THEME: EARTH AND SPACE PHYICS

TOPIC: STARS AND GALAXIES

The sky is clear at night with some bright twinkling objects in it. These objects appear as fixed points of light due to their great distance from the earth, but in real sense they are large and are in motion.

Some of these bodies are called stars. Stars exist in groups, known as galaxies, held together by gravity. The sun is also a star and it produces a huge amount of energy daily.

A galaxy is a collection of a large number of stars that are held together by the force of gravity.

The galaxy that comprises of our solar system is known as the **Milky Way Galaxy**. The nearest galaxy to us is the Andromeda galaxy. Other galaxies include Ciger galaxy, Pinwheel galaxy, the Sombrero galaxy and others.

The Milky way galaxy can be seen in the night sky with naked eyes either as not being cloudy, with no strong lights nearby or no moonlight, during some time in the year.

Measurement in the stars and galaxies.

Physical quantities such as mass and distance of the stars and galaxies are very huge. This makes it hard to measure them with the conventional (S.I) units of the quantities. For this reason, the scientists came up with other larger units that can easily accommodate these large quantities as shown below;

Unit	Abbreviation	What it is used to measure
Light year	Ly	A light year is a unit of astronomical distance equivalent to the distance light travels in one year. 1 ly = $3.0\text{x}10^8 365.25\text{x}24\text{x}3600 = 9.5\text{x}10^{15}$ m
Astronomical year	Au	This is a unit of length roughly the distance from the Earth to the sun, about 150 million kilometres
Solar mass	-	The mass of a star is measured in terms of the mass the sun, with one solar mass unit being equal to the mass of sun. eg a star whose mass is twice that of the sun is said to have two solar masses.
Solar radius	-	The radius of stars is also measured with respect to the radius of the sun, with one solar radius being equal to the radius of the sun. eg a star whose radius is three times that of the sun is said to have a radius of three solar radii.

Assignment

Convert the following;

(a) 7 au to m (b) $6\text{x}10^8$ km to au (c) 5 ly to km (d) $19\text{x}10^{12}$ to ly

How the sun produces the energy needed for life to survive on Earth.

Solar energy is created by nuclear fusion that takes place in the sun. Fusion occurs when protons of hydrogen atoms violently collide in the sun's core and fuse to create a helium atom. This process emits an enormous amount of energy.

Energy from the Sun makes life possible on Earth. It is responsible for photosynthesis in plants, vision in animals and many other natural processes, such as the movements of air and water that create weather.

Most plants need at least some sunlight to grow, so without light, there would be no plants, and without plants, there would not be oxygen for us to breathe. Infrared radiation from the Sun is responsible for heating the Earth's atmosphere and surface. Without energy from the Sun, the Earth would freeze. There would be no winds, ocean currents, or clouds to transport water.

Appearance of the sun

Scattering of radiations from the sun affects the color of light coming from the sun and sky. The short-wavelength blue and violet are scattered by molecules in the atmosphere much more than other colors of the spectrum. This is why blue and violet light reaches our eyes from all directions on a clear day. But because we can't see violet very well, the sky appears blue.

Scattering also explains the colors of the sunrise and sunset. Because the sun is low on the horizon, sunlight passes through more air (atmosphere) at sunset and sunrise than during the day, when the sun is higher in the sky. More atmosphere means more molecules to scatter the violet and blue light away from your eyes. If the path is long enough, all of the blue and violet light scatters out of your sight. The other colors continue on their way to your eyes. This is why sunsets are often yellow, orange, and red.

And because red has the longest wavelength of any visible light, the sun is red when it's on the horizon, where its extremely long path through the atmosphere blocks all other colors.

Our sun's surface temperature is about 600 k. In the Earth's atmosphere, the sun looks white, shining, with about equal amounts of blue and red light. It looks somehow also yellow as seen on Earth's surface because our planet scatters some of the blue light making the sky appear blue and the sun appears yellow.

Amount of energy produced by the sun.

