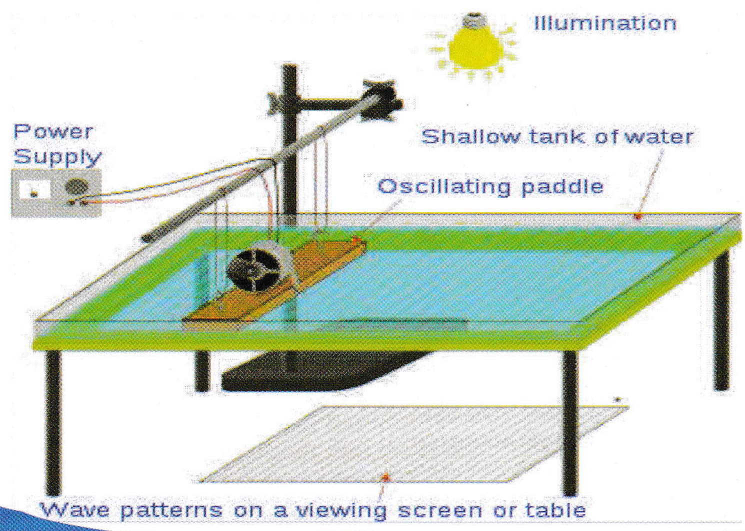
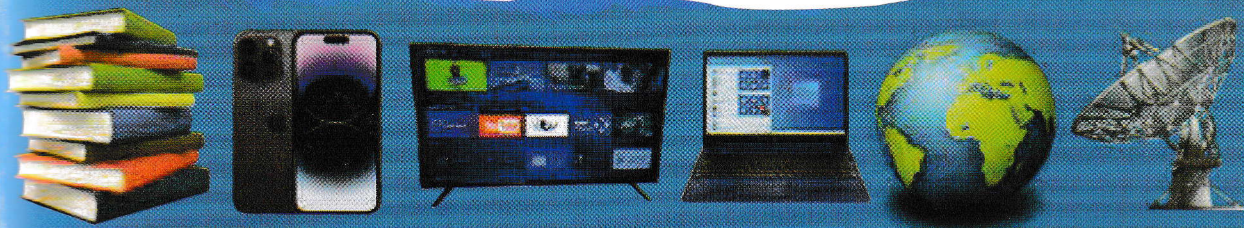
Module 4

PHYSICS

Stage II

Analysing Effects and Applications of Waves in Daily Life





Institute of Adult Education
Alternative Secondary Education Pathway

PHYSICS

STAGE II

Analysing Effects and Application of Waves in Daily Life

Institute of Adult Education
Alternative Secondary Education Pathway

Copyright

ISBN 978-9976-88-186-8

Institute of Adult Education
Alternative Secondary Education Pathway
P. O. Box 20679,
Bibi Titi Mohamed Street,
Dar es Salaam,
Tanzania

Tel: +255 22 2150838
Email: info@iae.ac.tz
Website: www.iae.ac.tz

Acknowledgement

This module is a product of the Institute of Adult Education (IAE) produced in 2021 for Alternative Education Pathway (AEP), and reflecting the current syllabi of 2010 secondary education in Tanzania, as recommended by Tanzania Institute of Education.

This module is indeed an outcome of concerted efforts of various experts from within and outside the IAE. The IAE profoundly acknowledges the valuable inputs of all stakeholders for devoting their time and resources to ensure effective preparation of this module.

IAE extends sincere gratitude to individuals who contributed in one way or another in accomplishing this task. The following staff from within and outside the IAE deserve special appreciation and recognition for their insightful contribution in writing and reviewing this module:

Baraka S. Kionywaki	Institute of Adult Education (Coordinator)
Amina M. Abubakar	Institute of Adult Education (Assistant Coordinator)
Mr. Anael Kitomari:	Dar es Salaam Secondary School (Writer)
Ms. Janeth Bahari	Kilakala Secondary School (Reviewer)
Mr. Japhary Ongera	Ruvu Secondary School (Reviewer)
Mr. Nasibu Mussa	Tunduru Secondary School (Reviewer)
Mr. Eric E. Samba	Institute of Adult Education (Editor)
Ms. Joyce Kimario	Institute of Adult Education (Secretary)
Ms. Theresia Mchilo	Institute of Adult Education (Secretary)

....

Dr. Michael W. Ng'umbi

Director

Institute of Adult Education

Contents

About this module

This Module has been produced by the Institute of Adult Education. All Modules produced by the Institute of Adult Education are structured in the same way as outlined below.

Module Structure

The Module Overview

The module overview gives you a general introduction to the module. Information contained in the module overview will help you to determine:

- If the module is suitable for you,
- What you already know,
- What you can expect from the module, and
- How much time you will need to invest to complete the module.

The overview also provides guidance on:

- Study skills,
- Where to get help,
- Module assignments and assessments,
- Activity icons, and
- Units.

We strongly recommend that. you read the overview *carefully* before starting your study.

The Module Content

The module is broken down into units. Each unit comprises:

- An introduction to the unit content,

- Unit outcomes,
- Core content of the unit with a variety of learning activities,
- A unit reflection,
- Assessments as applicable, and answers to assessments as applicable.

Resources

For those interested in learning more on this subject, we provide you with a list of additional resources at the end of this module 4; the resources are books, articles or web sites.

Your Comments

After completing this Module, we would appreciate if you take a few moments to give us your feedback on any aspect of this Module. Your feedback can include comments on:

- Module content and structure,
- Module reading materials and resources,
- Module assignments,
- Module assessments, and
- Module support (assigned tutors, technical help, etc.)

Your constructive feedback will help us to improve and enhance this module.

Module Overview

Welcome to this Module

Dear learner, welcome to Module 4 of Physics subject. This Module is about Analyzing Effects and Applications of Waves in Daily Life. Physics as among of science subjects is of very important in our life as we are living in the century of science and technology and introduction of science in our daily has transformed our lives. Physics governs our everyday lives and is involved in a number of activities we perform and things we use in our daily life. We discuss how physics plays its part in making analysis of effects of waves and how Physics playing its part to explore the applications of waves in our everyday life activities.

This Module consists of four units: In Unit 1 about Waves; Unit 2 about Electromagnetism; Unit 3 about Elementary Astronomy and Unit 4 explore about Geophysics.

After completing every unit, make sure that you pose and do the unit reflection. Make sure you keep all activities and unit reflection answers and other difficulties or interesting of yours in your portfolio. This will help you to check whether you have understood the unit or not. At the same time they prepare you step by step for the unit assignment. They are only important for you and therefore do not send them to your tutor.

I hope you will enjoy studying this Module.

General Competence

Upon completion of this Module, you should be able to apply concepts of waves, electromagnetism, elementary astronomy and geophysics in daily life.

Study skills

As an adult learner, your approach to learning is different from the approach you used during your school days. You choose what you want to study, have professional and/or personal motivation for doing so and fit your study activities around other professional or domestic responsibilities.

Essentially, you take control of your learning environment. As a consequence, you need to consider performance issues related to time management, goal setting, stress management, etc. Perhaps you also need to acquaint yourself in areas such as essay planning, coping with exams and using the web as a learning resource.

Your most significant considerations are *time* and *space* i.e. the time you dedicate to your learning and the environment in which you engage in that learning.

We recommend that, you take time nowbefore starting your self-study by familiarizing yourself with these issues. There are a number of excellent resources on the web. A few suggested links are:

http://www.how-to-study.com/

The "How to study" web site is dedicated to study skills resources. You will find links to study preparation (a list of nine essentials for a good study place), taking notes, strategies for reading text books, using reference sources, test anxiety.

http://www.ucc.vt.edu/stdysk/stdyhlp.html

This is the web site of the Virginia Tech, Division of Student Affairs. You will find links to time scheduling (including a "where does time go?" link), a study skill checklist, basic concentration techniques, control of the study environment, note taking, how to read essays for analysis, memory skills ("remembering").

http://www.howtostudy.org/resources.php

Another "How to study" web site with useful links to time management, efficient reading, questioning/listening/observing skills, getting the most out of doing ("hands-on" learning), memory building, tips for staying motivated, developing a learning plan.

The above links are our suggestions to start you on your way. At the time of writing the web links were active. If you want to look for more go to www.google.com and type "self-study basics", "self-study tips", "self-study skills" or similar.

Need Help?

Dear learner, in the course of your study, you may need help in various issues such as the location and how to get support from resource centres, clarification of various issues pertaining to your study materials (modules) and so on. If this happens, you are advised to ask for the help from your centre coordinator or facilitator. You can also visit the website of the Institute of Adult Education which is www.iae.ac.tz. And, you can call no +255 22 2150836 and ask for help.

Module Assessment

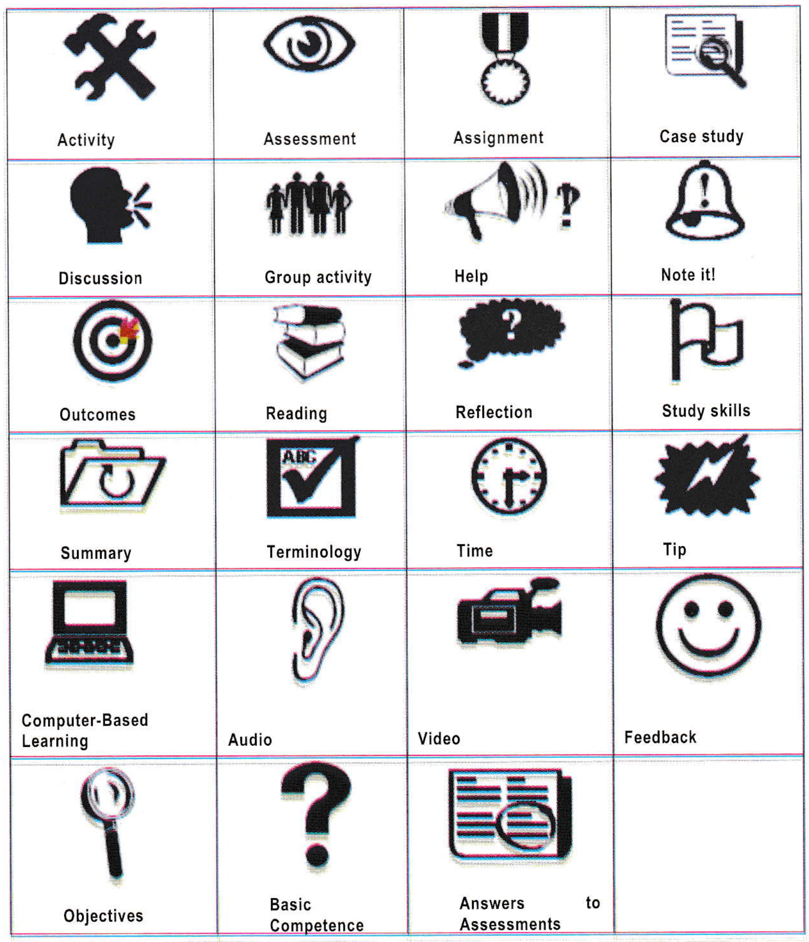
After each unit, you are required to attempt one unit assignment. These are not meant for submission rather for reflection on what you have learned in the whole module. You are also given tests and assignments for submission by being guided by your module facilitator. You will also sit for mock examinations to accomplish your continuous assessment.

Getting Around this module

Margin Icons

While working through this module you notice the frequent use of margin icons. These icons serve to "signpost" a particular piece of text, a new task or change in activity. They have been included to help you find your way around this module.

A complete icon set is shown below. We suggest that you familiarize yourself with the icons and their meaning before starting your study.



Unit 1

Analysing Waves

Introduction

Dear learner, welcome to this first Unit of Module four which is about Analysis of Waves. In this Unit, you learn about introduction to waves, behaviours of waves, propagation of waves, sound waves, music sound, electromagnetic spectrum and applications of electromagnetic waves in daily life. This unit helps you to understand ways of producing waves, for example, by dropping an object (stone) on a still pond of water, moving up and down continuously a free end of a rope tied to a tree, turning a toothed wheel while holding a card against the moving teeth, connecting an electric bell to the source of power and holding a steel wire tightly and pluck it between the bridge and many more with notable applications of waves in our real life.

Learning Outcomes

Upon completion of this Unit, you will be able to:

- explain the concept of wave, terms applied in wave and identify types of wave;
- explain different behaviors of waves and its application in daily life;
- describe the propagation of Mechanical and Electromagnetic wave;
- determine the relationship between frequencies, speed and wave length of a wave and determine the refractive index of a medium;
- identify sources of sound waves and explain the concept of audibility range;
- describe the insight of hearing, explain the concept of echo and reverberation and determine speed of sound in air;
- explain the concept of a musical sound and identify factors affecting loudness, pitch and quality of a musical sound;
- Identify the different musical instruments and explain the terms stationary waves, nodes and antinodes;
- determine the frequency of a musical note and distinguish between the fundamental note and overtones;
- explain the concept of resonance as applied to sound and construct a simple musical instrument;
- explain the concept of electromagnetic spectrum and identify the main bands of the electromagnetic spectrum;
- detect infrared, visible and ultraviolet rays and identify applications of electromagnetic waves in daily life and their importance in agriculture and climate.

Introduction to Waves

Dear learner, if you drop a stone at the centre of calm water pond, some disturbance will occur in water. The disturbance in form of ripples will spread outward in a circular pattern as seen in Figure 1.1

Figure 1.1: Water ripples

If you observe closely you will notice that water does not move. Instead, only disturbance is observed. This kind of disturbance is called a *wave.*

***A wave** is a periodic disturbance that transfers energy from one place to another.*

OR

A wave is the progressive disturbance propagated from a point in a medium (matter) on space without the movement of the points themselves.

For example, you hear sound because a wave (disturbance) travels from the source to the listener through the surrounding air.

Examples of waves include light, sound and water waves.

Important Terminologies Used in Waves

Dear learner, the following are some common terms used with waves.

1. Period

This is the time taken for the wave to repeat itself so as to make one complete cycle. It is represented by the letter T and the SI unit is second (s).

2. Amplitude

This is the maximum displacement of the wave from the equilibrium position. It is represented by the letter A and the SI unit is metre (m).

3. Crest and Trough

The crest is the point of maximum positive displacement of the wave from the equilibrium position. The trough is the point of maximum negative displacement of the wave from the equilibrium position as seen in Figure 1.2.

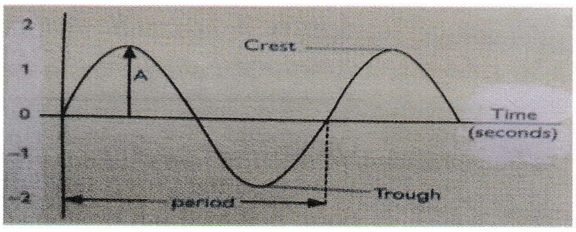


Figure 1.2: Features of a wave

4. Wave length

This is the distance between two successive or adjacent points such as crest to crest or trough to trough. It is the distance that the wave travels in one complete cycle. The wavelength is represented by the Greek letter Lamda (λ). The SI unit of wave length is metre (m). Wave length is as shown in Figure 1.3.

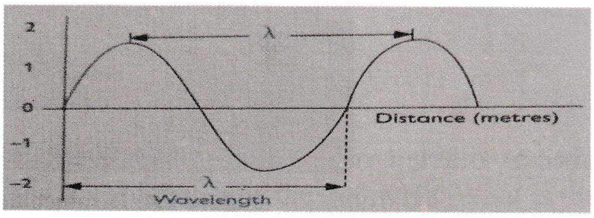


Figure 1.3: Wavelength of a wave

1. *Frequency*

This is the number of oscillations or pulses per unit time. It is represented by the letter f. The period and frequency of a wave are related by the equation $f = \frac{1}{T}$. Since time is measured in seconds, the unit of frequency is per second (s^{-1}). The SI unit of frequency is hertz (Hz). i.e. $1Hz = 1s^{-1}$.

2. *Wave velocity*

Wave velocity is the speed at which the wave moves through a medium or is the displacement of the wave per unit time.

Dear learner, there is the relationship between frequency, velocity and wavelength of a wave. This relation is explained below.

Since the wavelength is the distance the wave travels in one cycle and the period is the time the wave takes to complete one cycle, velocity v is given by:

$V = \frac{\lambda}{T} = \lambda \times \left(\frac{f}{1}\right) = \lambda f$ Since $T = \frac{1}{f}$

Now $V = \lambda f$

The above formula is called wave equation.

Dear learner, let us do the following examples by using the above formula.

Example 1

The graph in Figure 1.4 shows the displacement of a wave with time.

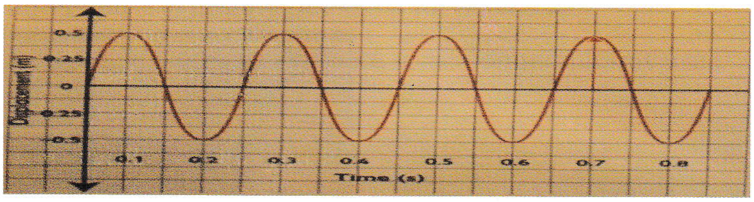


Figure 1.4: Displacement of a wave with time

Determine the amplitude, period and frequency of a wave.

Solution;

Data given;

The amplitude of the wave is 0.5m.

The period of the wave (T) = 0.2 seconds.

The frequency (f) = $f = \frac{1}{T} = \frac{1}{0.2\,s} = 5Hz$

Example 2

Calculate the velocity of the wave whose wavelength is $1.7 \times 10^{-2}\,m$ and frequency is $2x10^{14}$ Hz

Solution

Data given

Wave length (λ) = $1.7x10^{-2}$ m

Frequency (f) = $2x10^{14}$ Hz

Velocity (V) is calculated as follows:

$V = f\lambda = 2 \times 10^{14}\,Hz \times 1.7 \times 10^{-2}\,m = 3.4 \times 10^{12}\,m/s$

Example 3

Find the wavelength of sound wave whose frequency is 550 Hz and speed of 330 m/s.

Solution

Data given

Frequency (f) = 550 Hz

Speed (v) = 330 m/s

Wave length (λ) is obtained from the formula $v = f\lambda$. Make λ the subject and substitute the values we have:

$$\lambda = \frac{v}{f} = \frac{330\,m/s}{550\,Hz} = 0.6\,m$$

Example 4

The wave length of signals from a radio transmitter is 1500m and the frequency is the 200 KHz. What is the speed the radio wave travels? What is the wavelength of a transmitter operating at 1000 KHz?

Solution

Data given

Wavelength (λ) = 1500 m

Frequency (f) = 200 KHz = 200,000 Hz

Speed (v) is obtained from the formula $v = f\lambda$. Substitute the values we have:

$$v = f\lambda = 1500\,m \times 200000\,Hz = 3.0 \times 10^8\ m/s$$

Also given frequency (f) = 1000 KHz $= 10^6\ Hz$, wave length (λ) is obtained from the formula $v = f\lambda$. Make λ the subject and substitute the values we have:

$$\lambda = \frac{v}{f} = \frac{3.0 \times 10^8\ m/s}{10^6\ Hz} = 300\,m$$

Dear learner, I hope you have learned a lot about the concept of wave. Now, do the following activity.

Activity 1

1. Water ripples are caused to travel across the surface of a shallow tank by means of a suitable straight vibrator. The distance between two successive crests is 3.0cm and the wave travels 25.2cm in 1.2 seconds. Calculate the wavelength, velocity of waves and frequency of the vibrator.
2. The distance between successive crests of water ripples in a ripple tank experiment is 3.2 cm and their wave speed is 26cm/s. Determine the wave length, frequency and period of the ripples.
3. A radio station transmits waves at a frequency of 95.6 MHz. What is the wave length of the waves transmitted? ($c=3\times10^{8}\,m/s$).
4. A sound wave has a frequency of 16 KHz, what is the periodic time for the waves?

Types of Waves

Dear learner, let us discuss the types of waves. There are two broad categories of waves, these are: *electromagnetic waves* and *mechanical waves.* Let us explain each of these types.

i. Electromagnetic Waves

Electromagnetic waves are disturbances made up of electric and magnetic fields. They do not require a material medium for energy transfer. They can travel through vacuum. Example of electromagnetic wave is visible light.

ii. Mechanical Waves

A mechanical wave is a disturbance which is transported through a medium due to particle-to-particle interaction. A typical example of mechanical wave is a sound wave.

Mechanical waves require a material for energy transfer. Mechanical waves can further be subdivided into two categories based on the motion of the wave relative to the medium particles. These are *transverse* and *longitudinal* waves.

Behaviour of Waves

Dear learner, a wave can undergo reflection, refraction, interference and diffraction which are discussed below as follows.

i. Reflection of Wave

Dear learner, I hope you have an idea of the term reflection. In some modules of Physics stage 1 and 2 you learnt about reflection. Take some few minutes to review the unit about light in the said modules of stage 1 and 2. Likewise, in this part we are going to discuss the reflection of wave. It is my hope that you will enjoy learning this section.

Reflection of waves takes place at the boundary of the medium through which it is travelling or at any point where there is a change of wave velocity. Whenever a wave reaches a boundary through which it cannot pass, it will be reflected.

Reflection is *the bouncing back of wave on hitting the barriers.*

Common examples include the reflection of light, sound and water waves as shown in Figure 1.4.

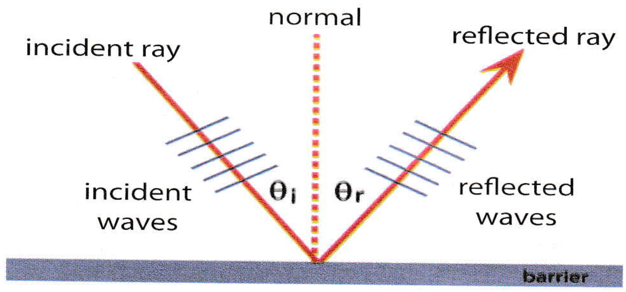


Figure 1.4: Reflection of waves

Laws of Reflection of Wave

Dear learner, we have already discussed the laws of reflection of light in Physics module 1 and 2. Let us now discuss the same laws but in terms of waves. These laws of reflection of light are as follows:

1. The incident ray, the reflected ray and the normal at the point of the incidence all lie on the same plane.
2. The angle which the incident ray makes with the normal is equal to the angle which the reflected ray makes to the same normal.

The characteristics of the reflection of wave are:

(a) It obeys the laws of reflection.

(b) The wavelength (λ) of the reflected wave is the same as that of the incident waves.

(c) The frequency (f) of the reflected waves is the same as that of the incident waves.

(d) Therefore, the speed (v) of the reflected waves is the same as that of the incident waves.

The Ripple Tank

The behaviours of waves can be conveniently studied using a ripple tank. The ripple tank consists of a transparent tray containing water with a point source of light above it, and a white screen below the floor of the tank. All the basic properties of waves, including reflection, refraction, interference and diffraction, can be demonstrated in a ripple tank shown in Figure 1.5.

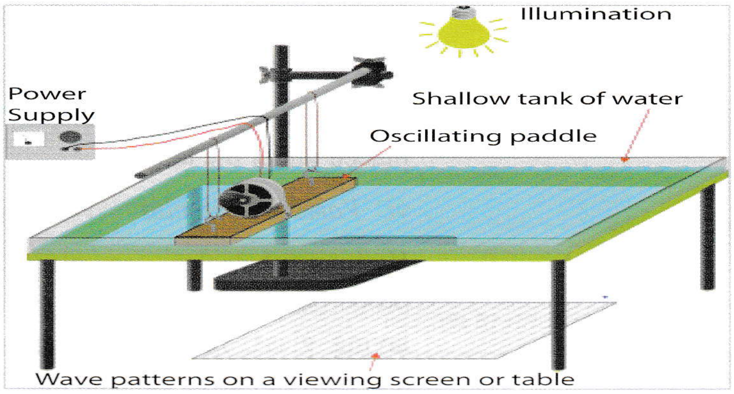


Figure 1.5: A ripple tank

Ripples may be generated by a piece of wood that is suspended above the tank on elastic bands so that it is just touching the surface. Screwed to wood is a motor that has an off centre weight attached to the axle. As the axle rotates the motor wobbles, shaking the wood and generating ripples.

Main Parts of a Ripple Tank

The ripple tank has the following parts:

i. Shallow tank of water

This is the source of waves in which an oscillating paddle generates parallel water waves.

ii. Motor

This is the rotating armature (axle) of an electric motor making the wooden (metal bar) to vibrate on water surface and generating ripples.

iii. Oscillating paddles

This is the one in which transforms mechanical energy generated by motor by off centre mass to wave merge energy in a shallow tank of water.

iv. Bulb/filament

Bulb or filament is used to illuminate the water surface to see the water waves onto the white board or white sheet below the ripple tank.

v. Paper sheet

A paper sheet is used to display shadow of the wave pattern placed under the tank.

vi. Various obstacles

Various obstacles are placed in the tray to observe properties of waves, e.g. diffraction. Examples are like laying glass, rectangular barrier, curved barrier (concave and convex barrier) and so on.

vii. Stroboscope

This enables the observer to see the waves as stationary.

viii. Laying glass

Laying glass is used to vary the depth (tray thickness) of water. This allows observing waves travelling from one medium to another medium.

ix. Metal bar

It is screwed to the electric motor and suspended above the ripple tank with rubber (elastic) bands and touching the water surface.

x. Power supply

Power supply is used to run an electric motor.

Applications of Reflection of Waves

Reflection of waves can be applied in the following aspects:

1. Reflection of light waves is used in the design of mirrors.
2. Reflection of sound waves is used in measuring distances.

3. Sonar (sound navigation and ranging) systems rely on the reflection of sound waves to assist ship in navigating, communicating, and detecting other vessels.
4. Detection of cracks in metals.

ii. Refraction of Waves

***Refraction** of a wave is the bending of waves at a boundary when the wave moves from one medium to another.*

The phenomenon is explained by the conservation of energy and conservation of momentum. Due to change of medium, the phase velocity of the wave is changed but its frequency remains constant. This is most commonly observed when a wave passes from one medium to another at any angle other than O^0 from the normal as shown in Figure 1.6

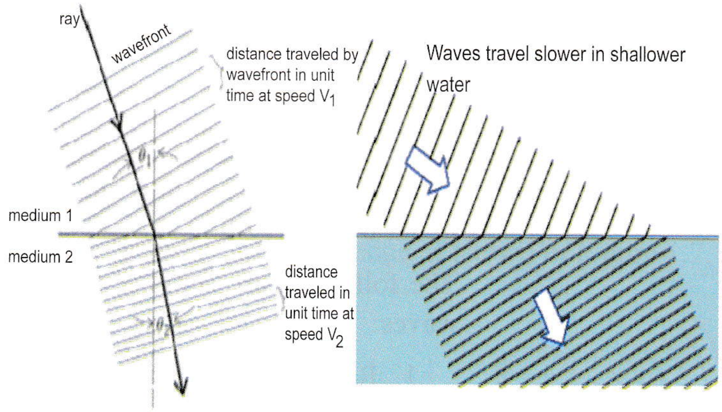


Figure 1.6: Refraction of a wave

Snell's Law

Refraction is described by Snell's law which states that "for a given pair of media and a wave with a single frequency, the ratio of the sin of the angle of incidence θ_1 and the angle of refraction θ_2 is equivalent to the ratio of phase velociti in the two media, or equivalently to the opposite ratio of th indices of refraction."

Mathematically;

$$\frac{Sin\theta_1}{Sin\theta_2}=\frac{v_1}{v_2}=\frac{\eta_1}{\eta_2}$$

Where:

1. v_1 and v_2 are velocities of wave in first medium anc second medium respectively.
2. η_1 and η_2 are respectively the refractive indices of the wave in first and second medium.
3. θ_1 and θ_2 are the angle of incidence and refraction respectively.

