Launch Lab
Relative Sizes of Earth, the Moon, and the Sun

Can you picture the relative sizes of Earth, the Moon, and the Sun? The Sun’s diameter is about 100 times larger than Earth’s diameter and about 400 times than that of the Moon. In this lab, you will compare the relative sizes of all three objects.

For a lab worksheet, use your StudentWorks™ Plus Online.
THEME FOCUS The Solar System and the Universe
Interactions between Earth, the Moon, and the Sun cause tides, moon phases, eclipses, and changes in seasons and the number of hours of daylight.

BIG Idea Gravitational forces cause the Moon to revolve around Earth and cause Earth to revolve around the Sun.

Section 1 • Earth in Space
Section 2 • Time and Seasons
Section 3 • Earth’s Moon
Earth in Space

MAIN Idea Earth revolves in an elliptical orbit around the Sun.

Real-World Reading Link Every day, you observe the Sun as it rises in the east, moves across the sky, and sets in the west. Many ancient astronomers believed that Earth was the center of a spinning universe. In fact, the Sun appears to move in the sky because Earth rotates.

Earth’s Size and Shape

Ancient astronomers observed the Earth-Moon-Sun system to make inferences about Earth’s size and shape. In fact, about two thousand years ago, the Greek astronomer Eratosthenes estimated the circumference of Earth with remarkable accuracy. These observations would eventually lead to a better understanding of Earth’s place in the solar system.

Ancient observations Earth’s shape is spherical. A sphere is a round, three-dimensional object, the surface of which is the same distance from the center in all directions. Even ancient astronomers knew that Earth was a sphere. How could ancient astronomers have known this was true?

Aristotle was one of these early astronomers. He made three different observations that indicated that Earth is a sphere. First, no matter where you are on Earth, objects fall straight down to the surface, as if they are falling toward the center of a sphere. Second, Earth’s shadow on the Moon during a lunar eclipse is always curved. Third, people in different parts of the world see different stars at night as shown in Figure 1. If Earth were flat, everyone would see the same stars.

Figure 1 Stars, such as Polaris, can only be seen in the Northern Hemisphere. Canopus, a star located in the Southern Hemisphere, can be seen southeast of a four-star constellation called the Southern Cross.

Explain Why do people in different parts of the world see different stars at night?
**Everyday evidence of Earth’s shape**  What have you seen, other than images of Earth from space, that shows Earth is a sphere? Think about walking toward someone over a hill. First, you see the top of the person’s head and then you can see more and more of that person. Similarly, if you sail toward a lighthouse, you see the top of the lighthouse first and then see more and more of it as you sail across Earth’s curved surface.

You can see other evidence, too. Just like ancient astronomers, you can see for yourself that objects always fall straight down. Gravity causes objects to fall in this way. Gravity is the force of attraction between two objects that depends on the mass of each object and the distance between them.

Gravity is also responsible for Earth’s spherical shape. Today, astronomers think Earth formed as objects in the early solar system crashed into each other and combined because of their gravitational attraction for each other. Energy released as objects crashed into the growing Earth caused Earth to be molten. Gravity then caused the molten Earth to form a sphere. As Earth cooled over time, distinct layers formed due to differences in density. These layers would eventually become the inner core, the outer core, the mantle, and the crust. **Figure 2** describes some other physical properties of Earth.

![Figure 2](image)

**Reading Check** Identify What are Earth’s four main layers?

**Table 1** Earth’s Physical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (pole to pole)</td>
<td>12,714 km</td>
</tr>
<tr>
<td>Diameter (through equator)</td>
<td>12,756 km</td>
</tr>
<tr>
<td>Circumference (poles)</td>
<td>40,008 km</td>
</tr>
<tr>
<td>Circumference (equator)</td>
<td>40,075 km</td>
</tr>
<tr>
<td>Mass</td>
<td>$5.98 \times 10^{24}$ kg</td>
</tr>
<tr>
<td>Average density</td>
<td>5.52 g/cm$^3$</td>
</tr>
<tr>
<td>Average distance to the Sun</td>
<td>149,600,000 km</td>
</tr>
<tr>
<td>Average distance to the Moon</td>
<td>384,400 km</td>
</tr>
<tr>
<td>Period of rotation</td>
<td>23 h, 56 min</td>
</tr>
<tr>
<td>Period of revolution</td>
<td>365 days, 6 h, 9 min</td>
</tr>
</tbody>
</table>
Earth’s Magnetic Field

Scientists hypothesize that Earth’s rotation and the circulation of molten metals in the outer core set up a strong magnetic field in and around Earth. This field resembles the field that surrounds a bar magnet, as shown in Figure 3. Earth’s magnetic field is concentrated at two ends of an imaginary axis running from Earth’s north magnetic pole to its south magnetic pole. This axis is tilted about 11.7° relative to Earth’s geographic North Pole.

Magnetic reversals The locations of Earth’s magnetic poles change slowly over time. Large-scale movements, called magnetic reversals, occur on average every 200,000 years. However, the most recent reversal happened 780,000 years ago. Data suggests that Earth’s magnetic field has weakened since the nineteenth century, although scientists are uncertain if a reversal is underway.

Auroras The Sun produces streams of electrically charged particles called the solar wind. An area within Earth’s magnetic field, called the magnetosphere, deflects these harmful particles. The particles spiral along Earth’s magnetic field lines toward the magnetic poles. They eventually collide with atoms and molecules in the atmosphere near the magnetic poles. These collisions cause some atoms and molecules to emit light. The light that results is called aurora borealis (northern lights) in the Northern Hemisphere, as shown in Figure 4, and is called aurora australis (southern lights) in the Southern Hemisphere.

Planet Earth

Earth orbits the Sun at an average distance of 149,600,000 km. Its orbit, like those of other objects in our solar system—planets, moons, asteroids, and comets—is elliptical. An ellipse is an elongated, closed curve with two foci. The Sun is not located at the center of the ellipse but at one of its two foci. This means the distance from Earth to the Sun varies during the year. Each year, Earth is closest to the Sun—about 147 million km away—in early January and is farthest from the Sun—about 152 million km away—in early July.
**Earth in the solar system** Earth is one of the eight planets in the solar system and is the only planet whose properties make it possible for life as we know it to survive today. Earth’s oxygen-rich atmosphere is one reason it is able to support large and complex life-forms.

