Grade 12 Earth and Space Science

SES4U

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Contents

Chapter 1

Unit 1: Astronomy

1.1 Episode 1: Standing up in the Milky Way

1. What is responsible for creating wind and keeping everything in the solar system in its clutches?
    - Gravity
2. What lies between Mars and Jupiter?
    - The asteroid belt
3. What had to be invented before we could discover Saturn and Neptune
    - The telescope
4. What is the name of the spacecraft that has travelled the farthest away from Earth?
    - Voyager 1
5. What is the Oort Cloud?
    - A cloud of billions of ice planetesimals surrounding the sun
6. What is the "addresss" of Earth in the cosmos?
    - Earth, Solar System, Orion Arm, Milky Way, Local Group, Virgo Supercluster, Laniakea Supercluster, Universe
7. Who was able to prove Giordano Bruno right 10 years after his death?
    - Galileo

1.2 Episode 4: A Spacetie Odyssey

1. Why do we see the Sun rise before it is over the horizon?
    - Because Earth's atmosphere refracts the Sun's image
2. How far away is Neptune from Earth (in light hours)?
    - 4.17 light hours
3. Using the idea of how fast light travels, how do scientists know our universe is older than 6500 years?
    - We know that there are objects farther than 6500 light year away from Earth.
4. Why does no one know what happened before the Big Bang?
    - No evidence survived
5. How long after the Big Bang did it take for stars to form?
    - Millions of years
6. What did Einstein call the "rules" that must be obeyed when traveling at high speeds?
    - Principle of relativity

1.3 Measuing the Universe

1.3.1 Some important constants

The speed of light c:

$$c = 3.00 * 10^8 \frac{m}{s}(3SD)$$

The distance of a light year:

$$\text{A light year} = 9.4608 * 10^{15} m(3SD)$$

The distance between Earth and Sun refers to the *Astronomicial Unit (AU)*

$$AU = 1.4958 * 10^{11} m(3SD)$$

One Parsec is 3.26 light years

$$\text{Parsec} = 3.0824 * 10^{16} m(3SD)$$

1.3.2 Unit Conversion

Example. If 1 inch = 2.54 cm, then 4.5 inches is equivalent to how many cm?

$$4.5 \text{ inch } * \frac{2.54cm}{1\ inch} = 11.43\ cm$$

$\therefore 1\ inch = 11.43cm$

1.3.3 Radar

This method is very accurate, it can measure the distance to the moon with an 3 cm precision!

Using radar in Astronomy has some limitations:

- Electromagnetic waves tend to *spread out with distance* causing weaker signals
- The furthest we can measure with this technique is with a few AUs

1.3.4 Parallex

Parallax refers to how closer objects appear to move compared to farther away objects. This is commonly used in video games to give the illusion of depth.

If we measure the angles that a star shifts using arcseconds, we arrive at how the persec is defined

$$d = \frac{1}{p} \tag{1.1}$$

d = distance in Parsec
p = parallax angle in arcseconds

*Remainder: The distance that can accurately be measured from the Earth using parallax is **100** parsecs.*

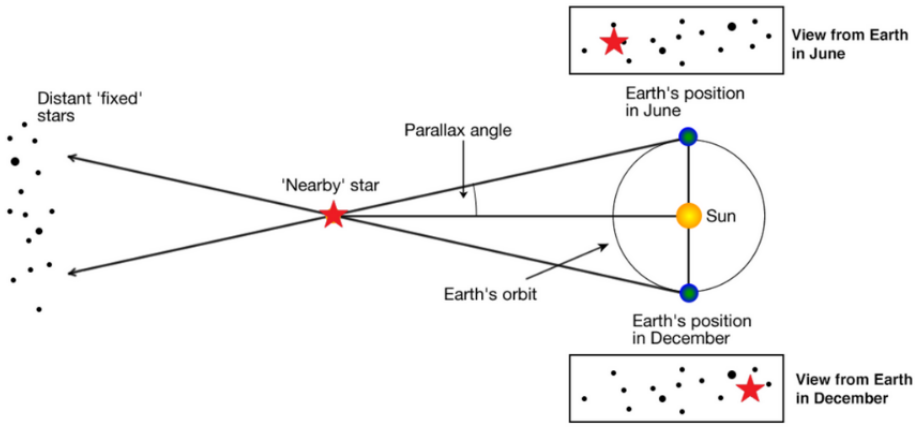


Figure 1.1: Parallax

1.4 Cepheid Variable Stars, Redshift and Hubble's Law

1.4.1 Apparent Magnitude and Absolute Magnitude

In this chapter, I will directly define few terms:

Definition 1.4.1. *Apparent magnitude = How bright an object appears from Earth's surface*

