Section 1

Earth in Space

Reading Preview

Key Concepts

- How does Earth move in space?
- What causes the cycle of seasons on Earth?

Key Terms

- astronomy
- axis
- rotation
- revolution
- orbit
- solstice
- equinox

Target Reading Skill

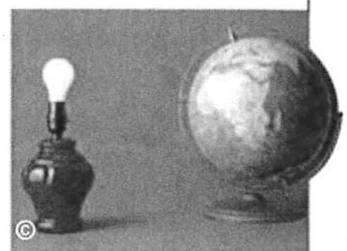
Using Prior Knowledge Your prior knowledge is what you already know before you read about a topic. Before you read, write what you know about seasons on Earth in a graphic organizer like the one below. As you read, write in what you learn.

What You Know
1. The sun's rays heat Earth. 2.

What You Learned
1. 2.

Lab zone Discover Activity

What Causes Day and Night?



1. Place a lamp with a bare bulb on a table to represent the sun. Put a globe at the end of the table about 1 meter away to represent Earth.
2. Turn the lamp on and darken the room. Which parts of the globe have light shining on them? Which parts are in shadow?
3. Find your location on the globe. Turn the globe once. Notice when it is lit—day—at your location and when it is dark—night.

Think It Over

Making Models What does one complete turn of the globe represent? In this model, how many seconds represent one day? How could you use the globe and bulb to represent a year?

Each year, ancient Egyptian farmers eagerly awaited the flood of the Nile River. For thousands of years, their planting was ruled by it. As soon as the Nile's floodwaters withdrew, the farmers had to be ready to plow and plant their fields along the river. Therefore, the Egyptians wanted to predict when the flood would occur. Around 3000 B.C., people noticed that the bright star Sirius first became visible in the early morning sky every year shortly before the flood began. The Egyptians used this knowledge to predict each year's flood. The ancient Egyptians were among the first people to study the stars. The study of the moon, stars, and other objects in space is called **astronomy**.

FIGURE 1
Ancient Egyptian Farmers
Egyptian farmers watched the sky in order to be prepared to plow and plant their fields.

How Earth Moves

Ancient astronomers studied the movements of the sun and the moon as they appeared to travel across the sky. It seemed to them as though Earth was standing still and the sun and moon were moving. Actually, the sun and moon seem to move across the sky each day because Earth is rotating on its axis. Earth also moves around the sun. **Earth moves through space in two major ways: rotation and revolution.**

Rotation The imaginary line that passes through Earth's center and the North and South poles is Earth's **axis.** The spinning of Earth on its axis is called **rotation.**

Earth's rotation causes day and night. As Earth rotates eastward, the sun appears to move westward across the sky. It is day on the side of Earth facing the sun. As Earth continues to turn to the east, the sun appears to set in the west. Sunlight can't reach the side of Earth facing away from the sun, so it is night there. It takes Earth about 24 hours to rotate once. As you know, each 24-hour cycle of day and night is called a day.

Revolution In addition to rotating on its axis, Earth travels around the sun. **Revolution** is the movement of one object around another. One complete revolution of Earth around the sun is called a year. Earth follows a path, or **orbit,** as it revolves around the sun. Earth's orbit is not quite circular. It is a slightly elongated circle, or ellipse.

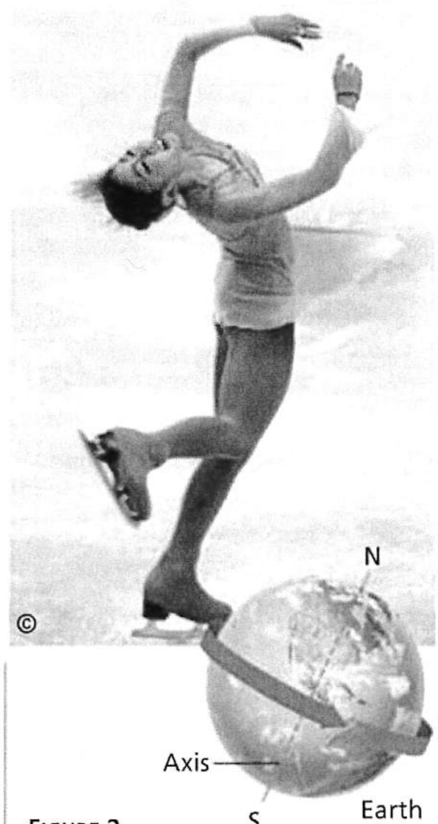


FIGURE 2
Rotation
The rotation of Earth on its axis is similar to the movement of the figure skater as she spins.

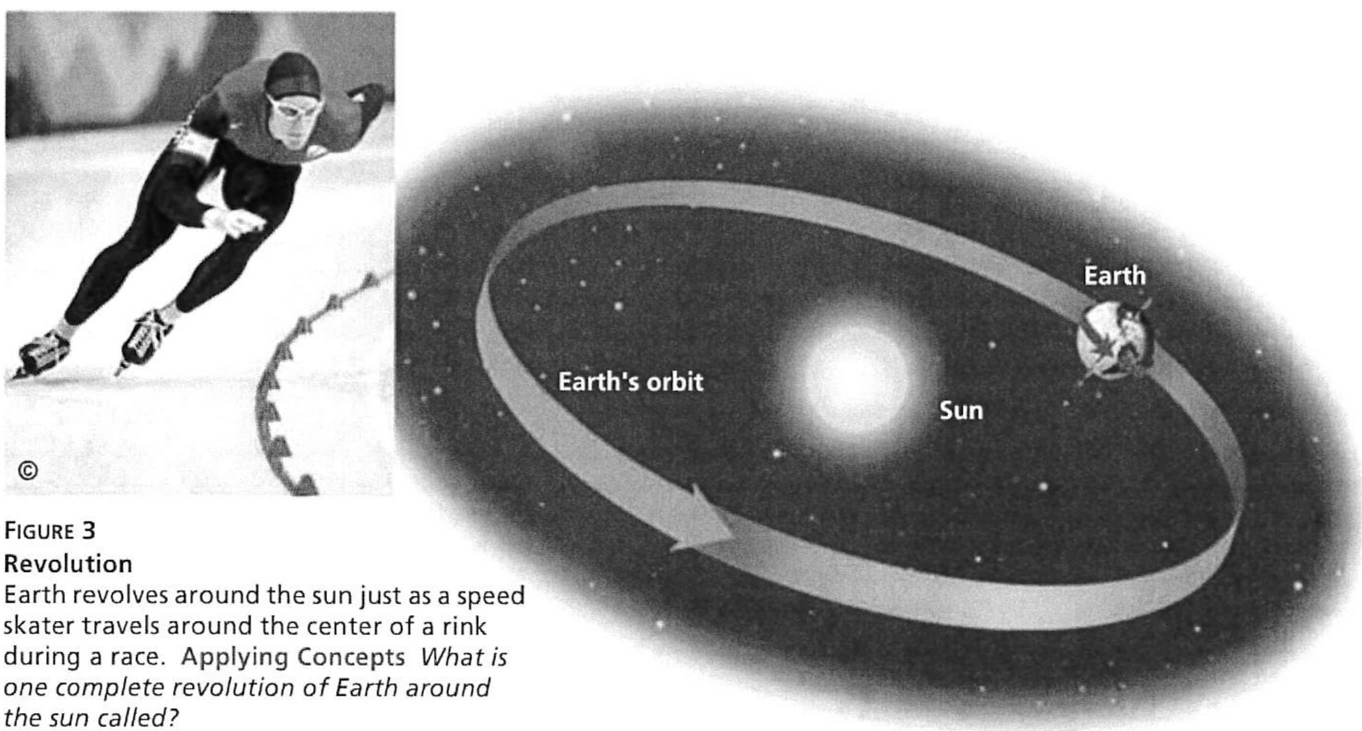
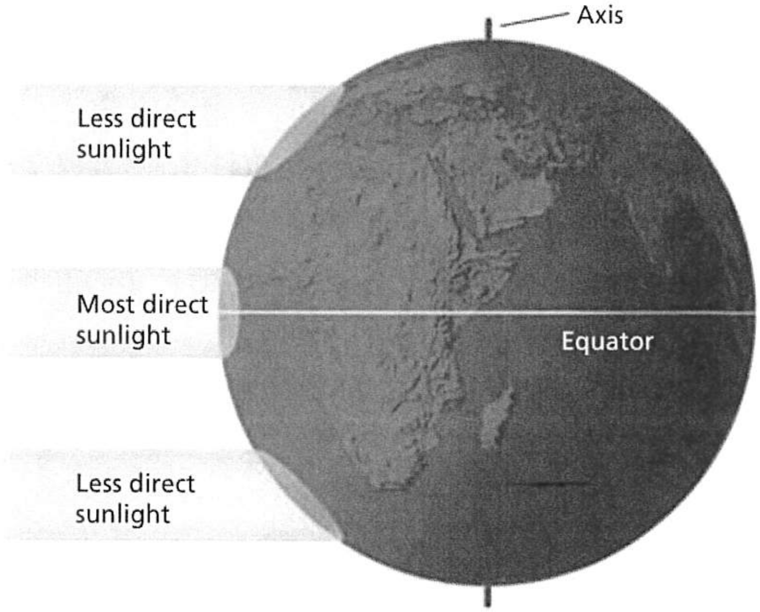


FIGURE 3
Revolution
Earth revolves around the sun just as a speed skater travels around the center of a rink during a race. Applying Concepts *What is one complete revolution of Earth around the sun called?*

FIGURE 4
Sunlight Striking Earth's Surface
Near the equator, sunlight strikes Earth's surface more directly and is less spread out than near the poles.
Relating Cause and Effect *Why is it usually colder near the poles than near the equator?*



Lab zone Try This Activity

Sun Shadows

The sun's shadow changes predictably through the day.

1. On a sunny day, stand outside in the sun and use a compass to find north.
2. Have your partner place a craft stick about one meter to the north of where you are standing. Repeat for east, south, and west.
3. Insert a meter stick in the ground at the center of the craft sticks. Make sure the stick is straight up.
4. Predict how the sun's shadow will move throughout the day.
5. Record the direction and length of the sun's shadow at noon and at regular intervals during the day.

Predicting How did the actual movement of the sun's shadow compare with your prediction? How do you think the direction and length of the sun's shadow at these same times would change over the next six months?

The Seasons on Earth

Most places outside the tropics and polar regions have four distinct seasons: winter, spring, summer, and autumn. But there are great differences in temperature from place to place. For instance, it is generally warmer near the equator than near the poles. Why is this so?

How Sunlight Hits Earth Figure 4 shows how sunlight strikes Earth's surface. Notice that sunlight hits Earth's surface most directly near the equator. Near the poles, sunlight arrives at a steep angle. As a result, it is spread out over a greater area. That is why it is warmer near the equator than near the poles.

Earth's Tilted Axis If Earth's axis were straight up and down relative to its orbit, temperatures would remain fairly constant year-round. There would be no seasons. **Earth has seasons because its axis is tilted as it revolves around the sun.**

Notice in Figure 5 that Earth's axis is always tilted at an angle of 23.5° from the vertical. As Earth revolves around the sun, the north end of its axis is tilted away from the sun for part of the year and toward the sun for part of the year.

Summer and winter are caused by Earth's tilt as it revolves around the sun. The change in seasons is not caused by changes in Earth's distance from the sun. In fact, Earth is farthest from the sun when it is summer in the Northern Hemisphere.

Reading Checkpoint **When is Earth farthest from the sun?**

FIGURE 5
The Seasons
The yearly cycle of the seasons is caused by the tilt of Earth's axis as it revolves around the sun.

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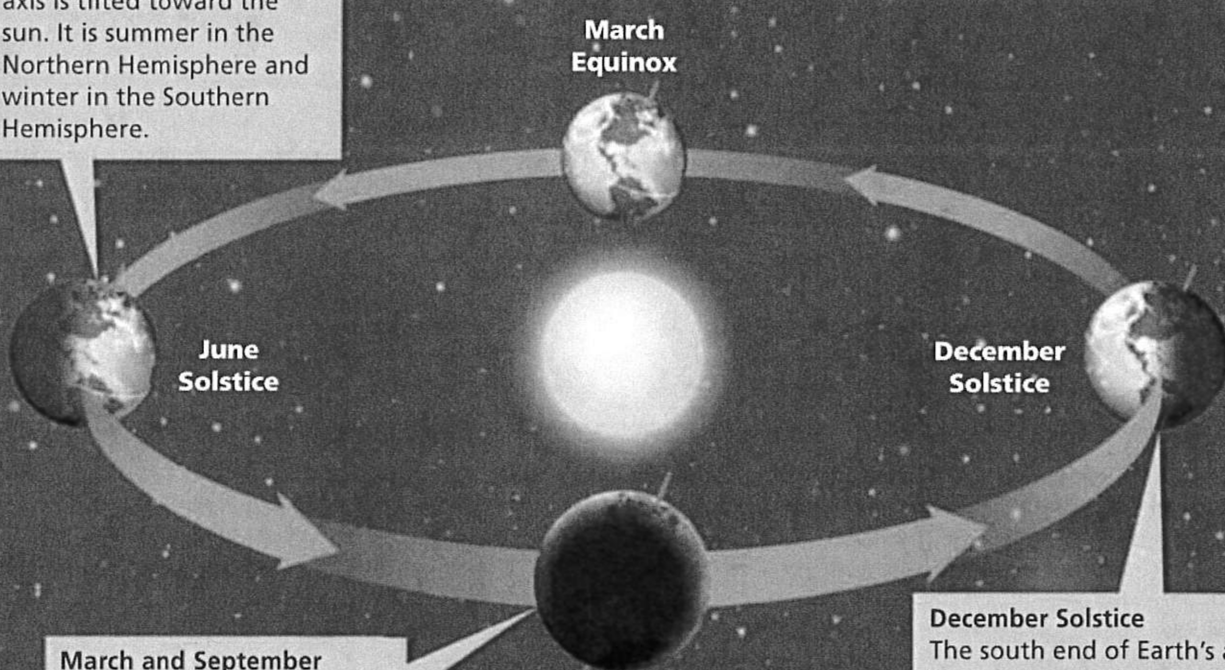
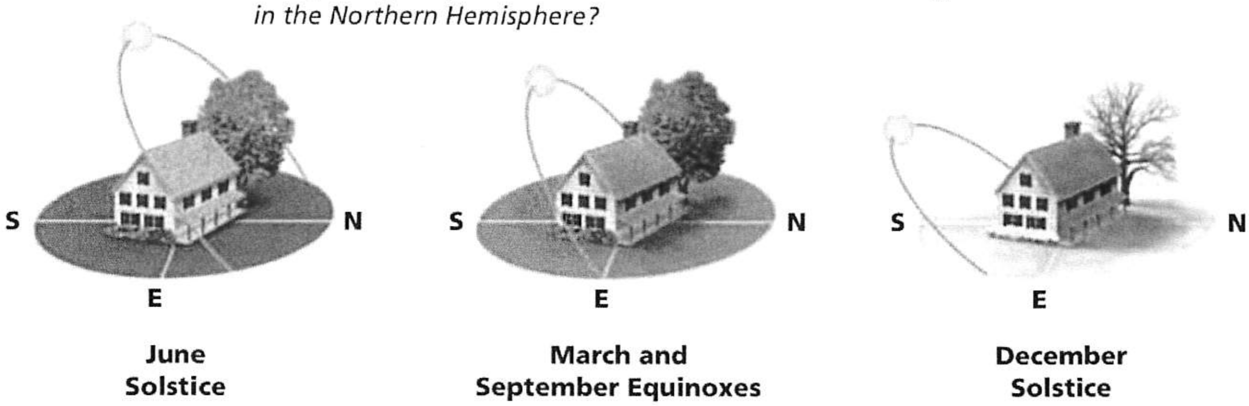
June Solstice
The north end of Earth's axis is tilted toward the sun. It is summer in the Northern Hemisphere and winter in the Southern Hemisphere.



March and September Equinoxes
Neither end of Earth's axis is tilted toward the sun. Both hemispheres receive the same amount of energy.

December Solstice
The south end of Earth's axis is tilted toward the sun. It is summer in the Southern Hemisphere and winter in the Northern Hemisphere.

The height of the sun above the horizon varies with the season.
Interpreting Graphics *When is the sun at its maximum height in the Northern Hemisphere?*



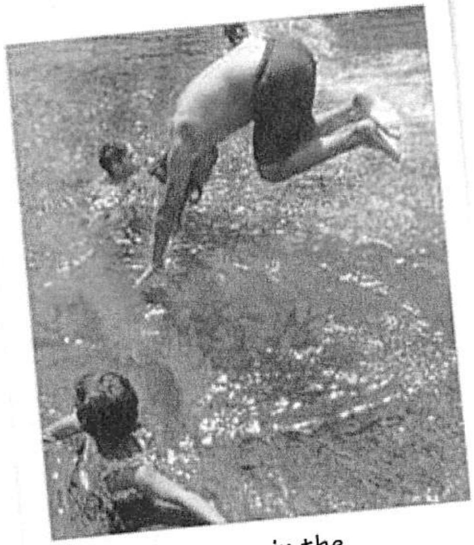


FIGURE 6
Solstices and Equinoxes

Summer in the Southern Hemisphere (left) occurs at the same time as winter in the Northern Hemisphere (right). Similarly, when it is spring in the Southern Hemisphere, it is fall in the Northern Hemisphere.
Interpreting Photographs *In which direction was Earth's axis pointing at the time that each of the photographs was taken?*

Earth in June In June, the north end of Earth's axis is tilted toward the sun. In the Northern Hemisphere, the noon sun is high in the sky and there are more hours of daylight than darkness. The combination of direct rays and more hours of sunlight heats the surface more in June than at any other time of the year. It is summer in the Northern Hemisphere.

