb. These inexpensive lamps can be found at hardware stores.
4. The white stickers (1-inch diameter) commonly used to mark prices on yard sale items may be used in this activity. Use permanent markers to color them yellow and black. The stickers can be found at office supply stores.

Materials

Each group should have the following:
- Flashlight
- 2- or 3-inch foam ball
- Pencil or craft stick
- 1 yellow sticker
- 1 black sticker

Safety

Students should observe general laboratory safety procedures while completing Investigation 26A.
26A Phases of the Moon

What causes the lunar cycle?

Why does the Moon appear to change shape over the course of a month? In this investigation you will model the lunar cycle and figure out if there really is a “dark side of the Moon.”

1. Think about it
   a. When was the last time you noticed the Moon? Describe or draw its shape.

b. You have probably noticed that the Moon doesn’t look the same every time you see it. But why?

2. Make a hypothesis

You’ve spent some time thinking about what the lunar cycle looks like. Why does the Moon appear to change shape?

   a. Create a hypothesis to explain why the Moon appears to change shape.
   b. What variable or variables do you think affect the way the Moon appears?

3. Model the lunar cycle

   a. Place a foam ball on a pencil or stick. This ball represents the Moon.
   b. Have another student hold a flashlight. The flashlight represents the Sun. Your head represents Earth.
   c. Hold the ball slightly above your head, at arm’s length from your face. Stand about one meter from the flashlight, which is held at the same level as the ball.
   d. Observe the Moon in each of the positions shown in Figure 3. Face the ball at each position.
   e. For each position, indicate how much of the ball is dark and how much is illuminated, in the graphic below. Use a pencil to show the shaded region. Leave the illuminated part white.

4. Thinking about what you observed

   a. When you see a full Moon in the sky, at which position (A–H) is the Moon seen from Earth?
   b. At which position (A–H) would the Moon not be visible from Earth?
   c. Revise or change your hypothesis if the activity changed your thinking about why the Moon appears to change shape. Why?
   d. If you hold the ball at eye-level, do the Moon phases appear as they do in real life? What does that tell you about the Moon’s actual orbit around Earth?

5. Is there a “dark side” of the Moon?

You may have noticed that the Moon has some darker areas shown as maria on its surface. Because the maria are always in the same location when we view the Moon, we know that the Moon doesn’t rotate. Now, model the lunar cycle and think about your hypothesis as you answer the questions below.

   a. If we always see one side of the Moon, does that mean that there is a side of the Moon that is always dark?
   b. Why not, then that we always see the same side of the Moon? Do you think the Moon rotates?

6. Test your ideas

   a. Place a yellow sticker on one side of the styrofoam ball. This sticker represents the side of the Earth that we can see from Earth. If the sticker always faces the Earth, does that tell you about the Moon’s actual orbit around Earth?
   b. Place a black sticker on the opposite side. If the sticker faces different walls at different times, you will know that the Moon does, in fact, rotate.
   c. If the yellow sticker faces different walls at different times, you will know the Moon does not rotate. If the sticker faces different walls at different times, you will know that the Moon never changes its orbit.
   d. If you hold the ball at eye-level, do the Moon phases appear as they do in real life? If so, how many complete rotations do you think the Moon makes during one orbit of Earth?

7. Thinking about what you observed

   a. Does the Moon rotate? How do you know?
   b. If so, how many complete rotations do you think the Moon makes during one orbit of Earth?
   c. Is one side of the Moon forever in darkness? Why or why not?
   d. Which is a better name for the side of the Moon we cannot see from Earth? The dark side of the Moon, or The far side of the Moon? Why?
Teaching Investigation 26A

1 Think about it
Many people enjoy looking at the night sky to see the Moon and stars. Is this something you enjoy?
   Students share answers.

When was the last time you noticed the Moon? What did it look like?
   Students share what they observed as they looked at the Moon.

Use the space provided on your handout to draw what you observed when you last looked at the Moon.
   Allow time for students to complete drawings.

Look at the drawings three or four of your classmates made. Are they all identical? You have probably noticed that the Moon doesn’t look the same every time you see it. But have you ever thought about how it changes over the course of a month? In the chart provided, draw the shapes of the Moon in the order that you think you would see them over the course of a month. Two views have been drawn to help you get started.
   Students may or may not have prior knowledge of the lunar cycle. Make it clear to students that it is okay to make their best guess, as they are not expected to know all about the Moon stages. The goal is to be able to make comparisons between what students think before doing the investigation and their impressions after the activity. Encourage students to discuss their ideas with group members as they sketch how the shape of the Moon changes over time.

How would you represent a “full” Moon?
   The full Moon would be an all-white circle. No part of it is shaded.

2 Make a hypothesis
The lunar cycle is the cycle of change in the appearance of the Moon due to the positions of Earth, the Moon, and the Sun. This is what you have represented as you sketched the changes in the Moon’s shape over a one-month period. Now that you have spent some time thinking about what the lunar cycle looks like, are you able to explain why the Moon appears to change shape? Discuss this question with members of your group. Then write a hypothesis to express your thoughts.
   Allow students to share their opinions. Lead a discussion to steer students toward understanding that the Moon appears to change shape as the angle formed by Earth, the Moon, and the Sun changes.

What factor or factors do you think might affect the way the Moon appears? Talk it over with your group members.
   The way the Moon appears depends on the position of the Moon relative to Earth and the Sun. Some common misconceptions about the variables that influence the appearance of the Moon
include the following: Earth’s shadow, the Sun’s shadow, Earth’s position in its orbit around the Sun, and the season of the year.

