

## Lesson Summary

- The Sun and all the objects held by its gravity make up the solar system.
- There are eight planets in the solar system: Mercury, Venus, Earth, Mars, Jupiter, Saturn, and Neptune. Some of the dwarf planets are Pluto, Eris, Ceres, Makemake, and Haumea.
- The ancient Greeks believed Earth was at the center of the universe and everything else orbited Earth.
- Copernicus proposed that Earth is a planet and that Earth and the other planets orbit the Sun.
- Planets are held by the force of gravity in elliptical orbits around the Sun.
- The solar system formed from a giant cloud of gas and dust about 4.6 billion years ago.
- This model explains why the planets all lie in one plane and orbit in the same direction around the Sun.

## Think Like A Cosmologist

1. What are the names of the 8 planets from the Sun outward?
2. Name 5 of the dwarf planets.
3. How old is the Sun?
4. How old are the Planets?
5. Describe the role of gravity in how the solar system functions. Why don't the planets fly off into space? Why aren't the planets pulled into the sun?

6. How does the nebular hypothesis explain how the solar system originated?
7. Why do you think so many people for so many centuries thought that Earth was the center of the universe?
8. People were pretty upset when Pluto was made a dwarf planet. Explain why Pluto is now classified as a dwarf planet.

#### Points to Consider

9. Would you expect all the planets in the solar system to be made of similar materials? Why or why not?
10. The planets are often divided into two groups: the inner planets and the outer planets. Which planets do you think are in each of these two groups? What do members of each group have in common?

# What Are Conditions Like on the Inner Planets?

## Lesson Objectives

- Describe the main features of each of the inner planets.
- Compare each of the inner planets to Earth and to one another.

## Introduction

The four inner planets (closest to the Sun - Mercury, Venus, Earth, and Mars) - are referred to as the inner planets. They are similar to Earth. All are solid, dense, and rocky. None of the inner planets have rings. Compared to the outer planets, the inner planets are small. They have shorter orbits around the Sun and they spin more slowly. Venus spins backwards and spins the slowest of all the planets.

All of the inner planets were geologically active at one time. They are all made of cooled igneous rock with inner iron cores. Earth has one big, round moon, while Mars has two very small, irregular moons. Mercury and Venus do not have moons.

## Section 1: Mercury

Mercury is the smallest planet. It has no moon. The planet is also closest to the Sun. As the Figure below shows, the surface of Mercury is covered with craters, like Earth's moon. The presence of impact craters that are so old means that Mercury hasn't changed much geologically for billions of years. With only a trace of an atmosphere, it has no weather to wear down the ancient craters.

### Short year, long days

Mercury is named after the Roman messenger god. Mercury was a messenger because he could run extremely fast. The Greeks gave the planet this name because Mercury appears to move very quickly in its orbit around the Sun. Mercury orbits the Sun in just 88 Earth days. Mercury has a very short **year** (one complete revolution around the sun), but it also has very long days. Mercury rotates slowly on its axis, turning exactly three times for every two times it orbits the Sun. This combination of rotation and orbital motion results in a solar day (noon to noon) on Mercury that is two Mercury years long.

Terms to know

- inner planets
- year

## 1.1 Extreme Temperatures

Mercury is very close to the Sun, so it can get very hot. Mercury also has virtually no atmosphere. As the planet rotates very slowly, the temperature varies tremendously. In direct sunlight, the surface can be as hot as 427°C (801°F). On the dark side, the surface can be as cold as -183°C (-297°F)! The coldest temperatures may be on the insides of craters. Most of Mercury is extremely dry. Scientists think that there may be a small amount of water, in the form of ice, at the planet's poles. The poles never receive direct sunlight.



## Section 2: Venus

Named after the Roman goddess of love, Venus is the only planet named after a female. Venus is sometimes called Earth's "sister planet." But just how similar is Venus to Earth? Venus is our nearest neighbor. Venus is most like Earth in size.

### A Harsh Environment

Viewed through a telescope, Venus looks smooth and featureless. The planet is covered by a thick layer of clouds. You can see the clouds in pictures of Venus, such as the Figure below. We make maps of the surface using radar, because the thick clouds won't allow us to take photographs of the surface of Venus.



Left - A topographical map of Venus produced by the Magellan probe using radar. Color differences enhance small scale structure.



Right - Venus in real color. The planet is covered by a thick layer of clouds.

The Figure above shows a topographical map of Venus. The map was produced by the Magellan probe in orbit around Venus. The spacecraft sent radar waves that reflected off Venus' surface to reveal mountains, valleys, vast lava plains, and canyons. Like Mercury, Venus does not have a moon.

Clouds on Earth are made of tiny water droplets. Venus' clouds are a lot less pleasant. They are made of tiny droplets of corrosive sulfuric acid! The atmosphere on Venus is so thick that the pressure on the surface of Venus is very high. In fact, it is 90 times greater than the pressure at Earth's surface! The thick atmosphere causes a strong greenhouse effect. As a result, Venus is the hottest planet. Even though it is farther from the sun, Venus is much hotter even than Mercury. Temperatures at the surface reach 464°C (867°F). That's hot enough to melt lead!

## Volcanoes

Venus has more volcanoes than any other planet. Most of the planet's surface is covered by lava flows and volcanoes. There are over a thousand large volcanoes and there are many more small volcanoes. Most of the volcanoes are now inactive. There are also a large number of craters. There is no clear evidence that Venus or any other planet besides Earth has tectonic plates.

## Motion and Appearance

Venus is the only planet that rotates clockwise as viewed from above the northern plane of the solar system. All of the other planets rotate counterclockwise. Venus turns slowly, making only one turn every 243 days. This is longer than a **year** on Venus! It takes Venus only 225 days to orbit the Sun.