The refractive index (η) of an optical medium is a dimensionless number that describe how light or any other radiation propagates through that medium.

For more details make reference to the Unit about light in the Physics Module of Stage two.

Applications of Refraction of Waves

Dear learner, we have already discussed about reflection of wave. Let us discuss how the refraction of wave is applied in our everyday life.

The following are some of the applications of refraction of waves:

1. Refraction is used in optical instruments such as microscopes and telescopes.
2. Refraction is used in the dispersion of white light.
3. In medicine, refraction is applied in correcting eye defects using lenses.

Worked Examples on Refraction of Waves

Dear learner, do the following worked examples which will help you to understand well on refraction of waves.

1. Explain why during the day sound from distant sources is not very clear unlike during the night.

Answer:

During the day sound waves are refracted upwards from the hot Earth, while at night, sound waves are refracted down wards, hence are much louder.

2. Give reason why the amplitude of the wave does not change as it crosses the boundary?

Answer:

Because there is no loss of energy therefore amplitude does not change.

iii. Diffraction of Waves

Diffraction *refers to a change in direction of waves as they pass through an opening or around a barrier in their path.*

It is the spreading of waves when they pass through a narrow opening or a sharp edge as shown in Figure 1.7.

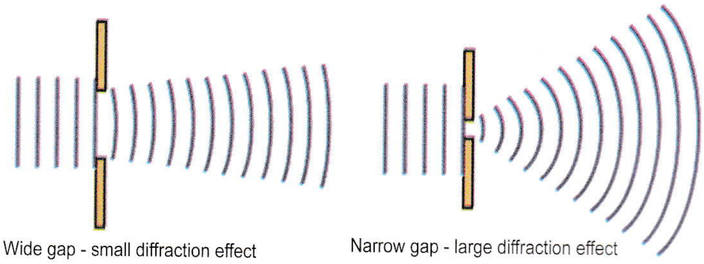


Figure 1.7: Diffraction of water waves

A clear diffraction is observed when the opening is about the size of the wavelengths of the wave. In diffraction, light spreads into the geometrical shadow.

Diffraction of water waves is observed in a harbour as waves bend around small boats and are found to disturb the water behind them. Diffraction of sound waves is commonly observed as we notice sound diffracting around corners, allowing us to hear others who are speaking to us from adjacent rooms.

Applications of Diffraction

The following are some of the applications of diffractions:

a) It is used in determining the crystal structure of materials.

b) It is used in measuring the coefficient of thermal expansion, crystallite size, and thickness of thin films.

c) We can hear sound from a corner or behind an obstacle because of the diffraction of sound.

d) Diffraction is used in holography.

iv. Interference of Waves

Interference *is a phenomenon in which two or more waves superpose to form a resultant wave of greater or lower amplitude.*

Interference is also described as the addition or superposition of two or more waves resulting in a new wave pattern.

The principle of superposition states that "the resultant displacement at any point is equal to the sum of the displacements of different waves at the point".

Types of Interference

Interference are of the two types namely; constructive interference and destructive interference. Below is the discussion of the two types of interference.

i. *Constructive Interference*

This occurs when a trough meets a trough or a crest meets crest producing maximum amplitude. In this case, two waves are vibrating in the same phase/direction.

ii. *Destructive Interference*

This occurs when a trough meets a crest; the resulting amplitude is smaller than the amplitude of the waves.

The waves with equal amplitude, cancel each other. Figure 1.8 shows these two types of interference.

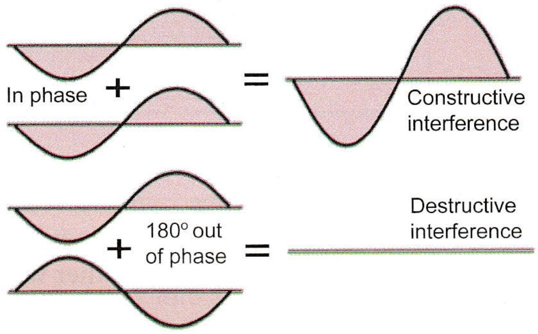


Figure 1.8: Constructive and destructive interference

Table 1.1 gives examples of the resultant displacement due to the interference of the two waves of different amplitude.

Table 1.1: Resultant displacements from interference

Amplitude of wave A	Amplitude of wave B	Resultant amplitude
+1	+1	+2
+2	-1	+1
-1	+1	0
+1	-2	-1
-1	-1	-2

In constructive interference, we get lines of increased disturbance. These lines are called antinodal lines. In destructive interference, we get lines to zero disturbances. These lines are called nodal lines. In the Figure 1.9 shows diffracted circle shaped water waves from two point sources e.g. dropping two pebbles near to each other in a pond. The waves pass through one another and result in both constructive and destructive interference.

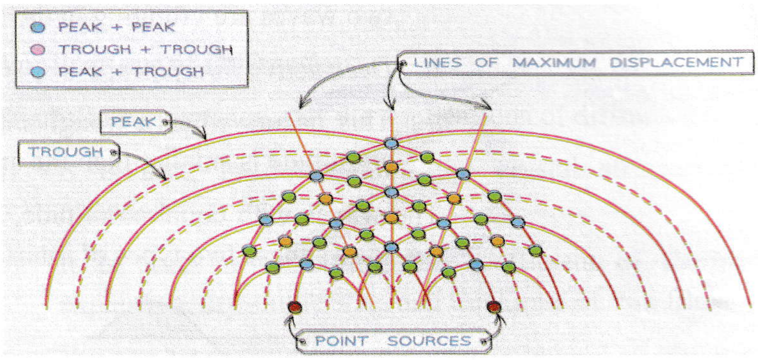


Figure 1.9 *Interference of waves*

The two waves interfere causing areas of constructive and destructive interference. The lines of maximum displacement occur when all the peaks and troughs line up with those on another wave.

Application of Interference of Waves

Dear learner, every property of a wave has the applications, the following are some of the applications of interference of waves:-

a) Interference is applied in creating holograms.

b) Destructive interference is used in noise reduction systems such as earphones.

c) Concert halls and auditorium are usually designed in such a way to reduce the amount of destructive interference.

Dear learner, the properties of waves can be demonstrated in the laboratory by using a ripple tank. There are activities which will help you to familiarize well with the behaviour of waves.

Activity 2

Aim: To observe the reflection of water waves in a ripple tank.

Materials: Ripple tank, barriers of different shapes (wooden block, glass plates and droppers).

Procedures:

1. Set up the material as shown in the Figure 1.10.

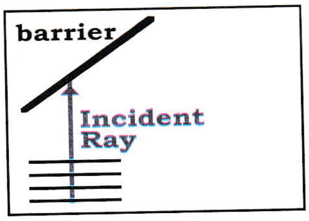


Figure 1.10

2. Generate some waves using the oscillating paddle of the ripple tank. Record your observations.
3. Pick some water into a dropper.
4. Hold the dropper about 2cm above the water surface.
5. Let out one drop of water into the middle of the ripple tank.
6. Observe how the water waves will be reflected after striking the barrier.
7. Draw the incident and the reflected wave patterns.
8. Change the angle of the barrier and repeat steps 2 - 7. Observe any changes in the reflected waves.
9. Replace the rectangular barrier with a curved one (concave) as shown in Figure 1.11.

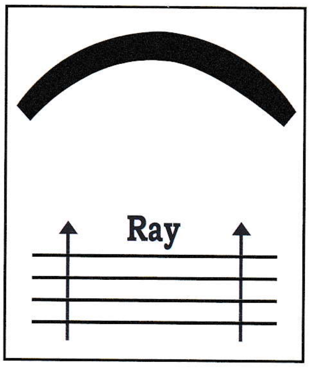


Figure 1.11: Concave barrier

10. Repeat steps 2-7 with the concave barrier.

Record all your observations.

Discuss the Following Questions

a) What happened to the incident water waves on reaching the rectangular barrier?

b) Draw a sketch of the incident and reflected waves.

c) Describe the wave pattern produced by the incident water waves on reaching the concave barrier.

Observation from the Activity 2

Straight waves in a ripple tank striking a straight barrier observe the laws of reflection, that is:-

1. The angle of incidence is equal to the angle of reflection.
2. The incident direction of progression, the normal and the reflected direction of progression all lie in the same plane.

The direction in which a wave is travelling is represented by an arrow. The arrow is called upon reaching the barrier placed within the water; the water waves bounce off the water and head in a different direction shown in Figure 1.12.

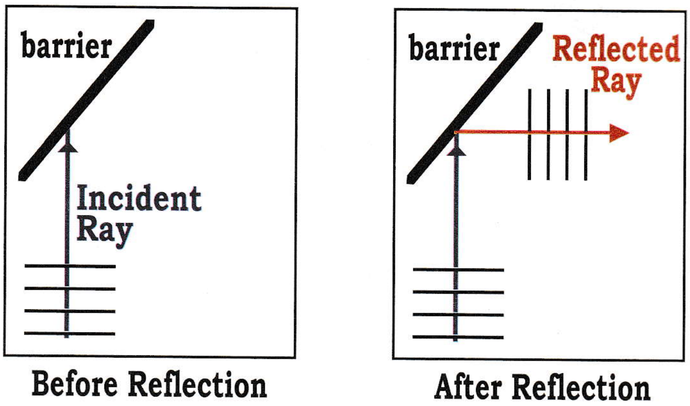


Figure 1.12: Reflection of water waves in plane surface

Upon reflection off on the parabolic barrier, the water wave will change direction and head towards a point known as the focal point. After passing through the focal point, the waves spread out through the water. This is also the case when circular water waves strike a straight or curved barrier as shown in Figure 1.13.

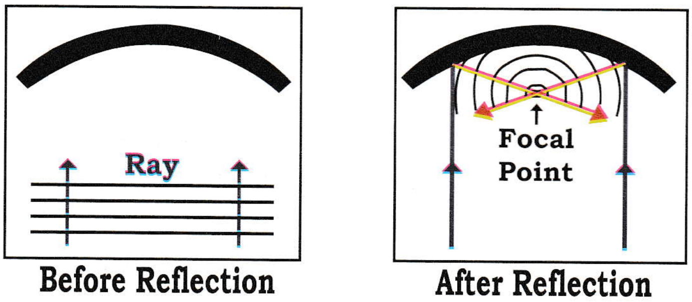


Figure 1.13: Reflection of water waves in concave surface

Activity 3

Aim: To observe the refraction of water waves in ripple tank.

Materials: Ripple tank and its accessories, metre rule.

Procedures:

1. Place a thick glass plate in one part of the ripple tank to make it shallow.
2. Fill the tank with water.
3. Produce some water waves using the vibrator.
4. Measure the distance between successive crests in the deeper part (λ) and shallow part (λ_1).

Perform the Following Questions

a) Workout the ratio $\frac{\lambda}{\lambda_1}$

b) How is the ratio related to the velocities of water waves in the deeper part and in the shallow part?

Observation from activity 3

We have observed that, when water waves travel from a deep part to a shallow part, the wavelength decreases. However, the frequency of the wave does not change. Since velocity v is given by λf, the velocity of the wave decreases with decrease on wavelength as shown in Figure 1.14.

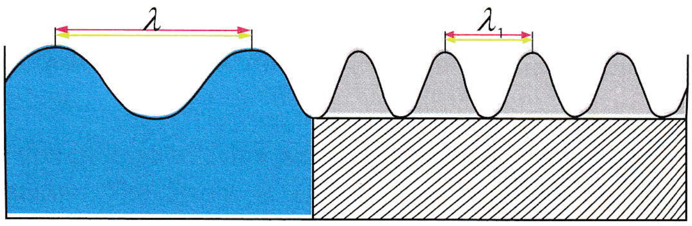


Figure 1.14: Change in the wavelength of wave

The ratio $\frac{\lambda}{\lambda_1}$ is also the ratio of velocities of water waves in the first medium (v) to that in the second medium (v_1).

That is: $\frac{\lambda}{\lambda_1} = \frac{v}{v}$

The velocity of water waves is high in the deep water than in shallow water. Note that, the ratio $\frac{v}{v_1}$ is the refractive index of the second medium relative to the first medium.

The refraction of water waves can be clearly observed if the boundary between the deep and shallow regions is at an angle to the incident wave fronts as shown in Figure 1.15.

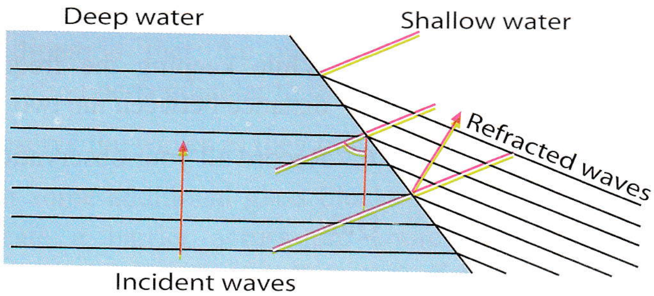


Figure 1.15: Refraction of water waves

Activity 4

Aim: To investigate the interference of water waves in a ripple tank.

Materials: Ripple tank, light source.

Procedures:

1. Attach two point sources to the wave generator.
2. Generate some water waves at a constant frequency. Observe the pattern created by waves.
3. Increase the frequency of the wave generator and observe what happens to the pattern created by the waves.
4. Decrease the frequency and again observe what happens to the pattern of the wave generated.
5. While keeping the frequency constant, increase the distance between the two point sources.
6. Record all your observations.

Quiz

Describe the pattern produced by the waves from the two point sources in each case.

Observation from the Activity 4

From the activity 4, we have observed that; water waves from the two identical point sources add up in certain directions (when a crest meets a crest or trough meets a trough) and counsel out in certain direction (when a crest meats a trough). When the water waves add up, constructive interference occurs. The water waves have increased amplitude along lines of constructive interference.

Destructive interference takes place where water waves counsel out. Water is quit still along lines of destructive interference.

Activity 5

Aim: To investigate the diffraction of water waves in a ripple tank.

Materials: Ripple tank, light source, mechanical wave generator and pencil.

Procedures:

1. Add water to the ripple tank to a deep of approximately 1cm.
2. Adjust the legs of the ripple tank to make the depth of the water as uniform as possible.
3. Place a glass block in the water across the tank.
4. Drop a pencil onto the water, just a few centimetres behind the glass block. The pencil should be aligned in a direction that the waves generated travel in a direction perpendicular to the edge of the glass block.
5. Observe the waves as they move past the glass block.
6. Put some additional glass blocks in the ripple tank to create a barrier across the entire tank. Leave an opening of about 1cm at the centre of the ripple tank.
7. Generate some straight waves using the mechanical wave generator.
8. Observe what happens to the waves as they move past the barrier.
9. Increase the size of the opening and then repeat at procedure 6.
10. Replace the straight wave source with a point source, then repeat step 6.
11. Record all your observations.

Quiz

a) Explain what happens to the waves on passing:

   i. The single glass block barrier.

   ii. The narrow opening.

b) What was the effect of increasing the size of the opening on the waves passing through the opening?

Observation from the Activity 5

When straight waves are approaching a barrier, the barrier obstructs the part of the wave front that strikes it. It only allows the part of the wave front that strikes it. The wave fronts that pass the barrier spread into the shadow area of the barrier.

This spreading out is what is known as diffraction. When the gap is narrow, the straight wave fronts are converted into circular wave fronts. These wave fronts appear to be produced by a new point source in the gap. They spread out round the edges of the opening in all directions.

When the gap is wide, the waves emerge almost straight, apart from a slight curvature, and spread out at the edges as shown in Figure 1.16.

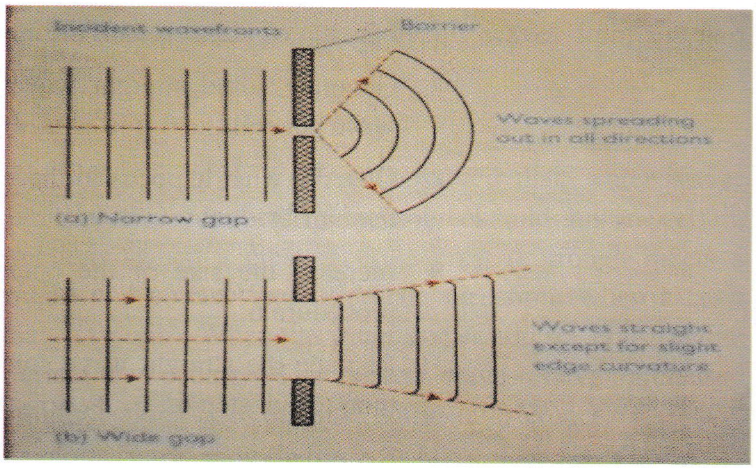


Figure 1.16: Diffraction of water waves

The amount of diffraction is greater when the width of the opening is the same as the wavelength of the waves.

Propagation of Waves

Dear learner, in this part we are going to discuss the motion (propagation) of mechanical waves. As we have discussed earlier, mechanical waves are of two types; transverse and longitudinal waves. we shall discuss the propagation of both types in details.

a) Propagation of Transverse Waves

In a transverse wave, the particle of the medium vibrates in a direction perpendicular to the direction of movement of the wave.

This means that the direction of particles medium is at right angles (90°) to the direction of movement of the wave as shown in Figure 1.17.

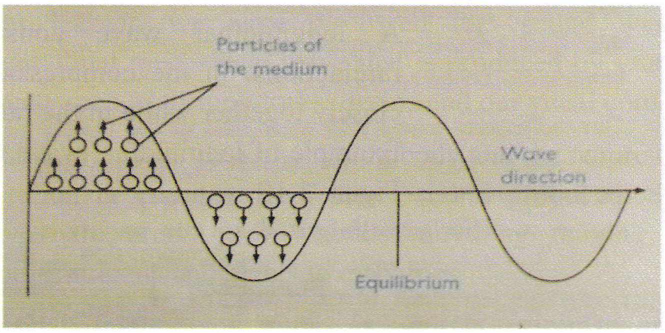


Figure 1.17: A transverse wave

Examples of transverse waves are water waves. In water, the particles of water moves up and down while the wave moves in a horizontal direction. That is why a boat or ship on the ocean moves up and down while the waves themselves move towards the shore as shown in Figure 1.18.

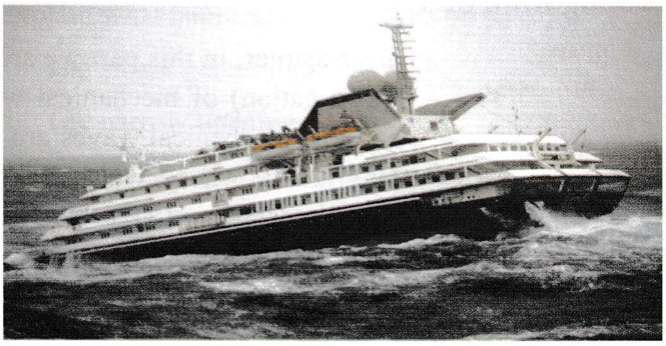


Figure 1.18: Ship in waves (transverse waves)

b) Propagation of Longitudinal Wave

In this type of wave, the particles of the material medium vibrate in a parallel direction to that of the wave motion. That is to say, the direction of motion of medium particles is the same as the direction of the wave itself.

A longitudinal wave consists of compression and rarefactions. In the compression, the particles are packed closely together while in the rarefaction they are spread out. Example of longitudinal wave is a sound wave as shown in Figure 1.19.

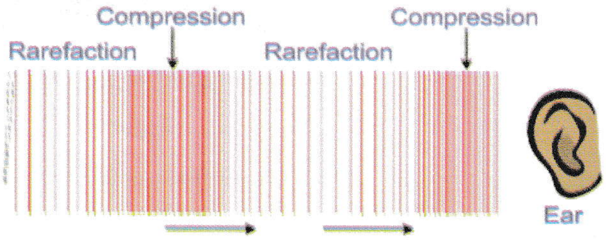


Figure 1.19: Longitudinal waves in sound

Note

Wave profile diagrams of waves travelling longitudinally and those travelling transversely appears as shown in Figure 1.20.

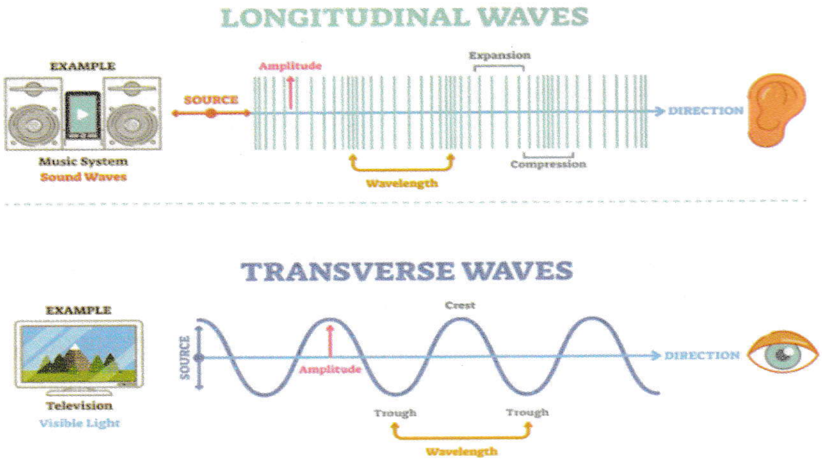


Figure 1.20: Wave travels longitudinally and in transverse.

Sound Waves

Dear learner, we have discussed that sound wave is longitudinal mechanical wave that is produced by vibrating objects such as turning forks, drums and our vocal cords.

Sound originates from a vibrating body and the nature of the vibration determines the type of sound produced. Sound waves are produced by almost anything ranging from people, animals and plants to machines.

Musical instruments such as guitars, violins, organs, recorders, flutes, marimbas and drums are designed to produce specific types of sounds.

Audibility Range

Audibility range is the range of frequencies that can be heard by humans or other animals.

The human audibility range is from 20Hz to 20,000 Hz. Sound with frequencies less than 20Hz are called *infrasonic* and sound with frequencies above 20,000 Hz is called *ultrasonic*

The average human ear can distinguish between two simultaneous sounds if their frequencies differ by at least 7 Hz. The upper limit of the audibility range decreases with age throughout a human's life.

The Human Ear

A human ear is the organ responsible for conversion of sound energy to mechanical energy to nerve impulse that transfers to the brain for interpretation. It can distinguish frequency, amplitude and direction.

Dear learner, the human ear consists of three parts. Namely; outer ear, middle ear and inner ear as shown in Figure 1.21.

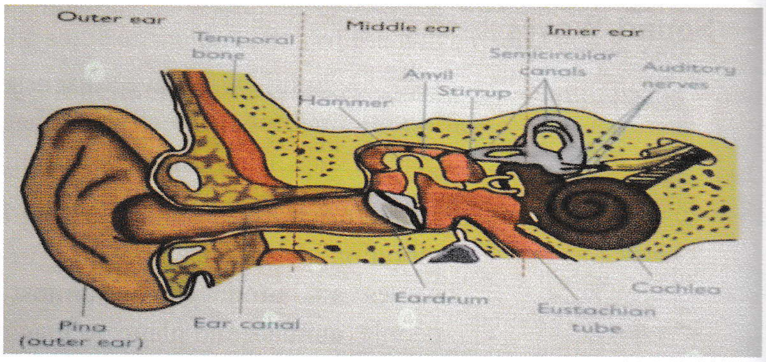


Figure 1.21: The human ear

The Outer Ear

The outer ear consists of earflap and the ear canal. The outer ear channels sound waves that reach the ear through the ear canal to the eardrum of the middle ear. In the outer ear, the sound is still in the form of a pressure wave, with an alternating pattern of high and low pressure regions.

The Middle Ear

The middle ear is an air - filled cavity that consists of an eardrum and three small inter connected bones; the hammer, anvil and stirrup. The Eustachian tube connects the middle ear to the throat. Its purpose is to regulate pressure.

A compression of the incoming sound wave forces the eardrum in ward and a rarefaction forces the eardrum outward. In this way, the air drum vibrates at the same frequency as an incoming sound wave. The movements of the eardrum set the hummer, anvil and stirrup into motion. The three tin bones amplify the vibration of the incoming sound wave. Because the stirrup is connected to the inner ear, the vibrations are transmitted to the fluid of the inner ear.

The Inner Ear

The inner ear consists of the cochlea, the semi-circular canals and the auditory nerve. The cochlea and the semi-circular canals are filled with water-like fluid. The fluid and nerve cells of the semi-circular canals help in maintaining the body balance. The inner surface of the cochlea is lined with hair-like nerve cells that differ in length. The nerve cells also have different degrees of resilience to the fluid which passes over them.

As a compressional wave moves from the interface between the hammer of the middle ear and the oval window of the inner ear through the cochlea, the small hair - like nerve cells are set in motion. Each hair-cell has a natural sensitivity to a particular frequency of vibration. When the frequency of the compressional wave matches the natural frequency of the nerve cell, that nerve cell vibrates with large amplitude making the cell release an electrical impulse which passes along the auditory nerve to the brain.

Echo and Reverberation

Dear learner, you might have experienced that when you are in an empty space or in front of a tall building or a hall and you shout loudly, you will observe that, faint sound resembling the original sound comes back after some delay of time. This perception of the reflected sound leads us to the discussion of echo and reverberation.

Dear learner, sound, like any other waves can be reflected. The reflection of sound wave can lead to two effects which are echo and reverberation.

Echo

***An** echo is a reflected sound which is heard distinctly from the original sound.*

It occurs when a sound wave is reflected and hence arrives to the listener after some time delay after the direct sound.

Echo is experienced in remote places, in rooms that are big and empty, in caves, in buildings and in big forests.

Applications of Echo

The following are some of application of echo.

1. *Measuring Distance*

By knowing the speed of sound and measuring the time it takes to hear the echo, and one can calculate the distance of the source.

2. *Measuring Velocity*

When a wave bounces off a moving object, the frequency of the sound waves changes. According to the relative velocity of the object, if the object is moving towards you, the frequency or pitch of the sound gets higher, and when it is moving away, the pitch gets lower.

3. *Bats can find Motions*

While flying around at night, the bat sends a sharp click or chirping sound and then hears a processes any echo from other objects in the area. Bats have large ears that are very sensitive to sound in certain wavelengths.

Reverberation

When a sound is produced in an enclosed space, multiple reflections will occur. Ideally, the enclosure should have dimensions of not less than 17m as shown in Figure 1.22.

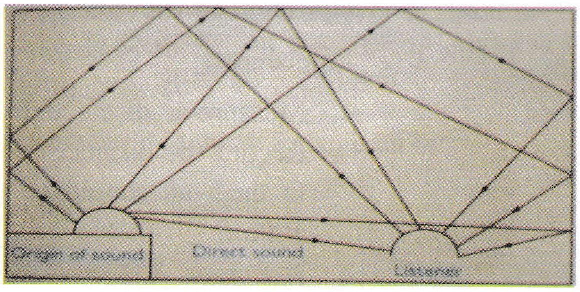


Figure 1.22: Reverberations

The multiple echoes tend to combine in the listener's ear to produce a louder, more sustained sound called *reverberation*. Reverberations are heard in places surrounded by cliffs and caves. Cinema halls and large halls are designed in a way to produce reverberations.

Velocity of Sound in Air

Dear learner, I hope you still remember when we learnt that sound is a mechanical wave. Sound can travel in air (gases), liquids and in solids; it cannot travel in a vacuum. The speed of sound in air is approximately 340m/s. Sound travels faster in solids than in liquids and air.

Dear learner, the velocity of sound in air can be found experimentally. The activity 5 guides you on how to find the velocity of sound in air experimentally.

Activity 6

Aim: To determine the speed of sound in air by echo method.