3 Model the lunar cycle

In this part of the investigation, you will model the lunar cycle. Place a foam ball on a pencil or stick. This ball represents the Moon. Have another student hold a flashlight. The flashlight represents the Sun. Your head represents Earth.

Hold the ball slightly above your head, at arm’s length from your face. Stand about 1 m from the flashlight, which is held at the same level as the ball. Observe the Moon in each of the positions shown in Figure 2. Face the ball at each position. For each position, indicate how much of the ball is dark and how much is illuminated. Use a pencil to show the shaded region. Leave the illuminated part white.

Explain to students that they are representing eight evenly spaced days within the approximately month-long (29.5-day) lunar cycle. Earth spins on its axis each day so that at some point during that 24-hour period, their hometown will face the Moon. The student holding the Moon model can think of his or her head as Earth and his or her nose as the location of the hometown. At each position, A–H, the student can imagine that he or she is looking at the Moon as seen from the hometown.

For simplicity’s sake, don’t ask the students to rotate, nor should you worry about whether it is day or night when Earth faces the Moon. Students may know that sometimes the Moon can be seen in the daytime if it is in the opposite part of the sky from the Sun. Examine sunrise/sunset and Moonrise/Moonset data for the current month as an extension activity. This data can be found at the U.S. Naval Observatory website located at aa.usno.navy.mil.

This activity works best if it is modeled for students before sending them off in groups. It may be helpful to have each group mark the floor with masking tape in the shape of a lower case letter “t.” The person holding the light can stand at the bottom of the “t.” The person who represents Earth stands where the two lines cross. Check to see that each group found Position A correctly.

4 Thinking about what you observed

If you could see the Sun-Moon-Earth system from above, you would see that half of the Moon is almost always illuminated by sunlight. Here on Earth, the fraction of the Moon that is illuminated appears to change as the Moon revolves around Earth.

The diagram shown in Part 4 shows how the Sun-Moon-Earth system appears from above. The different positions of the Moon are labeled A–H. When you see a full Moon in the sky, at which position is the Moon in its orbit?

It is at position C.
At which position would the Moon not be visible from Earth?

The Moon would not be visible from position G.

Go back to the hypothesis you wrote in Part 2. Considering what you have observed thus far, do you have different thoughts about why the Moon appears to change? If so, make changes to your hypothesis. Otherwise, record “no change” for your answer to question 2c.

Allow time for students to review what they originally wrote and to make any revisions.

If you hold the ball at eye level, do the Moon phases appear as they do in real life? What does that tell you about the Moon’s actual orbit around Earth?

It is helpful to have one group demonstrate what happens if you hold the Moon model at eye level. At the full Moon phase, the “Earth” (student’s head) blocks the light, and the Moon model does not reflect the sunlight. This is what happens during a lunar eclipse. Usually, Earth does not block the Sun’s light at the full Moon position, because the plane of the Moon’s orbit is tilted 5° with respect to Earth’s orbit. However, these two planes intersect in two places during each lunar cycle. As a result, the two orbits are occasionally aligned during a full Moon. Because of this alignment, Earth’s shadow temporarily blocks the sunlight from hitting the Moon. This causes a lunar eclipse. For a detailed description of a lunar eclipse, see section 26.2 of the student text. If the orbital planes are aligned during a new Moon, a solar eclipse occurs. For a detailed description of a solar eclipse, see Section 26.2 of the student text.

If Earth’s shadow does not usually block the Sun’s light from reaching the Moon, what causes the change in the Moon’s appearance from Earth?

Check students’ understanding to ensure they realize that the amount of reflected light we are able to see from Earth depends on the angle formed by the Sun, Earth, and the Moon.

Is there a “dark side” of the Moon?

When Galileo looked at the Moon through his rudimentary telescope in 1609, he thought the darker spots contained water, so he called them maria, which is the Latin word for “seas.” Now scientists believe these darker areas were formed by lava flows that cooled and hardened. Although we know they don’t contain water, the name maria has stuck. If you have looked at the Moon, you may have noticed these darker areas on its surface. Because the maria are always in the same location when we view the Moon, we know that we always see the same side of the Moon from Earth. As you prepare to answer the questions in Part 5, think about the model of the lunar cycle you created earlier.

Students complete their answers to questions. Once again, the focus here is to identify students’ initial impressions. They should feel free to express their ideas willingly, without fear of getting the wrong answer.
6 Test your ideas

To determine whether the Moon rotates, you will mark one side of your Moon model with a yellow sticker. You need to stand outside the Sun-Earth-Moon model, at point 1, 2, 3, or 4 in the diagram below, in order to detect rotation. If the sticker always faces the same classroom wall, you will know the Moon doesn’t rotate. If the sticker faces different walls at different times, you will know that the Moon does rotate.

Place a yellow sticker on one side of the foam ball. This sticker represents the side of the ball that we can see from Earth. Place a black sticker on the opposite side. You will play the role of an observer in space, outside of the Sun-Moon-Earth system. Choose position 1, 2, or 3 as shown in the diagram. Have another member of your group play the role of the Sun just like you did before. A third group member should hold the Moon model with the yellow sticker facing him or her. This student will model the lunar cycle just as you did in Part 3. Observe the yellow sticker as the Moon moves in its orbit. Notice whether the yellow sticker faces the same classroom wall throughout the activity.

Have one volunteer group model the process.

Watch the lunar cycle model one more time. This time, watch the black sticker. Notice whether the black sticker remains in the dark throughout the cycle. Switch roles within your group until everyone has observed the lunar cycle again.

