Patterns in the Solar System

This shadow on Earth was cast during a solar eclipse in 1999. During a solar eclipse, the moon moves directly between Earth and the sun, blocking the light from the sun and casting a shadow on Earth.

On Earth we experience many different patterns caused by Earth's position relative to the sun and moon. Some of these patterns are visible in the sky. Others we feel on our skin on a daily basis. In this unit, you will discover the effects of the Earth-sun-moon system on your daily life.

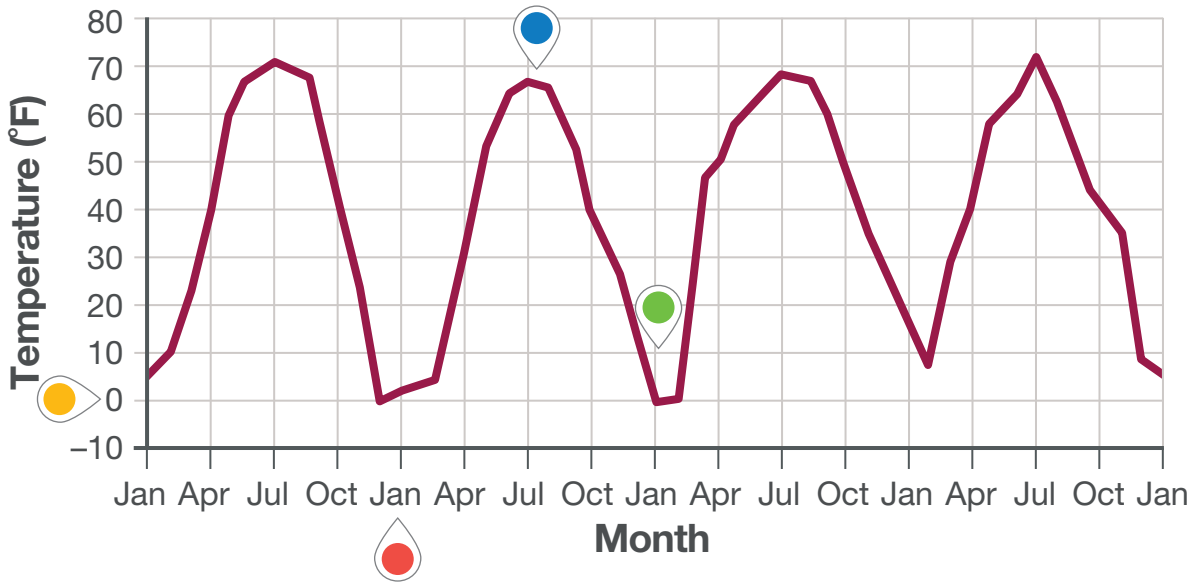
Why It Matters

Here are some questions to consider as you work through the unit. Can you answer any of the questions now? Revisit these questions at the end of the unit to apply what you discovered.

Questions	Notes
What causes seasons?	
Why does the moon's shape and brightness appear to change?	
What causes eclipses?	
How is a new moon the same as or different from a total lunar eclipse?	
How does the sun affect weather and climate?	
How does the Earth-sun-moon system affect life on Earth?	

Unit Starter: Identifying Patterns in Data

This graph represents typical average monthly temperatures for a location at about 45° north latitude in North America. Review these data and answer the following questions.



This line represents 0 °F.

Notice how many times January appears on the *x*-axis.

This peak occurs during one summer.

This valley occurs during one winter.

1. This graph includes data for one / two / four / five year(s) because the data show one / two / four / five peak(s), which correspond(s) to summer / winter.

2. Based on the graph, it can be predicted that next year in this location the average temperature in January will be around −10 °F / 5 °F / 15 °F. And that the average temperature in July will be around 50 °F / 60 °F / 70 °F.

Go online to download the Unit Project Worksheet to help you plan your project.

Unit Project

Investigate Eclipses in Your Area

When will the next solar or lunar eclipse happen in your area? Will it be a full or partial eclipse? Research information about an upcoming lunar or solar eclipse to plan an eclipse-viewing event for your community.

LESSON 1

The Earth-Sun-Moon System

The moon sometimes appears orange as it rises. When the moon is near the horizon, the bending of light in the atmosphere can also distort the moon's shape.

By the end of this lesson . . .

you will be able to explain patterns of the sun, moon, and stars as seen from Earth, monthly patterns of the moon, and eclipses.

Go online to view the digital version of the Hands-On Lab for this lesson and to download additional lab resources.

CAN YOU EXPLAIN IT?

Why can we see the moon at night and also during the day?

At night, the moon is the biggest, brightest object in the sky. If you look closely, you may also be able to see the moon during the day when the sun is also out.

1. How is the moon similar and different in the two photos?

2. Do you think the shape of the moon would appear to be different if photos were taken a few hours later than the photos shown here? If yes, how would its appearance change?

3. Do you think the shape of the moon would appear to be different if photos were taken one week later than the photos shown here? If yes, how would its appearance change?

EVIDENCE NOTEBOOK As you explore the lesson, gather evidence to help explain why we see the moon at night and also during the day.

Analyzing Daily Patterns in the Sky

You might think of day as the time when you are in school and night as the time when you are home with your family. Or you may think of day as the time when you are awake and night as the time when you are asleep. But the scientific meanings of day and night do not depend on our daily activities.

4. Look at the photo of the sun and Earth. Why is part of Earth light and part of Earth dark?

Although the sun is far away in space, it lights up Earth.

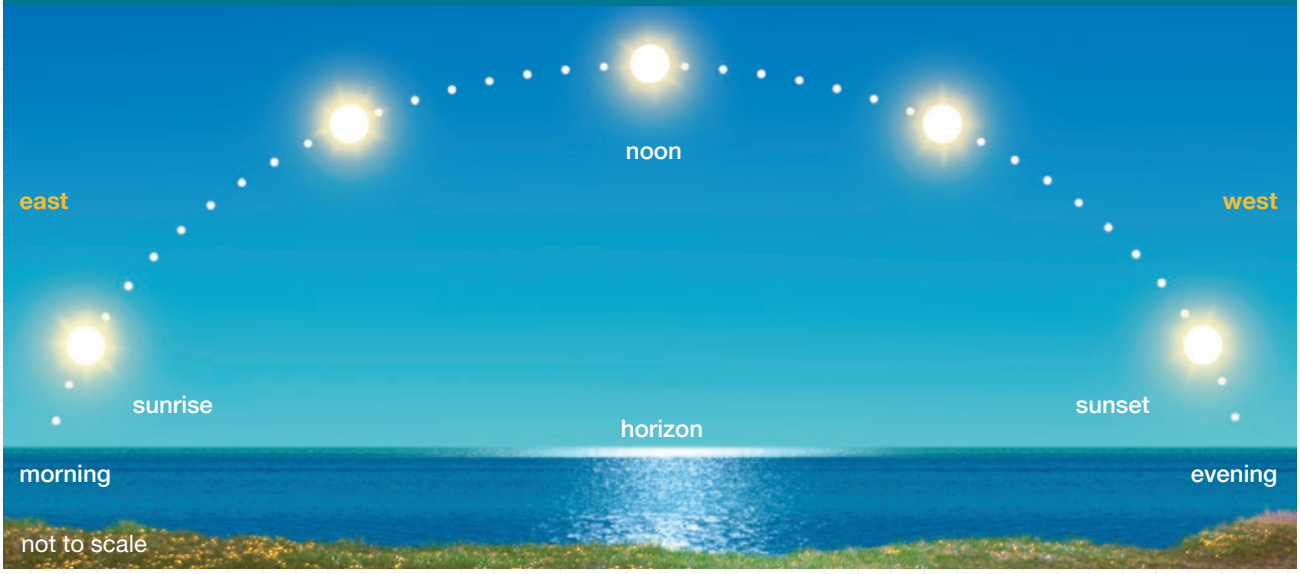
The Sun's Path in the Sky

The sun is always giving off light that reaches Earth. Yet, you experience a daily cycle of light and darkness. The period of time when the sun is directly shining on an area of Earth is daytime. Nighttime is when the sun is not shining directly on an area. The length of daytime and nighttime varies depending on where you are on Earth and the time of year. However, the periods of daytime and nighttime always add up to 24 hours a day on Earth.