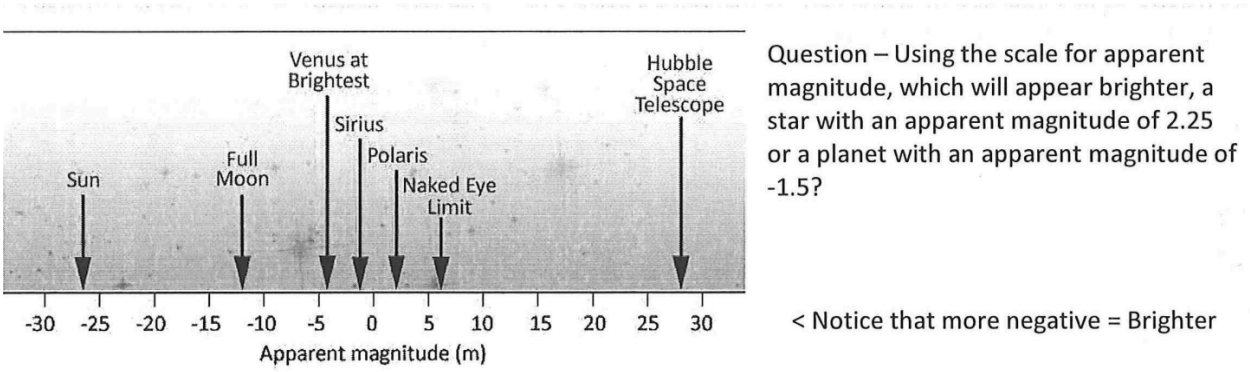


Figure 1.2: Apparent magnitude (m)

Definition 1.4.2. *Absolute Magnitude: How bright an object would appear if it was exactly 10 parsecs away*

1.4.2 Cepheid Variable stars

Definition 1.4.3. *Cepheids: Special stars that change how luminous they are at regular time intervals*

Cepheids "pulsate" with periods ranging from 1 to 100 days

1.4.3 Determining absolute magnitudes using Cepheld Variables

Absolute magnitudes of stars can be determined using cephelds. It was discovered that period of pulsation is directly related to the star's *lumonosity*

Definition 1.4.4. *lumonosity: The amount of energy emitted by a star each second.*

longer periods have higher luminosities

Cepheid Variables are also called "standard candles". Using this method, we can determine distances from 1000 parsecs up to 50 million parsecs

1.4.4 Hubble's Law

Hubble's Law states that:

The further away and object is, the faster moving away from us.

Hubble's law:

$$v = Hd$$

v = velocity of object in km/h
d = distance in megaparsecs (Mpc)
(1 Mpc = 1 million pc)
H = Hubble's constant

If the velocity of an object is known, we can then calculate their distance.

1.4.5 Redshift

Luckily, people can determine the the velocity of fast-moving objects with Redshift
Remember, Doppler Effect causes red shifts

1.4.6 Overall summary of this section

In this subsection, I will briefly summary what we learn for measuring the distance

To start off, we have radar:

Able to measure the distance to the moon with an 3 cm precision. **Distance:** few AUs

After Radar, we have **parallex**:

Using this formula:

$$d = \frac{1}{p}$$

p = parallax angle in parsec
d = distance in Parsec

We can measure objects 100 parsecs from our Earth

Then, we get **Cepheld Variables**:

We can use Cepheld's period of changes to determine lumonosity. Use period to determine the Absolute Magnitude, and use formula "Standard Candles" to determine distances.

This method can measure objects from 1000 parsecs to 50 million parsecs

Finally, we can use Redshift and Doppler Effect to determine the velocity of object:

Then use Hubble's Law:

$$v = Hd$$

v = the velocity of the object in km/h
H = Hubble constant
d = the distance of the object from our earth in Mpc

To determine further away distance of object

1.5 Cosmology

1.5.1 Some stupid theories

People used to think the sky was a giant dome and all the stars were spots on it

Study of Cosmology: *the study of the largest scale we know of: billions and billions of galaxies*

1.5.2 Is our Universe finite?

Olber's paradox: *If the universe is infinite, we would see light from every point in the sky. Then why is the sky dark at night?*

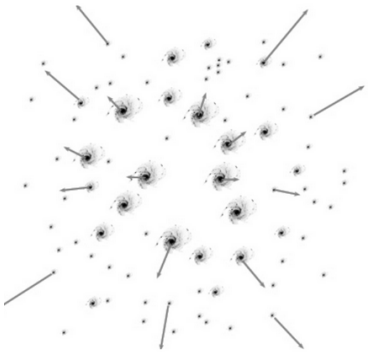
The fact that the sky is dark at night is a clue that the universe is not infinite

1.6 Developments in Cosmology

Theory of General relativity by Einsteinin 1916

1. Describe how space is curved by matters and energy
2. Predicted that the universe should expanded or contract, he added an extra term "Cosmological Constant", to make sure his equations were static
3. Later he said it was "the biggest blunder" of his life

Hubble discovers other galaxies and Hubble's Law in 1922 and 1929
He discovered:



! All galaxies were moving away from us

! All galaxies are Redshift

! Back to the past, the galaxies would all be closer together. There must be a time when all the galaxies overlap. This time happened 11.8 billions years ago. This is considered the age of the universe.

