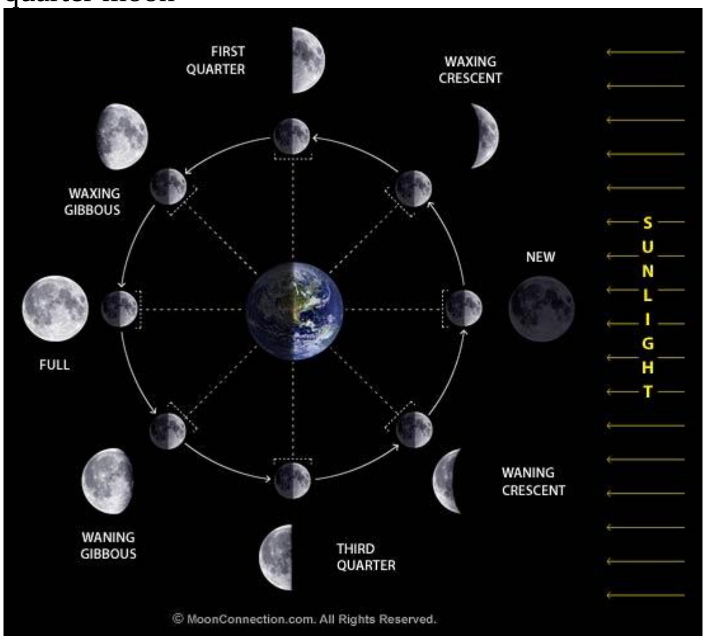
Competency 5

Knowledge of space science

1. Identify consequences of Earth's motions and orientation (e.g., seasons, tides, lunar phases).
   A. Rotation – the spinning of Earth on its own axis; produces the 24-hour day-night cycle
      a. Tides – the twice daily rise and fall of sea levels; the result of both the gravity of the moon and the gravity of the sun
         i. The result of the moon's gravity and the centrifugal force creates nearly equal tides on opposite sides of the Earth, causing sea levels to rise and fall twice a day
         ii. Spring tide – exceptionally high tides where the bulges occur (and very low tides where the water has been displaced); happen when the moon is at the full or new phase
         iii. Neap tide – moderate tides caused by the sun's gravitational pull and moon's gravitational pull working against each other; happen during the first and last quarter phases of the moon
   B. Revolution – Earth's elliptical orbital motion around the sun; takes 265 days, 6 hours, and 9 minutes
      a. Perihelion – closest approach to the sun in an elliptical orbit; Earth's occurs on about January 4^{th} of each year and is about 147090000 km
      b. Aphelion – farthest distance from the sun in an elliptical orbit; Earth's occurs on about July 4^{th} of each year and is about 152100000 km
   C. Seasons – caused by the tilt of Earth on its axis; Earth rotates at an inclination of 23.45 degrees from the plane of its orbit around the sun
      a. Different parts of Earth receive the sun's most direct rays at different times of the year, causing seasons
      b. When the North Pole tilts toward the sun, it is summer in the Northern Hemisphere and winter in the Southern Hemisphere
      c. When the South Pole tilts toward the sun, it is winter in the Northern Hemisphere and summer in the Southern Hemisphere
      d. Solstice – an event in which a planet's poles are most extremely inclined toward or away from the star it orbits
         i. Twice yearly phenomena in which solar declination reaches the Tropic of Cancer (Northern Hemisphere) and the Tropic of Capricorn (Southern Hemisphere)
         ii. Solar declination – the latitude of the Earth where the sun is directly overhead at noon
         iii. June Solstice – when solar declination is about 23.5°N (Tropic of Cancer); beginning of Northern Hemisphere summer and Southern Hemisphere winter
         iv. December Solstice – when solar declination is about 23.5°S (Tropic of Capricorn); beginning of Southern Hemisphere summer and Northern Hemisphere winter
      e. Equinox – an event during which the solar declination is 0° (the Equator) and the Northern and Southern hemispheres receive equal sunlight
   D. Lunar Phases – the amount of moon we can see, caused by the moon revolving around the Earth; changes occur in a cycle that takes 29.5 days to complete
      a. Waxing – appearing to grow in size
      b. Waning – appearing to shrink in size
      c. New moon – occurs when the moon is between the Earth and the sun, causing the side of the moon facing Earth to be shadowed
         i. Solar eclipse – occur when the moon is positioned between the Earth and the sun and the moon casts a shadow on Earth, blocking our view of the sun; can be total or partial; only visible to a small area
      d. Waxing crescent – occurs when about one fourth of the moon is illuminated; occurs after the new moon
      e. First quarter – when half the moon appears illuminated; occurs when the moon is at a right angle with respect to the sun when viewed from Earth; occurs when the moon is waxing
      f. Waxing gibbous – occurs when about three fourths of the moon is illuminated; occurs after the first quarter moon

