Astronomy - Part 1
Theories of the Universe / Solar System
STUDY GUIDE

S6E1. Obtain, evaluate, and communicate information about current scientific views of the universe and how those views evolved.

a. Ask questions to determine changes in models of Earth's **position in the solar system**, and **origins of the universe** as evidence that scientific theories change with the addition of new information. (*Clarification statement:* Students should consider Earth's position in **geocentric and heliocentric models** and the Big Bang as it describes the **formation of the universe**.)

b. Develop a model to represent the position of the solar system in the **Milky Way galaxy** and in the known universe.

c. Analyze and interpret data to **compare and contrast the planets** in our solar system in terms of:
   - size relative to Earth,
   - surface and atmospheric features,
   - relative distance from the sun, and
   - ability to support life.

d. Develop and use a model to explain the interaction of **gravity and inertia** that governs the motion of objects in the solar system. Ask questions to compare and contrast the characteristics, composition, and location of **comets, asteroids, and meteoroids**.

THEORIES OF THE UNIVERSE

	1. **Matter is anything that has mass and takes up space.** Matter is the "stuff" of the universe — the atoms, molecules and ions that make up all physical substances. Based on the **Law of Conservation of Mass**, mass cannot be created or destroyed during chemical and physical changes. **Mass is the amount of molecules in a substance.**
https://www.thoughtco.com/energy-definition-and-examples-2698976 (article) (potential and kinetic energy) https://www.youtube.com/embed/IqV5L66EP2E https://www.brainpop.com/science/energy/potentialenergy/ https://www.brainpop.com/science/energy/kineticenergy/	2. **Energy is the capacity of a system to do work.** Energy exists in many forms and cannot be created or destroyed within a system; it can only be conserved and converted from one form to another according to the **Law of Conservation of Energy**. There are two basic forms of energy: potential and kinetic. **Potential energy is the energy stored in an object due to its position** — for example, a bucket of water balanced over a doorway has the *potential* to fall. **Kinetic energy is the energy of motion.** Any moving object or particle has kinetic energy. The quantity of kinetic energy within an object or particle is based on its mass and speed. The standard unit of measurement (SI unit) of energy is the joule (J) or newton-meter (N * m). The joule is also the SI unit of work.
	3. **Potential and Kinetic energy** can be converted into other forms of energy. Thermal energy (thermal heat) moves throughout the universe through conduction, convection and radiation. **Conduction** is energy transferred by direct contact. **Convection** is energy transferred by the mass motion of molecules. **Radiation** is energy transferred by electromagnetic waves.

	4. Adding energy to matter causes a **physical change** — matter moves from one state to another. For example, adding thermal energy (heat) to liquid water causes it to become steam or vapor (a gas). Taking away energy also causes physical change, such as when liquid water becomes ice (a solid) when heat is removed. Physical change also can be caused by motion and pressure.
https://www.livescience.com/54667-bose-einstein-condensate.html	5. There are five known phases, or states, of matter: solids, liquids, gases, plasma and Bose-Einstein condensates. The main difference in the structures of each state is in the densities of the particles.
	6. In a **solid**, particles are packed tightly together so they are unable to move about very much. Particles of a solid have very low kinetic energy. The electrons of each atom are in motion, so the atoms have a small vibration, but they are fixed in their position. Solids have a definite shape. They do not conform to the shape of the container in which they are placed. They also have a definite volume. The particles of a solid are already so tightly packed together that increasing pressure will not compress the solid to a smaller volume.
	7. In the **liquid phase**, the particles of a substance have more kinetic energy than those in a solid. The liquid particles are not held in a regular arrangement, but are still very close to each other so liquids have a definite volume. Liquids, like solids, cannot be compressed. Particles of a liquid have just enough room to flow around each other, so liquids have an indefinite shape. A liquid will change shape to conform to its container. Force is spread evenly throughout the liquid, so when an object is placed in a liquid, the liquid particles are moved or displaced by the object.
	8. **Gas particles** have a great deal of space between them and have high kinetic energy. If unconfined, the particles of a gas will spread out indefinitely; if confined, the gas will expand to fill its container. When a gas is put under pressure by reducing the volume of the container, the space between particles is reduced, and the pressure exerted by their collisions increases. If the volume of the container is held constant, but the temperature of the gas increases, then the pressure will also increase. Gas particles have enough kinetic energy to overcome intermolecular forces that hold solids and liquids together, thus a gas has no definite volume and no definite shape.
	9. **Plasma is not a common state of matter here on Earth, but makes up 99% of matter in the universe. Stars are made up of plasma.** Plasma consists of highly charged particles with extremely high kinetic energy. The noble

