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.

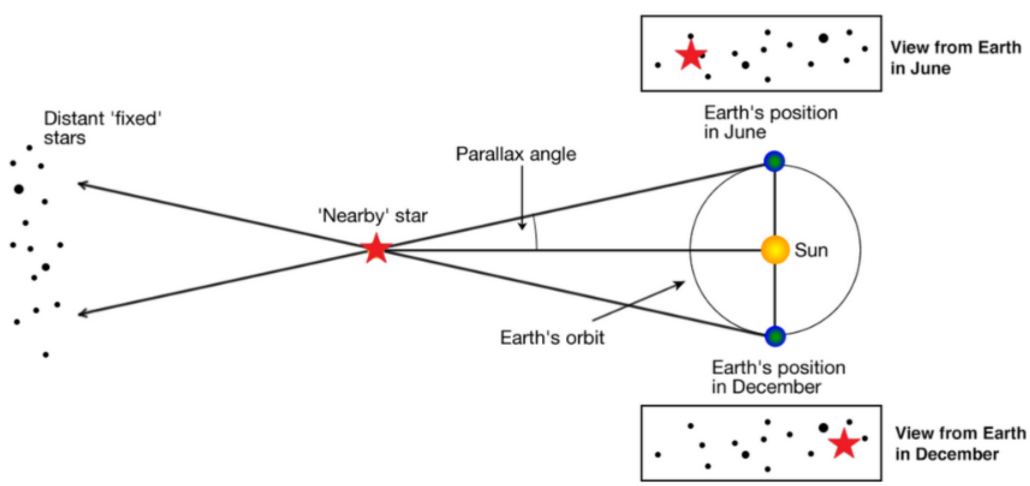


Figure 1.1: Parallax

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

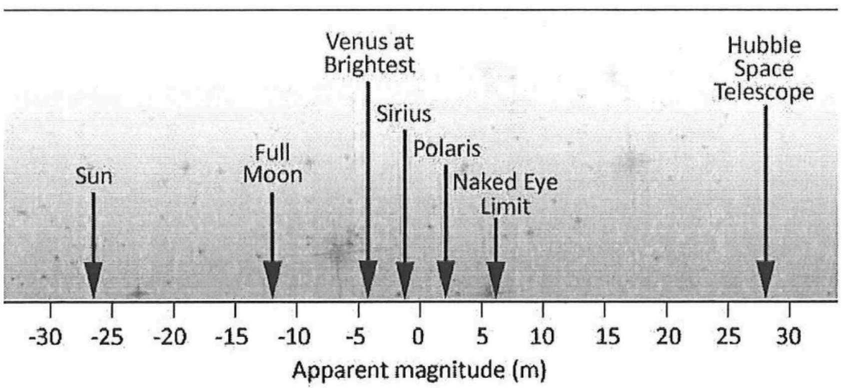
Remainder: The distance that can accurately be measured from the Earth using parallax is ***100*** *parsecs.*

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*



Question – Using the scale for apparent magnitude, which will appear brighter, a star with an apparent magnitude of 2.25 or a planet with an apparent magnitude of -1.5?

< Notice that more negative = Brighter

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?*

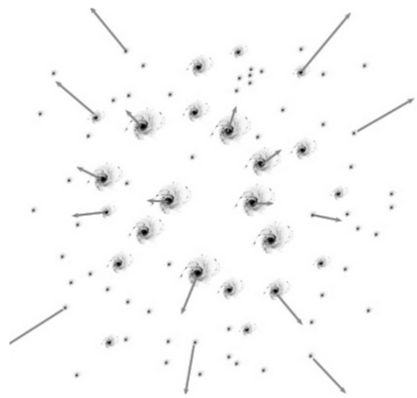
The fact that the sky is dark at night is a clue that the universe is not infinite

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"