g. Full moon – occurs when the moon is on the opposite side of Earth from the sun, causing the side of the moon facing Earth to be illuminated
   i. Lunar eclipse – occur when Earth is positioned precisely between the moon and sun and Earth's shadow falls on the surface of the moon, causing it to dim or appear red; occur during the full moon phase; can be total, partial, or penumbral
h. Waning gibbous – occurs when about three fourths of the moon is illuminated; occurs after the full moon
i. Last quarter – when half the moon appears illuminated; occurs when the moon is at a right angle with respect to the sun when viewed from Earth; occurs when the moon is waning
j. Waning crescent – occurs when about one fourth of the moon is illuminated; occurs after the last quarter moon



2. Identify the properties of stars and the factors that affect their evolutionary patterns.
   A. Properties of stars:
      a. Temperature – measured in Kelvin; coolest, reddest stars are about 2500 K; hottest stars can reach 50000 K
      b. Spectrum – light of various wavelengths that is emitted; color; depends on surface temperature (cooler stars tend to be redder, hotter stars are bluer)
      c. Luminosity – total amount of light energy emitted from a star per second; determined by the size of the star and its surface temperature
      d. Size (radius) – measured in terms of the sun's radius; part of what determines luminosity
         i. Solar radius – radius of the sun; 418000 miles (696000 kilometers)
      e. Mass – measured in terms of the sun's mass
         i. Solar mass – mass of the sun; 1.99×10^{30} kilograms (the mass of 330000 Earths)
      f. Movement – toward or away from Earth; rate of spin
      g. Magnitude – perceived brightness of a star
         i. Apparent magnitude – a star's brightness as observed from Earth
         ii. Absolute magnitude – apparent magnitude of the star if it was located 10 parsecs from Earth
            - Parsec – a measurement of distance in space; equal to 3.3 light-years, 19.8 trillion miles, or 33 trillion kilometers
            - Light-year – measurement of distance in space; the distance light can travel in one Earth year; equal to 6 trillion miles or 10 trillion kilometers

B. Hertzsprung-Russell Diagram (H-R Diagram) – a chart that reliably predicts the other qualities of stars based on their surface temperatures (X-axis: Kelvin; increases from right to left OR spectral class, which varies predictably with surface temperature) and luminosity (Y axis: ratio scale with 1 at the center; proceeds in both directions by exponents of 10; increases from bottom to top; can also be in terms of absolute magnitude)

a. Star colors are classified by letter from bluest/hottest to reddest/coolest: OBAFGKM

b. Most common unit of measurement is a luminosity equal to the sun

c. Main Sequence – phase that takes place when hydrogen fusion takes place in a star's core; a roughly diagonal, slightly S-curved line between the upper-left and lower-right corners of an H-R Diagram on which lines in this phase of life can be found; maintain a predictable relationship between luminosity and temperature: the brighter, the hotter

