WUNNA EDUCATIONAL SERVICES

EARTH, STARS, GALAXIES AND SATELITES

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THEME: EARTH AND SPACE SYSTEM

THE SOLAR SYSTEM

What you should know.

- How the Earth orbits around the sun and the moon around the Earth and the time taken for these orbits.
- The cause of day and night.
- Why the shape of the moon appears to change over a period of time when viewed from the Earth.
- How the tilt of the Earth gives rise to seasons in some parts of the world.
- The implications of the above for activities on Earth.
- Use a model to explain how the earth and moon move relative to the sun and use it to explain eclipses.
- The connection between the moon and ocean tides.
- The components of the solar system, and make a scale model of the planets and place them in order showing their relative distance from the Sun.
- The main characteristics of the inner four and outer four planets.
- Why the Earth is the only planet which supports life.
- The asteroid belt and where it is found in the Solar System.
- The origin and structure of the universe.

THE EARTHS' ORBIT ABOUT THE SUN & MOONS' ORBIT ABOUT THE EARTH.

The Earth revolves in an orbit around the Sun in 365.25 days, with reference to the stars, at a speed ranging from 29.29 to 30.29 kms-1. The 6 hours, 9 minutes (0.25 days) adds up to about an extra day every fourth year, which is designated in a leap year, an extra day added as February 29th.

The Moon takes about one month to orbit the Earth (27.3 days to complete a revolution, but 29.5 days to change from the present Moon to New Moon). As the Moon completes each 27.3-day orbit around Earth, both Earth and the Moon are moving around the Sun.
The Earth and the Moon's orbits are maintained by a gravitational force that attracts and keeps them in the orbit.

DAY AND NIGHT

Day and night are due to the Earth rotating on its axis, not its orbiting around the sun. The term 'one day' is determined by the time the Earth takes to rotate once on its axis and includes both day time and night time. When the Earth rotates a given part facing the sun, that part experiences day and when that Earth's part faces away from the sun, then that part experiences night.

Daytime is when you can see the sun from where you are, and its light and heat can reach you. Night-time is when the sun is on the other side of the Earth from you, and its light and heat don't get to you.
We get day and night because the Earth spins (or rotates) on an imaginary line called its axis and different parts of the planet are facing towards the Sun or away from it.
It takes 24 hours for the world to turn all the way around, and we call this a day. Over a year, the length of the daytime in the part of the Earth where you live changes. Days are longer in the summer and shorter in the winter.

It takes 24 hours for the Earth to turn all the way around (rotation). That makes one day and one night.
At any moment, half of the world is in daytime and half is in night time.

The world is like a ball. We call the top half the Northern hemisphere and the bottom half the Southern hemisphere. The imaginary line between them is called the equator.

In the Northern hemisphere, we have summer in June, July and August and winter is in December, January and February.
In summer the days are longer than they are in winter. In London, the longest day is about 16 hours and 39 minutes and the shortest is 7 hours and 45 minutes.

In the Southern hemisphere the seasons are the other way around. When it is summer in Europe, it is winter in Australia. Imagine celebrating Christmas on a long, hot summer day.

The imaginary line between the Eastern and Western hemispheres is called the 'Prime Meridian' and it goes through Greenwich Royal Observatory in London.

The world is split into time zones. Continental Europe is in the time zone to the east of Britain, so time is one hour ahead there; when it is 1pm in Britain it is 2pm in France.

Changes in the shape of the Moon

The Moon doesn't emit (give off) light itself, the 'moonlight' we see is actually the Sun's light reflected off the lunar surface. So, as the Moon orbits the Earth, the Sun lights up different parts of it, making it seem as if the Moon is changing shape. In actual fact, it's just our view of it that's altering…

1. It is a universal fact that the Moon does not produce light itself. It is the Sun who produces the light and the Moon reflects from the Sun's light.

2. Because of the Moon's changing position as it orbits our planet, the Sun's light focus on different parts of it, giving the illusion that the Moon is changing shape over time.

3. But the fact is that the Moon never changes its shape. The shape of the Moon that appears at night, is the only part of the Moon which is facing us and in sunlight.

4. There are eight total phases of the moon cycle, four primary phases, and four secondary phases.

5. The primary phases are the new moon, first quarter, full moon, and last quarter.

6. The secondary phases are waxing crescent, waxing gibbous, waning crescent, and waning gibbous. The term waxing refers to the growth of the moon's image, while the term waning refers to a shrinking image.

7. The moon changes its shape every day. The day on which the whole of the moon is visible is known as the full moon day. Thereafter every night the size of the bright part of the moon appears to become thinner day by day.

8. On the fifteenth day, the moon is not visible. This day is known as the "new moon day". On most days only a small portion of the moon appears in the sky. This is known as the crescent moon. Then again moon grows larger every day.

9. On the fifteenth day, once again we get a full view of the moon. The time period between one full moon to the next full moon is slightly longer than 29 days (~29.5 days). The various shapes of the bright part of the moon as seen during a month are called **phases of the moon**.

Seasons in some parts of the earth

As the earth spins on its axis, producing night and day, it also moves about the sun in an elliptical (elongated circle) orbit that requires about 365 1/4 days to complete. The earth's spin axis is tilted with respect to its orbital plane. This is what causes the seasons.

When the earth's axis points towards the sun, it is summer for that hemisphere. When the earth's axis points away, winter can be expected. Throughout the year, different parts of Earth receive the Sun's most direct rays. So, when the North Pole tilts toward the Sun, it's summer in the Northern Hemisphere. And when the South Pole tilts toward the Sun, it's winter in the Northern Hemisphere.

Implication of season on activities on earth.

The season on earth affects the various activities conducted by human beings. This ranges from human activities, agricultural activities and human life.

These activities are all affected by the seasons which arises from the changes in seasons.

Question.

Assess the impact and implications of changing seasons to the human and other activities on Earth.

Relative motion of the sun and moon and eclipse.

The Sun is the largest of the sun, Earth and Moon. The earth rotates about the sun and revolves about its own axis. The moon rotates about the Earth and the sun concurrently. When the Sun, Earth and the Moon are in a straight line, the shadow of the sun is cast either on the Earth or the Moon. This is referred to as an **eclipse**.

During a solar eclipse, the moon moves between the Earth and the sun and blocks the sunlight. The shadow is formed on Earth.

During a lunar eclipse, the Earth blocks the sun's light from reaching the moon. The shadow is formed on the moon as the Earth blocks light from reaching the moon. Since we are standing on Earth, what we see is that the moon gets dark. Other kinds of eclipses happen too.

Characteristics of inner and outer planets.

Density: Inner planets are denser than outer planets.
Composition: Outer planets are made of gas, ice, and rocks, whereas the inner planets are made of iron, nickel, and silicates.
Moons: Inner planets have very few to no moons around them, whereas the outer planets have dozens of moons orbiting them.

