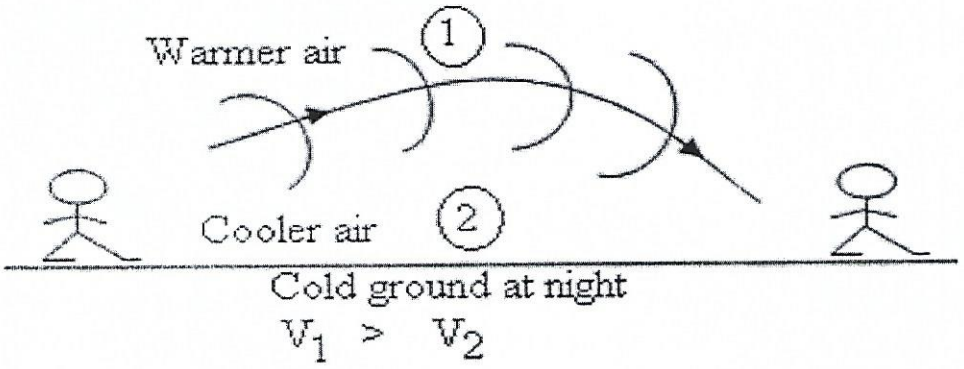
During day, the ground is hot and this makes the layers of air near the ground to be hot while that above the ground is generally cool. The wave fronts from the source are refracted away from the ground.

Refraction of sound during night.



During night, the ground is cool and this makers layers of air near the ground to be cool while above to be warm. The wave fronts from the source are refracted towards the ground making it easier to hear sound waves over long distances.

Sounds are more audible at night than during the day because the speed of sound in warm air exceeds that in cold air and refraction occurs. At night the air near the ground is usually cooler and refraction is towards the earth but during the day the reverse is usually true and this explains why radios are clearer at night than during day time.

QN: Why is it easier for sound waves to travel over a long distance at night than during day ?

2. Diffraction of sound.

This refers to the spreading of sound waves around corners or in gaps. When sound waves have wave length similar to the size of the gap, they are diffracted most.
Sound waves easily bend around corners because they have longer wavelength and are easily diffracted.
A person in one room can be heard by another person in the next room because of diffraction of sound waves.
The mouth acts as a gap and the waves from mouth spread and the person is able to hear the sound.
If you are sitting in a room and the door is open, you can hear music from a radio in the next room; the sound waves from the radio pass through the door and spread out into the room you are in.

Note: Light waves are not easily diffracted because they have short wave length.

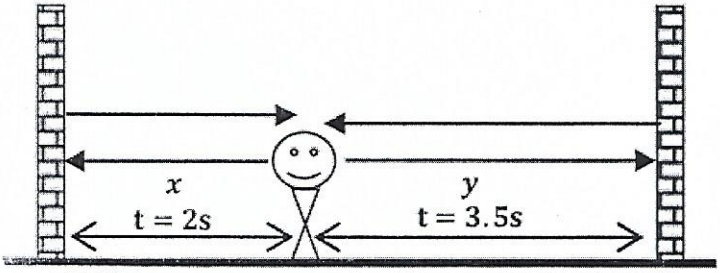
3. Interference of sound.

When two sound waves from two different sources overlap, they produce regions of loud sound and regions of quiet sound. The regions of loud sound are said to undergo constructive interference while regions of quiet are said to undergo destructive interference.

MUSICAL SOUNDS:

These are sounds composed of uniform and regular vibrations. Musical sounds are referred to as musical notes and a musical note is a sound of regular frequency.