At the same time south of the equator, the sun's energy is spread over a larger area. The sun is low in the sky and days are shorter than nights. The combination of less direct rays and fewer hours of sunlight heats Earth's surface less than at any other time of the year. It is winter in the Southern Hemisphere.

Earth in December In December, people in the Southern Hemisphere receive the most direct sunlight, so it is summer there. At the same time, the sun's rays in the Northern Hemisphere are more slanted and there are fewer hours of daylight. So it is winter in the Northern Hemisphere.

Solstices The sun reaches its greatest distance north or south of the equator twice each year. Each of these days, when the sun is farthest north or south of the equator, is known as a **solstice** (SOHL stis). The day when the sun is farthest north of the equator is the summer solstice in the Northern Hemisphere. It is also the winter solstice in the Southern Hemisphere. This solstice occurs around June 21 each year. It is the longest day of the year in the Northern Hemisphere and the shortest day of the year in the Southern Hemisphere.

Similarly, around December 21, the sun is farthest south of the equator. This is the winter solstice in the Northern Hemisphere and the summer solstice in the Southern Hemisphere.


October in the Southern Hemisphere
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© October in the Northern Hemisphere

Equinoxes Halfway between the solstices, neither hemisphere is tilted toward or away from the sun. This occurs twice a year, when the noon sun is directly overhead at the equator. Each of these days is known as an **equinox,** which means "equal night." During an equinox, day and night are each about 12 hours long everywhere on Earth. The vernal (spring) equinox occurs around March 21 and marks the beginning of spring in the Northern Hemisphere. The autumnal equinox occurs around September 22. It marks the beginning of fall in the Northern Hemisphere.

Reading Checkpoint What is an equinox?

Section 1 Assessment

Target Reading Skill **Using Prior Knowledge** Review your graphic organizer and revise it based on what you just learned in this section. Use it to help answer Question 2.

Reviewing Key Concepts

HINT **1. a. Identifying** What are the two major motions of Earth as it travels through space?

HINT **b. Explaining** Which motion causes day and night?

HINT **2. a. Relating Cause and Effect** What causes the seasons?

HINT **b. Comparing and Contrasting** What are solstices and equinoxes? How are they related to the seasons?

HINT **c. Predicting** How would the seasons be different if Earth were not tilted on its axis?

Writing in Science

Descriptive Paragraph What seasons occur where you live? Write a detailed paragraph describing the changes that take place each season in your region. Explain how seasonal changes in temperature and hours of daylight relate to changes in Earth's position as it moves around the sun.

Section 2

Integrating Physics

Gravity and Motion

Reading Preview

Key Concepts

- What determines the strength of the force of gravity between two objects?
- What two factors combine to keep the moon and Earth in orbit?

Key Terms

- force
- gravity
- law of universal gravitation
- mass
- weight
- inertia
- Newton's first law of motion

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a question for each heading. As you read, write answers to your questions.

Gravity

Question	Answer
What is gravity?	Gravity is . . .

Lab zone Discover Activity

Can You Remove the Bottom Penny?

1. Place 25 or so pennies in a stack on a table.
2. Write down your prediction of what will happen if you attempt to knock the bottom penny out of the stack.
3. Quickly slide a ruler along the surface of the table and strike the bottom penny. Observe what happens to the stack of pennies.
4. Repeat Step 3 several times, knocking more pennies from the bottom of the stack.

Think It Over

Developing Hypotheses Explain what happened to the stack of pennies as the bottom penny was knocked out of the stack.

Earth revolves around the sun in a nearly circular orbit. The moon orbits Earth in the same way. But what keeps Earth and the moon in orbit? Why don't they just fly off into space?

The first person to answer these questions was the English scientist Isaac Newton. Late in his life, Newton told a story of how watching an apple fall from a tree in 1666 had made him think about the moon's orbit. Newton realized that there must be a force acting between Earth and the moon that kept the moon in orbit. A **force** is a push or a pull. Most everyday forces require objects to be in contact. Newton realized that the force that holds the moon in orbit is different in that it acts over long distances between objects that are not in contact.

Gravity

Newton hypothesized that the force that pulls an apple to the ground also pulls the moon toward Earth, keeping it in orbit. This force, called **gravity,** attracts all objects toward each other. In Newton's day, most scientists thought that forces on Earth were different from those elsewhere in the universe. Although Newton did not discover gravity, he was the first person to realize that gravity occurs everywhere. Newton's **law of universal gravitation** states that every object in the universe attracts every other object.

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The force of gravity is measured in units called newtons, named after Isaac Newton. **The strength of the force of gravity between two objects depends on two factors: the masses of the objects and the distance between them.**

Gravity, Mass, and Weight According to the law of universal gravitation, all of the objects around you, including Earth and even this book, are pulling on you, just as you are pulling on them. Why don't you notice a pull between you and the book? Because the strength of gravity depends in part on the masses of each of the objects. **Mass** is the amount of matter in an object.

Because Earth is so massive, it exerts a much greater force on you than this book does. Similarly, Earth exerts a gravitational force on the moon, large enough to keep the moon in orbit. The moon also exerts a gravitational force on Earth, as you will learn later in this chapter when you study the tides.

The force of gravity on an object is known as its **weight**. Unlike mass, which doesn't change, an object's weight can change depending on its location. For example, on the moon you would weigh about one sixth of your weight on Earth. This is because the moon is much less massive than Earth, so the pull of the moon's gravity on you would be far less than that of Earth's gravity.

Gravity and Distance The strength of gravity is affected by the distance between two objects as well as their masses. The force of gravity decreases rapidly as distance increases. For example, if the distance between two objects were doubled, the force of gravity between them would decrease to one fourth of its original value.

Reading Checkpoint What is an object's weight?

FIGURE 7
Gravity, Mass, and Distance
The strength of the force of gravity between two objects depends on their masses and the distance between them.
Inferring *How would the force of gravity change if the distance between the objects decreased?*

Force of Gravity

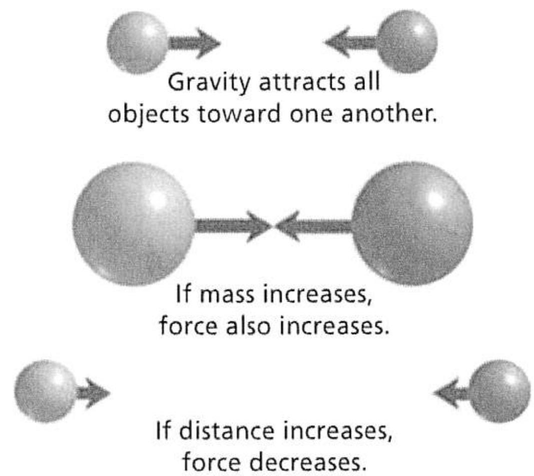
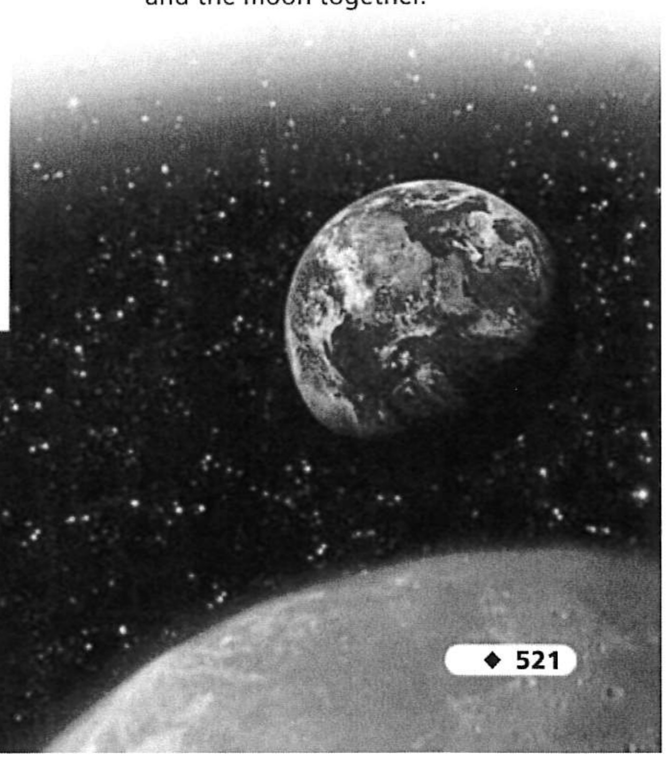


FIGURE 8
Earth Over the Moon
The force of gravity holds Earth and the moon together.



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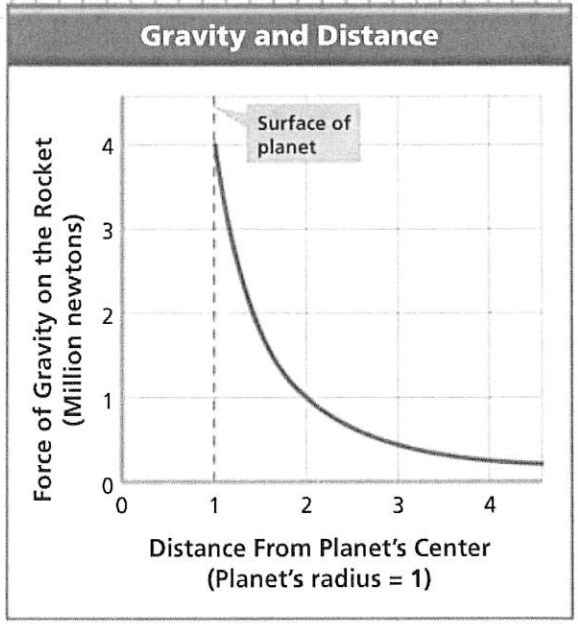
Math Analyzing Data

Gravity Versus Distance

As a rocket leaves a planet's surface, the force of gravity between the rocket and the planet changes. Use the graph at the right to answer the questions below.

1. **Reading Graphs** What two variables are being graphed? In what units is each variable measured?
2. **Reading Graphs** What is the force of gravity on the rocket at the planet's surface?
3. **Reading Graphs** What is the force of gravity on the rocket at a distance of two units (twice the planet's radius from its center)?
4. **Making Generalizations** In general, how does the force of gravity pulling on the rocket change as the distance between it and the planet increases?



Inertia and Orbital Motion

If the sun and Earth are constantly pulling on one another because of gravity, why doesn't Earth fall into the sun? Similarly, why doesn't the moon crash into Earth? The fact that such collisions have not occurred shows that there must be another factor at work. That factor is called inertia.

Inertia The tendency of an object to resist a change in motion is **inertia.** You feel the effects of inertia every day. When you are riding in a car and it stops suddenly, you keep moving forward. If you didn't have a seat belt on, your inertia could cause you to bump into the car's windshield or the seat in front of you. The more mass an object has, the greater its inertia. An object with greater inertia is more difficult to start or stop.

Isaac Newton stated his ideas about inertia as a scientific law. **Newton's first law of motion** says that an object at rest will stay at rest and an object in motion will stay in motion with a constant speed and direction unless acted on by a force.

Reading Checkpoint What is inertia?

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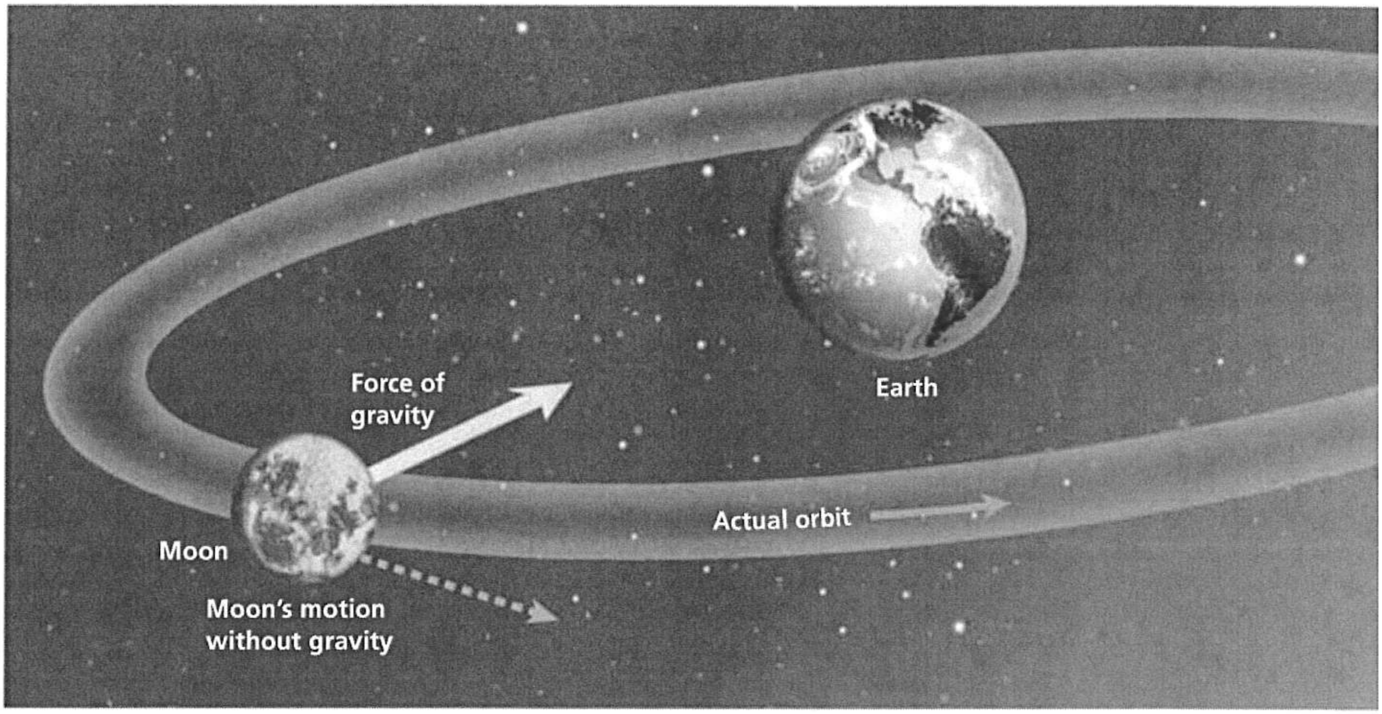


FIGURE 9
Gravity and Inertia
A combination of gravity and inertia keeps the moon in orbit around Earth. If there were no gravity, inertia would cause the moon to travel in a straight line.
Interpreting Diagrams *What would happen to the moon if it were not moving in orbit?*

Orbital Motion Why do Earth and the moon remain in their orbits? **Newton concluded that two factors—inertia and gravity—combine to keep Earth in orbit around the sun and the moon in orbit around Earth.**

As shown in Figure 9, Earth's gravity keeps pulling the moon toward it, preventing the moon from moving in a straight line. At the same time, the moon keeps moving ahead because of its inertia. If not for Earth's gravity, inertia would cause the moon to move off through space in a straight line. In the same way, Earth revolves around the sun because the sun's gravity pulls on it while Earth's inertia keeps it moving ahead.

Section 2 Assessment

Vocabulary Skill Latin Word Origins How does the Latin word origin of *gravity* help you to remember its meaning?

Reviewing Key Concepts

HINT 1. a. **Summarizing** What is the law of universal gravitation?
HINT b. **Reviewing** What two factors determine the force of gravity between two objects?
HINT c. **Predicting** Suppose the moon were closer to Earth. How would the force of gravity between Earth and the moon be different?
HINT 2. a. **Identifying** What two factors act together to keep Earth in orbit around the sun?
b. **Applying Concepts** Why doesn't Earth simply fall into the sun? HINT
c. **Predicting** How would Earth move if the sun (including its gravity) suddenly disappeared? Explain your answer. HINT

Writing in Science

Cause and Effect Paragraph Suppose you took a trip to the moon. Write a paragraph describing how and why your weight would change. Would your mass change too?

Section 3

Phases, Eclipses, and Tides

Reading Preview

Key Concepts

- What causes the phases of the moon?
- What are solar and lunar eclipses?
- What causes the tides?

Key Terms

- phases
- eclipse
- solar eclipse
- umbra
- penumbra
- lunar eclipse
- tide
- spring tide
- neap tide

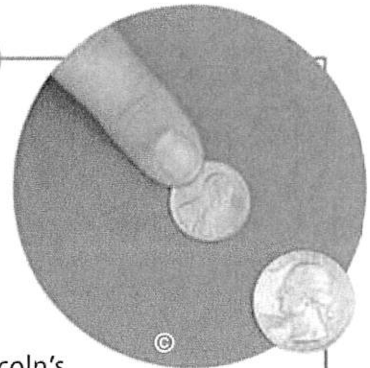
Target Reading Skill

Previewing Visuals Preview Figure 11. Then write two questions about the diagram of the phases of the moon in a graphic organizer like the one below. As you read, answer your questions.

Phases of the Moon

Q. Why does the moon have phases?
A.
Q.

Lab zone Discover Activity



How Does the Moon Move?

1. Place a quarter flat on your desk to represent Earth. Put a penny flat on your desk to represent the moon.
2. One side of the moon always faces Earth. Move the moon through one revolution around Earth, keeping Lincoln's face always looking at Earth. How many times did the penny make one complete rotation?

Think It Over

Inferring From the point of view of someone on Earth, does the moon seem to rotate? Explain your answer.

When you look up at the moon, you may see what looks like a face. Some people call this "the man in the moon." What you are really seeing is a pattern of light-colored and dark-colored areas on the moon's surface that just happens to look like a face. Oddly, this pattern never seems to move. That is, the same side of the moon, the "near side," always faces Earth. The "far side" of the moon always faces away from Earth. The reason has to do with how the moon moves in space.

Motions of the Moon

Like Earth, the moon moves through space in two ways. The moon revolves around Earth and also rotates on its own axis.