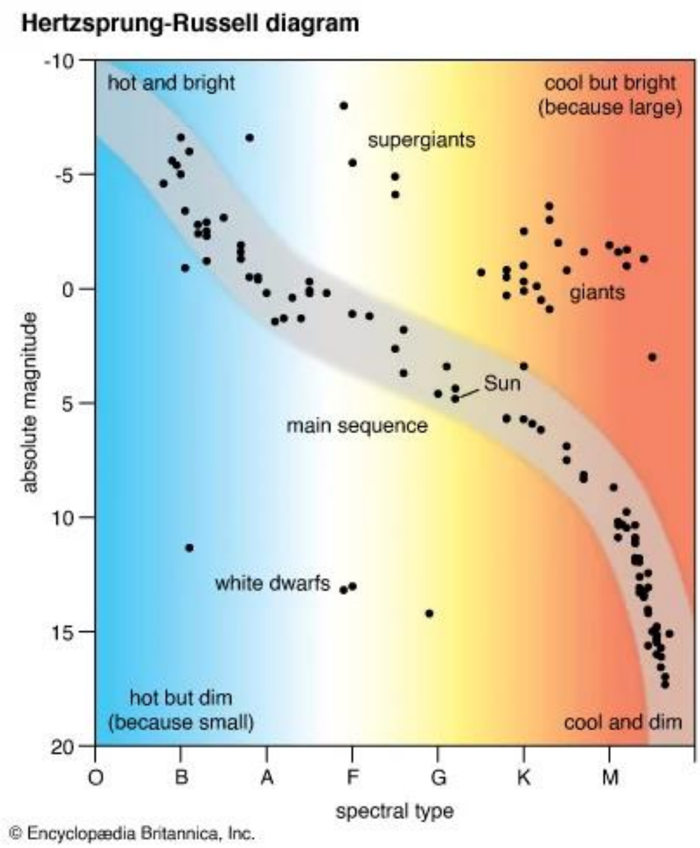
i. Both brightness and luminosity increase with mass; a star closer to the upper-left corner is "heavier" than our sun; a star closer to the lower-right corner will be "lighter"

d. Red Giants – stars found in the upper-right corner of an H-R Diagram; both bright and cool; core is hot enough to fuse helium and even heavier elements and has pushed its shell layers so far out that they can cool into the red spectrum; their great luminosity is due to their size

i. Bigger stars radiate more light energy (higher luminosity)

e. White Dwarfs – found in the lower-left corner of an H-R Diagram; both very hot and very dim; formed after a red giant of similar mass to the sun burns up all of its helium and gravity compresses its core as far as the carbon electrons within it will permit; enormous core heat as a result of its great density; all that remains of the star is the core, so core temperature is surface temperature

i. Smaller stars radiate less light energy (lower luminosity)



3. Identify devices and techniques for collecting and analyzing data about stars and other celestial objects.

A. Techniques for collecting data:

a. Hubble Space Telescope – first astronomical observatory to be placed into orbit around Earth with the ability to record images in wavelengths of light spanning from ultraviolet to near-infrared; launched on April 24th 1990 aboard space shuttle Discovery
   i. Located about 340 miles above Earth; makes 15 orbits per day (approximately one every 95 minutes); travels about 5 miles per second
   ii. Its mirror-based optical system (Optical Telescope Assembly; OTA) collects and focuses light from the universe to be analyzed by science and guidance instruments
   iii. Has two primary capture systems to capture images of the cosmos
      - Advanced Camera for Surveys (ACS) – installed on Hubble in 2002; designed primarily for wide-field imagery in visible wavelengths; has three cameras (channels) that capture different types of images
      - Wide Field Camera 3 (WFC3) – installed on Hubble in 2009; provides wide-field imagery in ultraviolet, visible, and infrared light; designed to compliment ACS and expand the imaging capabilities of Hubble in general
   iv. Utilizes two spectrographs (practice spectroscopy)
      - Spectroscopy – the science of breaking light down into its component parts, similar to how a prism splits whit light into a rainbow; any object that absorbs or emits light can be studied to determine characteristics such as temperature, density, chemical composition, and velocity
      - Cosmic Origins Spectrograph (COS) – spectrograph that measures exceedingly faint levels of ultraviolet light emanating from distant cosmic sources (such as quasars in remote galaxies)
      - Space Telescope Imaging Spectrograph (STIS) – versatile, “all purpose” spectrograph that handles bright objects well
   v. Has three interferometers (the Fine Guidance Systems; FGS)
      - Interferometers – help the Hubble telescope maintain a steady aim and serve as a scientific instrument; measure the relative positions and brightness of stars
      - When Hubble is pointing at a target, two of the three fine guidance sensors are used to lock the telescope onto the target
      - For certain observations, the third Fine Guidance Sensor can be used to gather scientific information about a target
      - Seek out stable point sources of light (guide stars) and then lock onto them to keep the telescope pointing steadily; when a light in the sky is not a point source, it cannot lock on and rejects the guide star (which is often a faraway galaxy or double-star system)