During the day, the sun appears to travel across the sky. If you wake up early enough, you can watch the sun rise on the eastern horizon. In the evening, you look to the west to see the sun set on the western horizon. The sun always follows an arc from east to west across the sky. It is highest at noon, but that does not mean it is directly overhead. In the Northern Hemisphere, you can see the sun follow an arc through the southern half of the sky.

Explore ONLINE!

The Daily Path of the Sun



The Stars' Path in the Sky

Stars shine day and night, but you can only see them after the sun sets. Much like the sun during the day, the stars appear to move east to west during the night. Groups of stars in specific patterns, such as Orion, are called *constellations*. They move through the sky during the night, but they do not change shape or size because the distance between any two stars stays the same. That means you always look for the same pattern of stars to find Orion.

5. Why do you think we see the stars at nighttime and the sun during daytime?

The streaks in this time-lapse photo are made as stars move across the sky during the night.

The Moon's Path in the Sky

After sunset, you might look east for the rising moon. But it is not there. Why is it not there? The moon always rises along the eastern horizon, appears to travel across the sky, and sets along the western horizon a few hours later. But the moon rises at different times during the month, in a regular pattern. Sometimes you can see it in the daytime and sometimes at night. When there are no clouds but you cannot see the moon, it is somewhere on the far side of Earth, below your horizon.

6. On one clear night, the moon is high in the sky when the sun sets. It is no longer visible after 11 p.m. Which describes the motion of the moon on this day? Circle all that apply.

A. The moon traveled from east to west.

B. The moon rose after the sun set.

C. The moon set before 11 p.m.

D. The moon rose during the daytime.

This time-lapse photo shows the moon rising. The sun, stars, and the moon move from east to west across the sky.

Hands-On Lab

Model the Apparent Motion of the Sun

You will model the Earth-sun system to develop an explanation for night and day and the apparent motion of the sun in the sky.

MATERIALS

- ball, styrene, on a stick
- lamp with removable shade
- markers
- tape

Procedure

STEP 1 **Act** Work with a partner. Choose who will play the part of the sun and who will play Earth. Write *sun* on one piece of paper and *Earth* on another, and tape the labels to each actor. Stand facing each other. Discuss how the motion of the sun or Earth can result in periods of daytime and nighttime on Earth.

STEP 2 **Act** If you are the actor playing Earth, stand facing the sun. Slowly turn in a circle toward your left. Keep your head in line with your body. Your head is representing Earth. Say *night* when you can no longer see the sun and say *day* when you first see the sun again. Take turns being Earth and the sun.
NOTE: Turning toward the left models Earth's counterclockwise movement as you are looking down at the North Pole.

STEP 3 Now use the lamp and foam ball to make a model that explains day and night. Write *Earth* on the tape and put the label around the center of the ball. Hold the ball in front of the lamp and turn the stick toward the left.

Analysis

STEP 4 When I was playing Earth and could see the sun, my face represented the part of Earth that was experiencing day / night.

When I could not see the sun, it was day / night.

When I first saw the sun, it was sunrise / sunset.

When I last saw the sun, it was sunrise / sunset.

It was morning / noon / midnight when I was directly facing the sun.

STEP 5 Think about a compass. If you are facing south, your right shoulder is west and your left shoulder is east. In what direction did you first see the sun in the morning? As you turned, in what direction did the sun seem to move throughout the day?

STEP 6 Based on your observations, why does the sun appear to move across the sky?

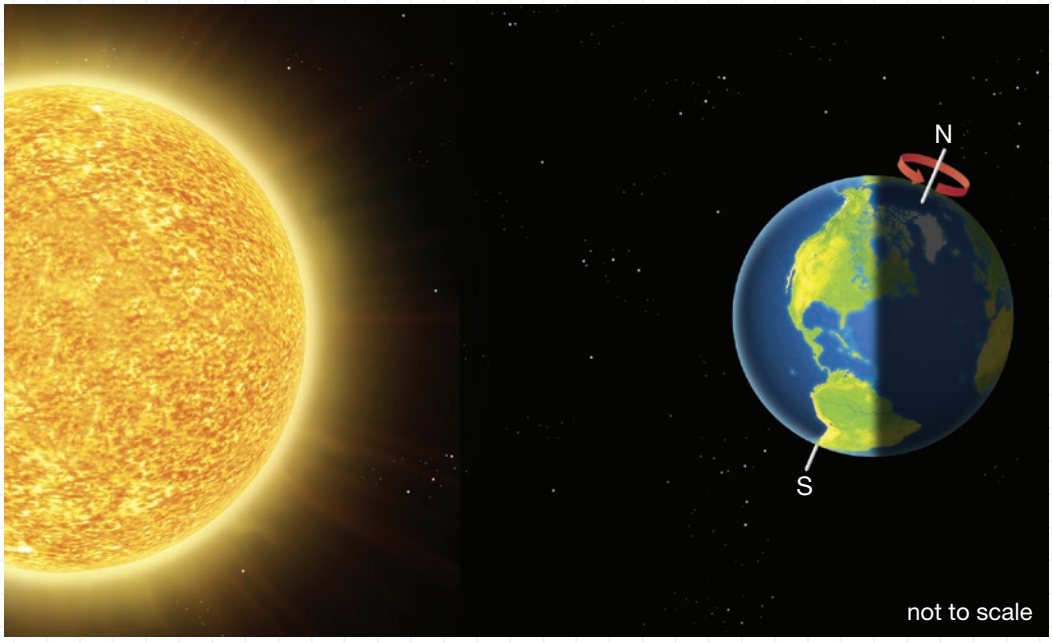
Earth's Rotation

When you spin around in one place, you are modeling Earth's rotation. Earth rotates around an imaginary axis running through the North and South Poles. Since you are on Earth, you do not feel it turning, but you experience the rotation in other ways.

Earth's Rotation Explains the Path of the Sun

The apparent motion of the sun, including daytime and nighttime, is caused by Earth's rotation. A day on Earth is 24 hours because Earth completes one full rotation during that time. As Earth spins, different parts of Earth face the sun. It is daytime when an area faces toward the sun and nighttime when it faces away from the sun.

If you were looking down on Earth from the North Pole, it would rotate counterclockwise. Therefore, on Earth, the eastern horizon turns toward the sun first in the morning. Throughout the day, the sun appears to move from east to west as Earth rotates. The sun sets below the western horizon because that is the last area to receive sunlight. The way the sun appears to move always follows the same pattern, rising in the east, moving in an arc across the sky from east to west, and setting in the west.



Different parts of Earth face the sun during a 24-hour day because Earth rotates.

7. How does the daily cycle of daytime and nighttime depend on Earth's rotation?

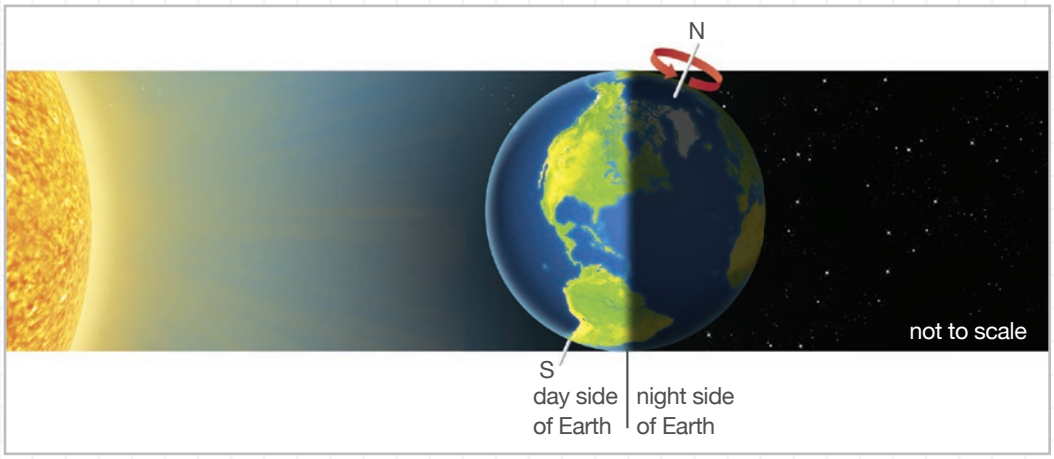
A. The sun rises in the west and sets in the east because Earth rotates west to east.