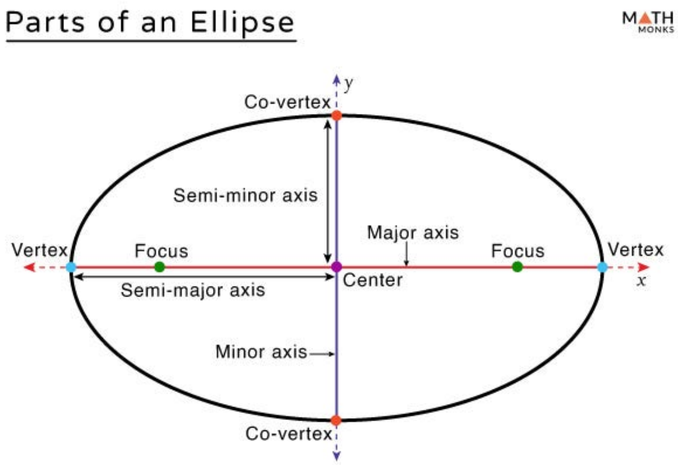
The alrger the mass, the more force is required to accelerate it.

"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***

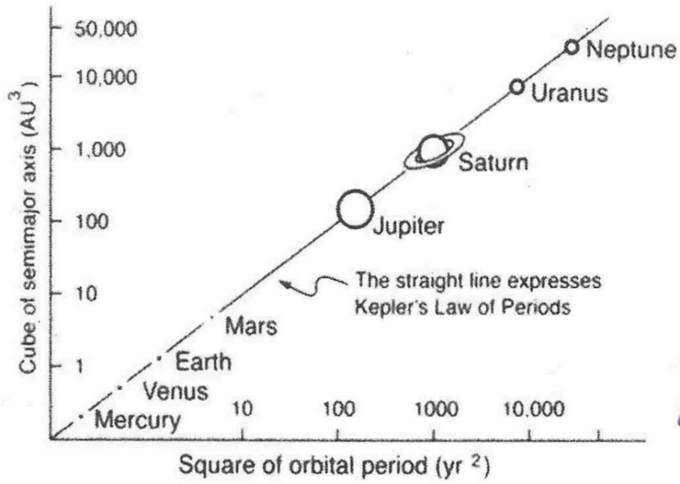
By the second law, we can make a conclusion. A planet moves fastest with it is at the **perihelion** and slowest when it is at the **aphelion**.

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)



←(Log graph)

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.

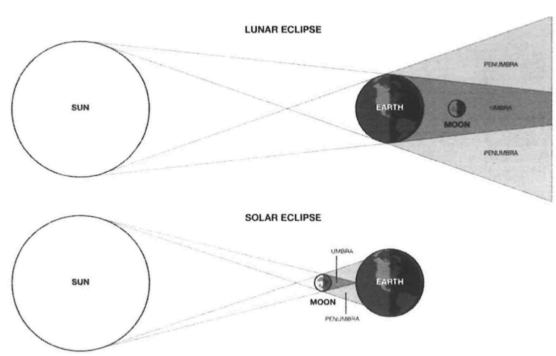
Neap tides happen when the Sun and moon are perpendicular. These tides are **lower** than normal.

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**

Chapter 3

Earth's Material & Geological Process

3.1 Documentary

1. The oldest objects in the solar system are **meteoroid**
2. The first rock to form on the Earth was **besalt**
3. Nature's physical building blocks are **minerals**
4. The foundation of the continents is what type of rock? **Granite**
5. One of the longest-lasting materials in nature is the gemstones **zincons**
6. The building blocks of life are **amino acids**
7. The first fossilized remnants of life found in the ancient rocks of Australia are called **stromatolites**
8. Photosynthesis led to the rise of the levels of **oxygen** gas
9. Today there are more than **5000** minerals on Earth
10. Trilobites are found as fossils today because of their **shells**

3.2 Rock cycle and Identification

3.2.1 Introduction to rock

Sedimentary Rock

Sedimentary Rock: Generally form from the compaction and cementation of sediments

Now here we have two different categories

Clastic: compacted sediments, classified by size. ex. Sandstone, conglomerate, siltstone

Organic or crystallite

- Evaporites
- Precipitates
- Biological matter ex. limestone

Metamorphic

Metamorphic Rock: Rocks that are changed as a result of intense heat and/or pressure

Contact metamorphism: Heat ex. schist, gneiss, marble

Regional metamorphism: Pressure

Igneous

Igneous Rock: Form from the cooling and solidification of lava or magma.