Solution:

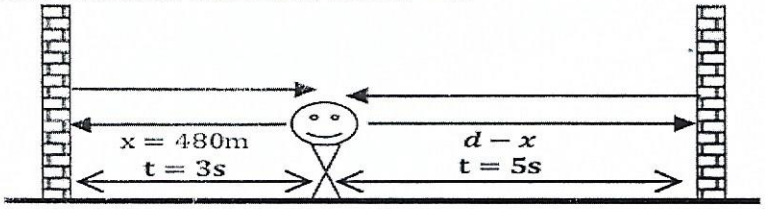


Case I	Case II
$V = \frac{2x}{t_1}$	$V = \frac{2x}{t_1}$
$330 = \frac{2x}{2} \Rightarrow 2x = 2 \times 330$	$330 = \frac{2y}{3.5} \Rightarrow 2y = 3.5 \times 330$
$x = 330\ m$	$y = 577.5\ m$
Distance between the cliffs, $d = x + y$	
$d = x + y$	
$d = 330 + 577.7$	
$d = 907.5\ m$	

10. A student, standing between two vertical cliffs and 480m from the nearest cliff shouted. She heard the 1st echo after 3 seconds and the second echo 2 seconds later. Calculate;
(i) the velocity of sound in air.
(ii)the distance between the cliffs.

Solution:

Let distance between cliffs = **d**



Case I	Case II
$V = \frac{2x}{t_1}$	$V = \frac{2(d-x)}{t_2}$
$V = \frac{2 \times 480}{3} \Rightarrow 3V = 960$	$320 = \frac{2(d-480)}{5}$
$V = 320\ ms^{-1}$	$2(d-480) = 5 \times 320$
	$d - 480 = 800$
	$d = 1280\ m$

EXERCISE:

1. A boy standing 100m from the foot of a high wall claps his hands and the echo reaches him 0.5s after. Calculate the speed of sound in air.
2. A sound wave is produced 600m away a high wall. If an echo is received after 4 seconds. Find the frequency of sound wave if the wave length is 2m.
3. A sound wave of frequency 250Hz is produced 120m away from a high wall. Calculate;
(i)the wavelength of the sound wave.

$$\text{Speed} = \frac{2(\text{distance})}{\text{time}}$$

$$V = \frac{2d}{t}$$

$$V = \frac{2 \times 34}{0.2}$$

$$V = 340\ ms^{-1}$$

2. A person standing 99m from a tall building claps his hands and hears an echo after 0.6 seconds. Calculate the velocity of sound in air.

Solution:

$$\text{Speed} = \frac{2(\text{distance})}{\text{time}}$$

$$V = \frac{2d}{t} = \frac{2 \times 99}{0.6} = 330\ ms^{-1}$$

$$V = 330\ ms^{-1}$$

3. A gun was fired and an echo from a cliff was heard 8 seconds later. If the velocity of sound is 340m/s, how far was the gun from the cliff?

Solution:

$$\text{Speed} = \frac{2(\text{distance})}{\text{time}}$$

$$V = \frac{2d}{t}$$

$$340 = \frac{2d}{8}$$

$$2d = 340 \times 8$$

$$2d = 2720$$

$$d = 1360\ m$$

4. A student is standing between two walls. He hears the first echo after 2 seconds and then another after a further 3 seconds. If the velocity of sound is 330m/s, find the distance between the walls.

Solution:

$V = \frac{2d_1}{t_1}$	$V = \frac{2d_2}{t_2}$
$330 = \frac{2d_1}{2} \Rightarrow 2d_1 = 660$	$330 = \frac{2d_2}{5} \Rightarrow 2d_2 = 1650$
$d_1 = 330\ m$	$d_2 = 825\ m$
$d = d_1 + d_2$ $d = 330 + 825$ $d = 1155m$	

5. A man is standing midway between two cliffs. He claps his hands and hears an echo after 3 seconds. Find the distance between the two cliffs.
(Velocity of sound = 330m/s)

Question
Explain why sound travels faster in solids than in liquids?