Alpher and Gamow calculate cosmic abundances in 1948

Alpher and Gamow assumed that the early universe was very hot and calculate the abundance of certain elements (other than hydrogen) during the early stages of the universe.

Helium - 25%
Deuterium - 0.001%
Lithium - 0.00000001%

This predictions were confirmed by observational evidences

The theory: *became known ass Big Bang Nuclear Synthesis*

Cosmic microwave background (CMB) was discovered in 1964

While trying building a telescope, Penzias and Wilson, accidentally discovered that there was a signal came from every direction in the sky. The signal has the same frequency as microwave and a temperature about 2.7 degrees kelvin.

The ssignal was latter interpreted to be the light from the early stages of universe.
It's the first light ever emitted from the Big Bang.

Singularity Theorems in 1968

Roger Penrose and Stephen Hawking proved mathematically that the universe must have started with a singularity

The means there was a beginning to the time itself

Chapter 2

Our Solar System

2.1 The Wonders of the Solar System

Q1

The further a planet is from the sun, the **slower** it's speed, and the **longer** one revolution around the Sun takes.

Q2

The type of celestial object appears to change its position amongst the stars from night to night is called **planet**

Q3

When the Earth "overtakes" Mars in orbit, Mars appears to move **backward** against the backgrounds of the stars.

Q4

Everything in our solar system was formed from a nebula, a giant **cloud** of gas and dust.

Q5

What type of event is thought to have disturbed the nebula and to have led to the formation of the solar system?

- A shock wave from a nearby supernova explosion.

Q7

The ring **nearest** Saturn are the fartest., just like planets orbiting the Sun.

Q8

Whater material makes up Saturn's rings? **Water ice**

2.2 Newton's Law of Gravitation

Remark. If you took or are taking SPH4U, the easiest way to revew this section is "Go check your physics note"

The equation for the Gravity:

$$F_g = \frac{GMm}{R^2} \tag{2.1}$$

The gravitational force acting between two objects is proportional to the **mass** of each object and inversely proportional to the **distance** betweem them squared"

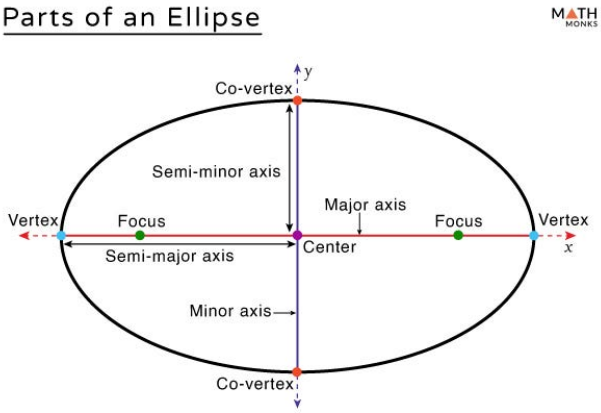
The alrger the mass, the more force is required to accelerate it.

"Accelerate" means to change **speed** or **direction**

When two objects are closer related in mass, they will orbit each other!

Try to do some physics questions before the unit test.

2.3 Kepler's Law of Planetory Motion



The sun is at one focus

There are two points in this diagram:

- The point closet to the Sun is called ***Perihelion***. *Peri* means *near* in the Latin.
- The point farthest from the Sun is called ***Aphelion***. *Ape* means *far* in the Latin.

2.3.1 Kepler's first law

Definition 2.3.1. *Planet's orbit in ellipses with the Sun at one focus*

Ellipses can be classified based on their **eccentricity**

$$e = \frac{c}{a}$$

e = Eccentricity
c = Distance from centre to a focus (in m(or Au))
a = Length of semi-major axis (in m(or Au))

The eccentricity of Earth's orbit is 0.02.

The most eccentric planetary orbit in our solar system is *Mercury*, which has a eccentricity of 0.2.

Coments tend to the the largest eccentricity very close to 1.

Here I want to discuss about the meaning of eccentricity:

- If an ellipse has an eccentricity of **0**, the object is orbit its sun in a **perfect circle**.
- If an ellipse has an eccentricity of **1**, the object is not in an **orbit**.

2.3.2 Kepler's second law

Definition 2.3.2. *A line segment joining a planet and the sun* ***sweeps out equal areas in equal amount time***

By the second law, we can make a conclusion. A planet moves fastest with it is at the **perihelion** and slowest when it is at the **aphelion**.