Intrusive: Formed from magma that cools and solidites underground

- Magma cools slowly
- Large crystal formed

Extrusive: Formed on the surface of Earth from lava.

- Lava cools quickly
- small or no crystal
- May be visiculars (Contains air bubbles)

3.3 Mineral Identification

Density

Steps to determine the density of a mineral:

1. Use a balance to weight its mass (in kg)
2. Fill a graduate cylinder with water, throw the mineral in to see how much the water rises in a graduate cylinder. (in mL)
3. Calculate $\frac{\text{mass}}{\text{volume}}$

How "light" or "heavy" an object is for this size.

Crystal

Minerals are amde of atoms in a repeating pattern and often from crystal

Possible options:

- Hexagon
- Cube
- Pyramid
- Rectangle

Luster

Luster is the way the mineral's surface reflect light.

Hardness

Hardness is a measure of how easily a mineral can be scratched. It is measured on a scale of 1 to 10 called Mohs scale.

Streak

The Streak is the color of a material's powder.

Remark. If the mineral is harder than the streak plate, it won't leave a streak.

Acid test

Some minerals cause hydrochloric acid to bubble and fizz.

3.4 Earthquakes

3.4.1 Terminology

Definition 3.4.1 (Focus). *Where the earthquake starts.*

Definition 3.4.2 (Epicentre). *The location on the surface directly above the surface.*

Definition 3.4.3 (Seismographs). *Instrument used to record the motion of the ground during an earthquake*

Definition 3.4.4 (Seismogram). *The graph which is recorded by the seismograph*

The tools can allow us to measure the intensity of earthquakes! The scale that is commonly used is called the Richter Scale

The scale involves measuring the amplitude of the largest wave at a specific distance from the epicentre

Remark. Ricter Scale is a quantity way to measure the magnitude of the earthquake. (An open-ended scale) Mercalli Scale is used to measure the intensity of the earthquake. (A closed scale)

3.4.2 Waves

These waves are ranked by their speed:

Body wave

Definition 3.4.5 (P-Wave). *Parallel to the direction of the wave (forward + backward)*

Definition 3.4.6 (S Wave). *Perpendicular to the direction of the wave (side by side)*

Surface wave

Definition 3.4.7 (Love wave). *Like water wave*

Definition 3.4.8 (raylight). *Rotate under ground*

3.5 Unit 3 - seminar Testable Question

3.5.1 Formation and Identification of minerals

Question 1

What is the definition of a mineral?

A solid inorganic substance that occurs naturally

Question 2

Explain streak, hardness and cleavage/fracture

- Streak: Used to determine the color of mineral in its powdered form, test by rubbing the mineral against a streak plate
- Hardness: use Moh's scale of hardness, compare hardness of an unknown minerals to the hardness of 10 known minerals and/or to the household objects
- Cleavage/fracture: different minerals break in different ways depending on their atomic structure.

3.5.2 Gemstones

Question 1

The disadvantage iof Chemical Vapor Deposition(CVD) diamonds?

Takes much more time to produce compared to a High Pressure Temperature (HPHT) diamonds

Questoin 2

Application of diamond:

- Nanodiamonds: The super small diamonds that aloow for many medical implication
- dental implants

Question 3

Blood diamonds:

- Mined in areas controlled by forces opposed to a country's government
- Sold to fund military action against that government
- Often extracted under conditions of forced labor

3.5.3 Marine geology - Deep sea sedimentation

What is a sedimentation?

- The settling of solid particles in fluid

What can sediments tell us about Earth's past climate?

- Past temperatures, climate and rainfall.

3.5.4 Investigate technologies to predict earthquakes, volcanoes and tsunamis

Which of the following gas are most often used when predicting volcanic eruptions?

- Sulfur Dioxide

Describe how the use of interferometry by Synthetic Aperture Radar (SAR) satelliets might help to detect earthquakes?

1. Interferometry takes two or more images of the same area of the Earth at different times
2. Analyzed for changes between images
3. Changes could be signs of an earthquakes

3.5.5 Investigate the Canadian Lithoprobe Project and how it enhanced our understanding of the Earth's interior.

What was the main goal of the Canadian Lithprobe project:

- To map the deep structure of Earth's crust using seismic technology

Which technology was most important in helping Lithprobe "see" inside of the Earth?

