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Lesson 1

Patterns of Motion in the Solar System

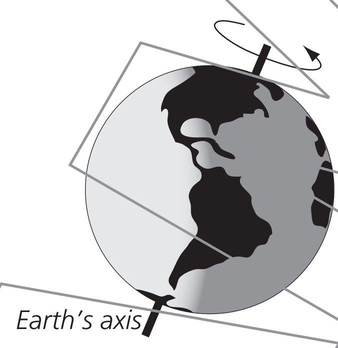
5-PS2-1; 5-ESS1-1, 2

If you look up into the sky on a clear night, you might think that Earth is alone in the universe. In fact, Earth is closely connected to many objects in space. Earth is part of a system of planets, moons, asteroids, and dwarf planets. At the center of the system is a star, the sun. This system, called the **solar system,** contains many objects that all move together in an orderly way due to **gravity,** a force that pulls an object toward another.

Motions of Earth and the Moon

Every day, the sun rises and sets. The moon and far-off stars shine in the sky at night. It is warm in the summer, and it gets colder in the winter. These natural patterns are a part of life. The movements of Earth and the moon around the sun cause these patterns. Because Earth and the moon move around the sun, we have seasons, moon phases, and day and night.

Earth and the moon are always moving. They both **rotate,** or spin on an axis. An **axis** is an imaginary line down the center of an object. The moon's axis is straight up and down. Earth's axis is not straight up and down. It is tilted to the side.



You have probably noticed that the sun moves across the sky during the day. It looks like the sun moves around Earth. However, the sun does not actually move around Earth. The sun appears to move across our sky because Earth rotates.

To understand how this works, think about sitting on a merry-go-round. As you look to the side, houses, trees, and other things seem to fly by. However, the houses and trees are not moving. Only the merry-go-round is moving. The merry-go-round is like Earth. The houses and trees are like the sun.

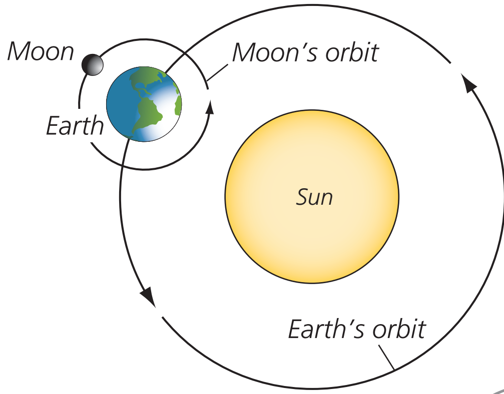
A solar system is a group of planets, moons, asteroids, and dwarf planets that move in patterns around a star.

Have you ever wondered why Earth keeps moving around the sun, or why the moon doesn't float away? It's all because of gravity, a force that pulls an object toward another. The sun's strong gravity pulls on Earth and keeps it moving in a path around it. The same thing happens with the moon—Earth's gravity keeps it close and makes it orbit our planet. Without gravity, everything would fly off into space!

To rotate is to spin on an imaginary line.

An axis is an imaginary line through the center of an object.

As Earth and the moon rotate, they also **revolve.** That means that they move in a path around other objects. These paths are called **orbits.** The moon orbits, or revolves around, Earth. Earth orbits, or revolves around, the sun. Gravity holds Earth and the moon in their orbits.



As Earth revolves around the sun, the moon revolves around Earth.

Which statement about the sun and Earth is true?

A As Earth revolves, it moves around the sun.

B As Earth rotates, the sun moves around Earth.

C As Earth revolves, the sun moves around Earth.

D As Earth rotates, both Earth and the sun stay in place.

Earth's rotation makes the sun seem to move around Earth. However, the sun does not actually move around Earth. Therefore, choices B and C are incorrect. Earth rotates around its axis and revolves, or moves, around the sun. Therefore, choice D is incorrect. Choice A is correct.

Days, Years, and Seasons

You have probably noticed that every year has four seasons. You have probably also noticed that the length of the day changes during a year. Earth's rotation and revolution cause both of these patterns. People use these patterns to make calendars.