Sunlight is the largest energy source to reach the Earth but, despite this, the intensity of the energy that reaches the Earth's surface is relatively low due to the radial spreading of solar radiation as it travels from the distant Sun. More of this sunlight is lost in the Earth's atmosphere and due to clouds, which between them scatter as much as 54% of the incoming light. As a result, the sunlight that reaches the ground is around 50% visible light and 45% infrared radiation with the rest being made up of small amounts of ultraviolet and other types of electromagnetic radiation.

Therefore, The sun produces a large amount of energy. However, only a small fraction of this energy reaches the earth, because most of it is reflected and scattered from other surfaces and absorbed by other molecules, which convert it to heat.

The amount of heat reaching the Earth is about 1338 watts per square metre. This is known as the solar constant.

Solar constant is the amount of solar energy received on Earth per unit area.

In addition to heat and light, the sun also emits a low-density stream of charged particles (mostly electrons and protons) known as the solar wind, which travels throughout the solar system at about 450 kms^{-1}. The solar wind and the much higher energy particles released by the sun can cause challenges on earth such as power surges and disturbance of radio waves.

The variation in color and brightness of the stars in the Milky way in terms of their size and distance from Earth.

Stars have a wide range of apparent brightness measured here on Earth. The variation in their brightness is caused by both variations in their surface temperature and variations in their distance.

Just like a burning flame, there are different colors seen and they are associated to the temperature of that region.

Also, the bigger the star, the brighter it is. The apparent brightness of stars varies with their size and distance from the observer. Anear by faint star can appear to be just as bright to us on Earth as a distant star.

Sirus, also called the Dog star is the brightest star in the night sky. The bright component of the blue-white Sirus star is 25.4 times as bright as the sun

The different stages in the life cycle of a star.

Stars are large celestial bodies that mainly consist of hydrogen and helium, the two lightest elements. They can have different sizes and temperatures and produce energy through continuous nuclear fusion reactions occurring in their core.

We benefit from the energy released by our local star, the sun, as it heats and illuminates the earth. Stars are formed in **a nebula** and go through different stages in their life cycle depending on their mass. These stages will be explained in more detail below.

The life cycle of a star is the sequence of events that takes place in the life of a star from its formation to its end. The life cycle of stars depends on their mass. All stars, regardless of their mass, are formed and behave similarly until they reach their main sequence stage. The initial three stages that occur for a star to enter its main sequence are described below

Stage 1: Formation of a star

A star is formed from a **nebula,** which is a huge cloud of interstellar dust and a mixture of gases, mostly comprising hydrogen (the most abundant element in the universe). The nebula is so vast that the weight of the dust and gases start to cause the nebula to contract under its own gravity

Stage 2: Protostar

Gravity pulls the dust and gas particles together to form **clusters** in the nebula, which results in particles gaining kinetic energy and colliding with each other. This process is known as **accretion**. The kinetic energy of the gas and dust particles increases the temperature of matter in the nebula clusters to millions of degrees Celsius. This forms a **protostar**, an infant star.

Stage 3: Main sequence of a star

Once a protostar has reached a high enough temperature through accretion, nuclear fusion of hydrogen to helium begins in its core. This **main sequence** begins once the temperature of the protostar core reaches around 15 million degrees Celsius. The nuclear fusion reactions release energy, which produces heat and Light, maintaining the core temperature so the fusion reaction is self-sustaining.

During the main sequence stage, an equilibrium is achieved in the star. The outward Force created from the expanding Pressure due to nuclear reactions is balanced with the inward gravitational force trying to collapse the star under its own mass. This is the most stable stage in a star's life cycle, as the star reaches a constant size where the outward pressure balances the gravitational contraction.

If the protostar mass is not large enough, it never gets hot enough for nuclear fusion to occur - therefore the star does not emit Light or heat and forms what we call a **brown dwarf,** which is a **substellar object.**

All stars follow a similar initial lifecycle, however, a star's behaviour following the main sequence is highly dependent on its **mass**. We consider two general mass categories of stars; sun-like stars (average stars) and massive stars, that is;

- If the mass of a star is at least **8 to 10 times** the mass of the Sun, the star is considered to be a **massive star**.
- If the mass of a star is more similar to the size of the Sun, the star is considered to be a **sun-like star (average star)**.

