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MODULE 4.

OBJECTIVES (4.1)

- **On completion of this module you will:**
  - Be able to understand by definition what is meant by a universe, galaxy and solar system.
  - Know the position of the planets in the solar system in terms of their distance from the sun.
  - Be able to point out the constellations of Orion, Scorpio and the Southern Cross.
  - Be able to determine a southerly direction making use of the Southern Cross.
  - Be able to describe the phases of the moon as it is viewed from earth.
  - Know what is meant by an eclipse and how to differentiate between a lunar and solar eclipse in terms of positioning of the Sun, Earth and Moon.
  - Know how the ocean tides are affected by the moon and the sun.

THE FOUNDATIONS OF ASTRONOMY (4.1.1).

- **What is Astronomy?**

  - The branch of science which deals with celestial objects, space and the physical universe as a whole. Because a field guide operates in open-air situations, a basic knowledge of astronomy is essential. Sitting around a camp-fire at night, with a clear sky and star-filled heavens, talking about stars and planets becomes a natural and fascinating topic for discussion.
  - **What does a field guide need to know about the Universe? Less summarize:**
    a) Our own solar system with the sun & its 8 major planets, and the moon.
    b) Stars.
    c) Galaxies.
    d) Important elements of the night skies.

TO GET A BASIC UNDERSTANDING OF THE NIGHT SKIES AND OUR PLACE IN SPACE, IT IS IMPORTANT TO TAKE NOTE OF THE FOLLOWING: (4.1.2)

- The sun is the closest star to earth.
- It takes the light from the 8 minutes to reach us.
- It takes light just 1 second to travel 300 000 km (the same as travelling from Maun to Francistown and back 300 times in 1 second). This shows how far the sun is from earth.
- Stars are very, very hot balls of gas that have no solid ground.
- The temperature of stars can be over 1 million degrees Celsius.
- The earth moves at the speed of 140 000 km/h to orbit the sun for 365 days.
- Planets like earth, are made of solid or semi-solid material and move in circles called orbits around a star (they don`t just float around in space).
- Stars produce their own light (like a torch), whereas planets only reflect light from stars (like a mirror).
- A system where planets revolve around a star is called a **Solar System.**
- A star (not a planet) will always be at the center of the solar system.
- Our solar system has 8 planets that orbit our star (the sun).
- Planet earth (our home) is the 3rd planet from the sun.
  - **Only 4 planets can be seen from Earth with naked eye, namely:**
- **Jupiter** – the largest planet in our solar system.
- **Saturn** – has big rings that surround the planet.
- **Venus** – the closest planet to us and the brightest object in the night sky after the moon. This planet is often incorrectly called the Evening star.
- **Mars** – the red planet (there may be life on Mars).
  - The way to see if a bright object in the sky is a planet or a star is to look at it through binoculars. Planets will look a pale round disc whereas stars will always look like pinpricks of light (just as they do without binoculars), because they are so far away.
    NB// Do not look directly at our sun under any circumstances or you will be permanently blinded!!!

THE SOLAR SYSTEM (4.1.3).

- Our solar system consists of the sun, which is a star and 8 planets. The planets in order from the sun are: **Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. (Remember them as: My Very Ernest Mother Just Sent Us Nuts).** The inner planets (Mercury, Venus, Earth & Mars) are small and solid, with a rocky surface. The next four planets (Jupiter, Saturn, Uranus and Neptune) are large and gaseous. The odd one out is Pluto, which is again a small rocky dwarf planet. The International Astronomical Union (IAU) down-graded the status of Pluto to that of a dwarf planet because it does not meet the criteria to be considered a full-sized planet. Specifically, it hasn't cleared its orbital neighborhood; meaning it shares its orbital space with other Kuiper Belt objects. Pluto is located in the **Kuiper Belt**, a region of icy bodies beyond Neptune orbit.
- All our planets revolve around the sun. The apparent path that the sun follows through the sky is called the **ecliptic.** Since planets closely follow the ecliptic, seeking them thus entails finding the ecliptic and then searching for bodies that are obviously planets. While Venus and Jupiter are large, bright and very conspicuous. Mars is reddish and smaller. Jupiter`s moons can be observed through binoculars and Saturn has its characteristic rings. Because planets revolve around the sun, they are mobile, and thus continually change their position relative to other heavenly bodies, whereas stars will remain in fixed positions relative to one another.
- When observed through binoculars, planets also appear as rounded objects, emitting a constant source of light, and this differs from stars which will not appear as rounded objects, but tend to flicker. Remember, planets reflect light, while stars generate light.