Materials: Two wooden blocks, stopwatch, measuring tape and vertical cliff or wall.

Procedures:

1. Measure a distance from a point (A) to the wall. Record the distance as d. The distance from point A to the wall should be above 17m, preferably above 100m.
2. Let one student stand at point A and hit the two wooden blocks together.
3. Another student also standing at point A, should measure the time interval (t) from the time of heating

to the time an echo is heard as shown in Figure 1.23.

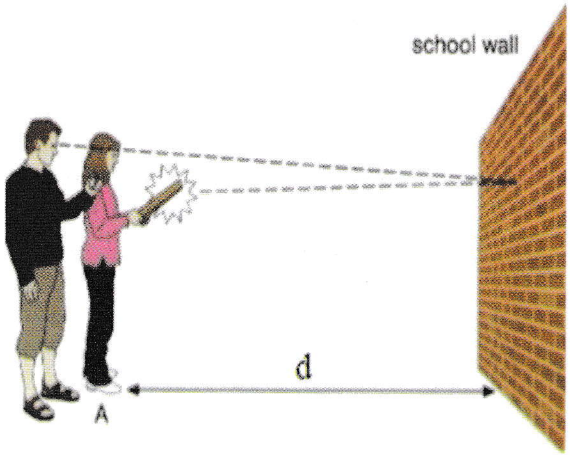


Figure 1.23

Quiz

Using the relationship $\text{Speed} = \frac{\text{distance}}{\text{time}}$, determine the speed of sound in air (v).

Observation from Activity 6

From the activity 6, we observe that, when the sound is produced, it travels distance d to the wall and back to the source covering the same distance in time t, the total distance moved by the sound wave in air will be $2d$ (to and from motion).

The speed of sound in this way is given by;

$$Velocity(v) = \frac{distance(d)}{time(t)} = \frac{2d}{t}$$

Substituting values of d and t, we get approximately 240 m/s.

Dear learner, study the following examples which are solved for you. Make sure that you note all important points for future references.

Example 5

Sound travelling towards a cliff 700m away takes 4.2 seconds for an echo to be heard. Calculate the velocity of sound in air.

Solution

Given that

Distance (d) = 700 m

Time (t) = 4.2 seconds

Velocity (v) is obtained from the formula $Velocity(v) = \frac{2d}{t}$.

Substitute the values we have:

$$Velocity(v) = \frac{2d}{t} = \frac{2 \times 700\,m}{4.2\,s} = 333.33\ m/s$$

Example 6

A student standing between two vertical walls and 480m from the nearest wall, shouted. She heard the first echo after 3 seconds and the sound 2 seconds later. Use this information to calculate:

a) Velocity of sound in air.

b) Distance between the two walls.

Solution

Given

First distance (d_1) = 480 m

First time (t_1) = 35 seconds

Second time (t_2) = 35 seconds

a) From the relation $Velocity(v) = \frac{2d}{t}$

$$Velocity(v) = \frac{2d_1}{t_1} = \frac{2 \times 480\,m}{3s} = 320\,m/s$$

$$\therefore v = 320\,m/s$$

b) Distance (d) is obtained as follows:

$$d = d_1 + d_2$$

Where
d_1 = distance from a girl to the nearest wall
d_2 = distance from a girl to the other wall
d = distance between the two waves

But $v = \frac{2d_2}{t_2} = \frac{2 \times d_2}{5s}$

$$d_2 = \frac{320\,m/s \times 5s}{2} = 800\,m$$

Therefore, $d = d_1 + d_2 = 480\,m + 800\,m = 1280\,m$

Factors Affecting the Velocity of Sound in Different Materials

Dear learner, the velocity of sound wave in material can be affected by various factors. The following are the factors influencing the velocity of sound waves:

1. **Nature of Material/Medium**

The speed of sound in air is about 340m/s, the speed of sound in water is about 1500m/s and speed of sound in iron is about 5130 m/s. Thus, sound travels slowest in gases, faster in liquid and fastest in solids.

2. **Temperature**

The speed of sound at O^0C is about 332m/s, but at 20^0C, the speed of sound is about 340 m/s. The speed of sound in air on a hot day is more than the speed of sound in a cold day.

3. **Humidity of Air**

The speed of sound in air is more in humidity air. As the humidity of air increases, the velocity of sound increases.

Activity 7

Dear learner, do the following questions.

1. Explain why a duck remains floating at the same place as wave passes by the water in a lake.
2. An electromagnetic wave such as light does not require a medium. Can you think of an example that would support this claim?
3. How can we distinguish experiment between longitudinal and transverse waves?
4. If a person places her ear to one end of a long iron pipeline, she can distinctly hear two sounds when a workman hammers the other end of the pipeline. Explain why this happens.
5. Explain why sound travels faster on a rainy day than on a dry day.
6. Consider a stretched spring, such as a slinky. The stretched spring can support longitudinal waves and transverse waves. How can you produce transverse waves on the spring? How can you produce longitudinal waves on the spring?
7. Is it possible for light to be diffracted when passing through an open window? Explain.
8. What is the Snell's law about?
9. A woman sees steam coming out from a factory whistle and three seconds later she hears the sound. If the velocity of sound in air was 360m/s, calculate the distance from the woman to the factory.
10. Two boys stand zoom apart on one side of a high vertical cliff at the same perpendicular distance from it. When one fires a gun, the other hears the sound 0.6 second after the flash and the second sound 0.25 second after the second. Calculate:

    a) The velocity of sound in air.

    b) The perpendicular distance of the boys from the cliff.

Musical Sounds

Dear learner, music is an organised sound which has some pattern. Music uses certain frequencies or combinations of frequencies called musical scale to produce sound that are pleasing to the human ear.

Noises on other hand, is random and without structure. All frequencies might occur and their combination is often not pleasing to the ear.

Properties of Musical Sounds

The musical sounds produced by different musical instruments have distinct properties that are used to describe them. These include loudness, pitch and timbre.

Loudness

Loudness is the intensity of the sound as perceived by the human ear. It is determined by the number of auditory nerve fibres activated by the sound wave and number of impulses carried by each fibre. Loudness is determined by the amplitude of sound wave. The larger the amplitude, the louder the sound.

Pitch

Pitch is a property of sound according to which sounds can be ordered on a scale from high to low. Pitch is determined by the frequency such that the higher the frequency, the higher the pitch of the sound produced.

Timbre

The timbre of a sound is also known as sound quality or colour. Timbre is a tone quality of sound (characteristic) produced by instrument that describes the differences amongst sounds of the same pitch and loudness. For example, sound produced by a guitar and trumpet differs only in timbre.

The timbre depends on fundamental frequency and overtone of sound waves.

Dear learner, I hope you have understood well about music sound and their properties, now practice the following activity.

Activity 8

1. Draw waveforms which are produced by two notes of:

   a) The same pitch but different loudness.

   b) Different quality.

2. State three (3) ways in which the musical notes may differ from each other.

3. State the wave properties on which loudness, pitch and quality of a musical note depends.

Musical Instruments

Dear learner, welcome to another part which is about musical instruments. Do you know any musical instrument? How do they differ from each other? If the answer is no! Don't worry you are going to understand them very well.

A musical instrument is a device constructed or modified for the purpose of making music. Musical instruments are divided into three categories based on how they initially produce sound. These are string, percussion and wind instruments.

i. String Instruments

They produce sound from stretched strings that are plucked, struck, rubbed, and bowed. Examples are guitar, violin, viola, harp, cello, piano and so on as shown in Figure 1.24.

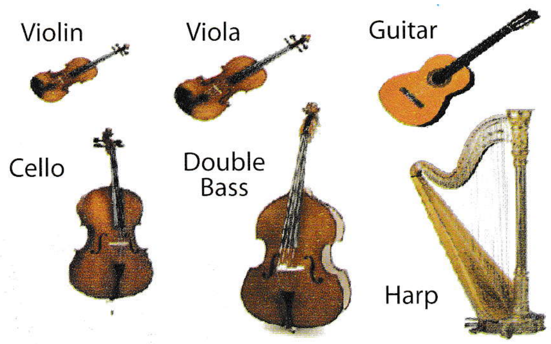


Figure 1.24: Some examples of string instruments

ii. Percussion Instruments

These produce musical sounds by being struck, shaken, rubbed, and scrapped or by any other action which sets the object into vibration. This group includes the drum, cymbals, tambourine, marimba, bell, and xylophone and so on as shown in Figure 1.25.

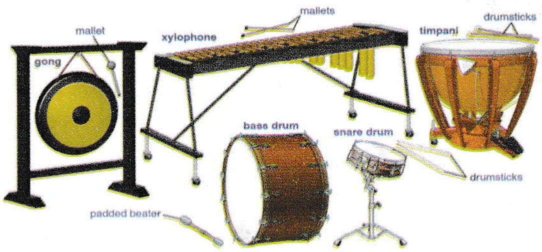


Figure 1.25: Some examples of percussion instruments

iii. Wind Instruments

They are made up of a pipe or tube in which column of air is set on vibration by the player blowing into or over a mouth piece of the end of tube or pipe. Examples of these are recorders, flutes, trumpets, saxophone, horn, and tuba as shown in Figure 1.26.

Figure 1.26: Some examples of wind instruments

Dear learner, I hope you have understood and enjoyed learning about musical instruments. Now, do the following activity.

Activity 9

Under your facilitator, make simple musical instruments of your choice and classify each instrument you have made into its respective category.

Standing or Stationery Waves

Dear learner, in the previous part you learnt about moving waves (progressive), and now we are going to discuss the standing (stationery) waves. I hope you are going to understand it very well. You are welcome and enjoy.

A stationery wave results when two waves which are travelling in apposite directions and along the same line within the same medium superpose (adds or subtracts). The two waves must also have approximately equal amplitude, same speed and frequency. The superposition of two such waves results to a point where displacement (amplitude of vibration) is always zero. These points are called nodes. Midway between the nodes are points where the maximum displacements are greater than anywhere else. These points are called antinodes.

The profile of a stationery wave does not travel. Although there is energy associated with the wave, energy does not pass along it.

Consider two transverse waves A and B with equal amplitudes, wavelengths and speeds travelling in opposite direction on a string.

As the waves pass each other, their amplitudes combine. If a crest of wave A combine with a trough of wave B, the two amplitudes cancel out and the net displacement of the medium particles will be zero as shown in Figure 1.25

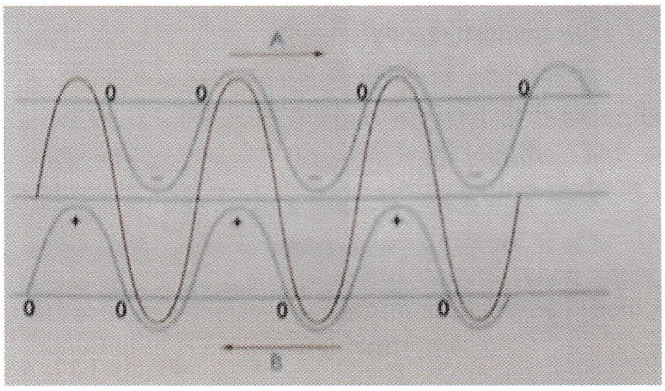


Figure 1.25: Superposition of waves

If crest of wave A combines with a crest of wave B, the result is a displacement twice as large as either A or B as shown in Figure 1.26

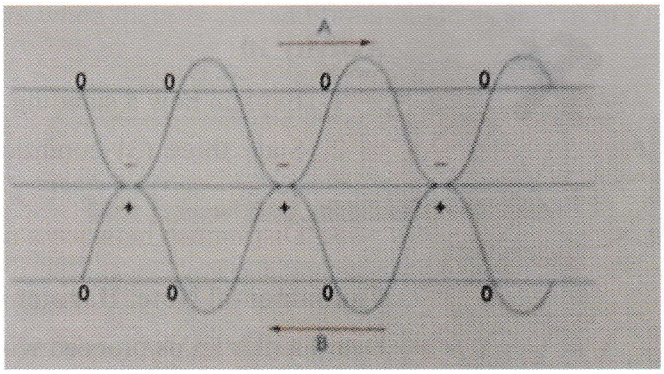


Figure 1.26: Production of a stationary wave

As the two waves pass along the string, their amplitudes will alternate between adding together and cancelling out. The result is a stationery wave that oscillates back and forth.

This happens when a wave is reflected off a fixed boundary. At a certain point along the string, the two waves always cancel out proving zero displacement (nodes) and at other points they add together to produce a maximum displacement (antinode).

There will be a node at each end of the string and there may be additional nodes. Antinodes occur at points halfway between the two successive nodes as shown in Figure 1.27.

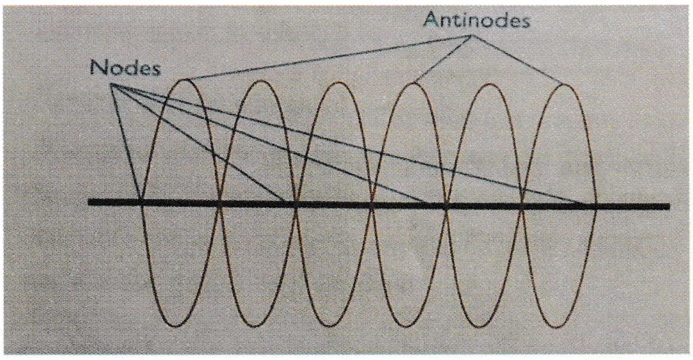


Figure 1.27: A stationary wave

Dear learner, I hope you here understood well about the standing waves, now practice the following activity 10

Activity 10

1. Explain how a standing wave is formed.
2. State three (3) conditions for a standing wave to occur.
3. Distinguish between a node and antinode.

Fundamental Note, Harmonic and Overtones

Dear learner let us proceed with fundamental note, harmonic and overtone, welcome.

Fundamental note *is the lowest possible note that a vibrating string or pipe can produce.*

The frequency produced by fundamental note is called *fundamental frequency*.

A note whose frequency is a whole number (n) times that of the fundamental is called the n^{th} harmonic. The first harmonic is therefore the fundamental note. The notes of higher frequency which are produced with the fundamental note are called overtones.

The first overtone is harmonic whose frequency is lowest amongst those with fundamental note.

Stationery waves on a string that is fixed at both ends are restricted to having only certain wavelengths. The wave must fit between the ends of the string with a node at each end.

The fundamental note of vibration occurs when there are nodes at each end and a single antinode between them. The fundamental note is called first harmonic.

The overtones of a note are notes of a higher frequency which are produced with the fundamental note. The first overtone is the harmonic where frequency is lowest amongst those with fundamental note. The second overtone is the next higher harmonic which is present. Higher harmonic occurs when there is one additional node as shown in Figure 1.28.

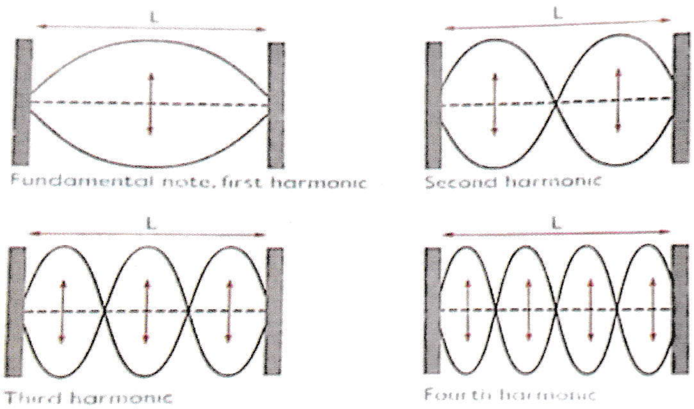


Figure 1.28: Fundamental notes and harmonics

The fundamental note consists of half a cycle. If the length of string is L then wavelength λ of fundamental note is given:

$$L = \frac{\lambda_1}{2}$$

$$\therefore \lambda_1 = 2L$$

The 2nd harmonic consists of one full cycle and has wavelength $\lambda_2 = L$

The 3rd harmonic consists of one full cycle plus half cycle giving its wavelength λ_3 equals to:

$$L = \frac{3\lambda_3}{2}$$

$$\therefore \lambda_3 = \frac{2L}{3}$$

In general, for a string of length, L fixed at both ends, the wavelength of nth harmonic is given as $\lambda_n = \frac{2L}{n}$

Since $v = f\lambda$, the frequency of the nth harmonic (f_n) is given as;

$$f_n = \frac{nv}{2L}$$

Factors Affecting the Frequency of a Vibrating Wire

Dear learner, welcome to another part which is about factors affecting the frequency of a vibrating wire. However, before discussing these factors, let us see the meaning of sonometer.

The Sonometer

This is an instrument used to study properties of waves, especially stationery waves. It is made up of a wire or string fixed on top of a box. The box increases the loudness of the sound produced by the wire as shown in Figure 1.29.

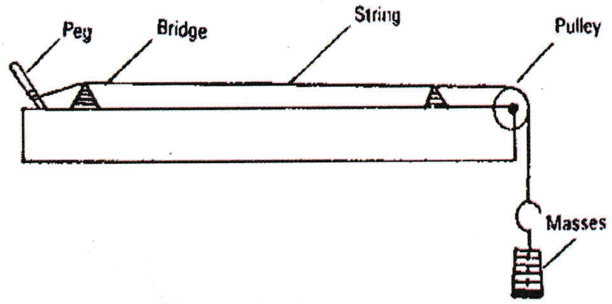


Figure 1.29: The sonometer

If the mid-point of the wire is plucked, the middle will form an antinode while the two fixed ends will have nodes.

Dear learner, note that:

1. The frequency (f) produced by a vibrating string depends on:
   a) The length of string (L).
   b) The velocity of wave (v).

2. The velocity (v) of waves on a stretched string depends on the:
   a) Tension (T) in the string
   b) The linear mass density (μ).

Therefore, the frequency of the sound produced by a vibrating wire depends on three factors which are:

1. The tension on wire
2. The length of the wire
3. The mass per unit length of wire.

Dear learner let us proceed with the following activity 11.

Activity 11

Aim: To investigate the factors that affects the frequency of a vibrating wire.
Materials: Slotted weights, a set of different tuning forks and sonometer with a steel wire.

Procedures:

1. Set up the sonometer as shown in Figure 1.30.

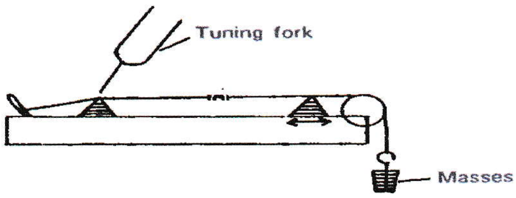


Figure 1.30: The Sonometer

   Note: The weight should be enough to keep the wire taut.
2. Select a turning fork with lowest frequency and set it into vibration. Pluck the wire at some time. If the two sounds are not in unison add or reduce weight until they are in unison.
3. Record the frequency (f) of the tuning fork and the distance between the bridges.
4. Sound another tuning fork and adjust the length between the bridges until the sounds produced are in unison.
5. Repeat the procedure for all the other tuning forks. Record your results in a table similar to the one shown in Table 2.1.
6.

Table 2.1: A table of results

Frequency of the tuning fork (f)	Length of the wire (L)	$\frac{1}{L}$

Quiz

a) Draw the graph of f against $\frac{1}{L}$.

b) Determine the gradient of the graph.

c) From the graph, how does the frequency of a vibrating wire vary with increase in the length of a wire?

Dear learner, the graph of f against $\frac{1}{L}$ is a straight line through the origin as shown in Figure 1.31.

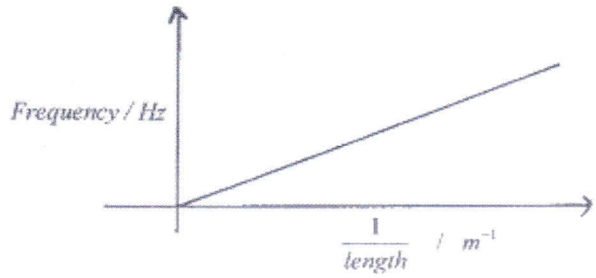


Figure 1.31: A nature of graph of f against $\frac{1}{L}$

This means that frequency is inversely proportional to the length of the wire i.e. $f \alpha \frac{1}{L}$ .... (1)

The frequency of the wire is directly proportional to the tension (T). From experiment, it has been observed that the frequency (f) is directly proportional to the square root of tension (T) on the wire i.e.

$f \alpha \sqrt{T}$ ....(2)

The frequency of the sound produced is inversely proportional to the mass per unit length (μ). If a thicker wire is used, the frequency decreases. From the experiment it has been established that frequency is inversely proportional to the square root of the mass per unit length. i.e.

$f \alpha \sqrt{\frac{1}{\mu}}$ ....(3)

Combination of the three equations, we get:

$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$ where, $\frac{1}{2}$ is a constant obtained from experiment.

Dear learner, study the following examples:

Example 7

The frequency obtained from plucking a string is 400Hz when tension is 2 N, find the:

i. Frequency when the tension is increased to 8N.
ii. Tension needed to produce a note of frequency 600Hz.

Solution

Given

i. Frequency (f_1) = 400Hz at tension (T_1) = 2N

Frequency (f_2) at tension (T_2) of 8N is calculated from a formula $f \alpha \sqrt{T}$

That is: $\frac{f_1}{f_2} = \sqrt{\frac{T_1}{T_2}}$. Substitute the values and solve for f_2 we have.

$$f_2 = f_1\sqrt{\frac{T_2}{T_1}} = 400\,Hz\sqrt{\frac{8\,N}{2\,N}} = 800\,Hz$$

ii. Tension (T_2) at frequency (f_2) of 600 Hz is calculated from: $\frac{f_1}{f_2} = \sqrt{\frac{T_1}{T_2}}$. Substitute the values and solve for T_2 we have:

$$T_2 = \left(\frac{f_2}{f_1}\right)^2 T_1 = \left(\frac{600\,Hz}{400\,Hz}\right)^2 \times 2\,N = 4.5\,N$$

Example 8

A string has a length of 75cm and a mass of 8.2g. The tension in the string is 18N. Find the frequencies of the 1^{st} and 3^{rd} harmonics.

Solution

Data given

Length (L) = 75 cm = 0.75 m, Mass (m) = 8.2 g = 0.0082 kg

Tension (T) = 18 N

The frequencies of first harmonic (f_1) and third harmonic (f_3) are calculated using a formula $f_n = \frac{nV}{2L}$ but $V = \sqrt{\frac{T}{\mu}}$ and

$\mu = \frac{m}{L}$

Therefore $V = \sqrt{\frac{TL}{m}} = \sqrt{\frac{18\,N \times 0.75\,m}{0.0082\,kg}} = 40.6\,m/s$

Finally $f_1 = \frac{V}{2L} = \frac{40.6\,m/s}{2 \times 0.75\,m} = 27\,Hz$ and

$f_3 = \frac{3V}{2L} = \frac{3 \times 40.6\,m/s}{2 \times 0.75\,m} = 81\,Hz$

Example 9

A string 0.5m long is stretched under a tension of 200N and its fundamental frequency is 400Hz. If the length of string is shortened to 0.35m and the tension is increased to 400N. Find the new fundamental frequency.

Solution

Given

Length (L_1) = 0.5m at tension (T_1) of 200N and frequency (f_1) of 400Hz

Length (L_2) = 0.35m at tension (T_2) of 400N

New fundamental frequency (f_2) is obtained from a relation:

$\frac{f_1}{f_2} = \frac{L_2}{L_1} \times \sqrt{\frac{T_1}{T_2}}$. Substitute the values and find f_2 we have:

$$f_2 = \frac{f_1 L_1}{L_2} \times \sqrt{\frac{T_2}{T_1}} = \frac{400\,Hz \times 0.5\,m}{0.35\,m} \times \sqrt{\frac{400\,N}{200\,N}} = 808\,Hz$$

Forced Vibration and Resonance

Dear learner, I hope you have understood very well about factors affecting frequency of stretched wire. Now, let us proceed with another part which is about forced vibration and resonance.

When the natural (resonant) frequency of a metal vessel is 200Hz, and a tuning fork of frequency 256Hz is set up into vibrations and its stem is placed in contact into the vessel, then the vessel will be forced to vibrate at a frequency of 256Hz. In such a case, the vessel is said to perform the forced vibration.

Forced vibrations *are vibrations produced in a body as a result of an external periodic vibration of frequency different from the natural frequency of a body.*

When the frequency of vibrations of a body is equal to the frequency of external vibrations, the amplitude of forced vibrations becomes maximum. This phenomenon is called resonance.

Resonance *occurs when a body or system frequency of forced vibrations is equal to the natural frequency of a body.*

Dear learner let us proceed with the activity 12.

Activity 12

Aim: To investigate resonance in an air column.

Materials: Graduated cylinder, glass tube, tuning fork, thermometer and water

Procedures:

1. Fill a graduated cylinder with water.
2. Partially insert a glass tube open at both ends.
3. Strike a tuning fork of known frequency and hold it over the open end of the tube as shown in Figure 1.32.

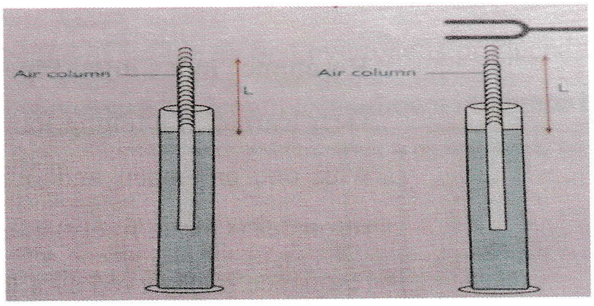


Figure 1.32: Resonance in a closed tube

4. Raise or lower the tube in the water to vary the loudness of the sound produced in the air column.
5. Note the point at which the loudest sound is produced.
6. Determine the length, L at which the loudest sound is produced.
7. Measure the room temperature using a thermometer

After performing the previous procedures attempt the following questions.

a) Determine the wavelength of the sound produced.

Calculate the speed of sound in air using the results obtained. Use the relationship $V = 331.5 + 0.60T(°C)$.

Water at the bottom of the tube acts as a seal, making the tube closed at one end. As the tube is raised or lowered, the volume of the sound produced will change. When the length of the air column produces a natural frequency of the tuning fork, resonance will occur. The volume of the sound will be relatively high.

Resonance in a Closed Pipe

Dear learner, if a tuning fork is sounded at the top of a tube with one end open and other closed, the air in the tube resonates (vibrate freely) at a certain length of the tube. The resonance is observed as a loud produced in the tube when the proper length is obtained. The first resonance occurs when air vibrates at its fundamental note or first harmonic as shown in Figure 1.33.

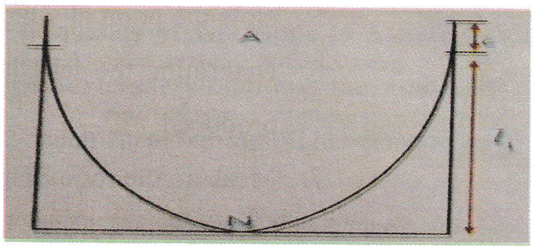


Figure 1.33: The fundamental note

The fundamental note consists of one - quarter cycle. The length

$$L_1 = \frac{1}{4}\lambda$$

In practice, the vibrations at an open end of a pipe extend into the free air, just outside. The actual position of associated displacement antinode is a short distance (C) beyond the end.

This distance is known as end correction. The effective length, L of the closed pipe is therefore L + C and that of open pipe is

L + 2C.

Considering the end correction $L_1 + C = \frac{1}{4}\lambda$

The second harmonic or first overtone is produced when the length is increased to length L_2 as shown in Figure 1.34.