Stars with larger masses are much hotter, appearing brighter in the sky - however, they also burn through their hydrogen fuel much faster, meaning their lifespans are much shorter than average stars. Because of this, large hot stars are also the rarest.

Stage 4; Red giant.

When the star hydrogen responsible for the nuclear reactions runs down, the star expands, cools and becomes a red giant. The massive stars become red supergiants since they are extremely massive. After this the star then dies out by becoming a black dwarf with no more luminous characteristics.

In summary, all stars are formed out of clouds of gas and dust, known as nebulae. Nuclear reactions occurring at the centre of the stars make them shine brightly for many years. Small stars burn their fuels slower than massive stars, therefore they last for several billion years. When the hydrogen responsible for the nuclear reactions begins to run out with time, they expand, cool and change colour to become red giants. From this stage, they undergo a death phase that sees them pass through a planetary nebulae phase to a white dwarf which cools down with time and stops glowing to become a black dwarf.

What a supernova is and how it a rise.

When the pressure drops low enough in a massive star, gravity suddenly takes over and the star collapses in just seconds. This collapse produces the explosion we call a supernova. Supernovae are so powerful they create new atomic nuclei.

A **s**upernova is a violent explosion that takes place at the end of a star's life cycle - and considered as the biggest explosion in space that humans can ever witness.

Supernovas are so bright that their peak luminosity can be compared to that of the entire galaxy before fading off over several weeks or months. This explosion then leaves behind either a black hole or a neutron star.

What are neutron stars and black holes are and how are they were formed.

Neutron stars are formed when a massive star runs out of fuel and collapses. The very central region of the star – the core – collapses, crushing together every proton and electron into a neutron.

Throughout much of their lives, stars maintain a delicate balancing act. Gravity tries to compress the star while the star's internal pressure exerts an outward push. And nuclear fusion at the star's core causes the outer pressure. In fact, this fusion *burning* is the process by which stars shine.

A neutron star has an abnormally strong magnetic field known as a magnetar, this can pull any metallic material from your pocket from as far away as the moon.

A black hole is an area of such immense gravity that nothing—not even light—can escape from it. Black holes form at the end of some stars' lives. The energy that held the star together disappears and it collapses in on itself producing a magnificent explosion.

TOPIC: SATELLITES AND COMMUNICATION

Topic outline

Types of artificial satellite, particularly geostationary satellites
Explain:
- how they are used in GPS navigation systems
- the value of photographs such as those taken by the Hubble Space Telescope.
- the purpose of the International Space Station and its role in space exploration

Satellite

A satellite is a body moving around a larger body in a curved path.
This path is called orbit.
The earth revolves around the sun (which is bigger than the earth), so it is a satellite .
The moon revolves around the earth so it is a satellite.

NB
A satellite that revolves around a star is called a planet , while that which revolves around a planet is called a moon.

Classification of satellites
Satellites are classified into two i.e
(i) Artificial satellites e.g
(ii) Natural satellites e.g moon, earth , Mars, Saturn, Neptune, Pluto, Uranus etc

Artificial satellites
Artificial satellites are machines that are launched into space and orbit around a body in space to do a specific purpose.
Artificial satellites are classified according to their function.