As the moon revolves around Earth, the relative positions of the moon, Earth, and sun change. **The changing relative positions of the moon, Earth, and sun cause the phases of the moon, eclipses, and tides.**

The moon rotates once on its axis in the same amount of time as it revolves around Earth. Thus, a "day" and a "year" on the moon are the same length. For this reason, the same side of the moon always faces Earth. The length of the moon's day is somewhat shorter than the 29.5 days between consecutive full moons. This is because as Earth revolves around the sun, the moon revolves around Earth.

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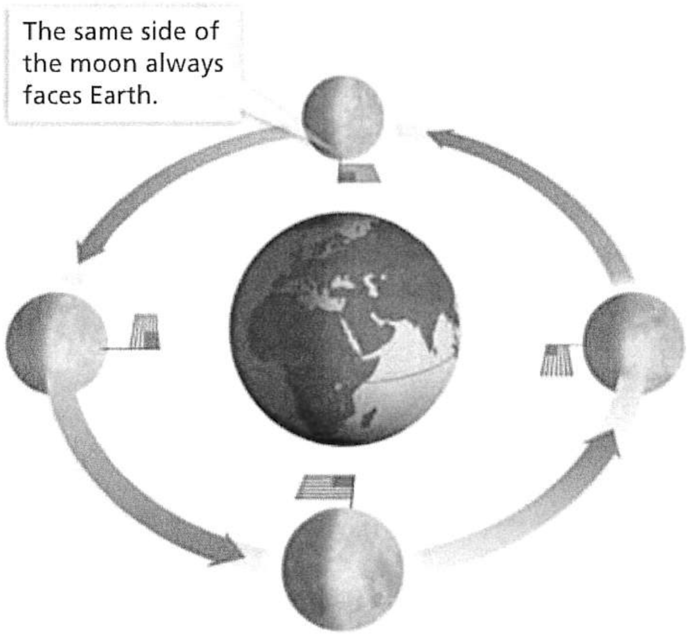


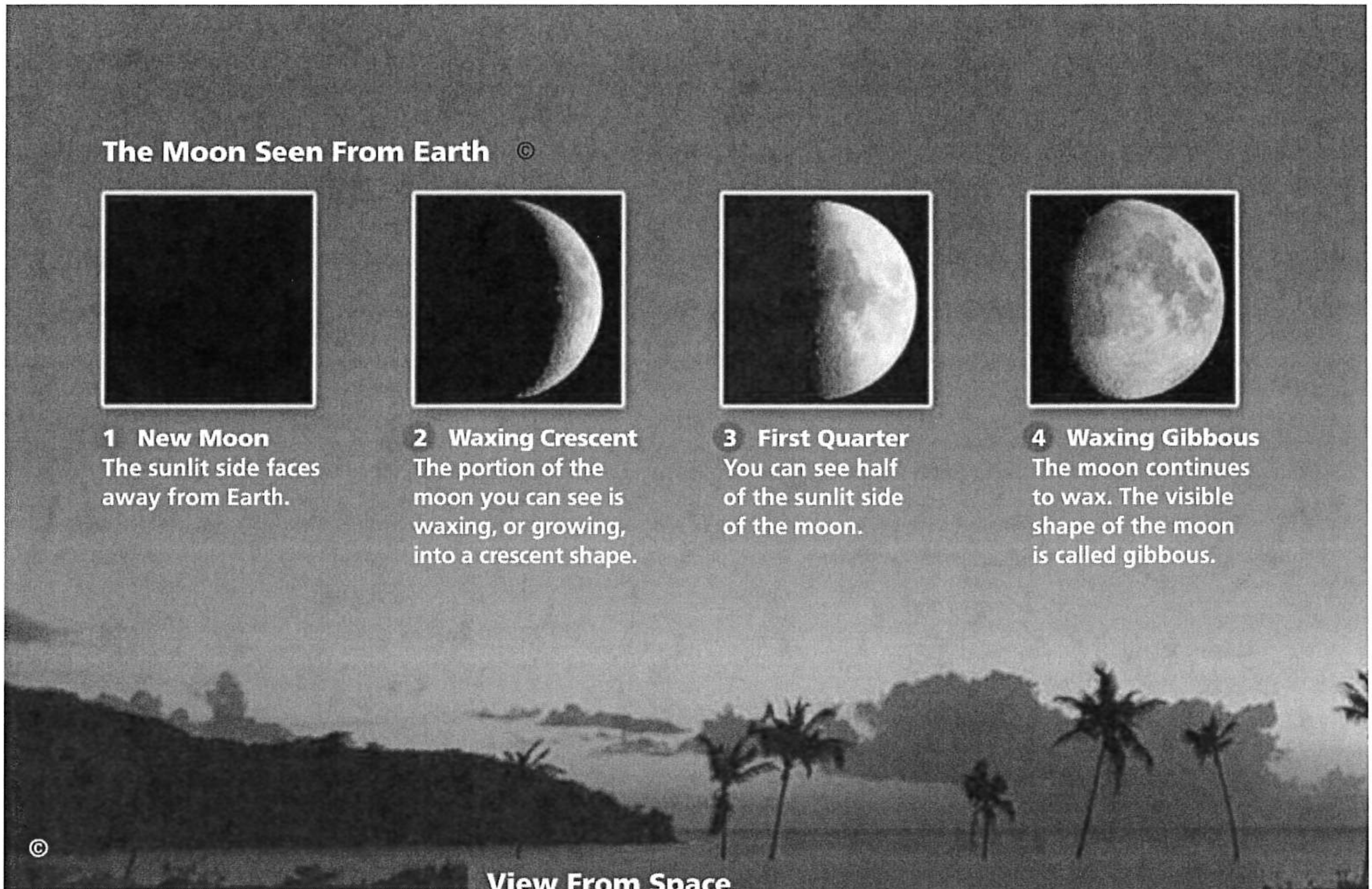
FIGURE 10
The Moon in Motion
The moon rotates on its axis and revolves around Earth in the same amount of time. As a result, the near side of the moon (shown with a flag) always faces Earth.
Interpreting Diagrams *Would Earth ever appear to set below the horizon for someone standing next to the flag on the moon? Explain.*

Phases of the Moon

On a clear night when the moon is full, the bright moonlight can keep you awake. But the moon does not produce the light you see. Instead, it reflects light from the sun. Imagine taking a flashlight into a dark room. If you were to shine the flashlight on a chair, you would see the chair because the light from your flashlight would bounce, or reflect, off the chair. In the same way that the chair wouldn't shine by itself, the moon doesn't give off light by itself. You can see the moon because it reflects the light of the sun.

When you see the moon in the sky, sometimes it appears round. Other times you see only a thin sliver, or crescent. The different shapes of the moon you see from Earth are called **phases.** The moon goes through its whole set of phases each time it makes a complete revolution around Earth.

Phases are caused by changes in the relative positions of the moon, Earth, and the sun. Because the sun lights the moon, half the moon is almost always in sunlight. However, since the moon revolves around Earth, you see the moon from different angles. The half of the moon that faces Earth is not always the half that is sunlit. **The phase of the moon you see depends on how much of the sunlit side of the moon faces Earth.**



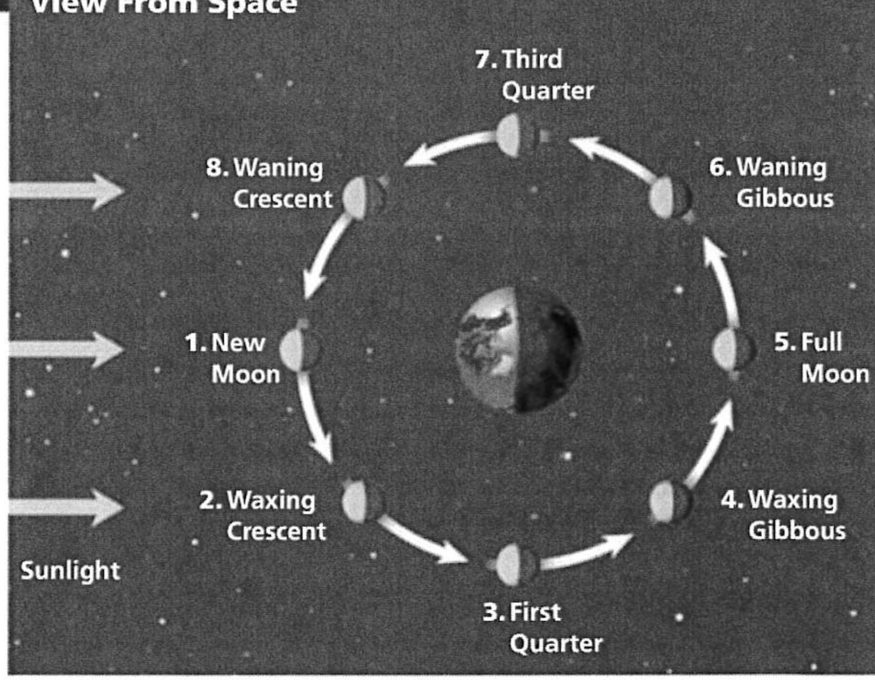


FIGURE 11
Phases of the Moon
The photos at the top of the page show how the phases of the moon appear when you look up at the moon from Earth's surface. The circular diagram at the right shows how the Earth and moon would appear to an observer in space as the moon revolves around Earth.
Interpreting Diagrams *During what phases are the moon, Earth, and sun aligned in a straight line?*

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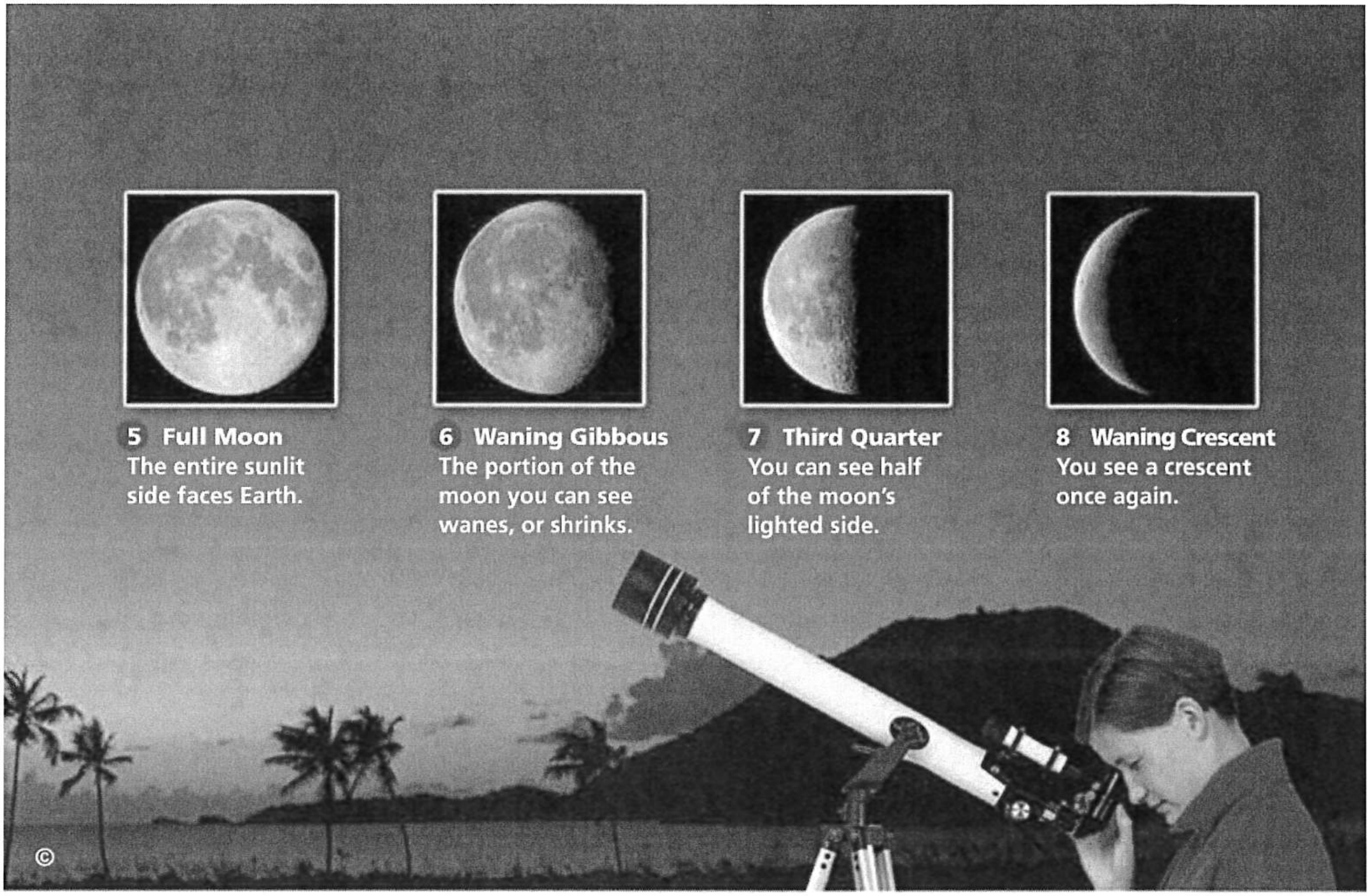


To understand the phases of the moon, study Figure 11. During the new moon, the side of the moon facing Earth is not lit because the sun is behind the moon. As the moon revolves around Earth, you see more and more of the lighted side of the moon every day, until the side of the moon you see is fully lit. As the moon continues in its orbit, you see less and less of the lighted side. About 29.5 days after the last new moon, the cycle is complete, and a new moon occurs again.

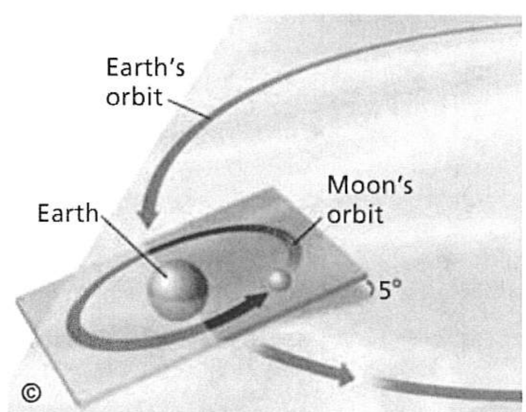
Reading Checkpoint What is a new moon?

Eclipses

As Figure 12 shows, the moon's orbit around Earth is slightly tilted with respect to Earth's orbit around the sun. As a result, in most months the moon revolves around Earth without moving into Earth's shadow or the moon's shadow hitting Earth.

When the moon's shadow hits Earth or Earth's shadow hits the moon, an eclipse occurs. When an object in space comes between the sun and a third object, it casts a shadow on that object, causing an **eclipse** (ih KLIPS) to take place. There are two types of eclipses: solar eclipses and lunar eclipses. (The words *solar* and *lunar* come from the Latin words for "sun" and "moon.")

FIGURE 12
The Moon's Orbit
The moon's orbit is tilted about 5 degrees relative to Earth's orbit around the sun.



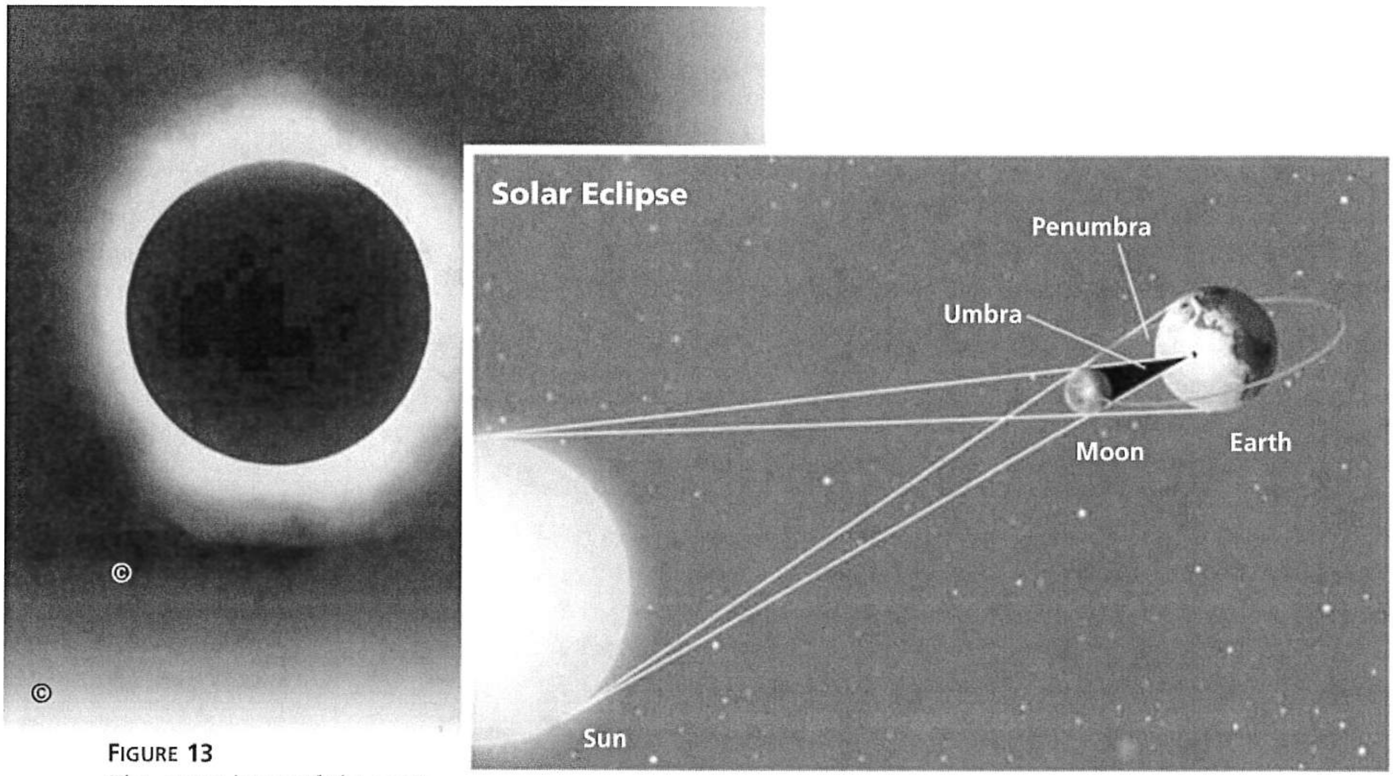


FIGURE 13
The outer layer of the sun's atmosphere, the solar corona, is visible surrounding the dark disk of the moon during a solar eclipse. During a solar eclipse, the moon blocks light from the sun, preventing sunlight from reaching parts of Earth's surface.