CONSTELLATIONS (4.1.4).

- Groups of stars often look like pictures (or so some people think) and they have been given names internationally. Star pictures are called **Constellations.**
- The three most conspicuous and asked about constellations in the southern skies are as follows:

- **The Southern Cross** – also called **Crux.**
- **Orion** – the Hunter.
- **Scorpio –** the Scorpion; also called **Scorpius.**

➢ **Things to Remember:**

- The true South Pole in the sky is an imaginary point which the long axis of Southern Cross always point south.
- In the Northern Hemisphere there is a relatively bright star **Polaris** (The North Star) in the position of the northern celestial pole, permanently pointing the Northern Pole of the sky.
- Beta Centauri – this is the pointer star closest to the Southern Cross. It is the tenth brightest star in our night sky and estimated to be more than 10 000 times brighter than our sun. This star is 490 light years from earth.
- Alpha Centauri – this is the further pointer to the Southern Cross and is 4.3 light years away from the earth. This is the third brightest star in the earth`s night sky, but it is only relatively bright because it

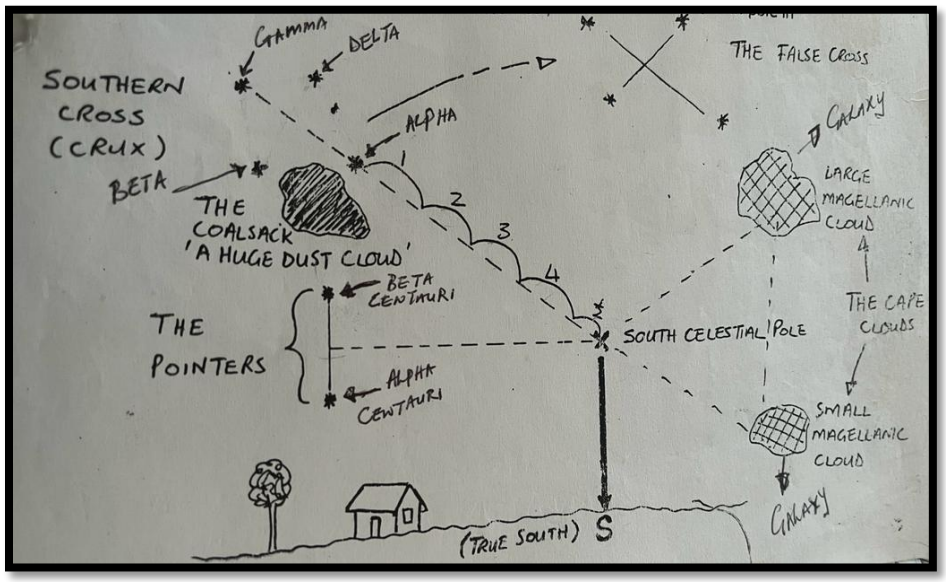
is so close to earth compared to other stars. Alpha Centauri is actually three stars orbiting each other, through binoculars you might see two of them.

- A Light Year – is the distance which light travels in a vacuum in one year. The speed of light is 300 000 km/second. It takes the sun`s rays about 8 minutes to travel from the sun to reach the earth.

