Chapter 12: The Solar System

The chapter explores the solar system, including the moon, the sun, sun and planets.

11.1 Objectives
By the end of the lesson, the students should be able to

- Describe the major components of the solar system
- Compare and contrast the planets in the solar system
- Describe the star found in the solar system (Sun)
- Describe the phases of the Moon
- Compare and contrast lunar and solar eclipses
- Compare and contrast asteroids, comets, and meteoroids

Academic Language (Vocabulary)
Here are some scientific terms you need to know for this chapter:

- Astronomer
- Telescope
- Constellation
- Planet
- Eclipse
- Satellite
- Gravity
- Rotation
- Revolution
- Orbital period

11.2 Lesson Content
Introduction

Space has always represented the unknown to us humans on Earth. Space represented the unknown because it seemed so far away and hard to describe. Still, throughout history, humans have understood our dependence on parts of the solar system, especially the Sun. Humans understood the Sun allows them to farm, stay warm, and impacted day and night. Weird things happened because of the Sun – ancient humans experienced eclipses and had no idea how to explain those events. Ancient scientists observed changes in the skies throughout the month and year. Those observations led them to believe in celestial movement, perhaps even orbits. Knowing only that mankind lived on this planet, ancient scientists, like the Greek Ptolemy, described a geocentric model of the solar system. The geocentric model explains the Earth as the center of the universe, with all other celestial bodies revolving around the Earth. Did ancient scientists even consider what was beyond the visible sky? Probably not until advances like telescopes helped them learn about the solar system.

Scientists have been using lenses for magnification for thousands of years. There is evidence that the principles of telescopes were known in the late 16th century, with the first telescopes were created in the Netherlands in 1608. These telescopes used a combination of two lenses to make distant objects appear both nearer and larger. The term telescope was coined by the Italian scientist and mathematician Galileo Galilei (1564–1642). Galileo built his first telescope in 1608 and continued to make improvements to the original telescope design. This instrument has

continued to improve and become stronger, allowing today's astronomers to learn more and more about outer space.

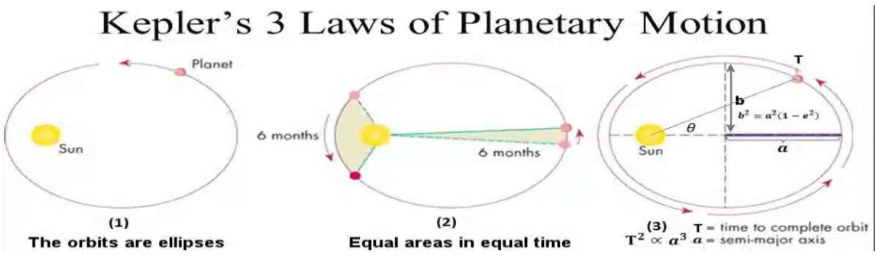
https://www.gettyimages.com/detail/news-photo/italian-astronomer-and-physicist-galileo-galilei-using-a-news-photo/50965499

Today, there are many types of telescopes, including refractive, reflective, and radio telescopes. Astronomers are scientists who study the universe beyond Earth. Using instruments like telescopes, astronomers can observe celestial objects at great distances.

11.3 The Solar System

The ancient scientists' idea of the solar system lasted over 1400 years. It took that long for other scientists to challenge Ptolemy's model of the solar system. Copernicus, and other scientists, learned more about the solar system by doing careful observations and keeping accurate measurements of those observations. The uses of telescopes helped scientists find celestial bodies that seemed to move, while others seemed to stay in place. Scientific discussions helped the scientists propose answers to some long help preconceptions and questions about the solar system.

It was Copernicus who suggested the Sun, rather than the Earth, was the center of the solar system. The newly proposed model was called the heliocentric system, or the sun-centered system. These scientists proposed all planets traveled in orbits around the Sun and in the same direction. An orbit is the path a planet moves around another object in space, for example around the Sun. Since orbits appear to have mathematical patterns, several mathematicians used mathematical calculations to discover the orbits were not circular but elliptical in shape. Johannes Kepler, using work from Tycho Brahe's celestial observations, formulated three laws of planetary motion. He found the orbits were elliptical rather than circular. His calculations showed the radius between a planet and the Sun sweeps in equal areas in equal times. It seems the closer the planet is to the Sun, the faster the planet moves. Finally, he calculated the further a planet is from the Sun, the longer it takes to orbit the Sun. Look at the figure below to see an illustration of Kepler's three laws of planetary motion.

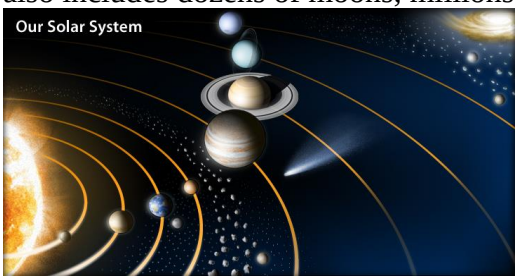


https://www.careerpower.in/school/physics/keplers-law

Another scientist, Galileo Galilei, used the telescope to make even closer observations of the planets, the Sun and the Moon. He actually observed and identified some of the moons rotating around Jupiter. Galileo found that planets were not just points of light, but appeared as circular disks. They were later found to be spheres. He observed the Moon's surface and described it as not being smooth. It was many years, however, before other scientists and religious authorities accepted these new ideas. In fact, Galileo was tried and convicted of heresy. He was placed under house arrest for the last year of his life for his radical ideas. As more scientific evidence can to light and supported his ideas, he was finally credited with having outstanding, groundbreaking ideas about the planets which make up our solar system.

As ancient scientists observed the night skies they saw that some of the bright objects moved around while others appeared to be stationary. They called these bright and odd bodies in the sky planets, which means "wanderers." Today we know that the planets are not stars, but members of our solar system that orbit the Sun. Scientists now know that planets reflect the light of the Sun and do not produce their own light. The objects that did not wander were identified as stars, some making patterns called constellations. Now, scientists know that our solar system is just a small part of the universe. Scientists do accept the heliocentric model of our small solar system, with the knowledge that the solar system is just a small part of the whole universe. It is called the solar system because the word "solar" is used to describe things related to our star.