When Do Solar Eclipses Occur? During a new moon, the moon lies between Earth and the sun. But most months, as you have seen, the moon travels a little above or below the sun in the sky. **A solar eclipse occurs when the moon passes directly between Earth and the sun, blocking sunlight from Earth.** The moon's shadow then hits Earth, as shown in Figure 13. So a **solar eclipse** occurs when a new moon blocks your view of the sun.

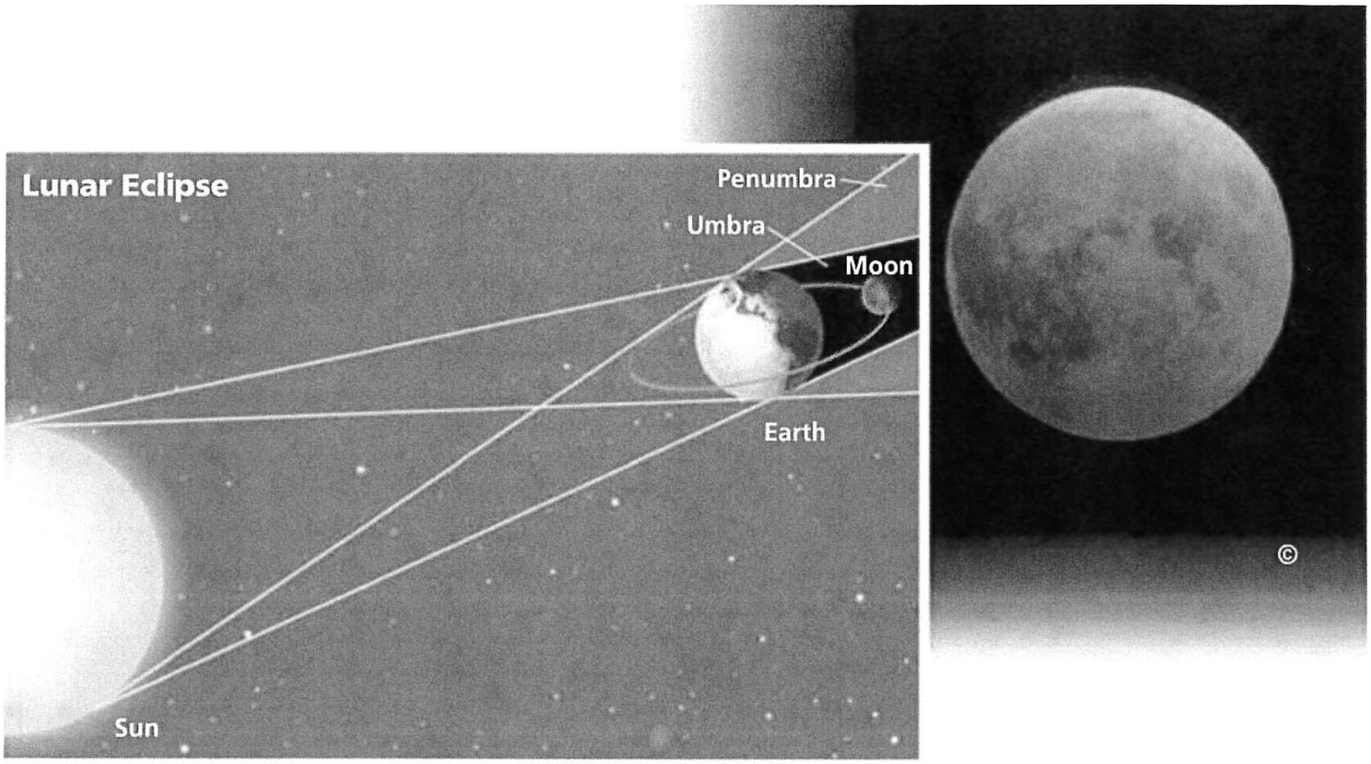
Lab zone Skills Activity

Making Models

Here is how you can draw a scale model of a solar eclipse. The moon's diameter is about one fourth Earth's diameter. The distance from Earth to the moon is about 30 times Earth's diameter. Make a scale drawing of the moon, Earth, and the distance between them. (*Hint:* Draw Earth 1 cm in diameter in one corner of the paper.) From the edges of the moon, draw and shade in a triangle just touching Earth to show the moon's umbra.

Total Solar Eclipses The very darkest part of the moon's shadow, the **umbra** (UM bruh), is cone-shaped. From any point in the umbra, light from the sun is completely blocked by the moon. The moon's umbra happens to be long enough so that the point of the cone can just reach a small part of Earth's surface. Only the people within the umbra experience a total solar eclipse. During the short period of a total solar eclipse, the sky grows as dark as night, even in the middle of a clear day. The air gets cool and the sky becomes an eerie color. You can see the stars and the solar corona, which is the faint outer atmosphere of the sun.

Partial Solar Eclipses In Figure 13, you can see that the moon casts another part of its shadow that is less dark than the umbra. This larger part of the shadow is called the **penumbra** (peh NUM bruh). In the penumbra, part of the sun is visible from Earth. During a solar eclipse, people in the penumbra see only a partial eclipse. Since an extremely bright part of the sun still remains visible, it is not safe to look directly at the sun during a partial solar eclipse (just as you wouldn't look directly at the sun during a normal day).



When Do Lunar Eclipses Occur? During most months, the moon moves near Earth's shadow but not quite into it. A **lunar eclipse** occurs at a full moon when Earth is directly between the moon and the sun. You can see a lunar eclipse in Figure 14. **During a lunar eclipse, Earth blocks sunlight from reaching the moon.** The moon is then in Earth's shadow and looks dim from Earth. Lunar eclipses occur only when there is a full moon because the moon is closest to Earth's shadow at that time.

Total Lunar Eclipses Like the moon's shadow in a solar eclipse, Earth's shadow has an umbra and a penumbra. When the moon is in Earth's umbra, you see a total lunar eclipse. You can see the edge of Earth's shadow on the moon before and after a total lunar eclipse.

Unlike a total solar eclipse, a total lunar eclipse can be seen anywhere on Earth that the moon is visible. So you are more likely to see a total lunar eclipse than a total solar eclipse.

Partial Lunar Eclipses For most lunar eclipses, Earth, the moon, and the sun are not quite in line, and only a partial lunar eclipse results. A partial lunar eclipse occurs when the moon passes partly into the umbra of Earth's shadow. The edge of the umbra appears blurry, and you can watch it pass across the moon for two or three hours.

Reading Checkpoint During which phase of the moon can lunar eclipses occur?

FIGURE 14
During a lunar eclipse, Earth blocks sunlight from reaching the moon's surface. The photo of the moon above was taken during a total lunar eclipse. The moon's reddish tint occurs because Earth's atmosphere bends some sunlight toward the moon.
Interpreting Diagrams *What is the difference between the umbra and the penumbra?*

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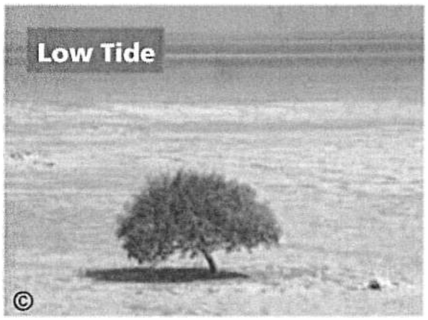


FIGURE 15 ©
High and Low Tides
In some locations, such as along this beach in Australia, there can be dramatic differences between the height of high and low tides.

Tides

Have you ever built a sand castle on an ocean beach? Was it washed away by rising water? This is an example of **tides,** the rise and fall of ocean water that occurs every 12.5 hours or so. The water rises for about six hours, then falls for about six hours, in a regular cycle.

The force of gravity pulls the moon and Earth (including the water on Earth's surface) toward each other. **Tides are caused mainly by differences in how much the moon's gravity pulls on different parts of Earth.**

The Tide Cycle Look at Figure 16. The force of the moon's gravity at point A, which is closer to the moon, is stronger than the force of the moon's gravity on Earth as a whole. The water flows toward point A, and a high tide forms.

The force of the moon's gravity at point C, which is on the far side of Earth from the moon, is weaker than the force of the moon's gravity on Earth as a whole. Earth is pulled toward the moon more strongly than the water at point C, so the water is "left behind." Water flows toward point C, and a high tide occurs there too. Between points A and C, water flows away from points B and D, causing low tides.

At any one time there are two places with high tides and two places with low tides on Earth. As Earth rotates, one high tide stays on the side of Earth facing the moon. The second high tide stays on the opposite side of Earth. Each location on Earth sweeps through those two high tides and two low tides every 25 hours or so.

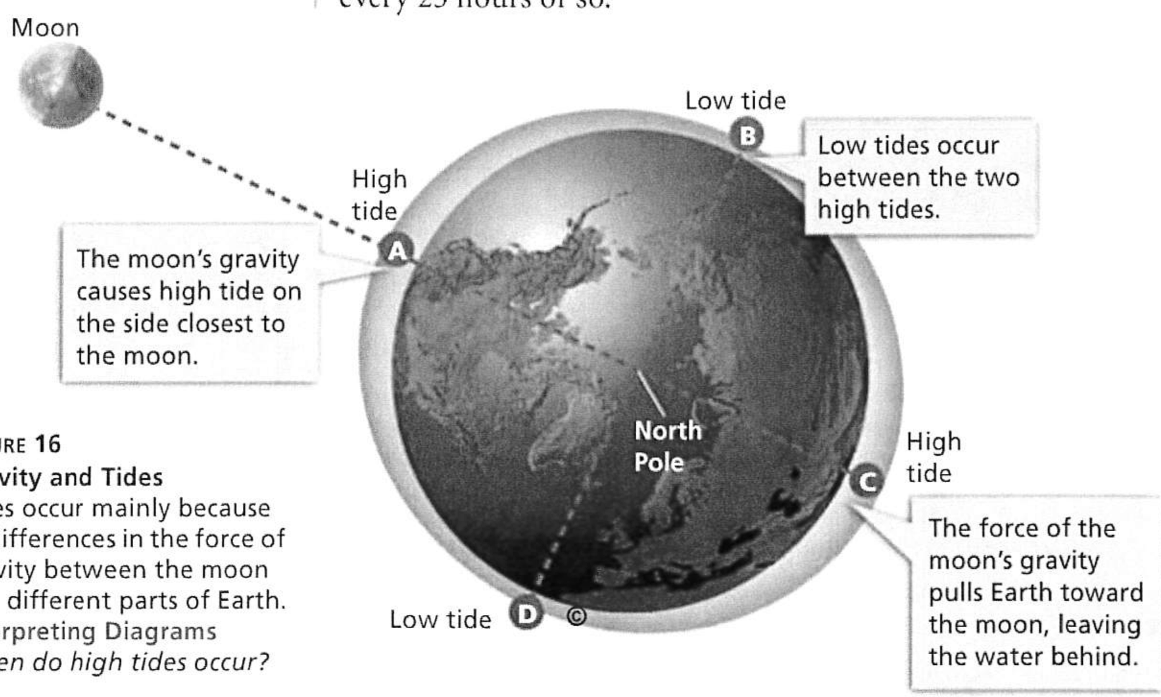


FIGURE 16
Gravity and Tides
Tides occur mainly because of differences in the force of gravity between the moon and different parts of Earth.
Interpreting Diagrams
When do high tides occur?

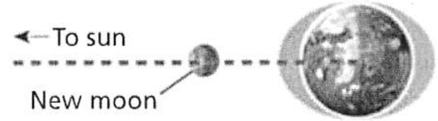
Spring Tides The sun's gravity also pulls on Earth's waters. As shown in the top diagram of Figure 17, the sun, moon, and Earth are nearly in a line during a new moon. The gravity of the sun and the moon pull in the same direction. Their combined forces produce a tide with the greatest difference between consecutive low and high tides, called a **spring tide.**

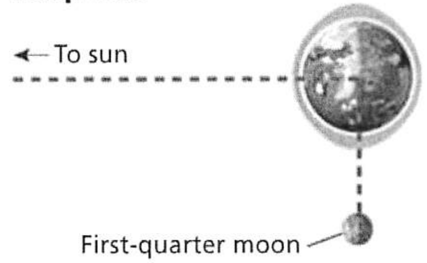
At full moon, the moon and the sun are on opposite sides of Earth. Since there are high tides on both sides of Earth, a spring tide is also produced. It doesn't matter in which order the sun, Earth, and moon line up. Spring tides occur twice a month, at new moon and at full moon.

Neap Tides During the moon's first-quarter and third-quarter phases, the line between Earth and the sun is at right angles to the line between Earth and the moon. The sun's pull is at right angles to the moon's pull. This arrangement produces a **neap tide,** a tide with the least difference between consecutive low and high tides. Neap tides occur twice a month.

Reading Checkpoint What is a neap tide?

FIGURE 17
Spring and Neap Tides
When Earth, the sun, and the moon are in a straight line (top), a spring tide occurs. When the moon is at a right angle to the sun (bottom), a neap tide occurs.





Section 3 Assessment

Target Reading Skill **Previewing Visuals** Refer to your questions and answers about Figure 11 to help you answer Question 1 below.

Reviewing Key Concepts

HINT HINT HINT HINT HINT HINT HINT HINT HINT

1. a. **Explaining** What causes the moon to shine?
   b. **Relating Cause and Effect** Why does the moon appear to change shape during the course of a month?
   c. **Interpreting Diagrams** Use Figure 11 to explain why you can't see the moon at the time of a new moon.
2. a. **Explaining** What is an eclipse?
   b. **Comparing and Contrasting** How is a solar eclipse different from a lunar eclipse?
   c. **Relating Cause and Effect** Why isn't there a solar eclipse and a lunar eclipse each month?
3. a. **Summarizing** What causes the tides?
   b. **Explaining** Explain why most coastal regions have two high tides and two low tides each day.
   c. **Comparing and Contrasting** Compare the size of high and low tides in a spring tide and a neap tide. What causes the difference?

Lab zone At-Home Activity

Tracking the Tides Use a daily newspaper or the Internet to track the height of high and low tides at a location of your choice for at least two weeks. Make a graph of your data, with the date as the *x*-axis and tide height as the *y*-axis. Also find the dates of the new moon and full moon and add them to your graph. Show your completed graph to a relative and explain what the graph shows.

Lab zone **Skills Lab**

A "Moonth" of Phases

Problem

What causes the phases of the moon?