➢ **Each Constellation with its Special Points will be dealt with Separately:**

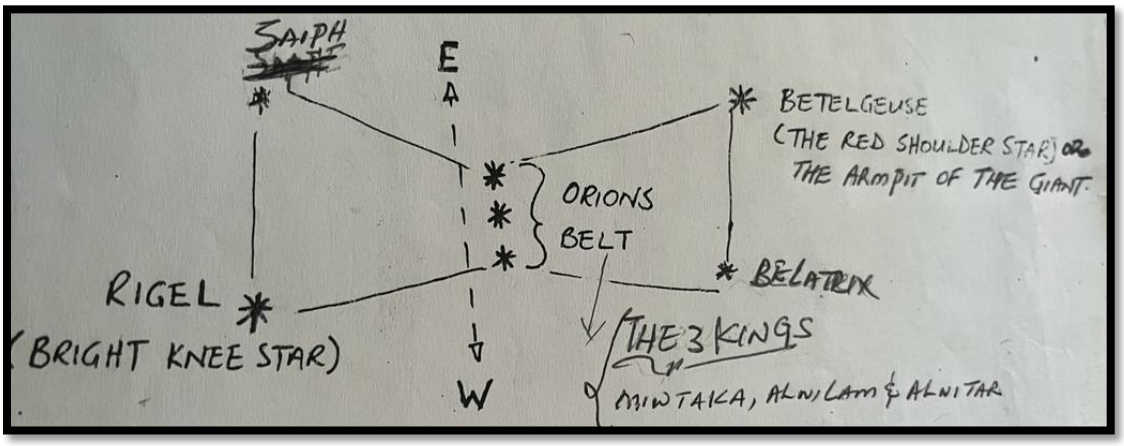
- **Southern Cross** – this constellation is very important for navigation because it is used to determine **True South.** Many visitors from the northern hemisphere (USA & Europe) are interested in seeing it because it is famous and it is not visible north of the equator and they have an equivalent beacon the North Star with which they want to compare.
- **How do you find south from the Southern Cross?**

- Method: Extend a line through the long axis of the cross out into space. Imagine a line running out into space from a point midway and at right angles to the 2 pointer stars. Where this 2 imaginary lines meet is the South Pole in the sky. Drop a line straight down to the horizon from this point to get **True South.**
- In the diagram below the main stars of the cross are depicted as are the stars and interesting points around, and connected to the cross. In addition, the two ways of determining the South Celestial Pole (south pole in the sky) and true south are shown below:



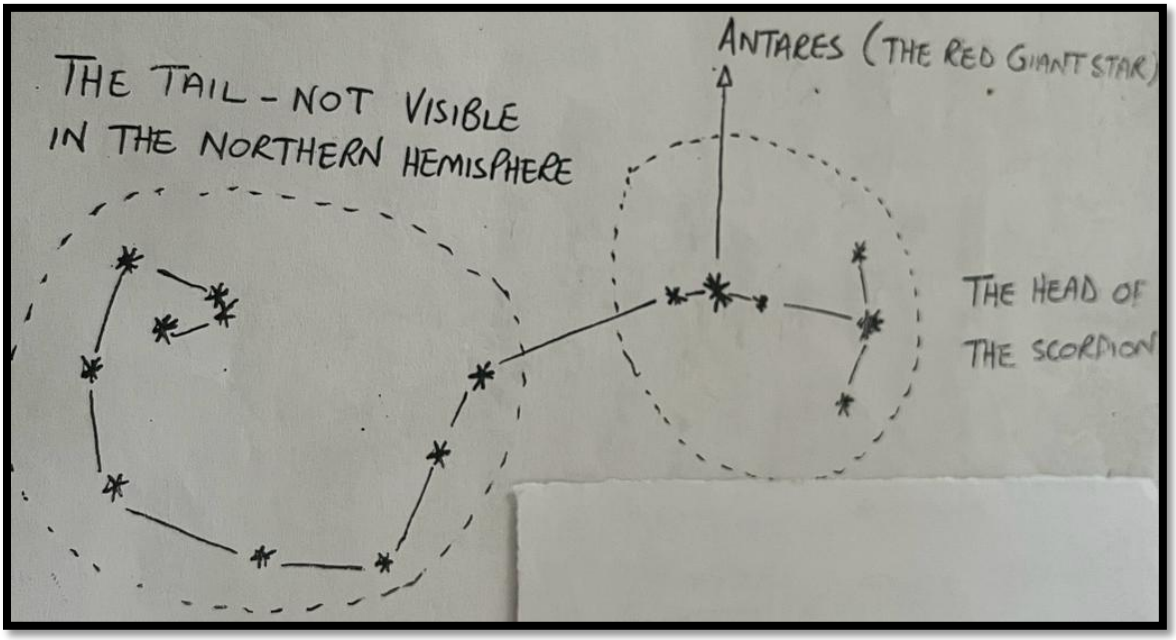
- **Orion** – this constellation depicts a hunter, named Orion. He is best seen in our summer months (not the hunting season) but he does hunt in the northern hemisphere winter skies where he was originally seen and named. The famous **Belt of Orion** comprises three stars in a row at his waist. These stars lie in a west/east direction – another way of finding direction at night.
- **Rigel** – the star at Orion's one knee is about 57 times brighter than the sun but very far away and so doesn`t appear so.
- **Betelgeuse** – which means "armpit" of the giant in Arabic is at Orion`s one shoulder. This star is red in color and is thousands of times bigger than our sun. The sun`s radius is about 696,340km.