b. Optical Telescopes – telescopes that are either refractors or reflectors that use lenses (refractors) or mirrors (reflectors) for their main light collecting elements

c. Solid Cosmic Samples – samples of meteorites, rock samples returned from the moon, cometary and asteroid dust samples returned by space probes, and interplanetary dust particles collected by aircraft in the stratosphere or by spacecraft

B. Techniques for analyzing:

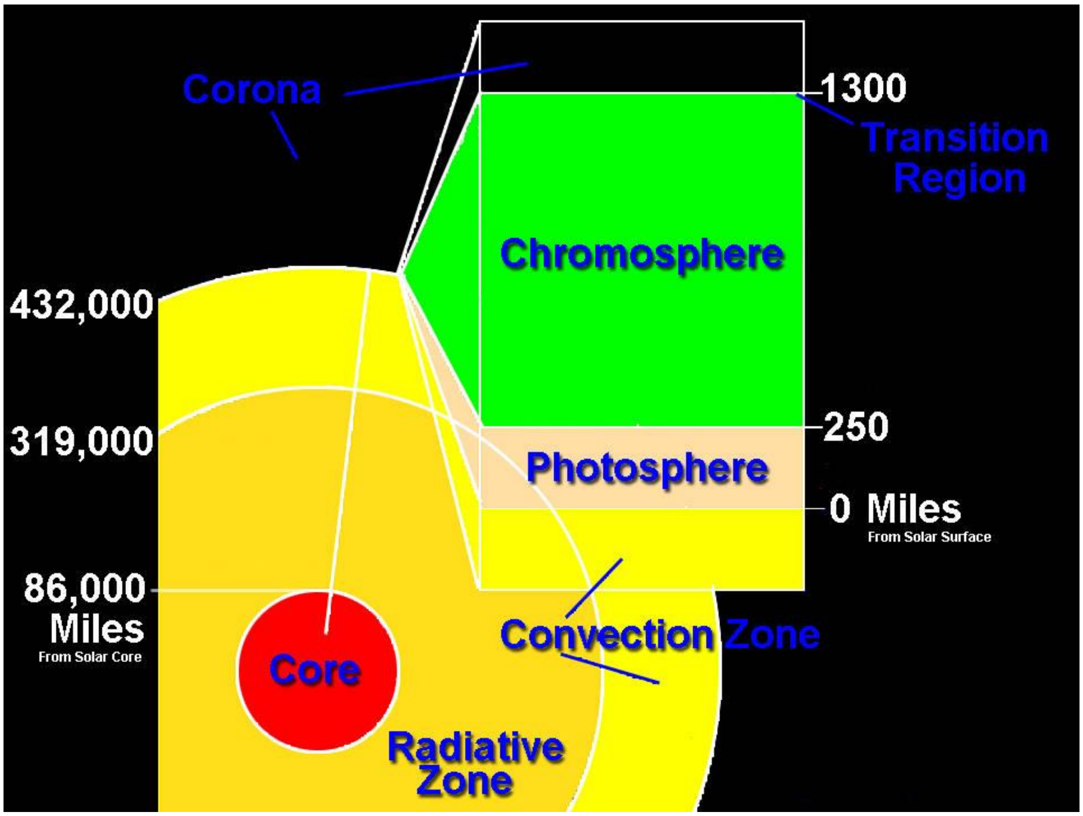
a. Spectroscopy – the most common method used by astronomers to determine the composition of stars, planets, and other objects; uses instruments with grating that spreads out the light of an object by wavelength
   i. Every element and combination of elements have a unique fingerprint that astronomers can look for in the spectrum of an object which can be used to determine the composition of an object; often appears as the absorption of light