- Seismic reflection and refraction surveys

The Canadian Lithoprobe Project helped scientists to better understand <u>Ancient Continental Collisions</u>

3.5.6 Investigate the structural engineering techniques and advance technology used to build earthquake-resistant infrastructure

1

What materials are base isolators typicall made out of?

- Lead, rubber, steel

2

How to turned mass dampers protect a building during an earthquake?

- It opposes the motion of the structure by swinging in the opposite direction

3

Why is steel typically added to concrete when structures are constructed?

- Concrete in strong under compression but weak under tension
- Adding steel allows it to bend without breaking during earthquakes

3.5.7 How have Earthquakes and volcanoes affected the development of cities?

According to the case study, what was the primary phenomenon that caused extensive damage in Christchurch, New Zealand, other than the seismic waves?

- Soil liquefaction

2

Explain the fundamental difference between "brittle failure" and "ductile design" in building materials when faced with seismic stress.

- Brittle failure occurs when rigid materials shatter or crack suddenly under stress
- Ductile design allows materials to flex and bend without breaking

3

For the “Earthquake Early Warning” (EEW) system, explain how it works, and a key limitation:

- Its primary function is to detect the fast P-waves to provide a warning to the public before the damaging S-waves arrive
- It provides a relatively short warning

3.5.8 Minerals and human health

What is hard water?

- Water containing high concentrations of dissolved minerals

Where does it come from:

- When rainwater, which is slightly acidic, filters through the ground, it dissolves minerals, which then goes into the groundwater

3.5.9 Critical minerals

List the four most important sectors that require critical minerals?

- Electronics, renewable energy, medical devices, military defense

Define ”critical Mineral”

- Elements and compounds that are essential for modern technologies
- Face a high risk of supply chain destruption due to factors like rarity, geographical concentration, or geopolitical issues

Production of critical minerals

- Upstream: extraction
- Midstream: Processing and refining
- Downstream: recycling

3.5.10 The geological composition of famous buildings and landmarks

What makes ancient Roman concrete special?

- Primary binding agent in the concrete was a mixture of lime and volcanci ash, which helped to give it self-healing abilities

---

Explain how and why limestone and granite was used in the Pyramids:

- Limestone
-
  - Makes up most of the outer layer to make the pyramid smooth and shiny
  - Relatively easy to quarry and shape
- granite
-
  - Makes up the internal structural elements
  - Used for its strength and status
  - More difficult to work with

3.5.11 Mining technologies

Two important methods of surface mining extraction

- Open pit mining: a mine is dig out on the ground's surface
- Quarrying: A type of open pit mine that primarily extract rocks

Sub-surface mining extraction method:

- Block Caving
- Ore deposit is undercut at different weak points
- The ore body then collapses under its own gravity into drawpoints where minerals are collected and transported

3.5.12 Oil and natural gas

Core mechanism of a seismic survey?

- Emitting vibrations into the ground and recording the reflected waves from rock layers

Key process that controls whether hydrocarbons become oil or natural gas?

- Kerogen breaks down into oil at lower temperatures and shallow depths
- Natural gas is produced at much higher temperature and deeper depth

temperature-controlled distillation

1. Crude oil is heated until it vaporizes
2. The hot vapor enters a distillation tower, where the bottom is very hot and the top is cooler
3. Light hydrocarbons rise higher in the twer, heavier hydrocarbons stay lower

3.5.13 Asteroid mining

Karman+'s long term plan after they mine materials from asteroids?

- They want to build and sustain things in space, where things like manufacturing and fuel production happens there.

What is a carbonaceous asteroid?

- The asteroid is rich in hydrated clays

How do catalytic converters in vehicles help with air pollution caused by vehicles?

- They reduce pollutants such as carbon monoxide and hydrocarbons by converting them into less hamful gases

3.5.14 Weathering and Erosion

How water can cause both mechancial and chemical weathering in the same rock at the same time.

- Mechancial - Water can physically break rock by freezing and expanding in cracks
- Chemical - Water can react with minerals and/or dissolve them

If there are two of the same type and size of rock, why does the rock with more surface area experience faster weathering?

- Because more of the rock is exposed to weathering agents like water, air and acids