B. It is morning on the part of Earth that is turning into the sun and evening on the part that is turning away from the sun.

C. The Northern Hemisphere experiences daytime while the Southern Hemisphere experiences nighttime because Earth rotates around its axis.

Earth's Rotation Explains the Path of the Stars

During the daytime, the sun is so bright that you cannot see other stars. Look at the diagram. The area of Earth that is experiencing nighttime faces away from the sun, so you are able to see the stars. As with the sun, the stars appear to move from east to west as Earth rotates. Throughout the night, different stars rise and set. The stars rise and become visible over the horizon as Earth rotates. For example, the constellation Orion comes into view in the eastern night sky around 9 p.m. in late November in the Northern Hemisphere. As Earth spins, Orion appears to move westward. Orion is at its highest point in the sky around midnight. Then Orion continues toward the west, where it sets.

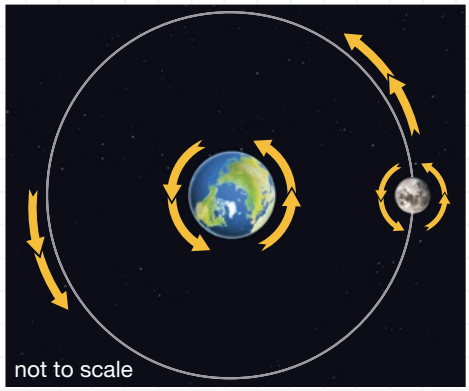


Stars are visible at night on the side of Earth facing away from the sun.

8. Stars appear to move because the Earth spins toward the east / west. People who live in the eastern United States see the same / different stars in the night sky as those who live in the western United States.

Earth's Rotation Explains the Path of the Moon

The moon also appears to move east to west in the sky as Earth rotates. However, the motion of the moon is a bit different than the motion of the sun and the stars because the moon orbits Earth. An **orbit** is the path that a body follows as it travels around another body in space. The moon circles around Earth in the same direction that Earth rotates—counterclockwise when looking down on the North Pole. The moon completes an orbit in 27.3 days, or about one month. Earth rotates much faster than the moon circles Earth. So, the moon's daily pattern of motion from east to west is mainly caused by Earth's rotation. The moon's orbit causes it to rise and set at different times of the day. The moon also appears to slowly move eastward with respect to the background of stars.



The moon orbits Earth in the same direction that Earth rotates.

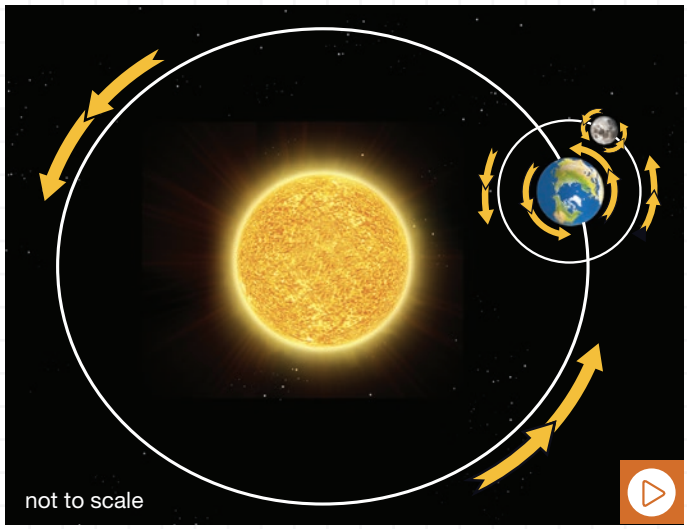
9. Discuss Why are the patterns of movement of the sun, stars, and the moon across Earth's sky similar?

EVIDENCE NOTEBOOK

10. How does the orbit of the moon help to explain why we can see the moon in the sky both during the day and at night? Record your evidence.

The Earth and Moon Move around the Sun

In addition to the fact that the stars appear to move across the sky every night, their rising times change throughout the course of the year. Stars seen from one location during one time of year may not be seen from that same location at a different time of year.



Earth completes one orbit around the sun in 365.25 days. The moon travels with Earth around the sun because it orbits Earth.

11. Use the Earth-sun-moon model. Which statements are true about the stars? Circle all that apply.

A. On a given day, you will only be able to see the stars that are in the opposite direction of the sun.

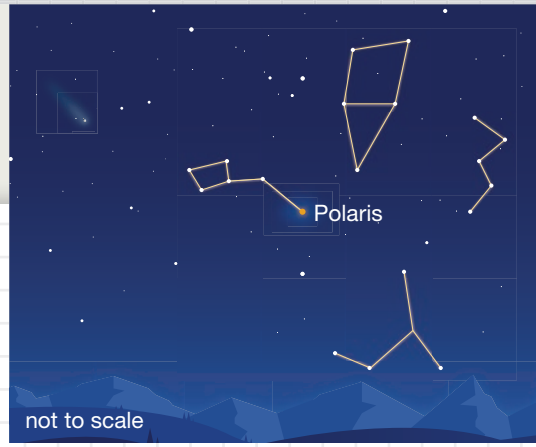
B. At opposite sides of Earth's orbit around the sun, a person at the same location on Earth would see the same stars in the night sky.

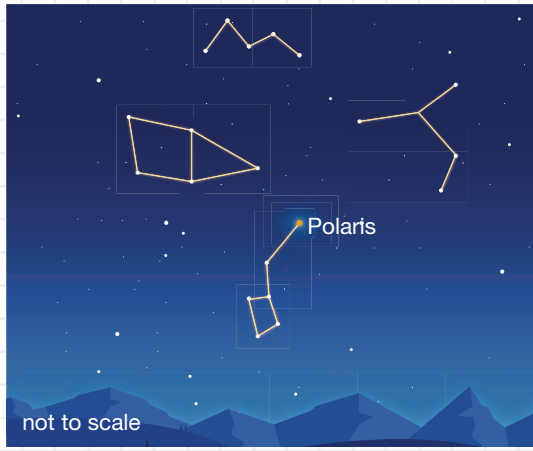
C. The different rising times of constellations in the night sky during the year provide evidence that Earth moves around the sun.

Earth orbits the sun and the moon orbits Earth. Earth brings the moon with it as it moves around the sun. One year is the time it takes for Earth to complete one revolution around the sun. In that time, Earth rotates on its axis 365.25 times, so there are 365.25 days in a year. And the moon goes through a full cycle of phases about 12 times in a year.

Do the Math
Analyze Star Motion

12. Polaris is also called the *North Star* because Earth's North Pole points toward it. As Earth rotates, other stars seem to spin around Polaris in a counterclockwise direction. In one day, the stars will make one complete circle (360°) around Polaris. Compare the positions of the constellations in the two diagrams. Calculate how many hours have passed between the first and second diagrams.





Analyzing Moon Phases

The moon is the brightest body in the night sky as seen from Earth. But it does not emit any light of its own. The light we see from the moon is light reflected from the sun. The sun always lights half of the moon, and the other half is always dark. As the moon rotates, the areas that are lit by the sun change. Light from the sun falls on Earth in the same way.

13. Discuss Does the fraction of the moon that receives sunlight ever change? Explain your reasoning.

The half of the moon facing the sun is lit. The other half is dark because the moon itself is not a source of light. It only reflects light from the sun.

Phases of the Moon

You know that the moon appears to move through the sky. It also appears to change shape. It changes from no moon at all, to a small crescent, to a full disc, and back to no moon. These changes are phases of the moon. A **phase** is the change in the sunlit area of one celestial body, such as the moon, as seen from another celestial body, such as Earth. You can predict the phase of the moon on any day because the phases happen in a regular pattern.

The phase that the moon is in on a given day is the same during the day and night, and then is just a little different the next day and night. The side of the moon that is lit is always the side closest to where the sun set. Each night as the crescent grows larger, the moon is seen higher in the sky. As the moon phase continues to grow, the moon is seen farther and farther away from where the sun set. When the moon is full, it rises at just about the time of sunset.