As Earth spins, some areas of the planet face the sun, and other areas face away from the sun. It is daytime in the areas facing the sun. It is night in the areas facing away from the sun. One day equals the time it takes for Earth to rotate once on its axis. It takes about 24 hours for Earth to rotate once on its axis. So, one day equals about 24 hours.

To revolve is to move in a path around another object.

An orbit is a circular path one object follows when it revolves around an object. The word *orbit* can also be used as a verb.

All the planets in the solar system revolve around the sun, and every planet rotates on an axis. However, the planets do not all move at the same speed.

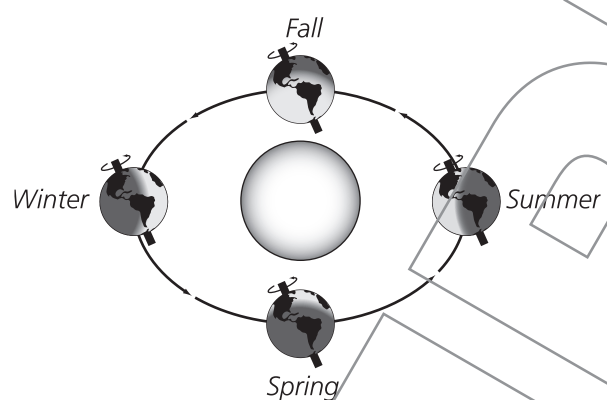
Planet	Rotation (Earth time)*
Mercury	59 days
Venus	243 days
Earth	1 day
Mars	1 day
Jupiter	10 hours
Saturn	11 hours
Uranus	17 hours
Neptune	16 hours
Planet	**Revolution (Earth time)***
Mercury	3 months
Venus	7.5 months
Earth	1 year
Mars	1.9 years
Jupiter	12 years
Saturn	29.5 years
Uranus	84 years
Neptune	165 years

*These are approximations.

The length of a year is based on Earth's revolution. It takes Earth about 365 days to make one orbit around the sun. One orbit around the sun equals one Earth year.

One year has four seasons: winter, spring, summer, and fall. We have seasons because Earth's axis is tilted. As Earth orbits the sun, different parts of the planet face the sun. When the top half of Earth is tilted toward the sun, the areas on the top half have summer. This is because the top half receives more direct sunlight. Those areas heat up.

The opposite is true in winter. During winter, the top half of Earth is tilted away from the sun. As a result, the areas on the top half receive less direct sunlight. They cool down. This is why the weather is generally warmer in summer and cooler in winter.



Earth's tilted axis is the reason we have seasons.

Have you ever noticed how shadows change during the day? The shadow cast by the sun's light is long in the morning and afternoon. It is shortest in the middle of the day, when the sun is at its highest point in the sky. Also, notice how the direction of the shadow changes during the day as the sun moves across the sky. Shadows also change with the seasons! During the summer, the sun takes a higher path in the sky. Summer shadows in the middle of the day are the shortest of the year.

Shadows are longest in the morning and afternoon, when the sun rises and sets. Shadows change direction as the sun moves across the sky.

Another pattern you can see is how the sun rises and sets at different times during the year. The sun rises earlier and sets later in the summer, making the days longer. The opposite is true for winter. The sun rises later and sets earlier, making the days shorter.

SEASONAL CHANGES IN DAYLIGHT HOURS IN NEW YORK

Season	Average Sunrise	Average Sunset	Average Daylight Hours
Spring	6:30 a.m.	7:30 p.m.	13 hours
Summer	5:30 a.m.	8:30 p.m.	15 hours
Fall	6:45 a.m.	6:30 p.m.	11 hours 45 minutes
Winter	7:15 a.m.	5:00 p.m.	9 hours 45 minutes

