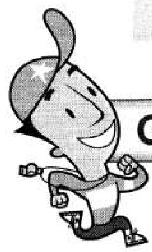
Name:	Class:	Date:

36 Gravity and Our Solar System

8.3-C28



Getting the Idea

Key Words
gravity
Newton's law of universal gravitation
mass
inertia

During the 1600s, Sir Isaac Newton investigated why objects fall to Earth. Newton realized that a force acts on objects and pulls them toward Earth's center. Newton theorized that this force, called gravity, acts everywhere in the universe, not just on Earth. Using Newton's theories, astronomers were able to explain the motions of the planets and other phenomena in the universe.

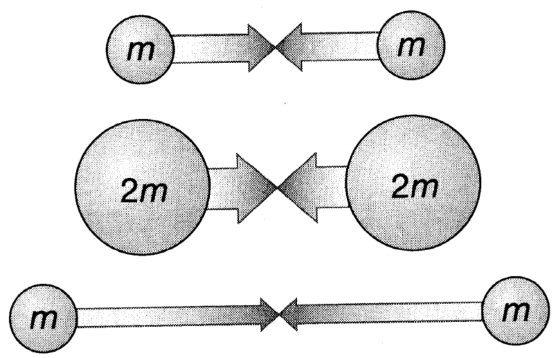
The Law of Universal Gravitation

As you learned in Chapter 2, **gravity** is an attractive force that works to pull objects together. **Newton's law of universal gravitation** states that the force of gravity acts between all objects in the universe. A gravitational attraction exists between any two objects, from the smallest particle of an atom to the largest star.

Gravity is the force that keeps you grounded on Earth and prevents you from floating off into space. The law of universal gravitation explains that just as you are attracted to Earth, Earth is attracted to you as well. You also share an attractive force with all the other objects around you. However, your gravity is much smaller when compared to that of Earth, so it is not even noticed.

The strength of the gravitational force between two objects depends on two factors: mass and distance. Recall that **mass** is the amount of matter in an object. The more mass an object has, the greater the gravitational attraction it exerts on another object. For small objects, such as two apples, this force is barely measurable. However, for larger objects, such as Earth and a weather satellite, the force is much greater. Earth's mass is so great that it exerts a strong gravitational force on a satellite. This is why a satellite can remain in orbit around Earth.

Distance is the other thing that affects the force of gravity between two objects. The force of gravity between two objects is inversely related to the distance between them. That is, as the distance between objects increases, the force of gravity between them decreases. As the distance decreases, the force of gravity increases. In other words, as objects move closer together, their pull on each other grows. As objects move farther apart, their pull on each other weakens. A good example is a traveling spacecraft. As the spacecraft moves away from Earth, the pull of Earth's gravity becomes weaker. At the same time, as the spacecraft moves closer to another planet, the pull of that planet's gravity increases.

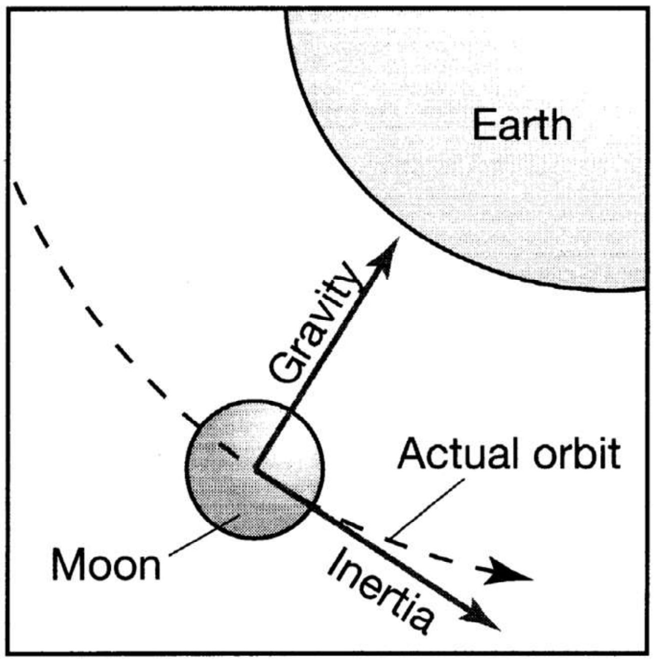


A satellite launched in March 2009 can measure the pull of Earth's gravity with great precision. Scientists plan to use data from this satellite to determine the thickness of ice sheets. They will also use it to study the movements of Earth's oceans. With these observations, they will build better computer models of how climate change will affect Earth.