Our solar system consists of our star, the Sun, and everything bound to it by gravity. This includes the planets Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune and the dwarf planets such as Pluto. Other dwarf planets include Ceres, Makemake, Haumea and Eris. It also includes dozens of moons, millions of asteroids, comets, and meteoroids.



https://skyandtelescope.org/astronomy-resources/solar-system-planets-how-many-are-there/

Our Sun is considered a medium size star, even though it is the largest object in our solar system and contains 99.86% of the solar system's mass. Each of the planets make one complete orbit around the Sun and each has an "orbital period." There are six planets, dwarf planets and other natural satellites orbiting in the solar system. The orbital period is determined by the planet's

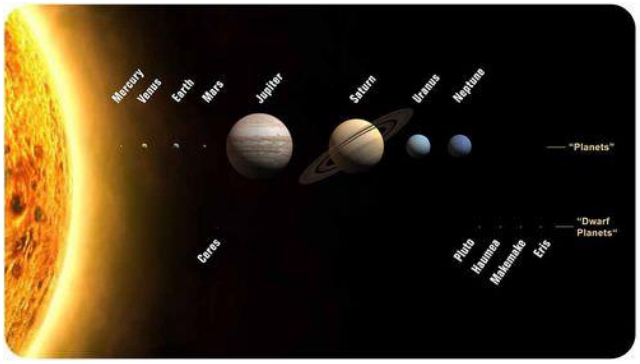
distance from the Sun. Those distances are measured in astronomical units (AU). An AU is defined as the distance from the Earth to the Sun.

The solar system was formed about 4.6 billion years ago. Scientists believe it was formed from the collapse of a giant interstellar molecular cloud that formed the Sun and the beginnings of a disk filled with material that solidified to form planets and other objects. The planets lying in the same plane supports this idea. As gravity pulled matter into the center of the disk, the density and pressure at the center became intense. When the pressure in the center of the disk was high enough, nuclear fusion began. A star was born—the Sun. The burning star stopped the disk from collapsing further. The material that formed the solar system consisted mostly of hydrogen, some helium, and some small amounts of heavier elements fused by previous generations of stars. These heavier elements, probably metals and silicates, are thought to have formed the rocky, or terrestrial planets. Matter condensed from the cloud and small pieces of dust started clumping together. Since there were small amounts of these materials, the terrestrial planets did not grow into large planets. On the other hand, the giant, or Jovian, planets formed further out and were formed using the plentiful materials. That allowed those planets to grow larger. As the hydrogen in the Sun reacts and is used up, forming helium, the Sun's life cycle will end. The Sun will most likely become a red giant, expand, and the solar system, as we know it, will no longer exist.

To summarize the formation of the solar system, scientists use this nebular hypothesis to explain some of the basic features of the solar system. This includes the following main ideas:

- The orbits of the planets lie in nearly the same plane with the Sun at the center,
- The planets revolve in the same direction,
- The planets mostly rotate in the same direction,
- The axes of rotation of the planets are mostly nearly perpendicular to the orbital plane, and
- The oldest moon rocks are 4.5 billion years.

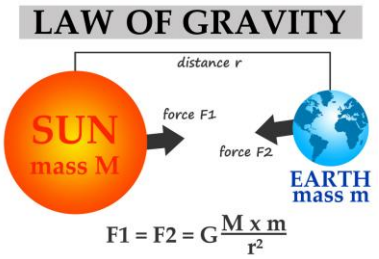
As a result, scientists describe the formation of the solar system as developing from a giant cloud of gas and dust about 4.6 billion years ago. Before examining the parts that make up the solar system, examine the illustration as we prepare to study the planets in the solar system:

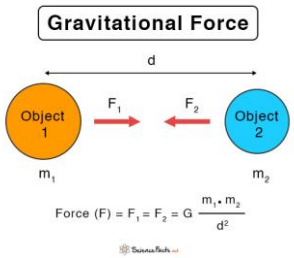


https://www.iau.org/public/themes/pluto/

11.4 Behavior of satellites in the Solar System

Yet another scientist, Isaac Newton, hypothesized that gravity keeps the planets in orbit, thus, the law of universal gravitation. It states, " Every body in the universe attracts every other body with a force that is directly proportional to their masses and inversely proportional to the square distance between them." The law looks like this when thinking about the solar system, and even the universe:



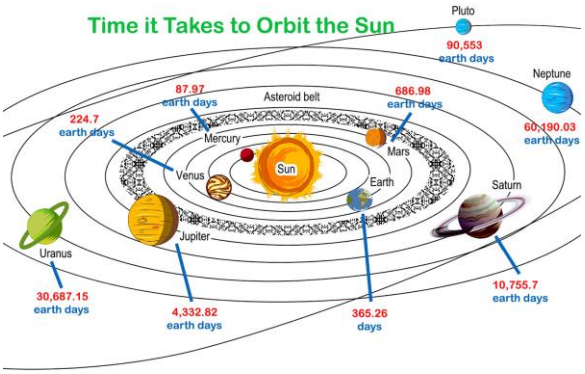


https://kidspressmagazine.com/science-for-kids/misc/misc/law-gravity.html
https://owlcation.com/stem/newton-law-gravitation-gravity-gravitational-force

In other words, mass and distance affect the attraction between objects in the universe. This discovery, as well as many others, helped encourage scientists to begin to learn more and more about satellites that exist within the solar system. Satellites include planets, moons, and other objects in the solar system.

Planets are satellites that orbit the Sun. Besides traveling around the Sun, each planet spins (rotates) on its axis. Scientists believe the axes are a result of collisions with each other, or other materials, as the planets were being formed. Planets spin at different speeds, impacting the length of the planet's day. Bigger or smaller planets spin at different speeds. The rotation of the planet is the time it takes for a planet to complete one rotation on its axis. In addition, almost all planets spin or rotate counterclockwise. Venus spins clockwise, which is east to west, and that is called retrograde. The rest of the planets spin west to east, counterclockwise. Another planet, Uranus, rolls on its side as it orbits the Sun. The rotation of the planet helps to determine the length of its day. For Earth, that time is approximately twenty-four (24) hours. Each planet has a different length of day. For example, Venus has the longest day at 243 Earth days, which is about 20 days longer than a Venus year. Planets not only rotate on an axis, they revolve around the Sun.

The revolution of the planets around the Sun accounts for the length of the planet's year. Revolution refers to the movement of a planet around the Sun. All of the planets in our solar system revolve around the sun. The revolution of the planets around the Sun accounts for one year. The period of revolution is the time it takes for a planet to make one complete orbit around the Sun accounts for one year, different for each planet. For Earth, that period is approximately 365 days. On other planets, the time or length of year is different. However, we measure the length of the year of other planets in comparison to Earth's day or year. For example, a year on Mercury is about 88 Earth days, while Jupiter's year is 11.9 Earth years. Planets closer to the Sun tend to have shorter years, while those further away have longer and longer years. Examine the figure below to compare the time it takes for each planet to orbit the Sun in Earth days:



https://planetfacts.org/length-of-year-for-planets-in-order/

Here is a comparison of the rotation (length of day) and revolution (length of year) of each planet:

Planet	Rotation Period	Revolution Period
Mercury	58.6 days	87.97 days
Venus	243 days	224.7 days
Earth	0.99 day	365.26 days
Mars	1.03 days	1.88 years
Jupiter	0.41 day	11.86 years
Saturn	0.45 day	29.46 years
Uranus	0.72 day	84.01 years
Neptune	0.67 day	164.80 ears

https://www.mathcounts.org/resources/planet-rotations-revolutions-0

11.5 Planets in the Solar System

The planets in the solar system are classified into two main groups: the inner and outer planets. The four planets closest to the Sun are called the inner planets. They are called terrestrial planets because of their rocky surfaces. These planets are Mercury, Venus, Earth and Mars. These planets are smaller than the outer planets, closer to the Sun, have rocky surfaces, have higher densities, and different compositions than the outer planets.

https://www.universetoday.com/33059/inner-planets/

Mercury is closest to the Sun and smaller than Earth. If you are wondering how small Mercury is, then you could compare it to Earth's Moon. In fact, Mercury is the smallest planet in the solar system, with a diameter of 4878 km (about 3031 miles) and, according to scientists, appears to be shrinking. It has no discernable atmosphere and no known moons. Mercury's surface is covered in craters, like our Moon. In fact, it has more craters than any other planet. The Caloris Basin is a huge crater left by a large meteor (about 100 km long) that impacted its surface. The crater is large enough to fit part of Europe to fit inside it (from Portugal to Germany). The following is an image of Mercury, showing how much it looks like our Moon:

https://en.wikipedia.org/wiki/Mercury_%28planet%29

Its gravity is less than Earth, about 1/3 that of Earth. Therefore, if you weigh 100 lbs. on Earth, you weigh about 38 lbs. on Mercury. The temperatures on Mercury's surface range from -173° to 427° C. However, it is not the hottest planet in the solar system. It is classified as a terrestrial planet because it consists of about 70% metallic and 30% silicate material, making it the second densest planet after Earth. Most scientists believe this is because of its large metal core. A day on Mercury is equal to approximately 176 Earth days because it has a slow rotation. However, it revolves around the Sun quickly, with a year consisting of about 88 Earth days (87.97 Earth days). In fact, Mercury is the fastest planet in the solar system, traveling at about 47 km per second (29 miles/sec). While Copernicus did observe orbiting planets in the early 16th century, Mercury was first observed by Galileo during the 17th century. Mercury can be viewed from Earth in the early morning or late evening. Ancient Greeks named it after Hermes and Mercury (the messenger in Roman mythology), because of its speed and it moved across the sky faster than any other planet. While Mariner 10 made a flyby (1974), the Hubble Space Telescope cannot view Mercury because the Sun's brightness would harm the electrical components of the telescope. Two NASA missions have explored Mercury: Mariner 10 did the flyby and MESSENGER, which was the first to orbit it. To learn more about Mercury, use these two websites: https://solarsystem.nasa.gov/planets/mercury/overview/ or here https://en.wikipedia.org/wiki/Mercury_%28planet%29 .

Venus is second only to the Moon in brightness in the night sky. The planet was named from ancient Roman mythology, as Venus was their goddess of love. It is the third brightest object in our sky and is often called the morning star or evening star. While Venus is often called Earth's twin, there are huge differences between the two planets. This is an image of Venus in comparison to Earth:

https://news.uchicago.edu/story/was-venus-ever-habitable-new-uchicago-study-casts-doubt

It is also a terrestrial planet, with a size and density close to Earth's. It has a rocky terrain, volcanos and a dense atmosphere. Venus also has a toxic atmosphere, thick and filled with carbon dioxide. It has a dense, yellowish cloud cover of sulfuric acid which prevents scientists from obtaining a clear understanding of its surface. This cloud cover contributes to its greenhouse effect, making it the hottest planet in the solar system. Its surface temperatures of 465 degrees Celsius - enough to melt lead. The planet has a high 'albedo factor' or ability to reflect solar radiation. Venus does not have plants to recycle carbon dioxide, thereby increasing the greenhouse effect. The dense gases trap the heat energy, raising surface temperatures. It goes around the sun quickly, in 225 earth days. However, Venus spins about its axis slowly, taking 243 earth days to rotate once. Hence a day on Venus is longer than its year. However, it has a retrograde rotation (spins clockwise as opposed to Earth's spin which is counterclockwise). Astronomers believe that in the early days when Venus was forming, a massive celestial body would have collided with it, toppling it and setting it on a reverse spin. This means sunrise is in the west instead of the east. As Venusian days are longer than its year, the planet has a sunrise every 117 earth days. So, by the time a day ends on Venus, two sunrises and a year have already

passed by. Venus is very close to Earth in size, density and gravity. Scientists have evidence of volcanism and tectonic deformation activity. Its surface has plains, channels, shield volcanoes and evidence of volcanic flows. Astronomers have observed huge, meandering lava channels (some even 6000km long) on Venus, indicating it has undergone tremendous volcanic activity in the past. Recently spacecraft detected bursts of sulfur dioxide spewing from the Venusian clouds, indicating that the planet could still be volcanically active. They deduce that there could be 37 active volcanoes on Venus. Finally, Venus has crushing air pressure at its surface – more than 90 times that of Earth – so if you stood on the surface you would be crushed! Finally, Venus has been visited by spacecrafts, including Mariner 2, Magellan and NASA's Pioneer Venus Multiprobes. New missions are planned to learn more about Venus. If you want to learn more, please use these links: https://solarsystem.nasa.gov/planets/venus/overview/ or use the following: https://en.wikipedia.org/wiki/Venus.

Earth, the third rocky planets, is the only one known to support life (as we know it). Water can exist on Earth in three phases, allowing the development of our atmosphere. Its surface is covered with 71% water and its terrestrial surfaces have many biomes. The presence of water is evidenced through oceans, ice caps, glaciers, rivers, streams, lakes and ponds. This leads to a great diversity on plant and animal life. It is the first innermost plate that has a natural satellite, our Moon. Before learning more about Earth, let's look at it from outer space:

https://pixabay.com/photos/earth-globe-planet-world-space-11015/

Looking at Earth from outer space allows us to see the presence of water. The 71% of the Earth that is covered in water makes up our oceans allows Earth's atmosphere to support our living world. Earth's oceans are called the hydrosphere. Only 29% of the Earth is terrestrial, with the majority of that land surface located in the Northern hemisphere. We call those land masses continents and those continents are covered in vegetation, has a level of humidity and supports the rest of life. Earth developed about 4.5 billion years ago during the formation of the early solar system. It is the densest planet in the solar system due to its composition of three layer composition of iron and silicates. The three layers include the crust, mantle and core. The crust is mainly normal silicate rocks, while the mantle and core are mostly alloy mixtures of iron. This metallic core results in Earth's magnetic fields. Earth's crust has features that are the result of the tectonic plates and volcanic activity. There are seven major tectonic plates which are in constant motion. Volcanic activity generally occurs around the tectonic plates. Earth has an atmosphere that supports life. The atmosphere, along with the oceans, helps maintain Earth's environment and constant temperatures. The atmosphere has a perfect balance of gases needed to maintain life. It is composed of 78% nitrogen, 21% oxygen, and 1% other ingredients. That atmosphere also protects Earth from meteoroids because they break up in Earth's atmosphere. The other "spheres" are the biospheres and magnetosphere. It rotates on an axis, taking a full twenty-four (24) hours to make a complete orbit. Its movement around the Sun (revolution) takes about 325.25 days, making one Earth year. Its satellite, the Moon, revolves around Earth in about 27.32 days (one month). The axial tilt of the Earth accounts for the seasons, resulting in

