18.1 Earth and Its Moon

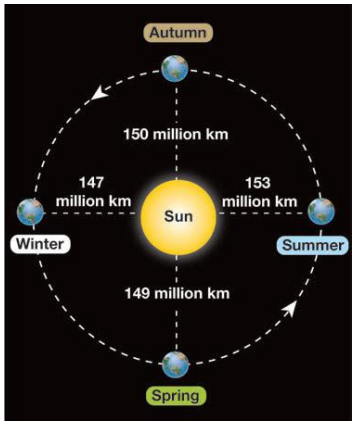
Revolving around Earth at a distance of 384,400 kilometers is our only moon. Since the invention of spacecraft, our knowledge of Earth and the Moon has grown tremendously. In fact, the Moon is the only natural object beyond Earth that humans have actually visited. In this section, you will learn important information about the Moon and how it compares to Earth.

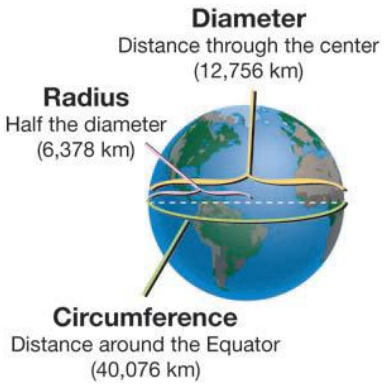
Earth's shape and orbit

Earth's shape Earth's shape is almost spherical except for a slight bulge at the equator. If you were to travel exactly once around along the equator, you would travel 40,076 kilometers. This distance is the *circumference* of Earth. The *diameter*, or the distance from one side to the other through the center, is 12,756 kilometers and its radius at the equator is equal to half of this value, or 6,378 kilometers (Figure 18.1). Because of its slight bulge at the equator, if you were to measure the radius from one of the poles it would be slightly less (6,357 kilometers).

Earth's orbit around the Sun

In Chapter 17, you read that the orbits of the planets are slightly elliptical but almost circular. Also, the Sun is not at the center of Earth's orbit. Because of this, the distance from Earth to the Sun changes as Earth revolves. Earth's minimum distance from the Sun is 146 million kilometers. Its maximum distance is 152 million kilometers. At any two points during its orbit, Earth is at a slightly different distance from the Sun. Figure 18.2 shows the distance of Earth from the Sun at the beginning of each season in the northern hemisphere.





Comparing Earth and the Moon

How far away is the Moon?

Earth's only moon revolves around us at a distance of 384,400 kilometers. While this may seem like a great distance, it is only a fraction of the distance between Earth and the Sun (an average of 150 million kilometers).

Diameter, mass, and density

If you travel in a relatively straight line from Boston, Massachusetts to Salt Lake City, Utah, you will have covered a distance that is about equal to the Moon's diameter of 3,476 kilometers. The Moon is about one quarter the size of Earth and its mass is 7.3×10^{22} kilograms, which is about one one-hundredth of Earth's mass. Because of the Moon's small mass, its gravity does not attract an atmosphere. Its density is 3.34 g/cm^3, which is much lower than Earth's. Figure 18.3 compares Earth and the Moon.

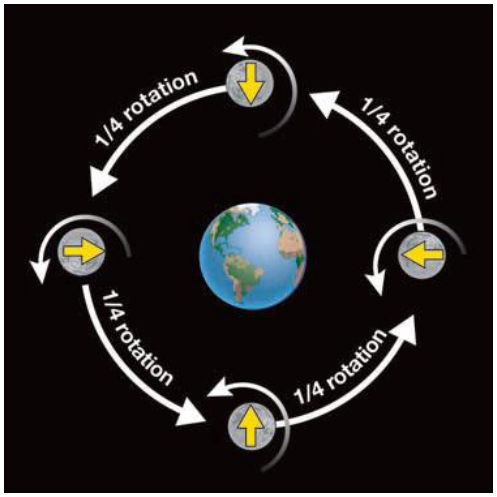
Gravitational force

Because the Moon has much less mass, its gravitational force is about one sixth as strong as the gravity on Earth. Earth exerts a gravitational force of 9.8 newtons on a 1-kilogram object. The Moon exerts a gravitational force of only 1.6 newtons on the same object. This means that a 1-kilogram object weighs 9.8 newtons (2.2 pounds) on Earth and the same object weighs only 1.6 newtons (0.36 pounds) on the Moon. A 2,500 pound car would weigh only 408 pounds on the Moon!

The Moon's rotation

If you have ever observed the Moon, you may have noticed that the same side of it faces Earth at all times. This does not mean that the Moon does not rotate. The Moon rotates much more slowly than Earth. Over millions of years, Earth's gravity has *locked* the Moon's rotation to its orbit around Earth. One lunar "day" takes 27.3 Earth days, exactly the same time it takes the Moon to complete one orbit around Earth (Figure 18.4).

Figure 18.4: *The amount of time it takes the Moon to complete a rotation is the same amount of time it takes it to revolve around Earth. Can you see why only one side of the Moon faces Earth at all times?*



How the Moon was formed

Where did the Moon come from?

Throughout history, there have been many different theories about the origin of the Moon. Before the Apollo landings that began in 1969, there were three main theories.