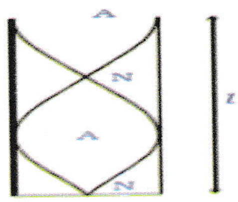


Figure 1.34: Second harmonic (first overtone)

The length $L_2 = \frac{3}{4}\lambda$ (neglecting end correction, C) and

$L_2 + C = \frac{3}{4}\lambda$ (With end correction, C)

Increasing the length of the tube will give the third resonance. This is the second overtone or third harmonic shown in Figure 1.35.

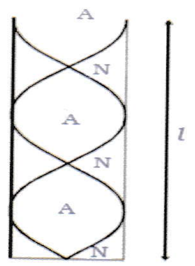


Figure 1.35: Third harmonic (second overtone)

The length $L_3 = \frac{5}{4}\lambda$ (neglecting end correction, C) and

$L_3 + C = \frac{5}{4}\lambda$ (With end correction, C)

Generally for any harmonic (n):

$L_n = (2n-1)\lambda \ or \ L_n + C = (2n-1)\lambda$

The frequency of vibrating air is the same as that of the tuning fork, and wavelength is calculated from the length of the tube.

Resonance in an Open Pipe

Dear leaner, I hope you have understood well about resonance in a closed pipe, now let us discuss the resonance in open pipes.

Open pipes have both ends open. An open pipe has antinodes on both ends. The fundamental note or first harmonic will be as shown in the Figure 1.36.

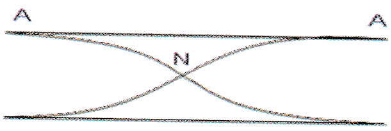


Figure 1.36: The fundamental note in an open pipe (first harmonic)

The length of tube, L_1 is equal to half the wavelength i.e. $L_1 = \frac{1}{2}\lambda$ but the tube has two end corrections, therefore

$$L_1 + 2C = \frac{1}{2}\lambda$$

The second harmonic or first overtone is obtained by increasing the length of the tube as in Figure 1.37.

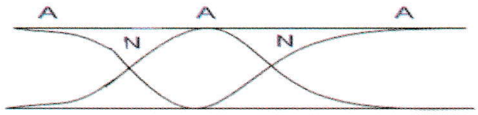


Figure 1.37: Second harmonic (first overtone)

The length of tube, L_2 is equal to wavelength i.e. $L_2 = \lambda$ but the tube has two end corrections, therefore $L_2 + 2C = \lambda$

Generally, for any harmonic(n) the length L_n and wavelength are related by the equation:

$$L_n + C = \frac{n\lambda}{2}$$

Dear learner, I hope you have understood the resonance in open and closed pipes. Now, let us observe the examples 10:

Example 10

A tuning fork of frequency 512Hz is sounded at the mouth of a tube closed of one end with a movable piston. It is found that resonance occurs when the column of air is 18cm long and again when the column is 51cm long. Determine the velocity of sound in air.

Solution

Given

Frequency (f) = 512Hz

Length (L_1) = 18cm

Length (L_2) = 51cm

Velocity (v) of sound is obtained using the equation $V = f\lambda$.

But λ is obtained as follows:

For a closed pipe $L_1 = \frac{1}{4}\lambda$ and $L_2 = \frac{3}{4}\lambda$ then

$$L_2 - L_1 = \frac{3}{4}\lambda - \frac{1}{4}\lambda = \frac{1}{2}\lambda$$

Therefore, $\lambda = 2(L_2 - L_1) = 2(51 - 18)cm = 66\,cm = 0.66\,m$

Then, $V = f\lambda = 512\,Hz \times 0.66\,m = 338\,m/s$

Example 11

In a closed pipe, the first resonance is at 23cm and second at 73cm. Determine the wavelength of the sound and the end correction of the pipe.

Solution

For a closed pipe

$$L_1 + C = \frac{1}{4}\lambda \Rightarrow 0.23m + C = \frac{1}{4}\lambda \quad \ldots\ldots (1)$$

$$L_2 + C = \frac{3}{4}\lambda \Rightarrow 0.73m + C = \frac{3}{4}\lambda \quad \ldots\ldots (2)$$

Solving equation 1 and 2 simultaneously we have:

$\lambda = 1\,\text{m}$ and $C = 0.02\,\text{m}$ or $2\,\text{cm}$

Example 12

A tuning fork of frequency 250Hz is used to produce resonance in an open pipe. Given that the velocity of sound in air is 350m/s, find the length of the tube which gives:

a) The first resonance.

b) The third resonance.

Solution

For an open pipe lengths of resonances are calculated from the equation $L_n = \frac{n\lambda}{2}$ but $\lambda = \frac{V}{f} = \frac{350\,m/s}{250\,Hz} = 1.4\,m$

a) The first resonance we have $L_1 = \frac{\lambda}{2} = \frac{1.4\,m}{2} = 0.7\,m$

b) The third resonance we have $L_3 = \frac{3\lambda}{2} = \frac{3 \times 0.7\,m}{2} = 2.1\,m$

Dear learner, now attempt the following Activity 13.

Activity 13

1. A pipe closed at one end has a length of 10cm. If the velocity of sound in the air pipe is 340m/s. Calculate the frequency of the:
   a) Fundamental.
   b) First overtone.
   c) Give reason why frequency of fundamental may change during the day?
2. Explain why the:
   i. pitch of the note from sounding organ pipe changes as the temperature rises.
   ii. same note produced by wind and string instruments has different quality.

Electromagnetic Spectrum

Dear learner, in the previous Unit you learned about two types of waves (mechanical and electromagnetic) wave. In this subunit you will learn about electromagnetic wave in detail.

Electromagnetic waves as you have learned in the previous part of this unit propagate through space or mater by the vibration or assimilation of an electric field and a magnetic field at right angles to one another. The waves travel perpendicularly to both electric and magnetic fields as seen in Figure 1.38.

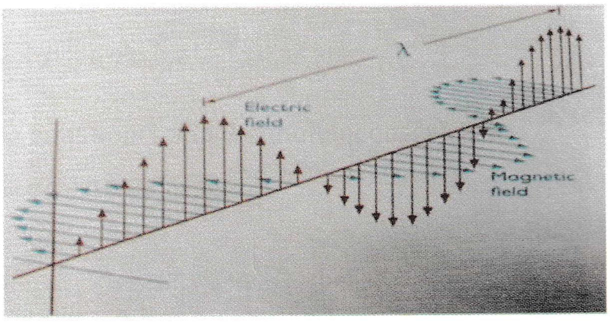


Figure 1.38: Electromagnetic wave

Electromagnetic waves are produced when electrically charged particles oscillate or change energy. The greater the energy changes, the higher the frequency of the resulting wave. In a vacuum, electromagnetic waves propagate at the speed of light.

Electromagnetic waves include radio waves, microwaves, infrared radiation, visible light, ultraviolet rays, x-rays and gamma rays.

Dear learner, let us now learn about properties of electromagnetic waves as follows:

i. They do not require a material medium to travel through.

ii. Like waves, they undergo reflection, refraction, interference and diffraction.

iii. All electromagnetic waves travel at the speed of light approximately 3×10^8 m/s in vacuum.

iv. They carry no electric charge.

v. They transfer energy from a source to a receiver in the form of oscillating electric and magnetic fields.

vi. They obey the wave equation $(C = f\lambda)$.

Electromagnetic Spectrum

Dear learner, electromagnetic spectrum is a continuous band of all electromagnetic waves arranged in order of increasing or decreasing frequencies or wavelength change. The electromagnetic spectrum can be divided into seven major regions or band as seen in the Table 1.3.

Table 1.3: Electromagnetic spectrum

Radiation	Approximate wavelength range / m	Approximate frequency range / Hz
Radio	> 0.1	< 3×10^{9}
Microwaves	0.1 - 1×10^{-3}	3×10^{9} - 3×10^{11}
Infra-red	1×10^{-3} - 7×10^{-7}	3×10^{11} - 4.3×10^{14}
Visible	4×10^{-7} - 7×10^{-7}	7.5×10^{14} - 4.3×10^{14}
Ultra-violet	4×10^{-7} - 1×10^{-8}	7.5×10^{14} - 3×10^{16}
X-rays	1×10^{-8} - 4×10^{-13}	3×10^{16} - 7.5×10^{20}
Gamma rays	1×10^{-10} - 1×10^{-16}	3×10^{18} - 3×10^{24}

The following observations can be made from the electromagnetic spectrum:

i. The electromagnetic spectrum is continuous such that each band merges into the next and there are no gaps in the frequencies. The different kinds of radiation gradually change from one another as their properties also gradually change.

ii. In some cases there is an overlap in the range of wavelengths. This is because sometimes the name given to the wave (radiation) is determined by the source and not the wavelength (or frequency) for example x-rays and gamma rays.

Dear learner, I hope you have understood about different bands of electromagnetic spectrum. Now, let us learn in detail one band after another.

1. Radio Wave

Radio waves have the longest wavelength in the electromagnetic spectrum. Radio waves can further be divided in long waves (LW), medium waves (MW) and short waves (SW). Short waves include very high frequency (VHF) and ultra-high frequency (UHF) waves.

Radio waves have frequencies from 300 GHz to as low as 3KHz and corresponding wave lengths ranging from 1 mm to 100 km.

Radio waves are generated by radio transmitters and received by radio receivers.

Sources of Dadio Waves

Radio waves are produced by:

i. Alternating electric currents flowing in special conductors called antennae.

ii. Special circuits called oscillators.

iii. Objects in space such as planets, comets, stars and galaxies.

Detection of Radio Waves

Radio waves are detected using specially designed antennae such as those used in radios and televisions.

Use of Radio Waves

Dear learner, the following are some uses of radio waves:

i. Broadcasting of information by radio and televisions channels.

ii. Astronomers use large telescope to collect and study radio waves from distant stars and galaxies.

2. Microwaves

Microwaves have short wavelength of between 10^{-4} m to about 0.1 m.

Sources of Microwaves

Microwaves are produced by oscillation of charges in special antennae mounted on dishes. Microwaves are also produced in devices called magnetrons.

Detection of Microwaves

Microwaves can be detected using special receivers which convert radio wave energy to sound. Radar which is an acronym for *radio detection and ranging* is a technology which uses radio waves to detect and determine the position of objects.

Uses of Microwaves

The uses of microwaves include the following:

i. Microwaves are used in cooking. In a microwave oven microwaves pass through the food and are absorbed by the food molecules. The absorbed energy causes the molecules to rapidly vibrate producing heat that heats or cooks the food.

ii. Radar (radio detection and ranging) system use microwaves to detect the position, speed and other characteristics of remote objects.

iii. Microwaves are used in long-distance communication because they are not affected by clouds or other atmospheric conditions.

3. Infra-red Waves

Infra-red radiation has a frequency of between 10^{12} Hz and 10^{14} Hz. Infra-red radiation lies between the visible light and microwaves in the electromagnetic spectrum. Infra-red radiations are close to the microwaves and have a heating effect.

Sources of Infra-red Waves

Infra-red radiation is produced by the vibration of atoms and molecules due to their thermal energy. All hot bodies emit infra-red radiation.

Detection of Infra-red Waves

Infrared radiation is invisible to the human eye. We can sense (far from visible light) infrared radiation as heat. If you hold your hand near an incandescent light bulb you can feel the infrared radiation being emitted. The devices used to detect infrared radiation include black bulb thermometers, photographic films, thermistors and photo transistors.

Uses of Infrared Waves

The following are some uses of infrared radiation:

i. Infrared radiation is used to cook food in conventional ovens and cookers.

ii. Infrared waves with wavelengths near the visible light are used in remote control, night vision devices and fibre-optic telecommunication.

iii. They are used in infra-red photography.

4. Visible Light

Visible light is the narrow range of electromagnetic wave frequencies to which human eyes are sensitive.

Sources of Visible Light

Visible light is produced by electron transitions within an atom. Approximately 50% of the radiation emitted by the Sun is visible light. We see objects because they either emit visible light or because they reflect visible light from another source.

Detection of Visible Light

Visible light is detected using the eyes, photographic films and photocells.

Uses of Visible Light

Visible light has many uses. These include vision, photography, and photosynthesis by plants.

5. Ultraviolet Light

Ultraviolet light has a shorter wavelength than visible light.

Sources of Ultraviolet Light

Ultraviolet radiation is produced by electron transitions in atoms like those that produce visible light, but more energetic. Ultraviolet is emitted by very hot objects. The Sun emits ultraviolet radiation. However, most of the ultraviolet radiation is absorbed by the atmosphere's ozone layer. Electric arcs used for welding also emit ultraviolet radiation.

Detection of Ultraviolet Light

The following are some of the devices which can be used to detect ultraviolet light.

i. Photographic films

Because ultraviolet light does not pass through ordinary glass, the camera must be fitted with quartz glass lenses.

ii. Fluorescent materials, which absorb ultraviolet light and re-emit it as visible light. Such materials glow on being struck by ultraviolet light.

Uses of Ultraviolet Light

The following are some of the uses of ultraviolet radiation

i. Ultraviolet radiation stimulates the production of vitamin D in the human skin. Vitamin D is essential in prevention of certain types of cancer and rickets.

ii. Ultraviolet radiation is also used in treatment of skin condition such as psoriasis.

iii. Ultraviolet is used as a germicidal agent in the sterilisation of food and purification of air and water.

iv. Fluorescent materials absorb ultraviolet radiation and re-emit it as visible light. In this way white materials are seen to glow. Reflective paints are made in this way. Some washing powders also contain fluorescent substances which glow in Sunlight making the clothes look brighter.

v. Ultraviolet radiation is used in banks to detect forged documents and fake currencies.

vi. Ultraviolet radiation is used extensibility in astronomical observations.

Warning: Prolonged exposure to solar ultraviolet can lead to damages on the skin, eye and the immune system.

6. X-rays

X-rays are electromagnetic waves with short wave lengths and very high frequency. X-rays are called ionising radiation because they can cause atoms and molecules with which they interact to lose one or more electrons, thus producing ions.

Sources of X-rays

X-rays are produced when electrons that have been accelerated to very high velocities hit a metal target. This process takes place in an x-ray tube.

Detection of X-rays

The following are some methods which can be used to detect x-rays.

i. Using a photographic plate.

ii. Using an x-ray film in a cassette.

iii. Using rare Earth element screens.

Uses of X-rays

The following are some uses of x-rays:

i. X-ray photography

When x-rays pass through a body they are better absorbed by dense tissues such as bone than by surrounding soft tissues. A pantograph of the emerging x-rays displays a shadow of the denser tissues.

ii. X-rays are used in the diagnosis and treatment of cancer.

7. Gamma Rays

Gamma rays are the most energetic of the electromagnetic waves. Like x-rays, they can cause ionisation in matter.

Sources of Gamma Rays

Gamma rays are produced in space by things such as solar flares, supernovae, neutron stars, black holes and active galaxies. Nearly all gamma radiation coming from space is absorbed by the Earth's atmosphere.

On the Earth, gamma rays are produced by radioactive decay of atoms (natural radioactivity) or nuclear fission (in atomic bombs and nuclear reactors).

Detection of Gamma Rays

Gamma rays can be detected using photographic films, Geiger - Muller tube or cloud chamber.

Uses of Gamma Rays

Gamma rays are the most penetrating of all radiations and have many of the same medical applications as x-rays.

Application of Electromagnetic Wave in Daily Life

Dear learner, electromagnetic waves are important in our daily lives as explained below:

i. Infra-red is a source of heat which is the favourable condition for growth of living organisms (plants and animals).

ii. Infra-red is used in drying objects.

iii. Visible light enables photosynthesis to take place in plants.

iv. Ultra- violet is one source of vitamin D in human beings.

v. X-rays are used to control pests and germs.

vi. Gamma rays are also used in agriculture to obtain new plant varieties which are disease-resistant and give more yields.

vii. Gamma rays are used for food preservation and sterilization. Food products are exposed to gamma radiation from the intense controlled sources to kills pests, bacterial, insects and parasites.

viii. Gamma rays are used in eradication of insect and pests. The best techniques for the control of insects and pests is Sterile Insect Technique (SIT).

Irradiation is used to sterilize mass-reared insects so that, while they remain sexually competitive, they cannot produce offspring. As a result, it enhances the crop production and preservation of natural resources.

Dear learner, I hope you have gained a lot in this unit, now do the following activity

Activity 14

1. Explain briefly how the concept of wave is applied in each of the following fields:
   a) Medicine.
   b) Scientific research.
2. A radio waves is a low-frequency light wave. Explain?
3. Explain why metals shine? Explain

Unit Reflection

Dear learner, now you have completed this Unit/ Reflect on the following questions to strengthen your knowledge about the Unit.

1. Do you think learning this Did you find this unit important to you? Give reasons.
2. Are there any applications of learning this unit in our real life activities? If yes what are they? Explain applicability of knowledge gained in this Unit in daily life.
3. Which part of this Unit have you understand more and why?
4. Which part in this Unit was more difficult to you and why?
5. What are your suggestions to improve the content of this unit?

Unit Assignment

1. A hospital uses an ultrasonic scanner to locate tumours in a tissue. What is the wavelength of sound in a tissue in which the speed of sound is 1.7km/s. The operating frequency of the scanner is 4.2MHz
2. A pendulum makes exactly 40 vibrations in 20 seconds. What is its period?
3. A periodic and repeating disturbance in a lake creates waves which emanate outward from its source to produce circular wave patterns. If the frequency of the source is 2Hz and the wave speed is 5m/s, calculate the distance between adjacent wave crest.
4. You learnt that light is electromagnetic wave that can travel through a vacuum. Can sound waves travel through a vacuum?
5. Explain briefly why sound produced in a hall with many people is heard more clearly than when the hall has few people.
6. An echo sounder produces a pulse and an echo is received from the sea - bed after 0.4 seconds. If the speed of the sound in water is 1500m/s, calculate the depth of the sea-bed.
7. Illustrate how plane water wave fronts are diffracted on passing through a narrow gap.
8. An old woman sitting in a gorge between two large cliffs gives a short sharp sound. She hears two echoes, the first after 1 second and the next after 1.5 seconds. The speed of sound is 340m/s, what is the distance between the two cliffs?
9. A girl standing 200m from the foot of a high wall claps her hands and the echo reaches her 1.16 seconds. Calculate the velocity of sound in air using this observation.

10. During a storm, explain why a flash of light is seen first before the sound.
11. (a) Why a musical note produced by an open pipe is softer than a note of the same fundamental frequency produced by closed pipe?

b) A steel wire hangs vertically from fixed point supporting a weight of 80N to its lower end. The length of the wire from fixed point to the weight is 1.5m; given the density of steel is $7800 kg/m^3$. Calculate the fundamental frequency emitted by the wire when it's plucked, if its diameter is 0.5 mm.

12. (a) Guitars have strings of varying thickness, which of the string (thickest, or thinnest) produce the highest frequency of musical notes? Explain.

    (b) A violin string has a length of 33cm and linear mass density of 6 g/m, and has fundamental frequency of 440 Hz. Find the;

    i. Wave velocity.
    ii. Mass of a string.
    iii. Tension in the string.

13. A closed pipe at one end has fundamental frequency of 400Hz, calculate the:

    a) Frequency of the first overtone.

    b) Fundamental frequency of an open pipe of the same length.

14. Explain why somebody gets Sun burn while in the shade of a beach umbrella?
15. Explain how electromagnetic wave is produced.
16. Radio wave is also a sound wave. Explain.
17. Explain why glass is transparent to visible light but not to ultra violet radiation and infrared radiation?

Unit 2

Applying Electromagnetism

Introduction

Dear learner, welcome to unit 2 of this Module. In the previous unit you learnt about waves. In that unit you learnt many concepts including types of waves. Can you use the two types of waves you have learnt? Well! Can you now briefly describe the electromagnetic waves? Very good!

In this Unit, we shall discuss about electromagnetism. This is a very interesting unit and very applicable in our daily life. Do you remember in modules of Stage 1 you learnt about Magnetism? Use a few minutes to share with your friend about magnetisation method. How many methods of magnetisation are there? Which method involves electric current? I hope you have noticed in your discussion that there is a relationship between electric current and magnetism, since electric current gives rise to magnetism.

***Electromagnetism** is the branch of Physics which deals with the study of relationship between magnetism and electric current.*

In general, we can obtain magnetism from electric current and also we can obtain electric current from magnetic field.

Electromagnetism can be expressed as the effect produced by the interaction of an electric current with a magnetic field. The interaction can result in a force causing the conductor carrying the current to move.

In this unit you are going to discuss electromagnetism in two parts, which are magnetic field due to a current carrying conductor and electromagnetic induction.

Learning Outcomes

Upon completion of this Unit, you will be able to:

- Explain how electric current produces magnetic field and identify the pattern of the magnetic field lines around a straight conductor;
- Determine the direction and presence of a force on a current - carrying conductor in a magnetic field;
- Determine the direction of force due to two current carrying conductors placed in a magnetic field;
- Explain the concept and the laws of electromagnetic induction;
- Explain the concepts of self and mutual induction and describe the mode of action of induction coil;
- Describe the mode of action of a.c and d.c generators and construct simple step-up and step-down transformers.

Magnetic Fields due to a Current Carrying Conductor

Dear learner, by now, the term magnetic field is familiar to you. You learnt it in Physics Module 5 of Stage I. Can you remind us what does it mean by the term magnetic field? Recall to your physics module 5 of stage I. Again, you have already learnt that an iron nail can be made a magnet by wrapping it with an insulated wire and the ends are connected to the battery. In this experiment, an iron core acts as the bar magnet temporally where you can trace its polarity (South Pole and North Pole). Consider the Figure 2.1.

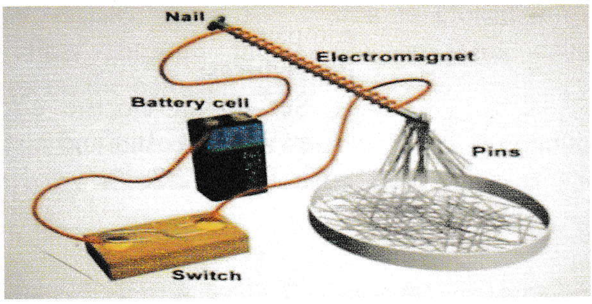


Figure 2.1: Magnetic fields due to current carrying conductor

From Fig.2.1we observe that; when an insulated wire is wrapped around the soft iron core and the ends are connected to the battery, the iron core becomes capable of picking up small pins. The iron core loses most of its magnetism when the current is switched off.

Hence, the conductor (wire) has magnetic field only when it conducts current. If no current is conducted by the conductor (wire), the conductor (wire) produces no magnetic fields.

Magnetic field *due to current carrying conductor is the magnetic field produced by the conductor when that particular conductor conducts the electric current.*

The activity 1 is used to demonstrate that an electric current produces a magnetic field.

Activity 1

Aim: To demonstrate that an electric current produces magnetic field.

Materials: Battery, switch, rheostat, wire and magnetic compass.

Procedures:

1. Set up an electric circuit composed of a battery, switch, rheostat and a straight piece of wire as shown in Figure 2.2.

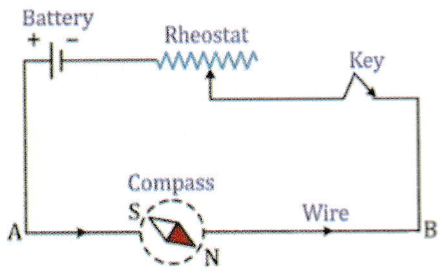


Figure 2.2: A compass on a wire carrying current

2. Hold a magnetic compass directly above wire AB and move the wire until it is in line with compass needle.
3. Close the switch to cause an electric current to flow from the positive terminal of the battery to A and on the B and return to the negative terminal of the battery. Record your observations.
4. Use the rheostat to increase and then decrease the current. Record your observations.
5. Raise the compass above the wire.
6. Open the switch and place the compass below wire AB. Close the switch. Record your observations.
   Reverse the battery and repeat the steps 1-6.

   Attempt the following exercise:
   a) What happens to the compass needle when the switch is closed?

   b) What happens to the compass needle when the current is increased and then decreased?

c) What happens to the deflection of the needle as the compass gets further from the wire?

Observation from Activity 1

We observe that, when the switch is closed, an electric current flow through the conductor. This causes the deflection on the compass needle.

The magnetic field around a current carrying conductor can be shown by means of magnetic field lines as shown in Figure 2.3

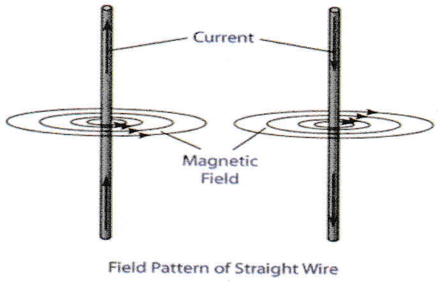


Figure 2.3: Magnetic field patterns around a conductor

Dear learner, magnetic field pattern can also be represented by a plan view. In the plan view, the conductor is represented by a circle. A dot in the circle shows that the current is coming out of the plane while a cross in the circle shows that the current is moving into the plane as shown in Figure 2.4.

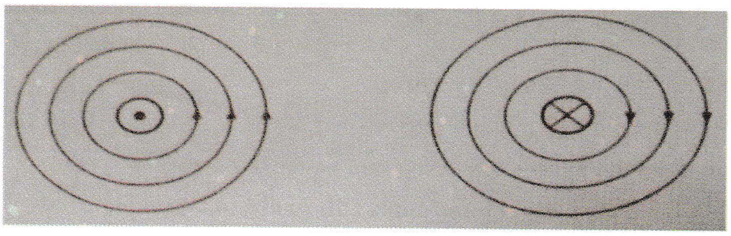


Figure 2.4: Plan view of magnetic field pattern around a conductor

The strength of magnetic field depends on the magnitude of the electric current. The higher the current the stronger the magnetic field and therefore the greater the deflection.

The strength of the magnetic field decreases as you move further from the conductor. There will be less deflection as the compass is drawn from the current - carrying conductor.

The Direction of Magnetic Field for a Straight Conductor

The direction of magnetic field created by the current flowing in a straight conductor is determined by applying the following two rules.-

i. The right -hand grip rule.

ii. The Maxwell's cork screw rule.

i. The Right-hand Grip Rule

The right-hand grip rule can be applied to a straight conductor or a solenoid carrying an electric current.

For the straight conductor:

The right-hand grip rule states that *"If you wrap your right hand around a straight wire with your thumb pointing in the direction of the electric current, then your fingers would be curling in the direction of the magnetic field."*

The rule is as shown in Figure 2.5.

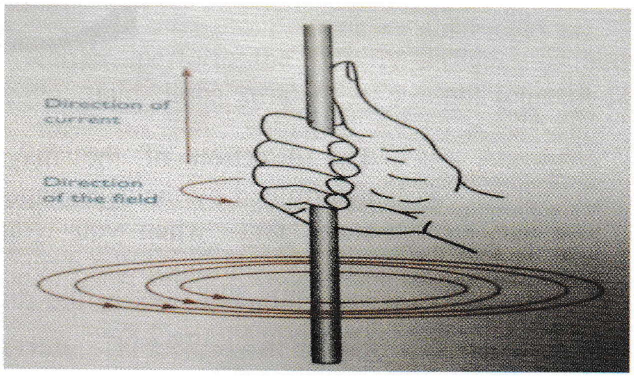


Figure 2.5: Right-hand grip rule

ii. The Maxwell's cork screw rule

Maxwell's cork screw rule states that, *"If a cork is screwed in the direction of the circulating current, then its end point moves in the direction of the magnetic lines of force"*

Consider Figure 2.6.