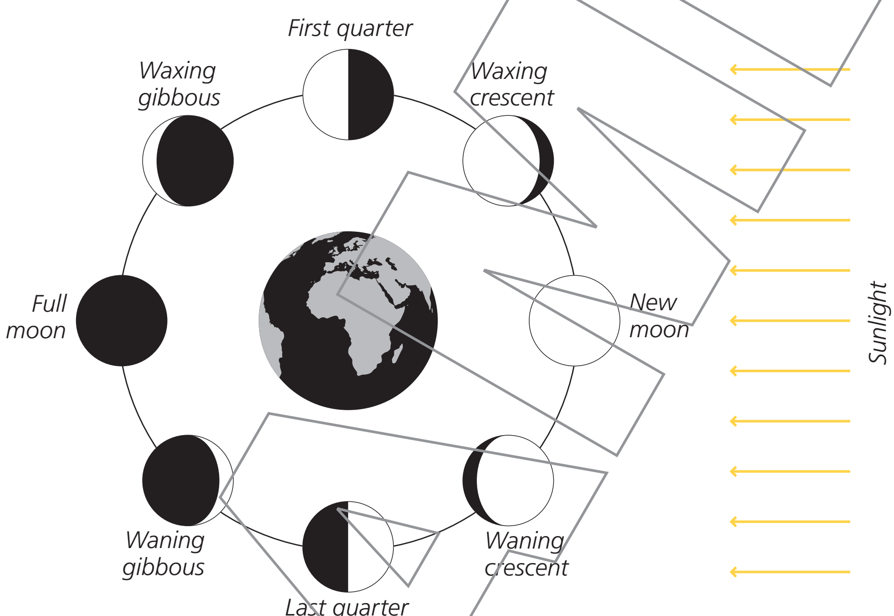
Remember, it's the rotation of Earth on its axis and the revolution of Earth around the sun that create patterns we can see. We say the sun "rises" in the east, but it's actually Earth's rotation that creates the path of the sun in the sky!

Moon Phases

The moon seems to change shape from night to night. Sometimes it is a full, round ball. Other times it's just a sliver, or no moon is seen at all! These different shapes are called **moon phases.**

Moon phases slowly change over a month. It takes about 14 days for the moon to slowly change from a new moon, which we cannot see, to a full moon.

We always see the same side of the moon. As the moon revolves around Earth due to gravity, it is also slowly rotating.



The cycle of moon phases takes about one month to complete.

The moon does not actually change shape every day. The motions of Earth and the moon around the sun are what make the moon seem to change shape. Unlike the sun, the moon does not make its own light. It reflects light from the sun. Half of the moon is always facing the sun. That half of the moon is bright. The other half is dark.

As the moon revolves around Earth, we see different parts of the lit half of the moon. When the moon and the sun are on opposite sides of Earth, we can see the entire lit half of the moon. The moon looks full. When the moon is between Earth and the sun, we can see only the dark half of the moon. When the moon is dark, we call it a “new” moon.

The phases of the moon are a pattern. They repeat every 29.5 days. That is about how long a month is. In fact, the length of months is based on the moon phases. Early calendars defined months as the amount of time it took the moon to go through all of its phases. One month is about as long as it takes for the moon to make one revolution around Earth.

There is only one full moon in most months. When there are two full moons in one month, the second moon is called a *blue moon*. Blue moons happen very rarely. That’s why the phrase “once in a blue moon” is used to refer to things that rarely happen.

Lily is making a booklet about Earth and the patterns we see that show how Earth moves in space. What should Lily include to help explain these ideas?

Lily should start her booklet with a page that explains gravity—a force we can’t see, but one that keeps planets, like Earth, in orbit around the sun. Next, she could add a page about how Earth orbits the sun on a tilted axis, which causes the seasons to change throughout the year. Then, Lily can show how Earth’s rotation causes day and night. Even though it looks like the sun moves across the sky, it’s really Earth spinning! Finally, she might include pages about how shadows change during the day, from long in the morning to short at noon and long again in the evening—all because of Earth’s rotation. Finally, Lily could include a page about the moon’s phases.

Measuring Time

The movements of Earth and the moon help people organize time into units. A year is based on Earth’s revolution around the sun. A month is about as long as the moon’s revolution around Earth. A day is equal to the time it takes for Earth to rotate once.