Because the orbit of Venus is inside Earth's orbit, Venus always appears close to the Sun. You can see Venus rising early in the morning, just before the Sun rises. For this reason, Venus is sometimes called "the morning star." When it sets in the evening, just after the Sun sets, it may be called "the evening star." Since planets only reflect the Sun's light, Venus should not be called a star at all! Venus is very bright because its clouds reflect sunlight very well. Venus is the brightest object in the sky besides the Sun and the Moon.

## Section 3: Earth

Earth is the third planet from the Sun, shown in the Figure below. Because it is our planet, we know a lot more about Earth than we do about any other planet. What are some of the main features of Earth?

### Oceans and Atmosphere

Earth is a very diverse planet. Water appears as vast oceans of liquid. Water is also seen as ice at the poles or as clouds. Earth also has large masses of land. Earth's average surface temperature is 14°C (59°F). At this temperature, water is a liquid. The oceans and the atmosphere help keep Earth's surface temperatures fairly steady.

Earth is the only planet known to have life. Conditions on Earth are ideal for life! The atmosphere and magnetic field filters out harmful

radiation. Water is abundant. Carbon dioxide was available for early life forms. The evolution of plants introduced more oxygen for animals.

#### Plate Tectonics

The Earth is divided into many plates. These plates move around on the surface. The plates collide or slide past each other. One may even plunge beneath another. Plate motions cause most geological activity. This activity includes earthquakes, volcanoes, and the buildup of mountains. The reason for plate movement is convection in the mantle. Earth is the only planet that we know has plate tectonics.

#### Earth's Motions and Moon

Earth rotates on its axis once every day. This is the length of an Earth day. Earth orbits the Sun once every 365.24 days. This is the length of an Earth year. Earth has one large moon. The moon orbits Earth once every 29.5 days with respect to the sun. This moon is covered with craters, and also has large impact basins that were later filled with lava. Many astronomers think that the Moon came into being from material that flew into space after Earth and a Mars-sized object collided during the formation of the solar system. This moon is not a captured asteroid like other moons in the solar system.



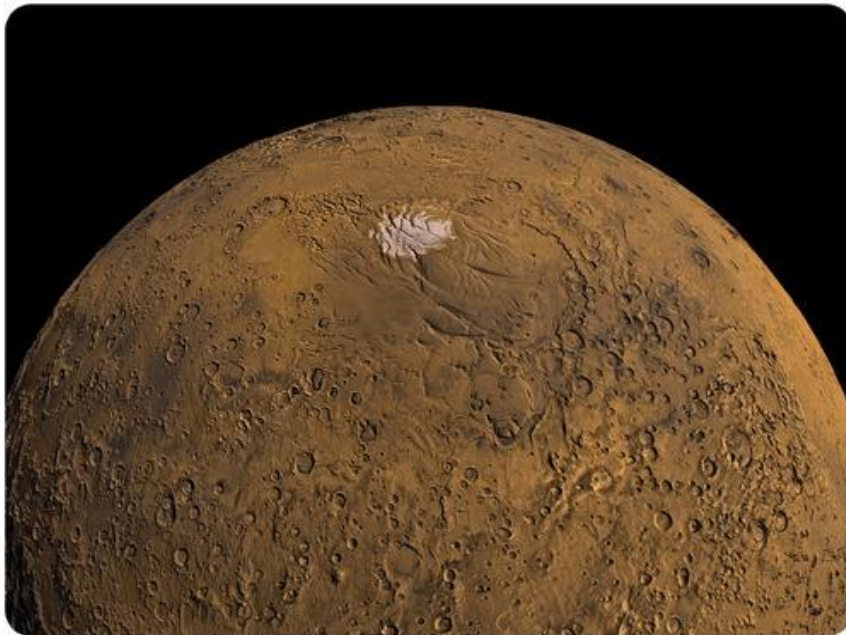
Extension: Life on Earth and elsewhere:

[nai.arc.nasa.gov/library/downloads/ERG.pdf](http://nai.arc.nasa.gov/library/downloads/ERG.pdf)

## Section 4: Mars

Mars, shown in the Figure below, is the fourth planet from the Sun. The Red Planet is the first planet beyond Earth's orbit. Mars' atmosphere is thin compared to Earth's. This means that there is much lower pressure at the surface. Mars also has a weak greenhouse effect, so temperatures are only slightly higher than they would be if the planet did not have an atmosphere.

Mars is the only planet that has a surface that can be observed from Earth through a telescope. As a result, it has been studied more than any other planet besides Earth. We have also sent many space probes to Mars. In April 2011, there were three scientific satellites in orbit around Mars. The rover, Opportunity, was still moving around on the surface. No humans have ever set foot on Mars. NASA and the European Space Agency have plans to send people to Mars. The goal is to do it sometime between 2030 and 2040. The expense and danger of these missions are phenomenal.