Why earth is the only planet that supports life.

The Earth has the right distance from the Sun, it is protected from harmful solar radiation by its magnetic field. It is also kept warm by an insulating atmosphere, and it has the right chemical ingredients for life, including water and carbon.

Earth is able to support life because it has a suitable temperature for living organisms along with the presence of oxygen and water that is required for the survival of all life forms
The Earth appears to be the only planet in the solar system with living creatures. In the solar system, the planets orbit around the Sun. Earth is the third planet from the Sun.

It is one of the inner planets. As far as we know, Earth is also the only planet that has liquid water. Earth's atmosphere has oxygen. The water and oxygen are crucial to life as we know it. Therefore the Earth is able to support life in it.

Asteroid belt and where it's found

The asteroid belt is a region within the solar system occupied by asteroids that are sparsely held together by gravity and occupying a region taking the shape of a gradient ring orbiting the Sun. Asteroids are small rocky bodies sometimes composed of iron and nickel, which orbit the Sun. The asteroid belt exists between the orbits of Mars and Jupiter, between 330 million and 480 million kilometres from the Sun.

Is the asteroid belt a failed planet?

Astronomers once thought that the asteroid belt was a failed planet that fragmented during the solar system's development. However, this hypothesis has largely been abandoned.
Astronomers now believe the asteroid belt never gravitationally accreted into a planet, but was kept from doing so because of the massive gravity from Jupiter's mass.

ORIGIN AND STRUCTURE OF UNIVERSE

The big-bang theory proposes that universe was formed from an infinitely dense and hot core of the material. The bang in the title suggests there was an explosive, outward expansion of all matter and space that created atoms. Spectroscopy confirms that hydrogen makes up about 74% of all matter in the universe.

The universe appears to have an infinite number of galaxies and solar systems and our solar system occupies a small section of this vast entirety. The origins of the universe and solar system set the context for conceptualizing the Earth’s origin and early history.

The mysterious details of events prior to and during the origin of the universe are subject to great scientific debate. The prevailing idea about how the universe was created is called the big-bang theory. Although the ideas behind the big-bang theory feel almost mystical, they are supported by Einstein’s theory of general relativity.

The big-bang theory proposes the universe was formed from an infinitely dense and hot core of the material. The bang in the title suggests there was an explosive, outward expansion of all matter and space that created atoms. Spectroscopy confirms that hydrogen makes up about 74% of all matter in the universe. Since its creation, the universe has been expanding for 13.8 billion years and recent observations suggest the rate of this expansion is increasing

STARS AND GALAXIES

Astronomers

Refer to a group of scientists that have interests focusing on study of stars and space.

Astronomy

Is the branch of science that involves the study of visible celestial objects present in the universe such as sun, stars, planet, moons, galaxies and nebulae.

The stars

A **star** is a luminous ball of gas, mostly hydrogen and helium, held together by its own gravity.

The Nuclear fusion reactions in the star's core support it against gravity and produce light and heat, as well as small amount of heavier elements. The closest star to our earth is the sun.

Source of energy in stars.

A star, like our sun, must also generate energy, otherwise it would shrink into a very dense and small body.

The sun and its source of energy.

Solar energy is created by **thermo-nuclear fusion** reactions that takes place in the sun's core, releasing vast amount of energy through two distinct reactions in which four hydrogen nuclei may eventually result in one helium nucleus. These are the **proton-proton chain** reaction by which most of the Sun's released energy and the **Carbon Nitrogen Oxygen (CNO) cycle**.

During the fusion process, radiant energy is liberated. In its core, the sun fuses 620 million metric tons of hydrogen and makes, 616 million metric tons of helium each second.

The proton-proton chain reaction:

$$1H + 1\ H \rightarrow 2D + e+ + ve$$

$$^{2}D + ^{1}H \rightarrow ^{3}He + \gamma$$

$$^{3}He + ^{3}He \rightarrow ^{4}He + ^{1}H + ^{1}H$$

Where ^{1}H is a proton, ^{2}D is Deuterium (hydrogen isotope), e^{+} is a positron, ν_e neutrino, ^{3}He is Helium−3, γ gamma ray photon and ^{4}He is Helium−4.

The total energy released by these reactions in turning 4 hydrogen atoms into 1 helium atom is 26.7 *MeV.*

The second sequence of reactions is **CNO cycle** in which 4 H nuclei may form one He nucleus. This cycle generates less than 10*percent* of the total solar energy output. It is a reaction which involves carbon atoms which are not used up in the reaction process.

$$12C + 1\ H \rightarrow 13N + \gamma$$

$$13N \rightarrow 13C + e+ + ve$$

$$13C + 1\ H \rightarrow 14N + \gamma\ 14N + 1\ H \rightarrow 15O + \gamma$$

$$15O \rightarrow 15N + e+ + ve$$

$$15N + 1\ H \rightarrow 12C + 4\ He + \gamma$$

Nuclear fusion is the combination of small nuclei to form bigger ones with release of energy.

The sun is the source of almost all energy on Earth, it produces too much energy and the earth only receives about over billionth of the sun's total energy output. The Earth reflects back a bigger percentage to the space.

Approximate amount of energy produced by the sun per second.

The sun releases 3.84x10^{26} W per second equivalent joules of energy 426 million metric tons (3846 septillion watts)

How energy produced in the core is transferred to the outer surface of the sun.

The energy produced in the solar core is in form of gamma rays, which diffuse very slowly occasionally colliding with other particles as they travel outward.

On collision, they lose their energy, liberating another gamma ray. Slowly the energy is transferred outward and it may take millions of years for photons to diffuse to the top of the **photosphere**.

In the **radiative zone**, radiative diffusion dominates the outward flow of heat. The next layer of the Sun is the **convective zone** where convection dominates the outward flow of heat. The outer layer of the Sun is the photosphere at which the temperature falls to around $5500K$

Stellar Atmospheres

The stellar atmosphere is the outer visible region of a star, lying above the star's **core**, **radiation zone** and **convection zone**.

The stellar atmosphere is divided into several regions of distinct character.

The photosphere

The photosphere is the stellar atmosphere's lowest and coolest layer, is normally its only visible part. Light escaping from the surface of the star comes from this region and passes through the higher layers. The Sun's photosphere has a temperature in the 5,770 K to 5,780 K range. Star spots, cool regions of disrupted magnetic field lie on the photosphere.

The chromosphere

Above the photosphere lies the chromosphere which is about 400 km above the solar surface (the photosphere). This part of the atmosphere first cools down and then starts to heat up to about 10 times the temperature of the photosphere.

The temperature in the chromosphere varies between about 4000 K at the bottom and 8000 K at the top.