- **The following diagram shows the main stars of Orion:**



- **Scorpio** – this constellation depicts the scorpion that supposedly almost killed Orion. Its beautiful curved tail is not visible in the northern hemisphere where they can only see the head and pincers. Antares (meaning almost Mars because it is red like planet Mars) is the big red star in the middle of the scorpion`s body and is almost size of our solar system.

- **Diagram of Scorpio:**



THE SUN (4.1.5).

- The sun is classed as a yellow dwarf with a diameter of about 1,392 530km and is a star in main sequence of the life cycle of stars. The radiation from the sun is emitted from its surface, known as the **photosphere**, where the temperature is 6 000 degrees Celsius. The real heat is generated deeper

inside the core of the sun, where nuclear reactions take place, fusing four hydrogen nuclei to form one nucleus helium. Because the light from the sun is so immensely bright, it must never be observed directly by looking at it. Safe observation can be made by indirect methods, such as projection boxes.

STARS.

- **Types of Stars and life cycle.**

- Stars are formed inside nebulae, which are clouds of gas and dust. As a nebulae collapse, matter becomes more densely packed and heats up; temperature will continue rising until the collapse has ceased and stability sets in. A number of proto-stars could be formed by this process.
- It is astounding to find that any star also goes through a life cycle. After the birth of the star, it enters what is known as the **Main Sequence** of its life cycle. During the stable period nuclear reactions are triggered and the star produces heat and light for approximately 10 000 years. After the main sequence, old age sets in and the star undergoes several changes depending on its mass.
- Stars with a mass greater than 3 solar masses will enter a shorter main sequence, where after they become red supergiant's and subsequently cause a supernova explosion. If its mass is smaller than 8 solar masses, it will end its life as a neutron star, a small body of immense density. Stars with a mass greater than 8 masses will collapse into a black hole.

- **Do Stars die?**

- Generally, the more massive the star the faster it burns up its fuel supply and the shorter its life. The most massive stars can burn out and explode in a supernova after only a few million years of fusion. A dead star becomes a black dwarf.

- **Colors of Stars.**

- The temperature of a star is related to its color. Our Sun is a yellow star with a surface temperature of around 6 000 degrees Celsius. While Sirius is a blue-white star of around 15 degrees Celsius, Betelgeuse is a red giant with a temperature of about 3 000degrees Celsius. Colder stars are red, with the color becoming yellow, white and bluish-white as stars become hotter.

- **Nebulae.**

- Nebulae are seen as faint misty patches in the sky. They are clouds of gas and dust. See the three types of nebulae below:
- **Emission Nebulae** – these contain hot and are lit up from the inside. The gas in the nebula glows in response to the emission of light from the stars contained inside.
- **Reflection Nebulae** – in this case light from the nearby stars is reflected by the cloud of gas and dust.
- **Dark Nebulae** – no stars are contained in these nebulae; therefore, no light is generated. They block out stars which lie behind them. The Coal Sack next to the Southern Cross is a dark nebula.

➢ **Comets, Meteors & Meteorites:**

- Comets (Latin – Stella Cometa, - Hairy Star), the head or nucleus of a comet usually consists of dust, frozen water vapor, glasses and solid matter; while the tail is made of billions of ice crystals and dust particles. The nucleus of a typical comet is usually about 10 km in diameter. The tail is blown away from the head by the so-called sun or solar wind, so it always points away from the sun. Solar wind is a thin stream of hot gasses continuously ejected from the outermost atmosphere (corona) of the

sun at a speed of 400km/second. As the comet approaches the sun, the solar heat evaporates the ice so that the comet brightens enormously.