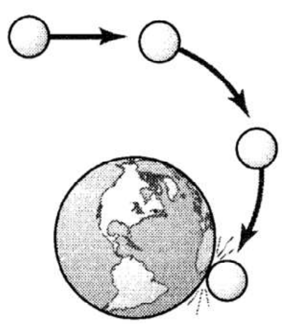
Gravity and Planetary Orbits

Since gravity pulls objects toward each other, what keeps the planets from crashing into the sun? Newton's first law of motion answers this question. As you learned in Lesson 13, this law states that an object at rest will stay at rest, and an object in motion will stay in motion, unless an unbalanced force acts on the object. Recall also from Lessons 13 and 14 that **inertia** is the tendency of an object to resist a change in its motion. Inertia is what keeps a heavy box in place on a ramp, where a light object would slide down. Inertia also keeps moving objects in motion along a straight path. The more mass the object has, the greater its inertia.

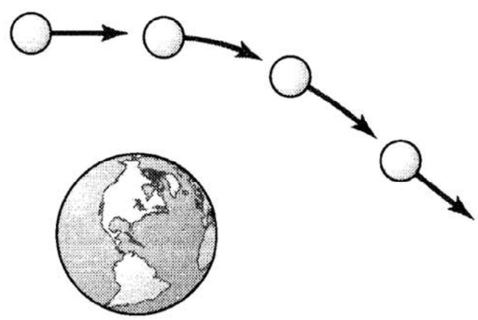
The diagram below shows how inertia and gravity work together to keep the moon orbiting Earth. First, the moon's inertia causes it to travel continuously in a straight line. At the same time, Earth's gravity is pulling the moon straight toward Earth. These combined forces cause the moon to move in a curved path around Earth. The moon would fly off into space without gravity.



The moon continues to orbit Earth because the moon's inertia and Earth's gravity are balanced. If Earth's gravity was too strong, the moon would crash into Earth. If the moon's inertia was too strong, it would travel away from Earth and out into space.



Gravity too strong—
object crashes

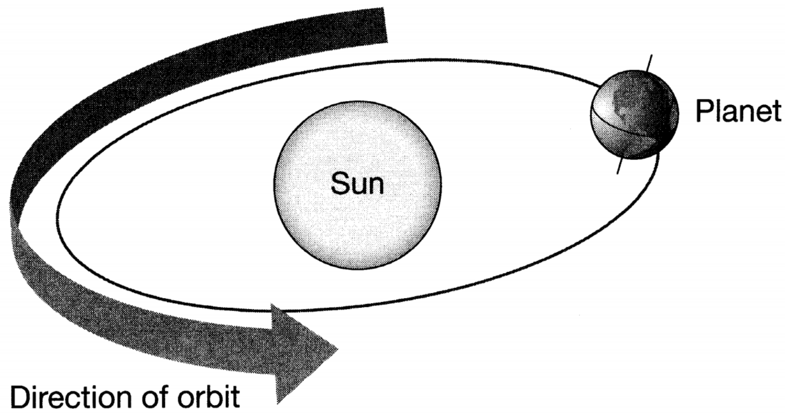


Inertia overcomes gravity—
object flies away

Did You Know?

Some comets have orbits that bring them repeatedly into the inner solar system. The most famous is Comet Halley, which appears every 76 years. Halley was last seen in 1986, and it will reappear in 2061. A more recent comet was Comet Hale-Bopp, which was seen in 1997. Hale Bopp will not be visible again until the year 4397.

You have seen how inertia and gravity work together to keep the moon in orbit around Earth. These are the same forces that keep the planets of the solar system in orbit around the sun. These orbiting planets, and the moons that orbit around them, travel in closed elliptical paths. An ellipse is shaped like an oval or flattened circle. The idea that the planets move around the sun in elliptical orbits was developed in the early 1600s by German astronomer Johannes Kepler. Before that, astronomers thought that the orbits of the planets were perfect circles.



Lesson

37 Earth's Motions

6.3-C9, 8.3-C29

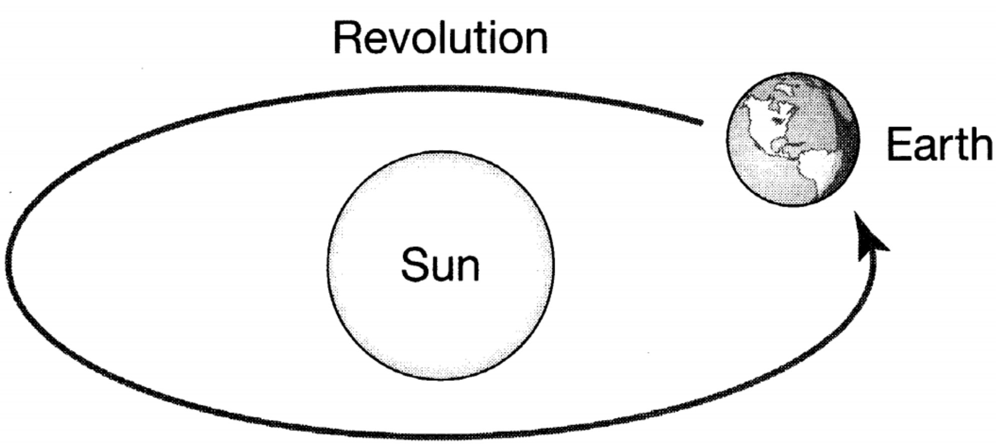
Getting the Idea

Key Words
revolve
period of revolution
rotate
axis
period of rotation
equator
Northern Hemisphere
Southern Hemisphere
solstice
equinox