**Comparison to Venus** Venus is nearly the same size as Earth, but atmospheric conditions on the two planets are very different, as shown in Figure 5. Venus’s atmosphere contains 96 percent carbon dioxide, but Earth’s atmosphere contains only about 0.04 percent carbon dioxide. One reason that Earth’s atmosphere contains significantly less carbon dioxide is that Earth’s oceans absorbed much of it early on.

The large concentration of carbon dioxide in Venus’s atmosphere traps some of the heat energy reflected from the planet’s surface and prevents it from escaping into space. This effect, called the greenhouse effect, causes the average surface temperature on Venus to exceed 460°C. On Earth, where the amount of atmospheric greenhouse gases is much lower, average temperatures are less extreme, about 15°C.

**Comparison to Mars** Mars is slightly more than half the diameter of Earth, and its surface gravitational pull is only about 38 percent as strong as Earth’s. This weak gravitational pull is not strong enough to hold a dense atmosphere around the planet. As a result, Mars’s atmosphere is only about 1.6 percent as dense as Earth’s atmosphere and its average surface temperature is about —63°C. Mars also lacks a magnetic field, which allows its atmosphere to be slowly stripped away by solar wind.

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**Section 1 Review**

**Section Summary**
- Earth has a spherical shape.
- Earth’s magnetosphere deflects harmful solar winds.
- Earth orbits the Sun in an elliptical orbit.
- Venus, Earth, and Mars differ in size and atmospheric conditions.

1. **MAIN Idea** Explain Earth’s orbit around the Sun.
2. **Describe** how gravity affected Earth’s shape.
3. **Explain** what produces Earth’s magnetic field.
4. **Compare and contrast** Venus’s atmosphere with Earth’s.
5. **Think Critically** Evidence indicates that Mars once had liquid water on its surface. Discuss some possible reasons why it has none today.

**Apply Math**

6. **Calculate** Earth’s circumference at the equator is 40,075 km. If it spins once each day, what is the speed of spinning in km/h?

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**Earth in Space**

**Online Quiz**
Time and Seasons

**MAIN Idea** Earth rotates on a tilted axis around the Sun, which causes a change in the length of a day and the seasons.

**Real-World Reading Link** Northern Alaska experiences nearly 24 hours of daylight during the summertime. The opposite is true during the wintertime, when the skies are dark nearly all day long.

**Measuring Time on Earth**

People can estimate the time of day by locating the position of the Sun in the sky. If you drew an imaginary line from north to south across the sky, the Sun would be near this position at 12:00 noon. Humans have used the relative positions of Earth, the Moon, and the Sun to measure time for thousands of years.

Around 3,000 B.C., the Babylonians devised a method of time-keeping using a counting technique based on increments of 60. They noticed that the Sun appeared to travel in a circular path through the sky. Because their counting technique was based on 60, they divided a circle into 360 parts called degrees. The symbol for degree (°) was taken from their symbol for the Sun.

**Earth movements measure time** Earth makes one complete turn on its axis every 24 hours. This spinning causes the Sun to appear to move across the sky from east to west, as shown in Figure 6. It takes 24 hours from when the Sun is highest in the sky (noon) until it is highest in the sky again (noon the next day). Each day as the Earth spins, it is daytime on the side of Earth facing the Sun and nighttime in Earth’s shadow.

![Figure 6](image_url) Earth spins on its axis one time per day. As it spins, the sunlit side of Earth is day and the shadow side is night.
**Time zones** If Earth spins approximately 360° in 24 hours, then it spins about 15° in one hour. This relationship was used to develop time zones. A **time zone** is an area 15° wide in which the time is the same. **Figure 7** shows the main time zones in the world. Ideally, time zones should be equal in size. However, for convenience, time zones are modified to fit around city, state, and country borders and other key sites.

**International Date Line** You can see that a problem would arise if you kept adjusting the time one hour earlier for every 15° time zone you travel from east to west. Eventually, the calculated time would be exactly 24 hours earlier. It cannot be two different days at the same spot, so a day is added to the time at the International Date Line (IDL). If it is Monday east of the date line, then it is Tuesday west of the date line.

The International Date Line is an imaginary line that extends through the middle of the Pacific Ocean (around islands, such as New Zealand) directly opposite the Prime Meridian. The Prime Meridian is an imaginary line that passes through Greenwich, England. All time is kept on a twenty-four hour clock based on Greenwich time, which is called Coordinated Universal Time (UTC). In some areas, this time is modified in summer so that there are more hours of daylight in the evening. This is referred to as Daylight Saving Time (DST).

**Think Critically** If you are in Russia immediately west of the IDL at 12:30 A.M. on Tuesday and fly east for one hour across the Bering Strait, what time and day will you arrive in Alaska?

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**Figure 7** The globe is divided into 24 time zones. Lines of longitude roughly parallel the locations of time-zone boundaries. Notice that the time is one hour earlier as you travel west through each time zone.
Rotation Recall that Earth spins one time on its axis each day. Rotation is the spinning of Earth on its axis, an imaginary line drawn from Earth’s North Pole to its South Pole. The apparent rising and setting of the Sun is due to Earth’s rotation.

The apparent movement of the Sun from noon one day until noon the next day is called a solar day. However, this period is longer than the time it takes Earth to rotate one time on its axis. This is because while Earth rotates, it also orbits the Sun.

Earth must rotate a bit more each day for the Sun to reach a position directly overhead at noon. However, if you measure time based on when a certain star rises above the horizon until that same star rises again, you will see a slightly shorter time period (23 h 56 m 4 s). This is called a sidereal day, and it is the true amount of time it takes for Earth to rotate once on its axis.

Revolution Earth travels around the Sun one time each year. Revolution is the motion of Earth in an elliptical orbit around the Sun. Figure 8 shows Earth’s annual revolution. As Earth revolves, the Sun appears to move through the skies compared to the fixed background positions of the stars.

The time it takes for the Sun to travel past all the fixed background stars is the same amount of time it takes Earth to complete one full revolution around the Sun, or one sidereal year. The ecliptic is defined as the plane of Earth’s orbit around the Sun. Because Earth is moving, the Sun also appears to move among the stars. The path that the Sun follows is also called the ecliptic. As Earth revolves around the Sun, the Sun appears to move past twelve constellations (star patterns) each year, which are called the zodiac, as shown in Figure 8. Each month, the constellation on the opposite side of the Sun relative to Earth cannot be seen because the area of sky near the Sun is too bright.

Interpret Which constellations are visible in November?
Why do seasons change?