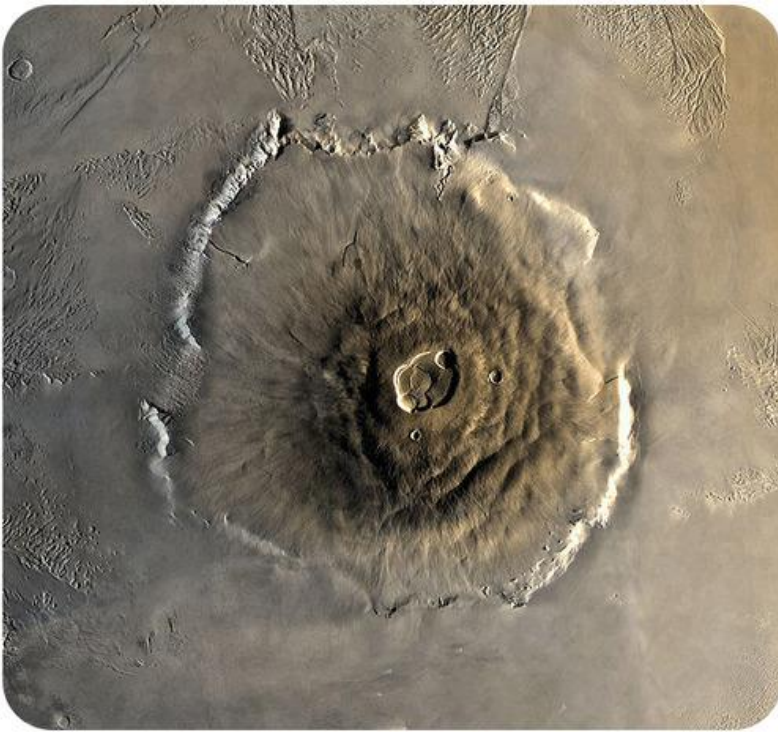


## A Red Planet

Viewed from Earth, Mars is red. This is due to large amounts of iron oxide in the soil. The ancient Greeks and Romans named the planet Mars after the god of war. The planet's red color reminded them of blood. Mars has only a very thin atmosphere, made up mostly of carbon dioxide.

## Surface Features

Mars is home to the largest volcano in the solar system. Olympus Mons is shown in the Figure below. Olympus Mons is a shield volcano. The volcano is similar to the volcanoes of the Hawaiian Islands. But Olympus Mons is a giant, about 27 km (16.7 miles/88,580 feet) tall. That's three times taller than Mount Everest! At its base, Olympus Mons is about the size of the entire state of Arizona.



The largest volcano in the solar system, Olympus Mons.



The largest canyon in the solar system, Valles Marineris

Mars also has the largest canyon in the solar system, Valles Marineris (the Figure below). This canyon is 4,000 km (2,500 miles) long. That's as long as Europe is wide! One-fifth of the circumference of Mars is covered by the canyon. Valles Marineris is 7 km (4.3 miles) deep. How about Earth's Grand Canyon? Earth's most famous canyon is only 446 km (277 miles) long and about 2 km (1.2 miles) deep.

Mars has mountains, canyons, and other features similar to Earth. But it doesn't have as much geological activity as Earth. There is no evidence of plate tectonics on Mars. There are also more craters on Mars than on Earth. But there are fewer craters than on the Moon. What does this suggest to you regarding Mars' plate tectonic history?

Is There Water on Mars?

Water on the surface of Mars can't be a liquid. This is because the pressure of the atmosphere and the temperature are too low. The planet does have a lot of water; it is in the form of ice. The south pole of

Mars has a very visible ice cap. Scientists also have evidence that there is a lot of ice just under the Martian surface.

Scientists think that there was once liquid water on the planet. There are many surface features that look like water-eroded canyons. Rovers and orbiters sent to Mars have found minerals that, on Earth, usually form in water. If there was liquid water on Mars, life might have existed there in the past.

### Two Martian Moons

Mars has two very small, irregular moons, Phobos and Deimos. These moons were discovered in 1877. They are named after the two sons of Ares, who followed their father into war. There are several explanations for the origin of these moons.

“Many scientists believe that Phobos and Deimos are asteroids that wandered close to Mars billions of years ago. The Martian atmosphere may have been thick enough to act as a brake slowing the small bodies to trap them in orbit. But other scientists say that the moons formed at the same time as Mars, or that they’re remnants of a larger moon that was shattered by a large meteor.”

<http://bit.ly/1beSCr0>

University of Texas McDonald Observatory

## Lesson Summary

- The four inner planets are small, dense, solid, rocky planets.
- Mercury is the smallest planet and the closest to the Sun. It has an extremely thin atmosphere so surface temperatures range from very hot to very cold. Like the Moon, it is covered with craters.
- Venus is the second planet from the Sun and the closest planet to Earth, in distance and in size. Venus has a very thick, corrosive atmosphere, and the surface temperature is extremely high.
- Radar maps of Venus show that it has mountains, canyons and volcanoes surrounded by plains of lava.
- Venus rotates slowly in a direction opposite to the direction of its orbit.
- Earth is the third planet from the Sun. It is the only planet with large amounts of liquid water, and the only planet known to support life. Earth is the only inner planet that has a large round moon.
- Mars is the fourth planet from the Sun. It has two small, irregular moons. Mars is red because of rust in its soil. Mars has the largest mountain and the largest canyon in the solar system.
- There is a lot of water ice in the polar ice caps and under the surface of Mars.

## Think Like An Astronomer

1. Name the four inner planets from nearest to the Sun to farthest out from the Sun.
2. Which planet is most like Earth? Why?
3. How do scientists get maps of Venus' surface? What do you see if you look at Venus from Earth through a telescope?

4. Which planet do you think has the smallest temperature range? Why?
5. If you were told to go to one of the three inner planets besides Earth to look for life where would you go? Why?
6. Venus is said to have runaway greenhouse effect? Why does it have such a large amount of greenhouse effect? Why do you think is meant by runaway greenhouse effect?

# What Are Conditions Like on the Outer Planets?

## Lesson Objectives

- Describe main features of the outer planets and their moons.
- Compare the outer planets to each other and to Earth.

## Introduction

Jupiter, Saturn, Uranus, and Neptune are the outer planets of our solar system. These are the four planets farthest from the Sun. The outer planets are much larger than the inner planets. Since they are mostly made of gases, they are also called gas giants.

The gas giants are mostly made of hydrogen and helium. These are the same elements that make up most of the Sun. Astronomers think that most of the nebula was hydrogen and helium. The inner planets lost these very light gases. In the inner solar system the gases were too hot for the gravity of the inner planets to keep them. In the outer solar system it was cold enough for the gravity of the planets to keep the colder slower moving hydrogen and helium gas.

All of the outer planets have numerous moons. They also have planetary rings made of ice. Only the rings of Saturn can be easily seen from Earth.

## Section 1: Jupiter

Jupiter is the largest planet in our solar system.