Transition Region

Above the chromosphere lies the transition region, where the temperature increases rapidly on a distance of only around $100km$. The transition region is a very narrow layer between the chromosphere and the corona, where the temperature rises dramatically from approximately 8000 to $500{,}000K$.

The Corona

The outermost part of the stellar atmosphere is the corona, a tenuous plasma which has a temperature above one million Kelvin. While all stars on the main sequence feature transition regions and corona, not all evolved stars do so. It seems that only some giants, and very few super giants, possess corona. The corona can be heated to such high temperatures due to magnetic field activity, but the exact mechanism remains unclear.

During a total solar eclipse, the photosphere of the Sun is obstructed, revealing its atmosphere's other layers. Observed during eclipse, the Sun's chromosphere appears briefly as a thin pinkish arc, and its corona is seen as a tufted halo. The same phenomenon in eclipsing binaries can make the chromosphere of giant stars visible.

Different energy changes that take place in the sun

Nuclear fusion, involves the combination of hydrogen nuclei to force helium with a tremendous release of energy inform of heat and light.

Electromagnetic radiation, such as visible light, ultra- violent and infrared radiation are emitted by the sun traveling through space inform of photons. Thermal energy from the sun's core is converted into electromagnetic radiation in the sun's radiative zone.

Gravitational energy. The sun's immense mass and gravity cause it to contract under its own weight releasing gravitational energy in the process. This gravity contributes to the sun's internal heat which in turn fuels nuclear fusion.

Importance of Solar Energy

However much the earth receives a very small portion of the energy from the sun (solar energy), it is this proportion that accounts for most life sustaining and energy, consuming process on Earth. Without the solar energy life would not exist on Earth.

Solar energy helps to support natural process like photosynthesis, transportation, germination, evaporation and percolation etc.

Photosynthesis. Solar energy provides the necessary light energy for plants to convert carbon-dioxide and water into glucose and water. This process is essential for the growth and survival of plants.

Transpiration. By heating the air and causing water to evaporate from the leaves of plants which helps in the movement of water and nutrients throughout the plant.

Germination. By providing the warmth necessary for seeds to sprout and begin growing.

Evaporation. By heating bodies of water causing water to change from liquid to vapour which is crucial for the water cycle.

Percolation. By warming the soil, which aids in the movement of water through the soil layers.

Energy sources that come from the sun

Solar Photovoltaic System which directly convert sunlight into electricity using the photovoltaic effect.

Solar Thermal Energy harnesses the sun's heat to produce electricity or provide heating e.g solar concentrations.

The size of the sun

When viewed from earth, the sun appears smaller than the earth, this is because the sun is too far away from the Earth (about $147{,}000{,}000Km$). The sun is about 150 million Km far away from the earth. But the sun is far much bigger than all the components of the solar system.

Size of the sun relative to other stars

The sun is an averaged sized star. There are both larger and smaller stars that exist, some large stars have a diameter that is 100 times greater than that of the sun. However, there are also stars that are a tenth of the sun.

Why do the other stars appear smaller than the sun to an observer on Earth?

This is because the sun is much closer to the Earth compared to other stars.

Variation in colour and Brightness of stars

Absolute Magnitude is the measure of a star's brightness as it is viewed at a standard distance from the earth.

Star colour	Approximate temperature
Blue/ O-type Star	25000K
White/ A - type star	10000K
Yellow/ G-type	6000K
Orange/ K- type	4000K
Red/ M-type	3000K

Others are the F-type (yellow-white), B-type (Blue-white)

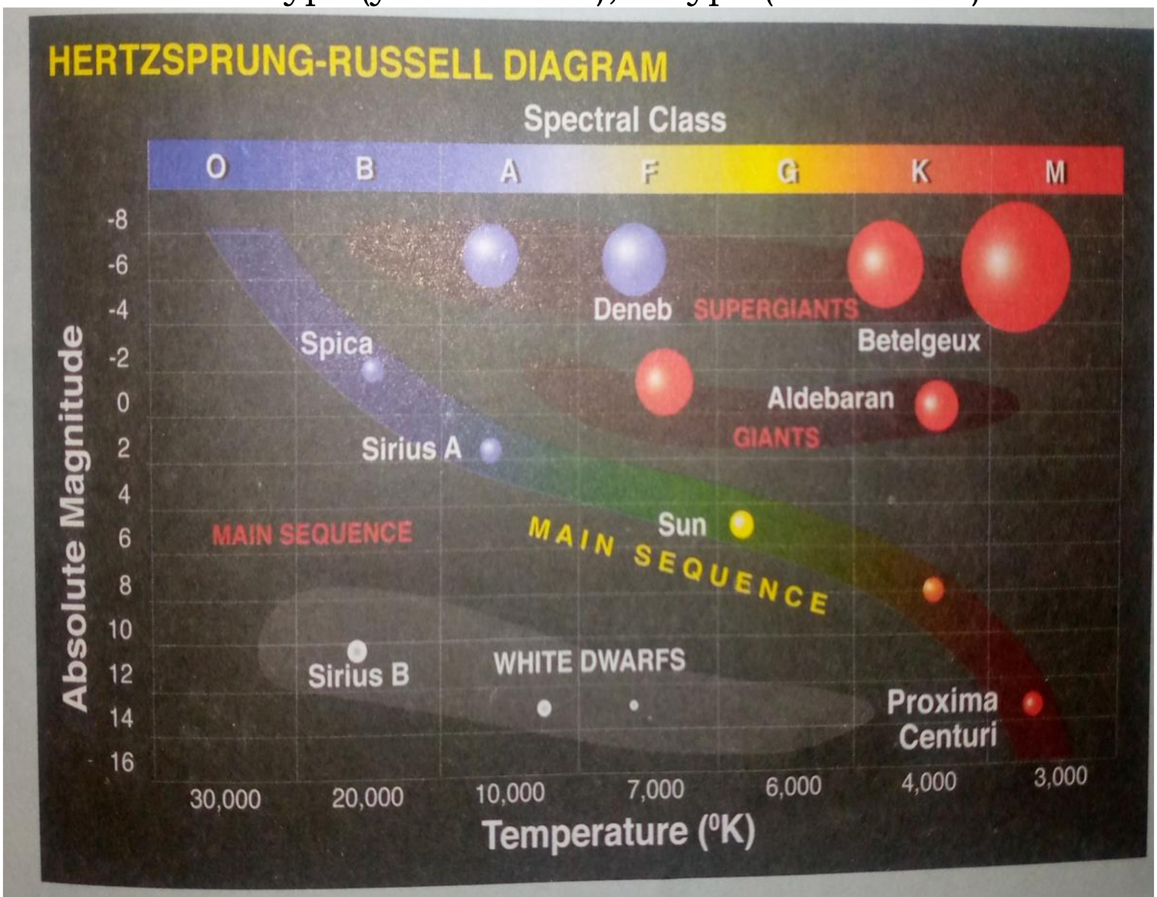


Figure 7.3: Hertzsprung Russel diagram

Factor that determine the brightness

1. The composition and distance from the earth
2. Size and temperature of the star

The apparent brightness of a star varies with distance from it, for instance the sun appears brighter when viewed from Venus than from the Earth because Venus is closer to the sun than the Earth.