- The wavelengths at which absorption lines occur are unique for each element and can be used to determine which elements are present; the amount of light that is absorbed can also provide information about how much of each element is present

b. Astrometry – measuring coordinates of celestial objects from images
c. Photometry – determining magnitudes of variable stars and/or solar system bodies
d. Image Analysis and Enhancement – quantifying digital imagery and applying a range of techniques, primarily through the use of image operators and convolution kernels

4. Explain the role of space exploration and its impact on technological advancements.
   A. The role of space exploration
      a. Helps to address fundamental questions about our place in the universe and the history of our solar system
      b. Expands technology, creates new industries, and helps foster a peaceful connection with other nations
      c. Improving healthcare (experiments performed in space help us understand health problems on Earth)
      d. Protecting our planet and environment (satellites provide data on climate change, measure pollution, and help protect our planet)
      e. Creating scientific and technical jobs
      f. Improving our day-to-day lives (improve products we use every day, weather forecasts, and communications worldwide)
      g. Enhancing safety on Earth (satellite data can be used to predict natural disasters and support emergency relief efforts)
   B. Technological advancements
      a. Global Positioning System (GPS) – originally developed for military precision navigation and weapon targeting purposes; provides users with positioning, navigation, and timing services
      b. Infrared ear thermometers – measure the amount of energy emitted by the eardrum in the same way that the temperature of stars and planets is measured
      c. Artificial limbs have been improved using advanced space program shock absorbing materials and robotics
      d. Digital image processing technology developed by the Jet Propulsion Laboratory (JPL) was adapted to help create modern CAT scanners and radiography
5. Identify the components of the solar system (e.g., Kuiper belt, Oort cloud), their characteristics, how they interact (e.g., solar winds, impacts, gravitational attraction), and how they evolve.
   A. Solar system – the planetary system in which we live; located in an outer spiral arm of the Milky Way galaxy; consists of the sun and everything bound to it by its gravity
   B. Sun – 4.5 billion-year-old yellow dwarf star at the center of our solar system; medium-sized star with a radius of about 435000 miles; about 93 million miles from Earth; made up of hydrogen and helium (hydrogen is fused to form helium in the core)
      a. Core – the part of the sun in which nuclear fusion reactions take place; temperatures exceed 15.7 million Kelvin; extends to about 25% of the sun's radius
      b. Radiative zone – part of the sun in which energy is transferred by thermal radiation; temperatures between 2 million and 7 million Kelvin; extends from 25% to 70% of the sun's radius
         i. Thermal radiation – photons released in the core travel a short distance, are absorbed by an ion, are released by the ion, and are absorbed by another ion; process can continue for 200000 years for one photon
      c. Convective zone – part of the sun in which heat is transferred through thermal convection; begins at around 70% of the sun's radius

d. Photosphere – the bright yellow visible "surface" of the sun; about 400 km thick; temperatures of about 6000 Kelvin; thermal columns from the convection zone are visible in this zone; where sunspots, solar flares, and solar prominences take form
e. Chromosphere – the pinkish-red layer of the sun; about 2000 km thick; temperatures range from 4400 Kelvin at the bottom to 25000 Kelvin at the top; gives off jets of burning gases (spicules)
f. Corona – wispy outermost layer of the sun; can extend millions of kilometers into space; gases burn at about 1 million Kelvin and move about 145 km per second
   i. Solar winds – a continual stream of protons and electrons from the sun's outermost atmosphere (the corona)



