17.1 About the Solar System

Ancient observers noticed that five bright objects seemed to wander among the stars at night. They called these objects *planets*, from the Greek word meaning "wandering star," and named them Mercury, Venus, Mars, Jupiter, and Saturn. In A.D. 140, the Greek astronomer Ptolemy "explained" that planets and the Moon orbited Earth. For the next 1,400 years, people believed this idea. Eventually, scientific evidence proved Ptolemy wrong.

Evidence that the planets orbit the Sun

Planets shine by reflecting sunlight

Today we know that planets are not stars. Stars give off their own light. We see the planets *because they reflect light from the Sun.* A **planet** is a massive object orbiting a star, like the Sun. For example, Venus is a planet. It appears as a crescent like the Moon, becoming dark at times. This is because Venus does not give off its own light. When Earth is on the same side of the Sun as Venus, we see Venus's shadowed side (Figure 17.1 top). The phases of Venus were discovered by the Italian astronomer Galileo Galilei (1564–1642) in the 1600s. This discovery was part of the scientific evidence that eventually overturned Ptolemy's model of the Earth-centered solar system.

Changing ideas about the solar system

Almost 100 years before Galileo, Polish astronomer Nicolaus Copernicus (1473–1543) had proposed that the planets orbited the Sun, but few believed him. Then, Galileo, using a telescope he built himself, made two discoveries that supported Copernicus's ideas. First, he argued that the phases of Venus could not be explained if Earth were at the center of the planets. Second, he observed that there were four moons orbiting Jupiter (Figure 17.1 bottom). This showed that not everything in the sky orbited around Earth.

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planet - a massive object orbiting a star like the Sun.

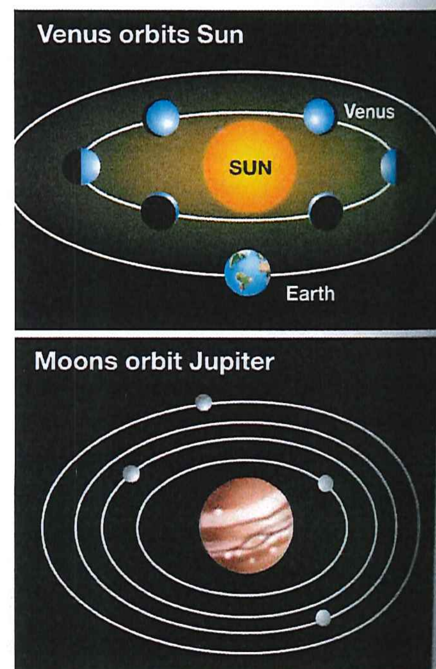

Figure 17.1: *Two of Galileo's discoveries that helped prove that Earth and the other planets orbit the Sun. The top diagram shows how the phases of Venus occur due to its orbit around the Sun. The bottom diagram depicts moons orbiting Jupiter. This observation proved that not all objects revolve around Earth.*

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Inner and oute
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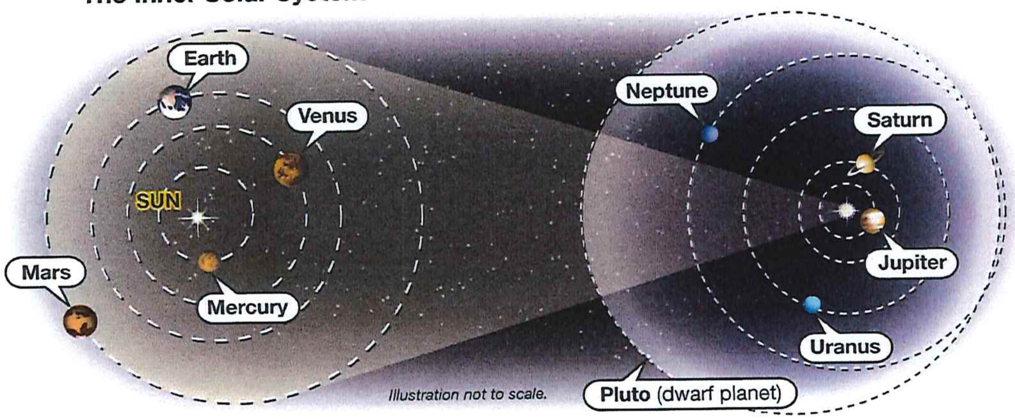
...at is the solar system?

...un, planets, ...ther objects Today, we define the **solar system** as the Sun and all objects that are bound by gravitational force to the Sun. The gravitational force (also called *gravity*) of the Sun keeps the solar system together just as gravity keeps the Moon in orbit around Earth.