winter, spring, summer and fall. Although not named after a Greek or Roman god/goddess, some historians believe Earth's name is from Thor's mother, the giantess whose name means "Earth." Others believe the name comes from a word that means "the ground." The relationship between the Earth and the Moon will be discussed later in the chapter. To read more about Earth, here are two sites: https://solarsystem.nasa.gov/planets/earth/overview/ or https://www.britannica.com/place/Earth or https://en.wikipedia.org/wiki/Earth#References.

Mars is a terrestrial planet and the fourth from the Sun and is about 4.5 billion years old. It is often called the red planet because the presence of finely grained iron oxide in the surface materials makes it appear red. While Mars seems to have an atmosphere, it is mostly carbon dioxide with small amounts of water vapor. It does appear to have (or had) polar ice caps made of water and covered with a thin layer of carbon dioxide. It appears to have dust storms and some surface craters. The "dust devils" sweep across the surface and make it look like it is trembling. The planet hosts the largest shield volcano called Olympus Mons and one of the largest canyons called Valles Narineris.

Other surface features indicate water may have existed at one time and flowed over the surface. This makes the planet the closest to having condition favorable to life. Take a careful examination of Mars's surface:

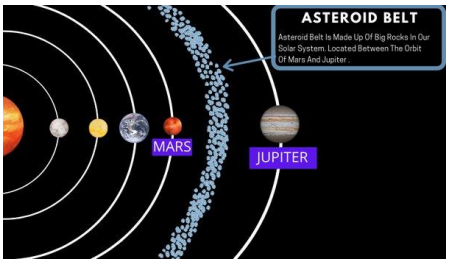
https://pixabay.com/photos/mars-red-planet-planet-space-11012/

While Mars is smaller than Earth, its day is about the same length as Earth (24 hours, 39 minutes), while its year is almost twice as long (about 686 days). Its composition indicates there are silicates on the crust, a metallic mantel, and has a metallic (iron and nickel) core, making it very similar to Earth's composition. However, it seems its northern hemisphere is flatter than the southern hemisphere which appears to have many impact craters. Mars has seasons (its axis is similar to that of Earth), but they seem to be twice as long as Earth's. It has two small natural satellites: Phobos and Deimos. These two moons may have been asteroids that were captured in Mars's orbit. Here is an image of the two moons:

https://mars.nasa.gov/all-about-mars/moons/summary/

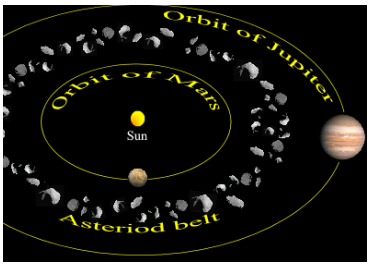
Mars is the last of the terrestrial planets and was named after the Roman god of war (the Greek names was Ares). More information can be found at the following sites: https://solarsystem.nasa.gov/planets/mars/overview/ or https://www.britannica.com/place/Mars-planet or https://www.nationalgeographic.com/science/article/mars-1 or https://en.wikipedia.org/wiki/Mars.

The terrestrial planets are separated from the outer, or Jovian, planets by an asteroid belt.



https://www.quora.com/What-is-asteroid-What-is-an-asteroid-belt

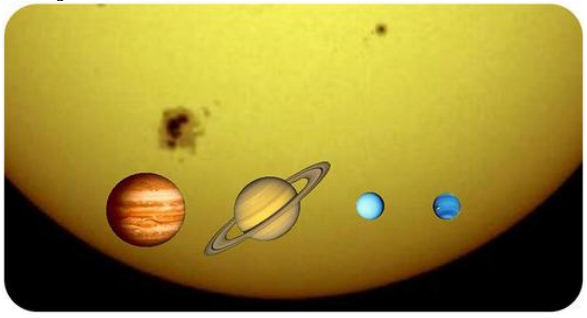
The asteroid belt has the majority of the known asteroids. It contains between 1.1 and 1.9 million asteroids that are larger than 1 km in diameter, but lots more smaller pieces. Asteroids are sometimes called minor planets, and some of the dwarf planets are, in fact, former asteroids. They are rocky pieces that appear to be left over from the formation of the solar system. Most of the solar system's asteroids are located in the asteroid belt. The asteroids can range in size from fairly large (530 m) to fairly small (10 m). Asteroids are classified into three main types: C-, S- and M-types. Each type has different compositions. For example, C-types, the most common, are mostly clay and silicate based. The S-types are silicate and iron. Finally, the M-types are metallic and made of nickel and iron. Most are irregularly shaped and have craters.



https://en.wikibooks.org/wiki/Wikijunior:Solar_System/Asteroid_belt

When all the asteroids are combined, the total mass of all the asteroids in the main asteroid belt is less than that of the Earth's Moon. Man's main concern about asteroid is the possibility that each has the potential to impact Earth. Here is more information: https://solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/overview/?page=0&per_page=40&order=name+asc&search=&condition_1=101%3Aparent_id&condition_2=asteroid%3Abody_type%3Ailike.

The outer, or Jovian, planets are located after the asteroid belt. There are four outer planets: Jupiter, Saturn, Uranus, and Neptune. The Jovian planets are larger, have gaseous surfaces, and are much less dense than the terrestrial planets. The outer planets probably consist of small, rocky cores surrounded by a liquid mantle and a gaseous shell. These planets are composed of light elements, such as hydrogen and helium. They are the only planets to have ring systems; many have numerous natural satellites.