The moon goes through phases during which it appears to change shape.

14. Why does the moon appear to change shape throughout each month?

- **A.** The fraction of the moon that is lit by the sun changes.
- **B.** Different parts of the moon become visible from Earth as the moon rotates.
- **C.** Different parts of the sunlit area are visible from Earth due to motions in the Earth-sun-moon system.

Hands-On Lab

Model Moon Phases

You will model the Earth-sun-moon system to develop an explanation for the changing appearance of the moon as seen from Earth.

MATERIALS

- ball, styrene, on a stick
- lamp with removable shade
- markers
- tape

Procedure

STEP 1 Continue working with your partner. The lamp (sun) should be placed at eye level. Use the marker and tape to label the polystyrene ball as *moon*.

STEP 2 **Act** Have the person playing Earth face the sun (the lamp). The other partner stands next to the sun, facing Earth. Earth holds the moon at arm's length so the moon is between Earth and the sun, then raises the moon so that the moon is slightly higher than his or her head. Record your observations of how much of the moon appears to be lit. Each partner records their observations in the appropriate column of the table.

STEP 3 **Act** Keeping the moon held in the same position at arm's length, Earth will slowly turn in a circle toward the left, stopping at each quarter turn. At each stop, the partners each record their observations of how much of the moon appears to be lit.

STEP 4 **Act** Switch roles and repeat STEPS 2 and 3, completing the table by recording your observations from the other perspective, either as Earth or next to the sun.

Orientation of Earth	Appearance of the moon from Earth	Appearance of the moon from the sun
Facing the sun		
1st quarter turn		
2nd quarter turn (facing away from the sun)		
3rd quarter turn		

Analysis

STEP 5 What is being modeled by the ball when the person playing Earth is turning in a circle?

A. Earth's rotation

B. the moon's rotation

C. Earth's orbit around the sun

D. the moon's orbit around Earth

STEP 6 When I was playing Earth, the shape of the area that was lit on the moon changed / stayed the same.

When I was facing the sun, the moon appeared to be completely dark / lit.

When I was facing away from the sun, the moon appeared to be completely dark / lit.

When I was observing the moon from the sun, the fraction of the moon that was lit changed / was always one half.

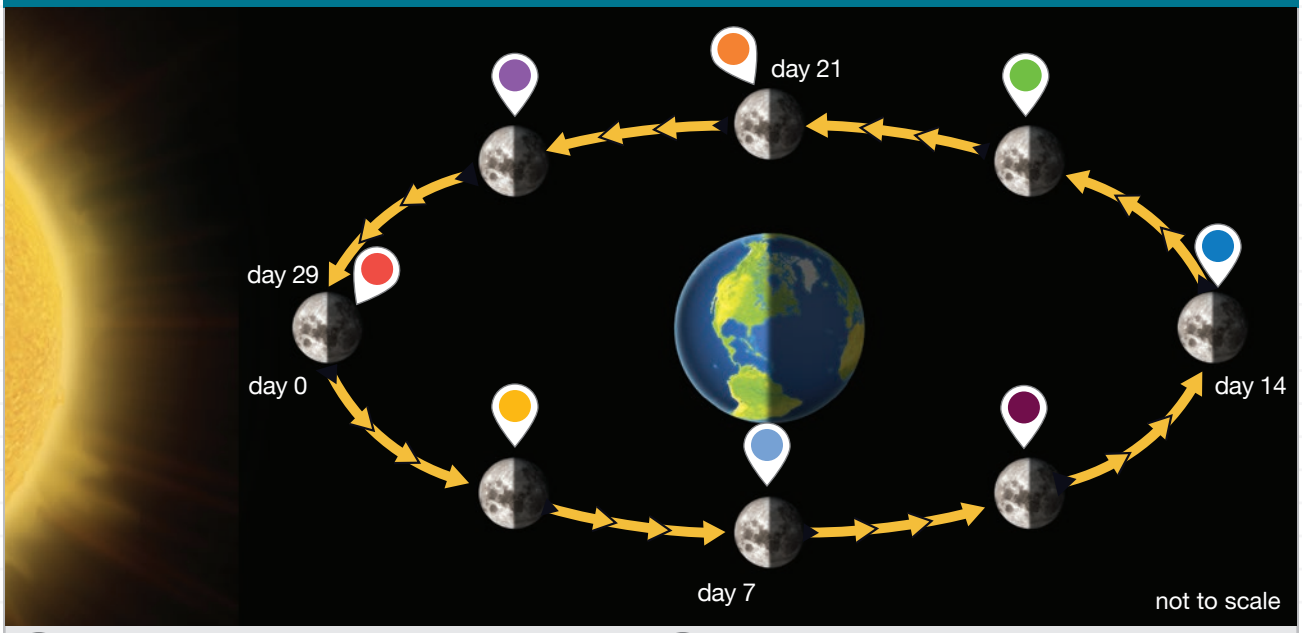
STEP 7 **Language SmArts** Compare the information that you have read so far in the text with what you observed in the experiment. Write an explanation for why the phases of the moon occur. Give examples from the model to support your explanation.

Types of Moon Phases

The appearance of the moon as seen from Earth changes as the moon orbits Earth. This happens because observers on Earth see different ratios of light to dark on the moon's surface. Think about what happens when the moon is between Earth and the sun. From Earth, the moon appears totally dark. This is called the new moon. As the moon moves through its orbit, the size of the sunlit part of the moon that you can see from Earth increases. The full moon occurs when Earth is between the moon and the sun. During a full moon, you can see the entire sunlit portion of the moon. As the moon moves farther in its orbit, the lit part of the moon you can see begins to decrease.

The pattern of surface features that you see on the surface of the moon is the same in any phase. The same side of the moon always faces Earth because the moon's orbit and the time the moon takes to rotate are the same. They are both about 27 days. The moon takes slightly longer—29.5 days—to complete one cycle of phases. This takes longer than 27 days because Earth is also moving in its orbit around the sun. Because Earth and the moon have changed position with respect to the sun, the moon must travel a little longer than 27 days to complete one cycle of phases.

Phases of the Moon



New moon The moon is between Earth and the sun. From Earth, the moon is completely dark because the side that reflects sunlight is facing away from Earth.

Full moon Earth is between the moon and sun. The entire sunlit fraction of the moon is visible from Earth.

Waxing crescent A thin sliver of the moon becomes visible and continues to grow. *Waxing* means the part of the moon we see is getting larger.

Waning gibbous The sunlit fraction of the moon that is visible from Earth decreases. *Waning* means that the part of the moon we see is getting smaller.

First quarter From Earth's Northern Hemisphere, the right half of the moon appears fully lit.

Third quarter From Earth's Northern Hemisphere, the left half of the moon appears fully lit.

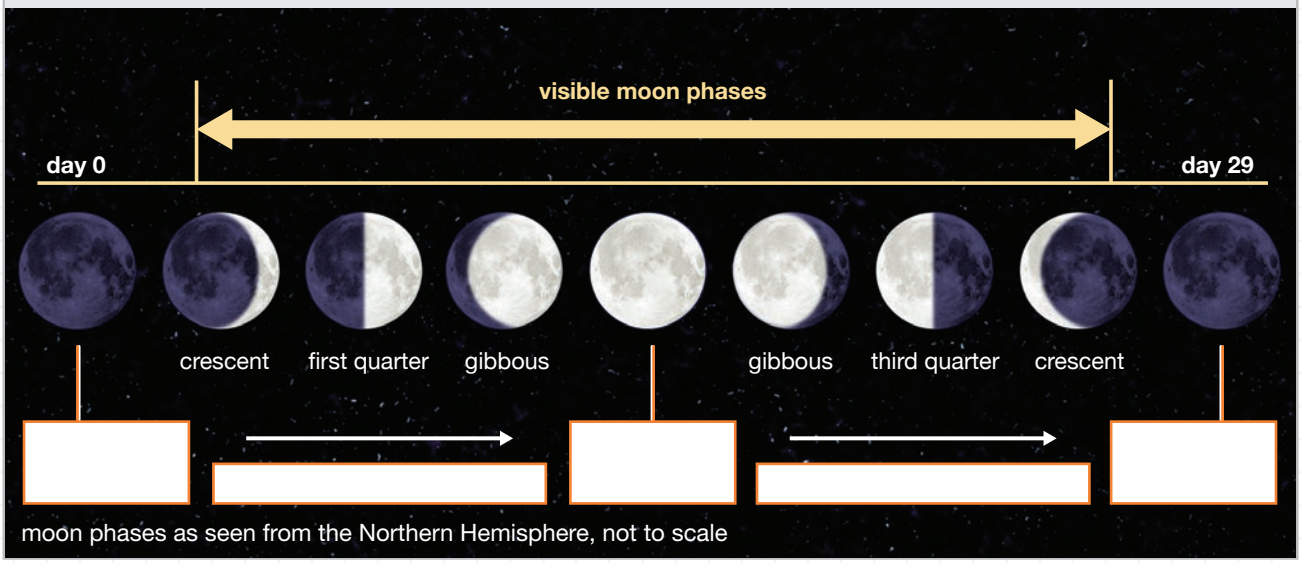
Waxing gibbous The sunlit fraction of the moon that is visible from Earth continues to grow.