Jupiter, shown in the figure on the next page, is the largest planet in our solar system. Jupiter is named for the king of the gods in Roman mythology.

Jupiter is truly a giant! The planet has 318 times the mass of Earth, and about 1400 times Earth's volume. So Jupiter is much less dense than Earth. Because Jupiter is so large, it reflects a lot of sunlight. When it is visible, it is the brightest object in the night sky besides the Sun. Jupiter is quite far from the Earth. The planet is more than five times as far from the Sun as Earth. It takes Jupiter about 12 Earth years to orbit once around the Sun.

### Terms to know

- Galilean moons
- gas giants
- outer planets
- planetary rings

### A Ball of Gas and Liquid

Since Jupiter is a gas giant, could a spacecraft land on its surface? The answer is no. There is no solid surface at all! Jupiter is made mostly of hydrogen, with some helium, and small amounts of other elements. The outer layers of the planet are gas. Deeper within the planet, the intense pressure condenses the gases into a liquid. Jupiter may have a small rocky core at its center.



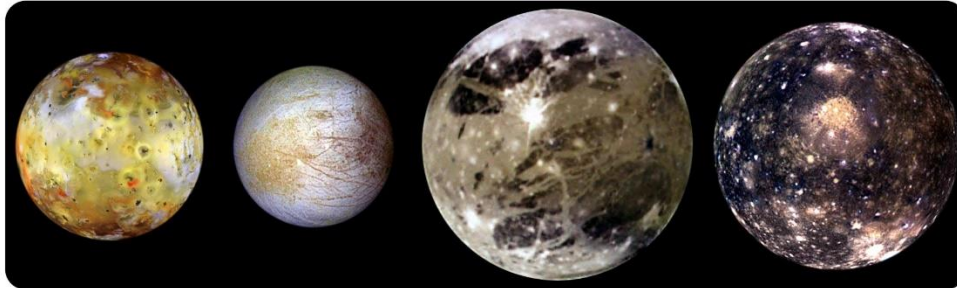
### A Stormy Atmosphere

Jupiter's atmosphere is made mostly of hydrogen and helium gas. There are also small amounts of other gases that contain hydrogen, like methane, ammonia and water vapor. Astronomers think that clouds in the atmosphere are particles of water, ice and compounds made of ammonia. Alternating cloud bands rotate around the planet in opposite directions. Colors in these cloud bands may come from complex organic molecules. The Great Red Spot, shown in the Figure above, is Jupiter's most noticeable feature. The spot is an enormous, oval-shaped storm. It can expand to be more than two times as wide as the entire Earth! Clouds in the storm rotate counterclockwise. They make one complete turn every six days or so. The Great Red Spot has been on Jupiter for at least 300 years. It may have been observed as early as 1664. It is possible that this storm is a permanent feature on Jupiter. No one knows for sure.

### Jupiter's Moons and Rings

Jupiter has lots of moons. As of 2012, we have discovered over 67 natural satellites of Jupiter. Four are big enough and bright enough to be seen from Earth using a pair of binoculars. These four moons were first discovered by Galileo in 1610. They are called the Galilean moons. The Figure below shows the four Galilean moons and their sizes relative to Jupiter's Great Red Spot. These moons are named Io, Europa, Ganymede, and Callisto. The Galilean moons are larger than even the

biggest dwarf planets, Pluto and Eris. Ganymede is the biggest moon in the solar system. It is even larger than the planet Mercury!



The Galilean moons are as large as small planets.

Scientists think that Europa is a good place to look for extraterrestrial life. Europa is the smallest of the Galilean moons. The moon's surface is a smooth layer of ice. Scientists think that the ice may sit on top of an ocean of liquid water. How could Europa have liquid water when it is so far from the Sun? Europa is heated by differences in Jupiter's gravity as Europa's distance changes during an orbit. These tidal forces are so great that they stretch and squash its moon. This could produce enough heat for there to be liquid water. Various missions have been discussed to explore Europa, including the idea to have a probe melt deep down through the ice into the ocean. However, no such mission has yet been attempted.

In 1979, two spacecrafts, Voyager 1 and Voyager 2, visited Jupiter and its moons. Photos from the Voyager missions showed that Jupiter has a ring system. This ring system is very faint, so it is very difficult to observe from Earth.

## Section 2: Saturn

Saturn, shown in the figure below, is famous for its beautiful rings. Saturn is the second largest planet in the solar system. Saturn's mass is about 95 times Earth's mass. The gas giant is 755 times Earth's volume. Despite its large size, Saturn is the least dense planet in our solar system. Saturn is actually less dense than water. This means that if there were a bathtub big enough, Saturn would float! In Roman



mythology, Saturn was the father of Jupiter. Saturn orbits the Sun once about every 30 Earth years.

Saturn is the least dense planet in our solar system.



Saturn's composition is similar to Jupiter's. The planet is made mostly of hydrogen and helium. These elements are gases in the outer layers and liquids in the deeper layers. Saturn may also have a small solid core. Saturn's upper atmosphere has clouds in bands of different colors. These clouds rotate rapidly around the planet. But Saturn has fewer storms than Jupiter.

#### Saturn's Rings

Saturn's rings were first observed by Galileo in 1610. He didn't know they were rings and thought that they were two large moons. One moon was on either side of the planet. In 1659, the Dutch astronomer Christiaan Huygens realized that they were rings circling Saturn's equator. The rings appear tilted. This is because Saturn's rotation axis is tilted about 27 degrees from a line perpendicular to its orbit.

The Voyager 1 spacecraft visited Saturn in 1980. Voyager 2 followed in 1981. These probes sent back detailed pictures of Saturn, its rings, and some of its moons. The Cassini spacecraft has been in orbit around Saturn since 2004. From the Voyager and Cassini data, we learned that Saturn's rings are made of mostly ice particles of different sizes with a little bit of dust. There are several gaps in the rings. The gaps result from gravitational interactions between the ring particles and Saturn's moons that orbit outside the ring or by a small moon orbiting within the gap.