- Comets are also part of our solar system, but their around the sun are much more elliptical than those of planets. Some may take hundreds of years to complete one orbit around the sun. Halley`s comet makes its appearance every 75 years.

➢ **Meteors & Meteorites:**

- Innumerable tiny particles are in orbit around the sun. Whenever one of these enters the atmosphere of the earth, a streak of light can be seen against the backdrop of the sky. The streak of light is caused by friction of the air in the atmosphere igniting the particle, and it burns out on its to the earth. These are commonly referred to as **Shooting Stars.** Some particles are large enough to reach the ground and they are known as Meteorites, and form a crater at the point of impact. At Grootfontein and Gibeon in Namibia several meteorites struck the earth, and can still be seen.

➢ **Galaxies:**

- A large collection of hundreds of millions stars and interstellar material, all gravitationally interacting and orbiting about a common Centre. All stars visible to unaided eye from earth belong to the earth`s galaxy, - **The Milky Way**. The sun with its associated planets is one star in this galaxy. The milky way was formed roughly 15 000 million years ago. The milky way rotates around a globular centre of our galaxy and will take about 250 million years to complete one rotation. The sun has only completed 20 revolutions since it was formed.
- Two types of galaxies exist, - namely: **Elliptical & Spiral galaxies**. Our milky way galaxy is a typical Spiral Galaxy, containing around 100 000 million stars. It is shaped like a discus, thicker in the middle than on the sides. Our galaxy is about 100 000 light years across, and 20 000 light years through its central bulge.
- Numerous other galaxies exist, some of which can be seen with naked eyes. The most prominent ones are called the **Small and Large magellanic Clouds,** which can be seen close to the South Celestial pole. They are about 170 000 light years from the sun.

THE MOON AND TIDAL WAVES (4.1.6).

- **The Moon:**

- The earth`s natural satellite, - the moon has a diameter of about 3 480km (2 160miles), and the moon is our closest neighbor. It orbits the earth in 27.3 days, which is precisely the time it takes to revolve its own axis. The result is that the same side of the moon is always orientated towards the earth. We can therefore only see one side of the moon from our position on the earth and it rises 45 minutes later each day. The surface of the moon consists of sand and rock, and is pock-marked with craters made by meteorites colliding with it.
- The mass of the moon is 81 times less than the mass of the earth. The pull of gravity at the moon`s surface is one-sixth that of the earth. The moon travels a distance of 384 403km around the earth at an

average speed of 3 700km (2 300miles). Although the moon appears bright to the eye, it reflects into space only 7% of the light that falls on it.

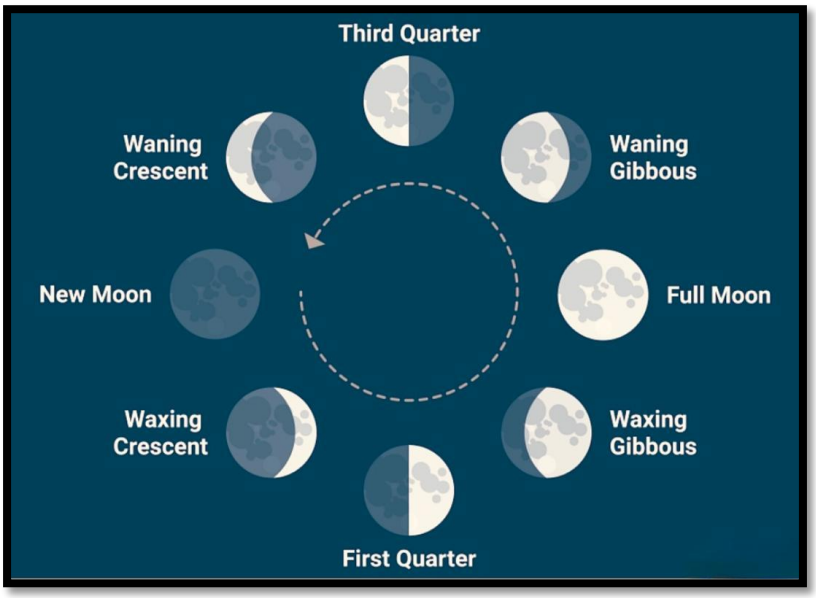
Is the Moon a planet too?