Waning crescent The visible fraction of the sunlit moon continues to decrease.

Phases of the Moon Observed from Earth

15. Write the missing labels for the phases of the moon. Some labels may be used more than once.

• full moon	• waning
• new moon	• waxing



moon phases as seen from the Northern Hemisphere, not to scale

16. During a full / new moon, Earth is between the sun and the moon. So, all of the light reflected from the moon is visible from Earth. The moon, Earth, and sun are aligned with Earth in the middle. The moon's sunlit half, which is its day / night side, faces Earth's day / night side. That is always the case on the night of a full moon.

EVIDENCE NOTEBOOK

17. How does the model of phases of the moon help to explain why we can see the moon in the sky both during the day and at night? Record your evidence.

Engineer It

Plan a Lunar Mission

You are planning an expedition to the moon. Astronauts will stay on the moon for four days to collect samples and data. You want them to land on part of the moon that is lit by the sun so they can see their surroundings. While on the moon, astronauts need to use radio waves to communicate with Earth. For the waves to reach Earth, your radio transmitter must be pointed toward Earth. Because the phases of the moon are predictable, you can choose the best days for the trip years before the launch.

18. During which phase(s) and where on the moon would you want to land? Explain. Draw a diagram to justify your choice.

Exploring Eclipses

You can make shadow puppets, such as the one in the photo, using a flashlight and your hands. You can also use paper cutouts to make shadows. Moving the cutout, or your hands, makes the shadow move.

19. In the photo, why does the shadow of a dog's head form on the wall behind the hand?

You can make a shadow puppet of a dog's head using your hand and a light source.

Eclipses

Earth and the moon block the light from the sun and form shadows behind them in space. Sometimes, the moon moves into Earth's shadow or Earth moves into the moon's shadow. Both events are called an *eclipse*. An **eclipse** happens when the shadow of one celestial body falls on another. Both solar and lunar eclipses, shown in the photos below, occur in the Earth-sun-moon system. During a *solar eclipse*, the shadow of the moon falls on Earth. During a *lunar eclipse*, the shadow of Earth falls on the moon.

A solar eclipse: from Earth, we can see the moon come between Earth and the sun.

A lunar eclipse: from Earth, we can see the shadow of Earth falling on the moon.

20. Use what you see in the photos to explain how shadows are formed during a solar eclipse and a lunar eclipse. Include the sun, moon, and Earth in your explanations.

Hands-On Lab

Model Solar and Lunar Eclipses

You will model the Earth-sun-moon system to develop an explanation for solar and lunar eclipses.

MATERIALS

- lamp with removable shade
- moon model from previous activity

Procedure and Analysis

STEP 1 Continue working with your partner. The lamp (sun) should be placed at eye level. One partner plays Earth first, completing STEPS 2–4. Then switch roles and have the other partner play Earth. Each partner records their own observations.

STEP 2 **Act** The partner playing Earth faces the sun. Earth holds the moon at arm's length so the moon and the sun are in a straight line with the moon directly between Earth and the sun.

STEP 3 **Act** Earth closes one eye and slowly turns toward the left. As you turn, stop when your view of the moon is completely covered in shadow. Record your observations of the alignment of the Earth-sun-moon system and what you see from Earth.

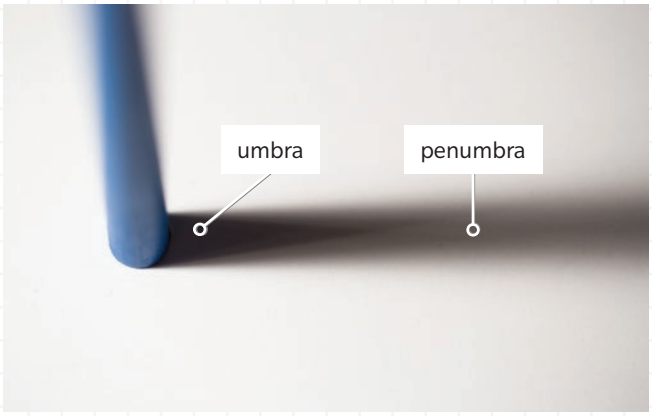
STEP 4 **Act** Earth continues to turn left. Stop when you notice that the moon blocks your view of the sun. Record your observations.

STEP 5 A solar eclipse happens when the sun is dark, which I observed in the model when my head / the ball was blocking my view of the lamp.
A lunar eclipse happens when the moon appears dark. I observed a lunar eclipse when my head / the lamp was putting a shadow on the ball.

STEP 6 If time allows, repeat STEPS 2–4, this time holding the moon slightly above your head. What differences do you see?

In the Shadow of the Moon

Solar eclipses occur when the moon moves between the sun and Earth. The moon blocks some sunlight from reaching Earth. The shadow that extends behind the moon has two cone-shaped parts, modeled in the photo. The darker, inner shadow is the *umbra*. The lighter, larger shadow is the *penumbra*.

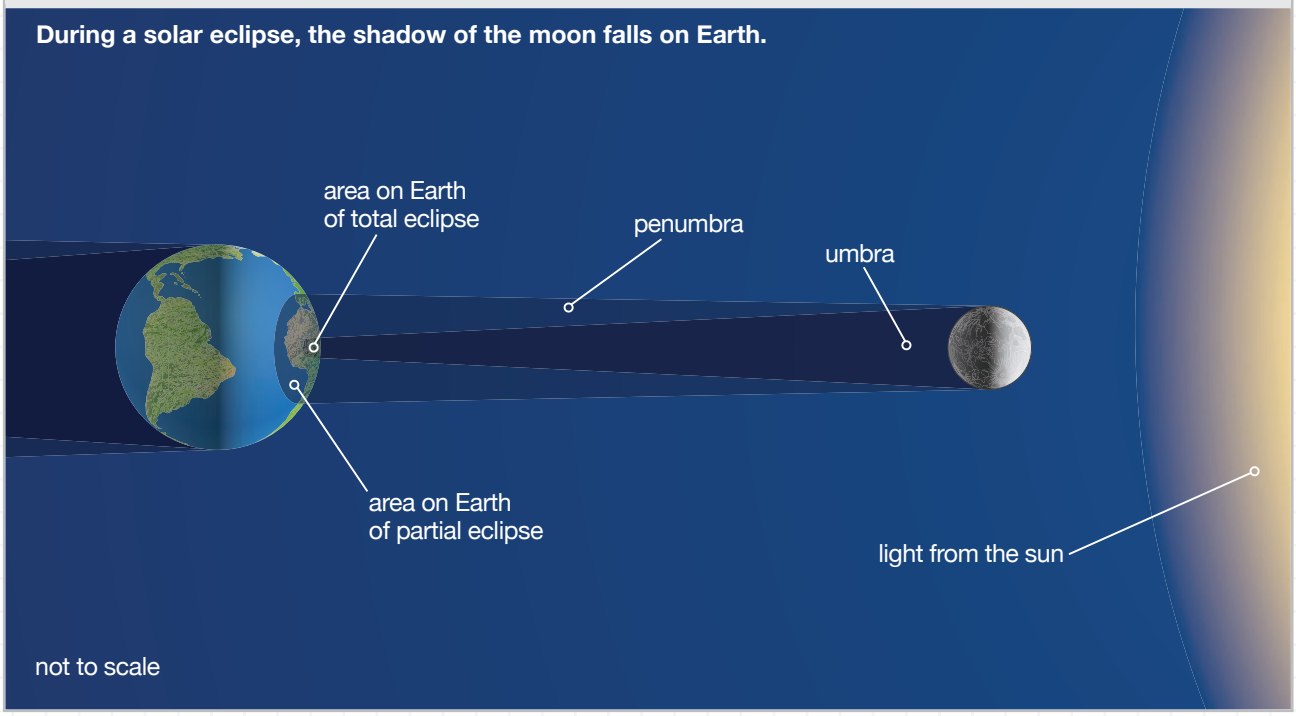


The umbra is the darkest part of a shadow. The penumbra is the lighter part of a shadow.