The solar system includes eight major planets and their moons, and a large number of smaller objects (dwarf planets, asteroids, comets, and meteors).



...er and outer planets The solar system is roughly divided into the *inner planets* (Mercury, Venus, Earth, and Mars) and the *outer planets* (Jupiter, Saturn, Uranus, and Neptune). The dwarf planet Pluto is the oldest known member of a smaller group of frozen worlds orbiting beyond Neptune. The diagram above shows the orbits of the planets (the planets are not shown to scale). Notice that Neptune is farther from the Sun than the dwarf planet Pluto over part of its orbit.

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solar system - the Sun and all objects that are bound by gravitational force to the Sun.

The orbits of the planets are not true circles, but *ellipses*. An ellipse is shaped like an oval. While the actual paths are close to circles, the Sun is not at the center, but is off to one side. For example, Mercury's orbit is shifted 21 percent to one side of the Sun.

Gravitational force

All objects attract

Gravitational force is the force of attraction between all objects. The gravitational force that you are most familiar with is the one between you and Earth. We call this force your *weight*. But gravitational force is also acting between the Sun, Earth, and the planets. All objects that have mass attract each other through gravitational forces.

Gravitational force is relatively weak

You don't notice the attractive force between ordinary objects because gravity is a relatively weak force. For example, a gravitational force exists between you and this book, but you cannot feel it because both masses are small (Figure 17.2). It takes a huge mass to create gravitational forces that are strong enough to feel. You notice the gravity between you and Earth because Earth's mass is huge.

The law of universal gravitation

The **law of universal gravitation** explains how the strength of the force depends on the mass of the objects and the distance between them. Gravitational force is directly related to the objects' mass. This means the gravitational force increases as the mass of the objects increases. The distance between objects also affects gravitational force. The closer objects are to each other, the stronger the gravitational force between them. The farther apart, the weaker the gravitational force.

Gravity on Earth and the Moon

The strength of gravity on the surface of Earth is 9.8 N/kg. Like pounds, newtons are a measure of force. There are 4.448 newtons in one pound. Earth and a 1-kilogram object attract each other with 9.8 newtons of force. In comparison, the strength of gravity on the Moon is only 1.6 N/kg. Your weight on the Moon would be one-sixth what it is now. The Moon's mass is much less than Earth's, so it creates less gravitational force.

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gravitational force - the force of attraction between all objects.

law of universal gravitation - states that the strength of the gravitational force depends on the mass of the objects and the distance between them.

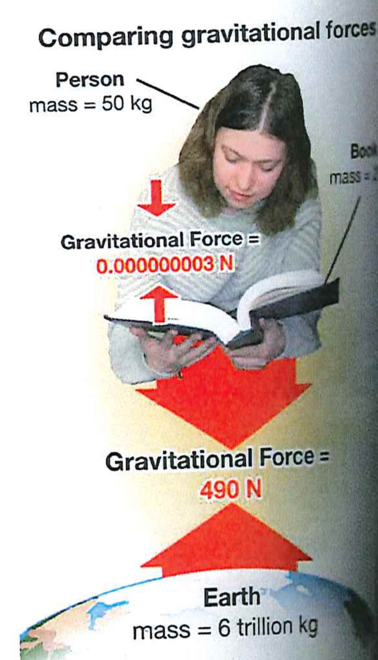
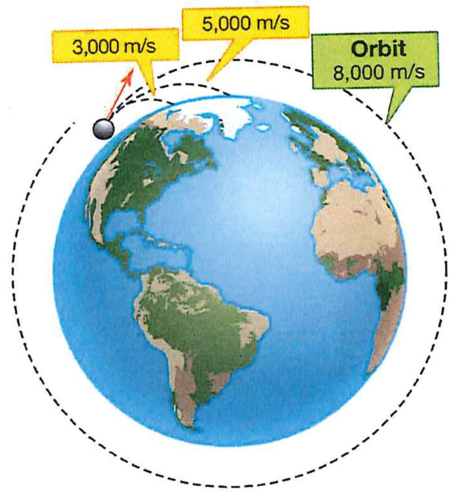


Figure 17.2: *The gravitational force between you and Earth is stronger than the force between you and your book because of Earth's large mass.*

Orbits

What is an orbit? An **orbit** is a regular, repeating path that an object in space follows around another object. An object in orbit is called a **satellite**. A satellite can be natural—like the Moon, or artificial—like the International Space Station.