- No, the Moon is not a planet; it is the Earth`s natural satellite, which orbits our planet. Planets, by definition orbits a star (our Sun) and are massive enough to have cleared their orbital path of other debris. The Moon orbits Earth, not the Sun and is therefore classified as a moon or natural satellite.
- Lunar Scientist Barbara Cohen explains how our moon functions very much like a planet. The IAU definition also excludes moons from being planets but a celestial body that is not luminous on its own, but reflects the sunlight falling on it. But did you know our moon functions like a planet? Like earth, our moon has a crust, a mantle and a core. These interior layers we think are present on most planets, even if the crust is made of rock or ice. So, when moon formed, it formed like a planet.
- Another hallmark of planet is that they have active geology (formation of rocks). The big dark splotches you see on the moon`s surface are lava flows. Yes, there were active volcanoes on the moon. The Apollo samples contain small beads of volcanic glass that tell us there were giant fire-functions on the moon too. Though volcanic activity on the moon ended about 3 billion years ago. Also, the Apollo mission picked up thousands of moon quakes on the moon and this tells us that the moon is not geologically dead; it is still acting like a planet today.
- The moon is an astronomical body orbiting the earth as its only natural satellite. It orbits was centered on the earth, but not sun. It was now earth`s “Satelles”, meaning servant from which our word satellite drives.

Phases of the moon:

- The phases of the moon are created by the position of the moon relative to the earth and the sun. As moon moves along its orbit around the earth, it shows progressively different phases. Half the moon is always in sunlight, just as half of earth has day, while the other half has night. The phases of the moon depend on how much the sunlit half can be seen at any one time.
- In the phase called New Moon, the face is completely in shadow, the dark hemisphere of the moon faces the earth. The moon is not visible during this phase because it is in the same part of the sky with the sun. About a week later, the moon is in first quarter, resembling a luminous half circle. At first quarter moon, the angle between the sun, moon and earth is 90 degrees and we see one-half of the illuminated hemisphere and one-half of the dark hemisphere.
- Another week later, the full moon shows its fully lighted surface. When the moon stands opposite the sun in the sky, we see the fully illuminated hemisphere. Moonrise occurs at sunset during full moon. A week afterwards, in its last quarter, the moon appears as a half circle again, and the entire cycle is repeated each lunar month. The moon is full when it is further away from the sun than the earth, and it is new when it closer. The moon is said to be waning when it progresses from full to new and to waxing as it proceeds again to full moon.

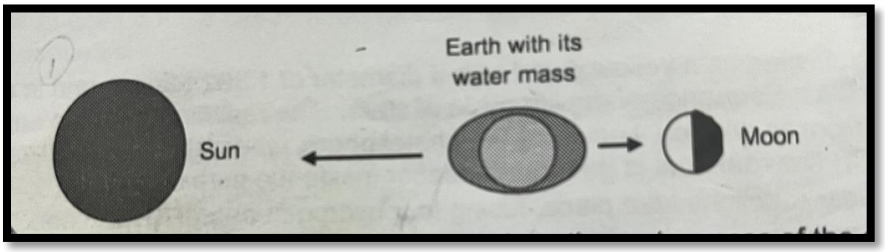
- **The Observer Standing on the Earth would see the following Phases of the Moon** (See diagram below)**:**



1. New Moon
2. Crescent Moon/Waxing Crescent (less than half moon).
3. First Quarter (half-moon).
4. Gibbous Moon/Waxing Gibbous (more than half moon).
5. Full Moon.
6. Gibbous Moon/Waning Moon.
7. Last Quarter.
8. Crescent Moon/Waning Crescent.

