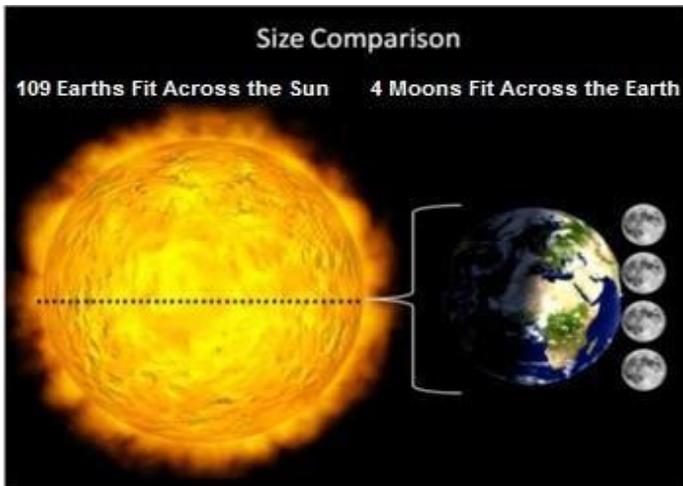


Earth, Sun, and Moon System

Reflect

In the image on the right, you see Earth in the foreground, our tiny Moon, and our Sun in the distance. The Moon orbits Earth, and the Earth–Moon system orbits the Sun. It is hard to imagine that the interactions of these three celestial objects, although so far away from each other, can cause day and night, seasons, moon phases, eclipses, and tides.



Understanding the size comparison of the Sun, Earth, and Moon will help you understand their motion. Earth is much bigger than the Moon. About 50 Moons could fit inside Earth. To compare diameters, you could line up four Moons across Earth.

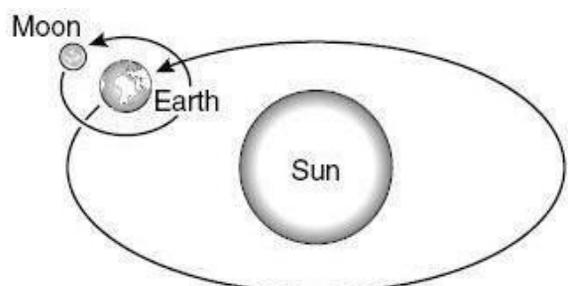
The Sun is even larger. About one million Earths could fit inside the Sun, and 100 Earths could fit across the face of the Sun.

Earth, Sun, and Moon System Motions

Rotation is the motion of a spinning object. The Sun and each of the planets and moons in our solar system rotate about an axis. An **axis** is an imaginary line about which each planet or moon spins. This imaginary line marks the center of a planet's or moon's rotation. Earth rotates on its axis about once every 24 hours, while the Moon rotates very slowly over the course of a month.



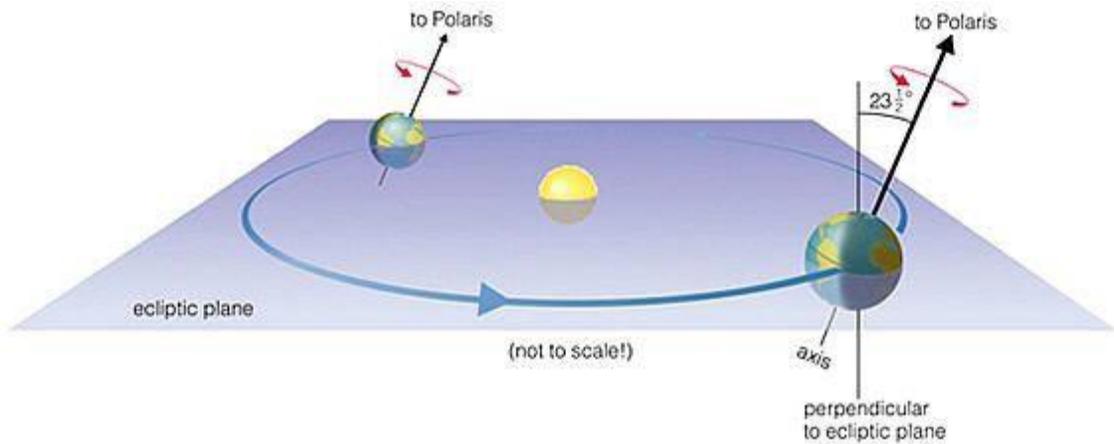
Revolution is orbiting another body. Earth (with our Moon) revolves around the Sun in one year (365¼ days). The Moon revolves around Earth in one month (approximately 27.3 days). Because the Moon rotates once and revolves once a month, the same side always faces Earth.