At least two solar eclipses occur every year. But, as the diagram below shows, the moon's shadow does not completely cover Earth. Only a small area is covered by the shadow, which is why not everyone on Earth can see every solar eclipse. To see a solar eclipse, you must be in the path of the moon's shadow. The dark umbra covers an even smaller area than the larger penumbra. As an area of Earth passes through the umbra, the sun appears to be totally eclipsed. The sun briefly goes dark, for a few minutes at most. It may seem like nighttime until that area of Earth moves out of the moon's shadow.

A Solar Eclipse

The moon casts a shadow on an area of Earth during a solar eclipse. The umbra is the smaller, darker part of the shadow. The umbra is surrounded by the lighter penumbra.



21. During a solar eclipse, the sun appears to go either fully or partially dark. Why can solar eclipses only be observed on certain parts of Earth? Circle all that apply.

A. The moon is smaller than Earth.

B. Only the people in the umbra will see the sun go totally dark.

C. People in the penumbra will see the sun go partially dark.

D. Solar eclipses only occur once every few years.

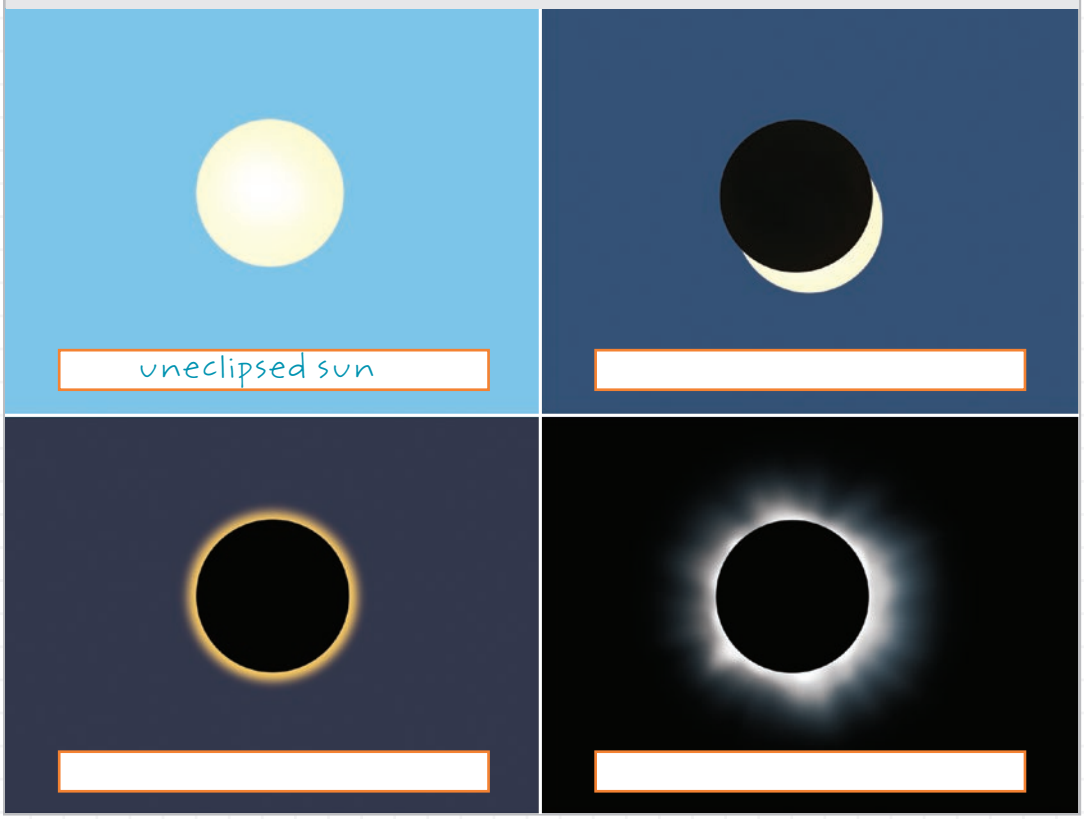
Types of Solar Eclipses

There are three types of solar eclipses. A *total solar eclipse* occurs when the sun appears to be completely blocked except for a bright halo of light. A total eclipse only happens when the Earth, moon, and sun are in a straight line. An *annular solar eclipse* also occurs when they are in a straight line. However, the moon is farther away from Earth in its orbit, and the umbra shadow does not quite reach Earth. So, the moon does not completely cover the sun. The sun's outer edges can be seen as a ring of light around the darker center during an annular eclipse. When a total eclipse of the sun occurs, only people who observe from the umbra will see the total eclipse. People who observe from the penumbra will see a *partial solar eclipse*, since from their point of view, the moon only blocks part of the sun's light.

Types of Solar Eclipses

22. Write the correct term from the word bank to label each image.

- annular solar eclipse
- ~~uneclipsed sun~~
- partial solar eclipse
- total solar eclipse

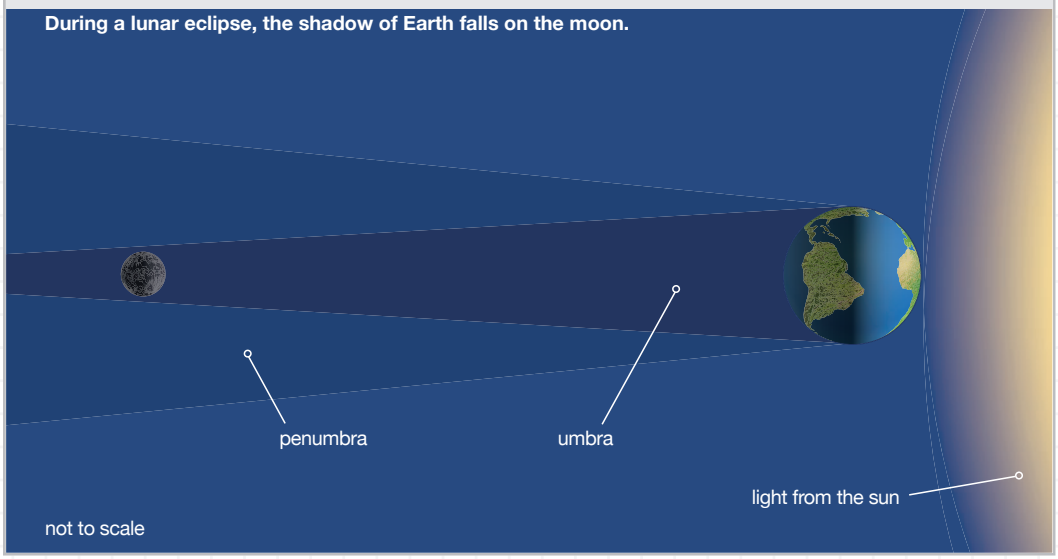


In the Shadow of Earth

During a lunar eclipse, Earth is between the moon and the sun. Because Earth is so much bigger than the moon, Earth's shadow covers the entire moon when they are aligned. As the diagram on the following page shows, Earth's shadow also has an umbra and penumbra. Remember, the moon reflects sunlight. When Earth blocks sunlight from reaching the moon, the moon appears dark. Instead of being totally dark, the moon often appears to be a rusty red color because Earth's atmosphere bends some sunlight into the shadow. Everyone who is on the dark side of Earth can see a lunar eclipse because Earth is casting the shadow.