Earth travels through space at a high speed. Earth is one of the many objects in the solar system that travel around the sun in elliptical orbits. In addition to orbiting the sun, Earth rotates around an imaginary line called its axis. These two movements determine the length of a year and of a day on Earth. Earth's tilt on its axis and orbit around the sun are responsible for Earth's seasons.

Length of a Year

Recall that Earth and the other objects in the solar system **revolve**, or circle, around the sun in elliptical orbits. Their movement around the sun is called revolution. An object's path around the sun is its orbit. The time in which a planet completes one orbit around the sun is its **period of revolution**. A planet's period of revolution determines the length of its year. For example, Earth takes 365.25 days to travel around the sun. Therefore, one year on Earth is equal to 365.25 days. The diagram below shows the path Earth takes as it travels around the sun while completing one year.



Did You Know?

Because it turns so slowly on its axis, Venus does not have weather in the sense that Earth does. The temperature is very high but does not change. However, Venus does have dense clouds and high-energy lightning.

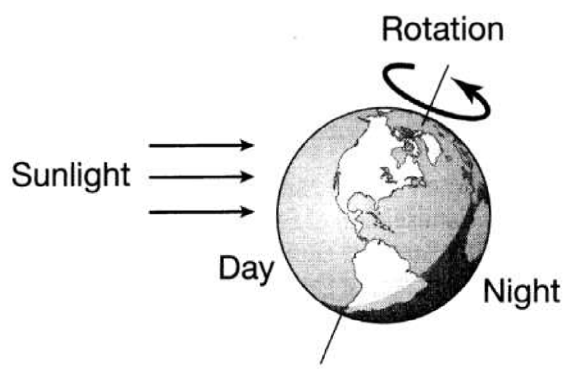
Planets that are farther from the sun have longer years, or longer periods of revolution, than the planets near the sun. The chart below shows the periods of revolution of all eight planets in our solar system.

Planet	Period of Rotation
Mercury	88 Earth days
Venus	224 Earth days
Earth	365.25 Earth days
Mars	687 Earth days

Planet	Period of Rotation
Jupiter	11.86 Earth years
Saturn	29.46 Earth years
Uranus	84.07 Earth years
Neptune	164.8 Earth years

Length of a Day

All the planets spin, or **rotate**, on their axes. An **axis** is an imaginary line that runs through the center of a planet from one pole to the other. The time in which a planet makes one full turn on its axis is its **period of rotation**. A planet's period of rotation is the length of its day. For instance, Earth takes 24 hours to complete one rotation. As a result, one day on Earth is 24 hours. The length of a day varies among the planets. In general, larger planets spin more rapidly than smaller ones. The four largest planets all have shorter days than Earth.



Like Earth, the moon rotates on its axis. The moon also revolves around Earth, taking almost 28 days to complete one revolution. Because the moon moves around Earth, we see changing shapes, or phases, of the moon. You will read more about the phases of the moon in the next lesson.

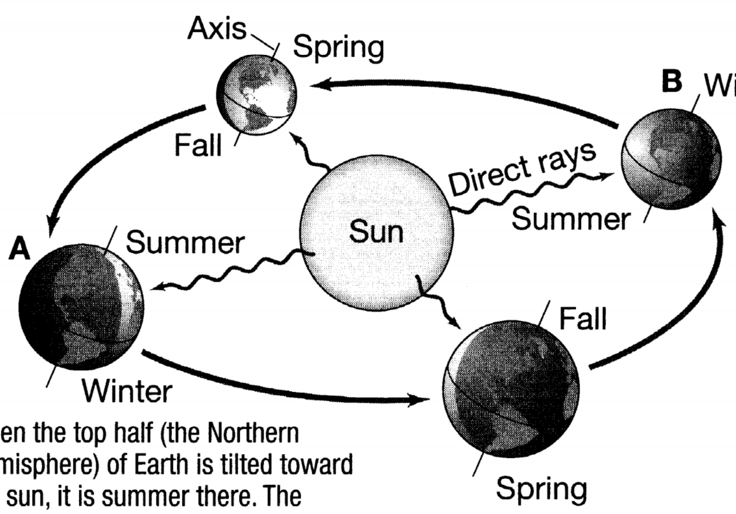
Did You Know?