C. Planets – celestial bodies that orbit a star, are big enough to have enough gravity to force it into a spherical shape, and are big enough that its gravity has cleared away any other objects of a similar size near its orbit around its star
   a. Inner planets – rocky planets located between the sun and the asteroid belt
      i. Mercury – smallest planet in the solar system and nearest to the sun; fastest planet in the solar system; no rings; no moons
      ii. Venus – similar in size to Earth; second planet from the sun; rotates very slowly on its axis; rotates around the sun more quickly than Earth; a day on Venus is longer than its year; retrograde rotation; no moons; no rings
      iii. Earth – our home planet; third planet from the sun; fifth largest planet; only planet with liquid water on its surface; no rings; one moon
      iv. Mars – fourth planet from the sun; second smallest planet; the location of two rovers, one lander, and one helicopter; no rings; two moons
   b. Outer planets – gas and ice giants located beyond the asteroid belt
      i. Jupiter – gas giant; largest planet; fifth planet from the sun; has a faint ring system; 75 moons

ii. Saturn – gas giant; second largest planet; sixth planet from the sun; large ring system; 53 known moons and 29 moons awaiting confirmation
iii. Uranus – seventh planet from the sun; third largest planet; first planet found with a telescope; ice giant; 27 known moons; 13 known rings; retrograde rotation; rotates on its side
iv. Neptune – eighth planet from the sun; ice giant; not visible to the naked eye; faint rings; 14 known moons

c. Dwarf Planets – a celestial body that orbits the sun, has enough mass to assume a nearly round shape, has not cleared the neighborhood around its orbit, and is not a moon
i. Pluto – orbited by five known moons, the largest of which is Charon, which is half the size of Pluto; has a radius of 715 miles; orbit is both elliptical and tilted (248 year long orbit that can take it as far as 49.3 AU from the sun and as close as 30 AU); spins almost on its side; exhibits retrograde rotation; located in the Kuiper belt
ii. Makemake – located in the Kuiper belt; has one provisional moon
iii. Haumea – roughly the same size as Pluto; football shaped; located in the Kuiper belt; two known moons
iv. Eris – one of the largest known dwarf planets in our solar system; similar in size to Pluto; has one very small moon; located in the Kuiper belt
v. Ceres – located in the asteroid belt; makes up almost a third of the asteroid belt's total mass

D. Moons – more than 200 known moons in our solar system

E. Asteroids – sometimes called minor planets; rocky, airless remnants left over from the early formation of our solar system; most can be found in the asteroid belt between Mars and Jupiter

F. Meteoroids – objects in space that range in size from dust grains to small asteroids; space rocks
a. Meteor – the fireball produced when a when a meteoroid enters the atmosphere at high speed and burns up
b. Meteorite – when a meteoroid that enters the atmosphere survives and reaches the ground

G. Kuiper belt – large region beyond the orbit of Neptune; astronomers think there are millions of small, icy objects in this region; location of Pluto; contain a variety of frozen compounds like ammonia and methane

H. Oort Cloud – most distant region of the solar system; believed to be a giant spherical shell surrounding the rest of the solar system; may contain billions or even trillions of objects; believed to be the source of most long-period comets

I. Comets – frozen leftovers from the formation of the solar system; composed of dust, rock, and ice; have a tail
a. Long-period comets – comets that take over 200 years to orbit the sun; can take as long as 30 million years to orbit the sun; are less predictable than short-period comets
b. Short-period comets – comets that take less than 200 years to orbit the sun; their appearance is predictable in many cases because they have passed by before