7 Thinking about what you observed

Does the Moon rotate? How do you know?

The Moon does rotate. If students have difficulty seeing that the Moon actually does rotate, try the following demonstration.

Have one student represent Earth and a different student hold the Moon model. Ask the student holding the Moon model to walk in a circle around Earth, without rotating his or her body. The student should face the same classroom wall the entire time, even though he or she will have to walk sideways and backwards at times. However, the student must keep the yellow sticker side of the Moon model facing Earth at all times. To do so, the student will have to rotate the Moon model in his or her hand.

Is one side of the Moon forever in darkness? Why or why not?

This is not the case. Students should have observed that the light shone on the black sticker at one point during the “orbit.”

Which is a better name for the side of the Moon that we are not able to see from Earth: the dark side or the far side?

Explain to students that far side is a more appropriate term. As students noticed in the previous step, there were times when the light shone on the black sticker. This is like the Sun shining on the far side of the Moon although we are not able to see it from Earth. Therefore, it is not always dark.
Lesson 26.1: Motion and the Solar System

Gravity was introduced in Chapter 5 as students first learned about forces. In this lesson, students will learn more about the force of gravity and how it influences Earth, the Sun, and the Moon. Students will also make comparisons between geocentric and heliocentric models of the solar system and examine the current depiction of the solar system.

Connect to Prior Knowledge: Gravity

Have students fill in a KWHL chart to identify what they know and want to know about gravity and the solar system. This activity also gives you the opportunity to identify misconceptions your students may have about gravity. Be sure to revisit the chart at the end of the lesson so that students can reflect on what they have learned.

Were any misconceptions exposed through the KWHL activity or as you asked students to explain the meaning of gravity? Common misconceptions are addressed below.

- Gravity is defined as “something that keeps us on the ground.” Explain to students that the force of gravity exists between any two masses. The force of gravity depends on the size of the masses as well as the distance between the centers of these masses.
- There is no gravity in space. Objects in space are affected by gravity. As a matter of fact, gravity keeps these objects in orbit. Have three student volunteers read aloud in the text each section of the lesson about orbits. Then ask students to use what they read to explain the significance of gravity to orbital motion. Have students apply Newton’s laws to justify their responses.
- A weightless object is also massless. The important fact for students to recall is that mass and weight are not the same thing. When students think about a weightless astronaut in space, they often forget that weight is affected by gravity; mass is not. Review the definitions of mass and weight. Remind students that mass depends on the matter in an object and is a measure of an object’s resistance to changes in motion. Therefore, an astronaut may be weightless, but he or she still has mass. Lead a discussion about microgravity to encourage student learning.
Motivate: Constellations

Constellations are groups of stars that form a pattern. This idea of naming star patterns comes from the ancient Greeks. Over time, humans have learned more about the stars in the night sky as well as the patterns they form. Many cultures developed stories and legends based on the patterns they observed. Explain to students that the constellations we see today are the same ones that were seen by others thousands of years ago. Astronomers have recognized and assigned names to 88 different constellations to date. Many have been named to honor kings, mythical gods, events, and objects. In modern times, astronomers use constellations to identify specific regions in the sky. Have students conduct research to learn more about particular constellations they find interesting. Ask students to share their names and any related circumstances or history.

Present the content

Guided Discussion: Solar System Models

Provide students with a list of guiding questions (Teaching Tip at right) to answer as you lead the discussion about the Earth-centered and Sun-centered models of the solar system. It may be helpful to have students read the corresponding lessons in the student text first, and then direct them to collaborate with one or two other students to answer the questions after you present the lesson. If class time does not permit, have students answer the questions for homework. You can also use these questions as a guide for reteaching.

Check for understanding

1. The current model of the solar system includes the Sun and other objects bound to it by the force of gravity. Name one example of each of the following included in the solar system: (a) an inner planet; (b) an outer planet; and (c) an object smaller than a planet. 

2. Which is closer to the Sun based on average distance: Mars or Saturn?

Reteach

Explain the meaning of gravity and its role in maintaining the solar system. Then talk about scientists whose work contributed to creating the current model of the solar system. Revisit the comparisons between the Earth-centered and Sun-centered models. Make a time line to describe the progression of thought from earlier times to Ptolemy’s and Copernicus’s models to modern ideas about the solar system.
Lesson 26.2: Motion and Astronomical Cycles

In many ways, human activity is governed by the rising and setting of the Sun—a daily occurrence that is the result of Earth’s rotation, or motion. This lesson focuses on how motion influences astronomical cycles on Earth.

Start the lesson

Connect to Prior Knowledge: The Lunar Cycle

Students were introduced to the lunar cycle as they completed Investigation 26A. Have a few volunteers describe what happens during the lunar cycle. Allow students to refer to their notes from the investigation as needed. Next, revisit the discussion about the rotation of the Moon (Parts 6 and 7) and whether it is proper to refer to the Moon’s far side as “dark.”

Ask students, “Does the Moon produce its own light?” Explain that it does not and that the Moonlight humans see is actually reflected. The Moon rotates on its axis as it orbits Earth. During the Moon’s orbit, different parts of it are illuminated by the Sun. The near side of the Moon faces Earth, and the appearance of the Moon depends on the amount of sunlight illuminated. For example, humans see a full Moon when it is near 100 percent illumination. A new Moon occurs when the Moon is exactly between Earth and the Sun. It appears “dark” because only the far side of the Moon is exposed to the Sun.