2.3.3 Kepler's Third Law

Definition 2.3.3. *The square of the orbital period of a planet directly proportional to the cube of the length of the semi-major axis of its orbit*

$$p^2 = a^3$$

p = orbital period in (years)
a = Length of semi-major axis (in Au)

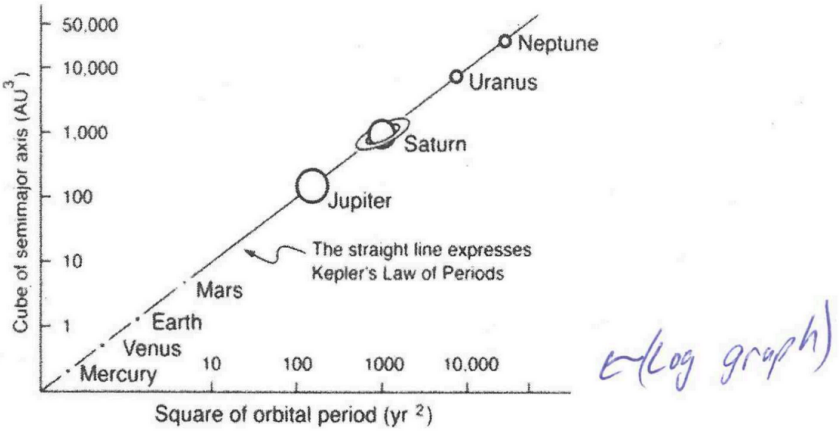


Figure 2.1: This is a log graph

The semi-major axis of an orbit is sometimes referred to as the **average** distance from the sun.

2.4 Sun-Earth-Moon System

2.4.1 Earth's Rotationsc

Foucault Pendulum

The direction that a pendulum swings appears to change as the Earth rotates under it.

One rotation of the earth takes **23hrs 56 minutes**

However, we define one day as the time it takes the **Sun** to return to the same position in the sky. This time takes **24 hrs**, longer than one rotation due to Earth's motion around the sun.

2.4.2 Earth's Orbit

The **Ecliptic plane** is an imaginary plane on which Earth's orbit lies. The Earth is tilted by 23.5 degree in relation to this plane. One orbit the Earth takes 365.25 day.

The tilt changes the Sun's position in hte sky throughout the year and accounts for the change of seasons.

The tropics is defined as the region between 23.5 degree north and 23.5 degree south latitude. Outside of the tropics, it is impossible for the sun to appear at exactly 90 degree.

2.4.3 Tide

The tides happen due to the moon's **gravational pull** on the Earth.

Spring tides happen when the Sun and moon align. The tides are **higher** than normal.

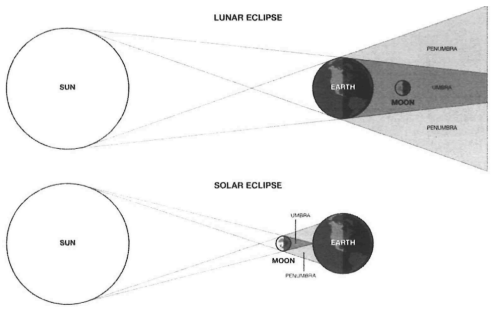
Neap tides happen when the Sun and moon are perpendicular. These tides are **lower** than normal.

One cycle of the tide happens every **12** cycles.

2.4.4 Eclipses

Definition 2.4.1. *Eclipses occur when one object passes through the **shadow** of another object.*

A full shadowm is called the **umbra** and a partial shadow is called the **penumbra**.



LUNAR ECLIPSE

The moon is in the **Earth's shadow**.

2.4.5 SOLAR ECLIPSE

The Earth is in the **Moon's shadow**.

2.5 The wonders of the Solar System: Episode: 5

Q1

- After he sees the tubeworms at the bottom of the ocean... The underwater city is one of the most bizarre environments on our planet. It's built around a **Hydrothermal bent**, a volcanic opening in the Earth's crust that pumps out clouds of sulphurous chemicals water heated to nearly 300 Celsius.

Q2

For life to exist, we only need three things:

- right **chemistry** set. Human body is made up with 40 elements, but actually 96% of human is only made of four of them, carbon, nitrogen, oxygen and hydrogen.
- We need a **power source**. We need a battery, something to make a flow of electrons that powers the processes of life. Most life on Earth uses the power of the sun.
- We need some kind of **medium** for life to play itself out in, for process to happen. On the Earth, the medium is **water**.

Q3

What is the **fundamental link** that is driving the search for life in our solar system?

- The link between liquid water and life.

Q4

For life to get a foothhold, you need more than that. You need areas of **standing water**.

Q7

Which of the Jupiter's moons has the greatest chance of finding life? **Europa**