	gases (helium, neon, argon, krypton, xenon and radon) are often used to make glowing signs by using electricity to ionize them to the plasma state. Stars are essentially superheated balls of plasma.
	10. As far as we know, there are only two other types of matter besides normal matter. These two types are **Antimatter** and **Dark Matter.**
	11. **Antimatter** is the opposite of matter. When matter comes in contact with antimatter, both explode, creating gamma rays. It is hypothesized that in the beginning of the universe there were near equal amounts of antimatter and matter. But for some reason matter won the battle, and because of this it is the main matter of our universe. The only way now to create antimatter is through high energy processes. In fact, even thunderstorms create antimatter.
	12. **Dark Matter** is a little known substance. It constitutes of about 23% of all the "stuff" in our universe. By measuring the motion of galaxies and the stars inside these galaxies, as well as measuring the effects of the gravity on stars and planets, Astronomers believe there is a relationship between galaxies and Dark Matter. Galaxies form around large clumps of Dark Matter, and are held together by Dark matter. Astronomers believe Dark Matter has an opposite effect to gravity pushing everything apart and thus contributing to the expansion of the Universe.
	13. A **Scientific Theory** is an explanation or model backed by results obtained from many tests or experiments. Scientific theories change when scientists discover new information. New technology, new tools, and/or new observations can provide new information.
	14. The most commonly accepted scientific theory today of the *formation of the universe* is the **Big Bang Theory**. Astronomers believe that the expanding universe is the result of an enormous and powerful explosion called the Big Bang Theory. The Big Bang Theory states that the universe began to expand with the **explosion of concentrated matter and energy** and has been expanding ever since. The theory states that the universe originated sometime between 10 billion and 150 billion years ago from a small volume of matter at extremely high density and temperature.
	15. After the Big Bang, dense clouds of gas and dust from the "bang" either collapsed or stuck together to form the parts of the universe we know today.
	16. Another scientific theory which has changed over centuries is the scientific model of our solar system – heliocentric or geocentric.

	17. Ancient Greeks such as **Aristotle** believed that the universe was perfect and finite, with the Earth at the exact center. This is the geocentric theory, which stated, the planets, moon, sun, and stars revolve around the Earth.
	18. In AD 140, the Greek astronomer **Claudius Ptolemy** revised the geocentric model to explain all the planetary motions. Ptolemy's theory is known as the **Geocentric Model** because he thought the Earth was the center of the universe and that the sun, stars and other planets revolved around it. He believed his theory for several reasons (1) gravity of all objects were attracted to the earth, which suggested to him that the Earth must be the center, (2) he thought the Earth did not move because objects fell in the same place if thrown up in the air. He thought if the Earth moved, objects would fall in a different place. Ptolemy's theory was unchallenged for nearly 1,300 years.
	19. In the early 1500's, the polish astronomer **Nicolaus Copernicus** discovered his revolutionary theory about the Sun. He suggested that the Sun, not the Earth, was the center of the solar system and the planets, including Earth, revolved around the sun in "perfect circles." Copernicus' theory is called the **Heliocentric Theory.** **Galileo** made additional observations using a telescope which supported the heliocentric theory. Galileo observed that Venus went through a full cycle of phases like the Moon. This could only be explained if Venus were orbiting the Sun.
	20. In the 1600's, a German astronomer, **Johannes Kepler**, supported Copernicus's belief with mathematics. He also proved that the planets travel in ellipses (ovals), not perfect circles, around the sun.

EARTH'S PLACE IN THE UNIVERSE

	21. The Universe includes living things, planets, stars, galaxies, dust clouds, light, and even time. The Universe contains billions of galaxies. A **galaxy** is a system of millions or billions of stars, together with gas and dust, held together by gravitational attraction. Therefore, the galaxy in which our solar system and essentially all of us live is just one of billions. The space between the stars and galaxies is largely empty.