COMMON UNITS OF TIME

Unit	Equal to …
Second (s)	—
Minute (min)	60 s
Hour (hr)	60 min
Day	1 rotation of Earth around its axis (about 24 hr)
Week	7 days
Month	about 1 revolution of the moon around Earth (29.5 days)
Year	1 revolution of Earth around the sun (about 365 days)

People create units of time because units make it easier to talk about time. However, many units do not line up exactly with the movements of Earth and the moon. Most months in our calendar are longer than 29.5 days. Also, Earth orbits the sun in slightly more than 365 days. That is the reason we have leap years. Every four years, we add a day to our calendar to make up for the extra time it takes Earth to orbit the sun.

We divide years, months, and days into smaller units to make it easier to keep track of time. We divide years into weeks, and we divide days into hours. For the same reason, we divide hours into minutes and seconds.

Constellations

Patterns of stars in the night sky are called **constellations.** As Earth revolves around the sun, constellations appear in different parts of the night sky. The constellations people can see in the sky depend on where Earth is in its orbit. For example, during the winter in New York, you have to look south to see the constellation Orion. During the fall, you have to look southeast. Constellations also look different to people living in different places on Earth.

These star maps show that constellations look different when seen from different parts of Earth at the same time of year.

Constellations also seem to move across the night sky throughout the night. Actually, the constellations themselves are not moving. They only seem to move because Earth is rotating.

A constellation is a group of stars that forms a pattern.

The ancient Greeks thought the shape of one group of stars looked like a hunter. They named the constellation "Orion," after a hunter in Greek mythology. The Lakota, a Native American tribe, saw Orion's belt as the bottom of a chief's hand.

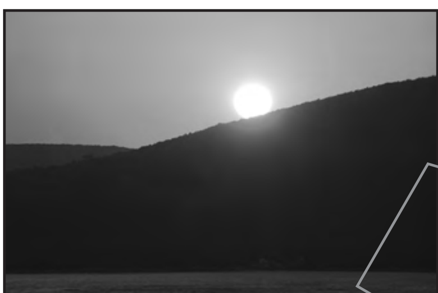
Padma looks at the night sky just after sunset. She notices a constellation near the horizon. Later that night, the same constellation is higher in the sky. Explain why this happened.

Constellations seem to move because Earth is rotating. As Earth rotates, different constellations become visible during the night. So, Earth's rotation makes the constellations seem to move.

The Distance of Stars

When you look at the night sky to find constellations, you might notice something else. Some stars shine brighter than others. We can see the sun during the day. But as it sets and the night sky darkens, you can also see how much brighter it is than any other stars. Let's find out why.

Stars are giant balls of hot gases, mostly hydrogen and helium. Stars shine because of the energy made deep inside them, where the gases are under extreme pressure and heat. This energy travels from the star and into space as light and heat. Even though stars are very far away, we can still see many in the night sky. Our sun is an average-sized star, but it looks much bigger and brighter than other stars because it's much closer to Earth.



Our sun is the closest star to Earth, which is why it appears so much brighter than other stars.

How bright a star *looks* from Earth is called **apparent brightness.** This depends on two things:

- how much light the star gives off
- how far away it is

A star that is far away might look dim, even if it gives off a lot of light. A closer star might look brighter, even if it gives off less light.

A star's actual amount of light is called its **true brightness,** or **absolute brightness.** But because we can't travel to the stars, scientists mostly use apparent brightness—how bright the star looks from Earth—because that's what we can measure using telescopes.