https://courses.lumenlearning.com/suny-earthscience/chapter/outer-planets/

Jupiter is the first of the Jovian planets. It is the largest planet and is almost large enough to be a star. It is the third brightest object in the night sky. Scientists believe it may have been the

first planet to form and is composed mostly of hydrogen and helium. It rotates rapidly, making a day only ten hours long. It is very far from the Sun, making an entire revolution 12 Earth years, one Jupiter year. While its surface appears to have alternating stripes, which are the cold, windy clouds of ammonia and water that float in Jupiter's atmosphere. The upper layer of Jupiter's atmosphere contains clouds of ammonia (NH_3) in bands of different colors. These bands rotate around the planet, but also swirl around in turbulent storms. The Great Red Spot is an enormous, oval-shaped storm found south of Jupiter's equator. This storm is more than three times as wide as the entire Earth. Clouds in the storm rotate in a counterclockwise direction, making one complete turn every six days or so. The Great Red Spot has been on Jupiter for at least 300 years, since astronomers could first see the storm through telescopes. Its most striking feature is its Great Red Spot, a giant storm that is many hundreds of years old and may be twice the size of Earth. Other scientists believe the Great Red Spot is a calm spot rather than a huge storm. By collecting data, scientists have found the Great Red Spot and much smaller disturbances moving in the current at the same latitude. The interior of the spot is remarkably tranquil, with no clear evidence for the expected upwelling of material from lower depths. The Red Spot is heating Jupiter's upper atmosphere from below and making it hundreds of degrees hotter than would be expected by being heated from the Sun. Examine the Red Spot on the following:

https://hubblesite.org/contents/media/images/2021/047/01FM5RERXN48PKG1DY25F91S81?news=true

Jupiter has a very large number of moons -- 63 have been discovered so far. Four are big enough and bright enough to be seen from Earth. Its moons, Galilean satellites, are named after Galileo because he first discovered the first four moons. These moons — Io, Europa, Ganymede, and Callisto — were first discovered by Galileo in 1610, so they are sometimes referred to as the Galilean moons. One of Jupiter's inner moons, Io, is thought to be one of the three bodies in the solar system that has active volcanoes (Earth and Triton being the other two.)The Galilean moons are larger than the dwarf planets Pluto, Ceres, and Eris. Ganymede is not only the biggest moon in the solar system it is even larger than the planet Mercury! To date, Jupiter has 95 known moons, with that number increasing as technology improves.

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 difficult to observe from Earth. In total, there have been nine spacecraft have visited Jupiter. Seven flew by the planet while two have orbited the planet. Jupiter has been known since ancient times and is named after the Greek god Zeus or the Roma god Jupiter. Learn more about Jupiter by reading on these sites: https://www.britannica.com/place/Jupiter-planet or https://solarsystem.nasa.gov/planets/jupiter/overview/ or https://en.wikipedia.org/wiki/Jupiter.

Saturn, along with Jupiter, is considered one of the gas giant planets. It takes Saturn about 29 Earth years to make one revolution around the Sun. Its day is about as long as Jupiter's day (10 hours 32 minutes). Its tilt is similar to Earth's meaning Saturn probably has seasons. It was the first planet to have been identified to have a ring system, which was discovered by Galileo in 1610. While it is now known that all the gas giants have ring systems, Saturn's is the most visible. Those rings are made of ice and rock and, while they appear to be solid, they are chunks

of material in orbit around the planet. Saturn's rings are thought to be pieces of comets, asteroids, or shattered moons that broke up before they reached the planet, torn apart by Saturn's powerful gravity. They are made of billions of small chunks of ice and rock coated with other materials such as dust. There appear to be seven rings, with several gaps between them. Saturn is second only to Jupiter in size.

https://starwalk.space/en/news/facts-about-saturn-explore-the-amazing-ringed-planet

Like the developing solar system, Saturn was formed from the solar nebula, about 4.5 billion years ago. However, it settled into its current orbit about 4 billion years ago. Its structure and composition are similar to Jupiter's but Saturn is slightly smaller. It has a really cold surface temperature, -185℃ to -122℃. It is composed mostly of hydrogen and helium, and has a density less than water. So far, scientists are not sure if it has a solid core. Saturn has 63 known moons, with 20 moons waiting to be named, making a total of 83 moons. Its moon, Titan, is larger than Mercury. It is the farthest planet from Earth that can be seen without a telescope and has been known since ancient times. It is named after the Roman god of agriculture and wealth, Saturnus (or the Greek god Kronos). Saturday is named after Saturn. Not many NASA missions have reached Saturn because it is so far; however, Pioneer 11 and Voyagers 1 and 2 flew by. Cassini orbited Saturn 284 times before it was vaporized in Saturn's atmosphere. To learn more about Saturn, please read the information at the following sites:
https://solarsystem.nasa.gov/planets/saturn/overview/- or
https://www.britannica.com/place/Saturn-planet or https://en.wikipedia.org/wiki/Saturn .

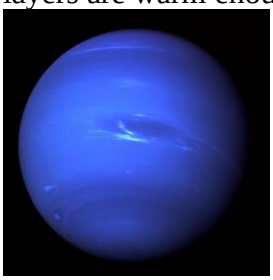
Uranus and Neptune are considered the other set of solar system twins. Both appear- pale greenish blue, which is a result of the presence of the methane gas in its atmosphere. The atmosphere, like the other gas giants, is mostly hydrogen and helium, with some methane. In fact, Uranus is an ice giant because it is mostly composed of "icy" materials. Incredible as it may seem, however, the temperatures on both sides of the planet are pretty much the same. It was the first planet found by using a telescope, but it was originally thought to be a comet or star. Several years later, it was accepted as a new planet due to efforts of Johann Bode. In the end, Bode named the planet after the Greek god of the sky, Uranus (Roman god Caelus). According to mythology, he was the father of the first Titans.

It takes about 17 hours for Saturn to rotate making a day on Uranus shorter than ours on Earth. However, it takes 84 Earth years to make one year on Uranus. Like Venus, Uranus rotates east to west but, surprisingly, it rotates on its side (like a bowling ball). Scientists believe it was hit by a large celestial object which tilted the planet during its formation. Its axis is almost 90 degrees! It may be the home to high winds and a persistent thunderstorm. Like Saturn, it has 13 known rings, with the inner rings being dark and the outer rings brightly colored.

https://www.bbc.com/future/article/20140822-the-mission-to-an-un-loved-planet

It seems to have 27 known moons and they are named after Shakespearean characters, including Titania and Oberon. Given its distance, few space craft have been to Uranus. Voyager 2 did a fly by but none have orbited the planet. To learn more about Uranus, try looking at these sites: https://solarsystem.nasa.gov/planets/uranus/overview/ or https://www.britannica.com/place/Uranus-planet or https://en.wikipedia.org/wiki/Uranus or https://kids.nationalgeographic.com/space/article/mission-to-uranus.