Because Earth orbits the Sun in an ellipse with the Sun at one of the foci, Earth is closest to the Sun one time each year. Earth is closest to the Sun in January. Based on distance, you might expect January to be the warmest month. However, you know this is not true in the Northern Hemisphere. Something else must cause a change in the seasons.

As shown in Figure 9, seasons are caused by the tilt of Earth’s rotational axis. Earth’s axis is tilted 23.5° from a line perpendicular to the plane of Earth’s orbit. This tilt causes the angle at which the Sun’s rays strike Earth’s surface to vary from 0° to 90°. It also causes the number of hours of daylight to differ throughout the year.

**Sun angle** Earth’s rotational axis always tilts in the same direction as Earth revolves around the Sun. This causes the Northern and Southern Hemispheres to be tilted toward the Sun at different times of the year. The hemisphere tilted toward the Sun receives more direct sunlight than the hemisphere tilted away from the Sun. As a result, the Sun’s rays strike Earth’s surface at a more direct angle—closer to 90°—during the summer months. Summers in the Northern and Southern Hemispheres are opposite. Figure 9 shows that when it is summer in the Northern Hemisphere in June, it is winter in the Southern Hemisphere.

Because sunlight is more direct during the summer months, sunlight is more intense in the summer and warms a smaller area of Earth’s surface to a greater extent. The opposite is true during the winter when sunlight energy strikes Earth less directly and is dispersed over a larger area of Earth’s surface.
The Sun’s rays strike Earth’s surface at a more direct angle in the Northern Hemisphere and the days are longer when the North Pole is tilted toward the Sun. The days are shorter and the Sun’s rays strike Earth’s surface at a less direct angle in the Northern Hemisphere when the North Pole is tilted away from the Sun.

**Figure 10** The Sun’s rays strike Earth’s surface at a more direct angle in the Northern Hemisphere and the days are longer when the North Pole is tilted toward the Sun. The days are shorter and the Sun’s rays strike Earth’s surface at a less direct angle in the Northern Hemisphere when the North Pole is tilted away from the Sun.

**Hours of daylight** During the summer, the Sun is above the horizon for more hours than it is when school begins in the fall. As the school year progresses, the number of hours of daylight decreases each day until it reaches a minimum in the Northern Hemisphere near December 21.

When do you think the number of hours of daylight would be at a maximum in the Northern Hemisphere? This happens six months later, around June 21. As shown in Figure 10, the hemisphere that is tilted toward the Sun receives more hours of daylight each day than the hemisphere that is tilted away from the Sun. The longer period of daylight is a second reason why summer is warmer than winter.

**Solstices** A solstice occurs when Earth’s rotational axis is tilted directly toward the Sun or away from the Sun. Summer solstice for the Northern Hemisphere occurs on June 20 or 21 when Earth’s Northern Hemisphere is tilted directly toward the Sun. Around the summer solstice, there are more hours of daylight than at any other time of the year. The Sun’s rays strike the surface in the Northern Hemisphere at a more direct angle, as shown in Figure 10.

The winter solstice occurs on December 21 or 22 when Earth’s Northern Hemisphere is tilted away from the Sun. There are fewer hours of daylight than at any other time of the year around the winter solstice. The Sun’s rays strike the surface at a lower angle. In the Southern Hemisphere, the occurrence of the winter and summer solstices is reversed.
**Equinoxes** The North Pole of Earth’s rotational axis is always oriented in the same direction in space—toward the star Polaris. The movement of Earth around the Sun causes Earth’s axis to tilt toward the Sun in summer and away from the Sun in winter. However, there are two times during the year when Earth’s axis does not tilt toward or away from the Sun.

At an **equinox** Earth’s rotational axis is perpendicular to a line drawn from the center of Earth to the center of the Sun. The Sun’s rays strike the equator at a direct angle on the spring and the fall equinoxes, as shown in Figure 11. During the spring and the fall equinoxes, the number of daylight hours and the number of nighttime hours are nearly the same all over the world. In the Northern Hemisphere, the spring equinox occurs on March 20 or 21 and the fall equinox occurs on September 22 or 23. In the Southern Hemisphere, the occurrence of the two equinoxes is reversed. It is fall in the Southern Hemisphere in March and spring in September.

**Reading Check** Describe What is the difference between a solstice and an equinox?

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**Section 2 Review**

**Section Summary**

- Time is measured using movements of Earth, the Moon, and the Sun.
- There are 24 time zones on Earth separated into 15° increments.
- Earth travels in an elliptical orbit around the Sun.
- Earth rotates on a tilted axis.
- Earth’s tilted axis causes changes in the seasons.

7. **MAIN Idea** Identify how long it takes Earth to rotate 360° on its axis.
8. **Explain** how a solar day differs from a sidereal day.
9. **Compare and contrast** rotation and revolution.
10. **Think Critically** How would seasons and the number of daylight hours vary if Earth’s axis were not tilted? Explain using a diagram.

**Apply Math**

11. **Calculate** It takes Earth about 365.25 days to make one trip around the Sun. As it does this, Earth travels 360° in its orbit around the Sun. How many degrees does Earth travel each day?
12. **Calculate** If it is 4:15 P.M. in one time zone, what is the time two time zones to the west?
LAB

The Intensity of Sunlight

Objectives

- **Model** different angles at which the Sun’s rays strike Earth’s surface.
- **Compare and contrast** the amount of heat from light striking at different angles.

**Background:** Earth is warmed differently depending on the angle of the Sun’s rays striking its surface.

**Question:** How does the angle that the Sun’s rays strike Earth’s surface cause seasons to change?

**Preparation**

**Materials**
- 75-W bulb in a goosenecked lamp
- alcohol thermometers (2)
- sheets of construction paper, same color (2)
- protractor
- masking tape
- permanent marker

**Safety Precautions**

**WARNING:** Do not touch the lamp or lightbulb without safety gloves. They stay hot after being turned off. Handle thermometers carefully.

**Procedure**

1. Read the procedure and safety information, and complete the lab form.
2. Copy the data table shown on this page.
3. Label the thermometers with masking tape T-1 and T-2, and record their temperatures in the data table.
4. Fold the construction paper to form a pocket that will conceal the thermometer’s bulb.

5. Place T-1 in the pocket, and lay it on a desktop. Turn on the lamp. Position the lamp so that light strikes the pocket at an angle of 75°.
6. Record the temperature of T-1 at 10 min and again at 20 min.
7. Repeat steps 4–6 using T-2 and the second sheet of construction paper. Position the lamp so that it is the same distance from the pocket on the desktop, but aim the lamp at an angle of 20°.