Examples of artificial satellites

1. **A communications satellite**

is an artificial satellite that relays and amplifies radio telecommunication signals via a transponder; it creates a communication channel between a source transmitter and a receiver at different locations on Earth. Communications satellites are used for television, telephone, radio, internet, and military applications. Many communications satellites are in geostationary orbit 22,300

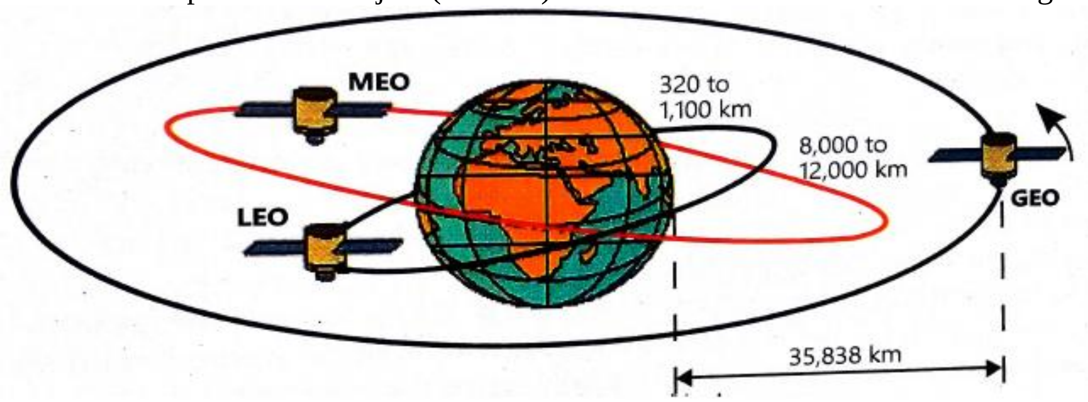
2. **Weather satellites**, such as GOES and Landsat, for monitoring the Earth's atmosphere and climate.

3. **Navigation satellites**, such as GPS and GLONASS, for providing location and timing information.

4. **Scientific satellites**, such as TERRIERS and Hubble Space Telescope, for conducting research and exploration.

SATELLITE ORBITS

Orbit is the curved path that an object (satellite) takes a round another satellite due to gravity.



Satellites orbiting the earth are placed in three orbits i.e

(i) **Low Earth Orbit (LEO)**

It is an orbit that is relatively close to the earth's surface, It is normally at an altitude of less than 1000 km but could be as **low** as 160 km above **Earth** above the earth's surface.

Satellites in this orbit are visible at a point on earth for a very short time , usually ranging from about 15 to 20 minutes.

(ii) **Medium, Earth Orbit (MEO)**

Is an Earth-centered orbit with an altitude above a low Earth orbit (LEO) and below a high Earth orbit (GEO).

It starts at roughly an altitude of 2,000 km (1,243 mi) above sea level and extends up to an altitude of 35,786 km (22,236 mi) above sea level and the time for one orbit is 12hours.

MEO is used for Global Navigation Satellite System spacecraft, such as GPS, GLONASS, Galileo, BeiDou.

It is also used by a variety of satellites with many different applications, including navigatiopn satelites like European Galileo System.

(iii) Geostationary Orbit (GEO)

This orbit also referred to as a **geosynchronous equatorial orbit** (**GEO**), is a circular geosynchronous orbit 35,786 km in altitude above Earth's equator, 42,164 km in radius from Earth's center, and following the direction of Earth's rotation.

An object in such an orbit has an orbital period equal to Earth's rotational period, one sidereal day, and so to ground observers it appears motionless, in a fixed position in the sky.

Communications satellites are often placed in a geostationary orbit so that Earth-based satellite antennas do not have to rotate to track them but can be pointed permanently at the position in the sky where the satellites are located. Weather satellites are also placed in this orbit for real-time monitoring and data collection, and navigation satellites to provide a known calibration point and enhance GPS accuracy.