EXAMPLES
1. Sound waves of frequency 3.3 KHz travel in air. Find their wavelength (Take speed of sound in air = 330m/s).
2. Two men stand a distance apart besides a long metal rail. One man places his ear against the rail while the other gives the rail a sharp knock with a hammer. Two sounds separated by a time interval of 0.5s, are heard by the first man. If the speed of sound in air is 330m/s, and that in the metal rail is 5280m/s , find the distance between the men.

Solution:

$$t_1 - t_2 = 0.5$$

$$\frac{x}{330} - \frac{x}{5280} = 0.5$$

$$x = 176 \text{ m}$$

How sound waves travel through air.
- Sound waves are produced by the vibration of air particles. As air particles vibrate, the vibration, produce energy which is transferred to the next particles that also vibrate in the same direction as the sound wave.
- The next particles are so made to vibrate and in doing so, they transfer their energy particles which also vibrate.

Properties of sound waves.
The sound waves have 4 properties i.e. reflection, refraction, diffraction and interference.

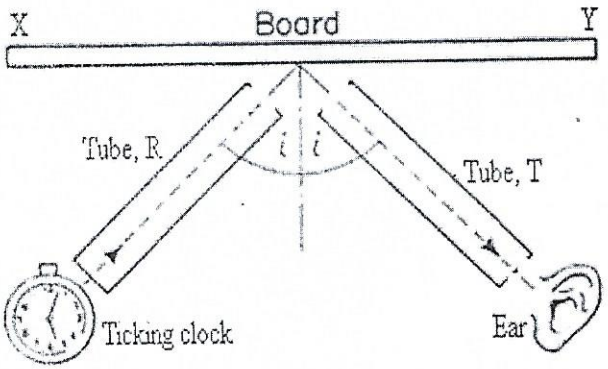
1. Reflection of sound waves.
Sound waves obey the laws of reflection that is they are reflected in the same way light waves are reflected

Laws of reflection of sound:

1st law
The incident wave, the reflected wave and the normal at the point of incidence all lie in the same plane.

2nd law
The angle of incidence of the wave is always equal to the angle of reflection of the wave.

Experiment to verify the laws of reflection of sound.



TOPIC 2: SOUND WAVES.

Sound waves can be defined as a form of energy which is produced by vibrating objects.
OR Sound waves are waves produced when particles of the medium are set into vibrations.
The medium in which sound waves travel can be a solid, a liquid or gas. In gases (air) sound waves travel forming regions of compressions and rare factions, hence sound waves cannot travel without a medium.

PROPERTIES OF SOUND WAVES

- Can be reflected, refracted, diffracted, polarized and undergo interference.
- They travel with a speed, V= 330m/s in air.
- They are longitudinal waves in nature.
- They require a material medium for their transmission and so they can not travel in a vacuum

SPECTRUM OF SOUND WAVES.

Frequency	**0-20Hz**	**20-20,000Hz**	**>20,000Hz**
Type of sound	Subsonic sound waves	Audible sound waves	Ultra sonic sound waves

Subsonic sound waves.
These are not audible to human ear because of very low frequency of less than 20Hz.
Audible sound waves.
These are audible to human ear. This frequency ranges from 20Hz - 20KHz.
Ultra sonic sound waves.
These are sound waves whose frequencies are above 20KHz.
They are not audible to human ears.
They are audible to whales, Dolphins, bats etc.

Application of ultra sound waves.

- ✔ They are used by bats to detect obstacles e.g. buildings a head.
- ✔ Used in spectacles of the blind to detect obstacles.
- ✔ Used in radio therapy to detect cracks and faults on welded joints.
- ✔ Used in industries to detect rocks in seas using sonar.
- ✔ Used to measure the depth of seas and other bodies.

Examples

1. A radio station broad casts at a frequency of 200 kHz and the wave length of its signal is 1500m. Calculate the;
(I) speed of the radio waves. ($3.0\times10^{8} m/s$)
(ii) wave length of another station that broad casts at a frequency of 250 Hz. [$\lambda =$ $1.2\times10^{6} m$]

2. An F.M radio, broad casts at a frequency of 88.8MHz. What is the wave length of the signal? [λ = 3.4m]

TRANSMISSION OF SOUND.