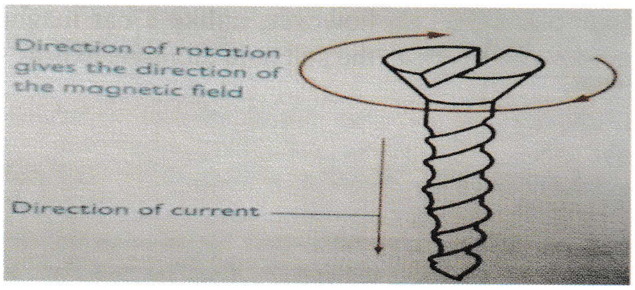


Figure 2.6: Maxwell's right-hand screw rule

For the solenoid, a solenoid is a long coil containing a large number of turns of insulated copper wire as shown in Figure 2.7.

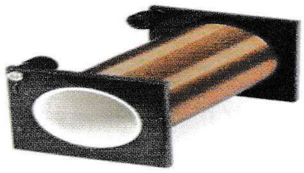


Figure 2.7: A solenoid

The direction of the magnetic field in a solenoid is determined by the right-hand grip rule for a solenoid which states that "when you wrap your right hand with your fingers pointing in the direction of the convectional current, your thumb points in the direction of the North pole." As shown in Figure 2.8.

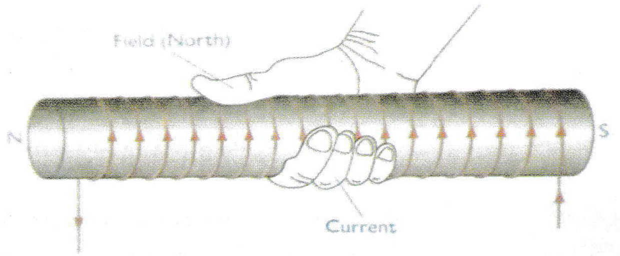


Figure 2.8: Right-hand grip rule for a solenoid

The magnetic field produced by current carrying solenoid is similar to the magnetic field produced by a bar magnet, however, unlike a bar magnet, the field lines pass through the solenoid along its axis as shown in Figure 2.9

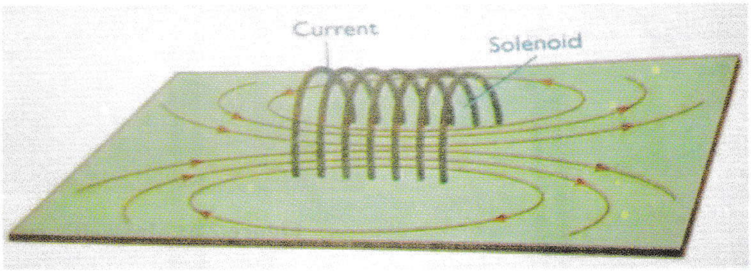


Figure 2.9: Magnetic field pattern generated by a solenoid

If current carrying solenoid is suspended freely, it comes to rest pointing North and South like a suspended magnetic needle. One end of the solenoid acts like North Pole and the other end as South Pole.

The strength of the magnetic field produced by a current carrying solenoid is directly proportional to the number of turns in the solenoid and the magnitude of the current flowing through the solenoid.

Dear learner, perform the activity 2 which is about the magnetic field lines around a straight current-carrying conductor.

Activity 2

Aim: To observe the magnetic field lines around a straight current-carrying wire.

Materials: Battery, switch, rheostat, wire, cardboard, iron fillings and magnetic compass.

Procedures:

1. Construct an electric circuit and run wire AB through a sheet of cardboard.
2. Close the switch so that current flows.
3. Gently shake iron fillings onto the cardboard around the wire as shown in Figure 2.10.

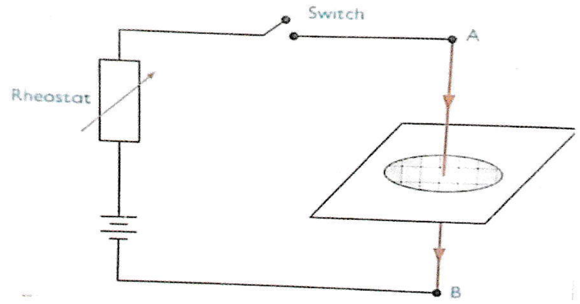


Figure 2.10: INSERT A TITLE

Observe the pattern formed.

4. Hold a compass at various locations around the wire and observe whether the patterns are clockwise or anticlockwise as in Figure 2.11

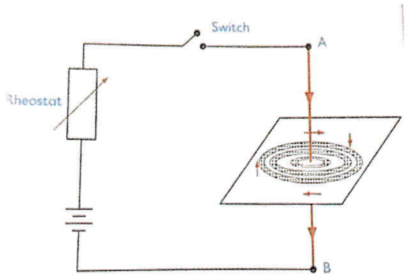


Figure 2.11

What types of patterns are formed?

Observation from the Activity 2

Dear learner, from the activity 2 in Fig.2.11, we observe that Iron fillings seem to form concentric circles around the wire on the cardboard. These circles represent the magnetic field lines. The direction of these lines can be traced by using Fleming right-hand grip rule or Maxwell's right hand screw rule.

Note

Fleming's right hand rule states that, *"If three fingers of the right hand are held mutually perpendicular to each other, then the thumb points in the direction of motion, fore finger (index finger) points in the direction of the field then the middle finger points in the direction of the induced current"*

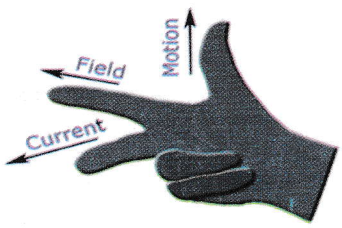


Figure 2.12: Fleming's right hand rule

Force on a Current Carrying Conductor in a Magnetic Field

Dear learner, a current carrying conductor experiences a force when placed in a magnetic field. If the conductor is freely suspended in the magnetic field, the force on it causes it to move.

This can be demonstrated as directed in the activity 3.

Activity 3

Aim: To investigate Fleming's left-hand rule

Materials: U-shaped magnet, two rigid copper rods (about 2 mm diameter and 2cm long), one piece of rigid copper rod(about 5cm long), wooden block (10cm x 10cm x 5cm), three size D-dry cells, switch and connecting wires.

Procedures:

1. Bend the two copper rods at the end (about 2cm from the end) to form L-shapes.
2. Fix the copper rods on the wooden block as shown in Figure 2.13.

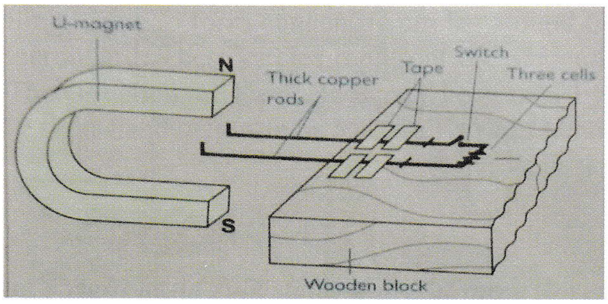


Figure 2.13: Two parallel copper rods carrying current

Note that:

The two rods should be separated by a distance of about 3cm and should also be parallel.

3. Bend the ends of the shorter copper rod. Place the rod at the ends of the two parallel copper rods.
4. Connect the set-up in a circuit as shown in Figure 2.14.

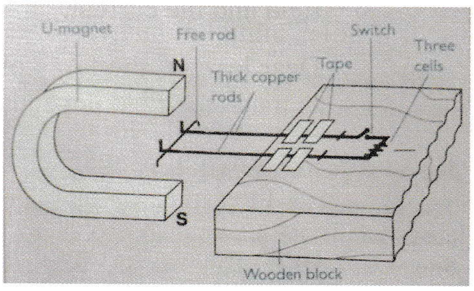


Figure 2.14: A free rod on parallel copper rods

5. Close the switch and observe the motion of the free copper rod.
6. Open the switch and rotate the magnet through 180^0 so that the South Pole is on the upper side.
7. Close the switch and again observe the motion of free copper rod.
8. Open the switch and return the magnet to its original orientation.
9. Reverse the direction of current by changing the orientation of the batteries.
10. Close the switch and observe what happens to the free copper rod. Record all your observations.

From the activity 3 describe the movement of the free copper rod in each case.

Observation from the Activity 3

From the activity 3 we observe that; the direction of magnetic field is perpendicular to that of the current.

The direction of the field is up and down while the direction of the current is on the orientation of the free rod which is horizontal.

When the switch is closed, the free rod moves either away or towards the block. This shows that, the force on the conductor (copper rod) is perpendicular to both the magnetic field and the current.

Dear learner, the force of current carrying conductor placed in magnetic field depends on the following factors:

a) Strength of magnetic field, the more the field, the large the force.

b) Amount of current flowing in the conductor. The large the current, the large the force.

c) Length of a conductor. The longer the conductor, the larger the force.

d) Sin of the angle $(Sin\theta)$ between the conductor and the field lines passing through it.

Fleming's Left hand Rule

Dear learner, in this part we are going to discuss the direction of force experienced by current carrying a conductor placed in a magnetic field. As we have discussed in the experiment (activity 3), current carrying wire experiences force when subjected to magnetic field. The directions in which that force acts are given by Fleming's left hand rule.

This rule is used to deduce the direction of force acting on current carrying conductor placed in a magnetic field.

Fleming's left hand rule states that, *"if you hold the index finger, the middle finger and the thumb of your left hand mutually perpendicular to each other so that the index finger points in the direction of magnetic field and the middle finger points in the direction of current in the conductor, then the thumb will point in the direction of the force acting on the conductor".*

The law is as described in Figure 2.15.

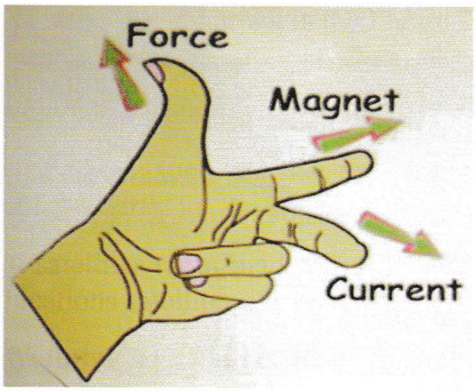


Figure 2.15: Fleming's left hand rule

Force between two Parallel Current Carrying Conductors

Consider two parallel current carrying conductors placed in neighbourhood such that some amount of current flow through the two conductors.

Each conductor will experience the force depending on the direction of the currents.

Case I

When the currents are moving in the same direction, the strips of the conductors attract each other.

When the currents flow in the same direction, the magnetic fields between the conductors cancel out, thus reducing the net field. However, on the outside the magnetic fields add up, thus increasing the net field.

Therefore, the magnetic field is weaker between the conductors than on the outside. The resultant force pushes the conductors toward each other. Consider Figure 2.16 (a)?

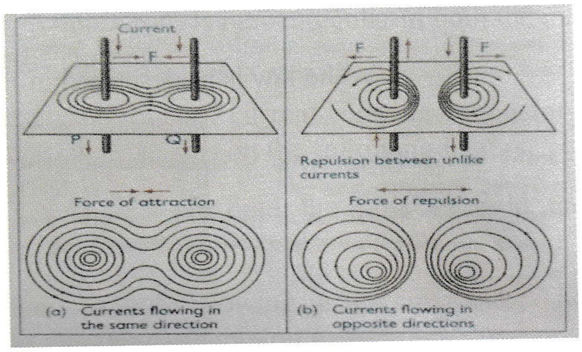


Figure 2.16 (a): Force between parallel current-carrying conductors

Case II

When the currents are moving in opposite directions, the strips of the conductors repel each other as shown in Figure 2.16 (b).(where is the said figure?)

When the currents are in opposite directions, the fields between the conductors add up, while they cancel out on the outside. The field between them is stronger than on the outside. The resultant force is towards the outside of each conductor, hence repulsion.

The direction of the force between two parallel conductors carrying currents can be demonstrated in the laboratory as guided by the activity 4.

Activity 4

Aim: To determine the direction of force produced by two parallel current - carrying conductors.

Materials: Two insulated copper wires (50cm long) without kinks, dry cells, a switch, connecting wires, crocodile clips, two blocks of wood (10cm x 5cm x 5cm) and thumb pins.

Procedures:

1. Secure the wooden blocks on the bench using adhesive tape. The distance from the end of one wooden block to the other should be about 50cm.

2. Stretch the copper wires between the wooden blocks and secure them in place using thumb pins.

3. Set up the materials as shown in the Figure 2.17.

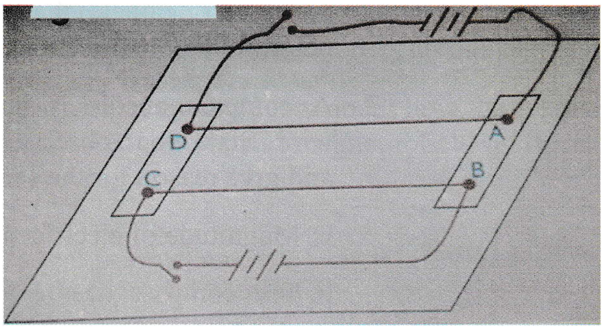


Figure 2.17: Insert a title

The connecting wires are connected to DC and BC and to the DC source with crocodile clips.

4. Close both switches and observes the behaviour of conductors AD and BC.

5. Open the switches and reverse the orientation of one set of the batteries so that the current through conductors AD and BC is in the same direction. Observe the behaviours of the two conductors.

Having learned from activity 4, explain the movements of the two copper wires when the currents are moving in:

a) opposite directions.

b) the same directions.

Observation from the Activity 4

From the activity 4, we observed that; when the currents are flowing in opposite directions, the conductors repel one another while when the currents are flowing in the same directions in the conductors, the conductors attract each other.

Dear learner, do the following exercise.

Activity 5

1. Describe the error that results from accidentally using your left rather than your right hand when determining the direction of a magnetic force.
2. A compass needle is placed near current carrying wire. State your observation for the following cases and give reason for the same in each case.
   i. Magnitude of electric current in wire is increased.
   ii. The compass needle is displaced away from the wire.
3. State the rules for finding the direction of the magnetic field produced around a current carrying conductor.
4. Describe the shape of the magnetic field lines around a current carrying straight conductor.

Electromagnetic Induction

Concept of Electromagnetic Induction

Dear learner, in the previous subunit you have learned that an electric current flowing through a conductor can produce magnetic field. The reverse of this also takes place such as a conductor moving through a magnetic field will have an electric current produced in it. An electric current will also be produced in the conductor if it is held stationary while the magnet is moving near the wire (the magnetic field changes).

Electromagnetic induction *is the production of an electromotive force (e.m.f) whenever there is a change in the magnetic field (magnetic flux) linking a conductor.*

Or

Electromagnetic induction is the production of an electromotive force across the conductor when it is exposed to a varying magnetic field. The e.m.f produced is called *induced e.m.f* and the resulting current is called *induced current*. Whenever there is a relative motion between a conductor (wire) and magnetic field such that the conductor cuts the magnetic field lines, there is an induced current.

Dear learner, let us now learn about how the relative motion between the conductor and magnetic field produces induced current.

1st Case in Upward Motion

Whenever there is a relative motion between the conductor and magnetic field, an induced current is produced. This is because there is a change in the magnetic flux linking a conductor.

2nd Case in Downward Motion

The current produced by the movement in one direction reverses when the direction of motion is reversed; hence current is induced as seen in Figure 2.8.

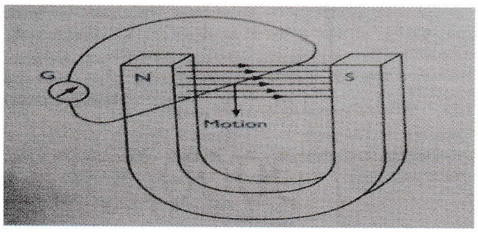


Figure 2.8: Downward motion-current induced

3rd Case Horizontal Motion

When the motion is such that the conductor is parallel to the field lines no current is produced as seen in Figure 2.19.

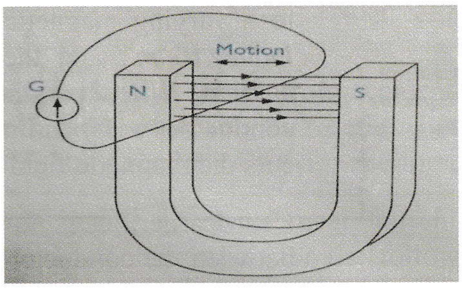


Figure 2.19: Horizontal motions-no current induced

What is demonstrated in Fig. 2.19 happens because the flux linking the conductor (wire) does not change.

An induced current and induced e.m.f is as a result of change of magnetic flux linking the conductor. It is not important what moves the magnet or conductor, so long as there is change of flux an induced current (or e.m.f) is produced.

Laws of Electromagnetic Induction

Dear learner, there are two laws of electromagnetic induction which are:

a) Lenz's law.

b) Faraday's law.

a) Lenz's Law

This law explains the direction of induced e.m.f.

Lenz's law states that *"the direction of induced e.m.f is such that the resulting induced current flows in such direction that oppose the change that cause it."* *OR*

"The direction of an induced current is always such that it opposes the change causing it".

This means that, the current is opposing the movement of the magnet (by trying to repel it). According to the Lenz's law, the following were observed:

1. When North Pole approaches to the end of the coil, the current in the coil flows such that a North Pole is formed at that end. When the North Pole is moved away, a South pole is formed as seen in Figure 2.20.

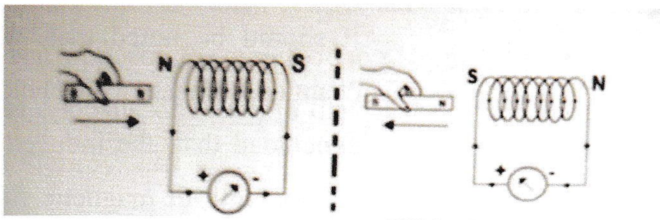


Figure 2.20: Lenz's law first observation

2. When South Pole is pushed towards the coil, a South pole is formed at the end of the coil, and when the South Pole is moved away, a North Pole is formed as seen in Figure 2.21.

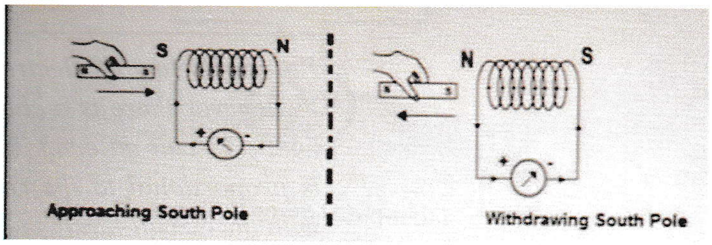


Figure 2.21: Lenz's law second observation

b) Faraday's Law

Faraday's law of electromagnetic induction relate the magnitude of induced e.m.f and the rate of change of the magnetic flux linking the conductor. The magnitude of the induced e.m.f and current increases with the increase in:

i. Speed of motion of the magnet or coil.
ii. The number of turns on the coil.
iii. The strength of the magnet.
iv. The cross section area of the conductor.

It should be noted that, when one parameter was being changed, others were held constant. We can therefore concluded that, the induced e.m.f (E) increases with speed (v), strength of magnetic field, number of turns in the coil and the cross-sectional area (A) of the coil. It can also be shown that winding the coil on a soft - iron core increases deflection of the galvanometer. Each of these factors causes a change in the magnetic flux linking the coil. This is the basis of Faraday's law of electromagnetic induction.

Faraday's law of electromagnetic induction states *that "whenever there is a change in the magnetic flux linked with a circuit an e.m.f. is induced, the strength of which is proportional to the rate of change of the flux linked with the circuit".*

Self-induction and Mutual Induction

Dear learner, I hope you have gained a lot, let us now learn about self-induction and mutual induction.

i. Self-Induction

When the current flowing in a conductor, there is a change in the magnetic flux linked with the conductor itself which produces an e.m.f in the conductor. This phenomenon is called *self-induction.*

***Self-induction** is defined as a phenomenon where by an induced e.m.f (back e.m.f) is produced within the same conductor when an a.c flows through the conductor.*

The induced e.m.f is called self-induced e.m.f or back e.m.f because it opposes the e.m.f of the supply and its current flows in opposite direction to that of the original current as seen in Figure 2.22.

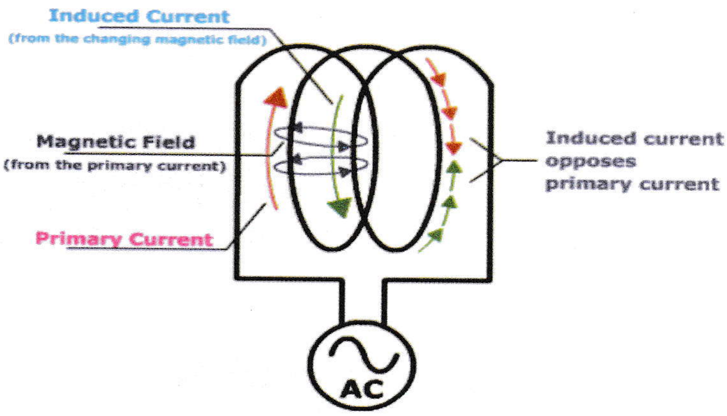


Figure 2.22: Self-induction

ii. Mutual Induction

When two coils are placed near each other, a varying (the change) current in one coil will induce a current in the other. This is called *mutual induction.*

The coil with a changing current is referred to as the primary coil while that in which current is induced is the secondary coil as shown in the Figure 2.23.

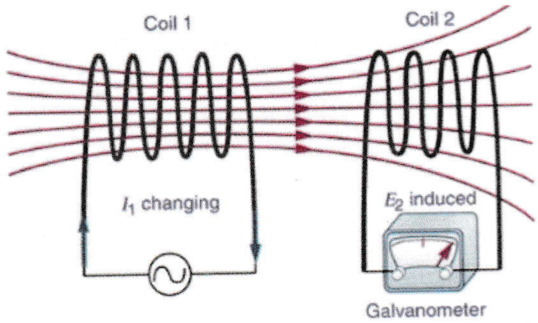


Figure 2.23: Mutual induction

In the Figure 2.24, the current in the primary coil is increased. This produces an increase magnetic flux in the secondary coil. In response, there is an induced e.m.f in the secondary coil producing current that in turn produces a magnetic field in opposition to the primary coil as seen in Fig. 2.23.

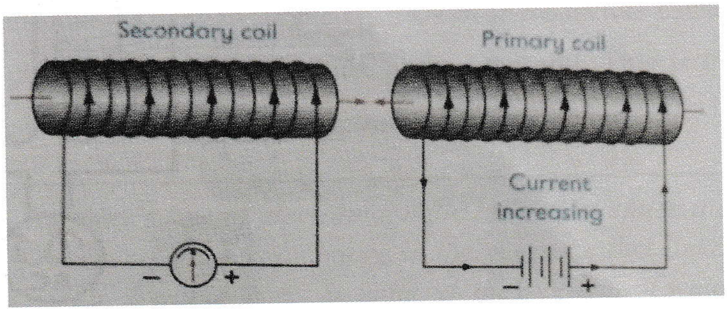


Figure 2.23: Increasing current in primary coil opposing current induced in secondary coil

The e.m.f induced in the secondary coil is proportional to the rate of change of the current in the primary coil.

Application of Electromagnetic Induction

Dear learner, I hope you have observed that electromagnetic induction is applicable in real life situations. do you think the knowledge of electromagnetic induction is applicable in our real life situations? If yes good! Now let us learn it here below.

Electromagnetic induction is applied in the working of:

1. Induction coil.
2. Production of eddy current.
3. Electric generator.
4. Transformer.

Now, do the following activity 6

Activity 6

1. State five ways by which the electric motor can be made to rotate faster.
2. Explain the term back e.m.f.

Induction Coil

Dear learner, an induction coil is an electrical device consisting of two coils; the primary coil and the secondary coil, wound one over the other on an iron core. It is used to produce high voltage alternating current from low direct current.

The primary coil is made up of tens or hundreds of turns of thick wire while the secondary coil consists of thousands of turns of fine wire. The secondary coil is wound on top of the primary coil as shown in Figure 2.24.

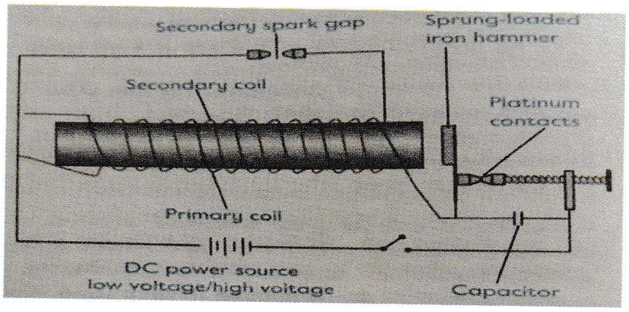


Figure 2.24: An induction coil

Mode of Action

An induction coil uses electromagnetic induction to produce high voltage in its secondary coil. The direct current in the primary coil is switched on and off by a make and break mechanism. This produces changes in current and magnetic field which are necessary for electromagnetic induction to occur in the secondary coil.

When the current in primary coil is switched on, the induced magnetism in the iron core attract the soft iron armature. The moving armature opens a gap between the two contacts which breaks the primary coil circuit. This switches off the current.

As the induced magnetism fades away, the armature springs back closes the contacts and completes the circuit again. This allows the current to flow in the primary coil again and this cycle of events repeats automatically.

The induced e.m.f is very large, usually in the order of hundreds of kilovolt (kv), such a high voltage is achieved because of two things;

1. The secondary coil has a large number of turns compared to the primary coil.
2. The rapid change in the primary current when switched on and off causes a rapid change in the magnetic field through the secondary coil.

Applications of the Induction Coil

1. An induction coil is commonly used in the ignition system of internal combustion of engines.
2. A smaller version of an induction coil is used to trigger the flash tubes used in camera and strobe light.
3. It is used in wireless telegraphy.
4. It is used in operating x-ray machines.
5. It is used in investigation of high voltage and conduction of electricity through gases (electric discharge).

Generators

Dear learner, in the previous lesson you learnt that an e.m.f is induced in a conductor in a magnetic field wherever there is a change in the magnetic flux linking the conductor. According to Lenz's law, this change is always opposed by a force so that work must be done to generate the e.m.f. Now, let us discuss about generators. Do you think electricity can be produced by using batteries only? Let us discuss together to get facts on this.

The generator *is an electrical device which produces electricity using the principle of electromagnetic induction by continuous motion of either a coil or a magnet.*

It converts mechanical energy to electrical energy. The generators can be in two main groups namely:

i. Alternating current generator (alternator) (a.c generator)

ii. Direct current generator (dynamo)

i. A.C Generators (Alternator)

An a.c generator utilizes the law of electromagnetic induction spinning a coil at a constant rate in a magnetic field to produce or induce an oscillating e.m.f.

The alternating current generator consists of an armature made up of several turns of insulated wire would on a soft iron core. The armature revolves freely on an axis between the poles of a powerful magnet which provides a strong magnetic field. Two slip rings are connected to the ends of the armature and two carbon brushes rest on the slip rings as shown in Figure 2.25.