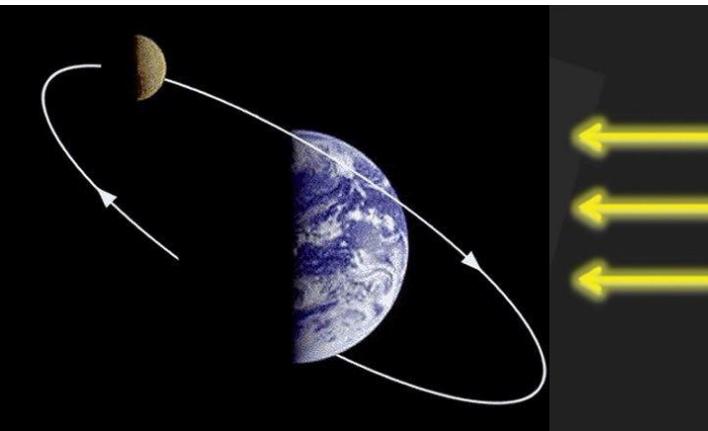
Earth, Sun, and Moon System

Look Out!

Earth does not tilt back and forth as it goes around the Sun. Earth revolves at a constant angle of 23.5° around the Sun. The northern end of Earth's axis, the geographic north pole, always points to the North Star, Polaris.



What Do You Think?



Day and Night

What do you think causes day and night on Earth? Rotation! As Earth spins on its axis, the side facing the Sun experiences daytime (about 12 hours), while the side of Earth facing away from the Sun experiences night (about 12 hours). The same occurs on the Moon, except the Moon's slow rotation causes daytime to last about two weeks and nighttime to last another two weeks. So a full day on the Moon would last about one month.

Reflect

Even though you can't feel it, Earth rotates very fast. Earth's rotation is so fast that it causes the planet to bulge out slightly at the equator and shrink slightly at the poles.

Therefore, Earth is not a perfect sphere. Earth's circumference is slightly wider at the equator than it is across the poles. This shape is called an **oblate spheroid**. In most photographs and diagrams, Earth typically looks like a perfect sphere. Because of this shape, solar energy travels in a straight line from the Sun and hits different parts of the curved Earth at different angles—more directly at the equator and less directly at the poles.



This clementine is an oblate spheroid. Earth is more rounded than this clementine.

Reflect

Although it appears to be glowing, the Moon does not produce its own light. Instead, the face of the Moon is illuminated by the Sun. Solar energy travels in a straight line from the Sun to Earth and the Moon so that the side of Earth or the Moon that faces the Sun is illuminated. Solar energy reflects off of the side of the Moon that faces the Sun and can travel to Earth. As it revolves around Earth, the Moon reflects different amounts of sunlight. As a result, we see different amounts of the Moon at different times of the month.

The Lunar Cycle

Our view of the sunny side of the Moon depends on the relative positions of Earth, the Moon, and the Sun. This happens in a predictable pattern called the **lunar cycle**, in which we observe different phases of the Moon. This diagram shows the eight phases of the lunar cycle. For example, in the diagram you can see that the full moon phase occurs when the Moon, Earth, and the Sun are in a straight line, resulting in the full moon appearing all night. However, when the Moon comes between Earth and the Sun, as in the new moon phase, the Moon rises and sets during the day and is not visible. Each phase is described in greater detail on the next page.



The lunar cycle occurs because the Sun illuminates varying amounts of the Moon facing Earth observers.

Look Out!

The Phases of the Moon

New moon occurs when the Moon is located directly between Earth and the Sun. As a result of this alignment, the Sun illuminates the side of the Moon that faces away from Earth. The Moon is not visible from Earth at night during the new moon phase because it rises and sets during the day.

Waxing crescent occurs when the new moon begins to change to a first quarter moon. (**Waxing** describes the period when we see more and more of the Moon from Earth.) During this phase, the Sun illuminates less than half of the side of the Moon facing Earth. As a result, the Moon appears as a crescent shape in the sky.

First quarter occurs when the waxing Moon is at a 90° angle relative to Earth and the Sun. During the first quarter phase, the Sun illuminates exactly half of the side of the Moon facing Earth. The first quarter phase is also called a half moon.

Waxing gibbous occurs as the first quarter moon changes to a full moon. During the waxing gibbous phase, the Sun illuminates more than half of the side of the Moon facing Earth. As a result, the Moon appears nearly full in the sky.