Sound requires a material medium for its transmission. It travels through liquids, solids and gases, travels better in solids and does not travel through a vacuum.

2. Applications of X-rays

Medical Applications

1. **Diagnostic Imaging**:
    - X-rays are widely used in **radiography** to create images of bones and internal organs (e.g., chest X-rays).
    - **CT Scans (Computed Tomography)** use X-rays to create detailed cross-sectional images of the body.
2. **Radiation Therapy**:
    - High-energy X-rays are used to destroy cancerous cells.

Industrial Applications

1. **Non-Destructive Testing (NDT)**:
    - Used to inspect materials for internal defects (e.g., cracks in metal or welds).
2. **Security Scanning**:
    - X-ray machines are used in airports and borders to scan luggage and cargo.

Scientific applications

1. **X-ray Crystallography**:
    - Determines the atomic and molecular structure of crystals (e.g., DNA, proteins).
2. **Astronomy**:
    - X-rays help study high-energy astronomical phenomena (e.g., black holes, supernovae).

3. Effects of X-rays

Positive Effects

1. **Medical Diagnosis and Treatment**:
    - Early detection of diseases like fractures, infections, and tumors.
    - Effective cancer treatment.

Negative Effects

Overexposure to X-rays can cause:

1. **Short-Term Effects**:
    - **Radiation burns**: Skin damage due to high doses.
    - **Nausea and fatigue**: Symptoms of acute radiation exposure.
2. **Long-Term Effects**:
    - **Cancer Risk**: DNA damage from ionizing radiation can lead to mutations and cancer.
    - **Cataracts**: High doses can cloud the eye lens.
    - **Infertility**: Damage to reproductive organs.
3. **Environmental Effects**:
    - Improper disposal of X-ray equipment can lead to environmental contamination

- **Cataracts**: Clouding of the lens.
- **Photokeratitis**: Painful condition also called "snow blindness."

- **Immune system suppression**: Weakens the body's ability to fight infections.

2. **On Materials and Environment**:
   - **Degradation of materials**: UV radiation can cause plastics, fabrics, and paints to deteriorate.
   - **Impact on ecosystems**: Excessive UV can harm aquatic organisms, phytoplankton, and plants.

2. X-rays

X-rays are a type of high-energy electromagnetic radiation used in medical imaging.

Effects of Overexposure

1. **On Human Health**:
   - **Tissue damage**: High doses can kill or damage cells.
   - **Cancer risk**: Repeated or high exposure increases the risk of cancer.
   - **Radiation burns**: Skin and tissue damage from excessive exposure.
2. **On Materials**:
   - Causes molecular bond disruptions, potentially leading to material damage or weakening over time.

3. Gamma Rays

Gamma rays are the most energetic form of electromagnetic radiation, often produced by radioactive decay or nuclear reactions.

Effects of Overexposure

1. **On Human Health**:
   - **DNA damage**: Can lead to mutations, cancer, or cell death.
   - **Acute radiation syndrome**: High doses cause nausea, vomiting, and, in severe cases, organ failure.
   - **Long-term effects**: Chronic exposure can lead to infertility, cataracts, and increased cancer risk.
2. **On Materials**:
   - **Structural weakening**: Gamma radiation can degrade metals, plastics, and other materials.

Protective Measures

1. **UV Radiation**:
   - Use **sunscreen**, wear protective clothing, and avoid prolonged sun exposure.
   - Wear **UV-blocking sunglasses** to protect your eyes.
2. **X-rays and Gamma Rays**:
   - Limit exposure to medical X-rays and use protective shields (e.g., lead aprons)

They have longer wavelength than gamma rays. They cause certain metals to emit electrons but destroy body tissues on exposure to the body for a long time. X-rays are produced by fast moving electrons on hitting the metal target.