- **Tidal Regulations:**

- The moon and the sun are also the major role players in the **Tidal Regulations.** During full moon the sun and the moon both draw the water mass of the oceans towards them, creating a **Spring Tide**. The pull of the moon is greater than that of the sun. Its effect is called the **Lunar Tide,** while the effect of the sun is called the **Solar Tide**.
- **See diagram below:**

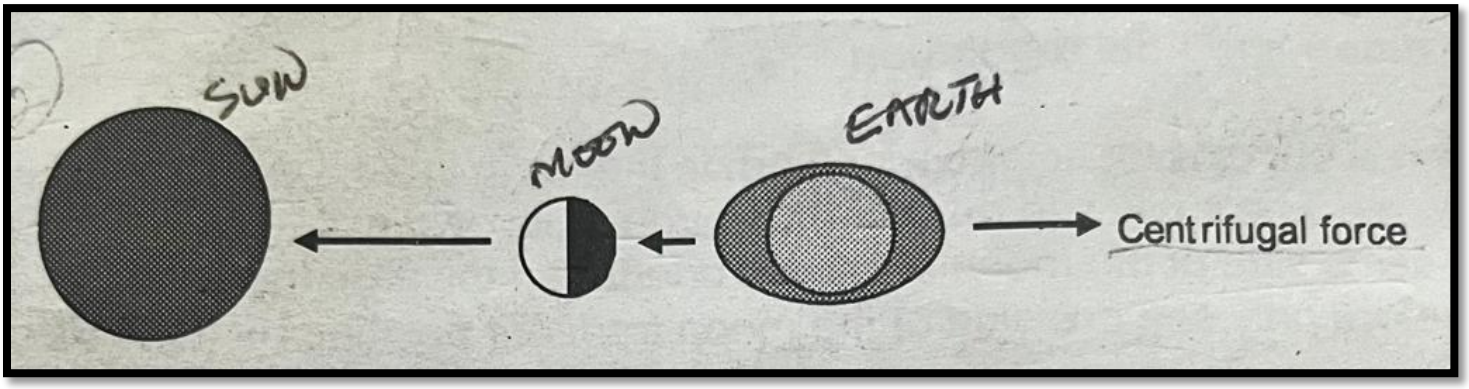


- **Tidal wave:**

- A tidal wave is a regularly reoccurring in shallow water wave caused by effects of the gravitational interactions between the sun, moon, & earth on the ocean. The term tidal wave is often used to refer to Tsunamis; however, this reference is incorrect as Tsunami is a series of waves caused by earth-quakes or undersea volcanic eruptions.

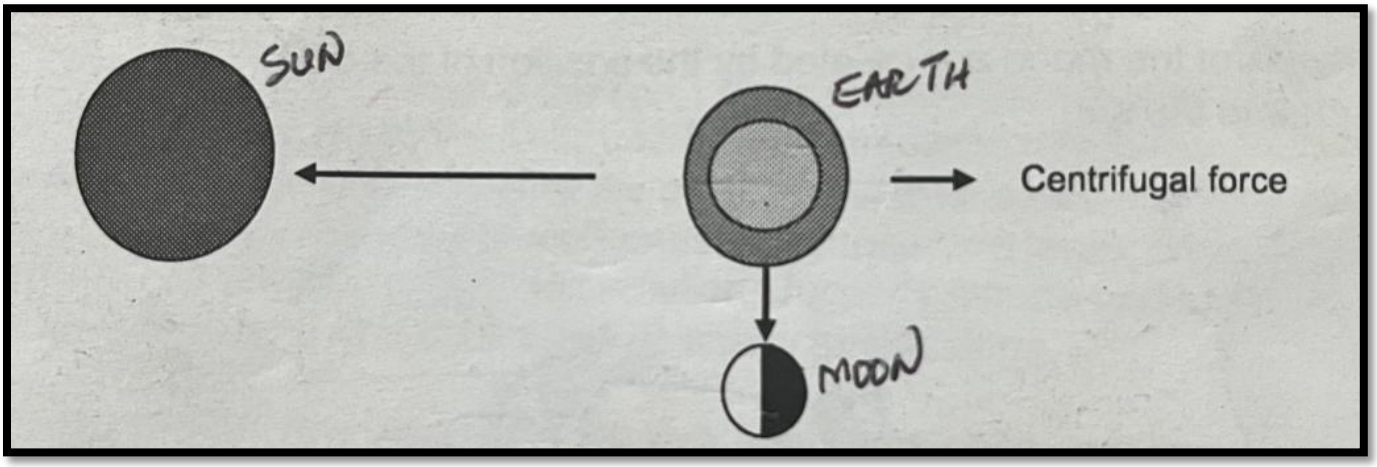
  - During new moon, the sun and the moon both pull together on the same side, creating an even stronger force and higher Spring Tide. Centrifugal Force creates a bulge in the ocean on the opposite side of the earth.