Full moon occurs when Earth is located between the Moon and the Sun. During the full moon phase, the Sun illuminates the whole side of the Moon facing Earth. During this phase, the Moon appears as a full circle in the sky.

Waning gibbous occurs as the full moon changes to a last quarter moon. (**Waning** describes the period when we see less and less of the Moon from Earth.) The waning gibbous phase is the mirror image of the waxing gibbous phase.

Last (third) quarter occurs when the waning Moon is at a 90° angle relative to Earth and the Sun. The last quarter phase (also called a half moon) is the mirror image of the first quarter phase.

Waning crescent occurs when the last quarter moon changes to a new moon. The waning crescent phase is the mirror image of the waxing crescent phase. A new moon follows the waning crescent phase, starting the cycle over again. The Moon takes approximately 28 days to complete one cycle.



Earth, Sun, and Moon System

When asked to identify the nearest star to Earth, some people think of a star in the night sky. However, the Sun is a star that is much closer to Earth than any star in the night sky. The Sun is at the center of the solar system—a group of planets, moons, and other rocky bodies. Even though the Sun is only a medium-sized star, it is massive compared to other objects in the solar system, such as planets. The Sun's powerful gravity keeps the rest of the solar system in orbit, or moving around the Sun. While it might seem that the Sun, or our solar system, is a special place, recent discoveries prove that to not be true. Through the efforts of specialized telescopes like the Kepler spacecraft, there is extensive evidence of numerous other solar systems in our galaxy. These are referred to as exosolar systems, and thousands of exosolar systems are now known to scientists. The Sun is located in one of the outer arms of the Milky Way. It is but one star in the Milky Way, and the solar system is but one system in the Milky Way.



Reflect

Galaxies

If you are in an area with low light pollution, you might spot the Milky Way at night. It is a band of diffuse, cloudy light that stretches across the night sky. It can easily be mistaken for clouds! That band of light is coming from billions of stars. The Milky Way is a galaxy, a collection of stars that are bound together by their mutual gravitational attraction. Every star in the Milky Way pulls on the Sun, and the Sun, in turn, pulls on every other star. For many hundreds or thousands of years, scientists thought that there was only one galaxy, the Milky Way. But around 100 years ago, we



realized that there are other galaxies in the universe. In fact, there are probably as many galaxies in the universe as there are stars in the Milky Way! One of the closest galaxies to us in the Milky Way is the Andromeda Galaxy. Roughly a million light years from Earth, Andromeda is the most distant object in the universe you can see without using a telescope. Andromeda has about twice as many stars as the Milky Way, and each of those stars is attracted to other stars within their own galaxy, just like the stars in the Milky Way.

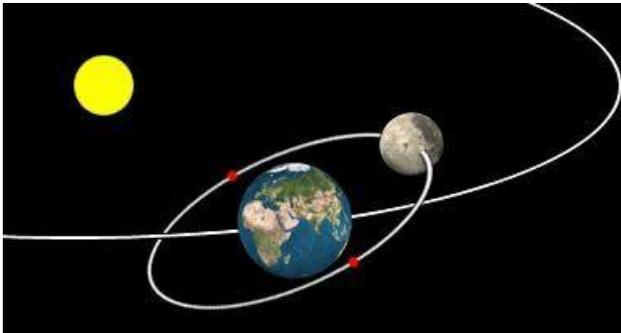
Earth, Sun, and Moon System

What Do You Think?

Eclipses

How do you think the Earth, Sun, and Moon system can explain **eclipses** of the Sun and the Moon? An eclipse occurs when one celestial object passes through the shadow or is put into shadow by another celestial object.

- **solar eclipse:** when the Moon blocks the Sun and the Moon's shadow falls along a small path on Earth
- **lunar eclipse:** when the Moon moves into Earth's shadow



We do not see solar and lunar eclipses every month because the Moon's orbital path around Earth is tilted with respect to the plane of Earth's orbit. Eclipses only occur when all three celestial bodies line up in the same plane. The points in the Moon's orbit where this occurs are called *nodes* (shown on the left as red dots). Eclipses only occur at these nodes.

Solar energy is prevented from reaching Earth during a solar eclipse because the Moon is located between the Sun and Earth.

Solar energy is prevented from reaching the Moon (and thus reflecting off of the Moon to Earth) during a lunar eclipse because Earth is located between the Sun and the Moon.

Because the Moon's orbital plane is tilted with respect to the plane of Earth's orbit

around the Sun, for a majority of time during an Earth month, the Moon is not in a position to block solar energy from reaching Earth, and Earth is not in a position to block solar energy from reaching the Moon.