The Solar Dynamics Observatory (SDO) has been engineered by NASA to measure space weather. In particular, it will help scientists predict and understand solar storms. During a solar storm, the sun releases a huge amount of magnetic energy. These storms can interfere with technology that people on Earth use every day, including satellites and power grids. Predicting solar storms may help engineers protect those devices.

The Seasons

Earth takes 365.25 days to orbit the sun. During this time, the part of Earth that receives direct rays from the sun changes. Recall that, while orbiting the sun, Earth also rotates on its axis. Earth's axis is tilted at 23.5°. This angle affects how much sunlight Earth's surface receives. The tilt causes the poles to point toward or away from the sun, depending on Earth's position in its orbit. Areas tilted toward the sun have longer days and higher temperatures (summer) because they receive more direct sunlight. Areas tilted away from the sun have shorter days and cooler temperatures (winter) because they receive less direct sunlight. If Earth were not tilted on its axis, there would be no seasons.

The diagram below shows that the direction in which Earth tilts does not change as it revolves around the sun. (In this diagram, Earth is always tilting right.) What does change is the orientation of Earth relative to the sun. For example, at position A, the South Pole is tilted away from the sun. At position B, the South Pole is tilted toward the sun.



When the top half (the Northern Hemisphere) of Earth is tilted toward the sun, it is summer there. The other half of Earth (the Southern Hemisphere) is having winter.

The opposite happens when it is winter in the Northern Hemisphere. The top half of Earth is now tilted away from the sun.

The **equator** is an imaginary line that divides Earth horizontally. The part of Earth north of the equator, sometimes called the "top" half, is the **Northern Hemisphere**. The "bottom" half of Earth, the region south of the equator, is the **Southern Hemisphere**. Connecticut and the rest of the United States is in the Northern Hemisphere. Australia, most of South America, part of Africa, and Antarctica are all in the Southern Hemisphere.

When the Northern Hemisphere is tilted toward the sun, the Southern Hemisphere is tilted away from the sun. It is summer in the hemisphere tilted toward the sun, and winter in the one tilted away from the sun.

Spring and fall occur when neither hemisphere is tilted toward or away from the sun. At the beginning of these seasons, the sun heats both hemispheres equally. Spring and fall temperatures tend to be mild. Since areas near the equator receive the most direct sunlight year-round, these regions are hot year-round.

A **solstice** is a point in Earth's orbit when a hemisphere is tilted toward or away from the sun as far as possible. Two solstices occur each year: a winter solstice and a summer solstice. In the Northern Hemisphere, the winter solstice is on December 21 or 22. This is the first day of winter. The summer solstice is on June 20 or 21, the first day of summer.

An **equinox** is a point in Earth's orbit when the planet is tilted neither toward nor away from the sun. There are two equinoxes each year. The vernal equinox, or first day of spring, occurs in the Northern Hemisphere on March 20 or 21. The autumnal equinox, or first day of fall, occurs in the Northern Hemisphere on September 22 or 23. Seasons in the Northern Hemisphere are always opposite to seasons in the Southern Hemisphere.

Lesson

38 Phases of the Moon and Tides

8.3-C29

Getting the Idea

Key Words

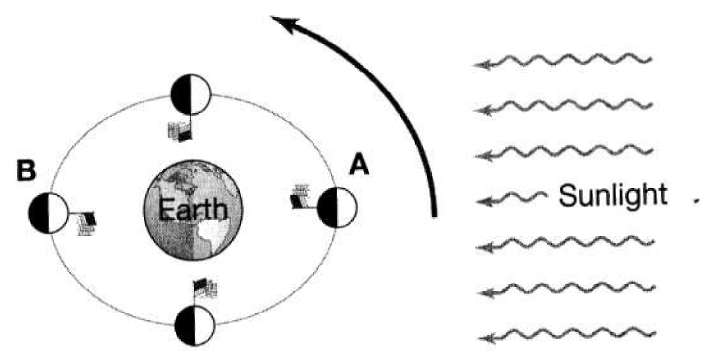
phase
new moon
full moon
waxing
waning
tide
high tide
low tide
spring tide
neap tide

The moon has always inspired feelings of mystery and curiosity. Since ancient times, people have charted and predicted changes in the moon's apparent shape. Today, scientists can explain these changes and understand the moon's effects on Earth.

Motions of the Moon

Like Earth, the moon moves through space in two patterns. First, it rotates on an axis. Second, it revolves around Earth. The changing position of the moon relative to Earth and the sun causes both the phases of the moon and Earth's ocean tides. As the moon revolves around Earth and rotates on its axis, the same side of the moon always faces Earth. This is because the moon takes the same amount of time to go around Earth once as it does to rotate once on its axis. By using a flag, the diagram below shows how the same side of the moon always faces Earth.