- **See diagram below:**



  - **Neap Tides** are caused during the first and last quarters of the moon, by the moon pulling at right angles to the force of the sun, thus reducing the directional pull. This results in low tidal variation, hence neap tides.

- **See diagram below:**

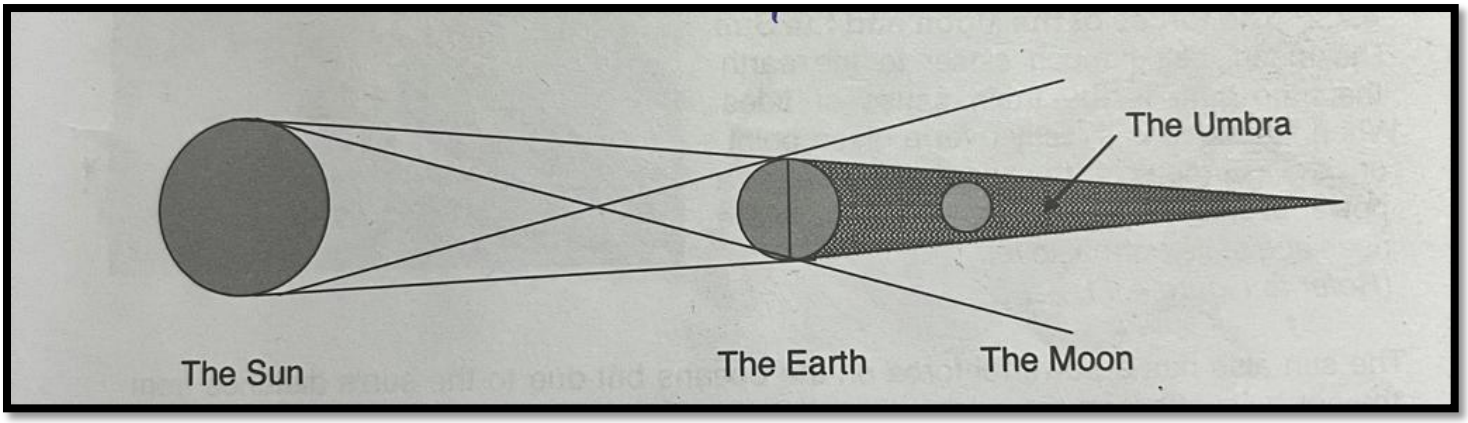


➢ **Eclipses:**

- The partial or complete hiding from view of an astronomical object, e.g., the sun or moon, when another astronomical object comes between it and the observer. This is, when the sun, earth and moon all move into a single straight line, an eclipse may occur. An eclipse can only occur at full moon or new moon. There are two basic types of eclipses that involve the earth:

1. A **Lunar Eclipse** (moon) – occurs when the earth is between the sun and the moon and its shadow (umbra) darkens the moon. The earth lit by the sun, casts a long conical shadow in space. At any point within that cone, the light of the sun is wholly obscured. This shadow cone is also called the **Umbra**. A total lunar eclipse occurs when the moon passes completely into the umbra. It moves directly through the centre and it is obscured for about 2 hours. This happens once every 18 years & 11.3 days.

- **See diagram below:**



2. **Solar Eclipse** (sun) – occurs when the moon is between the sun and the earth. A total solar eclipse is usually visible for about 3 minutes from a point in the center of the path of totality. In areas outside the band swept by the moon`s umbra but within the penumbra, the sun is only obscured, and a partial eclipse occurs.

- **See diagram below:**