Skills Focus

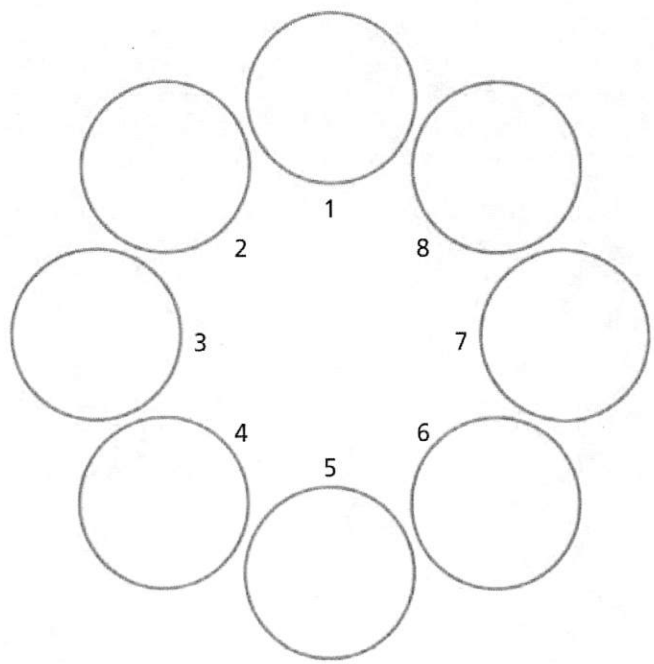
making models, observing, drawing conclusions

Materials

- floor lamp with 150-watt bulb
- pencils
- plastic foam balls

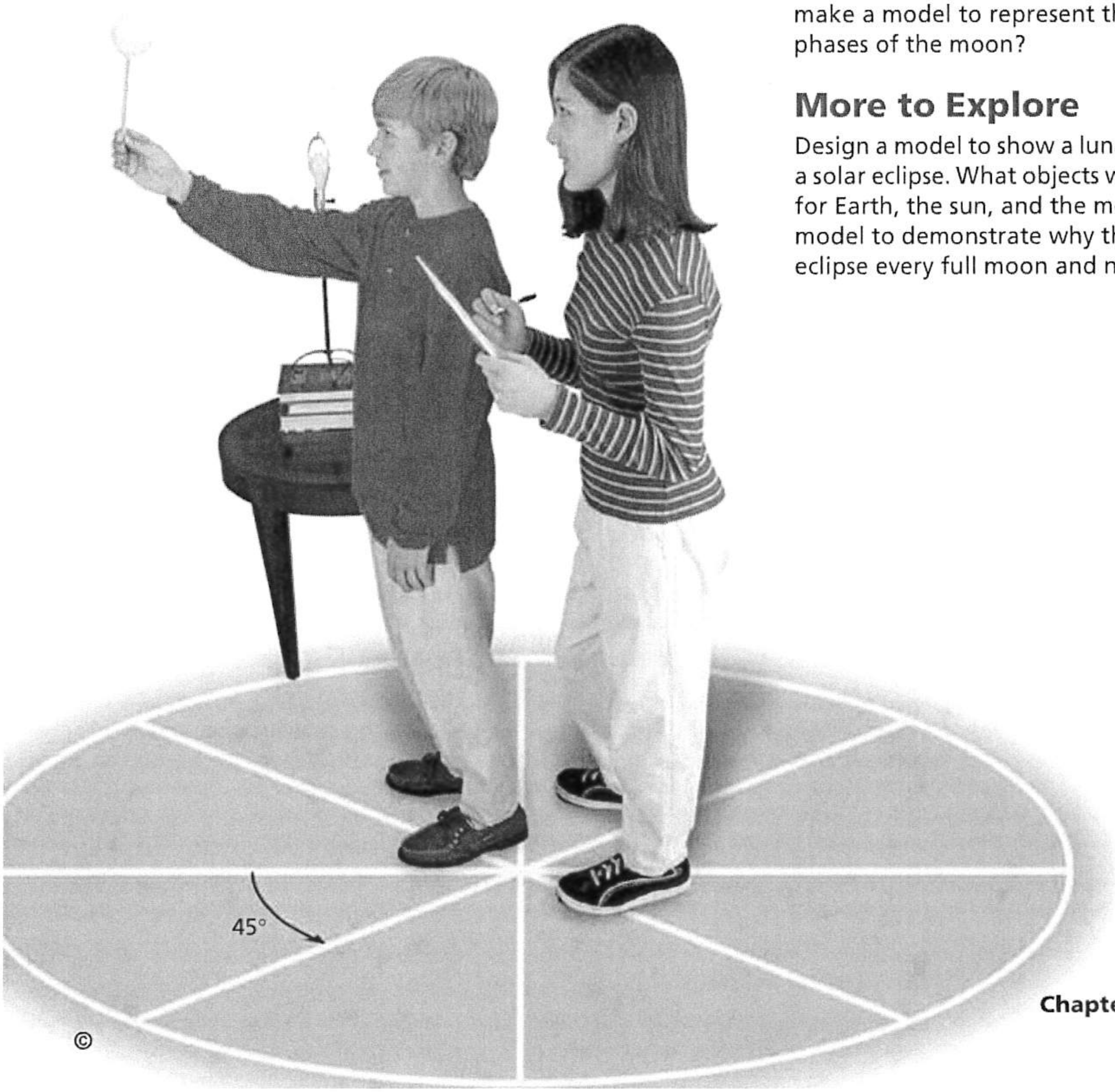
Procedure

1. Place a lamp in the center of the room. Remove the lampshade.
2. Close the doors and shades to darken the room, and switch on the lamp.
3. Carefully stick the point of a pencil into the plastic foam ball so that the pencil can be used as a "handle."
4. Draw 8 circles on a sheet of paper. Number them 1–8.
5. Have your partner hold the plastic foam ball at arm's length in front and slightly above his or her head so that the ball is between him or her and the lamp. **CAUTION:** *Do not look directly at the bulb.*
6. The ball should be about 1 to 1.5 m away from the lamp. Adjust the distance between the ball and the lamp so that the light shines brightly on the ball.
7. Stand directly behind your partner and observe what part of the ball facing you is lit by the lamp. If light is visible on the ball, draw the shape of the lighted part of the ball in the first circle.
8. Have your partner turn 45° to the left while keeping the ball in front and at arm's length.
9. Repeat Step 7. Be sure you are standing directly behind your partner.
10. Repeat Steps 8 and 9 six more times until your partner is facing the lamp again. See the photograph for the 8 positions.
11. Change places and repeat Steps 4–10.



Analyze and Conclude

1. Making Models In your model, what represents Earth? The sun? The moon?
2. Observing Refer back to your 8 circles. How much of the lighted part of the ball did you see when facing the lamp?
3. Classifying Label your drawings with the names of the phases of the moon. Which drawing represents a full moon? A new moon? Which represents a waxing crescent? A waning crescent?
4. Observing How much of the lighted part of the ball did you see after each turn?
5. Drawing Conclusions Whether you could see it or not, how much of the ball's surface was always lit by the lamp? Was the darkness of the new moon caused by an eclipse? Explain your answer.
6. Communicating Write a brief analysis of this lab. How well did making a model help you understand the phases of the moon? What are some disadvantages of using models? What is another way to make a model to represent the various phases of the moon?



More to Explore

Design a model to show a lunar eclipse and a solar eclipse. What objects would you use for Earth, the sun, and the moon? Use the model to demonstrate why there isn't an eclipse every full moon and new moon.

©

Section 4 Earth's Moon

Reading Preview

Key Concepts

- What features are found on the moon's surface?
- What are some characteristics of the moon?
- How did the moon form?

Key Terms

- telescope
- maria
- craters
- meteoroids

Target Reading Skill

Identifying Main Ideas As you read "The Moon's Surface," 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 moon's surface has a variety of features, such as . . .

Detail	Detail	Detail

Lab zone Discover Activity

Why Do Craters Look Different From Each Other?

The moon's surface has pits in it, called craters.

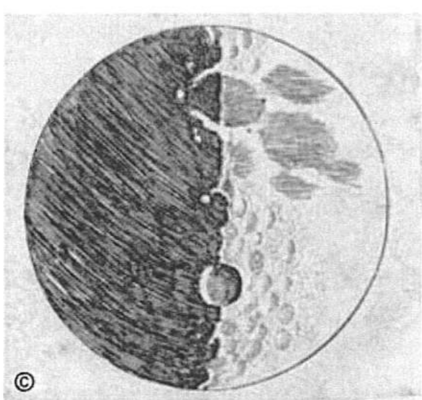
1. Put on your goggles. Fill a large plastic basin to a depth of 2 cm with sand.
2. Drop marbles of different masses from about 20 cm high. Take the marbles out and view the craters they created.
3. Predict what will happen if you drop marbles from a higher point. Smooth out the sand. Now drop marbles of different masses from about 50 cm high.
4. Take the marbles out and view the craters they left.

Think It Over

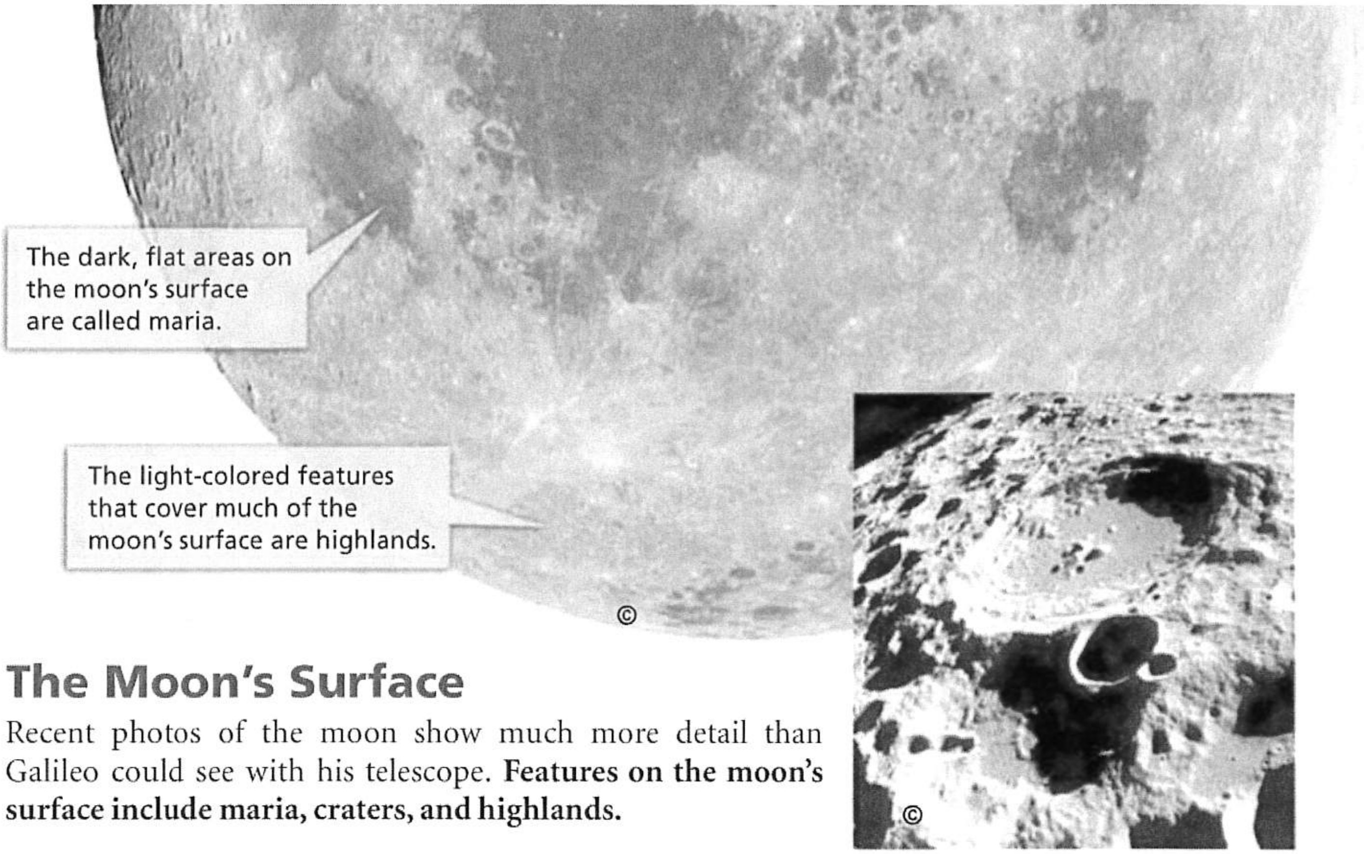
Developing Hypotheses In which step do you think the marbles were moving faster when they hit the sand? If objects hitting the moon caused craters, how did the speeds of the objects affect the sizes of the craters? How did the masses of the objects affect the sizes of the craters?

For thousands of years, people could see shapes on the surface of the moon, but didn't know what caused them. The ancient Greeks thought that the moon was perfectly smooth. It was not until about 400 years ago that scientists could study the moon more closely.

In 1609, the Italian scientist Galileo Galilei heard about a **telescope,** a device built to observe distant objects by making them appear closer. Galileo soon made his own telescope by putting two lenses in a wooden tube. The lenses focused the light coming through the tube, making distant objects seem closer. When Galileo pointed his telescope at the moon, he was able to see much more detail than anyone had ever seen before. What Galileo saw astounded him. Instead of the perfect sphere imagined by the Greeks, he saw that the moon has an irregular surface with a variety of remarkable features.



◀ Galileo used a telescope to help make this drawing of the moon.



The Moon's Surface

Recent photos of the moon show much more detail than Galileo could see with his telescope. **Features on the moon's surface include maria, craters, and highlands.**

Maria The moon's surface has dark, flat areas, which Galileo called **maria** (MAH ree uh), the Latin word for "seas." Galileo incorrectly thought that the maria were oceans. The maria are actually hardened rock formed from huge lava flows that occurred between 3 and 4 billion years ago.

Craters Galileo saw that the moon's surface is marked by large round pits called **craters.** Some craters are hundreds of kilometers across. For a long time, many scientists mistakenly thought that these craters had been made by volcanoes. Scientists now know that these craters were caused by the impacts of **meteoroids,** chunks of rock or dust from space.

The maria have few craters compared to surrounding areas. This means that most of the moon's craters formed from impacts early in its history, before the maria formed. On Earth, such ancient craters have disappeared. They were worn away over time by water, wind, and other forces. But since the moon has no liquid water or atmosphere, its surface has changed little for billions of years.

Highlands Galileo correctly inferred that some of the light-colored features he saw on the moon's surface were highlands, or mountains. The peaks of the lunar highlands and the rims of the craters cast dark shadows, which Galileo could see. The rugged lunar highlands cover much of the moon's surface.

Reading Checkpoint What are maria?

FIGURE 18
The Moon's Surface
The moon's surface is covered by craters, maria, and highlands. Craters on the moon formed from the impact of meteoroids. Most large craters are named after famous scientists or philosophers.
Observing *What are the light regions in the top photograph called?*

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Characteristics of the Moon

Would you want to take a vacation on the moon? At an average distance of about 384,000 kilometers (about 30 times Earth's diameter), the moon is Earth's closest neighbor in space. Despite its proximity, the moon is very different from Earth. **The moon is dry and airless. Compared to Earth, the moon is small and has large variations in its surface temperature.** If you visited the moon, you would need to wear a bulky space suit to provide air to breathe, protect against sunburn, and to keep you at a comfortable temperature.

FIGURE 19
The Moon's Size
The diameter of the moon is a little less than the distance across the contiguous United States.
Calculating *What is the ratio of the moon's diameter to the distance between Earth and the moon?*

Size and Density The moon is 3,476 kilometers in diameter, a little less than the distance across the United States. This is about one-fourth Earth's diameter. However, the moon has only one-eightieth as much mass as Earth. Though Earth has a very dense core, its outer layers are less dense. The moon's average density is similar to the density of Earth's outer layers.

Temperature and Atmosphere On the moon's surface, temperatures range from a torrid 130 °C in direct sunlight to a frigid –180 °C at night. Temperatures on the moon vary so much because it has no atmosphere. The moon's surface gravity is so weak that gases can easily escape into space.

Water The moon has no liquid water. However, there is evidence that there may be large patches of ice near the moon's poles. Some areas are shielded from sunlight by crater walls. Temperatures in these regions are so low that ice there would remain frozen. If a colony were built on the moon in the future, any such water would be very valuable. It would be very expensive to transport large amounts of water to the moon from Earth.

Reading Checkpoint **Where on the moon is there evidence of the existence of ice?**

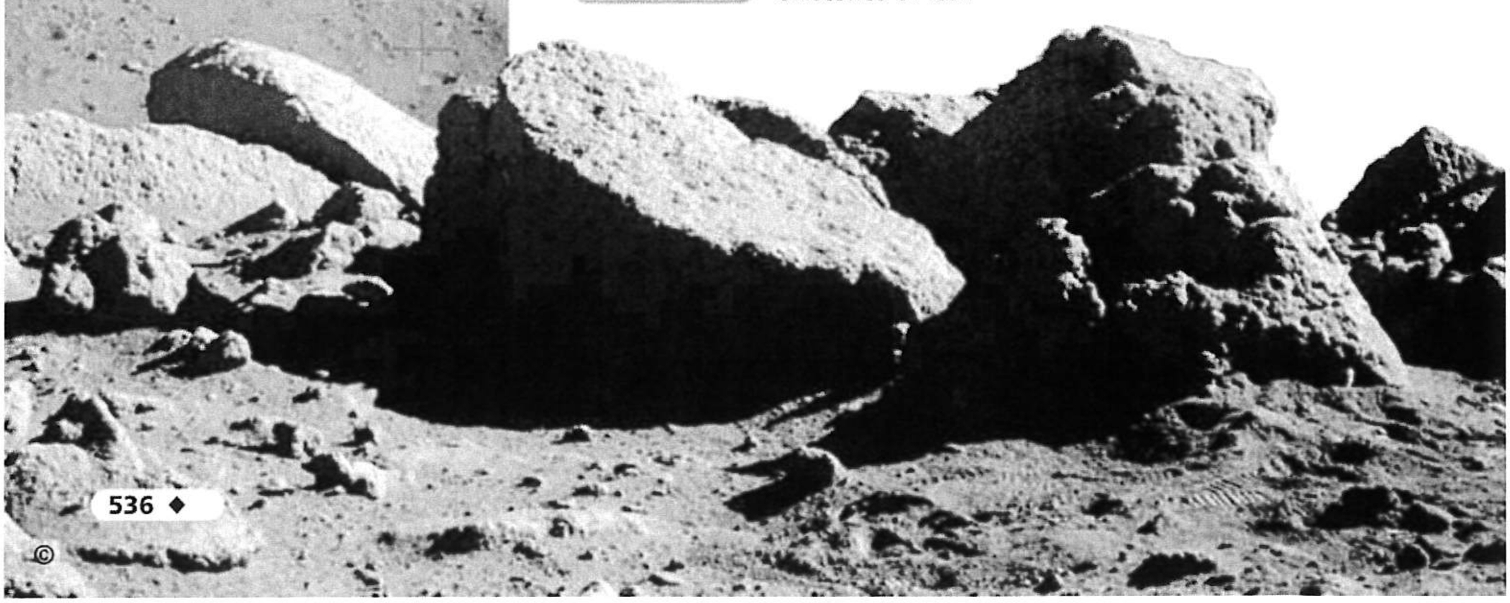

FIGURE 20
The Moon's Surface
This photo of a large boulder field and hills on the moon's surface was taken by one of the crew members of *Apollo 17.*

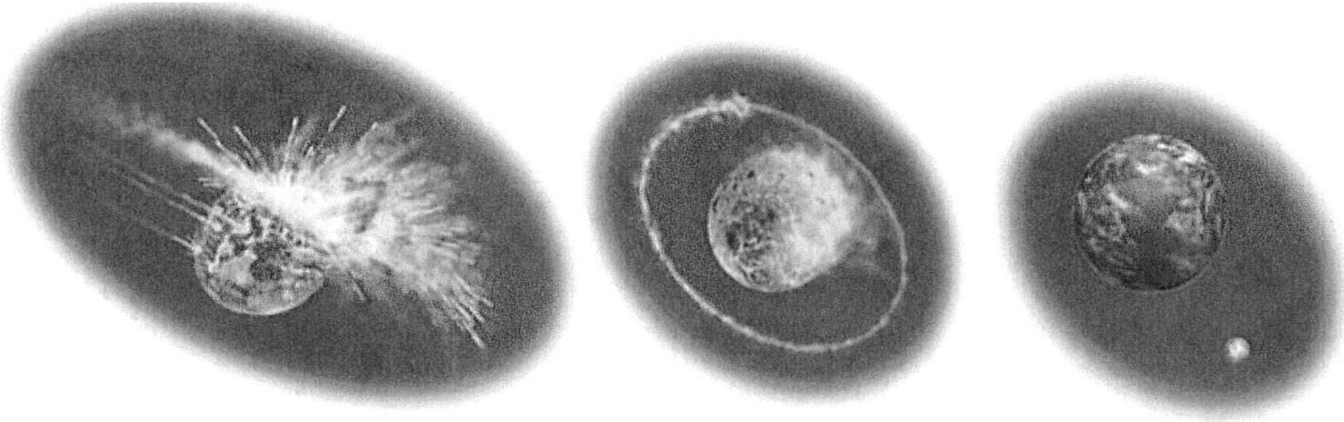

FIGURE 21
Formation of the Moon
According to the collision-ring theory, the moon formed early in Earth's history when a planet-sized object struck Earth. The resulting debris formed the moon.