Visible light:
Visible light helps us to see objects. It determines the colour of the object and the appearance of the object.

Ultra-violet [uv] light:
This is a type of radiation with wavelength just shorter than violet. The sun emits much of the energy in form of ultra-violet light but most of it is absorbed by the atmosphere.
Ultra-violet light causes certain metals to emit electrons, they cause photosynthesis in green plants and they cause blindness when too much of it falls into the eyes.

Infrared:
All objects emit infrared radiations. They cause the body temperature to rise because most of the heat in light is carried by infrared. Infrared enables us to get vitamin D.

Radio waves:
Radio waves are produced when electrons are accelerated in an aerial. They have the longest wavelength and lowest frequency. Radio waves can penetrate most materials.

Properties of electromagnetic waves.

- ✔ They are transverse waves in nature.
- ✔ They travel at a speed of light of $c=3.0\times10^{8}m/s$ in a vacuum.
- ✔ They do not need a material medium i.e they travel through vacuum..
- ✔ They have no specific charge
- ✔ They can be reflected, refracted, diffracted and undergo interference.
- ✔ They posses energy

Applications of electromagnetic waves.

1. Radio Waves

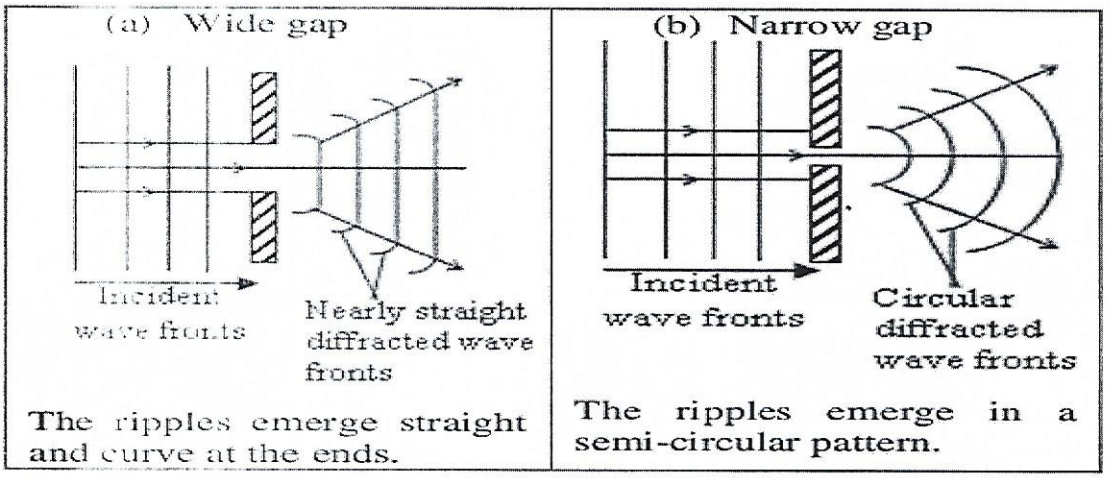
- **Applications:**
  - **Communication:** AM/FM radio, television broadcasting, and mobile networks.
  - **Navigation:** GPS and maritime communication.
  - **Astronomy:** Observing celestial phenomena like pulsars.

2. Microwaves

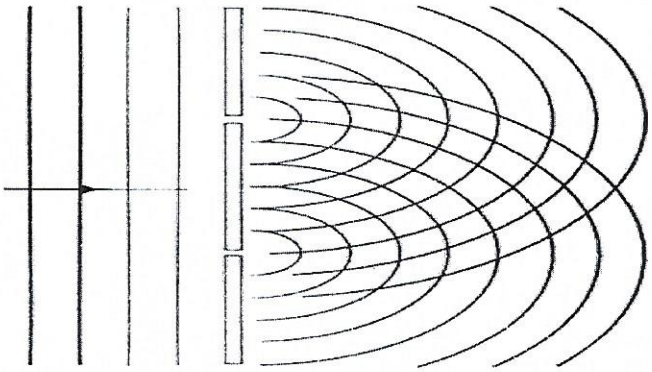
- **Applications:**
  - **Cooking:** Microwave ovens.
  - **Communication:** Satellite and wireless data transmission (Wi-Fi, Bluetooth).
  - **Radar:** Air traffic control, weather forecasting, and military applications.