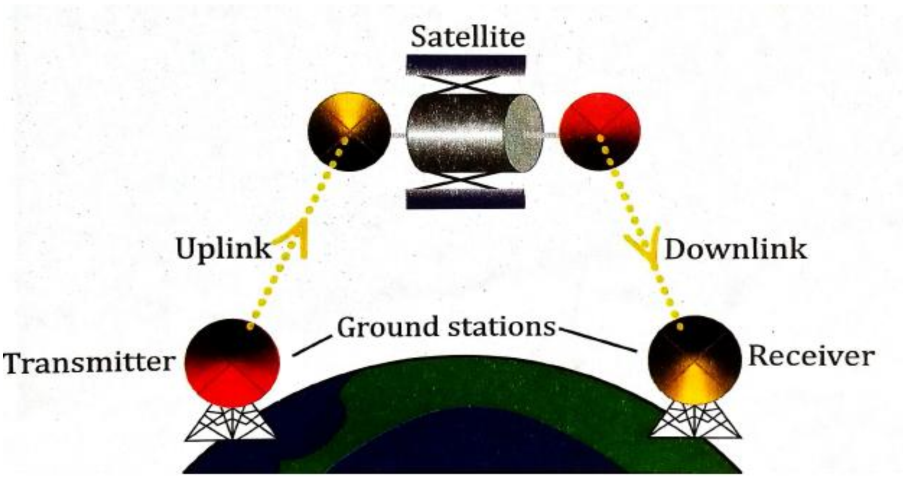
Geostationary satellites are launched via a temporary orbit, and placed in a slot above a particular point on the Earth's surface. The orbit requires some stationkeeping to keep its position, and modern retired satellites are placed in a higher graveyard orbit to avoid collisions

SATELLITE COMMUNICATION

Telecommunications use artificial satellite communication links to transmit information between various points on earth.

Artificial satellites orbiting the earth relay analog and digital signals that carry voices, videos and data from one location to different location worldwide.

How communication satellites work



It has two major components i.e
(i) **the space component**, which includes the satellite
(ii) **the ground components,** which includes the transmitter and the receiver

NB
(i) Uplink refers to sending of communication signals from the ground transmitter to the communication satellite.
(ii) Downlink refers to sending of reflected signals from the satellite to the ground receivers.

Global positioning system (GPS)
A global positioning system (GPS) is a network of satellites and receiving devices used to determine the location of something on Earth. Some GPS receivers are so accurate they can establish their location within 1 centimeter.
GPS receivers provide location in latitude, longitude, and altitude. They also provide the accurate time.
GPS is a system made up of three parts i.e satellite, ground stations and receivers.

satellites act like stars in constellations to help know where we are supposed to be at any given time.

The Hubble Space Telescope

The Hubble Space Telescope (often referred to as HST or Hubble) is a space telescope that was launched into low Earth orbit in 1990 and remains in operation.

It was not the first space telescope, but it is one of the largest and most versatile, renowned as a vital research tool and as a public relations boon for astronomy. The Hubble telescope is named after astronomer Edwin Hubble and is one of NASA's Great Observatories.

Hubble's orbit outside the distortion of Earth's atmosphere allows it to capture extremely high-resolution images with substantially lower background light than ground-based telescopes. It has recorded some of the most detailed visible light images, allowing a deep view into space.

Many Hubble observations have led to breakthroughs in astrophysics, such as determining the rate of expansion of the universe.

The International Space Station (ISS)

Is the largest structure the humans have ever put in space.

It is at an altitude of 400km, and travels at a speed of about 28000kmh^{-1} and orbits the earth every 92minutes.

It is maintained in low Earth orbit by a collaboration of five space agencies: NASA (United States), Roscosmos (Russia), JAXA (Japan), ESA (Europe), CSA (Canada), and their contractors.

Operationally the station is divided into two sections: the Russian Orbital Segment assembled by Roscosmos and the US Orbital Segment assembled by NASA, JAXA, ESA and CSA.

Its primary purpose is performing microgravity and space environment experiments.

In the 2010 United States National Space Policy, the ISS was given additional roles of serving commercial, diplomatic, and educational purposes.

Importance of space exploration

Scientists believe that there is likely to be life on other planets other than on earth , it is the only way to find out if it is true or not.

Following the launch of the Hubble Space Telescope, the telescope has revealed a number of stars with planets known as **exoplanets** which are in the habitable zone of their star.(a zone with similar conditions to those of earth). thus , there is possibility of life existing somewhere else in the universe.

Reading assignment

- ✓ Space exploration today
- ✓ Uganda's Space initiative