Why the Moon does not fall to Earth Earth and the other planets orbit the Sun. The Moon orbits Earth. Why doesn't the force of gravity pull Earth into the Sun (or the Moon into Earth)? To answer the question, imagine kicking a ball off the ground at an angle. If you kick it at a slow speed, it curves and falls back to the ground. The faster you kick the ball, the farther it goes before hitting the ground. If you could kick it fast enough, the curve of the ball's path would match the curvature of Earth. The ball would go into orbit instead of falling back to Earth. An object launched at 8,000 m/s will orbit Earth.



Inertia and gravitational force An orbit results from the balance between *inertia* (the forward motion of an object in space), and gravitational force. Because of inertia, the planets are moving in a direction at a right angle to the pulling force of gravity. A scientific law states that an object in motion will remain in motion unless something pushes or pulls on it. This means that without the pull of gravity, a planet would travel off into space in a straight line. The balance between the planet's inertia and the gravitational force between the planet and the Sun results in the planet's orbit (Figure 17.3).

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orbit - regular, repeating path that an object in space follows around another object.

satellite - an object in orbit around another object.

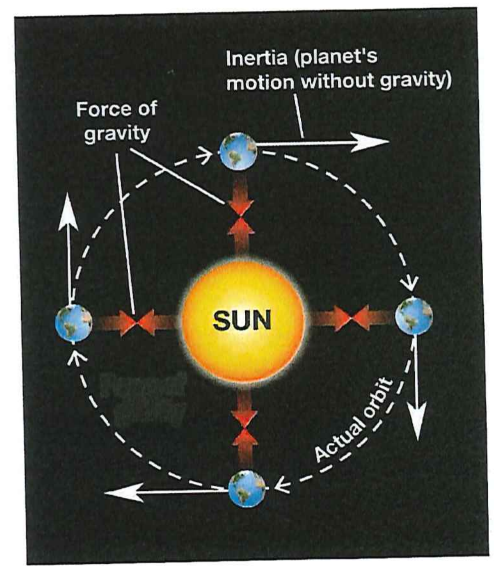
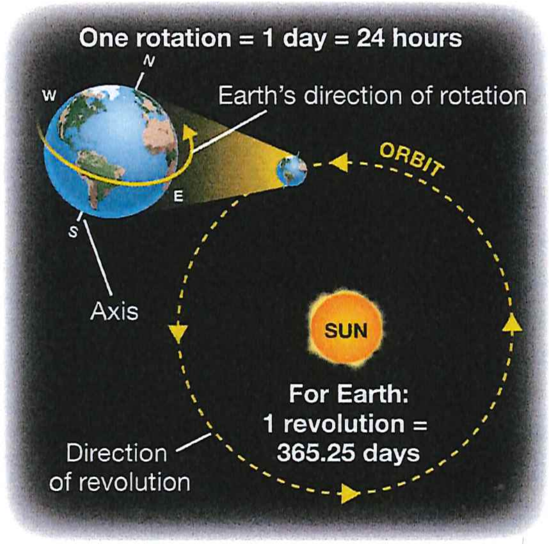


Figure 17.3: *An orbit results from the balance between inertia and gravitational force.*

Motion of the planets

The shape of orbits The orbits of the planets are slightly elliptical but almost circular. What's more significant is that the Sun is at a point called the *focus* that is offset from the center of the orbit. This causes the distance from the Sun to vary as a planet orbits (Figure 17.4).

Rotation In addition to orbiting the Sun, the planets also rotate. An **axis** is the imaginary line that passes through the center of a planet from pole to pole. The spinning of a planet on its axis is called its *rotation*. Earth, like most of the other planets, spins from west to east. One complete rotation is called a *day*. One Earth day is 24 hours long. This means it takes Earth 24 hours to complete one rotation on its axis. A day on Jupiter, the fastest rotator of the planets, is only about 10 hours long.



Revolution and years All of the planets orbit, or revolve, around the Sun in the same direction (counter-clockwise). A *year* is the time it takes a planet to complete one *revolution* around the Sun. A year on Earth takes approximately 365.25 days. A year on Mars takes 686.98 Earth days. The farther a planet is from the Sun, the longer it takes it to complete one revolution. One year on Neptune, the outermost planet, is 164.81 Earth years long! Table 17.1 on page 412 shows the rotation and revolution period for each planet.

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axis - the imaginary line that passes through the center of a planet from pole to pole.