#### Saturn's Moons

As of 2012, over 62 moons have been identified around Saturn. Only seven of Saturn's moons are round. All but one is smaller than Earth's moon. Some of the very small moons are found within the rings. All the

particles in the rings are like little moons, because they orbit around Saturn.

Saturn's largest moon, Titan, is about one and a half times the diameter of Earth's moon. Titan is even larger than the planet Mercury. Scientists are very interested in Titan. The moon has an atmosphere that is thought to be like Earth's first atmosphere. This atmosphere was around before life developed on Earth. Like Jupiter's moon, Europa, Titan may have a layer of liquid water under a layer of ice. Scientists now think that there are lakes on Titan's surface. Don't take a dip, though. These lakes contain liquid methane and ethane instead of water! Methane and ethane are compounds found in natural gas.

### Section 3: Uranus



Uranus is the 7th planet out from the Sun. Uranus' rings are almost perpendicular to the planet.

Uranus, shown in the figure above, is named for the Greek god of the sky, the father of Saturn. Astronomers pronounce the name "YOOR-uh-nuhs." Uranus was not known to ancient observers. The planet was first discovered with a telescope by the astronomer William Herschel in 1781.

Uranus is faint because it is very far away. Its distance from the Sun is 2.8 billion kilometers (1.8 billion miles). A photon from the Sun takes about 2 hours and 40 minutes to reach Uranus. Uranus orbits the Sun once about every 84 Earth years.

### An Icy Blue-Green Ball

Uranus is a lot like Jupiter and Saturn. The planet is composed mainly of hydrogen and helium, but Uranus has a higher percentage of “ices” than Jupiter and Saturn. These “ices” include water, ammonia, and methane. Uranus is also different because of its blue-green color. Methane gas absorbs red light so the reflected light gives Uranus a blue-green color. The atmosphere of Uranus has bands of clouds. These clouds are hard to see in normal light. The result is that the planet looks like a plain blue ball.

Uranus is the least massive outer planet. Its mass is only about 14 times the mass of Earth. Like all of the outer planets, Uranus is much less dense than Earth. Gravity is actually weaker than on Earth's surface. If you were at the top of the clouds on Uranus, you would weigh about 10 percent less than what you weigh on Earth.

### The Sideways Planet

All of the planets rotate on their axes in the same direction that they move around the Sun except for Venus and Uranus. While Venus rotates in the opposite direction, Uranus is tilted on its side. Its axis is almost parallel to its orbit. How did Uranus get this way? One possibility is that the planet was struck by a large planet-sized object as it was forming during the early days of the solar system.

### Rings and Moons of Uranus

Uranus has a faint system of rings, as shown in the Figure below. The rings circle the planet's equator. However, Uranus is tilted on its side. So the rings are almost perpendicular to the planet's orbit.

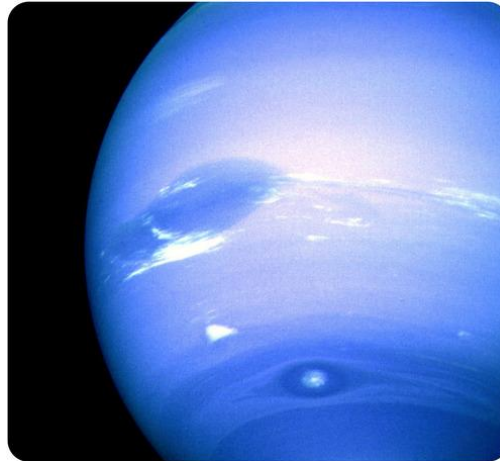


We have discovered 27 moons around Uranus. All but a few are named for characters from the plays of William Shakespeare.

## Section 4: Neptune

Neptune is shown in the Figure below. It is the eighth planet from the Sun. Neptune is so far away you need a telescope to see it from Earth. Neptune is the most distant planet in our solar system. It is nearly 4.5 billion kilometers (2.8 billion miles) from the Sun. One orbit around the Sun takes Neptune 165 Earth years.

Neptune has a great dark spot at the center left and a small dark spot at the bottom center.



Scientists guessed Neptune's existence before it was discovered. Uranus did not always appear exactly where it should. They said this was because a planet beyond Uranus was pulling on it. This gravitational pull was affecting its orbit. Neptune was discovered in 1846. It was just where scientists predicted it would be! The planet was named Neptune for the Roman god of the sea.

Uranus and Neptune are often considered "sister planets." They are very similar to each other. Neptune has slightly more mass than Uranus, but it is slightly smaller in size.

### Extremes of Cold and Wind

Like Uranus, Neptune is blue. The blue color is mostly caused by the absorption of red light by methane in Neptune's atmosphere. Neptune is not a smooth looking ball like Uranus. The planet has a few darker and lighter spots. When Voyager 2 visited Neptune in 1986, there was a large dark-blue spot south of the equator. This spot was called the Great Dark Spot. When the Hubble Space Telescope photographed

Neptune in 1994, the Great Dark Spot had disappeared. Another dark spot had appeared north of the equator. Neptune's appearance changes due to its turbulent atmosphere. Winds are stronger than on any other planet in the solar system. Wind speeds can reach 1,100 km/h (700 mph). This is close to the speed of sound! The rapid winds surprised astronomers. This is because Neptune receives little energy from the Sun to power weather systems. It is not surprising that Neptune is one of the coldest places in the solar system. Temperatures at the top of the clouds are about  $-218^{\circ}\text{C}$  ( $-360^{\circ}\text{F}$ ).

### Neptune's Rings and Moons

Like the other outer planets, Neptune has rings of ice and dust. These rings are much thinner and fainter than Saturn's. Neptune's rings may be unstable. They may change or disappear in a relatively short time.