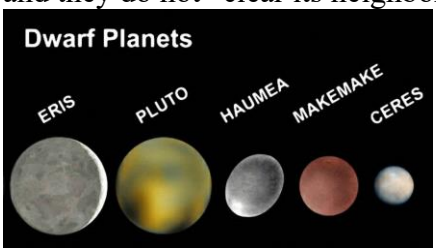
Neptune is the other ice giant in the outer planets. Again, it is composed of "icy" materials above a small, rocky core. It is composed, like Uranus, of water, methane and ammonia. Neptune's year is 165 Earth years long due to its distance from the Sun and the length of its revolution. An interesting fact is that, at times in its orbit, it exchanges places with Pluto. Its rotation, or orbital period, makes its day about 16 Earth hours long. Because of its axis tilt, it also has seasons. However, it is the coldest planet in the solar system, with an average temperature of -236°C. While the outer part is very cold, there may be evidence that its inner layers are warm enough to support evidence that Neptune might have an ocean.



https://solarsystem.nasa.gov/resources/611/neptune-full-disk-view/

Neptune's atmosphere contains hydrogen, helium and methane, giving the planet a bluish color. It is thought to have an additional component, as it is much brighter blue than Uranus. Some scientists believe that the carbon atoms from methane are exposed to very high temperatures and pressures and, as a result, form diamonds in Neptune's clouds. Neptune has the fastest winds in the solar system. Its atmosphere is very dynamic, having strong winds that can exceed 1000 km/hr. It is thought to be the windiest place in the solar system. Like Jupiter, it has a Great Dark Spot, thought to be a large, oval-shaped storm. This outer planet also has faint rings which were confirmed in 1984 by Voyager 2. The rings are very thin and there are five sets. Neptune is the only planet in the solar system that is not visible with the naked eye and was located in space using mathematical calculation. Finally, Neptune (Greek god Poseidon), named after the Roman god of the seas, has 14 moons, with Triton (Poseidon's son) being the largest. The rest of the moons are also named after Greek sea gods and nymphs. In fact, some scientists hypothesize that Triton was once a planet since it is larger than some dwarf planets. This is because it is the only moon in the solar system that orbits in the opposite direction to the planet's rotation (retrograde like Venus). Read more about Neptune: https://solarsystem.nasa.gov/planets/neptune/overview/ or https://www.britannica.com/place/Neptune-planet or https://en.wikipedia.org/wiki/Neptune.

Finally, there are five identified dwarf planets: Pluto, Ceres, Haumea, Makemake, and Eris. A dwarf planet has three characteristics: it must orbit the Sun, it must be pretty much spherical, and they do not "clear its neighborhood."



https://helpfulcolin.com/dwarf-planets-in-the-solar-system/

Ceres is located in the asteroid belt, but the other dwarf planets are located in the Kuiper Belt. It was not classified as a dwarf until 2006 because of its size and differences from the other asteroids. They're considered dwarfs because they are massive, round, and orbit the Sun, but haven't cleared their orbital path. Ceres is the largest object in the asteroid belt and was visited by NASA's Dawn (in 2015). Ceres orbits the sun in 4.6 Earth years and its day is 9 hours long. A cool fact: it is named for the Roman goddess of grain crops and harvests and the word cereal comes from the name!

There are four other dwarf planets we need to think about. Makemake is located in the Kuiper Belt, an area beyond Neptune. It is one of the brighter objects in that area, second after Pluto. Its year is 306 Earth years and day is 22.5 hours. It is classified as a dwarf planet and., along with Eris, was one of the objects that prompted the IAU to reconsider the definition of a planet and create the new group of dwarf planets. It is named after the Rapanui god of fertility.

Eris is about the same size as Pluto and was discovered in 2005. It has caused a great deal of debate about its identity as a planet or dwarf planet among scientists. The International Astronomical Union (IAU) announces that the dwarf planet known as Xena will be called Eris, after the Greek goddess of discord. Eris's moon is named Dysnomia, the demon goddess of lawlessness and the daughter of Eris. This is fitting since the discovery of Eris led to the demotion of Pluto from planet to dwarf planet amidst continuing debate in the science community and the public. Its year is 557 Earth years and its day is 26 hours long.

Haumea is named after the Hawaiian goddess of fertility. It has two confirmed moons. Namaka is the inner moon, and Hi'iaka is the outer moon. Both are named for the mythological daughters of Haumea. Hi'iaka is the patron goddess of the island of Hawaii and of hula dancers. Namaka is a water spirit in Hawaiian mythology. Its day is very short: about 4 hours long and its year is 285 Earth years. It, too, is located in the Kuiper Belt. It has the appearance of a football, rather than a sphere. Scientists say it may be the first known dwarf planet to have rings.

Finally, we come to Pluto. Once a planet in our solar system, it was reclassified as a dwarf planet in 2006. It is located in the Kuiper Belt and is known to exchange locations with Neptune and is sometimes closer to the Sun than Neptune. This is because it has an elliptical orbit rather than a circular one. A year is 248 Earth year and the day is very long: 153 hours or 6 Earth days! It appears to have methane frosted mountains on its surface which makes it appear to have snow. So far, five moons are attributed to Pluto, with Charon being the largest. It is thought that Pluto and Charon may be a double planet, as they orbit each other. According to NASA, Pluto – which is smaller than Earth's Moon – has a heart-shaped glacier that's the size of Texas and Oklahoma. It has blue skies, spinning moons, mountains as high as the Rockies, and it snows – but the snow is red. It has a thin atmosphere of nitrogen, methane and carbon dioxide, making it have a blue tint. It is named after the Roman god of the underworld (Greek god is Hades), and the moons are named for other mythological figures of the underworld. Charon is named for the river Styx boatman who ferries souls in the underworld. Nix is named for the mother of Charon,

who is also the goddess of darkness and night. Hydra is named for the nine-headed serpent that guards the underworld and Kerberos is named after the three-headed dog of Greek mythology, Styx is named for the mythological river that separates the world of the living from the realm of the dead. Pluto was designated a dwarf planet because it does not "clear its neighborhood." Overall, the dwarf planets are a set of very special satellites!

Here is a quick summary of the planets:

Certain Facts About Each Planet

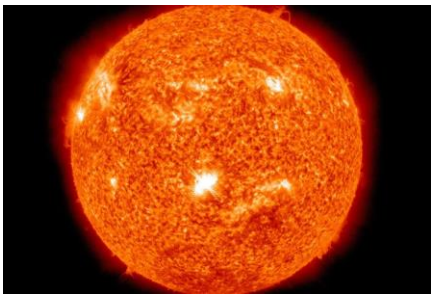
Planet	Distance from the sun (km)	Diameter (km)	Period of revolution (Earth days)	Period of rotation (Earth days)	Number of known moons
Mercury	59 910 000	4878	88 days	58.65 days	0
Venus	108 210 000	12 104	224.7 days	243 days	0
Earth	149 600 000	12 756	365 ¼ days	24 hours	1
Mars	227 940 000	8 787	687 days	24 hrs 37 min	2
Jupiter	778 340 000	142 800	12 years	9 hrs 55 min	62
Saturn	1 427 010 000	120 000	29 ½ years	10hrs 13 min	60
Uranus	2 869 600 000	51 120	84 years	17 hours	27
Neptune	4 496 700 000	49 528	165 years	19 hours	13

https://empoweryourknowledgeandhappytrivia.wordpress.com/2016/01/22/how-old-would-you-be-on-other-planets/

11.5 The Sun

The Sun is at the center of our solar system. It is a star and produces the light needed to maintain life on Earth. The Sun is located in the Milky Way galaxy in a spiral arm called the Orion Spur. It generates that energy through the reactions that occur in the Sun, making hydrogen into helium. It is the largest object in the solar system and contains 99.8% of the total mass of the system. It is considered a middle-aged yellow star. The Sun is the only star in our solar system and at the center of our solar system. Its gravity holds the solar system together. Everything in our solar system revolves around it – the planets, asteroids, comets, and tiny bits of space debris.