The Origin of the Moon

People have long wondered how the moon formed. Scientists have suggested many possible theories. For example, was the moon formed elsewhere in the solar system and captured by Earth's gravity as it came near? Was the moon formed near Earth at the same time that Earth formed? Scientists have found reasons to reject these ideas.

The theory of the moon's origin that seems to best fit the evidence is called the collision-ring theory. It is illustrated in Figure 21. About 4.5 billion years ago, when Earth was very young, the solar system was full of rocky debris. Some of this debris was the size of small planets. **Scientists theorize that a planet-sized object collided with Earth to form the moon.** Material from the object and Earth's outer layers was ejected into orbit around Earth, where it formed a ring. Gravity caused this material to combine to form the moon.

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Section 4 Assessment

Vocabulary Skill Latin Word Origins What are maria? Why did Galileo select the word *maria* for this feature of the moon? Does the Latin origin of this word accurately describe what scientists today know about the moon? Why or why not?

Reviewing Key Concept

1. a. **Identifying** Name three major features of the moon's surface. HINT
   b. **Explaining** How did the moon's craters form? HINT
   c. **Relating Cause and Effect** Why is the moon's surface much more heavily cratered than Earth's surface? HINT
2. a. **Describing** Describe the range of temperatures on the moon. HINT
   b. **Comparing and Contrasting** Compare Earth and the moon in terms of size and surface gravity. HINT
   c. **Relating Cause and Effect** What is the relationship between the moon's surface gravity, lack of an atmosphere, and temperature range? HINT
3. a. **Describing** What was the solar system like when the moon formed? HINT
   b. **Sequencing** Explain the various stages in the formation of the moon. HINT

Lab zone At-Home Activity

Moonwatching With an adult, observe the moon a few days after the first-quarter phase. Make a sketch of the features you see. Label the maria, craters, and highlands.

Section 5

Traveling Into Space

Reading Preview

Key Concepts

- How does a rocket work?
- What is the main advantage of a multistage rocket?
- What was the space race, and what were the major events in the human exploration of the moon?
- What are the roles of space shuttles, space stations, and space probes?

Key Terms

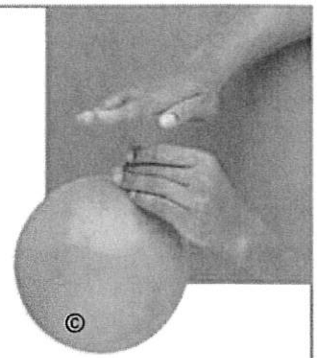
- rocket • thrust
- velocity • orbital velocity
- escape velocity • satellite
- space shuttle • space station
- space probe • rover

Target Reading Skill

Building Vocabulary Carefully read the definition of each key term. Also read the neighboring sentences. Then write a definition of each key term in your own words.

Lab zone Discover Activity

What Force Moves a Balloon?



1. Put on your goggles. Blow up a balloon and hold its neck closed with your fingers.
2. Point the far end of the balloon in a direction where there are no people. Put your free hand behind the balloon's neck, so you will be able to feel the force of the air from the balloon on your hand. Let go of the balloon. Observe what happens.
3. Repeat Steps 1 and 2 without your free hand behind the neck of the balloon.

Think It Over

Inferring What happened when you let go of the balloon? Which direction did the balloon move in comparison to the direction the air moved out of the balloon? What force do you think caused the balloon to move in that direction? Did the position of your free hand affect the balloon's movement?

You have probably seen a colorful fireworks display on the Fourth of July. As the fireworks moved skyward, you may have noticed a fiery gas rushing out of the tail end. Fireworks are actually rockets. A **rocket** is a device that expels gas in one direction to move in the opposite direction. The first rockets were made in China in the 1100s. These early rockets were very simple—they were arrows coated with a flammable powder that were lighted and shot with bows. By about 1200, the Chinese were using gunpowder inside their rockets.

Modern rockets were first developed in the early 1900s. The Russian physicist Konstantin Tsiolkovsky first described how rockets work and proposed designs for advanced rockets. The American physicist Robert Goddard went a step further and built rockets to test his designs.

Rocket design made major advances during World War II. The Germans used a rocket called the V2 to destroy both military and civilian targets. The designer of the V2, Wernher von Braun, came to the United States after the war. Von Braun later designed rockets used in the United States space program.

How Do Rockets Work?

A rocket works in much the same way as a balloon that is propelled through the air by releasing gas. In most rockets, fuel is burned to make hot gas. The gas pushes outward in every direction, but it can leave the rocket only through openings at the back. The movement of gas out of these openings moves the rocket forward. **A rocket moves forward when gases shooting out the back of the rocket push it in the opposite direction.**

Action and Reaction Forces The movement of a rocket demonstrates a basic law of physics: For every force, or action, there is an equal and opposite force, or reaction. The force of the air moving out of a balloon is an action force. An equal force—the reaction force—pushes the balloon forward.

The reaction force that propels a rocket forward is called **thrust.** The amount of thrust depends on several factors, including the mass and speed of the gases propelled out of the rocket. The greater the thrust, the greater a rocket's velocity. **Velocity** is speed in a given direction.

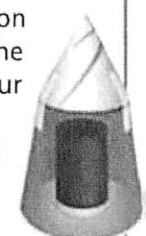
Orbital and Escape Velocity In order to lift off the ground, a rocket must have more upward thrust than the downward force of gravity. Once a rocket is off the ground, it must reach a certain velocity in order to go into orbit. **Orbital velocity** is the velocity a rocket must achieve to establish an orbit around Earth. If the rocket moves slower than orbital velocity, Earth's gravity will cause it to fall back to the surface. If the rocket has a velocity of 40,200 km/h or more, it can escape Earth's gravity and fly off into space. **Escape velocity** is the velocity a rocket must reach to fly beyond a planet's gravitational pull.

Lab zone Try This Activity

Be a Rocket Scientist

You can build a rocket.

1. Use a plastic or paper cup as the rocket body. Cut out a paper nose cone. Tape it to the bottom of the cup.
2. Obtain an empty film canister with a lid that snaps on inside the canister. Go outside to do Steps 3–5.
3. Fill the canister about one-quarter full with water.
4. Put on your goggles. Now add half of a fizzing antacid tablet to the film canister and quickly snap on the lid.
5. Place the canister on the ground with the lid down. Place your rocket over the canister and stand back.



Observing What action happened inside the film canister? What was the reaction of the rocket?

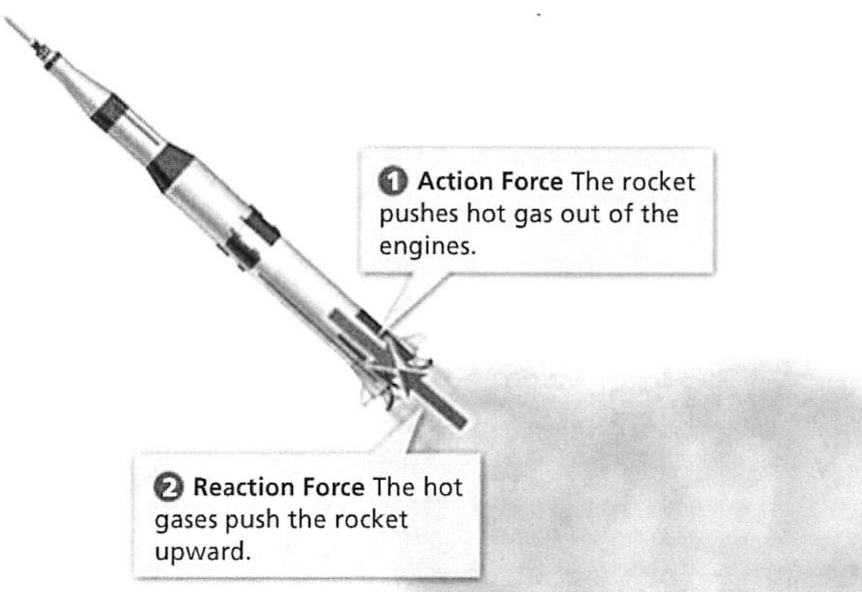
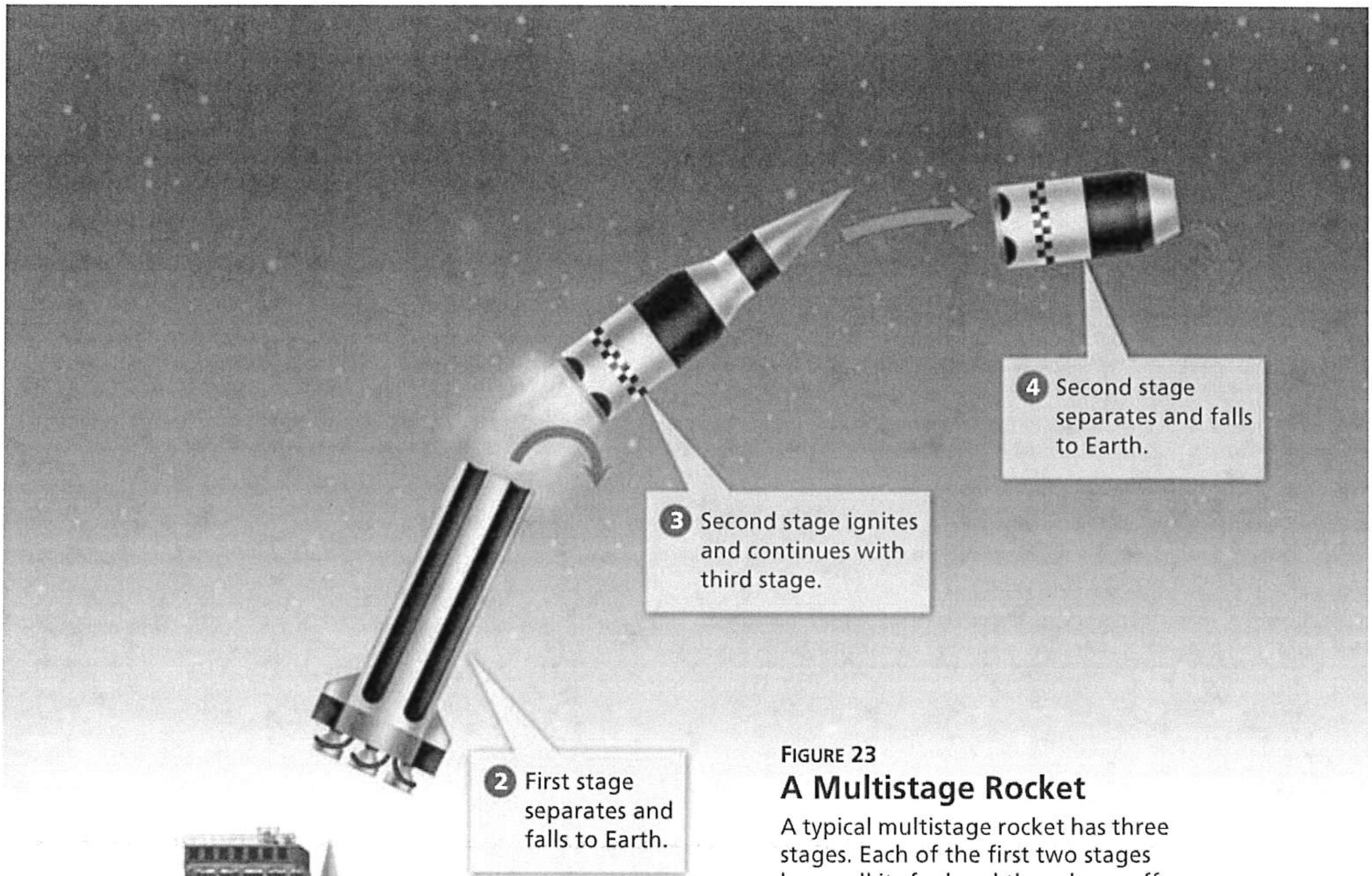


FIGURE 22
Rocket Action and Reaction
The force of gas propelled out of the back of a rocket (action) produces an opposing force (reaction) that propels the rocket forward.
Interpreting Diagrams *How can a rocket rise from the ground into space?*



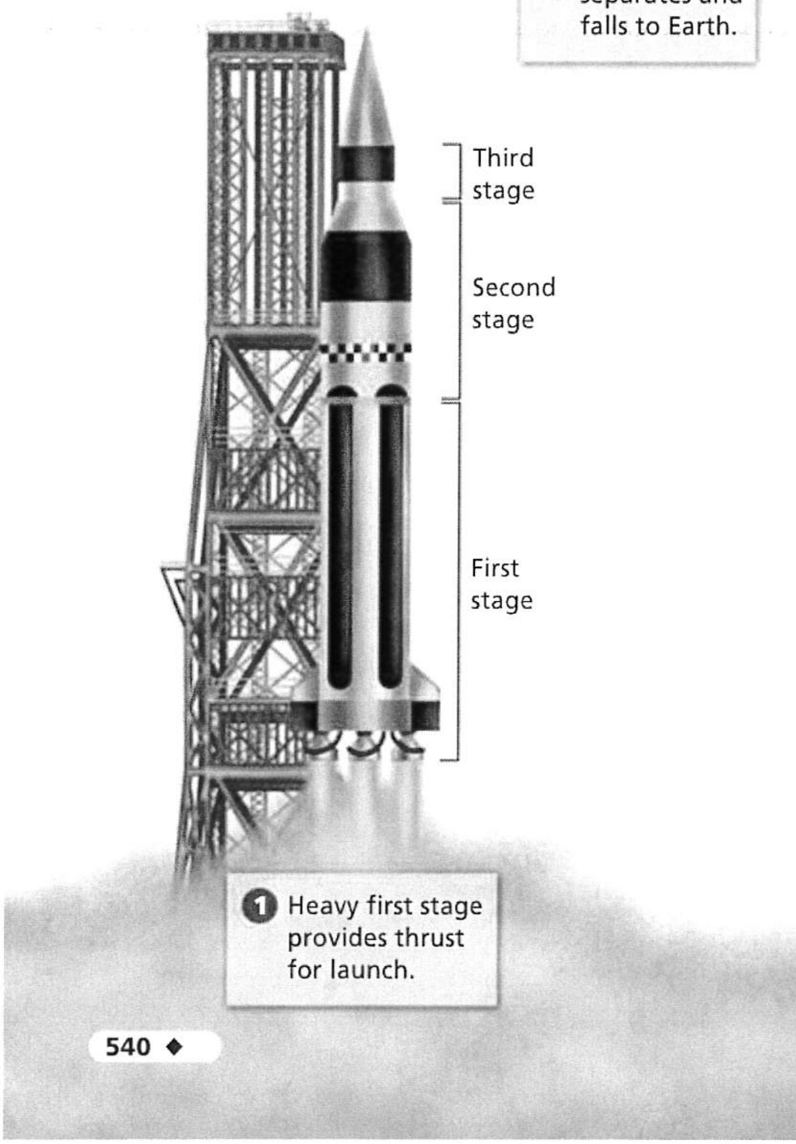


FIGURE 23

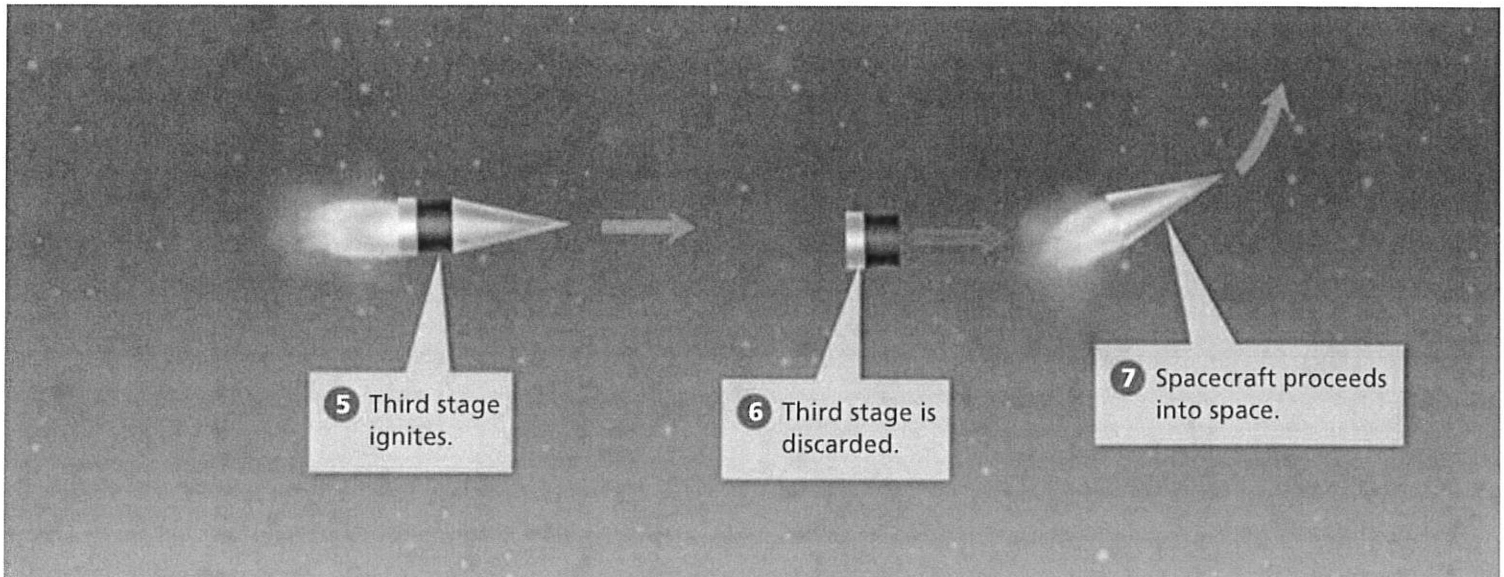
A Multistage Rocket

A typical multistage rocket has three stages. Each of the first two stages burns all its fuel and then drops off. The next stage then takes over. Interpreting Diagrams *Which part of the rocket reaches the rocket's final destination?*

Multistage Rockets

A rocket can carry only so much fuel. As the fuel in a rocket burns, its fuel chambers begin to empty. Even though much of the rocket is empty, the whole rocket must still be pushed upward by the remaining fuel. But what if the empty part of the rocket could be thrown off? Then the remaining fuel wouldn't have to push a partially empty rocket. This is the idea behind multistage rockets.