Neptune has 13 known moons. Only Triton, shown in the Figure below, has enough mass to be round. Triton orbits in the direction opposite to Neptune's orbit. Because of this, scientists think Triton did not form around Neptune. The satellite may have been captured by Neptune's gravity as it passed very close to Neptune.



Neptune's moon  
Triton.

## Lesson Summary

- The four outer planets — Jupiter, Saturn, Uranus, and Neptune — are all gas giants made mostly of hydrogen and helium. Their thick outer layers are gases and have liquid interiors.
- All of the outer planets have lots of moons, as well as planetary rings made of dust and other particles.
- Jupiter is the largest planet in the solar system. It has bands of different colored clouds, and a long-lasting storm called the Great Red Spot.
- Jupiter has over 60 moons. The four biggest were discovered by Galileo, and are called the Galilean moons.
- One of the Galilean moons, Europa, may have an ocean of liquid water under a layer of ice. The conditions in this ocean might be right for life to have developed.
- Saturn is smaller than Jupiter, but very similar to Jupiter. Saturn has a large system of beautiful rings.
- Saturn's largest moon, Titan, has an atmosphere similar to Earth's atmosphere before life formed.
- Uranus and Neptune were discovered using a telescope. They are similar to each other in size and composition. They are both smaller than Jupiter and Saturn, and also have more icy materials.
- Uranus is tilted on its side, probably due to a collision with a large object in the distant past.
- Neptune is very cold and has very strong winds. It had a large dark spot that disappeared. Another dark spot appeared on another part of the planet. These dark spots are storms in Neptune's atmosphere.

## Think Like An Astronomer

1. Why were the Galilean moons given that name? What are they?
2. How are the outer planets different from the inner planets?

3. If you were given the task of finding life in the outer solar system where would you look?
4. The atmosphere of Saturn's moon Titan may resemble the early Earth's atmosphere. Why is this interesting to scientists?

#### POINTS TO CONSIDER

5. The inner planets are small and rocky, while the outer planets are large and made of gases. Why might the planets have formed into these two groups?
6. We have discussed the Sun, the planets, and the moons of the planets. What other objects can you think of that can be found in our solar system?



# What Other Objects are in the Solar System?

## Lesson Objectives

- Locate and describe the asteroid belt.
- Explain where comets come from and what causes their tails.
- Discuss the differences between meteors, meteoroids, and meteorites.

## Introduction

Debris. Space junk. After the Sun and planets formed, there was some material left over. These small chunks didn't get close enough to a large body to be pulled in by its gravity. They now inhabit the solar system as asteroids and comets.

## Section 1: Asteroids

Asteroids are very small, irregularly shaped, rocky bodies. Asteroids orbit the Sun, but they are more like giant rocks than planets. Since they are small, they do not have enough gravity to become round. They are too small to have an atmosphere. Except for a few of the largest asteroids, they are too small to have internal heat, so they are not geologically active. These asteroids can only change due to a collision. A collision may cause the asteroid to break up. It may create craters and melt some of the rocky material on the asteroid's surface. An asteroid may strike a planet if it comes near enough to be pulled in by its gravity. The Figure below shows a typical asteroid.



Asteroid Ida with its tiny moon Dactyl.

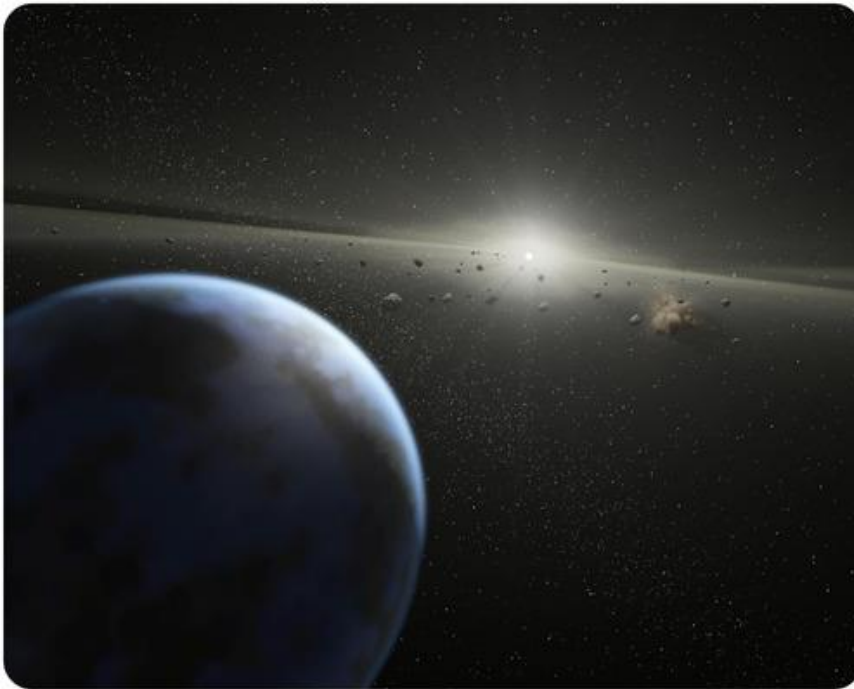
## The Asteroid Belt

### Terms to know

- asteroid
- asteroid belt
- comet
- Kuiper belt
- meteor
- meteoroid
- meteor shower

Hundreds of thousands of asteroids have been found in our solar system. They are now being discovered at a rate of tens of thousands of new asteroids per year! The majority are located in between the orbits of Mars and Jupiter. This region is called the asteroid belt, as shown in the Figure below. There are many thousands of asteroids in the asteroid belt. Still, their total mass adds up to only about 4 percent of Earth's moon.

Asteroids formed at the same time as the rest of the solar system. Although there are many in the asteroid belt, Jupiter's gravity kept the material in this region from forming into a planet, throwing much of it either out of the solar system or into the Sun.



The asteroid belt is between Mars and Jupiter.