A Lunar Eclipse

During a lunar eclipse, the moon is in Earth's shadow. Little light from the sun reaches the moon.



23. Analyze the image. Then write all or part to complete the paragraph.

During a lunar eclipse, the moon can become either partially or entirely dark. The outer or *penumbral* shadow is an area where Earth blocks _____ of the sun's rays from reaching the moon. In contrast, the inner or *umbral* shadow is a region where Earth blocks _____ direct sunlight from reaching the moon.

Types of Lunar Eclipses

During a lunar eclipse, the moon may appear totally or partially dark depending on where it passes through Earth's shadow. The time-lapse photo shows multiple images of the moon taken over about three and a half hours. The photo shows a *total lunar eclipse*, which occurs when the whole moon passes through the umbra. During a *partial lunar eclipse*, only part of the moon passes through the umbra. The part of the moon that passes through Earth's shadow becomes dark. There is one more type of lunar eclipse—the *penumbral lunar eclipse*. It occurs when the moon passes through the penumbra. While total and partial eclipses are easy to observe, penumbral eclipses are difficult to see. The penumbra is a lighter shadow and sunlight still reaches the moon when it passes through this part of Earth's shadow.

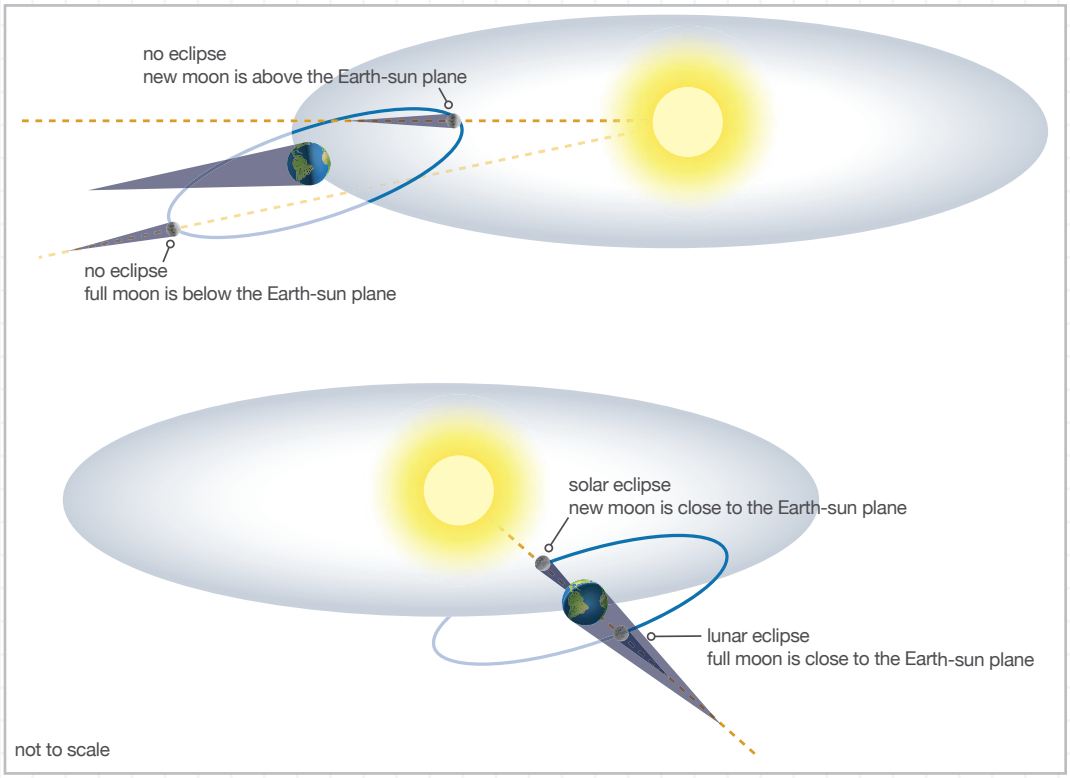
As the moon passes through Earth's umbra, more of it becomes dark. It turns a reddish-orange instead of being totally dark because Earth's atmosphere bends sunlight into the shadow.

24. Write total, partial, or penumbral to complete the paragraph.

If the entire moon passes through the part of Earth's shadow called the umbra, a _____ lunar eclipse will occur. If the moon passes only through the penumbra, a _____ lunar eclipse will occur.

Timing of Eclipses

Every time the moon orbits Earth, the moon comes between the sun and Earth, and Earth comes between the moon and the sun. Yet eclipses do not occur every time the moon orbits Earth. To understand why, you need to think of space in three dimensions. Think of the sun and Earth's nearly circular orbit around the sun in a flat plane. The moon's orbit is not in the same plane, although it may appear that way in many two-dimensional diagrams. The moon's orbit is actually tilted about 5° to the Earth-sun plane as the diagram shows. Because of this tilted orbit, the moon is usually above or below Earth during its orbit instead of being aligned in the same plane as Earth. So, the moon and Earth usually do not pass through each other's shadows.



The moon spends half its time above the Earth-sun plane and half its time below this plane. The moon only passes through Earth's shadow when it is in the same plane as Earth and the sun.

25. Because its orbit is tilted with respect to the Earth-sun plane, the moon spends most of its time either above or below the plane. How many times would the moon cross through the Earth-sun plane each time it orbits Earth? Explain.

Phases of the Moon During Eclipses

26. What phase will the moon always be in when a solar eclipse happens? When a lunar eclipse happens? Draw diagrams to support your answers.

Continue Your Exploration

Name: Date:

Check out the path below or go online to choose one of the other paths shown.

People in Science

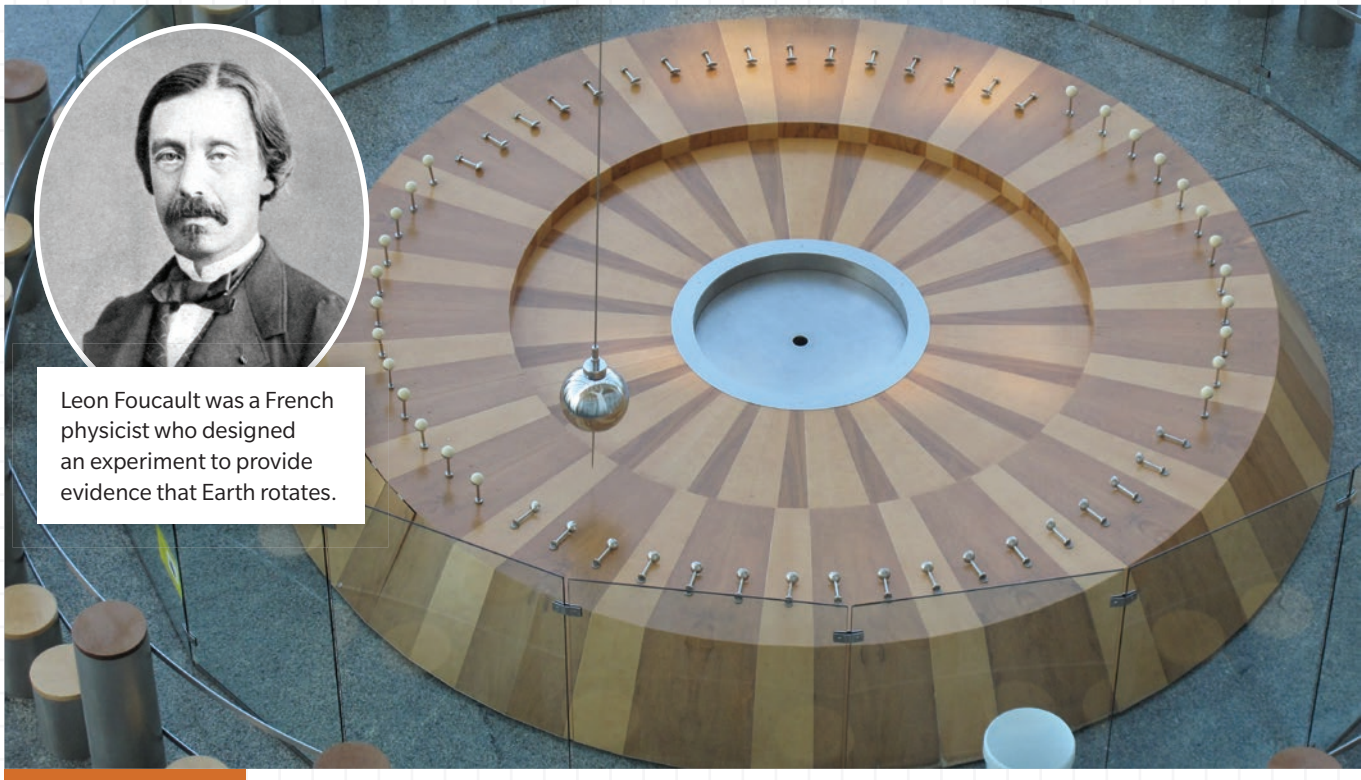
- **Hands-on Labs**
- **Using Shadows and Shade**
- **Propose Your Own Path**

Go online to choose one of these other paths.