Konstantin Tsiolkovsky proposed the idea of multistage rockets in 1903. **The main advantage of a multistage rocket is that the total weight of the rocket is greatly reduced as the rocket rises.**



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In a multistage rocket, smaller rockets, or stages, are placed one on top of the other and then fired in succession. Figure 23 shows how a multistage rocket works. As each stage of the rocket uses up its fuel, the empty fuel container falls away. The next stage then ignites and continues powering the rocket toward its destination. At the end, there is just a single stage left, the very top of the rocket.

In the 1960s, the development of powerful multistage rockets such as the *Saturn V* made it possible to send spacecraft to the moon and the solar system beyond. The mighty *Saturn V* rocket stood 111 meters tall—higher than the length of a football field. It was by far the most powerful rocket ever built. Today, multistage rockets are used to launch a wide variety of satellites and space probes.

Reading Checkpoint: **What is a multistage rocket?**

The Race for Space

In the 1950s, the United States and the Soviet Union began to compete in the exploration of space. At that time, the Soviet Union was the greatest rival to the United States in politics and military power. The tensions between the two countries were so high that they were said to be in a "cold war." These tensions increased in 1957 when the Soviets launched a satellite, *Sputnik I,* into orbit. The United States responded by speeding up its own space program. **The rivalry between the United States and the Soviet Union over the exploration of space was known as the "space race."**

FIGURE 24
John Glenn
Friendship 7 lifted off from Cape Canaveral, Florida, in February 1962. It carried astronaut John Glenn, the first American to orbit Earth. The closeup photo shows Glenn climbing into the *Friendship 7* space capsule.
Observing *Where on the rocket was the space capsule located?*

The First Artificial Satellites A **satellite** is an object that revolves around another object in space. The moon is a natural satellite of Earth. A spacecraft orbiting Earth is an artificial satellite. *Sputnik I* was the first artificial satellite. This success by the Soviets caused great alarm in the United States.

The United States responded in early 1958 by launching its own satellite, *Explorer 1,* into orbit. Over the next few years, both the United States and the Soviet Union placed many more satellites into orbit around Earth.

Later in 1958, the United States established a government agency in charge of its space program, called the National Aeronautics and Space Administration (NASA). NASA brought together the talents of many scientists and engineers who worked together to solve the many difficult technical problems of space flight.

Humans in Space In 1961 the space race heated up even more when the Soviets launched the first human into space. Yuri Gagarin flew one orbit around Earth aboard *Vostok 1.* Less than a month later, astronaut Alan Shepard became the first American in space. His tiny spacecraft, called *Freedom 7,* was part of the U.S. Mercury space program. Other Soviet cosmonauts and American astronauts soon followed into space.

The first American to orbit Earth was John Glenn, who was launched into space in 1962 aboard *Friendship 7.* The spacecraft he traveled in was called a space capsule because it was like a small cap on the end of the rocket. The tiny capsule orbited Earth three times before returning to the surface.

Reading Checkpoint **Who was the first American in space?**

Missions to the Moon

"I believe that this nation should commit itself to achieving the goal, before the decade is out, of landing a man on the moon and returning him safely to Earth." With these words from a May 1961 speech, President John F. Kennedy launched an enormous program of space exploration and scientific research. **The American effort to land astronauts on the moon was named the Apollo program.**

Exploring the Moon Between 1964 and 1972, the United States and the Soviet Union sent many unpiloted spacecraft to explore the moon. When a U.S. spacecraft called *Surveyor* landed on the moon, it didn't sink into the surface. This proved that the moon had a solid surface. Next, scientists searched for a suitable place to land humans on the moon.

The Moon Landings In July 1969, three American astronauts circled the moon aboard *Apollo 11*. Once in orbit, Neil Armstrong and Buzz Aldrin entered a tiny spacecraft called *Eagle*. On July 20, the *Eagle* descended toward a flat area on the moon's surface called the Sea of Tranquility. When Armstrong radioed that the *Eagle* had landed, cheers rang out at the NASA Space Center in Houston. A few hours later, Armstrong and Aldrin left the *Eagle* to explore the moon. When Armstrong first set foot on the surface, he said, "That's one small step for man, one giant leap for mankind." Armstrong meant to say, "That's one small step for *a* man," meaning himself, but in his excitement he never said the "a."

Lab zone Skills Activity

Calculating

If you went to the moon, your weight would be about one sixth of your weight on Earth. Recall that in SI, weight is measured in newtons (1 lb ≈ 4.5 N). To find the approximate weight of an object on the moon, divide its weight on Earth by six.

An astronaut weighs 667 N on Earth. She wears a spacesuit and equipment that weigh 636 N on Earth. What is the astronaut's total weight on the moon?

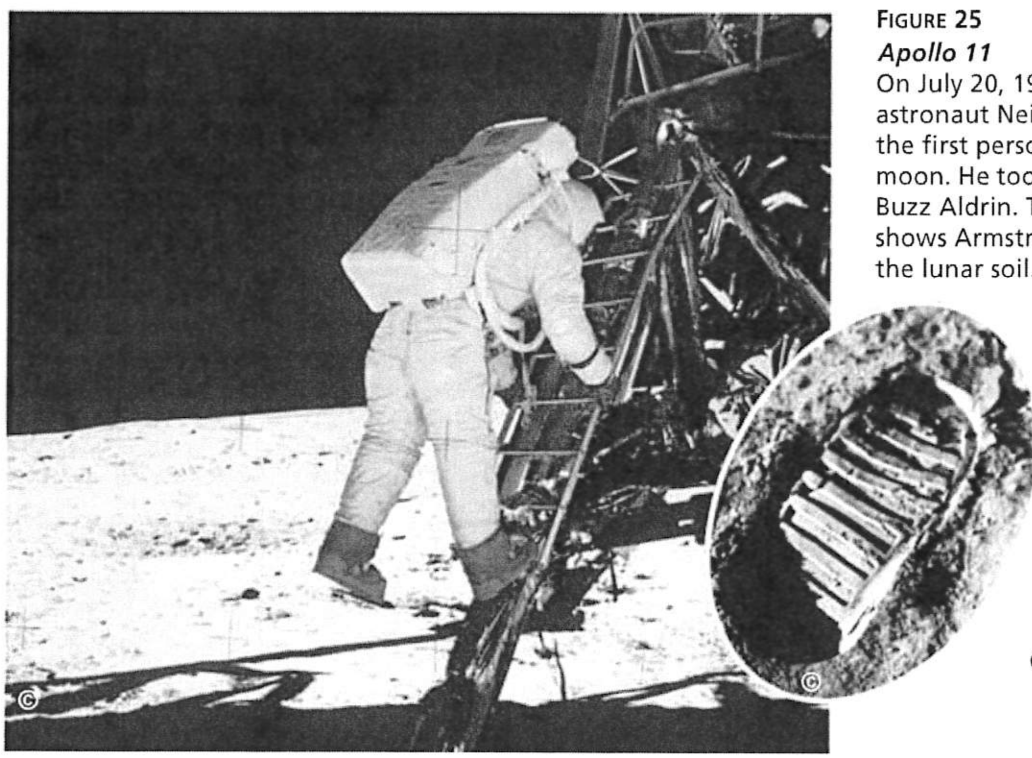


FIGURE 25
Apollo 11
On July 20, 1969, *Apollo 11* astronaut Neil Armstrong became the first person to walk on the moon. He took this photograph of Buzz Aldrin. The inset photo shows Armstrong's footprint on the lunar soil.

Exploring Space Today

After the great success of the moon landings, the question for space exploration was, "What comes next?" Scientists and public officials decided to build space shuttles and space stations where astronauts can live and work. They also sent space probes to explore the rest of the solar system.

Space Shuttles Before 1983, spacecraft could be used only once. In contrast, a space shuttle is like an airplane—it can fly, land, and then fly again. A **space shuttle** is a spacecraft that can carry a crew into space, return to Earth, and then be reused for the same purpose. A shuttle includes large rockets that launch it into orbit and then fall away. At the end of a mission, a shuttle returns to Earth by landing like an airplane. **NASA has used space shuttles to perform many important tasks. These include taking satellites into orbit, repairing damaged satellites, and carrying astronauts and equipment to and from space stations.**

Space Stations A **space station** is a large artificial satellite on which people can live and work for long periods. **A space station provides a place where long-term observations and experiments can be carried out in space.** In the 1970s and 1980s, both the United States and the Soviet Union placed space stations in orbit.

In the 1980s, the United States and 15 other countries began planning the construction of the International Space Station. The first module, or section, of the station was placed into orbit in 1998. Since then, many other modules have been added. On board, astronauts and scientists from many countries are carrying out experiments in various fields of science.

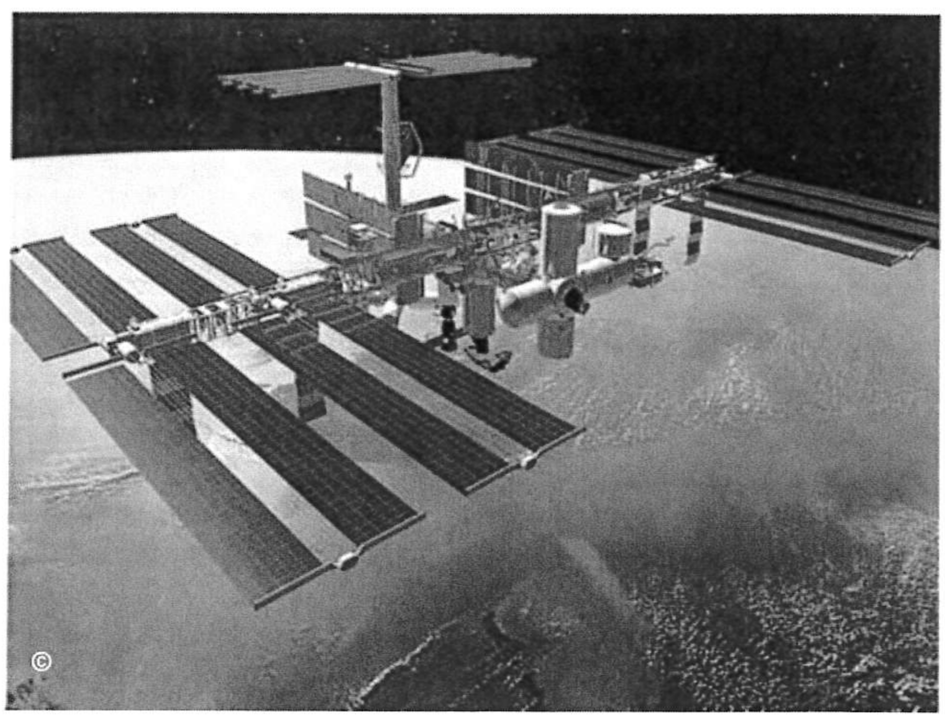


FIGURE 26
International Space Station
This is an artist's view of how the International Space Station will look when completed. It will be longer than a football field, and the living space will be about as large as the inside of the largest passenger jet.

Space Probes People have not yet traveled farther than the moon. Yet, scientists have gathered great amounts of information about other parts of the solar system. This data was collected by space probes. A **space probe** is a spacecraft that carries scientific instruments that can collect data, but has no human crew. **Space probes gather data about distant parts of the solar system where humans cannot easily travel.**

Each space probe is designed for a specific mission. Some probes are designed to land on a certain planet. Other probes are designed to fly by and collect data about more than one planet. Thus, each probe is unique. Still, probes have some features in common. Each probe has a power system to produce electricity, a communication system to send and receive signals, and scientific instruments to collect data or perform experiments.

The scientific instruments that a probe contains depend on the probe's mission. Some probes are equipped to photograph and analyze the atmosphere of a planet. Other probes are equipped to land on a planet and analyze the materials on its surface. Some probes have small robots called **rovers** that move around on the surface. A rover typically has instruments that collect and analyze soil and rock samples.

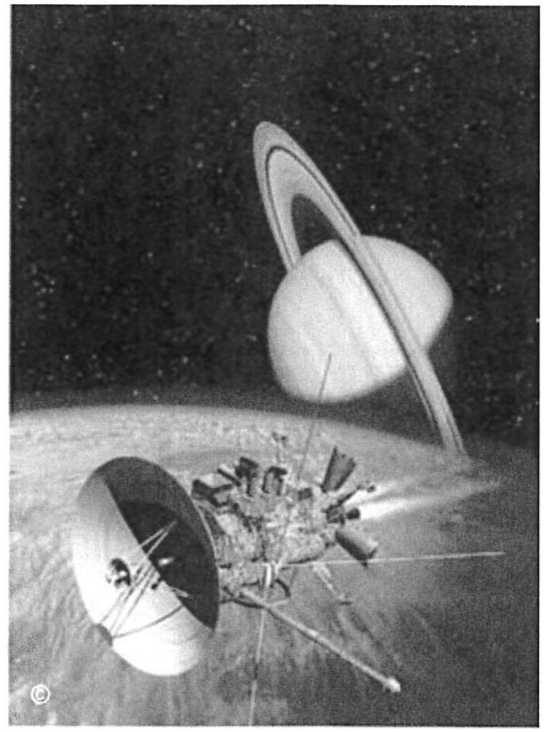


FIGURE 27
Cassini
The space probe *Cassini* is exploring Saturn's moons. It launched a smaller probe, *Huygens,* to explore Titan, Saturn's largest moon.

Reading Checkpoint What is a rover?

Section 5 Assessment

Target Reading Skill **Building Vocabulary** Use your definitions to help answer the questions below.

Reviewing Key Concepts

HINT HINT HINT
1. a. **Explaining** What is a rocket?
   b. **Explaining** How do rockets create thrust?
   c. **Interpreting Diagrams** Use Figure 22 to explain how a rocket moves forward.

HINT HINT
2. a. **Describing** Describe how a multistage rocket works.
   b. **Comparing and Contrasting** What is the main advantage of a multistage rocket compared to a single-stage rocket?

HINT HINT
3. a. **Summarizing** What was the "space race"?
   b. **Sequencing** Place these events in the correct sequence: first humans on the moon, *Sputnik I,* first American in space, John Glenn orbits Earth, NASA formed, Yuri Gagarin orbits Earth.

4. a. **Describing** What is the space shuttle? What is its main advantage? HINT
   b. **Defining** What is a space station? A space probe? HINT
   c. **Comparing and Contrasting** What are the roles of space shuttles, space stations, and probes in the space program? HINT

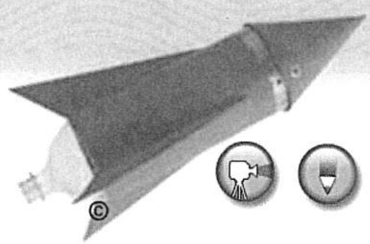
Lab zone At-Home Activity

Landmarks in Space Flight Interview someone who remembers the early space programs. Prepare your questions in advance, such as: What did you think when you heard that *Sputnik* was in orbit? How did you feel when the first Americans went into space? Did you watch any of the space flights on TV? You may want to record your interview and then write it out later.

Lab zone **Technology Lab**

• Tech & Design •

Design and Build a Water Rocket



Problem

Can you design and build a rocket propelled by water and compressed air?

Design Skills

observing, evaluating the design, redesigning

Materials

- large round balloon • tap water
- graduated cylinder • modeling clay
- 50 paper clips in a plastic bag
- empty 2-liter soda bottle • poster board
- scissors • hot glue gun or tape
- bucket, 5 gallon • stopwatch
- rocket launcher and tire pump (one per class)

Procedure

PART 1 Research and Investigate

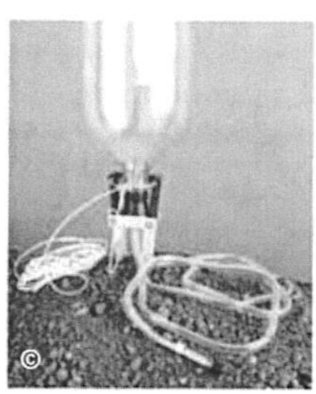
1. Copy the data table onto a separate sheet of paper.