There are many stars in space as there are grains of sand in seas, the luminosity of a star is measure its brightness. Astronomers measure a star's brightness by examining the amount of energy it emits per second. The more energy emitted, the higher the brightness. This energy emitted per second is measured in **watts.**

The brightest star in the sky is **Sirius**, also known as the "Dog star" or the Alpha Canis Majoris, because of its position in the constellation Canis Major.

Parsec is the distance from which the radius of the earth's orbit, 1AU, subtends and angle of 1".

Light year(ly).Is the distance travelled by light through a vacuum in one Julian year.
($1\,ly = 9.4607 \times^{15} m$).
One parsec is equivalent to $3.226ly$.

The **radiant flux** is the total amount of light energy of all wavelengths that crosses a unit area oriented perpendicular to the direction of the light's travel per unit time.

Imagine a star of luminosity, **L** surrounded by huge spherical shell of radius r. Then assuming that no light is absorbed during its journey out to the shell, the radiant flux,**F** measured at distance, **r** is related to the star's luminosity by:

$$F = \frac{L}{4\pi r^2},$$

where $4\pi r^2$ is the area of the sphere. **Inverse Square law** of light states that the radiant flux is inversely proportional to the square of the distance from the star.

Why Star Appear to twinkle?

This appearance is due to the effect of the atmosphere, when light from the stars enter the atmosphere, it is continuously refracted by regions with different temperatures and optical densities.

LIFE CYCLE OF A STAR

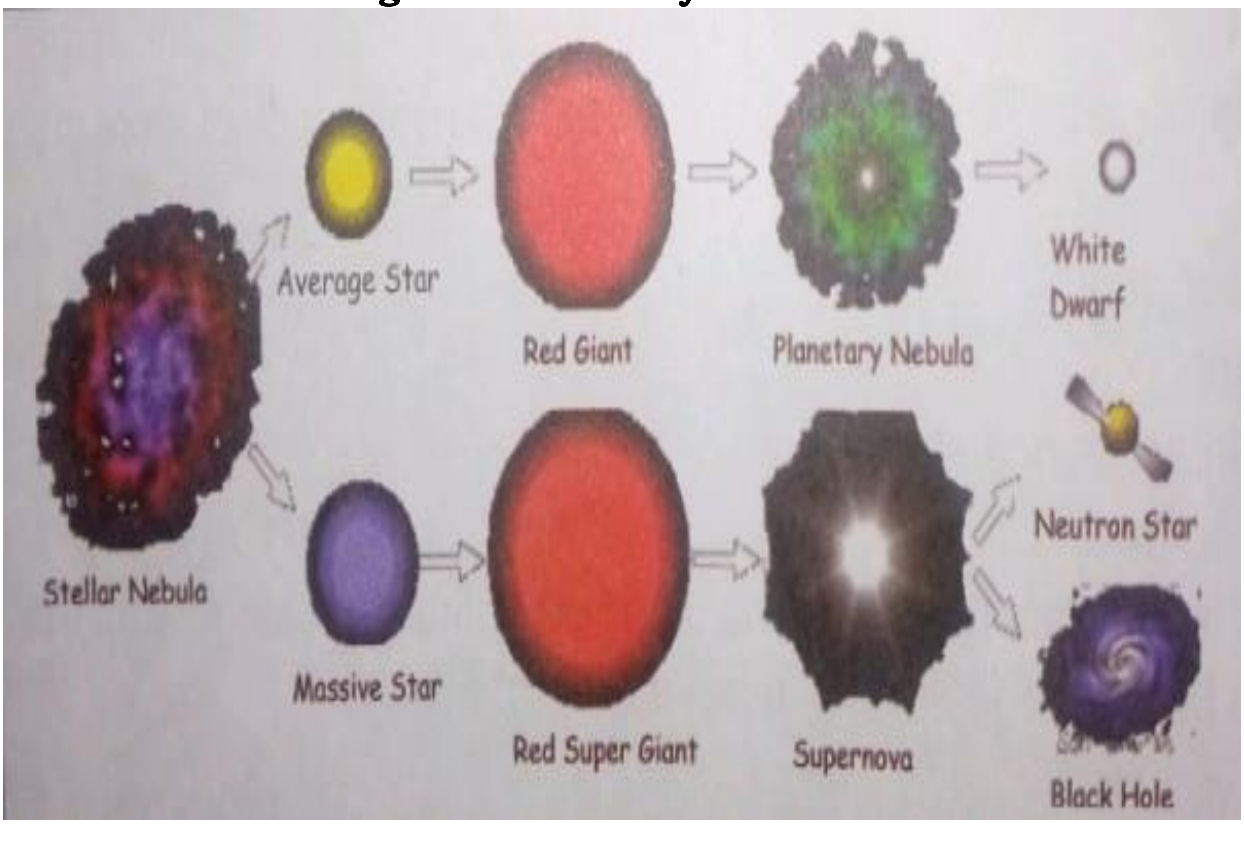
Stars and humans share similar phases in their life cycles, stars begin their lives as dense clouds of gas and dust.

Like humans, stars spend most of their life in the Main Sequence stage (adulthood).

If a star begins its life with a great amount of mass, it burns hot and fast to maintain equilibrium. So fuel runs out so quickly. The star dies young with a super massive explosion, an average sized star lives longer (about 10 billion years) and dies a quiet peaceful death.

A star life cycle is determined by its mass, the larger its mass the shorter in its life cycle. A star's mass is determined by the amount of matter that is available in its nebula, the giant cloud of gas and dust from which it was born.

Stages in the life cycle of a star



Stellar nebula. Stars are formed from massive clouds of gas and dust called nebulae. The process begins when a region with a nebula becomes denser due to gravitational forces. As the density increases the temperature rises nuclear fusion reactions are ignited, leading to birth of a star.

Protostar stage

This is the first phase, **Protostar** is a collection of gas that has come from a collapsed giant molecular could. After many years, the gravity and pressure increases, causing the collapse of the protostar. The gravitational pressure holding the star together is the source of all the energy released by the protostar. At this stage, nuclear fusion reactions have not yet been ignited. This phase of a star lasts for $100{,}000\,years$.