Leon Foucault, Physicist

By 1850, it was widely accepted that Earth rotates on its axis. But a French physicist, Leon Foucault (FOO•koh), was the first person to design an instrument that demonstrated Earth's rotation.

Foucault realized that he could show Earth's rotation using a carefully designed pendulum. A pendulum is a ball that hangs by a wire from a fixed point. Once the ball is released, it swings back and forth. Foucault used a 67-meter-long wire and designed the pendulum so that it could swing in any direction. He hung his first pendulum from the Paris Observatory in 1851. The swinging pendulum appeared to gradually change its direction of swing over the course of a day. This change in direction was evidence that Earth was rotating.



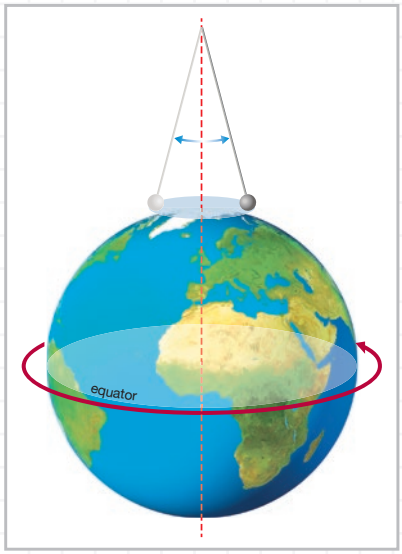
Leon Foucault was a French physicist who designed an experiment to provide evidence that Earth rotates.

Explore ONLINE!

Foucault's pendulum appears to move as Earth rotates under it. Throughout the day, this pendulum knocks down pegs to show how its swing gradually changes direction.

Continue Your Exploration

1. Why was it necessary for Foucault's pendulum to swing freely in all directions in order for it to demonstrate that Earth rotates?



2. How does the explanation for the way Foucault's pendulum appears to move relate to the explanation for why the sun, moon, and stars appear to circle Earth every 24 hours?

3. Do the Math Locations other than the North and South Poles move in a circle around Earth's axis as Earth rotates. Because of this motion, Foucault's pendulum does not complete a full circle in one day. For example, it only turns 270° in one day in Paris. How many hours would it take to complete one full circle (360°) in Paris?

A. 11

B. 18

C. 27

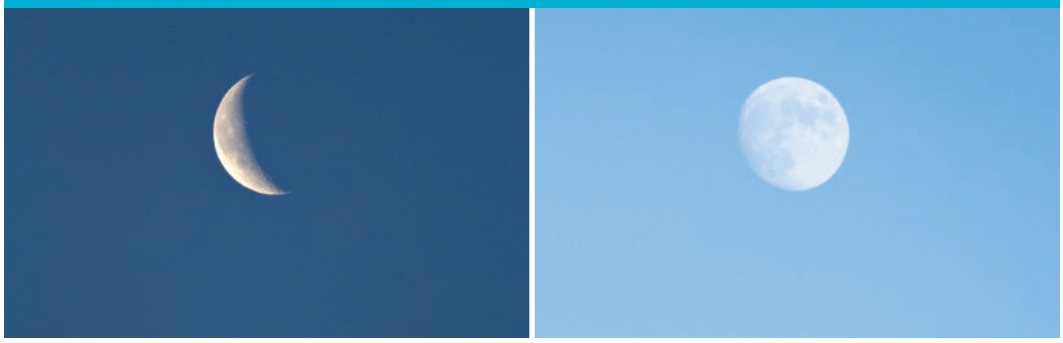
D. 32

4. Collaborate With a group, prepare a multimedia presentation to explain how Foucault's pendulum works. Consider including videos or demonstrations.

Can You Explain It?

Name: **Date:**

Why can we see the moon at night and also during the day?



EVIDENCE NOTEBOOK

Refer to the notes in your Evidence Notebook to help you construct an explanation for why the moon is visible at night and during the day.

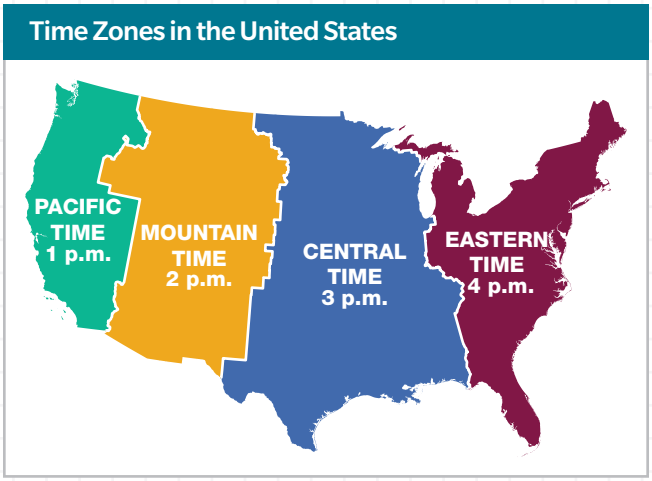
1. State your claim. Make sure your claim fully explains why you can see the moon during the daytime and the nighttime.

2. Summarize the evidence you have gathered to support your claim and explain your reasoning.

Checkpoints

Answer the following questions to check your understanding of the lesson.

Use the map to answer Questions 3-4.



3. The sun will rise first in the Eastern / Pacific Time Zone. As it appears to move across the sky, it will rise in the Central / Mountain Time Zone next. At the end of the day, sunset will occur last in the Eastern / Pacific Time Zone.

4. When the sun sets in the Central Time Zone, in which time zones will it be night? Circle all that apply.

A. Central

B. Eastern

C. Mountain

D. Pacific

Use the photos to answer Questions 5-6.

5. Why are appearances of the moon in each photo different from each other? Circle all that apply.

A. Both photos show phases of the moon.

B. The top photo shows an eclipse and the bottom photo shows a phase.

C. The moon in the bottom photo occurs about once every month.

D. The moon in the top photo only occurs when the moon is in Earth' shadow.

6. The moon in the bottom photo is in its third quarter. How will the moon look after it moves another quarter of the way through its orbit?

A. The same as it looks in the photo.

B. The full circle of the moon will be lit.

C. The moon will be completely dark.

D. The quarter moon will be lit on the other side.

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7. In August 2017, a total solar eclipse was visible from the United States. A total solar eclipse happens when Earth / the moon moves directly in front of the moon / sun. A total solar eclipse can be seen from everywhere / a narrow path on Earth.

Interactive Review

Complete this section to review the main concepts of the lesson.

The sun, stars, and moon appear to move across the sky because of Earth's rotation.

A. Describe the movement of the sun, stars, and moon across the sky.

The moon goes through a pattern of phases over a period of 29.5 days. Phases change as the fraction of the sunlit area of the moon that is visible from Earth changes.

B. What explains the difference in appearance between a full moon and a new moon? Include the arrangement of the sun, moon, and Earth in your explanation.

Eclipses happen when Earth is in the shadow of the moon or the moon is in the shadow of Earth.

C. Explain the difference between a partial eclipse and a total eclipse. Use either a solar eclipse or a lunar eclipse as an example.