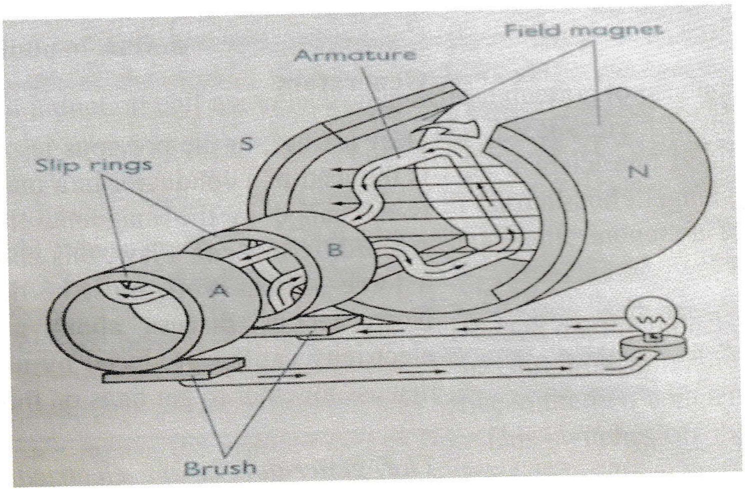


Figure 2.25: A simple a.c generator

When the coil is vertical, no cutting of magnetic lines of force takes place although the number of lines linking the coils is maximum.

The rate of change of magnetic flux is zero and as a result, no e.m.f is induced in the coil as shown in Figure 2.26.

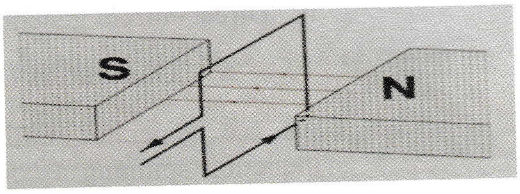


Figure 2.26: Coil vertical no. e.m.f induced

When the armature is parallel to the magnetic field, the rate of change of magnetic flux is maximum and the motion of the coil is perpendicular to the magnetic field hence an e.m.f is induced along the sides of the coil as shown in Figure 2.27.

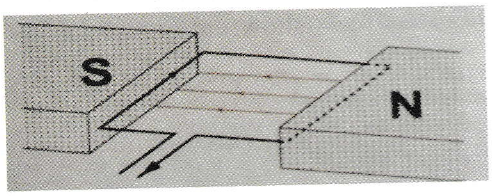


Figure 2.27: Coil horizontal: maximum e.m.f induced

After a 180^0 turn, starting from the vertical position, the sides of the loop interchange and the current in the loop is reversed. This means that the e.m.f is positive for one half of the cycle and negative for the other half.

The maximum induced e.m.f is at 90^0 rotations from the vertical position and the minimum (maximum negative) is at 270^0 rotation. If there is an external circuit, the current through it would also have a maximum value at 90 as in Figure 2.28.

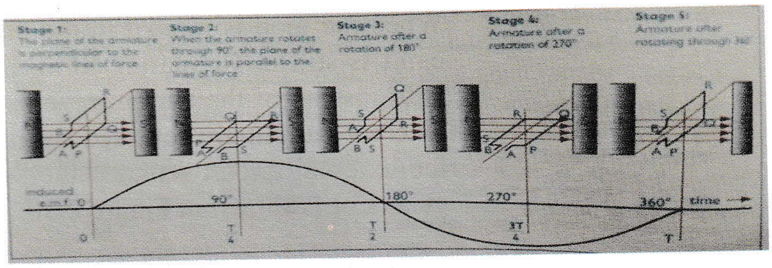


Figure 2.28: Stages of a.c generator

Minimum at 270^0, the kind of current obtained is called an alienating current and the corresponding voltage (e.m.f) is the alternating voltage.

The number of cycles produced per second is called frequency of the a.c. The alternating current obtained is led to an external circuit through the slip rings and the carbon brushes.

ii. D.C Generator (Dynamo)

Dear learner, a d.c generator is made by replacing the slip rings in the a.c generator with a commutator. Each half of the commutator ring is called a commutator segment and is insulated from the other half. Each end of the rotating loop of wire is connected to a commutator segment. Two carbon brushes connected to the outside circuit rest against the rotating commutator.

In d.c generator, the commutator rotates with loop of wire just as the slip rings do with the rotor of an a.c generator.

Figure 2.29 shows a simple d.c generator.

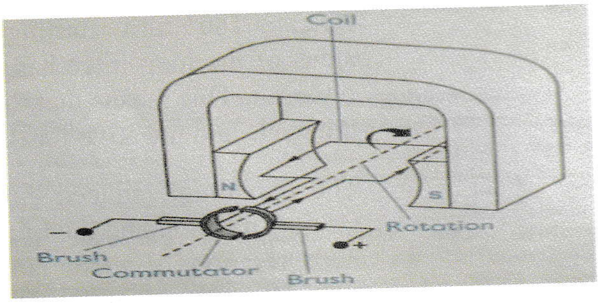


Figure 2.29: A d.c generator

When the loop is rotated in the magnetic field, the induced e.m.f is still in alternating form. However, after rotation of 180^0 instead of the current reversing, the connections to the external current are reversed so that the current direction in the external circuit remains the same. The output of a d.c generator is shown in Figure 2.30.

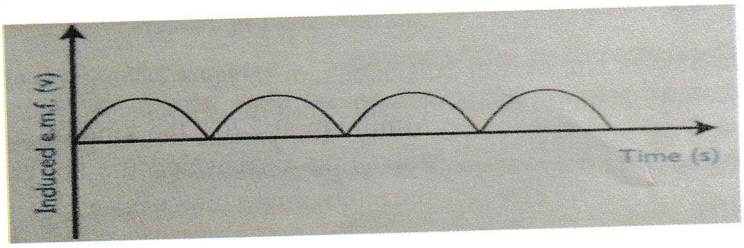


Figure 2.30: Output of d.c generator

Dear learner, note that the lower half cycle is not cult-off but it is reversed.

Advantages of A.C Generator

The following are some advantages of a.c generators over d.c generators:

1. Commutators are complex and costly to construct hence many d.c generators are being replaced by the a.c generators with electronic rectifiers.

2. Transformers work on a.c only. Transformers help in conservation of electric power during transmission by allowing it to be stepped up, then down.

3. Frequency of a.c generator is very precisely controlled hence we can have motor with accurate speed. Such those motors used in electric clocks, tape recorders and so on.

Dear learner, the magnitude of the e.m.f in generator can be made large by:

1. Using coil of large number of turns.
2. Winding coil on soft iron core to maximize magnetic flux.
3. Increasing the speed of rotation of coil.
4. Using strong magnets for the strong magnetic fields.

Dear learner, I hope you have understood about generators. Now, do the following activity 7.

Activity 7

1. What structural differences are there between d.c and a.c generator?
2. What are the purposes of:

   (a) The armature;

   (b) Brushes;

   (c) Accumulator of a d.c generator.
3. Explain briefly how the magnitude of e.m.f induced in a.c generator can be improved.
4. List four devices in which the generators are used in daily life.

The Transformer

Dear learner, let us proceed with another part of this unit which is about transformers. Do you know what the use of transformers is? If no relax! We are going to discuss it very well. You are welcome.

Transformer *is a device which changes an alternating voltage from one value to another of greater or smaller value using mutual induction.*

A transformer is made up of two coils each with a different number of loops, linked by an iron core so that the magnetic flux from one passes through to the other. When the flux generated by one coil changes (as it does continuous in an a.c power source) the flux passing through the other will change, inducing a voltage in the second coil.

In a standard transformer, the two coils are usually wrapped around the same iron core ensuring that the magnetic flux is the same through both coils. The coil that provides the flux, that is the coil connected to the a.c power source, is known as the primary coil. The coil in which the voltage is induced is known as the secondary coil.

When the number of turns in the secondary coil (Ns) is higher than the number of turns, in primary coil (Np), the secondary voltage will be higher than the primary voltage. This is called *a step up transformer.* Figure 2.31 shows the step-up transformer.

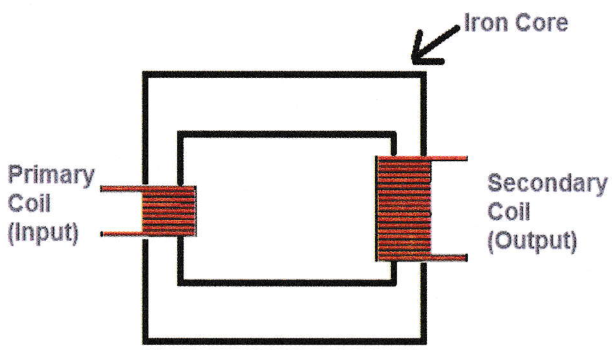


Figure 2.31: A step-up transformer

When the number of turns in the secondary coil is less than those in the primary coil, the primary voltage is greater than the secondary voltage.

This is known as a step-down transformer. Figure 2.32 shows the step-down transformer.

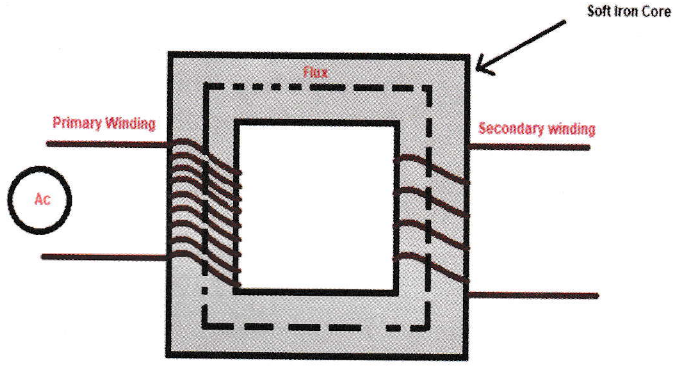


Figure 2.32: A step-down transformer

The Transformer Equation

Dear learner, we have already seen that the e.m.f induced in a coil depends on the number of turns in the coil. In fact it can be shown that the e.m.f is directly proportional to the number of turns. In transformer all the magnetic flux in the primary coil links the secondary coil (ideal situation).
The primary p.d (Vp) is connected to the primary coil of turn (Np) while the secondary pd (Vs) is taken from the secondary coil of turn (Ns).

Therefore, $V_p \alpha N_p$ and $V_s \alpha N_s$ this means that:

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

Assuming that the loss of power in the transformer is negligible, the power in the primary coil is equal to the power in the secondary coil i.e.

$$I_p V_p = I_s V_s$$

Where I_p *and* I_s are the primary and secondary currents respectively.

Therefore,

$$\frac{V_p}{V_s}=\frac{N_p}{N_s}=\frac{I_s}{I_p}$$

This equation shows that, when the voltage in transformer is stepped up, the current is stepped down and vice versa.

Transformer Efficiency (ε)

Dear learner, transformer efficiency (ε) is the ratio of power in secondary coil (Ps) to power in primary coils (Pp) expressed as percentage.

$$Efficiency(\varepsilon)=\frac{P_s}{P_p}\times 100\%$$

But $P=IV$

$$\varepsilon=\frac{I_sV_s}{I_pV_p}\times 100\%$$

Dear learner, I hope you have understood well about transformer. Now, let us do some examples.

Example 1

A transformer is used to step down 240V mains supply to 12V for laboratory use. If the primary coil has 600 turns, determine the number of turns in the secondary coil.

Solution;

Given;

Primary voltage (Vp) = 240V

Secondary voltage (Vs) = 12V

Number of turns in primary (Np) = 600

Number of turns in secondary (Ns) is calculated from a transformer equation $\frac{N_p}{N_s}=\frac{V_p}{V_s}$.

Make Ns the subject and substitute the values.

$$N_s=\frac{V_s\times N_p}{V_p}=\frac{12V\times 600}{240V}=30$$

Example 2

A step up transformer has 10,000 turns in the secondary coil and 100 turns through the primary coil. An alternating current of 5.0A flows in the primary circuit when connected to a 120V a.c supply.

a) Calculate the voltage across the secondary coil.

b) If the transformer has an efficiency of 90%, what is the current in the secondary coil?

Solution;

Given;

Number of turns in secondary (Ns) = 10,000

Number of turns in primary (Np) = 100

Current in primary coil (Ip) = 5.0A

Voltage in primary (Vp) = 12V

(a) Voltage in secondary (Vs) is calculated from transformer equation $\frac{N_p}{N_s} = \frac{V_p}{V_s}$. Make Vs the subject and substitute the values, we have:

$$V_s = \frac{N_s \times V_p}{N_p} = \frac{10000 \times 12V}{100} = 1200V$$

(b) Current in secondary coil is calculated from the formula $I_s = \frac{P_s}{V_s}$

But power in secondary (Ps) is obtained from the formula

$\varepsilon = \frac{P_s}{P_p} \times 100\%$ and power in primary is

$$P_p = I_p \times V_p = 5.0A \times 12.0V = 60W$$

Then,

$$P_s = \varepsilon \times P_p = \left(\frac{90}{100}\right) \times 60W = 54W$$

Therefore,

$$I_s = \frac{P_s}{V_s} = \frac{54W}{1200V} = 0.045A$$

Uses of a Transformer

Dear learner, transformers are used in power stations to step up voltage for transmission from the station to the area of consumption. The stepping up reduces the current so that losses due to resistance in the transmitting wires are reduced. Transformers are used in television sets, radios, telephones and laboratories to obtain a 12 volt supply on benches. A bell transformer can be used to ring electric bells. It steps down the 230V a.c mains supply to 4 V.

Dear learner, I hope you have understood well about transformers. Now, do the following Activity 8.

Activity 8

1. Figure 2.33 shows a coil in a magnetic field. The coil is rotated in direction shown by the arrow.

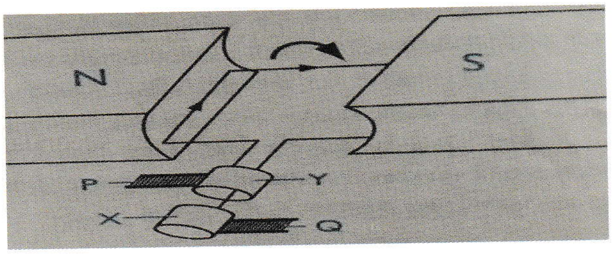


Figure 2.33: A coil in magnetic field

a) Name the parts labelled X and Y.

b) The terminals P and Q are connected to C.R.O, sketch the graph of the electromotive force (e.m.f) produced against time.

c) State two factors that affect the magnitude of the e.m.f.

d) Explain the changes that should be made in the a.c generator to produce a direct current.

2. Does transformer step up (a) Power? (b) Energy? What law governs these transformations?

Power Loses in Transformers

Dear learner, for ideal transformers, energy conserved and transformer is 100% efficiency. In practice, it is impossible; hence there are power losses which do not allow efficiency of 100%. The losses of power in transformers may be due to the following factors:

1. Resistance of coils (copper losses).
2. Eddy currents (iron losses).
3. Leakage of magnetic fields (magnetic losses).
4. Hysteresis energy losses in soft iron (Hysteresis losses) which is the energy wasted due to magnetizing and demagnetizing of iron core.

Unit Reflection

You have come to the end of this unit.

1. What are the interesting things that you have learnt?
2. Where and how can you apply them in your daily life? and
3. What are the difficult areas you have encountered?

Unit Assignment

After completing reading this Unit, do the following questions, and keep your work in your portfolio.

1. What happens to current carrying conductor when placed in a magnetic field?
2. A magnetic compass shows a deflection when placed near a current - carrying wire. How will the deflection of the compass get affected if the current in the wire is increased? Give reasons. Support your answer with a reason.
3. Sketch magnetic lines of a force for current carrying solenoid.
4. Strength of a magnetic field of a current carrying solenoid can be affected by various factors. Explain them.
5. State two laws that determine the direction of the magnetic field for a straight conductor. State them.
6. A current of 0.6A is passed through a step up transformer with primary coil of 200 turns. Current of 0.1A is obtained in secondary coil. Find the:

   (i) Number of secondary turns.

   (ii) Secondary voltage if primary voltage is 240V mains.
7. Draw the diagram of a simple transformer and then explain the principle on which the transformer works.
8. Describe briefly the apparatus you would use to enable the output of a 12V a.c generator to give an a.c supply of 240V.

9. Describe briefly one practical application of an induction coil.

Unit 3

Describing Elementary Astronomy

Introduction

Dear learner, welcome to Unit 3 of this Module. In thisUnit, you learn about the universe and all heavenly bodies which include stars, planets, moons and others. In this Unit, you learn introduction to astronomy, solar system, constellations, the Earth and the moon. This will help you to understand and know different things found in the universe and their properties. I hope you will enjoy learning this Unit.

Learning Outcomes

Upon completion of this Unit, you will be able to:

- explain the concept and importance of astronomy in everyday life;
- distinguish between a star and a planet;
- explain the force of gravitation which maintains celestial orbits;
- explain the concept of constellations; identify constellations and their uses in everyday life;
- describe the surface features and temperature of the moon and explain the causes of ocean tides.

Introduction to Astronomy

Dear learner, the word astronomy is derived from the Greek word "*astron*" meaning "*star*" and *nomos* meaning "*laws or cultures*." The literal meaning of the word astronomy therefore is "*law of the stars.*"

***Astronomy** is the branch of science that deals with study of the origin, evolution, composition, distance and the motion of all bodies (objects) and scattered matter in the universe.*

The universe is the totality of space and time together with matter and energy. People who are involved in astronomy are known as *astronomers*. Astronomers study the objects that compose the physical universe: stars, planets, moon, galaxies and nebulae.

Astronomy is one of the oldest fields of science. Early astronomy involved observing the regular patterns of the motions of visible celestial objects, especially the Sun, moon, stars and planets with the naked eye. An example of astronomy was the study of the changing position of the Sun along the horizon or the changing appearances of stars in the course of the year. These were used to establish agricultural and ritual calendars.

Importance of Astronomy to Man Kind

Astronomy has been an important tool for thousands of years. The following are some ways in which astronomy is important:

i. It was the earliest method of measuring time. A day was the duration between Sunrise and Sunset while a month was derived from phases of the moon. The year was derived from the changing position of Sun rise.

ii. It was used to develop calendars that made it possible to predict the seasons. The seasons were very important in agriculture as they detect the planting time and the harvesting time.

iii. It was used in both land and sea navigation based on the knowledge of the position of the Sun during the day and the stars at night.

iv. Today astronomy helps us to understand where the Earth and the life it supports originated from and how it evolved.

v. Astronomy presents a new frontier for exploration.

The Solar System

The solar system consists of the Sun surrounded by planets, comets and asteroids in orbit. Most planets in the solar system have moons in orbit around them.

The solar system is made up of the Sun and the celestial objects bound to it by gravity. These objects include the eight planets and their known moons and billions of small bodies that include asteroids, comets, meteoroids and interplanetary dust as shown in Figure 3.1.

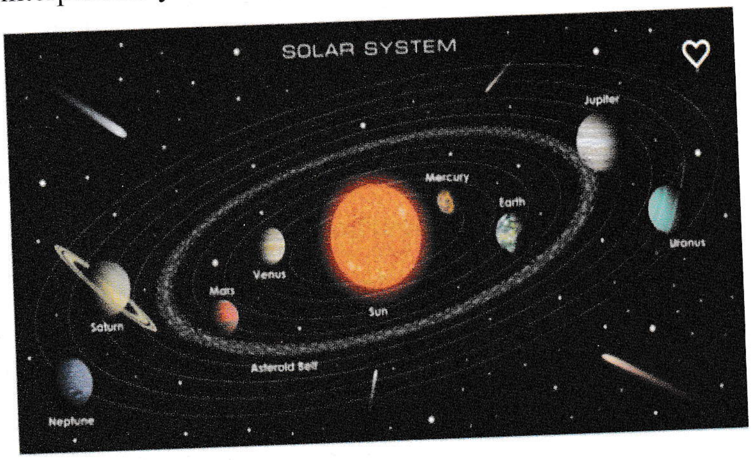


Figure 3.1: Solar system

Dear learner, let us learn about components of solar system (stars, planets, asteroids, meteoroids, comets, and interplanetary dust). Let us start looking at stars and planets and the differences between them.

1. A Star

***A star** is a large celestial body made up of hot gases known as plasma.*

Plasma refers to an ionised gas in which a certain proportion of electrons are free rather than bound to an atom or molecule.

Stars radiate energy derived from the thermonuclear reactions in the interior region. The Sun is a large star and is also the closest star to the Earth at a mean distance of 149.60 million kilometres.

This distance is known as the astronomical unit (AU) and it is used to measure distances across the solar system (1 AU = 149.60 million km).

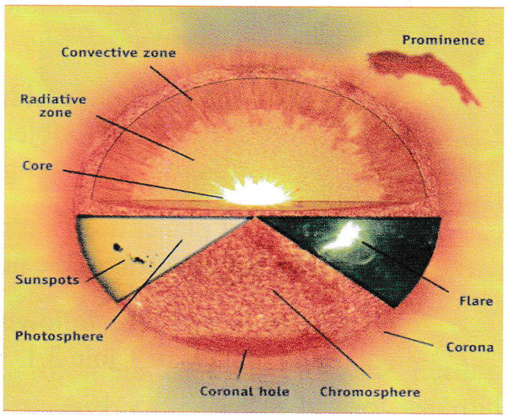


Figure 3.2: Structure of the Sun

A giant collection of stars, gas and dust is called a *galaxy*. Most stars in the universe are in the galaxies. Nearly all of the stars visible in the night sky are within our own galaxy which is called *Milky Way galaxy*.

2. Planets

***A planet** is a celestial body moving in an elliptical orbit round a star.*

It is a major (large) object which is in orbit around a star. They are held in orbit by the gravitational pull of the Sun. The planets take different amounts of time to go around the Sun. A single orbit is called the planet's year and the further out a planet is, the longer its year takes. The obits of the planets in the solar system are almost circular with the Sun near the centre.

There are eight planets which are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. The following are the three defining characteristics of a planet:

i. It is a celestial body that orbits a star.

ii. It is massive enough so that its own gravity causes it to assume a spherical shape.

iii. It has cleared the neighbourhood objects around its orbit.

Dear learner, Pluto resides in an area of space populated by numerous other objects. It is no longer considered a planet. Pluto is now designated a dwarf planet.

A dwarf planet does not meet the third characteristic such that has not cleared the neighbourhood around its orbit.

Dear learner, the following are differences between stars and planets in Table 3.1

Table 3.1: Difference between Stars and Planets

Stars	Planets
Emit their own light	Do not emit their own light
Twinkle at night	Do not twinkle at night
Appear to be moving from East to West	Planets move around the Sun from West to East
Their temperatures are usually very high	Their temperatures depend on their distances from the Sun

Countless in number	They are eight in the solar system.
Very big in size but they appear small because they are very far away	Very small in size as compared to stars
Are in gaseous form	Are in solid form

3. Asteroids

Asteroids are comprised of rocks and metals and are smaller than planets. Most of them are found in "asteroid belt," in orbit around the Sun between Mars and Jupiter. Asteroids can crash into each other. When they do, they may break apart and their orbit may change as seen in Figure 3.3.

Figure 3.3: Asteroid

The orbits of some asteroids cross the Earth's orbit. At various time during the Earth's history, asteroids have hit the Earth.

When this happened, a tremendous amount of energy was released, throwing up billions of tonnes of dust. This huge dust cloud block heat and light from the Sun, making the Earth very cold.

4. Meteors and Meteorites

Meteors are asteroids which enter the Earth's atmosphere and burn completely before reaching the Earth's surface. They are also called shouting stars as seen in Figure 3.4.

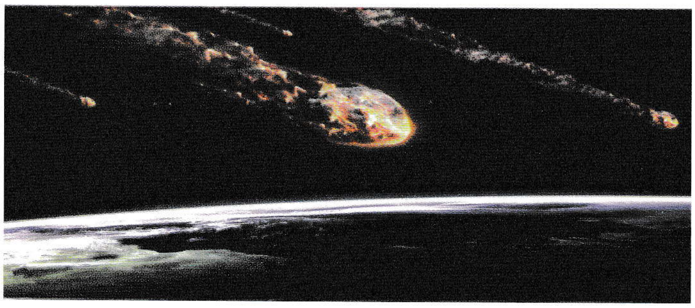


Figure 3.4: Meteors

Meteorites are meteors that survive the passage through the Earth and reach the ground. A meteorite is a piece of rock or metal that has fallen to the Earth's surface from outer space as a meteor.

5. Comets

Comets are balls of ice and dust in orbit around the Sun. The orbits of comets are different from those of planets, they are elliptical. A comet's orbit takes it very close to the Sun and then far away again. The time to complete an orbit varies. Some comets take a few years, while others take millions to complete orbit as seen in Figure 3.5.

Figure 3.5: Comets

Comets are often visible from the Earth when they get close to the Sun, because the Sun's heat vaporises material from their surface, and this vapour forms a tail which always points away from the Sun.

Satellite

A satellite *is anything that orbits a celestial body (star, planet, and moon).*

There are two types of satellites which are:

i. Natural satellites such as the moon is a natural satellite of the Earth.

ii. Artificial satellites (man-made satellites) for example communications satellite.

Force that Maintains Celestial Bodies in their Orbits

Dear learner, do you know the force that maintains all celestial bodies in their orbit? Can you mention the name of that force? If you don't know just relax but if you know relate with the following. Relate your answers with what is discussed below:

The force that maintains celestial bodies in their orbits is called *gravitation force.*

Gravitation force *is the attractive force existing between any two objects that have mass.*

It pulls objects together and acts on all matter on the universe, hence it is sometimes referred to as *universal gravitation.*

Since gravitational force acts on all matter in the universe from the largest stars to the smallest atoms, it is often called so (universal gravitation). Sir Isaac Newton was the first person to fully recognise that the force holding an object to the Earth is the same as the force holding the moon, the planet and other heavenly bodies in their orbits. According to Newton's law of universal gravitation, "every single point mass attracts every other point mass by a force directed along the line joining the two masses."

***Newton's law of universal gravitation states that** "any two bodies in the universe attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.*

That is:

$$F = \frac{GM_1M_2}{r^2}$$

Where F = Magnitude of the attractive force between the two point masses

G = Universal gravitation constant

M_1= Mass of the first point mass

M_2 = Mass of the second point mass

r = Distance between the centres of the two point masses

Force of Gravity

This is the gravitational force that attracts a body towards the centre of the Earth. It is the force that holds us on the ground and causes objects to fall back to the ground after being thrown up in the air.

The further you move away from the centre of the Earth, the weaker the force becomes. This is why the astronaut in space can float without falling because the gravitational force is almost zero in the outer space.

But if astronaut goes in the outer space, he/she needs a space suit. This special suit is important because it is used to:

i. Protect his body from low pressure;
ii. Supply astronaut with oxygen to breath;

iii. Supply water to drink during space walks;
iv. Protect his/her body from being injured from impact of small bits of space dust;
v. Protect the astronaut from cold and dangerous radiations.

Now try to do the following activity 1 to assess your understanding.

Activity 1

1. Write seven properties of moon.
2. Briefly explain how astronomy gave rise to the 12 months of the year.
3. Name two objects in space which are the Earth's nearest neighbour.
4. How do the planets stay in orbit around the Sun?
5. What is the hottest planet in our solar system?
6. Why is Pluto not a planet as it used to be?

Constellations

Dear learner,

A constellation *is a small group of very bright stars that forms a definite shape or pattern when viewed from the Earth.*

The patterns formed are likened to have familiar objects on the Earth e.g. people, animals mythological characters, things and so on as a way of remembering stars.

The motion of the Earth around the Sun causes position of constellations to change for an observer of a given place on the Earth. Some are visible in a particular period of the year while others are brightest in a particular month. Figure 3.6 shows some definite shapes of constellations.

Figure 3.6: Some definite shapes of constellations

There are about 88 known constellations. Some examples of known constellations are shown in the Figure 3.7.