The far side of the Moon is the portion we do not see. It is not correct to use the term “dark side” to refer to the far side of the Moon because it is not always dark. How much of the Moon humans actually see depends on the Moon phase. The Moon phases, which result from the changing position of the Moon and Earth relative to the Sun, are shown above.

Have students refer to the diagram to describe how the Moon would appear to people on Earth when it is in each phase.

Vocabulary

axis - the imaginary line that passes through the center of a planet from pole to pole.
rotation - the spinning of a planet on its axis.
year - the amount of time it takes for a planet to complete one revolution around the Sun.
lunar cycle - the cycle of change in the appearance of the Moon due to the positions of Earth, the Moon, and the Sun.
lunar eclipse - an event that occurs when the Moon passes through Earth’s shadow.
solar eclipse - an event that occurs when the Moon’s shadow falls on Earth.
tide - a cycle of rising and falling ocean levels.

Address Misconceptions: Seasons

While most students have a basic understanding of the temperature changes associated with the seasons, they may believe the only reason for seasons is due to Earth’s distance from the Sun. The reality is that Earth is actually closer to the Sun in December than it is in the summer month of June.

Explain that the seasons are caused by the 23.5° tilt of Earth’s axis of rotation relative to its orbit. The northern hemisphere of Earth is tilted toward the Sun in June and experiences summer. At this time, the sunlight is more direct and the days are longer. Earth’s southern hemisphere is tilted away from the Sun in June and experiences winter. At this time, the sunlight is less direct and the days are shorter. What happens six months later? The northern hemisphere experiences winter while the southern hemisphere experiences summer.
**Motivate: Keeping Track of Time**

Ask students, “Can you imagine a time when there were no clocks?” Allow students a few moments to think about what you have asked. Then ask students to describe how humans can tell time without clocks. Record their responses on the board. Did anyone mention using the Sun to tell time? If not, ask students if they know what a sundial is. If so, have a volunteer explain its purpose. Bring a sundial to class and point to its parts while you explain its function. If time permits allow students time to search the Internet for ideas about how to make a sundial. Then have a “show and tell” session for students to share their sundial ideas with classmates.

**Present the Content**

**Active Learning: Solar and Lunar Eclipses**

Materials needed (per group): student texts, poster board, set of markers, scissors, globe, 3-inch foam ball, LED flashlight with adjustable beam or utility lamp

Divide students into groups of 4–6 students. You will need an even number of groups. Direct one-half of the groups to read the one-page lesson on lunar eclipses and the other groups to read about solar eclipses. After completing the reading, have each group develop a two- or three-dimensional model to teach their topic to a different group. Allow 20 minutes for the reading and development of the model. If time permits, ask students to rehearse their presentation for you before teaching the material to another group. Student presentations should answer the following questions:

1. What is special about the Earth-Moon-Sun system when this type of eclipse occurs?
2. Can everyone on Earth see this type of eclipse? If not, who can see it?

**Check for Understanding**

1. Tides are caused by the Moon’s force of gravity. How might tides be affected if the Moon’s mass is increased?

2. Fill in the blank: A _____ (solar, lunar) eclipse occurs when the Moon lies between the Sun and Earth.

**Reteach**

Use the diagrams featured throughout the lesson to clarify what happens during the astronomical cycles. With each discussion ask students to identify the relative positions of Earth, the Moon, and the Sun.
Investigation 26B: Earth’s Seasons

This investigation will help students determine the most significant cause of Earth’s seasons. Students will use a multimeter with leads and a solar cell to measure the variations in light intensity as the distance from Earth to the Sun is measured and as the angle of Earth’s axial tilt changes. Students will then compare the intensity measurements to deduce which variable has the greater effect. After completing the investigation, students will know that Earth’s seasons are caused mostly by Earth’s axial tilt.

Key Question
What causes the seasons?

Objectives
Students will:
• Use comparisons of light intensity measurements to infer that the primary cause of Earth’s seasons is its axial tilt.
• Dispel the common misconception that Earth’s seasons are primarily due to its distance from the Sun.

Setup
1. One class period is needed to complete the investigation.
2. Students work in small groups of three to five.
3. Before students proceed with the investigation, have them complete the prelab activity described in the opening to the investigation dialogue. This is essential to students’ success with the activity.

Materials
Each group should have the following:
• Globe
• Solar (PV) cell
• Multimeter
• Metric tape measure
• Masking tape

Vocabulary
axis - the imaginary line that passes through the center of a planet from pole to pole.
rotation - the spinning of a planet on its axis.

Safety
Students should observe general laboratory safety procedures while completing Investigation 26B.
INVESTIGATION 26B: EARTH’S SEASONS

26B Earth’s Seasons

What causes the seasons?

Why do the seasons occur? Is it because the summer is longer, and the sunlight is more intense, in the Northern Hemisphere, and the winter is longer, and the sunlight is more intense, in the Southern Hemisphere? What causes these variations in the amount of light intensity Earth receives during different parts of its orbit around the Sun? In other words, why do we have seasons?

1. What is the main cause of the annual cycle we call seasons? How does this cause affect Earth’s tilt relative to the Sun? How does it affect Earth’s distance from the Sun?

2. Why do the seasons occur? In the summertime, it is hotter, the days are longer, and the sunlight is more intense. In the winter, it is colder, the days are shorter, and the sunlight is less intense. What causes these variations in the amount of light intensity Earth receives during different parts of its orbit around the Sun?