6. Evaluate celestial objects in order to determine formation, age, location, characteristics, and evolution.

A. The Universe
a. Formation – in a particular instant, all the matter and energy we can observe (which was concentrated into a region smaller than a dime) began to expand and cool at an incredibly rapid rate (the Big Bang)
b. Age – approximately 15 billion years old
c. Evolution – continuous uniform expansion
i. Major events during the first minute of expansion:
- By the time the temperature had dropped to 100 million times that of the sun's core, the forces of nature assumed their present properties; quarks roamed freely

- When the universe had expanded an additional 1000 times, all the measurable matter filled a region the size of the solar system; free quarks became confined in neutrons and protons
- After the universe grew by another factor of 1000, protons and neutrons combined to form atomic nuclei (most of the helium and deuterium present today); still too hot for atomic nuclei to capture electrons

ii. After 300000 years, neutral atoms appeared in abundance; universe was 1/1000 of its present size
iii. Neutral atoms began to form into gas clouds which later evolved into stars
iv. When the universe reached 1/5 of its present size, stars formed groups recognizable as young galaxies
v. When the universe was ½ of its present size, nuclear reactions in stars had produced most of the heavy elements from which terrestrial planets were made
vi. Our solar system formed 5 billion years ago, when the universe was 2/3 its present size

B. Local Group – galaxies within roughly 5 million light-years of space around us
   a. Location – outskirts of the Virgo Supercluster, Universe
   b. Characteristics – composed of three large galaxies (Andromeda, Milky Way, and Triangulum) and around 50 dwarf galaxies

C. Milky Way Galaxy – the galaxy that includes the Solar System; name describes the appearance from Earth
   a. Formation – began as a spherical cloud of gas that was born collapsing inward; the Milky Way's flat disk and central bulge formed at approximately the same time
   b. Age – 13.61 billion years
   c. Location – Local Group, Virgo Supercluster, Laniakea Supercluster, Universe
   d. Characteristics – barred spiral galaxy with large pivoting arms; Sagittarius A* supermassive black hole is at the center
   e. Evolution – will likely grow primarily through star formation

D. Orion-Cygnus Arm
   a. Location – between the Perseus and Carina-Sagittarius arms, Milky Way Galaxy, Local Group, Virgo Supercluster, Laniakea Supercluster, Universe
   b. Characteristics – about 25000 light-years long; previously thought to be 16000 light-years long

E. Oort Cloud – believed to be a giant spherical shell surrounding the rest of the solar system
   a. Age – 4.6 billion years
   b. Location – Local Interstellar Cloud, Local Cavity, Orion-Cygnus Arm, Milky Way Galaxy, Local Group, Virgo Supercluster, Laniakea Supercluster, Universe
   c. Characteristics – may contain billions or even trillions of objects; believed to be the source of most long-period comets

F. Solar system – the star system in which the planet Earth is located
   a. Formation – a dense cloud of interstellar dust and gas collapsed, forming a solar nebula
   b. Age – 4.571 billion years
   c. Location – Oort Cloud, Local Interstellar Cloud, Local Cavity, Orion-Cygnus Arm, Milky Way Galaxy, Local Group, Virgo Supercluster, Laniakea Supercluster, Universe
   d. Characteristics – 8 primary planets; at least 5 dwarf planets, over 200 known moons

Glossary

Rotation - the spinning of Earth on its own axis; produces the 24-hour day-night cycle
Tides - the twice daily rise and fall of sea levels; the result of both the gravity of the moon and the gravity of the sun
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Chromosphere - the pinkish-red layer of the sun; about 2000 km thick; temperatures range from 4400 Kelvin at the bottom to 25000 Kelvin at the top; gives off jets of burning gases (spicules)

Corona - wispy outermost layer of the sun; can extend millions of kilometers into space; gases burn at about 1 million Kelvin and move about 145 km per second