Moon's Orbit Around Earth

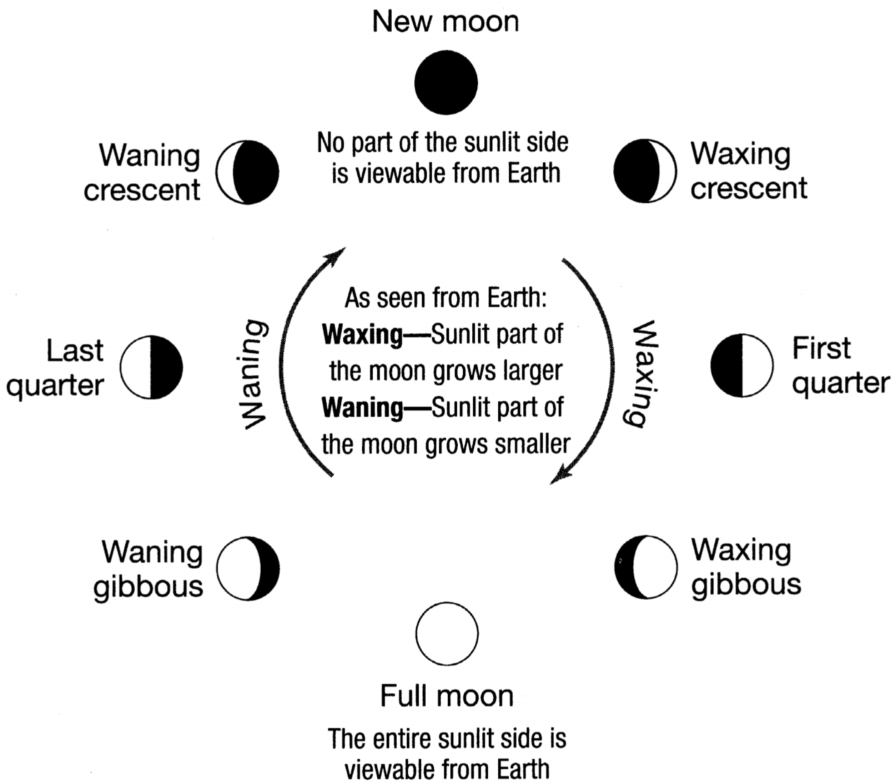


The moon does not produce its own light. It shines because its surface reflects light from the sun. The diagram above shows that at any time, half of the moon is lit by the sun and the other half is in darkness.

Did You Know?

If you look at a crescent moon just before sunset, you may see the dark part of the moon as a pale gray circle. This area of the moon is lit by sunlight reflected off Earth's atmosphere.

As the moon revolves around Earth, different amounts of the side of the moon that faces Earth are lit. Sometimes the entire half that faces Earth is lit. At other times, the entire side of the moon facing Earth is dark. The shape of the lit portion of the moon we see is called a **phase** of the moon. Look at the diagram below. Notice that in the phase called a **new moon**, only the shadowed side of the moon faces Earth. None of the lit portion can be seen. In the phase called a **full moon**, all the moon's lit portion can be seen from Earth.

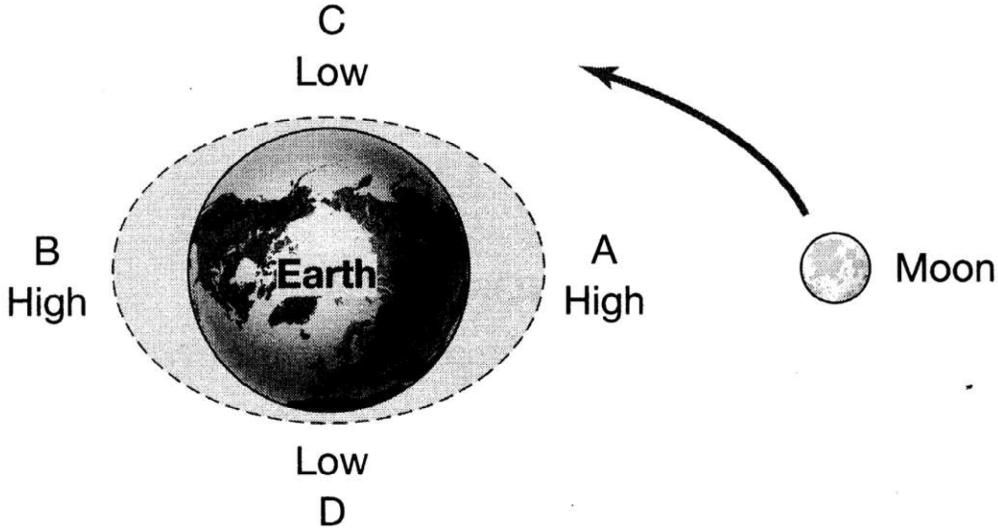


As more of the side of the moon facing Earth is in sunlight, the phases are said to be **waxing**. The phases wax from new moon to full moon. As the sunlit area of the moon that we can see shrinks, the phases are said to be **waning**. The phases wane from full moon to new moon. The moon goes through all its phases about every 29.5 days.