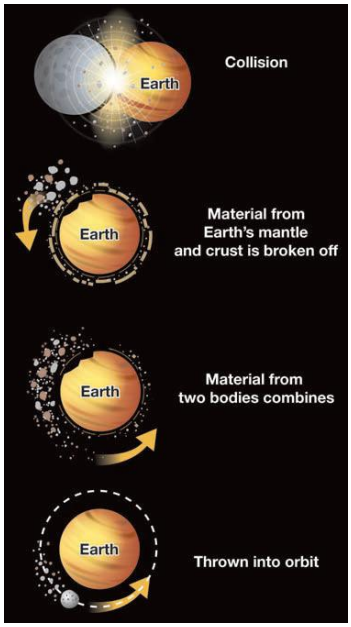
1. Some scientists hypothesized that the Moon split off Earth during a period of very fast rotation.
2. Others thought that the Moon formed somewhere else and was "captured" by Earth's gravity.
3. Still others proposed that the Moon and Earth were formed together from a group of smaller chunks of matter when the solar system formed.

Analyzing lunar rocks

When scientists analyzed lunar rocks, they found that they were composed of much less iron and nickel than Earth. Recall that Earth's *core* is composed mostly of iron and nickel. The composition of lunar rocks closely resembled that of Earth's *mantle*. They also found that the Moon's density was the same as Earth's mantle and crust combined.

The giant impact theory

These discoveries gave rise to the **giant impact theory** that is widely accepted today. This theory proposes that about 4.5 billion years ago, an object about the size of Mars collided with Earth, causing material from Earth's mantle and crust to break off. This material, combined with material from the colliding object, was thrown into orbit around Earth and became the Moon. The Moon's spherical shape was a result of gravity and the remaining particles impacted the Moon to form craters. Figure 18.5 shows how the Moon was formed based on this theory.



Surface features of the Moon

Craters If you look at the Moon through a telescope, you can see the three main features of its surface: craters, highlands, and maria (Figure 18.6). **Craters** are large, round pits that cover much of the Moon's surface. For many years astronomers believed they were caused by volcanoes. It was only about 50 years ago that scientists concluded that the craters were caused by the impact of meteoroids—large rocks from space. One of the Moon's largest craters, named Copernicus, is hundreds of kilometers across.

Highlands and marias

When you look at the Moon, some areas appear bright, while others appear dark. The brighter areas are called *highlands* because they are higher in elevation. The darker areas are called *maria* (Latin for "seas") because early observers believed they were oceans. Maria are actually low, dry areas that were flooded with molten lava billions of years ago when the Moon was formed. Among the maria you can see through a telescope is a large one named the Sea of Rains.

Tides

Tides are caused by the Moon's gravity

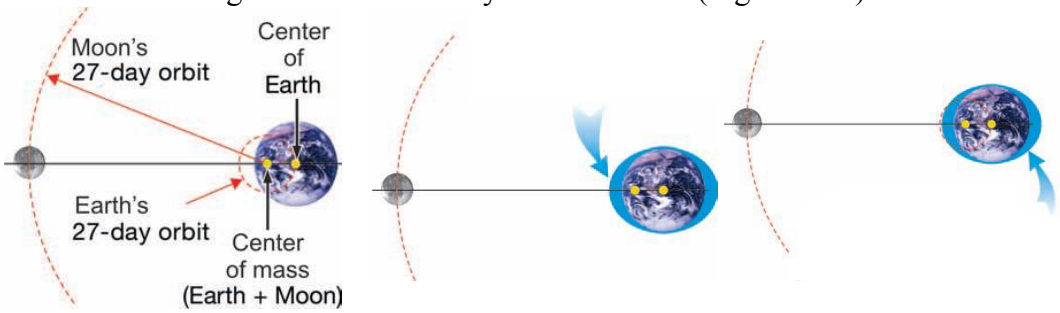
As Earth rotates beneath the Moon, its mass feels a small, "Moonward" force of 0.00003 N from the Moon's gravity. Earth is made of rock that resists this small force, but because water flows, the Moon causes water to slide toward the place directly under the Moon on Earth's surface (Figure 18.7). In most places, ocean levels rise and fall twice each day as the Moon revolves around Earth and Earth rotates. The daily cycle of rising and falling ocean levels is called a **tide**. The Moon passes overhead once every 24 hours. So, you would expect the tide to rise only once every 24 hours. But the oceans on the side of Earth directly *opposite* the Moon also rise. What causes this "second" tide?

The center of mass

The answer is that the Moon does not really orbit Earth as if Earth were fixed in place. Instead, Earth and the Moon orbit around a common *center of mass*. Imagine balancing Earth and the Moon on a giant see-saw. There is a point at which the see-saw balances even though Earth is much heavier than the Moon. That point is the center of mass of the Earth−Moon system.

Explaining the "second" tide

When you turn a corner sharply in a car, your body slides to the outside of the curve, away from the center. This happens because your body wants to move in a straight line in the direction it was going *before* the turn. This is the explanation for the tide on the side of Earth that does not face the Moon. As Earth revolves around the center of mass, the ocean on the opposite side from the Moon is "flung outward" a little by its own inertia (Figure 18.8).



18.1 Section Review

1. Draw and label a diagram below using these terms: radius, circumference, diameter.

2. For a planet, which is the greatest distance, its diameter or its circumference?

3. Is Earth a perfect sphere? Explain your answer.

4. Why doesn't the Moon have an atmosphere?

5. Why would an elephant weigh much less on the Moon than it weighs on Earth?

6. Arrange the events below in order of occurrence.
a. Material from Earth's mantle and crust is broken off.
b. A collision with a large body occurs.
c. An object is thrown into orbit around Earth.
d. Material from Earth and an object are combined.

7. Name and describe three features of the Moon that you can see through a telescope.

8. What are tides? What causes the "second" tide on the opposite side of Earth from the Moon?