**Conclude and Apply**

1. **Compare and contrast** the temperature readings of each thermometer.
2. **Infer** Which angle models the Sun’s position during the summer and which models the Sun’s position during the winter?
3. **Explain** how changes in the angle at which sunlight strikes Earth’s surface are the main causes of Earth’s changing seasons.

**Data Table**

<table>
<thead>
<tr>
<th>Thermometer</th>
<th>Original Temperature</th>
<th>Temperature at 10 min</th>
<th>Temperature at 20 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Communicate Your Data**

Compile your classmates’ data. Find the average temperatures—original, at 10 min, and at 20 min—for T-1 and T-2. Compare and contrast your results with the class averages. Determine any sources of error that might explain these differences.
Section 3

Earth’s Moon

**MAIN Idea** Tides, Moon phases, and eclipses result from interactions between the Moon, Earth, and the Sun.

**Real-World Reading Link** You might have noticed that features on the Moon’s surface resemble a face staring down from the sky. What are these features? The face is actually made of landscape features on the Moon’s surface, including dark-colored basins and light-colored highlands.

**Movement of the Moon**

You have seen the Moon move across the sky from east to west, just like the Sun. This apparent movement is, like the Sun’s, caused by Earth’s rotation. The Moon rises and sets at different times of the day and appears in different phases.

**Revolution and rotation** The Moon revolves around Earth. It takes 27.3 days for the Moon to revolve around Earth relative to a background star. This period of revolution is called a sidereal month. Because Earth also revolves around the Sun, it takes two more days for the Moon to line up with Earth and the Sun again. A complete cycle of Moon phases is 29.5 days. This period of revolution is known as a synodic month.

Many people think the Moon does not rotate because the same side is always facing Earth. This is not true. As shown in **Figure 12**, the Moon keeps the same side facing Earth because it takes 27.3 days to rotate once on its axis—the same amount of time that it takes to revolve once around Earth. You can model this behavior by having a friend move a ball around you while keeping the same side of it facing you. You will only see one side of the ball if the ball revolves and rotates at exactly the same rate.

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**Figure 12** The Moon revolves around Earth at exactly the same rate that it rotates on its axis. **Explain why the same side of the Moon always faces Earth.**
How does the Moon affect Earth?

If you have ever been to the ocean, you have probably noticed that over a period of several hours, the height of the ocean seems to change. One or two times a day, the water on the shore reaches its highest level and then recedes to its lowest level. Over weeks and months, the heights and times of the highest and lowest ocean levels vary.

These daily changes, called tides, are caused by Earth’s rotation and the combined gravitational forces of the Moon and the Sun. A **tide** is a rise or fall in the ocean surface. High tide occurs when gravity causes the ocean surface to rise. Low tide occurs when the ocean surface falls as the Moon and the Sun’s gravity pulls the ocean in two different directions.

**EXAMPLE Problem 1**

**Estimate Tide Times**  The Moon rises an average of 52.7 min later each day. If the time of high tide is known for one day, this formula can be used to determine when high tide will occur on the next day or any successive day.

\[ T_N = T_0 + N \times 52.7 \text{ min} \]

In this formula, \( T_0 \) is the original time of high tide on a given day and \( T_N \) is the time of high tide on any successive day. \( N \) is the number of days later for which you wish to determine the time of high tide. If the original high tide is at 1:00 P.M., find the time of high tide in 7 days.

**Identify the Unknown:** \( T_N \) = the time of high tide in 7 days

**List the Knowns:**
- \( T_0 \) = original time of high tide = 1:00 P.M.
- \( N \) = the number of days later = 7

**Set Up the Problem:**

\[ T_N = T_0 + N \times 52.7 \text{ min} \]

**Solve the Problem:**

Substitute the known values into the equation for time.

\[ T_N = 1:00 \text{ P.M.} + 7 \times 52.7 \text{ min} = 1:00 \text{ P.M.} + 369 \text{ min} \]
\[ T_N = 1:00 \text{ P.M.} + 6 \text{ h } 09 \text{ min} = 7:09 \text{ P.M.} \]

**Check the Answer:** If you consider the length of an hour, then 52.7 minutes is just short of an hour. A 6-hour change in the tides over 7 days time is a good estimation.

**PRACTICE Problems**

13. Low tide is the best time to hunt for seashells. If you see that the tide is low at noon on Thursday, when during the day will it be low on the following Sunday?

14. **Challenge** If it is high tide at midnight on Saturday, at what time did high tide occur one week earlier?
Causes of tides A tide on Earth is caused by the gravitational attraction between the Moon and the Sun and large bodies of water on Earth. These gravitational forces can create a tidal bulge. In large bodies of water, this bulge can cause sea levels to rise up to 2 meters per day. A rise in sea level is called high tide. Six hours later as the sea level falls, a tidal depression produces a low tide.

High tide and low tide The gravitational attraction between the Moon, the Sun, and large bodies of water depends on the distance between them. For example, the closer the Moon is to water, the stronger the pull. As a result, water on the side of Earth facing the Moon is pulled more strongly toward the Moon, producing a bulge and high tides, as shown in Figure 13. As Earth rotates, these forces are balanced and high tides occur on the opposite side of Earth. Where a bulge is absent, low tides coincide with tidal depressions, as shown in Figure 13.

Spring tides and neap tides As Earth rotates and the Moon revolves, different areas experience high and low tides. The Sun is much more massive than the Moon, but it is also much farther away. Because of this, the Moon has a greater effect on Earth’s tides than the Sun. However, the Sun does have some affect on tides. It can strengthen or weaken the Moon’s tidal effect. When the Moon and the Sun are aligned, they pull together with a greater force, producing stronger tides called spring tides, as shown in Figure 13. However, when the Moon and the Sun are at a right angle relative to Earth, they produce weaker tides called neap tides.

Moonlight The Moon shines because it reflects sunlight from its surface. Just as half of Earth experiences day while the other half experiences night, half of the Moon is illuminated while the other half is dark. As the Moon orbits Earth, different areas of the side that faces Earth reflect sunlight, causing the Moon’s appearance to change. A moon phase reflects the change in appearance of the Moon as seen from Earth. The phase that you see depends on the positions of the Moon, Earth, and the Sun.
**Moon phases** During a new moon, the Sun shines on the side of the Moon facing away from Earth. The side of the Moon facing Earth receives no sunlight. The Moon is in the sky, but it cannot be seen. A new moon occurs when the Moon is between Earth and the Sun.