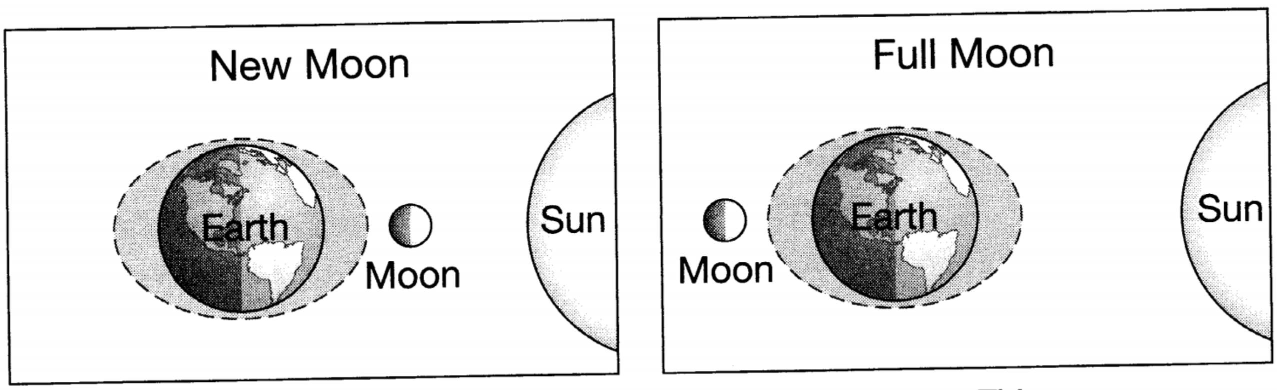
Tides

The changing positions of the moon relative to Earth and the sun produce ocean tides on Earth. The **tide** is the regular rise and fall of Earth's oceans along the coasts. Tides are explained by Newton's law of universal gravitation. As you learned in Lesson 36, this scientific law states that every object in the universe attracts every other object. The moon's gravity attracts Earth and everything on it, including its waters, which are free to move. Tides are largely caused by how much the moon's gravity pulls on different parts of Earth.

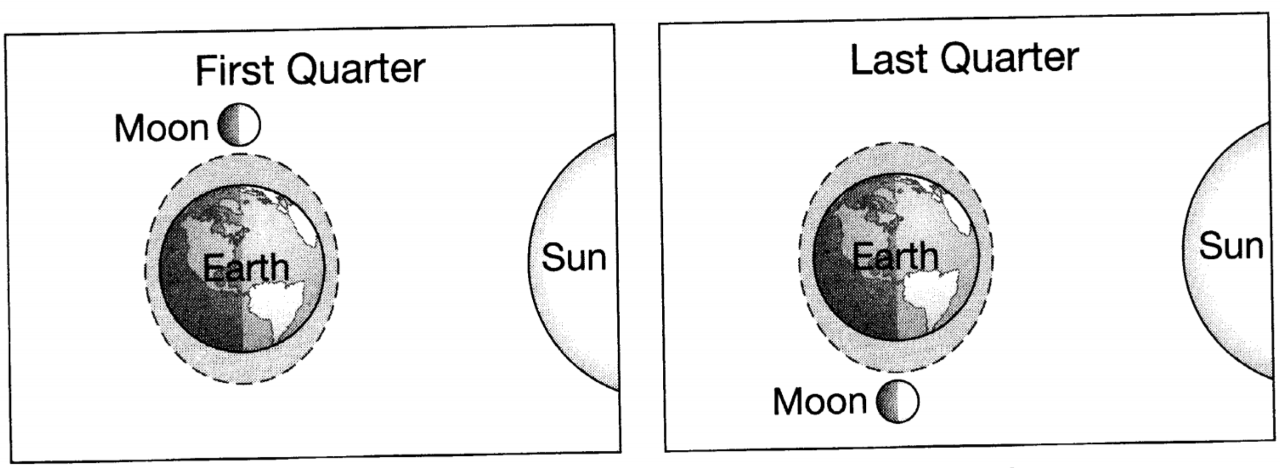
Look at the diagram below. When the moon's gravity pulls on Earth's surface water, it causes the oceans to bulge on the side of Earth nearest to the moon (A). At the same time, the moon's gravity pulls Earth toward the moon, leaving behind ocean on the opposite side (B). This produces high tides on opposite sides of Earth. A **high tide** is the highest level of water along a shore. As shown in the diagram, areas between the two high-tide regions experience low tides (C and D). A **low tide** is the lowest level of water along a shore. At any time, two regions on Earth are experiencing high tides and two regions are experiencing low tides. Most places experience two high tides and two low tides each day.