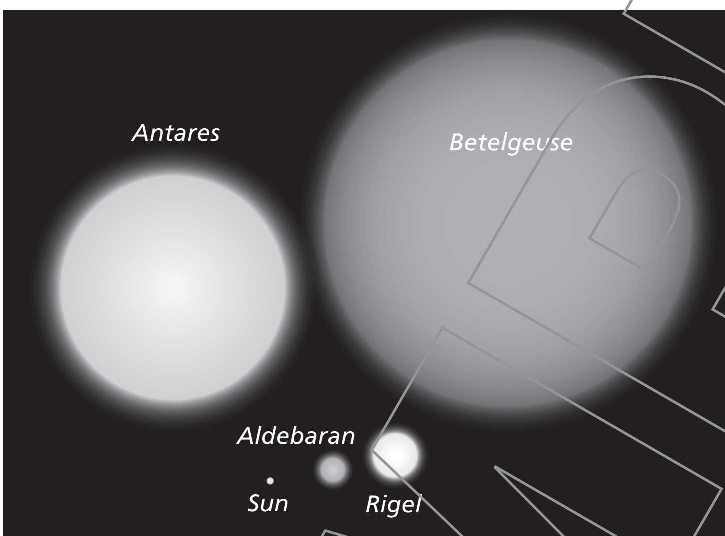
The apparent brightness of huge stars can be deceiving. They can appear tiny and dim from Earth, but in reality, they can be many times bigger than the sun. The largest known star in the universe is UY Scuti, which is 1,700 times larger than the sun. It can't be seen without a telescope!

The true brightness, or the absolute brightness, of stars gives us a better picture to compare different stars. For example, the true brightness of UY Scuti is 340,000 times more than the sun's!

Later, if they know how far away the star is, they can also figure out its true brightness.

The closest star to the sun, Proxima Centauri, is about four light-years away. A **light-year** is how scientists measure huge distances in space. It's the distance light travels in one year—about 9.5 trillion kilometers (or nearly 6 trillion miles)! Most of the stars we see in the night sky without a telescope are only a few hundred to a few thousand light-years away. Even though that sounds very far, those stars are close compared to how big the universe is. All of them are in a small part of our Milky Way galaxy, which is made up of hundreds of billions of stars. So when we look up at night, we see just a tiny part of our own galaxy, and the light from those stars has taken years to reach us!

A light-year is a measurement of distance, not time, so the term "year" might be deceiving. A light-year is a huge distance. If you could travel in a car going 100 km/hour (60 miles per hour), it would take you over ten million years to travel the distance of a light-year!



The sun is just an average-sized star. The largest known star, UY Scuti, would be the size of this page in comparison.

Why Does the Sun Look So Bright?

You can explore the connection between distance and brightness using objects you may have at school. Experiments like this can be used to gather evidence that you can use to support your ideas, arguments, and models.

Try this experiment about light brightness.

Materials Needed:

- **flashlight**
- **a dark room**
- **ruler or tape measure**
- **notebook or paper with a pencil or pen to record your observations**

Instructions:

1. Turn off the lights in the room.
2. Stand next to the wall with the flashlight. Point the flashlight directly at the wall and turn it on.
3. Move the flashlight 1 foot from the wall. Observe how bright the light looks on the wall.
4. Move the flashlight 3 feet away from the wall. How does the light on the wall change?
5. Move it 6 feet away. What do you notice now?

What did you see?

You probably noticed that the farther away the flashlight got, the dimmer the light looked on the wall. That's because the light spreads out more the farther it is from the wall. The same thing happens with stars in space. Even a very bright star will appear dim if it is far from Earth.

Before you begin, make a claim: How do you think the distance between the flashlight and the wall will affect how bright the light looks? After completing the investigation, revisit your claim. Was your prediction correct? What evidence from your observations supports your thinking?

Activities like the flashlight experiment help you understand how to gather evidence to support your ideas and models. Think about how you used the flashlight. What did the flashlight represent? You held the flashlight at different places away from the wall. What did that represent?

Making an Argument from Evidence

In science, we don't argue by shouting—we argue by showing evidence. That means using facts, observations, or data to prove a point. Let's make an argument about why the sun looks brighter than other stars.

- **Claim:** The sun looks brighter than other stars because it is much closer to Earth.
- **Evidence:** The flashlight activity showed that light looks dimmer the farther away it is. The sun is 93 million miles from Earth. Other stars are trillions of miles away.
- **Reasoning:** Since the sun is closer than other stars, its light doesn't have to travel as far. That's why it appears brighter, even if other stars are giving off more light in space.