**Waxing phases** After a new moon, moon phases are said to be waxing—the portion that we see appears larger each night, as shown in Figure 14. A few days after a new moon, the first phase that we see is called the waxing crescent. About a week after a new moon, one-half of the Moon is visible—or one-quarter of the Moon’s surface—is lit. This moon phase is called the first-quarter moon.

The moon is in the waxing gibbous phase from the first-quarter moon until full moon. A full moon occurs when the side of the Moon facing us is entirely illuminated, which means the side that we see is fully lit by sunlight. At this time, Earth is between the Moon and the Sun.

**Reading Check** Explain what happens when the Moon is waxing?
Waning phases  After a full moon, the illuminated area that we see appears smaller each night. The phases are waning. About three weeks after a new moon, one-half of the Moon—the opposite side from the first-quarter moon—is lit. When a small sliver of the side of the Moon facing Earth is lit, the Moon is in the waning crescent phase.

A complete cycle of moon phases, as shown in Figure 14, takes about 29.5 days, which is almost equal to one month. The word month is derived from the same Latin root as Moon, *mensis*. If a month begins with a full moon, it is possible that the same month will end with a second full moon. For this to happen, the month would have to be either 30 or 31 days long. It is common to call a second full moon in the same month a blue moon.

**Eclipses**

Imagine that you lived thousands of years ago when very little was known about the Sun. Would you have been concerned if the sky suddenly went dark during the day? Think of how humans from long ago must have reacted when the Moon passed between Earth and the Sun blocking light and heat, as it does during an eclipse.

**Cause of eclipses** We now know what causes eclipses of both the Sun and the Moon. Eclipses occur when Earth or the Moon temporarily blocks light traveling toward another object. Sometimes, during a new moon, the shadow cast by the Moon falls on Earth, completely blocking out the Sun. During a full moon, a shadow cast by Earth falls on the Moon, completely blocking out the Moon’s reflected light. Eclipses occur when the Sun, the Moon, and Earth are perfectly aligned. Because the Moon’s orbit is tilted about 5° from the ecliptic—the plane of Earth’s orbit around the Sun—eclipses only occur a few times per year.

In order for the Moon to block out the Sun, it must appear to be the same size. In fact, the diameters of the Sun and the Moon appear to have almost the same size when viewed from Earth because the Sun is so far away. Because the Sun is about 400 times larger than the Moon, it also must be about 400 times farther from Earth for the Moon to completely block the Sun.
Solar eclipses A solar eclipse occurs when the Moon moves directly between the Sun and Earth and casts a shadow on Earth. The darkest portion of the Moon's shadow is called the umbra, as shown in Figure 15. The only portion of the Sun that is visible during a total solar eclipse is part of its atmosphere, which appears as a pearly white glow around the edge of the eclipsing Moon. This is the only time the entire disk of the new moon phase can be photographed. It appears black against the Sun.

The penumbra (puh NUM bruh) is a lighter shadow on Earth’s surface that surrounds the umbra. People within the area covered by a penumbra experience a partial solar eclipse. The penumbra affects a much larger area than the umbra, as shown in Figure 15.

WARNING: Never look directly at the Sun. The light can permanently damage your eyes.

Reading Check Describe the relative positions of the Moon, the Sun, and Earth during a total solar eclipse.

Lunar eclipses A lunar eclipse occurs when Earth passes between the Sun and the Moon and casts a shadow on the Moon. A lunar eclipse begins when the Moon moves into Earth’s penumbra. As the Moon continues to move, it enters Earth’s umbra, and you see a curved shadow on the Moon’s surface. When the Moon moves completely into Earth’s umbra, a total lunar eclipse occurs, as shown in Figure 16. A lunar eclipse can only occur when the Moon enters a full moon phase. During a full moon phase, Earth blocks light from the Sun that would otherwise reflect off of the Moon’s surface.

A partial lunar eclipse can occur when only a portion of the Moon moves into Earth’s umbra. The remainder of the Moon is in Earth’s penumbra and therefore receives some direct sunlight. A partial lunar eclipse can also occur when the Moon is partially or totally within Earth’s penumbra.

The Moon sometimes becomes red during an eclipse because light from the Sun is scattered and refracted by Earth’s atmosphere. Longer wavelength red light is affected less than shorter wavelengths, so more red light falls on the Moon.
Frequency of eclipses  A total solar eclipse, as shown in Figure 17, can occur as often as twice a year. Most people, however, live their entire lives without witnessing one. You may never see a total solar eclipse, but it is almost certain you will have an opportunity to see a total lunar eclipse. Figure 18 shows a lunar eclipse in progress.

The reason why it is so rare to view a total solar eclipse is that only those people in the small area where the Moon’s umbra strikes Earth can see a total solar eclipse. And even then, the skies must be clear. In contrast, opportunities to witness a total lunar eclipse are much more frequent. During a lunar eclipse, all of the Moon is in Earth’s umbra. As a result, anyone on the night side of Earth can see a lunar eclipse. Notice the umbra is much smaller during a total solar eclipse when compared to a total lunar eclipse. Even on the daylight side of Earth, relatively few people have the opportunity to see a solar eclipse.
The Moon’s Surface

When you look at the Moon, you can see many of its larger surface features. Craters, maria, and mountains can be seen easily through a small telescope or a pair of binoculars. What are these different features, how did they form, and what do they tell us about the Moon’s history and interior?

Craters, maria, and mountains Impacts by asteroids and comets formed many depressions on the Moon’s surface. These depressions, which are called craters, formed throughout the course of the Moon’s history. Surrounding many craters are ray patterns produced by lighter-colored material from just below the lunar surface that was blasted out on impact, like the patterns visible in Figure 19. This lighter material then settled on top of the darker surface material around the craters.

During some of the impact events as these craters formed, cracks opened up in the crust. These cracks became conduits for lava, which erupted and filled in the craters creating surface features called maria (MAH ree uh). Maria are the dark-colored, flat, lava-filled regions on the Moon’s surface. Surrounding these maria are areas that were thrust upward from impact events. These mountainous regions are called highlands.

Apollo astronauts sampled igneous rocks from maria. Scientists determined that the rocks are 3–4 billion years old. These are the youngest rocks on the Moon. This indicates that the craters formed after the Moon’s surface cooled. However, the maria formed early enough in the Moon’s history that molten rock still remained in the Moon’s interior at that time. This is no longer true. Today, the Moon is composed of only solid layers.