The sun's gravity also pulls on Earth. The relative positions of Earth, the moon, and the sun produce spring and neap tides. **Spring tides** are tides with the greatest difference between high and low tide. **Neap tides** are tides with the least difference between high and low. The illustration below shows how the relative positions of the Earth, moon, and sun produce both spring and neap tides. Notice that each type of tide occurs during specific phases of the moon.



Alignment of Moon, Sun, and Earth during Spring Tides



Alignment of Moon, Sun, and Earth during Neap Tides

Lesson

39 Eclipses

8.3-C29

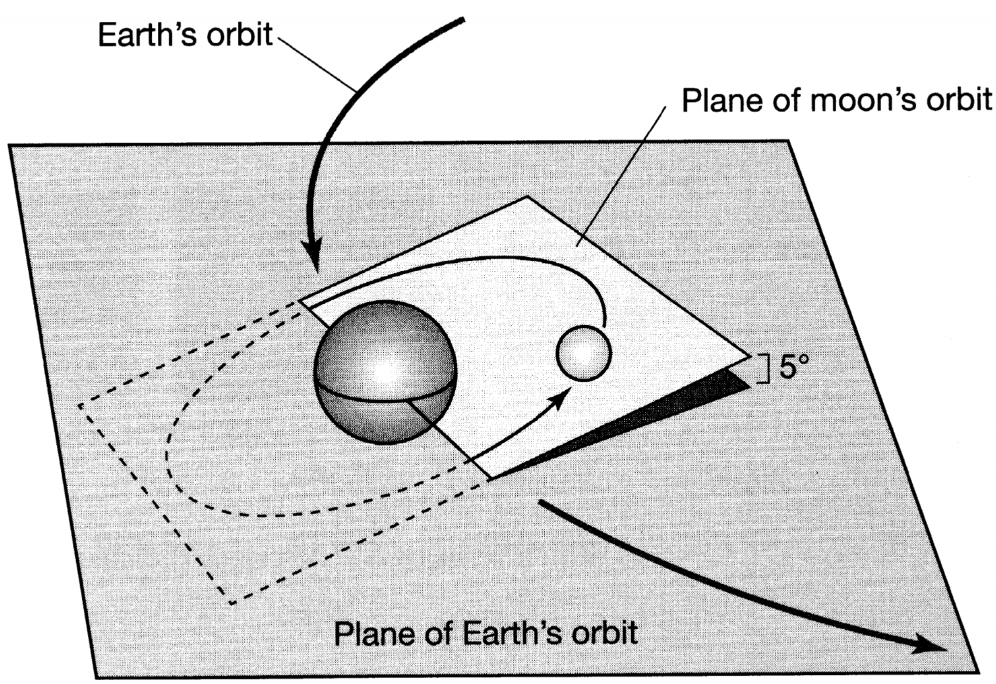
Getting the Idea

Key Words
eclipse
solar eclipse
umbra
corona
penumbra
lunar eclipse

When something in space comes between the sun and another object, it casts a shadow onto that object. This is called an **eclipse**. Eclipses can occur when the moon, the sun, and Earth are aligned in space. The two types of eclipses are solar eclipses and lunar eclipses.

Solar Eclipses

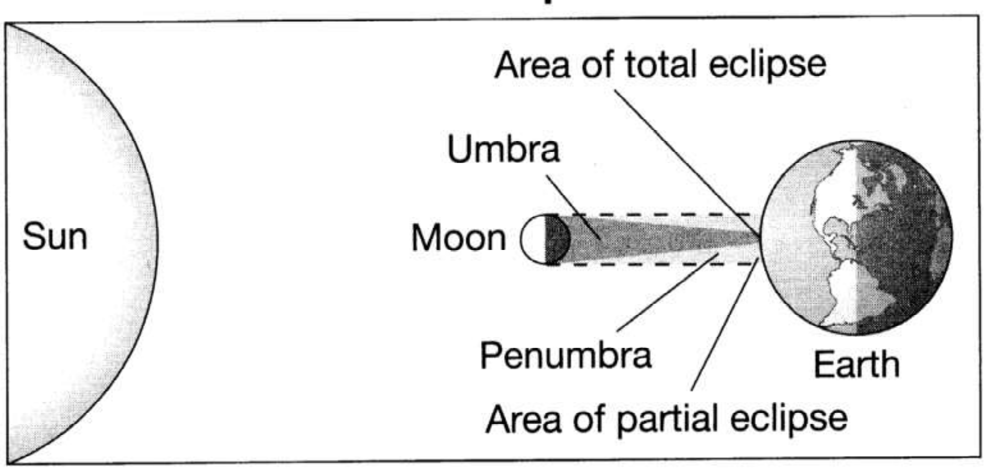
The moon's orbit around Earth is slightly tilted relative to Earth's orbit around the sun. As a result, the moon usually travels slightly above or below Earth.