T-Tauri Star

At this stage, the stars do not have enough pressure and temperature to ignite nuclear fusion in their cores. The stars are lie the main Sequence stars in terms of their temperature, but they are brighter and larger. T-Tauri stars can experience high geomagnetic activity. This is exhibited by the presence of sunspots, high intensity, X-rays flares and powerful stellar winds. This stage of the star lasts about $100{,}000{,}000\,years$

Main Sequence Star

Most of the stars in the Milky way Galaxy and in the universe fall under this category. Our sun and its nearest neighbors sirius and Alpha Centauri are main sequence stars. The source of all the energy released by the star at this stage is fusion of hydrogen to form helium in the star's core. The star is in a state of hydrostatic equilibrium whereby the star's gravitational pressure and the light pressure due to the thermo-nuclear fusion reactions in the core counter balance each other. In this case, the star is able to maintain a spherical shape due to this balance.

Red Giant Star

After some time, a star can use up all its stock of fuel (hydrogen in its core). When this happens, the thermo-nuclear fusion reaction in the core stop and the star collapses under its own gravity.

This is because there is no longer outward light pressure from fusion reactions to counter balance the inward pressure due to gravity.

Then a shell of hydrogen around the core is forced to ignite fusion reactions to extend the life of this star. This causes the star to dramatically increase in size, hence becoming a red giant star which can be hundred times larger than a main sequence star.

Planetary Nebula or Supernova Stage

For average stars such as the sun, it sheds its outer layers to form a planetary nebula.

The remaining core becomes a white Dwarf, Massive stars undergo **catastrophic supernova explosion** at the end of their lives. These explosions disperse heavy elements into space and can result in the formation of **neutron stars or black holes**.

White Dwarf Stage

Eventually the star will run out of the fuel in its core. Further, if the star lacks the mass to force higher elements into fusion reactions, it becomes a white dwarf. In this case, the fusion reactions in the core have stopped and there is no longer outward light pressure to counter balance the inward gravitational pressure. Hence the star collapses under its own gravity. During collapse, however an electron degenerate gas forms in the core. This provides sufficient degeneracy pressure as it is compressed to resist further collapse.

White dwarfs are luminous because they have trapped a large amount of heat. A white dwarf shines because it was once a hot star. It eventually cools down to the ambient temperature of the background universe. White Dwarfs take billions of years to cool down.

Red dwarf Star

These are the most common stars in the universe. There are a ”type” of main Sequence stars that are much cooler than the main sequence stars because they have low mass. Such stars are able to keep nuclear fusion of hydrogen in their cores and can conserve their hydrogen fuel longer than most other stars. Some red dwarfs can last up to about ten trillion years.

Neutron stars or black holes formation

Stars with masses between 1.35 and 2.1 times the mass of the sun do not form white dwarfs after nuclear fusion stops in their cores. Such a star dies in a catastrophic supernova explosion, retaining a core which becomes a neutron star which is entirely composed of neutrons. The intense gravity of the neutron star force electrons and neutrons together, forming neutrons. For more massive stars, such supernova explosions result into black holes instead of neutron stars.

Supergiant Stars

These are the largest stars in the universe, they are much bigger than the sun in terms of mass.

These kind of stars are consuming their hydrogen fuel at a much faster rate than other stars, hence they end up consuming all the fuel in their cores within a few billion years. They tend to live fast and die young by catastrophic supernova explosions.

Briefly; **Neutron star** is the collapsed core of a massive star that has undergone a supernova explosion. Neutron stars are incredibly dense, with a mass about 14 times that of the sun but a radius of only, about 10Km. They are composed almost entirely of neutrons and possess extremely strong gravitational and magnetic fields.

Black hole is a region in space where gravity is so strong that nothing not even light can escape from it. It forms when a massive star, typically with a mass greater than 20 times that of the sun, reaches the end of its life cycle. As a massive star collapses in on itself at the end of its life, it causes its outer layer to explode as a supernova, while its dense core keeps collapsing under the force of gravity.

The extreme density of the core compresses the atoms and subatomic particles to a point where they are crushed into an infinitely small space forming a singularity. The boundary surrounding the a singularity is known as the ”**even horizon**”, which marks the point of no return.

A supernova, is a violent and spectacular explosion that occurs at the end of a star’s life. It is the result of a star running out of nuclear fuel and collapsing under its own gravity.

The intense gravitational compression heats and ignites the remaining mass, causing a tremendous explosion that can outshine an entire galaxy for a brief period.

Brightness of supernovae, supernovae are spectacular events that can be so bright to a point of outshining their entire galaxies for a few days or even months. They can be seen across the universe.

Difference between a white dwarf and black hole

A white dwarf is a dense compact celestial object formed from the remnants of low or medium mass stars composed primarily of carbon and oxygen while a black hole is a region in space where gravity is so strong that nothing not even light can escape from it.

Factors that determine the life expectancy of a star

Mass. This affects its gravitational pull and the pressure and temperature at its core. Average stars last longer than massive stars.

Composition. The amount of hydrogen and helium it contains. Where a star exhaust its hydrogen supply, it can no longer produce energy through fusion.

Rate of Nuclear fusion. Heavier stars burn their fuel more quickly causing them to exhaust their nuclear fuel and collapse more rapidly than their lower mass counter parts.

GALAXIES

A galaxy is a huge collection of gas, dust, and billions of stars and their solar systems, all held together by gravity. OR is a massive system that is bound together by gravity, consisting of stars, stellar remnants, interstellar gas, dust and dark matter.

Galaxies range from dwarf to super giants with stars, all orbiting the galactic centre of mass. Our galaxy, the Milky-way galaxy, has a supermassive black hole in the middle. In a galaxy, there are very many stars arranged in a recognizable shape called constellations. Different galaxies have constellation e.g elliptical, and others are irregular.

How Galaxies are formed

The current cosmological models of the universe are based on the big bang theory. Thousands of years after the big bang, light elements like hydrogen and helium started to form in a process called recombination. Density fluctuations in the earliest matter led to the formation of larger structures. The primodial structures eventually become galaxies. The first halo stars then appeared.

The halo stars may have been massive and could have quickly consumed their fuel and detonated in supernova explosions, releasing heavier elements into the interstellar space.

This was followed by ionization of the neutral hydrogen by the first population of stars. This created expanding bubbles in space that could allow light to go through readily.

Evolution of Stars

Key structures in a galaxy begin to appear after about a billion years. These include; globular clusters, the central supermassive black hole and the galactic bulge of population II stars. The supermassive black hole limits the total additional matter added unto a galaxy, hence regulating the growth of galaxies. During the early stages of the galaxy, it undergoes a major burst of star formation.

In the following billions of years, the accumulated matter and structures settle and form a galactic disc. Throughout the lifetime of a galaxy, absorption of incoming matter for example high velocity clouds and dwarf galaxies continues. As the stellar matters forms and dies, the abundances of heavy elements increases until planets are allowed to form.