Regolith When NASA scientists started to plan for missions to the Moon, they were concerned about whether the Moon’s surface would be able to support spacecraft. To test this, seven unoccupied Surveyor spacecraft were sent to land on the Moon’s surface to determine the feasibility of lunar landings in the future. One Surveyor craft actually bounced a few times as it landed on the side of a crater. What was this material on which the spacecraft had landed?

Scientists would soon discover that the Surveyor spacecraft had landed on a material called regolith. Regolith is a layer of dusty lunar material produced by collisions between asteroids and comets and the Moon. In some locations on the Moon’s surface, this regolith is almost 40 meters thick; in other locations, it is only a few centimeters thick. Some regolith is coarse, and some is a fine dust. If you watch astronauts walking on the Moon, you will notice that they often kick up a lot of dust.
The Moon's Interior

The presence of maria on the Moon's surface helps scientists to infer the structure of the Moon's interior. If cracks in the crust were produced by impacts and if lava erupted onto the surface, then the interior of the Moon just below its surface must have been molten at that time. It is believed that this was the case and that as the Moon cooled to what it is like today, its interior separated into layers.

Other information about the Moon's interior comes from seismographs left on the Moon by Apollo astronauts. Seismographs measure vibrations on the Moon's surface. Just as earthquakes allow scientists to map Earth's interior, moonquakes have helped scientists to study the Moon's interior. Figure 20 shows a model of the Moon's interior. The Moon is composed of three solid layers, which include a crust, a mantle, and a core.

Recent Exploration

More than 20 years after the Apollo program ended, the Clementine spacecraft was placed in lunar orbit. Clementine compiled a detailed map of the Moon's surface, including the South Pole-Aitken Basin, which is the oldest identifiable impact feature on the Moon's surface. It is also the largest and deepest impact basin or depression found so far anywhere in the solar system, measuring 12 km in depth and 2,500 km in diameter.

Because the angle of sunlight is always low near the poles, much of Aitken Basin remains in the Moon’s shadow as it rotates. This location is therefore colder, and ice deposits from impacting comets have collected here. The Clementine spacecraft, the Lunar Prospector spacecraft, and the LCROSS satellite have all collected evidence that supports the hypothesis that water-ice has accumulated in the basin.

Vocabulary

Impact

Science usage the collision of a meteor, an asteroid, or a comet with another object like a planet or moon
Scientists hypothesize that a meteor impact event killed the dinosaurs.

Common usage the effect that someone or something has on another person, group of people, or object
The teacher had an impact on the students' decision to pursue astronomy in college.
According to the giant impact theory, the Moon formed after a large, Mars-sized body collided with the primitive Earth. The collision melted and vaporized some of Earth's crust and mantle. Some of this material eventually condensed to form the Moon.

**Figure 21** According to the giant impact theory, a large, Mars-sized body collided with primitive Earth approximately 4.4 billion years ago. The violent collision melted and vaporized some of Earth's crust and mantle and sent it into space.

**Clementine** Data from *Clementine* confirmed that the crust on the side of the Moon facing Earth is much thinner than crust on the far side. Data also suggested that the crust thins under impact basins where high density materials have been discovered. *Clementine* also provided information on the mineral content of Moon rocks.

**Lunar Prospector** In 1998, the *Lunar Prospector* spacecraft orbited the Moon, taking photographs of the Moon's surface. Maps made using these photographs confirmed the *Clementine* data. Also, data from *Lunar Prospector* indicated that the Moon has a small, iron-rich core about 600 km in diameter. *Lunar Prospector* also conducted a detailed study of the Moon's surface searching for clues as to its origin and structure. In 2009, NASA's *Robotic Lunar Exploration Program* launched the *Lunar Reconnaissance Orbiter* to map the Moon's surface in search of landing sites for future missions to the Moon.

**Origin of the Moon**

Prior to the data obtained from the *Apollo* space missions, there were three hypotheses about the Moon's origin. The first was that the Moon was captured by Earth's gravity (the capture hypothesis). It had formed elsewhere and wandered near Earth. The second hypothesis was that the Moon condensed from the same material as Earth during the early evolution of the solar system (the binary accretion hypothesis). The third hypothesis was that a huge mass of molten material was ejected from Earth while Earth was still molten (the fission hypothesis). The goal of one *Apollo* mission was to help evaluate the validity of these three hypotheses. Instead, the mission showed that none of the hypotheses could explain the Moon's composition. **Figure 21** illustrates the fourth explanation, the giant impact theory, which gained support from the *Apollo* missions.
**Giant Impact Theory**  Data gathered by the Apollo missions led many scientists to form a new giant impact theory, which has gained wide acceptance among astronomers. According to this theory, the Moon formed about 4.4 billion years ago when a Mars-sized object collided with Earth. After colliding, the cores of the two bodies combined and settled toward the center of primitive Earth. Gas and other rock were thrown into orbit. Some fell back to Earth, but the remainder condensed into a large mass, forming the Moon.

This theory helps to explain how the Moon and Earth are similar, yet not similar enough to have formed from the same condensing mass. If the core of the Mars-sized body were added to the core of Earth, this explains why the Moon’s composition is like Earth’s mantle and why the Moon has a much smaller central core than expected.

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**Section 3 Review**

**Section Summary**

- The Moon and the Sun cause Earth’s tides.
- As the Moon revolves, the Sun illuminates different amounts of the side facing Earth, causing a lunar phase cycle.
- The alignment of Earth, the Moon, and the Sun produces eclipses.
- The Moon’s surface has craters, mountains, and maria.

15. **MAIN Idea** Illustrate and explain each of the Moon’s phases.
16. **Compare and contrast** solar and lunar eclipses.
17. **Describe** how surface features on the Moon help to infer its history.
18. **Explain** how tides form.
19. **Think Critically** Why is it important to future space exploration if the Moon has water-ice near its surface?

**Apply Math**

20. **Calculate** Suppose scientists estimate that the amount of water frozen at the Moon’s south pole is 100,000 m³. If this deposit were spread over an area measuring 160 m by 125 m, how many meters deep would the deposit be?
LAB The Moon’s Surface Features

Objectives
- Identify prominent surface features on the Moon.
- Determine the relative ages of features on the Moon.
- Locate the Apollo landing sites on the Moon.

Background: When you look at a full moon in the night sky, you can see light and dark areas. When you look through binoculars or a small telescope, you can see many craters and dark-colored maria. Many craters are named after philosophers and scientists. The maria are named for what early scientists thought they saw there; for example, Oceanus Procellarum is Latin for “ocean of storms.” Can you tell the difference between an old crater and one that has formed more recently? If craters are found on a maria, which of the features is older? If one crater partially covers another, which one formed first?