3. Distance from the Sun (km)

<table>
<thead>
<tr>
<th>Position</th>
<th>Distance from the Sun (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>147,000,000</td>
</tr>
<tr>
<td>B</td>
<td>147,000,000</td>
</tr>
<tr>
<td>C</td>
<td>149,000,000</td>
</tr>
<tr>
<td>D</td>
<td>153,000,000</td>
</tr>
</tbody>
</table>

4. In what way do the changes in the distance from the Sun affect the amount of sunlight received by Earth? How does this affect the amount of energy that goes into heating Earth’s surface?

5. Table 1: Scale distances

<table>
<thead>
<tr>
<th>Position</th>
<th>Scale distance from the Sun (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>147,000,000</td>
</tr>
<tr>
<td>B</td>
<td>147,000,000</td>
</tr>
<tr>
<td>C</td>
<td>149,000,000</td>
</tr>
<tr>
<td>D</td>
<td>153,000,000</td>
</tr>
</tbody>
</table>

6. Use the scale distance in which 1 centimeter represents 1 million kilometers. Therefore, a distance of 1 centimeter represents 100 million kilometers. Use this scale distance to set up a model of Earth’s orbit around the Sun. The graphic at right shows you what Earth’s orbit looks like. The distance between the Sun and Earth changes during the year. Earth’s North–South axis is its axis of rotation. This axis is always tilted in the same direction, at the same angle, and always points to the North Star, which is very far away. As a result, if you were standing on Earth’s North Pole, the North Star would always be directly overhead.

7. To start the investigation, come up with a hypothesis stating why you think the seasons occur. Do you think they are caused by Earth’s changing distance from the Sun? Do you think Earth’s tilt causes the seasons? Do you think both factors play a role? Or do you think another factor causes the seasons?

8. Setting up a model of Earth’s orbit

a. Take your solar cell and digital meter with you.

b. Attach the leads of your digital meter to the solar cell. Set the digital meter to measure direct current in milliamperes. You will take 2 measurements.

9. The first measurement will measure how the distance between the Sun and Earth affects light intensity. Measure the milliamps of current produced by the solar cell at the middle of your globe. This way, no tilt is involved, and only distance will impact the current produced by the solar cell. Hold your solar cell flat against the middle of your globe. This way, no tilt is involved, and only distance will impact the current produced by the solar cell.

10. The second measurement will measure how Earth’s tilt affects light intensity. Move your globe at one of the 4 positions; A, B, C, or D (diagram, right). Your group will carefully place your globe will represent one position in Earth’s orbit—A, B, C, or D (diagram, right). Your group will carefully place your globe at one of the 4 positions; A, B, C, or D. To do this, part of your team will have to move the globe and part will have to operate the tape measure.

11. Extend your tape measure out so you have about 5 cm more tape than the length you will need. Use a 1 mm reading to position one end of the globe and then measure the scale distance from the Sun in millimeters. This scale distance will have to operate the tape measure.

12. Place the exact length of tape (scale distance from the Sun) you are measuring directly over the center of the unlit light bulb. Record your data in Table 2.

13. Repeat both measurements at the other two globes and record the data in Table 2.

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4. Examine the intensity of the light that falls on the globe.

Now you are ready to look at variations in the light intensity that falls at greater the light intensity, the more electricity your solar cell produces. The solar cell output allows us to find differences in light intensity at different places.

5. Use the scale distance of 1 centimeter = 1 million kilometers, determine the scale distance for positions B, C, and D. Write the scale distance in the third column of Table 1.

6. Extend your tape measure out so you have about 5 cm more tape than the length you will need. Use a 1 mm reading to position one end of the globe and then measure the scale distance from the Sun in millimeters. This scale distance will have to operate the tape measure.

7. Place the exact length of tape (scale distance from the Sun) you are measuring directly over the center of the unlit light bulb. Record your data in Table 2.

8. Repeat both measurements at the other two globes and record the data in Table 2.

9. Measuring the Effect of Distance

a. The second measurement will measure how Earth’s tilt affects light intensity. Measure the milliamps of current produced by the solar cell at the middle of your globe. This way, no tilt is involved, and only distance will impact the current produced by the solar cell. Hold your solar cell flat against the middle of your globe.

b. The second measurement will measure how Earth’s tilt affects light intensity. Measure the milliamps of current produced by the solar cell at the middle of your globe. This way, no tilt is involved, and only distance will impact the current produced by the solar cell.

10. Examine the intensity of the light that falls on the globe.

Now you are ready to look at variations in the light intensity that falls at greater the light intensity, the more electricity your solar cell produces. The solar cell output allows us to find differences in light intensity at different places.

11. Use the scale distance of 1 centimeter = 1 million kilometers, determine the scale distance for positions B, C, and D. Write the scale distance in the third column of Table 1.

12. Extend your tape measure out so you have about 5 cm more tape than the length you will need. Use a 1 mm reading to position one end of the globe and then measure the scale distance from the Sun in millimeters. This scale distance will have to operate the tape measure.

13. Place the exact length of tape (scale distance from the Sun) you are measuring directly over the center of the unlit light bulb. Record your data in Table 2.

14. Repeat both measurements at the other two globes and record the data in Table 2.

15. Measuring the Effect of Tilt

a. The second measurement will measure how Earth’s tilt affects light intensity. Measure the milliamps of current produced by the solar cell at the middle of your globe. This way, no tilt is involved, and only distance will impact the current produced by the solar cell.

b. The second measurement will measure how Earth’s tilt affects light intensity. Measure the milliamps of current produced by the solar cell at the middle of your globe. This way, no tilt is involved, and only distance will impact the current produced by the solar cell.

16. Examine the intensity of the light that falls on the globe.

Now you are ready to look at variations in the light intensity that falls at greater the light intensity, the more electricity your solar cell produces. The solar cell output allows us to find differences in light intensity at different places.