The Sun's outer visible layer is called the photosphere and is very hot. There are no many eruptions on the Sun that the surface appears very mottled. The part of the Sun we see from Earth – the part we call *the surface* – is the photosphere. The Sun doesn't actually have a solid surface because it's a ball of plasma, which is a form of matter. The nuclear reactions are occurring in the Sun's core. The energy is carried to the Sun's surface through its convection currents. At the surface, the energy is released as heat and light energy. The chromosphere is above the photosphere. Solar energy passes through this region on its way out from the center of the Sun. Faculae and flares arise in the chromosphere, Faculae are bright luminous hydrogen clouds that form above regions where sunspots are about to form.



Https://education.nationalgeographic.org/resource/sun/

Flares are bright filaments of hot gas emerging from sunspot regions. Sunspots are dark depressions on the photosphere with a typical temperature of 4000°C.

The corona is the outer part of the Sun's atmosphere. It is in this region that prominences appear. Prominences are immense clouds of glowing gas that erupt from the upper chromosphere. The outer region of the corona stretches far into space and consists of particles traveling slowly away from the Sun. Above the Sun's surface are its thin chromosphere and the huge corona (crown). This is where we see features such as solar prominences, flares, and coronal mass ejections. The latter two are giant explosions of energy and particles that can reach Earth. The corona can only be seen during total solar eclipses.

https://www.nasa.gov/image-feature/2017-total-solar-eclipse

The Sun appears to have been active for 4.6 billion year and has enough "fuel" to maintain another 5 billion years or so. After that time, the "fuel" will be used up and the Sun will expand into a red giant star, becoming so large that it will engulf Mercury and Venus, and possibly Earth as well. After a billion years as a red giant, it will suddenly collapse into a white dwarf that is the final end product of the life cycle of a star like our Sun. It may take a trillion years to cool off completely. The Sun has been called by many names. The Latin word for Sun is "sol," which is the main adjective for all things Sun-related: solar. Helios, the Sun god in ancient Greek mythology, lends his name to many Sun-related terms.

11. 7 Earth and Moon Relationships

Finally, let's look at Earth's only satellite: The Moon. In Latin, the moon is called "Luna."

Earth's moon is the brightest object in the sky (excluding the Sun) but does not make its own light. The Moon reflects the light from the Sun, just like all the planets. It is the fifth largest moon in the solar system. Scientists believe the Moon resulted when a celestial object collided with Earth sometime during the formation of the solar system. The Moon was likely formed after a Mars-sized body collided with Earth several billion years ago. It is the Moon that makes Earth a more livable planet by moderating our home planet's wobble on its axis, leading to a relatively stable climate.

The Moon has a solid, rocky surface cratered and pitted from impacts by asteroids, meteorites, and comets. The Moon has a very special honor: it is closest to the Earth and the only celestial

body that humans have ever visited. It is about 385,000 km away from Earth and has about 1/6 of Earth's gravity. In other words, if you weight 100 lbs. on Earth, you would weigh 20 lbs. on the Moon. That is one reason why our space suits have such a high mass – to keep out Moonwalkers on solid ground.

It takes about 27 days for the Moon to revolve around the Earth. When we observe the Moon from Earth, it appears to go through phases. Those phases are a result of sunlight reflecting off the Moon's surface and the fact that we cannot always see the entire face of the Moon. At the new moon phase, the lighted half of the moon faces away from the Earth so we see a dark moon. At the crescent phases, we only see a small portion of the lighted side of the moon, At the quarter phase, we see one fourth of the lighted side. Finally, at the full moon, we see the entire lighted side. As the moon appears to "grow," we call that the waxing of the moon. The waning moon appears to get smaller. Review the phases of the Moon in this diagram:

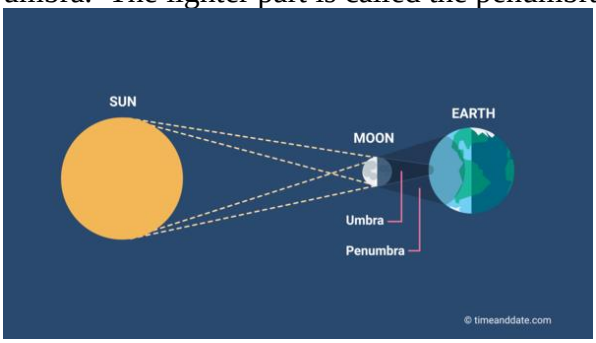
https://solarsystem.nasa.gov/resources/676/phases-of-the-moon/

The Moon is rotating at the same rate that it revolves around Earth (called synchronous rotation), so the same hemisphere faces Earth all the time. Some people call the far side – the hemisphere we never see from Earth – the "dark side" but that's misleading. As the Moon orbits Earth, different parts are in sunlight or darkness at different times. The changing illumination is why, from our perspective, the Moon goes through phases. During a "full moon," the hemisphere of the Moon we can see from Earth is fully illuminated by the Sun. And a "new moon" occurs when the far side of the Moon has full sunlight, and the side facing us is having its night. Because the Moon goes through the phases in about 27 days, there are months when there are two full moons. This is called a "blue moon," giving rise to the phrase: "once in a blue moon" meaning it is a rare occasion or occurrence.

The light areas of the Moon are known as the highlands. The dark features, called maria (Latin for seas), are impact basins that were filled with lava between 4.2 and 1.2 billion years ago. Rilles are long, deep cracks running through maria bedrock. These light and dark areas represent rocks of different compositions and ages, which provide evidence for how the early crust may have crystallized from a lunar magma ocean. There are many craters on the surface of the Moon. These are believed to result from meteoroids hitting the Moon's surface. There is no real soil on the Moon and the atmosphere is very thin.