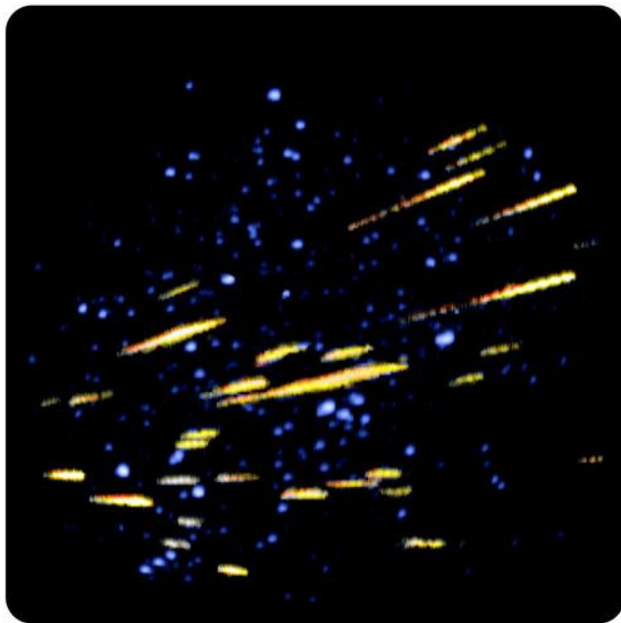
### Near-Earth Asteroids

Near-Earth asteroids have orbits that come near to or cross Earth's orbit. This means that they could possibly collide with Earth. There are over 10,000 known near-Earth asteroids. Small asteroids do sometimes

collide with Earth. An asteroid about 5-10 m in diameter hits about once per year. About a thousand of the known near-Earth asteroids are much bigger. They are over 1 kilometer in diameter. When large asteroids hit Earth in the past, many organisms died. At times, many species became extinct. Astronomers keep looking for near-Earth asteroids. They hope to predict a possible collision early so they can try to stop it.

## Section 2: Meteors

If you look at the sky on a dark night, you may see a meteor, like in the Figure below. A meteor forms a streak of light across the sky. People call them shooting stars because that's what they look like. But meteors are not stars at all. The light you see comes from a small piece of matter burning up as it flies through Earth's atmosphere.



Meteors burning up as they fall through Earth's atmosphere.

### Meteoroids

Before these small pieces of matter enter Earth's atmosphere, they are called meteoroids. Meteoroids are as large as boulders or as small as tiny sand grains. Larger objects are called asteroids; smaller objects are interplanetary dust. Meteoroids sometimes cluster together in long trails. They are the debris left behind by comets. When Earth passes through

a comet trail, there is a meteor shower. During a meteor shower, there are many more meteors than normal for a night or two.

### Meteorites

A meteoroid that passes very close to Earth is dragged towards Earth by gravity and enters the atmosphere. As it enters the atmosphere, it compresses the air in front of it, producing enormous heat and the meteoroid starts to vaporize. As it flies through the atmosphere, it leaves a trail of glowing gases. The object is now a meteor. Most meteors vaporize in the atmosphere. They never reach Earth's surface. Large meteoroids may not burn up entirely in the atmosphere. Some pieces of the rock may survive and land on Earth's surface. Once on the ground, it is called a meteorite.

Meteorites provide clues about our solar system. Almost all were formed in the early solar system (the Figure below). Some were part of larger asteroids that have been broken apart. A tiny fraction are rocks from nearby bodies like Mars or the Moon. For this to happen, an asteroid smashed into Mars or the Moon and sent up debris into space. After spending a long time orbiting the Sun, a bit of the debris landed on



Earth as a meteorite.

The Mars Rover, Opportunity, found a metal meteorite on the Red Planet.

## Section 3: Comets

Comets are small, icy objects that orbit the Sun. Comets have highly elliptical orbits. Their orbits carry them from close to the Sun to the solar system's outer edges. When a comet gets close to the Sun, its outer layers of ice melt and evaporate. The vaporized gas and dust forms an atmosphere around the comet. This atmosphere is called a coma. Radiation and particles streaming from the Sun push some of this gas and dust into a long tail. A comet's tail always points away from the Sun, no matter which way the comet is moving. Why do you think that is? The Figure below shows Comet Hale-Bopp, which shone brightly for several months in 1997.

Gases in the coma and tail of a comet reflect light from the Sun. Because comets are very small, they are very hard to see except when they are surrounded by a coma. That is why they are more easily discovered and seen when they are in the inner solar system. They are nearly impossible to see as they move back to the outer solar system. The time it takes a comet to complete one orbit is called the comet's period. The first comet whose period was calculated was Halley's Comet. Its period is about 76 years. Halley's Comet last traveled through the inner solar system in 1986. The comet will appear to Earth observers again in 2061 and pass closest to the Sun in 2062. Who will look up at it?

### Where Comets Come From

Some comets have periods of 200 years or less. They are called short period comets. Short period comets are from a region beyond the orbit of Neptune called the Kuiper Belt. Kuiper is pronounced "KI-per," rhyming with "viper." The Kuiper Belt is home to comets, asteroids, and at least two dwarf planets.

Some comets have periods of thousands or even millions of years. Most long-period comets come from a very distant region of the solar system. This region is called the Oort cloud. The Oort cloud is about 50,000-100,000 times the distance from the Sun to Earth. Comets carry materials in from the outer solar system. Comets may have brought water into the early Earth. Other substances could also have come from comets.