Galaxies can be modified by interactions and mergers, hence affecting their content and morphology. Galaxies are more prone to mergers during their earliest stages of formation. For example, the milky-way galaxy and the neighboring Andromeda galaxy are moving towards each other at about $10 km/s$. Depending on their movement, they may collide in the next six billion years.

Galaxy Morphological Classification

Galaxies are classified according to their apparent shape (visual morphology). Galaxies are of three main types: **ellipticals, spirals and irregulars**. The Hubble Classification sequence or scheme gives a more extensive description of the galaxy types based on their appearance.

However, the Hubble sequence is entirely based on visual morphology and therefore it can miss some other important characteristics of galaxies for example star formation rate in star but galaxies and activity in the core in active galaxies.

Some of the types of galaxies according to the Hubble classification sequence. The letters E, S and SB indicate a type of elliptical, spiral and barred spiral galaxy respectively. The lower case letters a, b, and c indicate the degree of tightness of the spiral arms.

Correlation of Morphology

The Three main Types/ Morphologies of galaxies

Elliptical galaxies

These galaxies have an ellipsoidal shape which are almost spherical. They do not have spiral arms. The Hubble sequence classifies elliptical galaxies based on their ellipticity, ranging from those that are almost spherical as $E0$ to those which are highly elongated as $E7$.

These galaxies have a low portion of open clusters and a reduced rate of new star formation. They are generally dominated by older, more evolved stars that are orbiting the common center of gravity in random directions. Most elliptical galaxies are as a result of interaction of galaxies. This results in collisions and mergers.

Spiral galaxies

They have a typical disk shape. Most of their stars are abundantly concentrated near their centres with an arm- lie group of stars extending from their central nucleus.

Spiral galaxies consist of a rotating disk of stars and interstellar medium and a central bulge of generally older stars. Brighter arms extend radially outward from the central bulge.

In the Hubble classification, these galaxies are indicated by letter 'S' plus lower case letters a, b, or c, that indicate the degree of tightness of the spiral arms and the size of the central bulge.

Simply. "Have a flat, rotating disk containing a large number of stars and interstellar gas e.g Milky way.

These galaxies are thought to have formed through a process called "**cold collapse**". In this process, cold gas clouds in the early universe contract under their self-gravity, leading to the formation of stars and galaxies.

The angular momentum of the gas clouds causes the galaxies to spin, giving rise to the spiral structure."

Barred-Spiral Galaxy

Most of the spiral galaxies have a linear bar-shaped band of stars that extends outward to either sides of the core, then merges into the spiral arm structure. In the Hubble classification scheme, these are indicated by letters 'SB' together with a lower case letter a, b or c, that indicates the form of the spiral arms.

The bars are temporary structures that can result from a density wave radiating outward from the core or from tidal interaction with another galaxy. Most of these galaxies are active. This may be a result of gas being channelled into the galaxy core through the spiral arms.

Other galactic Morphologies

Peculiar Galaxies

Peculiar galaxies are those with unusual properties that arise from tidal interactions with other galaxies. For example the ring galaxy forms when a smaller galaxy passes through the core of a spiral galaxy. A ring galaxy possess a ring-like structure of stars and interstellar matter surrounding a bare core. The Andromeda galaxy also exhibits ring-like structure if viewed in infrared part of the electromagnetic spectrum.

Lenticular Galaxy

A lenticular galaxies are intermediates forms that possess properties of both spiral and elliptical galaxies. These are classified in the Hubble scheme as type 'S0'.

They have ill-defined spiral arms as well as an elliptical halo of stars. The barred lenticular galaxies are identified by the Hubble classification as 'SBO'.

Irregular Galaxies

These galaxies have no symmetry

There are several galactic formations that cannot be classified into the elliptical or spiral morphologies. These kinds are known as irregular galaxies, with tow broad categories.

The IRR-I galaxies possess some structures, however they do not align well with the Hubble Classification Scheme. Whereas the IRR-II galaxies do not have any structure that resemble a Hubble classification.

Dwarf Galaxies

Most galaxies in the universe are dwarf galaxies. They are relatively small compared with other galactic formations, containing fewer numbers of stars as well. Many such galaxies orbit larger galaxies. For example the Milky-way galaxy has a satellites.

Dwarf galaxies may as well be classified into elliptical, spiral or irregular. Small dwarf elliptical galaxies are called dwarf ellipsoidal galaxies and they barely resemble large elliptical galaxies.

Galactic Morphologies Due to Unusual Dynamics and Activities

Interacting Galaxies. Galaxies exist in clusters, within which their average separation is about an order of magnitude larger than their diameters. Therefore, interactions between galaxies are frequent and such processes play an important role in their evolution. Interacting galaxies are of three kinds:

Collisions occur when two galaxies which have sufficient relative momentum not to merge pass directly through each other. The stars within these interacting galaxies will pass through without colliding. However, the gas and dust within the two galactic forms tend to interact. As the interstellar medium becomes disrupted and compressed, bursts of new star formation are triggered. Collisions distort the shape of one or both galaxies, forming bars, rings, or tail-like structures.

Galactic mergers occur under extreme interactions. The relative momentum of the two interacting galaxies is insufficient to allow them to pass through each other. They gradually merge together to form a single larger galaxy. Mergers result in significant changes in morphology, as compared to the original galaxies.

Cannibalism occurs in cases where one of the galaxies interacting is much more massive than the other. The larger galaxy will remain relatively undisturbed by the merger, while the smaller galaxy is torn apart. For example the Milky-way galaxy is currently in the process of cannibalizing the Sagittarius dwarf elliptical galaxy and the Canis major dwarf galaxy.

Starburst Galaxies

Stars are created within the galaxy from a reserve of cold gas that forms giant molecular clouds. They exhibit an increase in star formation rate as compared to other galaxies.

At that rate, the stars consume their reserve of gas in a lifespan lower than that of other galaxies. Hence starburst galaxies last for a relatively short period of time of approximately 10 million years.

These galaxies consist dusty concentrations of gas and newly formed stars, including massive stars. Massive stars are known to trigger supernova explosions, resulting in expanding remnants that interact with the surrounding gas. This in turn ignite chain reaction of star formation that spread throughout the gaseous region. This activity stops when the gas is completely used up.

Active Nucleus Galaxies

In an active galactic nucleus, a significant portion of the total energy output from the galaxy is emitted by a source other than the stars, dust and interstellar medium. The standard model for an active galactic nucleus is based upon an accretion disc that forms around a supermassive black hole (SMBH) at the core region.

The radiation from an active galactic nucleus comes from gravitational energy of matter as it falls toward the black hole from the disc.

In some cases a pair of energetic jets ejects particles from the core of the galaxy at velocities close to the speed of light for example:

Seyfert galaxies are active galaxies that emit high-energy radiation in form of x-rays.