To make a **scientific argument,** you make a claim, back it up with evidence, and explain the reasoning that connects the evidence to the claim.

A claim is a statement or answer that tells what you believe or think.

Evidence is facts or data that support your claim.

Reasoning is the explanation or conclusion that connects your evidence to your claim.

Scientific Argument

Claim
↓
Evidence
↓
Reasoning

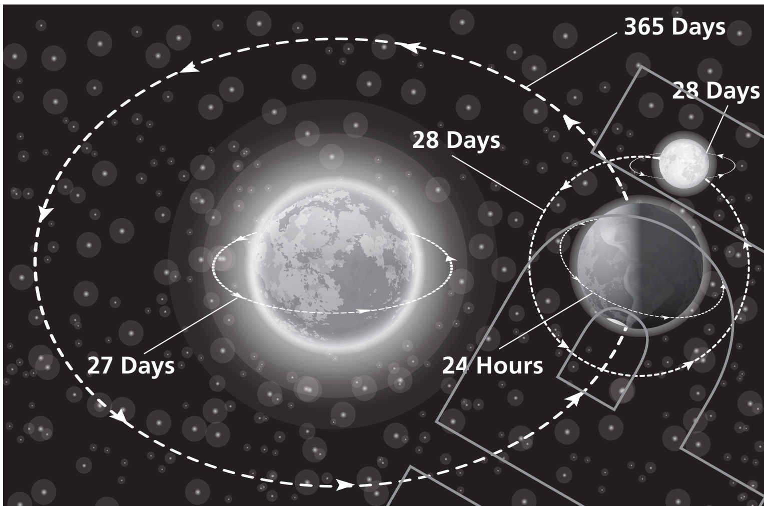
Why is it important to use evidence when explaining why the sun looks brighter than other stars?

It's important to use evidence so others understand that the sun only appears brighter because it's closer, not because it gives off more light. Using data like distances and models helps prove that apparent brightness depends on how far a star is from Earth.

It's Your Turn

Please read each question carefully. For each multiple-choice question, circle the letter of the correct response. For a constructed-response question, write your answer on the lines.

Base your answers to questions 1 through 4 on the image below and on your knowledge of science.



1 As Earth revolves around the sun, what patterns do you see in the night sky from Earth?

A The constellations you can see in the night sky will be lower in the winter.

B The constellations you can see in the night sky will change with the seasons.

C The constellations you can see in the night sky will be brighter in the summer.

D The constellations you can see in the night sky will change with the moon phases.

2 Which of these describes the role of gravity between Earth, the sun, and the moon?

A Earth's gravity keeps the moon in orbit around it, which explains why we see different moon phases.

B The sun's gravity keeps Earth in orbit around the moon, which explains why we see different seasons.

C The sun's gravity keeps the moon in orbit around Earth, which explains why we see different shadows each day.

D Earth's gravity keeps the moon in orbit around it, which explains why we see different constellations each season.

3 Which of these describes the movement of Earth on its axis?

A Shadows are longest in the middle of the day.
B Shadows are longest when the sun rises and sets.
C Shadows are shortest in the early hours of the day.
D Shadows are shortest when the sun is low in the sky.

4 Which of these describes Earth's position when it is summer in New York?

A Earth's axis is parallel to the sun.
B Earth's revolution is closest to the sun.
C Earth's axis is pointed towards the sun.
D Earth's revolution is farthest from the sun.

5 What did the flashlight model help show about stars?

A Light gets stronger the farther it travels.
B A star looks dimmer when it is closer.
C Distance affects how bright a light appears.
D All flashlights shine equally, no matter the distance.

6 Joe made a drawing of different stars, showing the sun as the largest. He told his friend that the stars he sees at night are not as bright, so they must be smaller than the sun. Identify if Joe's statement is correct or incorrect. Based on the evidence, make a claim by explaining why the statement is correct or incorrect.

Answer: ______________________________

Claim: ______________________________

____