17. Use the scale distance of 1 centimeter = 1 million kilometers, determine the scale distance for positions B, C, and D. Write the scale distance in the third column of Table 1.

18. Extend your tape measure out so you have about 5 cm more tape than the length you will need. Use a 1 mm reading to position one end of the globe and then measure the scale distance from the Sun in millimeters. This scale distance will have to operate the tape measure.

19. Place the exact length of tape (scale distance from the Sun) you are measuring directly over the center of the unlit light bulb. Record your data in Table 2.

20. Repeat both measurements at the other two globes and record the data in Table 2.

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5. Table 2: Globe position data

<table>
<thead>
<tr>
<th>Position</th>
<th>Distance from the Sun (km)</th>
<th>Scale distance from the Sun (cm)</th>
<th>Current at Tropic of Cancer (mA)</th>
<th>Current at Tropic of Cancer (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>147,000,000</td>
<td>147</td>
<td>114</td>
<td>108</td>
</tr>
<tr>
<td>B</td>
<td>147,000,000</td>
<td>147</td>
<td>114</td>
<td>108</td>
</tr>
<tr>
<td>C</td>
<td>149,000,000</td>
<td>149</td>
<td>114</td>
<td>108</td>
</tr>
<tr>
<td>D</td>
<td>153,000,000</td>
<td>153</td>
<td>114</td>
<td>108</td>
</tr>
</tbody>
</table>

6. Analyzing your data

a. Why is it important to measure the current produced at the middle of the globe and also at the Tropics of Cancer?

b. The largest change we see in distance from Earth to the Sun is from 147,000,000 kilometers to 153,000,000 kilometers. While 6,000,000 kilometers is not a short distance, find the percent change in distance using the following formula:

Percent Change = \( \frac{\text{final value} - \text{initial value}}{\text{initial value}} \) × 100

Does this percent change seem large or small to you?

b. Based on your data, how much does light intensity change as these distances change?

b. How much did the angle of the solar cell change at the four different positions you measured on the Tropic of Cancer? Did the difference in angle seem large or small to you?

b. According to your results, how much does light intensity change as the angle changes?

6. Conclusions

a. Of the two factors—distance from the light source and axial tilt—which has a greater effect on light intensity?

b. Based on your light intensity results, which of the two factors plays the most significant role in causing the seasons? Was your hypothesis supported by your results?

b. Based on your results, which position (A, B, C, or D) represents the first day of winter in the Northern Hemisphere? Which position represents the first day of summer in the Northern Hemisphere? Explain your answer.

b. At which position (A, B, C, or D) does the Northern Hemisphere receive the most intense light? The least intense light?

b. Which quarter represents summer in the Northern Hemisphere? Which quarter represents summer in the Southern Hemisphere? Explain your reasoning.
Teaching Investigation 26B

Pre-Lab Activity (from Setup Step #3)

Give each group its own solar cell and multimeter. Allow students some time to discover how the current reading changes when they move close to or farther away from a light source. They also need to see the shadow effect: If a group member’s head is shadowing the solar cell when readings are taken, the data will be off. Even the leads that go from the solar cell to the meter can cast shadows. Have each group answer the following questions:

- What happens to the current reading on the multimeter when you get close to a light source? What happens when you move away?
- Where in the room can you get the highest reading?
- What happens if you cover the solar cell with your hand?

Discuss these questions as a class before moving on to the investigation.

1. What is the main cause of the annual cycle we call seasons?

Almost everyone has a favorite season. Some people enjoy the beautiful flowers and the mild temperatures of spring, while others look forward to snow and winter activities such as skiing. In today’s investigation, you will learn about the causes of seasons. Take a moment to look at the graphic shown in Part 1. It shows what Earth’s orbit around the Sun looks like. From the graphic, you can see that the distance between Earth and the Sun varies during the year.

Allow time for students to identify these differences.

Earth’s axis of rotation is its north–south axis. What is an axis, and what do we mean by axis of rotation?

Review the meanings of these terms as introduced in Lesson 26.2.

Earth’s axis of rotation is always tilted in the same direction, at the same angle, and always points to the North Star, which is quite a distance away. As a result, if you were standing on Earth’s North Pole, the North Star would always be directly overhead.

Use the illustration to demonstrate this to students.

Why do you think seasons occur? Discuss your thoughts with members of your group and then come up with a hypothesis that reflects what you believe.

Students develop their hypotheses. The questions listed in Part 1a are designed to determine what preconceptions (or misconceptions) students may have about the factors that determine Earth’s seasons. At this time, it is not important to answer the question correctly. The goal is to find out what students already know and determine if they truly understand the related concepts discussed in Lesson 26.2. The tilt of Earth’s axis is the most significant cause of seasons, but it is fine to accept all responses at this point. Students will be able to revisit this question at the close of the investigation.

Classroom Setup

You should have a light source with a 100-watt light bulb. The source should not have a lamp shade or cover over the light bulb. The light source should be placed on a table at the center of the classroom. Place the light source on books if necessary so that the light bulb is level with the equator on the globe. Four tables should be placed around the light source as shown in the diagram below.

Turn off the overhead lights before taking measurements.
Look at the diagram. Which quarter of the diagram represents summer in the northern hemisphere? Students use the diagram to arrive at an answer. The correct response is from D to A because at position D, Earth is tilted toward the Sun. Students may choose other answers for numerous reasons. Wait until the end of the investigation to clarify misconceptions because it is highly probable that students will be able to infer the correct responses based on their own observations.