During a new moon, however, the moon sometimes passes directly between the sun and Earth. When it does, the moon blocks the sun's light and casts a shadow on Earth. This shadow is called a **solar eclipse**. A solar eclipse begins slowly. The moon takes about one hour to cover the sun completely.

Depending on where you stand on Earth, you may experience a total solar eclipse or a partial solar eclipse. A total solar eclipse is visible in the **umbra**, the darkest inner part of the moon's shadow. During a total solar eclipse, a bright-blue daytime sky can grow as dark as night, and stars become visible. The **corona**, or outermost layer of the sun's atmosphere, can be seen as a white halo surrounding the darkened sun. As shown in the diagram below, the umbra reaches only a small area of Earth's surface. As a result, only a few people experience a total solar eclipse.

Solar Eclipse



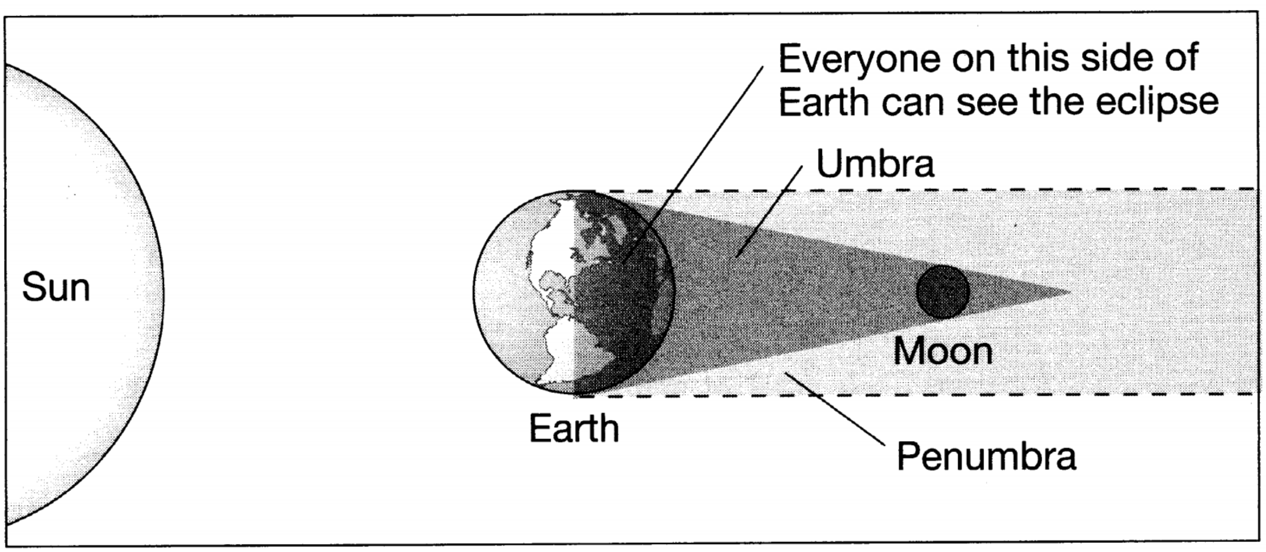
A partial solar eclipse is visible in the **penumbra**, the large outer part of the moon's shadow. The penumbra is not as dark as the umbra. Those who are viewing the eclipse from the penumbra can still see part of the sun. Therefore, the sky does not grow as dark as in a total eclipse.

Lunar Eclipses

During a **lunar eclipse**, the moon passes into Earth's shadow. A lunar eclipse can take place only during a full moon, when the entire lit side of the moon can be seen from Earth. During a lunar eclipse, Earth is between the sun and the moon. In this position, Earth blocks much of the sun's light from striking the moon. In other words, Earth gets in the way.

Like the moon's shadow during a solar eclipse, Earth's shadow has both an umbra and a penumbra. As the moon moves from the penumbra to the umbra, you see the curved shadow of Earth fall onto the moon's surface. Finally, when the moon is completely in the umbra, the moon is totally eclipsed. During a total lunar eclipse, the moon can appear dim with a reddish tint, because Earth's atmosphere bends some sunlight toward the moon. Unlike a total solar eclipse, a total lunar eclipse can be seen from anywhere on the night-time half of Earth. The diagram shows the position of Earth and the moon during a total eclipse.

Lunar Eclipse



During most lunar eclipses, the sun, the moon, and Earth are not completely aligned. As a result, most lunar eclipses are partial. During a partial lunar eclipse, the moon is never entirely in Earth's umbra.