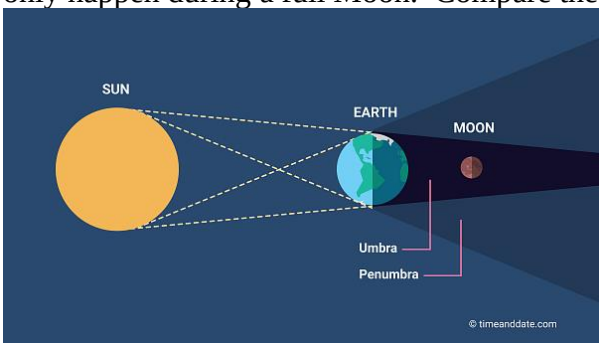
Eclipses

The moving moon sometimes becomes involved in eclipses. Solar eclipses occur when the Sun, the Moon, and Earth line up, either fully or partially. Depending on how they align, eclipses provide a unique, exciting view of either the Sun or the Moon. A solar eclipse happens when the Moon passes between the Sun and Earth, casting a shadow on Earth that either fully or partially blocks the Sun's light in some areas. This only happens occasionally, because the Moon doesn't orbit in the exact same plane as the Sun and Earth do. The time when they are aligned is known as eclipse season, which happens twice a year. When the alignment is not exactly perfect, partial eclipses can occur. Partial eclipses are not as dramatic as a total eclipse, but still interesting to observe. The darkest part of the shadow made by the Moon during a solar eclipse is called the umbra. The lighter part is called the penumbra. Look at the picture and find the two shadows:



https://www.timeanddate.com/eclipse/umbra-shadow.html

The other type of eclipse is a lunar eclipse. Lunar eclipses occur at the full moon phase. When Earth is positioned precisely between the Moon and Sun, Earth's shadow falls upon the surface of the Moon, dimming it and sometimes turning the lunar surface a striking red over the course of a few hours. Each lunar eclipse is visible from half of Earth. During a total lunar eclipse, the Moon moves into the inner part of Earth's shadow, or the umbra. Some of the sunlight passing through Earth's atmosphere reaches the Moon's surface, lighting it dimly. Total lunar eclipses only happen during a full Moon. Compare the lunar eclipse with the solar eclipse above:



https://www.timeanddate.com/eclipse/total-lunar-eclipse.html

To learn more about the moon phases and eclipses, review the following sites: https://moon.nasa.gov/moon-in-motion/phases-eclipses-supermoons/moon-phases/ and https://solarsystem.nasa.gov/eclipses/about-eclipses/types/.

11.8 Other Solar System Components

There are numerous smaller bodies the solar system. Meteoroids, smaller pieces of space rock, are also found in the solar system. They are pieces of rock or ice fragments moving through space. The name of the meteorite changes, depending on its location. When one of them enters the Earth's atmosphere, air molecules rub against it, heats it, and produces a streak of light (friction). We call these shoot stars, but they are really meteors. During meteor showers,

many meteors "rain" through the atmosphere and look like many shooting stars. Meteor showers occur when the meteors travel in the same direction and at nearly the same speed as Earth. When meteoroids enter Earth's atmosphere (or that of another planet, like Mars) at high speed and burn up, the fireballs or "shooting stars" are called meteors. When a meteoroid survives a trip through the atmosphere and hits the ground, it's called a meteorite. Generally, these are very small pieces, but, on occasion, large ones hit Earth and leave craters on Earth's surface. The best known crater is Barringer Crater near Winslow, Arizona.

https://www.history.com/news/biggest-impact-craters-north-america-meteors

There are roughly 180 known impact craters worldwide and fully a third of them, including some of the biggest, are located in North America. According to scientists, one of those impacts, dating roughly 66 million years ago on Mexico's Yucatán Peninsula, triggered the mass extinction event that wiped out the dinosaurs.

Asteroids are small bodies of rocks that can be as small as a grain of sand or large enough, like Ceres, to be labeled a dwarf planet. The largest asteroid not classified as a dwarf planet is called Vespa, and is in the asteroid belt. Most asteroids lie between Mars and Jupiter, the asteroid belt, and travel in an elliptical orbit around the Sun. Since many have irregular shapes, some scientists believe they are a result of a planet that broke up. Other scientists believe asteroids exist because they did not join together to become another planet between Mars and Jupiter. Asteroids, sometimes called minor planets, are rocky, airless remnants left over from the early formation of our solar system about 4.6 billion years ago. There are three classifications of asteroids, each defined by the composition. The three broad composition classes of asteroids are C-, S-, and M-types. The C-type (chondrite) asteroids are most common and probably consist of clay and silicate rocks, making them dark in appearance. They are among the most ancient objects in the solar system. The S-types ("stony") are made up of silicate materials and nickel-iron. The M-types are metallic (nickel-iron). Some asteroids are named, including one called Mr. Spock and seven named after the crew of the Space Shuttle Columbia.

Finally, comets are made of frozen gases that hold together pieces of rocky and metallic materials. Comets have highly eccentric orbits that can enter and leave the solar system. According to NASA, comets are cosmic snowballs of frozen gases, rock, and dust that orbit the Sun. When a comet's orbit brings it close to the Sun, it heats up and spews dust and gases into a giant glowing head larger than most planets. The dust and gases form a tail that stretches away from the Sun for millions of miles. There are two types of comets short-period and long-period comets. Short-period comets have orbital periods less than 200 years and tend to orbit the Sun. Halley's comet and Hale-Bopp comet are examples of short-period comets. They have a glowing head called a coma and, as the comet nears the Sun, the melting ice produces a "tail." The "tail" always points away from the Sun. Short-period comets may originate from the Kuiper Belt, a region beyond Neptune.

https://en.wikipedia.org/wiki/Halley%27s_Comet

Long-period comets do not seem bound to orbit the Sun in the plane of the solar system. Their orbital period is longer than 200 years. They appear to be distributed in all directions from the Sun, forming a spherical shell around the Sun called the Oort cloud.

https://astronomy.swin.edu.au/cosmos/l/Long-period+Comets

To date, scientists acknowledge three long period comets: comet Hyakutake is the longest period comet, with an orbital period of about 70,000 years, Comet C/2006 P1 with an orbital period of about 92,000 years and Comet West with an orbital period of about 250,000 years.

11.9 Summary

As you can see, mankind has studied the solar system and its planets for centuries. As long as mankind has looked to the skies, humans have asked questions about what objects exist in space. Telescopes allowed humans to learn more about outer space, as well as identify the objects that are not visible with the naked eye. Cultures have stories around the skies, built calendars around the stars, and worshipped celestial bodies. Humans are still studying the solar system. We are again planning trips to the Moon and sending unmanned satellites to outlying planets. Studying the solar system may well lead to humans eventually living on other planets, and, maybe even our Moon.

Exercises:

1) What does the solar system comprise of?
2) How many planets are there in our solar system?
3) What is a planet and what is a star?
4) What is the closest planet to the sun?
5) What is the closest planet to Earth?
6) What is the largest planet in the solar system?
7) Is the moon a planet?
8) Top 10 Facts About sun and earth
9) Why does everything orbit around the sun?
10) What is the Milky Way galaxy?