Blazers are active galaxies with a relativistic jet that is pointed towards the Earth.

A radio galaxy is one that emits radio frequencies from relativistic jets.

Low-ionization nuclear emission-line regions (**LINERs**): The **LINNER-type** galaxies emission is dominated by weakly ionized elements.

SATELLITES AND COMMUNICATION

Satellites

This refers to space-based object moving in a loop (an orbit) around a larger object. The path through which the satellites moves is called an **orbit**. The satellites are primarily grouped;

- Natural satellites
- Artificial satellites

The satellites follow different paths (orbit) at varying altitudes. These are determined by the purpose of a satellite. The satellite orbits are largely categorised into three basic groups as follows.

1. **Low Earth Orbit (LEO)**

This is an orbit positioned relative to the centre of the earth within an altitude range of 2000Km (1200miles) or less.

Most of the artificial space objects are found in the low earth orbit, they are fast moving which enable them to overcome the gravitation pull.

2. **Medium Earth Orbit (MEO)**

This is referred to as an intermediate circular orbit positioned at an altitude of about 20000 Km (12000 miles). It is above the low earth orbit but below geosynchronous orbit. This is where most artificial satellites are stationed.

3. **High Earth Orbit (HEO)**

This is at an altitude of 36000Km and this gives the satellite benefit of taking exactly one day to orbit the earth and return to the same position above it at the same time of the day.

Examples of satellites found in this orbit are communications and weather satellites.

QUESTION

How satellites hold in their positions in the space without falling back to the earth.

Artificial satellites

These are man-made objects that orbit the earth and other planets in the solar system. They are usually semi-independent computer controlled systems, i.e the satellites can operate by themselves or as part of a larger system, this is called a **satellite formation** or **satellite constellation**.

Broad categorization of artificial satellites.

1. **Fixed satellites system**. These are satellites used in handling of billions of voice, data and video transmission tasks across countries and continents between the points on the earth's surface.

2. **Mobile satellites system**. These are used in remote regions, tracking of vehicles, ships, people and air crafts in reference to the rest of the world and other mobile or stationary communication units. They serve as navigation systems.

3. **Scientific research satellites (commercial and non-commercial)**. These provide meteorological information, land survey data (e.g remote sensing) and other different scientific research applications such as earth science, marine science and atmospheric research.

Artificial Satellites are of great importance in the following ways.

- They are used for communication. These help in relying of data signals, voice and videos.
- They are used in weather forecasting system.
- They are used in the global positioning systems (GPS)
- They are used for making star maps and maps of planetary surfaces.

The following are examples of artificial satellites and their uses.

Astronomical satellites

These are used for observing distant planets, galaxies and other outer space objects **Bio-satellites.** These satellites are used to carry living organisms into space for scientific experimentation.

Communication satellites

These satellites facilitate telecommunications process.

Earth observation satellites

These satellites are generally used for environment related activities such as environmental monitoring, meteorology and map making.

Navigation satellites.

These satellites use radio signals. The signals allow mobile receivers on the ground to determine their exact location with good measure of accuracies in real life.

Killer satellites

These are satellites which are specially designed to detect and destroy enemy warheads, satellites and other space assets with high level of precision.

Miniaturized satellites

These are satellites of low masses and small sizes categorized as mini satellites (500 - 1000 Kg), Micro satellites (below 100kg) and nano satellites (below 10kg).

Crewed space craft (spaceships)

These are satellites made with capacity to safely carry human beings into space and back to the earth. These satellites can also be used a transport to and from the orbital stations. **Reconnaissance satellites**

These are either observation satellites or communication satellites deployed for military or intelligence activities. Information gathered by these types of satellites are treated as highly confidential by such states.

Space stations

These are artificial orbital structures designed in such a way that they can support human life when on exploration in the outer space. i.e the International Space Station, the space stations are differentiated from other crew space crafts by lack of landing facilities and and are designed from medium-term living in the orbit ranging from periods of weeks, months or years.

Recovery satellites

These are satellites that provide recovery of reconnaissance, biological, space-production and other pay loads from orbit to earth.

Weather satellites

These satellites help in gathering crucial weather data such as pictures of cloud formations which help meteorologist to interpret and predict the earth's weather and climate pattern.

Tether satellites

These are satellites which are connected to another satellite by a thin cable called a **tether**.

GEOSTATIONARY SATELLITES

A **geostationary satellite** is an earth orbiting satellite. It is positioned directly over the equator and revolves in the same direction as the earth (west to east) then returns to the same position after each complete day.

A geostationary satellite is stationed in a geostationary orbit, these satellites form a geosynchronous network and it's a communication based network. They also have an **advantage** in that they remain permanently fixed in exactly the same position in the sky as viewed from any fixed location on earth and this implies that ground based antennas/usually a small dish positioned such that it aims at the hoover, does not need to track them but can remain fixed in one direction without further adjustment.

Another **advantage** the geostationary satellites experience minimal interferences from surface- based sources and other satellites due to highly directional antennas.

Classification of geostationary satellites

Most of the satellites are earth orbiting satellites, they are categorised as follows;

1. Communication and Broadcasting satellites
2. Global positioning satellites
3. Remote sensing satellites

Communication and Broadcasting satellites

Are artificial satellites that relay and receive signals from an earth station and then retransmit the signals to other earth stations.

They move in a geostationary orbit, every communication satellite involves the transmission of information from an originating ground station to the satellite, followed by a retransmission of the information from the satellite back to the ground.

This retransmission can be either to select number of ground stations or broadcast to everyone in a large geographical area.

Communication and broadcasting satellites are generally used to relay radio waves from one place to another, they catch signals from ground stations (earth - based satellites dishes) and amplify them to posses enough strength to continue their motion until they bounce back to second ground station.

Uses of signals transferred in the communication and broadcasting satellites.

They are used to transfer telephone calls, internet data, radio and television broadcasts.

Communication satellites are very useful in facilitating communication to and from remote areas where ordinary wired or wireless communication cannot reach. Therefore such remote areas do not necessarily need telecommunication masts. e.g NASA communication satellite.

In Uganda today, satellite communication is heavily employed in digital television Broadcasting. This is done under the regulation and supervision of Uganda Communication Commission (UCC).

Below are some of the satellite technologies used in television communication in Uganda;

(a) **Digital Terrestrial Television (DTT)**

Is the technology for broadcast television in which land based television stations broadcast television content by radio waves to television in consumer's residences in a digital format.

The television signals are beamed by surface- based stations to land - based receivers that decode signals to the television sets. Examples are GoTV, Star times, DSTV, AZAM TV, ZUKU TV and Free to Air set-top boxes.

(b) **Direct to Home (DTH) or satellite TV**

Satellite TV transmission is a service that delivers television programing to viewers by relaying it from a communications satellite orbiting the earth directly to the viewer's location.