Question: Can you determine the relative age of the Moon’s surface features?

Make a Plan
1. Read the procedure and safety information, and complete the lab form.
2. Research surface features on the Moon.
3. Familiarize yourself with some of the more prominent surface features of the Moon. A few examples have been provided in the photos below and the data table on the next page.
4. Identify several surface features that you wish to investigate in more detail.
5. Create a table or a spreadsheet to compare and contrast these surface features and to try to determine their relative ages.
YOUR DATA

Compare your map of the Moon with the maps labeled by other students in your class. Discuss why individual maps may be labeled differently or why map illustrations may look different.

Test the Model

1. Look for examples of younger craters (those with sharp sides and peaks in the center) and examples of older craters (those with sides that are worn down or missing).
2. Use the Internet to locate a large-scale labeled map of the Moon. Locate, identify, and label the prominent surface features that you identified in your table or spreadsheet.

Conclude and Apply

1. Infer from your study of the maps of surface features on the Moon whether Copernicus Crater or Grimaldi Crater is older. Do the same for Fra Mauro Crater and Tycho Crater. Explain each answer.
2. Explain Based on your observations of surface features, propose a site where NASA scientists should attempt to land spacecraft in the future. Is there a location that would be best suited to build a lunar space station?

Follow Your Plan

1. Describe each of the surface features that you studied on the map.
2. Identify any surface features that appear to overlap on the map, and determine which of features formed first.

Analyze Your Data

<table>
<thead>
<tr>
<th>Maria</th>
<th>Description</th>
<th>Apollo Landing Sites</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mare Crisium</td>
<td></td>
<td>11-Mare Tranquillitatus</td>
<td></td>
</tr>
<tr>
<td>Mare Tranquillitatus</td>
<td></td>
<td>12-Oceanus Procellarum</td>
<td></td>
</tr>
<tr>
<td>Craters</td>
<td>Highlands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kepler</td>
<td>Alps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plato</td>
<td>Mt. Hadley</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tycho</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copernicus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grimaldi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fra Mauro</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data Table

Compare your map of the Moon with the maps labeled by other students in your class. Discuss why individual maps may be labeled differently or why map illustrations may look different.
As he declared in “one small step for man, one giant leap for mankind,” astronaut Neil Armstrong became the first person to step onto the surface of the Moon. From 1968 to 1972, a total of six Apollo missions successfully landed on the lunar surface. As shown in Figure 1, Apollo astronauts collected data and made observations that expanded scientific frontiers.

An important study  Why was it so important to land on the Moon? With no plate tectonics, no volcanism, and no atmosphere, the surface of the Moon holds the complete geologic record of its 4.4 billion years since formation. By studying the Moon, scientists learn about the evolution of our own planet and the conditions in which early life on Earth might have first appeared.

Data collected during the Apollo program led to the discovery that the Moon’s interior is layered, similar to Earth’s interior. These layers include a crust, a mantle, and a core. Rocks sampled from the lunar surface are old. In fact, the youngest rocks on the Moon are older than the oldest rocks on Earth.

Advances in science and technology  The last Apollo mission left the Moon in 1972. Since then, scientists have continued to study the Moon, sending unpiloted probes and satellites to map its surface. Scientists have also been analyzing new data about how the solar system formed. Advances in computers and technology have made it possible to study the samples brought back by the Apollo astronauts in ways previously not thought possible.

Scientists have developed new hypotheses about how the Moon was formed and how life first appeared on Earth. Investigations of the lunar surface are now considered critical to help scientists understand the early history of the solar system.

Future missions  NASA’s space shuttle program entered retirement in 2010. NASA is now designing the newest fleet of spacecraft to take astronauts to the Moon, to Mars, and possibly beyond. NASA is also exploring the possibility of building space stations for extended stays on the Moon and Mars. NASA will continue studying scientific discoveries from the past in order to expand scientific frontiers in the future.
**Section 1 Earth in Space**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition/Description</th>
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</thead>
<tbody>
<tr>
<td>ellipse (p. 920)</td>
<td></td>
</tr>
<tr>
<td>sphere (p. 918)</td>
<td></td>
</tr>
</tbody>
</table>

**MAIN Idea**

- Earth revolves in an elliptical orbit around the Sun.
- Earth has a spherical shape.
- Earth's magnetosphere deflects harmful solar winds.
- Earth orbits the Sun in an elliptical orbit.
- Venus, Earth, and Mars differ in size and atmospheric conditions.

**Section 2 Time and Seasons**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition/Description</th>
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<tbody>
<tr>
<td>ecliptic (p. 924)</td>
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<tr>
<td>equinox (p. 927)</td>
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<tr>
<td>revolution (p. 924)</td>
<td></td>
</tr>
<tr>
<td>rotation (p. 924)</td>
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<tr>
<td>solstice (p. 926)</td>
<td></td>
</tr>
<tr>
<td>time zone (p. 923)</td>
<td></td>
</tr>
</tbody>
</table>

**MAIN Idea**

- Earth rotates on a tilted axis around the Sun, which causes a change in the length of a day and the seasons.
- Time is measured using movements of Earth, the Moon, and the Sun.
- There are 24 time zones on Earth separated into 15° increments.
- Earth travels in an elliptical orbit around the Sun.
- Earth rotates on a tilted axis.
- Earth's tilted axis causes changes in the seasons.

**Section 3 Earth’s Moon**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>lunar eclipse (p. 934)</td>
<td></td>
</tr>
<tr>
<td>maria (p. 936)</td>
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</tr>
<tr>
<td>moon phase (p. 931)</td>
<td></td>
</tr>
<tr>
<td>regolith (p. 936)</td>
<td></td>
</tr>
<tr>
<td>solar eclipse (p. 934)</td>
<td></td>
</tr>
<tr>
<td>tide (p. 930)</td>
<td></td>
</tr>
</tbody>
</table>

**MAIN Idea**

- Tides, Moon phases, and eclipses result from interactions between the Moon, Earth, and the Sun.
- The Moon and the Sun cause Earth's tides.
- As the Moon revolves, the Sun illuminates different amounts of the side facing Earth, causing a lunar phase cycle.
- The alignment of Earth, the Moon, and the Sun produces eclipses.
- The Moon's surface has craters, mountains, and maria.
Use Vocabulary

Match each phrase with the correct term from the Study Guide.