Solar Winds - a continual stream of protons and electrons from the sun’s outermost atmosphere (the corona)

Planets - celestial bodies that orbit a star, are big enough to have enough gravity to force it into a spherical shape, and are big enough that its gravity has cleared away any other objects of a similar size near its orbit around its star

Inner Planets - rocky planets located between the sun and the asteroid belt

Mercury - smallest planet in the solar system and nearest to the sun; fastest planet in the solar system; no rings; no moons

Venus - similar in size to Earth; second planet from the sun; rotates very slowly on its axis; rotates around the sun more quickly than Earth; a day on Venus is longer than its year; retrograde rotation; no moons; no rings

Earth - our home planet; third planet from the sun; fifth largest planet; only planet with liquid water on its surface; no rings; one moon

Mars - fourth planet from the sun; second smallest planet; the location of two rovers, one lander, and one helicopter; no rings; two moons

Outer Planets - gas and ice giants located beyond the asteroid belt

Jupiter - gas giant; largest planet; fifth planet from the sun; has a faint ring system; 75 moons

Saturn - gas giant; second largest planet; sixth planet from the sun; large ring system; 53 known moons and 29 moons awaiting confirmation
Uranus - seventh planet from the sun; third largest planet; first planet found with a telescope; ice giant; 27 known moons; 13 known rings; retrograde rotation; rotates on its side
Neptune - eighth planet from the sun; ice giant; not visible to the naked eye; faint rings; 14 known moons
Dwarf Planets - a celestial body that orbits the sun, has enough mass to assume a nearly round shape, has not cleared the neighborhood around its orbit, and is not a moon
Pluto - orbited by five known moons, the largest of which is Charon, which is half the size of Pluto; has a radius of 715 miles; orbit is both elliptical and tilted (248 year long orbit that can take it as far as 49.3 AU from the sun and as close as 30 AU); spins almost on its side; exhibits retrograde rotation; located in the Kuiper belt
Makemake - located in the Kuiper belt; has one provisional moon
Haumea - roughly the same size as Pluto; football shaped; located in the Kuiper belt; two known moons
Eris - one of the largest known dwarf planets in our solar system; similar in size to Pluto; has one very small moon; located in the Kuiper belt
Ceres - located in the asteroid belt; makes up almost a third of the asteroid belt’s total mass
Moons - smaller bodies orbiting a planet or dwarf planet; more than 200 are known to exist in our solar system
Asteroids - sometimes called minor planets; rocky, airless remnants left over from the early formation of our solar system; most can be found in the asteroid belt between Mars and Jupiter
Meteroids - objects in space that range in size from dust grains to small asteroids; space rocks
Meteor - the fireball produced when a when a meteoroid enters the atmosphere at high speed and burns up
Meteorite - when a meteoroid that enters the atmosphere survives and reaches the ground
Kuiper Belt - large region beyond the orbit of Neptune; astronomers think there are millions of small, icy objects in this region; location of Pluto; contain a variety of frozen compounds like ammonia and methane
Oort Cloud - most distant region of the solar system; believed to be a giant spherical shell surrounding the rest of the solar system; may contain billions or even trillions of objects; believed to be the source of most long-period comets
Comets - frozen leftovers from the formation of the solar system; composed of dust, rock, and ice; have a tail
Long-Period Comets - comets that take over 200 years to orbit the sun; can take as long as 30 million years to orbit the sun; are less predictable than short-period comets
Short-Period Comets - comets that take less than 200 years to orbit the sun; their appearance is predictable in many cases because they have passed by before
Local Group - galaxies within roughly 5 million light-years of space around us
Milky Way Galaxy - the spiral galaxy that includes the Solar System; name describes the appearance from Earth
Orion-Cygnus Arm - arm of the Milky Way galaxy where our solar system is located
Oort Cloud - believed to be a giant spherical shell surrounding the rest of the solar system
Solar System - the star system in which the planet Earth is located

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