### Setting up a model of Earth’s orbit

In Part 1, you read that Earth’s distance from the Sun varies slightly as it orbits the Sun. Now you will create a model that represents the changes in Earth–Sun distance. It is impossible to measure millions of kilometers in your classroom, but you can use a scaled distance in which 1 cm represents 1 million km. Therefore, a distance of 150 million km is represented by 150 cm. Using the scale distance of 1 cm = 1 million km, determine the scale distance for positions B, C, and D. Write the scale distance in the third column of Table 1.

Recall that Earth’s north–south axis is its axis of rotation and that it always points toward the North Star. For this reason, we need to choose a place to represent the North Star. We also have to choose a place for the Sun. This position will be fixed, so no one should move it once it is set.

Designate the location of the North Star and the Sun. Point it out to students and remind them that it is not to be moved. Instruct students to gather the materials needed for this part: a globe, solar cell, tape measure, and masking tape. The light source used to represent the Sun needs to be at least 100 watts. It is also important that the room is fairly dark so that ambient light from the Sun does not affect the solar-cell readings. Cover any windows before students begin to collect data. If you are using white tables or tables with a glossy finish, you may find that light reflected from the tables is absorbed by the solar cells, causing errors in the data. To solve this problem, cover the tables with black construction paper before taping down the globes.

Your globe will represent one position in Earth’s orbit—A, B, C, or D. Your group will carefully place the globe at one of the 4 positions. To do this, part of your team will have to move the globe and part will have to operate the tape measure. Extend your tape measure out so you have about 5 cm more tape than the length you need to measure. Lock the tape measure into place and while holding the locking end in your hand, allow the tape to stick out directly at the globe.

Point out the different positions. It may be helpful to label the stations A, B, C, and D, ensuring that the labels match the investigation diagram.

Place the exact length of tape (scale distance from the Sun) you are measuring directly over the center of the unlit light bulb representing the Sun. Move your globe until the center of the globe touches the extended end of the tape measure. The center of your globe should be aligned with the center of the light bulb. All four globes should have their axes pointing in the same direction. Use the diagram and the North Star sign as your guide. Once your globe is the correct distance from...
the Sun and has its axis pointing in the right direction, tape the globe’s base to the table. The globe should be able to withstand a bump or two without moving.

If time is limited, measure the distances and tape down the globes ahead of time. Have each group re-check one station.

Look at your setup. What do the four globes in your model represent?

The globes represent Earth’s position at different times of the year as it orbits around the Sun.

In what direction do the north–south axes of each globe point? Why is this so?

The axes point toward the North Star due to the fixed position of Earth’s axial tilt throughout its orbit.

3 Examining the intensity of the light that falls on the globe

Now you are ready to look at variations in the light intensity that falls on each globe. The greater the light intensity, the more electricity your solar cell produces. Measuring the solar-cell output allows us to find differences in light intensity at different places on the globes. Use the same solar cell and multimeter throughout the investigation. Your group will move around the room from globe to globe, following Earth’s path around the Sun.

Students set up the solar cell by attaching the leads. The meter should be set to measure current.

You will take two measurements at each position. The first measurement will determine how the distance between the Sun and Earth affects light intensity. The second measurement will measure how Earth’s tilt affects light intensity. For the first measurement, you will measure the milliamps of current produced by the solar cell at the middle of your globe. This is important because you are trying to determine the effect of distance only on the current produced.

Refer students to the graphic for the setup.

For the second measurement, you want to find out the effect of Earth’s tilt only. Therefore, you will move the solar cell up to the Tropic of Cancer to obtain your measurement. You will repeat this process at each globe and then record your data in Table 2. Transfer the scale distance from the Sun measurements from Table 1 to the third column of Table 2.

There are small differences in the efficiency of the solar cells. Therefore, you will achieve more consistent and meaningful results if each group uses its own solar cell and multimeter throughout the data-gathering process.

4 Analyzing your data

Think about what you did in the last part of the investigation. You measured the current produced at the middle of the globe and then at the Tropic of Cancer. Why was this important?

This is important because you are able to determine the effect of specific variables in each instance.

Table 2: Globe position data

<table>
<thead>
<tr>
<th>Position</th>
<th>Distance from the Sun (km)</th>
<th>Scale distance from the Sun (cm)</th>
<th>Current at middle of globe (mA)</th>
<th>Current at Tropic of Cancer (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
That is correct. You can only decide which factor—distance or axial tilt—has the most significant effect by isolating it. The largest change we see in distance from Earth to the Sun is from 147 million km to 153 million km, a difference of about 6 million km. What is the percent change in distance?

Students apply the formula to determine the percentage of change.

Do you think this percentage of change is large or small?

Students share opinions. They should conclude that the change is relatively small.

Now think about the difference in the angle of the solar cells at the four positions. Was this difference large or small?

The difference should be noticeably large based on students’ collected data.

How did the changes in light intensity with respect to distance compare to the changes you observed due to changes in the angle?

The changes in light intensity were more significant with respect to angle changes.

5 Conclusions

In this investigation, you sought to determine the cause of Earth’s seasons. You considered two factors: the distance from Earth to the Sun and Earth’s axial tilt. You collected data in the form of light intensity measurements to help you arrive at an answer. What can you conclude about the cause of Earth’s seasons based on your observations?

Earth’s seasons are caused by its axial tilt.

Think about your original hypothesis when the question was first posed. Was your hypothesis correct?

Students share answers.

Go back to the diagram in Part 1. Which position (A–D) represents the first day of summer in the northern hemisphere? How about the first day of winter? What is the basis of your answer?