21. dark-colored, relatively flat areas on the Moon
   A) equator
   B) mid-latitudes
   C) poles
   D) rotational axis

22. Earth spinning on its axis
   A) equator
   B) mid-latitudes
   C) poles
   D) rotational axis

23. the rise and fall in Earth's oceans caused by the gravity of the Moon and the Sun
   A) partial lunar
   B) partial solar
   C) total lunar
   D) total solar

24. a round, three-dimensional object, the surface of which is the same distance from the center in all directions
   A) partial lunar
   B) partial solar
   C) total lunar
   D) total solar

25. BIG Idea Earth moving in orbit around the Sun
   A) partial lunar
   B) partial solar
   C) total lunar
   D) total solar

26. eclipse that occurs during a new moon
   A) partial lunar
   B) partial solar
   C) total lunar
   D) total solar

27. occurs when Earth's axis points directly toward or away from the Sun
   A) partial lunar
   B) partial solar
   C) total lunar
   D) total solar

28. the change in the appearance of the Moon as seen from Earth
   A) partial lunar
   B) partial solar
   C) total lunar
   D) total solar

29. the apparent path of the Sun
   A) partial lunar
   B) partial solar
   C) total lunar
   D) total solar

Check Concepts

30. How long is the lunar phase cycle?
   A) 14 days
   B) 27.3 days
   C) 29.5 days
   D) 365 days

31. In the Northern Hemisphere, Earth's rotational axis points directly toward the Sun during the
   A) summer solstice.
   B) winter solstice.
   C) fall equinox.
   D) spring equinox.

32. Where is Earth's circumference the greatest?
   A) equator
   B) mid-latitudes
   C) poles
   D) rotational axis

33. Which eclipse do you experience if you are standing in the Moon's umbra?
   A) partial lunar
   B) partial solar
   C) total lunar
   D) total solar

34. Which phase occurs when the Moon is on the opposite side of Earth from the Sun?
   A) partial lunar
   B) partial solar
   C) total lunar
   D) total solar

35. Which gas contributes to the extreme greenhouse effect on Venus?
   A) carbon dioxide
   B) oxygen
   C) nitrogen
   D) sulfur dioxide

36. On average, how many degrees of longitude are contained in one time zone?
   A) 0.5°
   B) 15°
   C) 23.5°
   D) 30°

37. Which occurs a few days after a full moon?
   A) waning crescent
   B) waxing crescent
   C) waning gibbous
   D) waxing gibbous

38. Which season begins around December 21 in the Southern Hemisphere?
   A) spring
   B) summer
   C) fall
   D) winter
Interpret Graphics

39. Make an illustration showing how magnetic force lines surrounding Earth are similar to those surrounding a bar magnet.

Use the table below to answer question 40.

<table>
<thead>
<tr>
<th>Earth’s Physical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (pole to pole)</td>
</tr>
<tr>
<td>Diameter (through equator)</td>
</tr>
<tr>
<td>Circumference (poles)</td>
</tr>
<tr>
<td>Circumference (equator)</td>
</tr>
<tr>
<td>Average distance to the Sun</td>
</tr>
<tr>
<td>Average distance to the Moon</td>
</tr>
</tbody>
</table>

40. How many times farther from Earth is the Sun, compared to the Moon?

Think Critically

41. Infer why more craters are present on the Moon’s surface than on Earth’s. Hint: Consider the presence of an atmosphere.

42. Theme Focus Explain why seasons are opposite in the Northern Hemisphere and in the Southern Hemisphere.

43. Explain why a lunar base would best be built on a lunar plateau that is always in sunlight.

44. Analyze why the Moon has a greater effect on Earth’s tides than the Sun, even though the Sun is much more massive.

45. Explain why Alaska receives nearly 24 hours of daylight in the summertime and nearly 24 hours of darkness in the wintertime.

46. Describe two factors that influence Earth’s magnetic field.

47. Develop an explanation for how the thickness of the Moon’s crust might play a part in the fact that the side of the Moon facing Earth has more maria than the side facing away from Earth.

48. Summarize the steps of the giant impact theory.

49. Compare and contrast the Moon’s interior structure with Earth’s interior structure.

Apply Math

Use the figure below to answer questions 50–51.

50. Model If you are making a scale model of the Moon, which has a diameter of approximately 3,500 km, what scale should you use to create a model that is approximately 35 cm in diameter?

51. Calculate Using your scale from question 48, what would the thicknesses be, in centimeters, for the near side crust and the far side crust?
Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the figure below to answer question 1.

1. Which theory explaining the Moon’s origin is illustrated above?
   A. binary accretion theory
   B. capture theory
   C. fission theory
   D. giant impact theory

2. How far is Earth’s magnetic axis tilted from its geographic axis?
   A. 5°
   B. 11.7°
   C. 15°
   D. 23.5°

3. What kind of eclipse occurs when Earth blocks light from reaching the Moon?
   A. solar
   B. new
   C. full
   D. lunar

4. In what way are Venus and Earth similar?
   A. atmospheric density
   B. liquid water oceans
   C. presence of greenhouse gases in atmosphere
   D. surface temperature

Use the figure below to answer question 5.

5. What day is illustrated in the figure above?
   A. spring equinox
   B. fall equinox
   C. the summer solstice in the Northern Hemisphere
   D. the winter solstice in the Northern Hemisphere

6. Which is a group of constellations through which the Sun appears to move?
   A. ecliptic
   B. equinox
   C. solstice
   D. zodiac

7. Which Earth layer is responsible for generating the strong magnetic field around Earth?
   A. inner core
   B. outer core
   C. mantle
   D. crust

8. During which month of the year is Earth farthest from the Sun?
   A. January
   B. April
   C. July
   D. September
9. How much longer is a sidereal month than a lunar phase cycle?

Use the figure below to answer question 10.

10. If it is 9:00 AM in New York City, what time is it in San Francisco?

11. If the collision of two planetary-sized objects (Earth and another object) formed the Moon, why is the Moon’s solid core so small compared to Earth’s iron-rich core?

12. What may have caused the CO₂ percentage difference between Earth’s atmosphere compared to the atmospheres of Venus and Mars?

13. What is the International Date Line?

14. Part A Which one of the features in the image above is older—the crater or the lava flow? Part B How does interpretation of the Moon’s surface features help astronomers to understand the Moon’s history?

15. How does the tilt of Earth’s rotational axis affect the length of a day throughout the year?

16. How have recent Moon missions helped scientists to understand the Moon’s formation?