	22. The **Milky Way Galaxy** contains single star systems, double stars, and dust and gas. It is a spiral galaxy because it has spiral arms that wind outward from the center. Thousands of years ago people thought the stars appeared as a patchy band of light like a flowing river of milk, thus the name Milky Way.
	23. A **planetary system** is a star and all of the celestial bodies that revolve around it. An example of a planetary system is our **solar system** which consists of a huge star we call the sun, eight planets, the moons of the planets, comets, asteroids, meteoroids, dwarf planets (Ceres, Eris, Pluto, Haumea and Makemake) and other celestial bodies orbiting the sun including the **Asteroid Belt** and the **Kuiper Belt.** Our solar system is located on the outer rim (arm) of the Milky Way Galaxy.
	24. The Solar System is inside a disk-shaped galaxy of stars known as the **Milky Way**, and orbits in one of the spiral arms at 26,000 light years from the center of the galaxy. A **light year** is how far light can travel in one year moving at 186,000 miles per second (approx. 5.88 trillion miles). We **can't see** the spiral structure of the galaxy from our planet because we are inside the disk and have no means of taking images from above or below the galaxy. The Milky Way is one of billions of galaxies in the universe.
	25. The **Sun** is a medium-sized star located near the edge of the Milky Way, part of which can be seen as a glowing band of light that spans the sky on a very clear night. The sun is composed of 70% hydrogen and 28% helium. It is the main part in our solar system. That is where the name "solar" came from. The Sun lies at the center of the solar system. It contains more than 99 percent of the system's mass. The immense pull of its gravity holds the planets, dwarf planets, asteroids, comets, and other bodies in orbit around it. The sun's energy is created through fission and fusion reactions. **Fission** is the division of one atom into two, and **fusion** is the combination of two lighter atoms into a larger one.

SOLAR SYSTEM

	26. The planets of our solar system differ in size, composition, surface and atmospheric features, and distance from the Sun. The planets move around the Sun in elliptical (oval) orbits. The planets are divided into two groups – the **inner planets** are smaller, closer to the sun, and have rocky crusts with dense mantles and cores. These planets are called the **terrestrial planets.** Their insides, surfaces and atmospheres formed in similar ways and follow similar patterns.
	27. **Mercury** is the closest planet to the sun, and the second smallest of the eight planets. It was named by the Romans after a messenger of the gods, because it seems to move faster than the other planets. Even though this is the closest planet to the sun and the sun appears 2 ½ times larger than it does on Earth, the sky is always black. This is because Mercury contains no atmosphere to provide the scattering of light. Mercury consists of craters, high multi-ring basins, and lava flows. Scientists believe that Mercury is about 70% metal and 30% silicate
	28. **Venus** is known as the "jewel of the sky." Venus is surrounded by thick clouds made up of sulfuric acid. It is also known as Earth's sister planet. However, Venus has no oceans and is surrounded by an atmosphere that consists mainly of carbon dioxide. A Venusian's day is 243 of Earth's days. At least 85% of Venus' surface is made up of volcanoes or volcano features.
	29. **Earth** is the only known planet that is able to maintain life! It is made up of 78% nitrogen, 21% oxygen, and 1% of other substances. Our Earth travels at about 67,000 miles per hour. The Earth also has 1 moon.
	30. **Mars** is the fourth planet from the sun. It is known as the red planet, because the rocks, soil, and sky have a red tint. Mars was named after the god of war. One reason scientists believe that there could be life on Mars is because of the seasonal color changes it has. The average temperature on Mars is -81 degrees Fahrenheit.
	31. The second group of planets is called the **outer planets** and are larger, farther away from the Sun and do not have solid surfaces. These planets are also called the **Gas Giants** - Jupiter, Saturn, Uranus and Neptune. They are made mainly of hydrogen, helium and other gases.
	32. **Jupiter** is the fifth planet from the sun. Jupiter could equal up to more than 1,000 Earths. It also contains more matter than all of the other planets combined. There are four rings on Jupiter, but they aren't visible to Earth. Jupiter has 67 moons. The Great Red Spot, the most recognizable feature on Jupiter, is a storm nearly three times the size Earth.

	33. **Saturn** is the sixth planet from the sun. It is also the second largest of the eight planets. One significant factor of Saturn is its very visible rings. Winds move at very high speeds around Saturn. Saturn has 53 recognized moons.
	34. **Uranus** is the seventh planet from the sun. It is the third largest in the solar system. It is 83% hydrogen, 15% helium, and 2% other substances. Uranus' has a greenish color to it due to methane. Uranus also has a variety of narrow rings and orbits on its side.
	35. **Neptune** is the eighth planet from the sun, and it is also the fourth largest planet. Neptune has eight moons. Neptune's bluish tint is from the fact that is made up of 1% methane. One outstanding feature of Neptune is a large storm known as the Great Dark Spot approximately the size of Earth. A second smaller storm known as the Small Dark Spot is comparable in size to Earth's moon.
	36. **Pluto**, formerly known as the ninth planet from the sun was reclassified as a dwarf planet in 2006 because it does not meet all the characteristics of a true planet. Little was known about this dwarf planet until recently. After a 9 ½ year journey, the New Horizons probe reached Pluto on July 14, 2015 and has provided lots of new information. Pluto is smaller than seven of the moons in our solar system, but has five moons of its own.