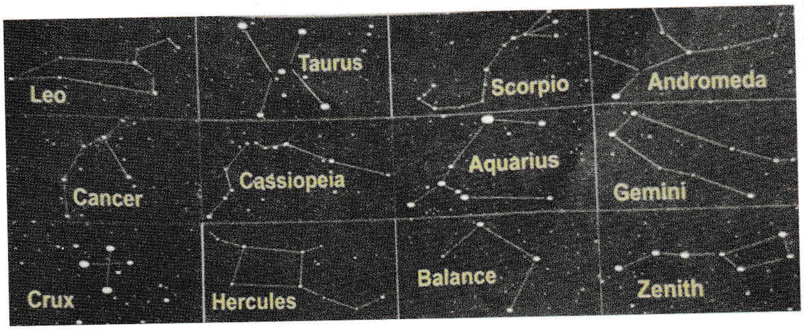


Figure 3.7: Common constellations

Uses of Constellations

Dear leaner, let us discuss the applications of the constellations in our daily life.

1. Religious

People in early days thought that the gods lived in the heavens and that the gods crated the constellations. Many cultures believed that the positions of stars were their god's way of telling stories. Indeed, the Greek named the constellations after their mythological heroes and legends. For example to the ancient Greeks, Orion was a great hunter. He was the son of Neptune (god of the sea).

2. ***Agriculture***

Before there were proper calendars, people had no way of determining when to sow or harvest except by the stars. Constellations made the patterns of stars easy to remember. The ancient people knew. For example, that when the constellation Orion started to be fully visible, winter was coming soon. The constellations allowed farmers to plan ahead.

3. ***Navigation***

This allowed for ships to travel across the globe. It allowed the discovery of America, the spread of European cultures and civilizations as we know it today. Navigation helped travellers to determine the direction of their destinations by locating neighboring constellations.

Dear learner, I hope you have understood about constellations, now do the following activity 2:

Activity 2

Under the supervision of your facilitator, Form a group of five students and draw any five constellations on a manila paper.

The Earth and the Moon

Dear learner, the Earth and its moon form a unique pair in the solar system. Consider Figure 3.7.

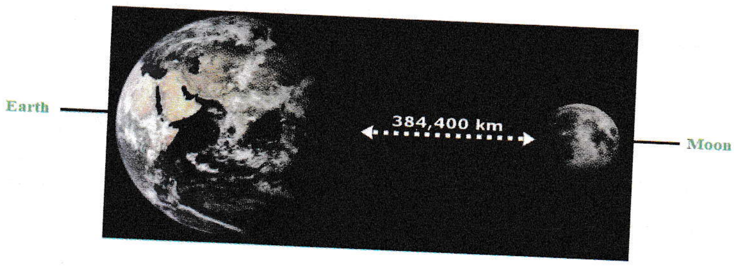


Figure 3.7: The Earth and moon

The moon of the Earth is the sixth largest in the solar system. It has a diameter of 3476 km and mass of 7.35 x 10^{22} kg. Besides the Earth, the moon is the only other body in the solar system upon which human kind walked. Like the Earth, the moon has an Iron core surrounded by a rocky mantle and crust. Unlike the Earth, no part of the moon's Iron core is molten so it doesn't have a magnetic field. Surface gravity on the moon is about 1/6 that on the Earth. An object weighing 60kg on the Earth would only weigh 10kg on the moon. The moon revolves in an anticlockwise direction around the Earth in an elliptical orbit. The moon orbit is tilted at 5^0 relative to Earth's orbit around the Sun.

The distance between the Earth and the moon varies from nearest the Earth (perigee) where it is 356,000km to the furthest from the Earth (apogee) where it is 406,000km. The average distance is 384,000km. It takes the moon 27.3 Earths' day to complete one orbit, a period of time called the *sidereal month*. The moon also rotates about its axis at a rate equal to its rate of revolution. In other words, while the moon is completing one orbit around the Earth, it also spins. The result is that the same side of the moon is always facing the Earth. The side facing the Earth is called *the near side* while the side that faces away is called the *far side*.

The spinning of the Earth causes the moon to rise and set each day just like the Sun. However, because of the moon orbital motion around the Earth, it rises about 50 minutes a day. As a result, the moon can be seen at different times of the day and night during a month. Temperatures on the surface of the moon are on average 107^0C during the day and -53^0C during the night.

Surface Features of the Moon

Dear learner, let us proceed with the features of the moon.

Do you know what contains the surface of the moon? Let us discuss together as follows:

There are two primary types of terrain/features on the moon; these are the heavily cratered very cold *lunar highlands* and relatively smooth and younger *Maria.*

From the Earth, the moon's surface appears to have bright and dark regions when viewed with unaided eye. The bright areas are the lunar highlands that have many creators and are covered with a highly reflective layer of five dusts. The highlands are geologically the oldest parts of the moon's surface. The dark regions are low areas similar to ocean basins on the Earth. They are filled with dark solidified lava and are fewer creatures than the highlands. Galileo called these areas *Maria,* the Italian word for seas, because their dark smooth surfaces appeared to be large bodies of water as shown in Figure 3.8.

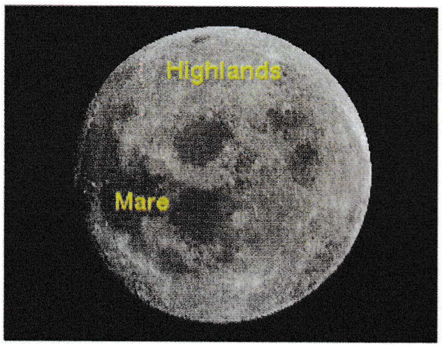


Figure 3.8: Photography of the moon's surface showing highlands and Maria

The Maria, which makes about 16% of the moon's surface, are huge impact craters that were later flooded with molten lava. Most of Maria is covered with regolith, a mixture of fine dusts and rocky debris produced by meteor impact.

Ocean Tides

Dear leaner, I hope you are competent now about the moon. Let us discuss about ocean tides. Have you ever visited any lake/ocean shores? Do you know why sometimes the level of water rises and fall? Answers to these questions will be obtained in the discussion below about ocean tides:

Tides

***Tides** are periodic rises and falls of large bodies of water.*

Tides are caused by the gravitational interaction between the Earth and the moon. The Earth and the moon are attracted to each other, just like magnets are attracted to each other. The moon tries to pull at anything on the Earth to bring it closer. But the Earth is able to hold onto everything except water. Since water is always moving, the Earth cannot hold onto it and the moon is able to pull at it. This results in the ocean tides. Each day there are two high tides and two low tides.

The ocean is constantly moving from high tide to low tide, and then back to high tide. There is a time interval of about 12 hours and 25 minutes between the two high tides.

How Tides Occur

Dear learner, let us now discuss about how tides occurs.

Tides occur due to the gravitational attraction of the moon causing the oceans to bulge out in the direction of the moon. Another bulge occurs on the opposite side since the Earth is also being pulled towards the moon (and away from the water on the far side). An Ocean level fluctuates daily as the Sun, moon and the Earth interacts.

As the moon travels around the Earth, and as they travel together around the Sun, the combined gravitational forces cause the world ocean water levels to rise and fall. Since the Earth is rotating while this is happening, two tides occur each day. Refer Figure 3.9.

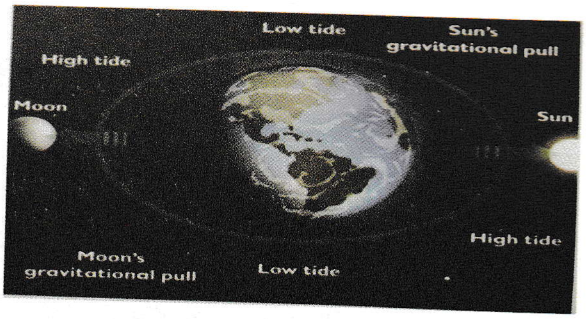


Figure 3.9: Ocean tides

Types of Tides

Dear learner, there are two main types of tides, which are:

i. Spring tides.

ii. Neap tides.

i. Spring Tides

Spring tides occur during the full moon and the new moon. During this time, the Earth, the Sun and moon are in a line. The gravitational forces of the moon and the Sun both contribute to the tides. There are times the high tides are very high and the low tides are very low. These are known as *a spring high tide* and *a spring low tide,* respectively. Spring tides are especially strong tides. Consider Figure 3.10.

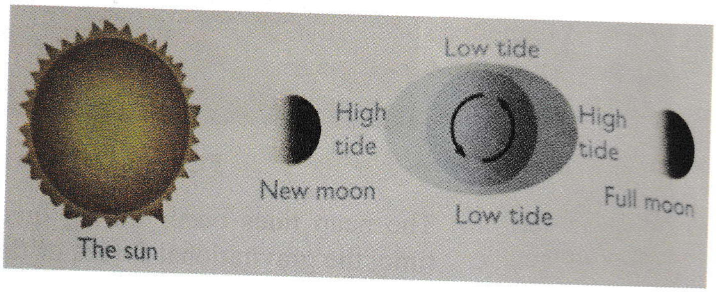


Figure 3.10: Spring tides

Proxigean spring tide is a rare unusually high tide. The proxigean spring tide occurs when the moon is both unusually close to the Earth (proxigee) and in the new moon phase (when the moon is between the Sun and the Earth); it occurs at most every 1.5 years as shown in Figure 3.11.

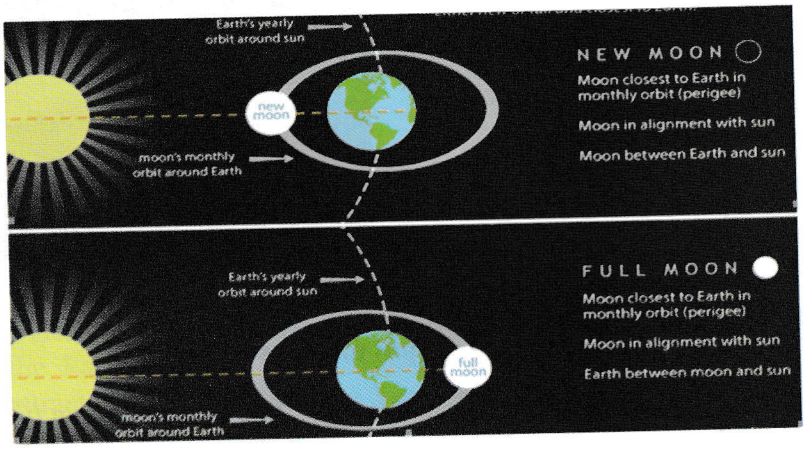


Figure 3.11: A proxigean spring tide

ii. Neap Tides

Dear learner, neap tide occurs when the Sun and the moon are not aligned, the gravitational force cancels each other out and the tides are not very high or very low. These are called neap tides as shown in Figure 3.12.

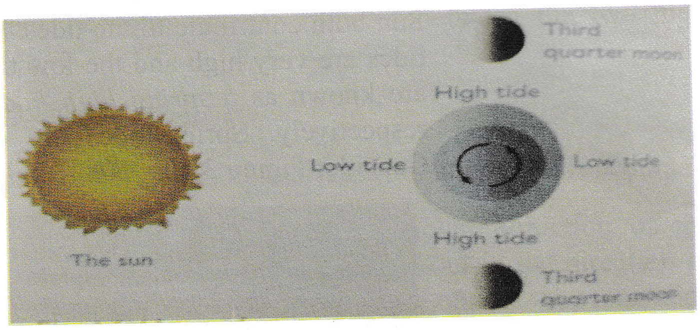


Figure 3.12: Neap tides

The neap tides occur during quarter moon. During this time, the gravitational forces of the moon and the Sun are perpendicular to one another (with respect to the Earth). This causes the bulges to cancel each other. The result is smaller differences between high and low tide and is known as a neap tide. Neap tides are especially weak tides.

Dear learner, I hope you have understood very well about ocean tides. Now, do the following activity 3.

Activity 3

1. (a) Explain two types of tides.

   (b) With the aid of diagram, describe how ocean tides are formed.

2. Is Leo a galaxy or a constellation? Give reason(s) to your answer.

Unit Reflection

Dear learner, make reflection on the following exercise to check if you understood the unit.

1. Do you think what you learnt in this unit is important to you?
2. Which part of the Unit did you find most important and why?
3. Did you face any challenges when studying this unit? If yes, how did you solve those challenges?
4. What should be done to improve this unit?

Unit Assignment

Dear learner, you have completed studying Unit 3. Now, do the following assignment. Make sure you put your work in your portfolio.

1. State the reasons why an astronaut in space:

   a) Needs a special space suit to prevent blood from boiling.

   b) Can float without falling.

   c) Uses small jets of gas in his/her movements instead of swimming like a fish in water.

2. Can humans breath in space as they can on Earth? (give reason).

3. Which planets in the solar system:

   a) Have satellites?

   b) Is famous for its big red spot on it

   c) Is famous for the beautiful rings that surround it.

4. a) Why a day and a year on the moon has the same length?

   b) Why does the moon change its shapes as the month progresses?

5. a) Explain why orion is a constellation.

   b) Explain the three (3) uses of the constellations.

6. a) What is an ocean tide? Explain how ocean tides occur?

   (b) Give the differences between a spring and a neap tides.

Unit 4

Describing Geophysics

Introduction

Dear learner, in the previous Unit, you learnt about elementary astronomy. In this Unit, you study about the Earth by using physics concept. The study focuses on interior structure of the Earth and its composition as well as the structure and composition of atmosphere.

We also study about things which happen in the Earth for example Earth quake and volcanoes, greenhouse effect and global warming.

Dear learner, you have realized that this Unit comprises a lot of geography concepts. The Unit is known as Geophysics.

Geophysics *is the branch of science that is concerned with the physical, chemical, geological, astronomical and other characteristic properties of the Earth.*

Learning Outcomes

Upon completion of this unit, you will be able to:

- Describe the structure and composition of the layers of the Earth;
- Explain the importance of the layers of the Earth;
- Explain the origin of volcanoes and Earth quake and describe the effects of volcanoes;
- Describe the principle of measurement of Earthquake and identify precautions against Earthquake hazards;
- Describe the vertical structure and composition of the atmosphere and explain the importance of various layers of the atmosphere;
- Explain the greenhouse effect and identify its sources;

- Explain the occurrence of global warming and state its consequences.

Structure and Composition of the Earth

Dear learner, we have discussed that in Geophysics we study the Earth's properties by using the knowledge of Physics. We live on the surface of the Earth where we conduct various activities such as mining, agricultural activities, constructions of roads and construction of buildings. It is therefore important to study the structure and composition of the Earth.

Therefore, when we say structure of the Earth, we mean the layers of the Earth from the outermost part towards the Earth's innermost part.

The structure of the Earth is composed of three major zones arranged in concentric manner. These are crust, mantle and the core as shown in Figure 4.

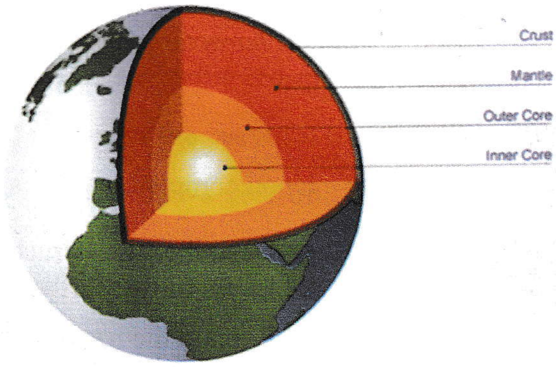


Figure 4.1: Interior structure of the Earth

Dear learner, we need to discuss each part of these three; crust, mantle and core in terms of its thickness and composition.

a) The Crust

This is the outer solid layer of the Earth. It is extremely thin (about 5 to 15km) compared to radius of the Earth (about 6371 km).

There are two types of crusts, namely; continental crust and oceanic crust.

i. *Continental Crust*
   It is heterogeneous crust with low density about 2 – 2.8 tonnes per cubic metres (tonnes/m^3). It is mainly composed by granites and sedimentary rocks. Land mass and mountains are located at continental crust. It is 30 to 70km thick.

ii. *Oceanic Crust*
   This is basaltic crust with high density about 3 – 3.1 tonnes per cubic metre (tonnes/m^3). It is about 8km thick.

Both the continental and the oceanic crusts float on the denser mantle because of their lower densities. The continental crust floats on the mantle at higher elevation, forming the land masses and mountains.

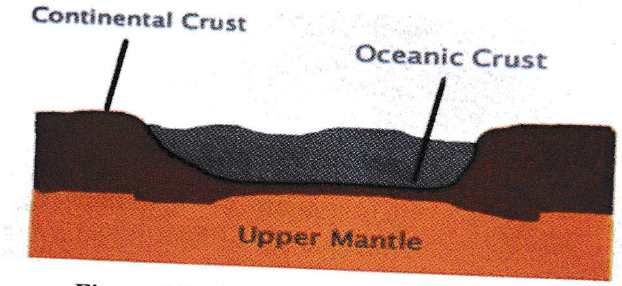


Figure 4.2: Continental and oceanic crusts

Note

The boundary between the crust and the mantle is called *Mohorovicic* discontinuity or simply *Moho*.

b) The Mantle

The mantle is the zone between the core and the crust. It begins from the moho and extends to approximately 2,900km below the Earth's surface up to its boundary with the Earth's core which is called the Gutenberg discontinuity.

Note

Gutenberg discontinuity is the boundary between the mantle and core of the Earth.

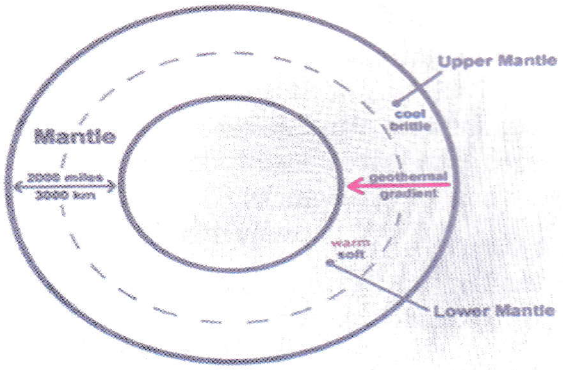


Figure 4.3: Shows the structure of mantle.

The mantle contains about 70% of the Earth's mass. The mantle is composed of plastic rocks (both in solid and molten states).

The upper surface of the mantle has the temperature of about 870°C, and this temperature increases downwards through the mantle to about 2,200^{0}C near the core. This steady increase of temperature with depth is known as the *geothermal gradient*.

Circulation of materials in the mantle is the main mechanism of heat transfer from the core of the Earth to the outer regions of the Earth. It is the main force that drives the movement of continents as well as volcanism and Earthquakes.

c) The Core

This is the innermost part of the Earth. It extends from the Gutenberg discontinuity to the Earth's geometric centre. It consists of two distinct regions which are the outer core and inner core as shown in Figure 4.4.

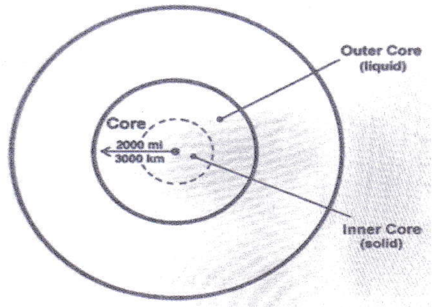


Figure 4.4: The outer and inner core of the Earth

i. Outer Core

The outer core is the second largest layer and is composed of liquid of *molten nickel* and *iron* known as *Magma.* It is about 2200km thick. The Magma surrounds the inner core and creates the Earth's Magnetic field.

ii. Inner Core

The inner core is the hottest part of the Earth. Its surface temperature is estimated to be approximately 5700K (about 5430 ^{0}C) which is as hot as the surface of the Sun. It is made of solid Iron and Nickel that is under so much pressure thus cannot melt.

It is 1200km thick (radius) and heavy radioactivities elements within the core generate the intense heat as they decay.

Inner core is solid even though its temperature is higher than the outer cure.

Tectonic Plates

Dear learner, as we have discussed in this part of the unit that, the crust continental and oceanic float on mantle, the Earth's crust cracked into huge pieces called tectonic plates.

Tectonic plates *are the huge pieces of cracked Earth's crust and mantle parts which float over semi-molten rock.*

They are also called lithospheric plate. They move about very slow speed. The movements of tectonic plates mean that some continents are moving apart and some are moving towards each other. This process is referred as *continental drift*.

Continental drift has going on for some hundreds of millions of years. Tectonic movements have split the continents as they exist today. Figure 4.5 shows the Earth's tectonic plates.

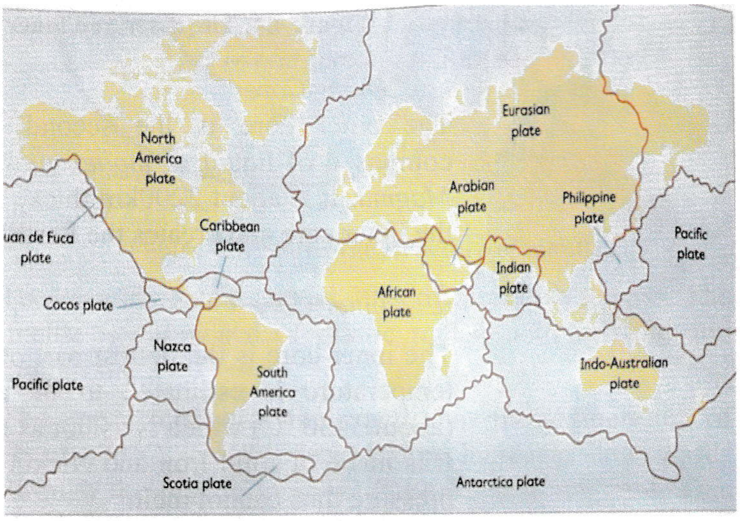


Figure 4.5: The Earth's tectonic plate

Tectonic Boundaries

The tectonic boundary *is the line where two tectonic plates meet.*

There are three main types of boundaries, namely; destructive, constructive and conservative boundaries.

These three boundaries are explained below:

1. Destructive Boundary

This is the one found at the edges of two plates moving towards each other. It is also known as convergent boundary as shown in Figure 4.6.

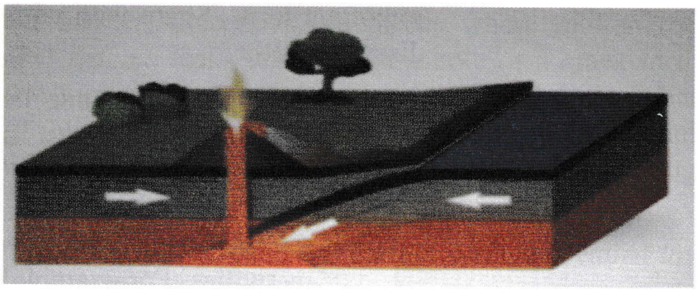


Figure 4.6: Destructive boundary

2. *Constructive Boundary*

This is formed at the edges of two plates moving away from each other. It is also known as divergent boundary as shown in Figure 4.7.

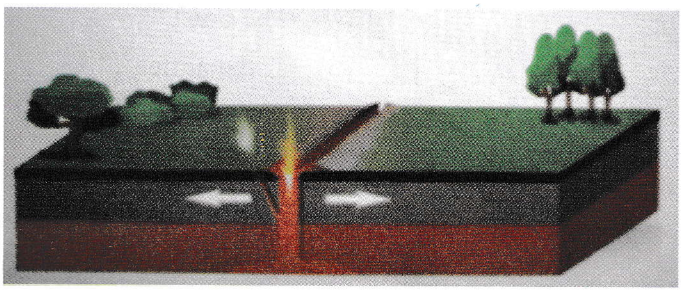


Figure 4.7: Constructive boundary

3. *Conservative Boundaries*

These are formed when two plates slide past each other without moving apart or towards each other as shown in Figure 4.8.

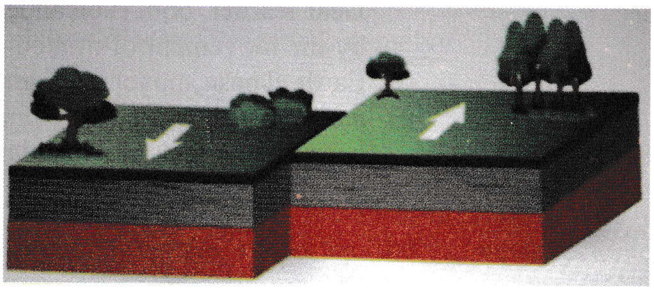


Figure 4.8: Conservative boundaries

Importance of the Layers of the Earth

Dear learner, think of how the layers of the Earth are important to us. Share with your friend and then we will discuss together:

(i) They support life, due to abundance of Oxygen. For example, crust supports life to living organisms which uses Oxygen present in it for their survival.

(ii) It is the place where we do our day to day activities. For example, on the Earth we do our agricultural activities and mining on the crust.

Activity 1

Answer the following questions:

1. Draw a cross section of the Earth's interior region and on it show:
   (a) The crust
   (b) The mantle
   (c) The outer core
   (d) The inner core
2. Explain the usefulness of the layers of the Earth.
3. Briefly explain three types of boundaries of tectonic plate.
4. How can you differentiate continental drift from tectonic plate?

Earthquakes and Volcanoes

Dear learner, both (volcanoes and Earthquake) are caused by the movement of molten rock and heat deep inside the Earth. These movements are referred to as *subterranean movements*. Most Earthquakes and volcanic activity happen near tectonic boundaries.

The Origin of Volcanoes

Dear learner, volcanoes are places where molten rock called *magma* leaks out through a hole or a crack in the Earth's crust. Magma originates from the mantle, where high temperature and pressure cause the rocks to melt. When a large pool of magma has formed it rises through the denser rock layer towards the Earth's surface.

Magma that has reached the Earth's surface is called *lava* as seen in Figure 4.8.

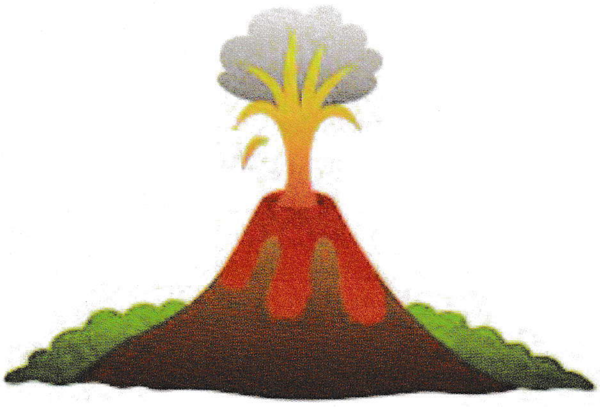


Figure 4.8 Volcanic eruptions with lava

Most volcanoes form long constructive and destructive boundaries between tectonic plates however, a few form plate boundaries.

Types of Volcanoes

There are two types of volcanoes namely:

i. Fissure volcanoes.
ii. Central volcanoes.

i. Fissure Volcanoes

These occur along the cracks in and between tectonic plates.

They can be many kilometres long. Lava is usually ejected quietly and continuously forming enormous plains or plateaus of basaltic volcanic rock as seen in Figure 4.9.

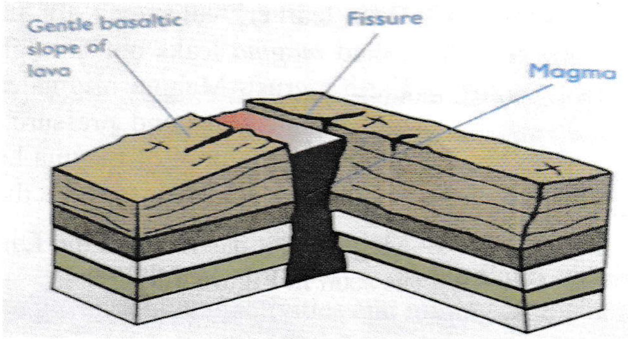


Figure 4.9: Fissure volcanoes

ii. Central Volcanoes

These have a single vertical main vent through which magma reaches the Earth's surface. They usually develop a cone shape that builds up from successive layers of lava and ash. The process by which magma is forced from interior of the Earth through a vent in the Earth crust is called *Vulcanicity* as seen in Figure 4.10.