These signals are received by a satellite dish mounted on one's premises which are connected to a decoder. These signals are then decoded into a format that is viewable on a television set. Example of such service providers include: DSTV, StarTimes, Zuku TV e.t.c

Global Positioning Systems (GPS)

This is a global navigation satellite system (GNSS) that provides location, velocity and time synchronization. GPS is commonly used in cars, smart phones, smart watches e.t.c

The GPS provides critical positioning capabilities to military, civil and commercial users around the world.

GPS is made up of three main components called segments that work together to provide site or location information. The segments include;

Space (satellite). The satellites circling the earth, transmitting signals to users on the geographical position and time of the day.

Ground control. The control segment is made up of earth based monitor stations, master control stations and ground antennas. Control activities include tracking and operating the satellites in space and monitoring transmission.

User equipment. These are GPS receivers and transmitters a such as smart watches, smart phones and telematics devices.

How global positioning system works

GPS works through a technique called **trilateration**. This is determining a position by knowing your distance from at least 3 known points. In GPS, those known points are the satellites themselves. Trilateration connects signals from satellites to output location information. Satellites send signals which are read and interpreted by GPS device on or near the earth's surface.

How to calculate the location of a GPS device using the Satellites

The GPS device reads signals from at least four satellites. Each satellite in a network circles the earth two times a day and each sends a unique signal, Orbital parameters and time, At any one time, a GPS device can read signals from six or satellites.

How this works

When a satellite sends a signal, it creates a sphere with a radius measured from the GPS device to the satellite. When a second satellite is added, it creates a second sphere and location is narrowed down to one of the points where the spheres intersect. With the addition of third satellite, the device location can finally be traced because the device is now at the point of intersection of the three circles.

This means that each satellite produces a sphere and the intersection of the three spheres produces two points from which the point nearest to Earth is chosen.

As the device moves, its radius (distance to the satellite) changes. When the radius changes, new spheres are produced, giving us a new position. We can use that data, combined with the time from the satellite, to determine velocity, calculate the distance to our destination and the estimated time of arrival (ETA).

Uses of global Positioning System (GPS)

1. Surveyors use the GPS information to help them carry out accurate surveys and mappings.

2. Navigation, It helps people to easily move from one place to another.

3. Tracking of Objects. Wildlife organisations often use this technology to locate where-abouts of some wildlife when carrying out population counts.

4. Determining location of people. Smartphone being GPS device has often been used to precisely locate whereabouts of individuals.

5. Timing. GPS is useful aid in taking accurate time measurements.

Applications of the global Positioning System

Emergency response

During an emergency or natural disaster, first responders often use GPS for mapping the affected area. They asses and predict what weather conditions is likely to be, and to keep track of emergency personnel.

Health and fitness

Smart watches and wearable technology can track fitness activity (such as running distance) and benchmark it against a similar demographic. This technology was employed during the COVID period to help athletes in different countries to compete without coming together.

Construction, mining, and off-road tracking

From locating equipment to measuring and improving asset allocation, GPS enables companies to increase return on their assets.

Transportation

Logistics companies implement telematics systems to improve driver productivity and safety.

Research

GPS are used in monitoring earthquakes and shifting of tectonic plates. It's also helpful in research device in precise identification of individuals' locations at any point in time during research activity. Geographical Information System (GIS) has proved to be of great assistance to researchers in mapping the x-tics of the surroundings.

GIS and GPS allowing effective methods of examining the relationship between the natural and built environment and location based physical activity.

Hubble Space Telescope

Is a space craft traveling around the earth. It is estimated that it moves at a speed of about 5 miles per second. It faces towards space and takes photograph of planets, stars, comets and galaxies e.g NASA's Hubble Space Telescope was taken on the fifth servicing mission to the observatory in 2009.

"Hubble space telescope is the world's largest telescope. It is based in the space. It was named after the **American astronomer Edwin P Hubble who lived between 1889 and 1953**. Dr. Hubble postulated about an expanding universe which led to the **Big bang theory.**

Hubble has seen stars being born and die. It has seen galaxies that are trillions of miles away. It has been comet pieces crash into the gases above Jupiter. Scientists are learning a lot about space from Hubble Pictures. The Hubble space telescope does not travel to stars, planets or galaxies. It takes pictures of them as it whirls around the earth at about 17000 meters per hour.

INTERNATIONAL SPACE STATION (ISS)

Is a large space craft which orbits the earth. It is placed at average altitude of approximately 250 miles. ISS serves as a home for crews of astronauts and cosmonauts when living in the space. It travels at 17500 miles per hour.

It is a collaborative project by several countries which include; United States of America, Canada, Japan, Russia and countries from the European Space Agency.

The space station also serves as a unique science laboratory. NASA is using the Space Station to learn more about living and working in space.

Role of International Space Station.

Physical Sciences

The space environment allows accelerated materials testing. The micro gravity effects on fluid physics easily exposes underlying mechanisms with in physical systems.

Life Sciences

Researchers study effects of spaceflight on living organisms which allow them to advance pharmaceutical development and to augment earth- based studies in fundamental biology medicine, agriculture and biotechnology.

Remote sensing

ISS can be used as a platform for earth observation and remote sensing. This facilitates broad range studies in basic and applied science across many fields including the study of earth's surface and atmosphere.

Technology development

The ISS provides a suitable platform for researchers to validate technologies for space crafts, satellites and materials which require to withstand harsh conditions on earth.

Education

ISS National Lab & D is unique and exciting, providing a new resource for project- based learning and for using modern breakthrough to illustrate traditional science concepts and inspire a new generation of innovators.

Question

1. (a) What are the uses of artificial satellites?

(b) Discus how people's lives would be disrupted in the absence of satellites.

2. (a) What is GPS and how does it work? (b)What are the uses of GPS?

3. (a) What is Hubble space telescope?

(b) What makes Hubble Space telescope different from telescopes on earth?

(c) What is NASA and other space agencies learning from the Hubble Space Telescope?

4. (a) Describe any three areas of research on the International Space station? (b) Why is the Space Station important?

ACTIVITY OF INTEGRATION

1. Many people in Uganda own vehicles and motor cycles which are brought after hard work and several years of saving, these vehicles need to be monitored for guaranteed security. Unfortunately, many Ugandans are not aware of how to do this.

As a student of physics, Prepare a write up of not more than one page sensitising them on how they can easily monitor the vehicles.

2. Information in Uganda is passed onto the citizen through radios, mobile phones and televisions. Despite the advent of the internet and social media, radio and televisions remains extremely popular in most parts of Uganda. Unfortunately, the network signals in some areas cannot enable this to be done with ease. As a student of physics, write a report to media houses in Uganda showing how the signals can easily be relayed without loss so that each and every Ugandan gets access to information.