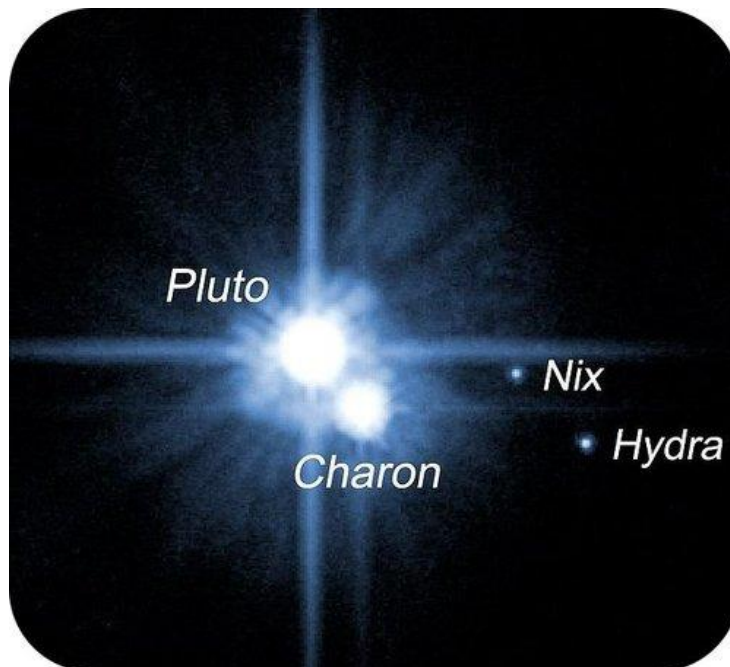
## Section 4: Dwarf Planets

For over seven decades, Pluto was classified as a planet. But new solar system objects were discovered that were similar to Pluto. They were small like Pluto. Their orbits were also similar to Pluto's orbit in that they are more elliptical and tilted compared to planet orbits. These objects and many more small objects form a "belt" beyond Neptune. Astronomers debated whether to classify these new objects as planets. Eventually they decided to reclassify Pluto. Astronomers made a category called dwarf planets. There are five dwarf planets in our solar system: Ceres, Pluto, Makemake, Haumea and Eris.

### Pluto

For decades Pluto was classified as a planet. But as they slowly discovered more about this object, scientists knew it was an unusual planet. The other outer planets are all gas giants. Pluto is small, icy and rocky. With a diameter of about 2400 kilometers, it has only about 1/5 the mass of Earth's Moon. The other planets orbit in nearly the same plane. Pluto's orbit is tilted. While most planets have nearly circular orbits, the orbit of Pluto is more elliptical. The orbit even crosses inside the orbit of Neptune. Pluto's orbit is in the Kuiper belt.

We have discovered more than 1000 Kuiper objects. Pluto has 5 moons of own. The largest, Charon, is A few astronomers classify Pluto and Charon as double dwarf planet (see the figure below). Two smaller



belt

its

big.

a

moons, Nix and Hydra, were discovered in 2005. The last two small moons, Kerberos and Styx were found in 2011 and 2012.

Pluto with its moons: Charon, Nix and Hydra.

## Lesson Summary

- Asteroids are irregularly-shaped, rocky bodies that orbit the Sun. Most of them are found in the asteroid belt, between the orbits of Mars and Jupiter.
- Meteoroids are smaller than asteroids, ranging from the size of boulders to the size of sand grains. When meteoroids enter Earth's atmosphere, they vaporize, creating a trail of glowing gas called a meteor. If any of the meteoroid reaches Earth, the remaining object is called a meteorite.
- Comets are small, icy objects that orbit the Sun in very elliptical orbits. When they are close to the Sun, they form comas and tails, which glow and make the comet more visible.
- Short-period comets come from the Kuiper belt, beyond Neptune. Long-period comets come from the very distant Oort cloud.
- Dwarf planets are spherical bodies that orbit the Sun, but that have not cleared their orbit of smaller bodies.

## Think Like An Astronomer

1. Define each of the following: asteroid, meteoroid, meteorite, meteor, planet, dwarf planet.
2. Which type of asteroid is most likely to hit Earth?
3. What is the asteroid belt? Why are there so many asteroids orbiting in this location?
4. What damage can an asteroid do when it hits Earth?



# Chapter 1 Glossary

- **Astronomical Units**- One astronomical unit is defined as the distance from Earth to the Sun.
- **Big Bang Theory**- the theory that the universe originated sometime between 10 billion and 20 billion years ago from the cataclysmic explosion of a small volume of matter at extremely high density and temperature  
<http://wordnetweb.princeton.edu/perl/webwn?s=big+bang+theory>
- **Black hole**- a region of space having a gravitational field so intense that no matter or radiation can escape.
- **Doppler Effect**- an increase (or decrease) in the frequency of sound, light, or other waves as the source and observer move toward (or away from) each other. The effect causes the sudden change in pitch noticeable in a passing siren, as well as the redshift seen by astronomers.
- **Dwarf planet**- a celestial body resembling a small planet but lacking certain technical criteria that are required for it to be classed as such.
- **Inner Planet**- closest to the Sun - Mercury, Venus, Earth, and Mars
- **Main sequence star**- hydrogen nuclei fuse to form helium nuclei
- **Nebula**- a big cloud of gas and dust
- **Neutron Star**- celestial object of very small radius (typically 18 miles/30 km) and very high density, composed predominantly of closely packed neutrons.
- **Nuclear Fusion**- a nuclear reaction in which atomic nuclei of low atomic number fuse to form a heavier nucleus with the release of energy.
- **Planet**- a celestial body moving in an elliptical orbit around a star.
- **Red Giant**- a very large star of high luminosity and low surface temperature
- **Red shift** - the shift of spectral lines toward longer wavelengths (the red end of the spectrum) in radiation from distant galaxies and celestial objects

- **Solar System**- the collection of eight planets and their moons in orbit around the sun, together with smaller bodies in the form of asteroids, meteoroids, and comets.
- **Star**- A self-luminous celestial body consisting of a mass of gas held together by its own gravity.
- **Supernova**- a star that suddenly increases greatly in brightness because of a catastrophic explosion that ejects most of its mass
- **Universe**- all existing matter and space considered as a whole; the cosmos.
- **Year**- one complete revolution around the sun