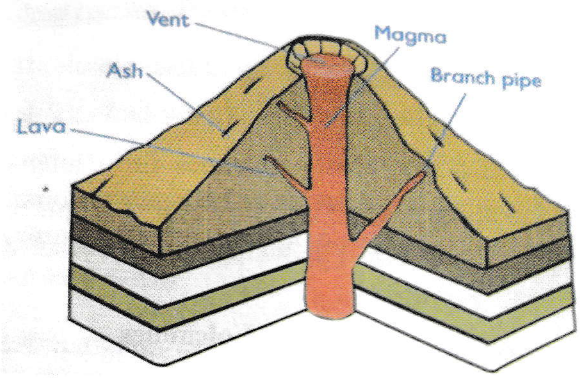


Figure 4.10: Central volcanoes

Classification of Volcanoes

Dear learner, volcanoes are classified into three categories based on their frequency of eruption, which are: active, dormant and extinct volcanoes.

i. ***Active Volcanoes***

These are volcanoes that either *erupt* constantly or have erupted in recent time; examples of active volcanoes are Mount Nyiragongo (Congo), Santa Maria (Guatemala) and Oldoinyo Lengai (Tanzania).

ii. ***Dormant Volcanoes***

These are volcanoes that have been inactive for some time (a few thousand years) but can erupt again. Examples of dormant volcanoes are Mount Kilimanjaro (Tanzania) and Mount Fuji (Japan).

iii. ***Extinct Volcanoes***

These volcanoes have not erupted in recorded history. They will probably never erupt. Example of extinct volcano is Mount Thielsen (USA).

Effects of Volcanoes

Dear learner, volcanoes have negative and positive effects to human beings, amongst them are:

i. ***Negative Effects***

a) Destruction of property and loss of human life. Eruption occurring close to human settlements may spill and destroy lives and property.

b) Environmental Pollution. Ash discharged very high into the stratosphere can have negative consequences on the ozone layer.

c) Lahars. Ash and mud can mix with rain and melting snow forming Lahars. Lahars are mud flows flowing at very fast.

d) Acidic rain. Gas emissions from volcanoes are a natural contributor to acidic rain.

e) Accident. Ash throw into the air by eruptions can present a hazard to air craft, especially jet air craft where the particles can be melted by the high operating temperature.

ii. Positive Effects of Volcanoes

a) Landscape formation. Volcanoes lead to formation of mountains, islands, plateaus and valley.

b) Tourism. Provide extraordinary scenery so beautiful and natural that they attract tourists to the area, bringing in some economic value.

c) Geothermal energy. Places close to volcanic activities tend to have higher potential for geothermal energy which can be an advantage to the towns and cities.

d) Soil formation. Ash and lava breakdown become soil that are rich in nutrients and become good area for crop planting activities.

e) Minerals. Volcanoes also bring valuable minerals to the Earth's surface. The minerals are important economic resources.

Earthquakes

Dear learner, welcome to this part on Earth quakes. Have you ever experienced sudden shaking of the Earth's surface in your life? What were the causes of the shaking? Did the shaking lead to any destructions to human life and property? Let us discuss in detail about the earthquake.

***Earthquakes** is a sudden shaking of the Earth's surface caused by a release of energy accumulated with or along edges of tectonic plate.*

OR

Earthquakes is a suddenly motion/shaking and trembling that results from the movement of rocks beneath the Earth's surface.

Every year about 10,000 earthquakes happen but most are so small that they can only be detected by very sensitive instruments. Earthquakes also occur as a result of movement of magma at constructive boundaries under volcanoes and where continental plates collide and push mountain ranges.

How Earthquakes Occur

Earthquake mostly occur on or near the boundaries between tectonic plates. However, earthquakes can also occur far from plate boundaries. Such earthquakes probably occur as a result of faults formed millions of years ago.

Most earthquakes occur on or near destructive and constructive boundaries of tectonic plates. Tectonic plates grind past each other, rather than slide past each other. They can become locked together due to friction. For some time, they don't move and energy building up as shown in Figure 4.11

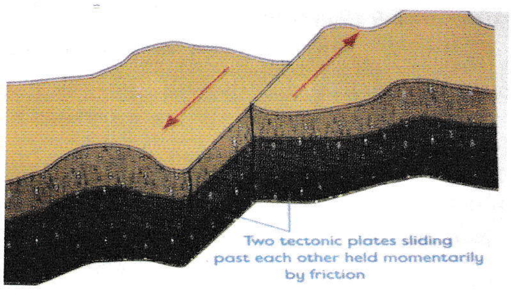


Figure 4.11: Earthquake build-up

Pressure builds between them until the frictional force holding the plate together gives away. The plates moves suddenly releasing pressure (energy) and then hold together again. This sudden jerk is what is felt as an earthquake.

The point within the Earth where an earthquake begins is called *focus* or *hypocentre* of the earthquake. Earthquake rarely occur along constructive plate boundaries.

The epicentre is a point on the surface of the Earth directly above the focus.

The strength of the earthquakes (how much ground is shaken) depends on types of soil or rock around the epicentre, depth from the epicentre, size and length of faults.

The earthquake produces vibration (waves) and these waves carry energy as they travel outwards through the solid Earth materials. The waves due to the earthquakes are known as *seismic waves*.

Types of Seismic Waves

Dear learner, there are three categories of seismic waves namely;

i. Primary wave (P).

ii. Secondary waves (S).

iii. Surface waves as shown in Figure 4.12.

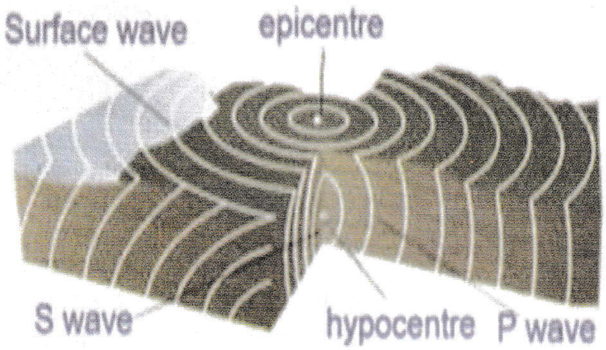


Figure 4.12: Seismic waves

i. Primary waves (P-waves) are the first waves released from hypocentre (focus) i.e. fastest moving waves. These waves compress and expand the ground hence cause buildings to contract and expand. They can move through liquid and solid.

ii. Secondary waves (S-waves) are waves that arrive on the surface after primary waves. They are felt as a series of side to side tremors. Figure 4.13 shows both P-waves and S-waves.

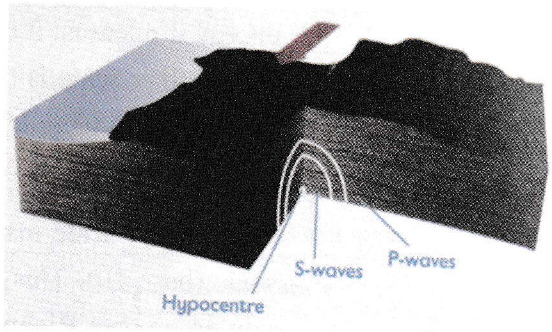


Figure 4.13: P-waves and S-waves

iii. Surface waves radiates outward from a point on the Earth's surface directly above the hypocentre. This point is called the *epicentre* of the earthquake. There are two types of surface wave. These are *Rayleigh waves* and *Love waves*. *Rayleigh waves* create a rolling movement that makes the land surface move up and down.

Love waves make the ground shift from side to side. It is a surface wave that damage the surface structure such as buildings and hydroelectric power plants. Figure 4.14 shows this kind of wave.

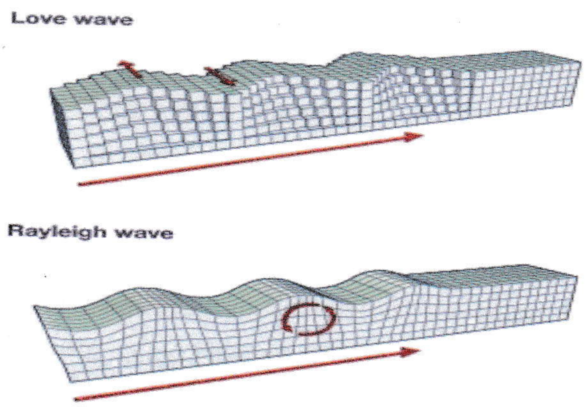


Figure 4.14: Surface waves

Earthquake Scales

Dear learner, the nature of an earthquake is usually described by measuring two properties; the magnitude and intensity.

The magnitude of an earthquake is a measure of the energy it releases; it is usually measured on *Richter scale*. The Richter scale is based on the amplitude of the largest seismic wave recorded for an Earthquake, no matter what type was the strongest.

The Richter scale magnitudes are based on a logarithmic scale (base 10). This means that for every whole number you go up on a Richter scale, the amplitude of the ground motion goes up ten times. Using Richter scale, an earthquake of magnitude 7.0 would result in ten times the level of ground shaking as an earthquake of magnitude 6.0.

The Richter scale can be used to describe earthquake which are so small that they are expressed in negative numbers, the scale has 0 upper limit.

The intensity of an earthquake is a measure of its strength based on the changes it causes to the land scape. The intensity of an earthquake is usually measured on the modified Mercalli intensity scale. The scale is calibrated from 1 to 12. On this scale, level 1 is a minor tremor that causes no damage whereas 12 causes total devastation. Table 4.1 and 4.2 show a description of the Richter scale and 12 levels on the modified Mercalli intensity scale respectively.

Table 4.1: Richter scale table

Richter Magnitude	*Earthquake Effects*
0 - 2	Not felt by people
2 - 3	Felt little by people
3 - 4	Ceiling lights swing
4 - 5	Walls crack
5 - 6	Furniture moves
6 - 7	Some buildings collapse
7 - 8	Many buildings destroyed
8 - Up	Total destruction of buildings, bridges and roads

Table 4.2: Mercalli intensity scale

Number	Effect
I.	Not felt
II.	Felt by persons at rest, on upper floors, or favourably places
III.	Felt indoors. Vibration like passing of light truck.
IV.	Vibration like passing of heavy trucks.
V.	Felt outdoors. Small unstable objects displaced or upset.
VI.	Felt by all. Furniture moved. Weak plaster/masonry cracks.
VII.	Difficult to stand. Damage to masonry and chimneys.
VIII.	Partial collapse of masonry. Frame houses moved.
IX.	Masonry seriously damaged or destroyed.
X.	Many buildings and bridges destroyed.
XI.	Rails bent greatly. Pipelines severely damaged.
XII.	Damaged nearly total.

Note that, an earthquake can only have one magnitude. However, its intensity is reduced as the seismic waves spread out from the hypocentre, just the same way the loudness of a sound changes as you move away from the source.

The Seismograph

Dear learner, welcome to the next part on seismograph.

The seismograph is an instrument used to record ground movements caused by earthquakes. The seismograph records both the magnitude and the intensity of the earthquake.

Seismograph has three types which are: simple pendulum seismograph, inverted pendulum seismograph and recording the pendulum motion. The recording of the motion of the pendulum can be done through Optical mechanical or electronic methods.

Earthquake Hazards

Dear learner, I hope you have understood very well about earthquakes measurement instruments, now let us proceed with the next part on earthquakes hazards.

The following are effects (hazards) of earthquakes:

1. Landslides

Earthquakes can cause unstable hillsides, mountain slopes and cliffs to move downwards, creating landslides.

2. Snow slopes

Earthquakes can also trigger avalanches on snow slopes which can collide with people, houses etc.

3. TSunamis

Tsunamis are the huge water waves causing water to rise or fall. When a tsunami reaches shallow water, it slows down, its wavelength reduced and its height grows.

4. Collapsing of Buildings

A strong earthquake can flatten a whole city. An example, is the Japanese city of Kobe which was completely flattened by an earthquake measuring 7.2 on the Richter scale. as shown in the figure 4.15.

Figure 4.15: Effect of an earthquake

5. Fire Outbreak

Breaking of gas or oil pipes and collapsing of electricity lines activate fire outbreak.

6. Loss of Life

People in areas where an earthquake has stricken may get buried under buildings and soil or get hurt or even get killed when items fall on them.

7. Floods

Tsunamis lead to coastal floods since ocean water suddenly rises above its normal.

8. Backward Rivers

Tilting ground can also make rivers change their course. This can result in the creation of earthquake lakes that cover huge tracts of previously settled land.

Earthquake Warming Signs

Dear learner, before the earthquake happens, there are some indications that warn us that the earthquake is about to happen. Below are some of the earthquake warming signs:

a) Thermal Indication

Few months before the earthquake, the average temperature of a particular area increases. For example, on the day of earthquake occurrence, the temperature of a place becomes about 5°C to 9^0C above the average normal temperature for that day.

b) Water Indicator

About one or three days before an earthquake, there is:

i. Sudden rise or fall in water levels in wells. The rise can be as high as one meter. The well water may turn muddy.

ii. At times, a fountain appears inside the well; sometimes a fountain may appear in the ground. This normal happens a few hours before the quake.

iii. There is also a sudden and rapid increase or decrease of water flow in the rivers. This happens about one to two days before the quake.

c) Seismo Electromagnetic Indicator

When temperature rises, results in geomagnetic field which reduces propagation of electromagnetic waves (radio, television and telephone). This is a very reliable indicator. It is usually recorded about 10 to 20 hours before the quake.

d) Animal Indicator

Between 10 and 20 hours before the occurrence of an earthquake, the entire animal kingdom becomes highly disturbed and restless.

e) Human Indicator

Sensitive patients in hospitals became highly disturbed before an earthquake. They exhibit a sudden rise in blood pressure, heart trouble, headache, migraine and respiratory disorders. The number of outpatient in hospitals increases by five to seven times, some 10 to 20 hours before the quake.

Precautions to be Taken during an Earthquake

Dear learner, the following are the precautions to be taken during the earthquake occurrence:

1. If you are indoors during an earthquake, drop, cover and hold on. Get under a desk, table or bench. Hold on to one of the legs and cover your eyes. If there is no table or desk nearby, sit down against an interior wall.
2. Pick a safe place where things will not fall on you.
3. Wait in your safe place until the shaking stops, then check to see if you are hurt.
4. Move carefully and watch out for things that have fallen or broken, creating hazards. Be ready for additional earthquakes called aftershocks.
5. Be on the lookout for fires. Fire is the most common earthquake-related hazard due to damaged gas and electrical lines.
6. If you must leave a building after the shaking stops, use the stairs and not the elevator.

Structure and Ccomposition of the Atmosphere

Dear learner, the Earth is surrounded above it by a layer of gases containing numerous small suspended solid and liquid particles. This layer is called the *atmosphere*. The atmosphere consists largely of a mixture of gases extending to a height of many kilometres above the Earth. It has no outer boundary. It just fades into space. The dense part of atmosphere lies within 30km above the Earth's surface.

Structure of the Atmosphere

The atmosphere is divided into five regions based on its thermal characteristics (temperature changes), chemical composition, movement and density. The five regions are;

1. Troposphere.
2. Stratosphere.
3. Mesosphere.
4. Thermosphere.
5. Exosphere.

The layers mentioned are shown in Figure 4.16.

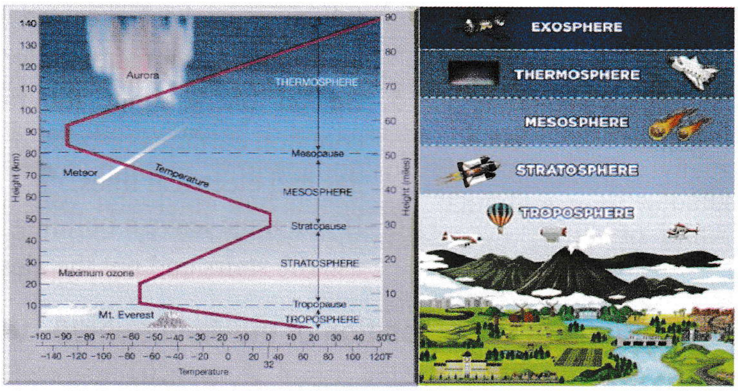


Figure 4.16: Layers of the atmosphere

1. Troposphere

This is the region nearest to the Earth. It extends to an altitude of up to 10km above the poles and 20km above the equator. This region is the densest part of the atmosphere. It contains most of the atmosphere's water vapour. The temperature in this region decreases with altitude at an average rate of 6^0C/km.

The troposphere is well mixed. Air molecules can travel to the top of the troposphere and back down again in just a few days. This mixing encourages changing weather. Most weather phenomena occur in the troposphere.

Clouds and rain are formed within this region.

The boundary which separates the troposphere and the stratosphere is called the ***tropopause***. At the *tropopause* the temperatures stop decreasing with height and become constant. The *tropopause* has an average height of 10km.

Dear learner, do you know troposphere layer is important to us? If yes good the following are the importance of troposphere

i. The troposphere controls the climate and ultimately determines the quality of the Earth.

ii. The layer contains gases which include Oxygen which is used for respiration by animals and Carbon dioxide which is use by plants in photosynthesis.

iii. The Nitrogen found in this layer also provides an inactive environment for many chemical processes to take place. The gases also support many important chemical processes such as combustion, weathering and oxidation.

2. Stratosphere

This layer starts from the tropopause and extends to 50km high. It is more stable, drier and less dense compared to the troposphere. The temperature slowly increases with altitude due to the presence of ozone layer which absorbs ultraviolet rays from the Sun.

The ozone layer lies in the middle of the stratosphere between 20 and 30km. Ozone (O_3) is a triatomic form of Oxygen. The stratosphere together with troposphere is collectively known as the lower atmosphere. The boundary which separates the stratosphere from the outer layer is called *stratopause***.**

Advantages of Stratosphere

The following are the advantages or importance of this layer:

i. It absorbs the ultraviolet radiations which are harmful to both plants and animals from reaching the Earth's surface.

ii. It prevents large storms from extending much beyond the troposphere due its stability.

3. Mesosphere

It starts just above the stratosphere and extends to 85km high. The temperature of this layer decreases with altitude. The lowest temperature of the atmosphere occurs within this region (- 90^{0}C)

This is the layer where most meteors burn while entering the Earth's atmosphere. The boundary which separates the mesosphere from the thermosphere is called the *mesopause.*

4. Thermosphere

This layer is just above the mesopause and extends up to 690km high. In this layer the temperature increases with altitude due to Sun's heat. The temperature in this region can go as high as 1,727^{o}C and chemical reactions occur faster in this region than on the Earth's surface. This layer is also known as the upper atmosphere.

The lower part of the thermosphere, from 80 to 550km above the Earth's surfaces, contains the ionosphere, a region containing high concentration of charged particle called ions and free electrons.

Importance of Ionosphere

i. The large number of free electrons in the ionosphere allow the propagation of electromagnetic waves.

ii. It absorbs the dangerous radiations like x-rays and extreme ultraviolet (EUV) radiation.

iii. It plays an important role in communication of radio waves.

5. Exosphere

This is the outermost region of the atmosphere. In this region the atmospheric gas pressure is very low such that light atoms such as Hydrogen and Helium may acquire sufficient energy to escape the Earth's gravitational pull. The upper part of the exosphere is called *magnetosphere*. The motion of ions in this region is strongly constrained by the presence of the Earth's magnetic field. This is the region where satellite orbits the Earth.

Activity 2

1. Explain briefly five warning signs of the earthquake.
2. Describe five negative and five positive effects of volcanic eruption.
3. How do earthquake cause damage?
4. What is the relationship between volcanoes and earthquake?
5. Will more shocks be felt after a strong earthquake?
6. Does the rate of earthquakes increase during the cold weather? Give reasons.
7. Can people cause earthquakes to occur?

The Greenhouse Effect and Global Warming

Dear learner, can you think of the effects of cutting down trees, bush fire, and the smoke from factories and motor vehicles? In the previous part of this Unit you learnt about structure and composition of the atmosphere. We have discussed in that part that the atmosphere is composed with various gases such as Oxygen, ozone layers amongst others.

In this Unit, you are going to learn about the greenhouse effect and global warming. You will learn many things such as the relationship between cutting trees and the increase in global temperature and how smoke from industries, motor vehicles and bush fire affect the Earth's temperature. Let us start to discuss about the greenhouse effect.

Greenhouse Effect

Greenhouse effect *is the process in which the emission of radiation by the atmosphere warms the Earth's surface.*

When the heat from the Sun reaches the Earth's surface in form of sunlight, some of it is absorbed by the Earth. The rest is radiated back to the atmosphere at a longer wavelength than the incoming sunlight.

Some of these longer wavelengths are absorbed by greenhouse gases in the atmosphere before they are lost into space.

The absorption of this long-wave radiant energy warms the atmosphere. The greenhouse gases act like a mirror, reflecting back to the Earth some of the heat energy which would otherwise be lost to space.

Sources of Greenhouse Effect

The sources of greenhouse effect include;

a) Carbon dioxide (CO_2).

b) Methane CH_4.

c) Chlorofluorocarbons (CFCs).

d) Nitrous oxide (Dinitrogen oxide).

Dear learner, let us discuss these four gases as follows:

a) Carbon dioxide (CO_2)

Carbon dioxide is the main greenhouse gas. The gas contributes over 50% of the greenhouse effect.

The following are some of the sources of Carbon dioxide:

i. Burning of vegetation.

ii. Burning of fossil fuels (coal, oil and natural gas).

b) Methane (CH_4)

It is one of the trace gases in the atmosphere that is considered to play a major role in the greenhouse effect.

The main sources of Methane are:

i. Agriculture activities. It is released from wetlands, such as rice fields and from animals' dungs.

ii. Mining of coal and oil.

iii. Biomass burning.

iv. Anaerobic decomposition of organic waste in landfills.

Note

Methane molecules have a lifetime of 10 years in the atmosphere.

c) Nitrous oxide (Dinitrogen oxide N_2O)

This is the third most important greenhouse gas for the enhanced greenhouse effect after CO_2 and CH_4.

The sources of N_2O include:

i. Combustion of fossil fuels in vehicles and power stations.

ii. Use of Nitrogenous fertilizers.

iii. Burning of vegetation.

iv. Animal waste.

d) Chlorofluorocarbons (CFCs)

Chlorofluorocarbons are organic compounds made up of Chlorine, Fluorine and Carbon. The source of CFCs in the atmosphere includes fridges, air conditioners, sprays and aerosols. CFCs are extremely effective greenhouse gases. A CFCs molecule is 10,000 times more effective in trapping heat than a Carbon dioxide molecule.

Global Warming

The effect is caused by greenhouse gases. These gases are produced from natural and industrial processes.

Global warming is primarily a problem of too much Carbon dioxide (CO_2) in the atmosphere which acts as a blanket, trapping heat and warming the planet (Earth).

As we burn fossil fuels like coal, oil and natural gas for energy or cut-down and burn forests to create pastures and plantations, Carbon accumulates and overloads our atmosphere.

***Global warming** is the increase of average temperatures near or on the surface of the Earth as a result of greenhouse effect.*

Consequences of Global Warming

Dear learner, global warming has the effects on the Earth as explained below:

i. Increases in the temperature of the oceans.

ii. Rise in sea levels due to melting of land ice. This will lead to coastal flooding of the coastal land.

iii. Acidification of the oceans, CO_2 dissolves in water and forms a weak Carbonic acid.

iv. Extreme weather events which include floods, drought, heat waves, hurricanes and tornadoes.

v. Destroying of agriculture and fisheries. This will be observed into forests, farms and cities whereby they will face troublesome brought by heat waves, heavy downpours, increased flooding and new pests.

vi. Melting glaciers, snowmelt and severe droughts will cause more dramatic water shortages and increase the risk of wildfires.

vii. Extinction (death) of some animal and plant species. Disruption of habitats such as coral reefs and Alpine meadows could drive many plant and animal species to extinction.

Solutions to Minimize Global Warming

Dear learner, we have already discussed the consequences of global warming. Can you explain the ways on how to minimize global warming? Share with your friend and relate your answers from the discussion with the following solutions:

i. Reduce the use of fossil fuels by using public transport which will minimize the number of vehicles in the roads.

ii. Use of fuel - efficient cars.

iii. Use of renewable sources of energy such as solar and wind.

iv. Afforestation; Replant trees that would absorb Carbon dioxide.

v. Countries to make a policy of minimizing the emission of greenhouse gases. Example Kyoto protocol.

Activity 3

1. What does global warming have to do with rising sea level?
2. Describe four gases that contribute to global warming.
3. Explain the effects of global warming.

Unit Reflection

Dear learner, make reflection of the Unit by attempting the following questions:

1. Do you think that you have learnt a competent content?
2. Do you think that the content in this unit is applicable to your life? Explain how the content in this Unit is applicable to your life.
3. What part of this unit challenges you most? Did you face any challenges in this Unit? If yes, explain how you solved them.
4. What steps did you take to overcome those challenges?
5. What part of this unit is mostly interested to you? Which part of the Unit did you enjoy most and why?

Unit Assignment

After completing studying this unit, do the following questions. Make sure you put your work in your portfolio. Dear learner, you have reached the end of the Unit. Attempt the following exercise and keep your work in the portfolio.

1. How can you differentiate the boundary between the mantle and crust from the boundary between the mantle and the core?
2. Explain how life would be without the layers of the Earth.
3. How heat inside the mantle affects the life on the surface of the Earth?
4. Explain why the outer core of the Earth is liquid while the inner core is solid even though the temperature is high.
5. Explain what is seismograph and its mode of action.
6. Explain how volcanoes occur.
7. Explain briefly three precautions that can be taken against Earthquake hazards.
8. Does the Earth open up during an Earthquake? Explain.
9. Where do earthquakes occur?
10. Can Earthquake be predicted? Explain.
11. Are there certain months of the year that are more seismically active than others? Why?

12. Does a small earthquake indicates that a larger earthquake is coming?
13. What was the greatest earthquake in the world history?
14. How can you explain the global warming?
15. Explain the measures that can be taken to control global warming.
16. Explain how cutting of trees contribute to global warming.

Activities Answers

UNIT 1

Activity 1

1. 3 cm , 21 cm/s, 7 Hz

2. 3.2 cm, 8.125 Hz, 0.123 seconds

3. 14 m

4. $6.25\times10^{-5}\,s$

Activity 6

9. 1080 m

10 (a) 333.33 m/s (b) 100.3 m

Activity 12

1. (a) 850 Hz (b) 2550 Hz

References

Abbott, A. F. (1997). Ordinary level Physics: Third edition Heinemann, England.

Akril, T., Bennet, G. & Millar, C. (1989). Physics: 5th edition Edward Arnold: Great Britain Edinburgh England Edition, Hazell Watson and Viney Ltd, Great Britain.

Nelkon, M. (1981). Principles of physics, 8th edition: Longman Edinburgh, England.

Oxford (2014). Physics for secondary schools form 3 & 4: First edition Oxford University Press, DSM, Tanzania.

SCSU & MOEVT (2010). Physics for secondary schools, Form 1 and 2: Oxford.

Oxford TIE & Bob Mc Duell (2010). Physics Form 3 & 4 student's book Person Education Ltd.

TIE (1993). Physics for Secondary School Book 2: Educational publisher, Dsm, Tanzania.

Whelan, P. M. & Hodgson, M. J. (1989). Essential Principles of physics; Second Edition, University Press (T) Ltd. DSM, Tanzania.

Institute of Adult Education
P.O. Box 20679,
Dar es Salaam
Tel: +255 22 2150836
E-mail: info@iae.ac.tz,
Website: www.iae.ac.tz

ISBN 978-9976-88-186-8

9 789976 881868