MOTION OF OBJECTS IN THE SOLAR SYSTEM

	37. During the 1600's, Kepler made observations of planets and their movements around the Sun. He discovered that planets travel around the Sun in a particular path called an **orbit**. An orbit is the path of an object in space as it moves around another object because of gravity.
	38. **Gravity** is the force that objects exert on each other because of their mass. **Isaac Newton's** L**aw of Universal Gravitation** states that every object in the universe attracts every other object. Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the solar system. The gravitational attractions of the planets, either individually or as a group are so small

	because of the distances between the planets that they cannot possibly have a significant destructive effect on one another or on the Earth and its inhabitants.
	39. Earth rotates around an imaginary line running through its center called an **axis of rotation. The Earth's spin axis is tilted 23.5° which creates our seasons**. At any one time, about half of Earth is in sunlight and half is dark. **The Earth completes its rotation every 24 hours (1 day).**
	40. A year is the time it takes Earth to orbit the Sun once. A **revolution** is the motion of one object around another. **The Earth orbits (revolves) around the sun every 365 ¼ days (1 year).**
	41. The **Earth's gravitational force** keeps the moon orbiting the earth. The moon rises in the east and sets in the west daily, but its position in the sky moves EASTWARD by about 13 degrees per day. The moon rises and sets almost 1 hour later each night. It takes 27 days, 7 hours, and 43 minutes for our Moon to complete one full orbit around Earth. However, it takes our Moon **about 29.5 days** to complete one cycle of phases (from new Moon to new Moon).
	42. **Inertia** is an object's resistance to any change in its motion. Like all objects with mass, planets have a tendency to resist changes to their direction and speed of movement. Objects at rest will stay at rest, and objects moving will continue to move in a straight line unless they are acted on by an unbalanced force. Without the **Sun's gravitational force** between it and the planet, the planet would travel off into space in a straight line. However, because of the force of gravity, planets travel in curved orbits. **Newton's First Law of Motion is known as the Law of Inertia.**
	43. The time it takes for an object to complete one revolution around the sun depends on the speed at which it is moving and the size of its orbit. Objects more distant from the sun's gravitational pull move slower than those that are closer. Earth's period of revolution is about 365 ¼ days (year); planets that are more distant from the sun take longer to orbit (revolve) around the sun, resulting in longer years.
	44. Early Greek and Roman astronomers were the first to observe that planets seem to move around in the sky while **stars appear to be more stationary**.
	45. The rotation of the Earth on its axis causes all **objects** to **appear to move** around the **sky** once each day. This is the same reason that the sun rises in the east and sets in the west. Stars that are low in the east when

	the night begins are high in the sky halfway through the night and low in the west by daybreak the next day. During the day, the stars continue to move across the sky, but the sun is so bright that they can't be seen. Of course, the stars aren't moving relative to the Earth's position in space. They just appear to move to human stargazers.

OJBECTS IN THE SOLAR SYSTEM

	46. Comets and asteroids are objects that are smaller than planets in our solar system that orbit the Sun and also vary in size, composition and characteristics.
	47. **Comets** are composed of dust and rock mixed with frozen water, methane and ammonia. Comets are considered to be like a large, dirty snowball and travel around the sun in **elliptical orbits**.
	48. When a comet nears the sun, some of it melts and forms a long tail (gases in the comet are vaporized by the sun). When a comet moves farther away from the sun, the tail disappears.
	49. Short-period comets that complete their orbits in less than 200 years are thought to originate from the disk-shaped Kuiper Belt, while long-period comets that take more than 200 years to return are thought to come from the spherical Oort Cloud. The **Kuiper Belt** is a disk shaped region composed of thousands of icy bodies that lies beyond the orbit of Neptune. Pluto, now considered a dwarf planet, dwells in the Kuiper Belt. The **Oort Cloud** is believed to be a thick bubble composed of icy debris that surrounds our solar system. The Oort Cloud lies well past the Kuiper Belt.
	50. After a comet has passed close to the Sun many times, it breaks apart. The small pieces from the comet spread out. These pieces of dust and rock, along with those coming from other sources, are called **Meteoroids**. Meteoroid is a "space rock" that is still in space.
	51. **Meteor** is a meteoroid that burns up in the earth's atmosphere (Shooting Star). A Meteor is considered harmless even though it can be viewed from earth at times.

	52. **Meteorite** is a meteoroid that hits the earth's surface.
	53. An **asteroid** is a piece of rock similar to the material formed into planets. It is smaller than a planet but larger than a meteoroid.
	54. Most asteroids are located in an area between the orbits of Mars and Jupiter called the **Asteroid Belt**. Asteroid Belt is composed of rocky remnants left over from the formation of our solar system.