The first day of summer is at point D because Earth’s northern hemisphere is angled directly toward the Sun. The reverse is true at point B, the first day of winter, because Earth is angled away from the Sun. Use the diagram to illustrate this point. Use the diagram to guide students as they answer the remaining questions in Part 5. Be sure students make the connection between the intensity of light and the way that Earth is tilted to determine seasons.
Lesson 26.3: Objects in the Solar System

In this lesson, students will learn about the components of the solar system, including smaller objects such as asteroids, meteors, and comets. They will also study the properties that are unique to each planet, including temperature, appearance, and atmosphere.

Connect to Prior Knowledge: Moon Facts

The Moon has been discussed in previous lessons. Use the questions listed below to review what students have already learned and find out what they know about characteristics of the Moon that will be discussed in this lesson.

1. What percentage of the Moon is visible from Earth?
2. How would you describe the lunar cycle?
3. Does the Moon produce its own light? What is the significance of the phrases near side and far side when speaking about the visibility of the Moon?
4. How does an object’s mass on Earth compare to its mass on the Moon? What is the relationship between the weight of an object on Earth and on the Moon? What factor is responsible for this difference?

Motivate: Solar System Newscast

Have students work in small groups to produce a three- to five-minute newscast about one of the planets, the Moon, the Sun, or another object in the solar system. A sample 30-point rubric for assessing the newscast is provided on the next page. Students will need audio visual equipment to complete the newscast project. Some students may have access to equipment at home. Speak with your school’s technology person to arrange a check out system for students who do not have access to equipment at home.

Involve students in assessing their classmates’ broadcasts. One way to do so is to have 50 percent of the total grade reflect your scoring from the rubric. The other half of the grade would come from peer evaluation. In this manner, the newscast would be worth 60 points. Take the average of the peer evaluation scores and add it to your score to arrive at the total points earned. After all newscasts have been presented, encourage students to share the following with classmates:

- Two new facts they learned about the planets or other objects in the solar system;
- Two questions they still have;
- One opportunity for improving any group’s presentation; and
- One thing they really liked about each group’s newscast

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**Vocabulary**

**planet** - a celestial body that (1) is in orbit around the Sun; (2) is nearly round in shape; and (3) has cleared its orbit of other objects.

**terrestrial planets** - Mercury, Venus, Earth, and Mars.

**gas planets** - Jupiter, Saturn, Uranus, and Neptune.

**Moon** - a natural satellite orbiting a planet or other body, such as a dwarf planet.

**giant impact theory** - a scientific theory that explains how the Moon was formed.

**asteroid** - an object that orbits the Sun but is too small to be considered a planet.

**comet** - an object in space made mostly of ice and dust.

**meteor** - a chunk of burning rock traveling through Earth’s atmosphere.

**meteorite** - a meteor that passes through Earth’s atmosphere and strikes the ground.
### LESSON 26.3: OBJECTS IN THE SOLAR SYSTEM

#### Solar System Newscast Rubric

<table>
<thead>
<tr>
<th>Category</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>Evidence of research is clear. Four or more examples of new facts learned from the research are discussed.</td>
<td>Evidence of research is clear. Three examples of new facts learned from the research are discussed.</td>
<td>It appears that some research was conducted. Two examples of new facts learned are discussed.</td>
<td>There is little evidence of research. One or two examples of new facts learned are discussed.</td>
</tr>
<tr>
<td>Accuracy</td>
<td>All content reported is accurate.</td>
<td>Most of the content reported is accurate.</td>
<td>Less than half of the content reported is accurate.</td>
<td>No accurate facts were reported in the newscast.</td>
</tr>
<tr>
<td>Graphics</td>
<td>Graphics are clearly visible, labeled, and completely relevant.</td>
<td>Graphics are visible, with some labeling, and are mostly relevant.</td>
<td>Graphics are a bit unclear, not labeled, but appear somewhat relevant.</td>
<td>No graphics were used in the newscast.</td>
</tr>
<tr>
<td>Group Work</td>
<td>Each group member assisted. Everyone worked well together.</td>
<td>Most members assisted. Almost everyone worked well together.</td>
<td>Only a few members assisted. The group did not work well together.</td>
<td>It appears that one person did all the work. The group functioned poorly.</td>
</tr>
<tr>
<td>Presentation</td>
<td>The purpose of the newscast is clear. All parts of the newscast flow well and are connected.</td>
<td>The purpose of the newscast is somewhat clear. Most parts of the newscast are connected.</td>
<td>The purpose of the newscast is quite unclear. Many parts deviated from a central theme.</td>
<td>No purpose is established and the newscast is disconnected.</td>
</tr>
<tr>
<td>Time</td>
<td>The newscast was within 3–5 minutes and was well paced.</td>
<td>The newscast was within 3–5 minutes but seemed slow or rushed.</td>
<td>The newscast was less than 30 seconds over or under the allotted time.</td>
<td>The newscast was far too long or was extremely short.</td>
</tr>
</tbody>
</table>

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**Present the content**

Develop an outline of main ideas and concepts for the lesson. Photocopy and distribute them to students to use as a reference as you lead the discussion. Be sure to leave space for students to add their own notes, mark passages that are unclear, and write questions they want to ask.

**Check for understanding**

1. Name one terrestrial planet and one gas planet.
2. Name and describe one object in the solar system other than a planet, the Sun, or the Moon.

**Reteach**

Review how the Moon was formed and discuss its properties. Have students refer to Figure 26.23 as you lead this discussion. Review the features of the planets and other solar system objects.