Data Table	
Volume of Water (mL)	Motion of Balloon
No water	

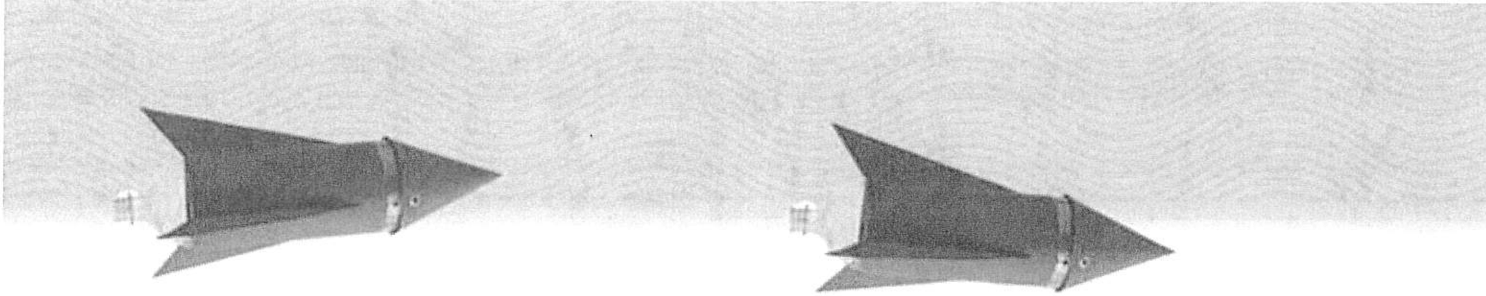
2. In an outdoor area approved by your teacher, blow up a large round balloon. Hold the balloon so the opening is pointing down. Release the balloon and observe what occurs. ***CAUTION:*** *If you are allergic to latex, do not handle the balloon.*
3. Measure 50 mL of water with a graduated cylinder. Pour the water into the balloon. Blow it up to about the same size as the balloon in Step 2. Hold the opening down and release the balloon. Observe what happens.
4. Repeat Step 3 twice, varying the amount of water each time. Record your observations in the data table.

PART 2 Design and Build

5. You and a partner will design and build a water rocket using the materials provided or approved by your teacher. Your rocket must
   - be made from an empty 2-liter soda bottle
   - have fins and a removable nose cone
   - carry a load of 50 paper clips
   - use air only or a mixture of air and water as a propulsion system
   - be launched on the class rocket launcher
   - remain in the air for at least 5 seconds
6. Begin by thinking about how your rocket will work and how you would like it to look. Sketch your design and make a list of materials that you will need.
7. Rockets often have a set of fins to stabilize them in flight. Consider the best shape for fins, and decide how many fins your rocket needs. Use poster board to make your fins.
8. Decide how to safely and securely carry a load of 50 paper clips in your rocket.
9. Based on what you learned in Part 1, decide how much, if any, water to pour into your rocket.
10. After you obtain your teacher's approval, build your rocket.



◀ **Rocket launcher**



PART 3 Evaluate and Redesign

11. Test your rocket by launching it on the rocket launcher provided by your teacher. **CAUTION:** *Make sure that the rocket is launched vertically in a safe, open area that is at least 30 m across. All observers should wear goggles and stay at least 8–10 m away from the rocket launcher. The rocket should be pumped to a pressure of no more than 50 pounds per square inch.*
12. Use a stopwatch to determine your rocket's flight time (how long it stays in the air).
13. Record in a data table the results of your own launch and your classmates' launches.
14. Compare your design and results with those of your classmates.

Analyze and Conclude

1. **Observing** What did you observe about the motion of the balloon as more and more water was added?
2. **Drawing Conclusions** What purpose did adding water to the balloon serve?
3. **Designing a Solution** How did your results in Part 1 affect your decision about how much water, if any, to add to your rocket?
4. **Evaluating the Design** Did your rocket meet all the criteria listed in Step 5? Explain.
5. **Evaluating the Design** How did your rocket design compare to the rockets built by your classmates? Which rocket had the greatest flight time? What design features resulted in the most successful launches?
6. **Redesigning** Based on your launch results and your response to Question 5, explain how you could improve your rocket. How do you think these changes would help your rocket's performance?
7. **Evaluating the Impact on Society** Explain how an understanding of rocket propulsion has made space travel possible.

Communicate

Write a paragraph that describes how you designed and built your rocket. Explain how it worked. Include a labeled sketch of your design.

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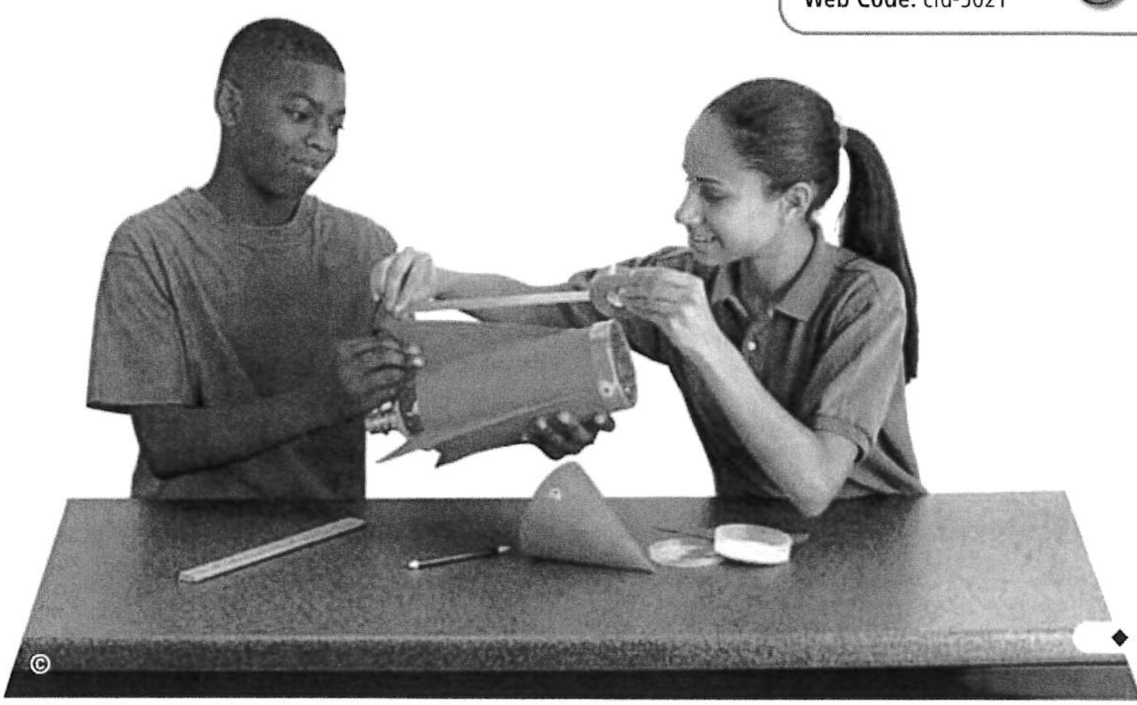


Chapter 15 Study Guide

The BIG Idea

Earth in space The motions of Earth and the moon and their position relative to the sun result in day and night, the seasons, phases of the moon, eclipses, and tides.

1 Earth in Space

Key Concepts

Earth moves through space in two major ways: rotation and revolution.

Earth has seasons because its axis is tilted as it revolves around the sun.

Key Terms

astronomy, axis, rotation, revolution, orbit, solstice, equinox

2 Gravity and Motion

Key Concepts

The strength of the force of gravity between two objects depends on two factors: the masses of the objects and the distance between them.

Newton concluded that two factors—inertia and gravity—combine to keep Earth and the moon in their orbits.

Key Terms

- force
- gravity
- law of universal gravitation
- mass
- weight
- inertia
- Newton's first law of motion

3 Phases, Eclipses, and Tides

Key Concepts

The changing relative positions of the moon, Earth, and sun cause the phases of the moon, eclipses, and tides.

The phase of the moon you see depends on how much of the sunlit side of the moon faces Earth.

A solar eclipse occurs when the moon passes directly between Earth and the sun.

During a lunar eclipse, Earth blocks sunlight from reaching the moon.

Tides are caused mainly by differences in how much the moon's gravity pulls on Earth.

Key Terms

phases, eclipse, solar eclipse, umbra, penumbra, lunar eclipse, tide, spring tide, neap tide

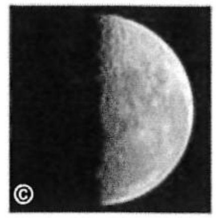
4 Earth's Moon

Key Concepts

Features on the moon's surface include maria, craters, and highlands.

The moon is dry and airless. Compared to Earth, the moon is small and has large variations in its surface temperature.

Scientists theorize that a planet-sized object collided with Earth to form the moon.



Key Terms

telescope, maria, craters, meteoroids

5 Traveling Into Space

Key Concepts

A rocket moves forward when gases shooting out the back of the rocket push it in the opposite direction.

The main advantage of a multistage rocket is that the total weight of the rocket is greatly reduced as the rocket rises.

The rivalry between the United States and the Soviet Union over the exploration of space was known as the "space race."

The American effort to land astronauts on the moon was named the Apollo program.

NASA has used space shuttles to perform many important tasks. These include taking satellites into orbit, repairing damaged satellites, and carrying astronauts and equipment to and from space stations.

A space station provides a place where long-term observations and experiments can be carried out in space.

Space probes gather data about distant parts of the solar system where humans cannot easily travel.

Key Terms

- rocket
- thrust
- velocity
- orbital velocity
- escape velocity
- satellite
- space shuttle
- space station
- space probe
- rover

Review and Assessment

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Organizing Information

Comparing and Contrasting Copy the graphic organizer onto a separate sheet of paper. Then complete it and add a title. (For more on Comparing and Contrasting, see the Skills Handbook.)

Astronaut	Year	Spacecraft	Accomplishment
Yuri Gagarin	1961	a. ___?___	First human in space
Alan Shepard	b. ___?___	*Freedom 7*	c. ___?___
d. ___?___	1962	*Friendship 7*	e. ___?___
Neil Armstrong	f. ___?___	g. ___?___	First human to walk on the moon

Reviewing Key Terms

Choose the letter of the best answer.

HINT
1. The movement of Earth around the sun once a year is called Earth's
   a. inertia.
   b. rotation.
   c. revolution.
   d. axis.

HINT
2. The tendency of an object to resist a change in motion is called
   a. gravity.
   b. inertia.
   c. force.
   d. the law of universal gravitation.

HINT
3. When Earth's shadow falls on the moon, the shadow causes a
   a. new moon.
   b. solar eclipse.
   c. full moon.
   d. lunar eclipse.

HINT
4. The craters on the moon were caused by
   a. tides.
   b. volcanoes.
   c. meteoroids.
   d. maria.

HINT
5. A device that expels gas in one direction to move in the opposite direction is a
   a. rocket.
   b. space probe.
   c. space station.
   d. rover.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

6. Earth's spinning on its axis is called <u>rotation</u>. HINT
7. The force that attracts all objects toward each other is called <u>inertia</u>. HINT
8. The tilt of Earth's axis as Earth revolves around the sun causes <u>eclipses</u>. HINT
9. The greatest difference between low and high tides occurs during a <u>neap</u> tide. HINT
10. A large artificial satellite on which people can live for long periods is a <u>space station</u>. HINT

Writing in Science

News Report Imagine that you are a reporter asked to write a story about the origin of the moon. Write an article explaining how the moon formed.

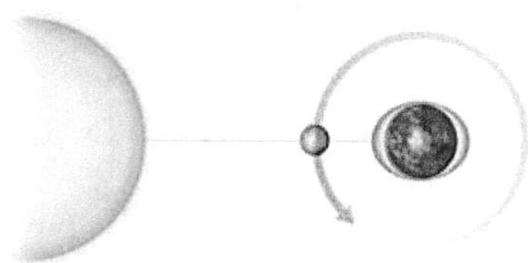
Discovery Channel School

Earth, Moon, and Sun
Video Preview
Video Field Trip
▶ Video Assessment

Review and Assessment

Checking Concepts

11. Explain how the length of the day and year are related to Earth's movement through space.
12. Suppose you moved two objects farther apart. How would this affect the force of gravity between those objects?
13. Explain Newton's first law of motion in your own words.
14. Why does the moon have phases?
15. Why do more people see a total lunar eclipse than a total solar eclipse?
16. Why is there a high tide on the side of Earth closest to the moon? On the side of Earth farthest from the moon?
17. Does the diagram below show a spring tide or a neap tide? How do you know?



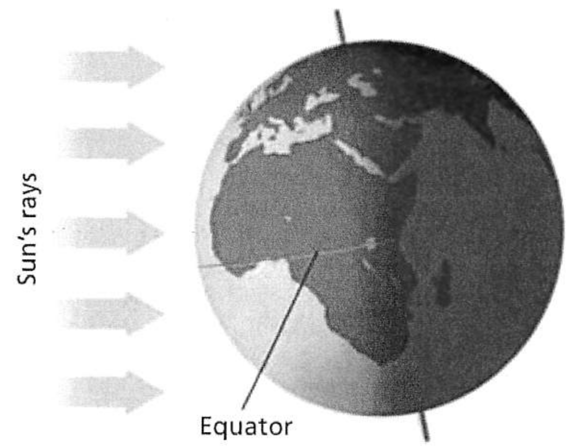
18. How did the invention of the telescope contribute to our knowledge of the moon's surface?
19. Why do temperatures vary so much on the moon?
20. Explain how scientists think the moon originated.

Thinking Critically

21. **Inferring** Mars's axis is tilted at about the same angle as Earth's axis. Do you think Mars has seasons? Explain your answer.
22. **Comparing and Contrasting** How are mass and weight different?
23. **Calculating** Suppose a person weighs 450 newtons (about 100 pounds) on Earth. How much would she weigh on the moon?
24. **Posing Questions** Suppose you were assigned to design a spacesuit for astronauts to wear on the moon. What characteristics of the moon would be important to consider in your design?
25. **Making Judgments** Do you think that the benefits of the Apollo program outweighed the program's costs? Explain.

Applying Skills

Use the illustration below to answer Questions 26–28.



26. **Interpreting Diagrams** On which hemisphere are the sun's rays falling most directly?
27. **Inferring** In the Northern Hemisphere, is it the summer solstice, winter solstice, or one of the equinoxes? How do you know?
28. **Predicting** Six months after this illustration, Earth will have revolved halfway around the sun. Draw a diagram that shows which end of Earth's axis will be tilted toward the sun.

Lab zone Chapter Project

Performance Assessment Present your observation log, map, and drawings of the moon. Some ways to graph your data include time of moonrise for each date; how often you saw the moon in each direction; or how often you saw the moon at a specific time. Display your graphs. Discuss any patterns that you discovered.

Preparing for the CRCT

Test-Taking Tip

Interpreting a Diagram

When answering questions about diagrams, examine the diagram carefully, including labels. For example, the numbers on the diagram shown above Question 5 indicate the locations of the moon in its orbit around Earth. Study the diagram and answer the sample question below.

Sample Question

When the moon is in location 3, a person standing on Earth at night would see

A a full moon.
B a crescent moon.
C a quarter moon.
D a new moon.

Answer

The correct answer is **A.** The diagram shows that when the moon is at location 3, Earth is between the moon and the sun. Therefore, the sun lights the entire side of the moon facing Earth.

Choose the letter of the best answer.

1. You observe a thin crescent moon in the western sky during the early evening. About two weeks later, a full moon is visible in the eastern sky during the early evening. Which conclusion is best supported by these observations?

A The moon revolves around Earth.
B The moon rotates on its axis.
C Earth revolves around the sun.
D Earth's axis is tilted relative to the moon.

S6E2.a

2. Only one side of the moon is visible from Earth because

A the moon does not rotate on its axis.
B the moon does not revolve around Earth.
C the moon rotates faster than it revolves.
D the moon revolves once and rotates once in the same period of time. **S6E1.d**

3. What type of eclipse occurs when Earth's umbra covers the moon?

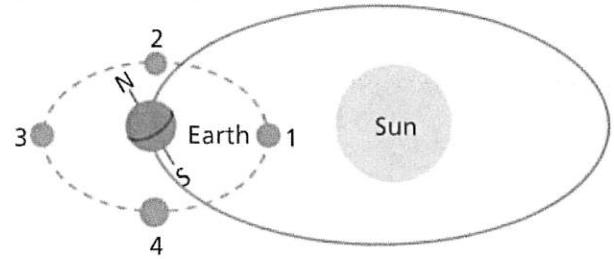
A a partial solar eclipse
B a total solar eclipse
C a partial lunar eclipse
D a total lunar eclipse **S6E2.b**

4. What force must a rocket overcome to be launched into space?

A thrust **B** gravity
C orbital velocity **D** escape velocity

S6E1.e

The diagram below shows the relative positions of the sun, moon, and Earth. The numbers indicate specific locations of the moon in its orbit. Use the diagram to answer Questions 5 and 6.



5. Which of the following can occur when the moon is at location 1?

A only a lunar eclipse
B only a solar eclipse
C both a solar and a lunar eclipse
D neither a solar nor a lunar eclipse **S6E2.b**

6. When the moon is at location 2, at most coastal locations there would be

A only one high tide each day.
B only one low tide each day.
C two high tides and two low tides each day, with the most difference between high and low tide.
D two high tides and two low tides each day, with the least difference between high and low tide.

S6E1.e

Constructed Response

7. The sun rises on the east coast of the United States before it rises on the west coast of the United States. Explain why this happens.

S6E1.d