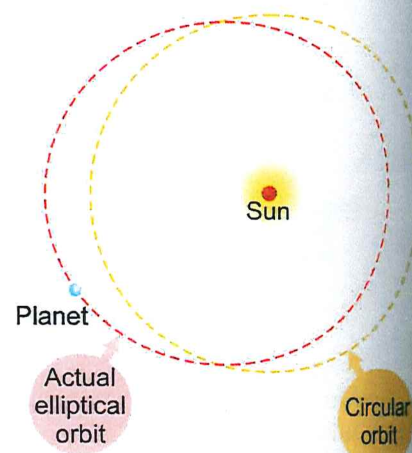


Figure 17.4: *Orbits are almost circular (ellipses). The Sun is at a point called the* focus *that is offset from the center.*

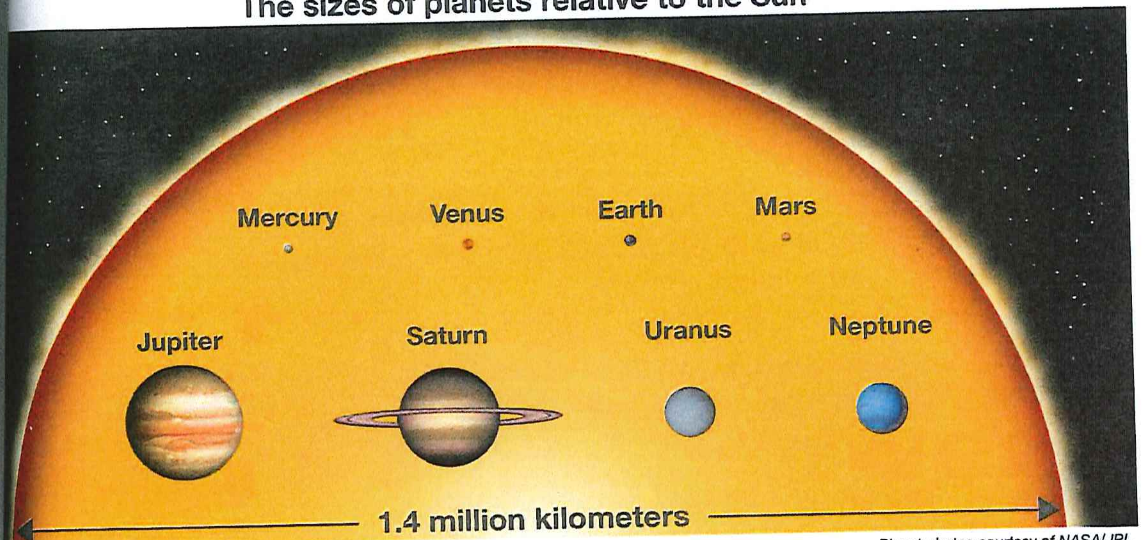
Comparing

Relative

...paring size and distance in the solar system

...lative sizes The Sun is by far the largest object in the solar system. The next largest objects are the planets Jupiter, Saturn, Uranus, and Neptune. As you can see from the scale diagram below, the planets Mercury, Venus, Earth, and Mars appear as small dots compared with the size of the Sun.

The sizes of planets relative to the Sun



Planet photos courtesy of NASA/JPL.

Distance Astronomers often use the distance of Earth from the Sun as a measurement of distance in the solar system. One **astronomical unit** (AU) is equal to 150 million kilometers, or the distance from Earth to the Sun. Mercury is 58 million kilometers from the Sun. To convert this distance to astronomical units, divide it by 150 million kilometers (or divide 58 by 150). Mercury is 0.39 AU from the Sun (Figure 17.5). Figure 17.6 lists the planets and the distance of each of them from the Sun in AU.

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astronomical unit - equal to 150 million km, or the distance from Earth to the Sun.

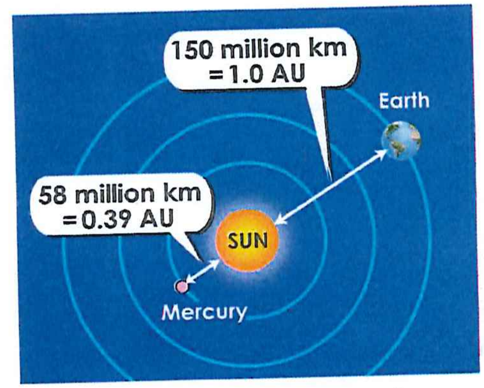

Figure 17.5: *One AU is equal to 150 million kilometers. If Earth is 1.0 AU from the Sun, then Mercury, with a distance of 58 million kilometers, is 0.39 AU from the Sun.*

Planet	Average distance from the Sun (AU)
Mercury	0.39
Venus	0.72
Earth	1.0
Mars	1.5
Jupiter	5.2
Saturn	9.5
Uranus	19.2
Neptune	30.0

Figure 17.6: *Distances of the planets from the Sun in AU.*