3. Infrared Waves

- **Applications:**
  - **Thermal Imaging:** Night vision devices and medical imaging.
  - **Remote Controls:** Controlling TVs and other electronic devices.
  - **Heating:** Infrared heaters and drying processes
  - **Astronomy:** studying distant stars and galaxies.



If there are two or more gaps in a barrier the waves will be diffracted and interference of waves takes place.



NB: ***1.*** When waves undergo diffraction, wave length and velocity remain constant.

2. Waves spread out more (i.e greatly diffracted) when the wave length is longer. Thus, sound waves are more diffracted than light waves because the wave length of sound is greater than that of light. Therefore sound can be heard in hidden corners.

3. Diffraction (spreading) increases with decrease in the width of the slit. Wider gaps produce less diffraction.

QUESTION:

Why is it that the reception of TV and FM radio is poor in the valley?

The degree of diffraction of waves depends on the wavelength of the waves and the width of the gap they pass through. When waves pass through a gap that is almost the same width as their wavelength, they spread out as they emerge from the other side. If the gap is very wide compared with the wavelength, little or no spreading occurs except at the edges of the gap.

If the wavelength of the waves is shorter, the spreading(diffraction) effect is much smaller as well. This is why TV waves are much more difficult to receive in hilly areas than radio waves. In the valley, both the TV and FM waves encounter many obstacles hence more loss in energy. Therefore by the time the signals reach the receipt, they are weak.

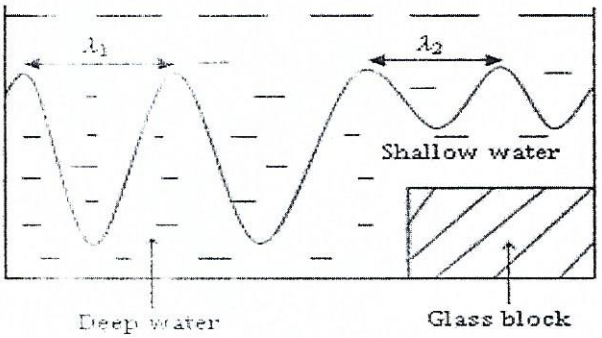
(d) **INTERFERENCE OF WAVES**

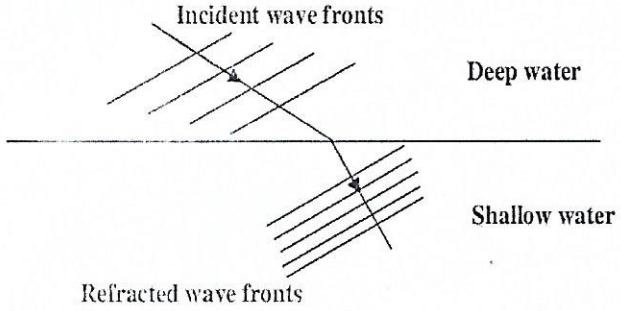
This is the effect which occurs when two waves of the same speed, frequency, wave length and amplitude traveling in the same direction meet. The waves merge and combine and the ability of the waves to combine together is called the principle of super position.

(b) **REFRACTION OF WAVES**

This is change in direction of the wave when a wave moves from one medium to another of different optical densities. When a wave is refracted there is **change in wave length and speed but the frequency and the period remain constant.** Waves formed in a ripple tank can be refracted by placing a sheet of glass in water to make it shallow.

When a wave moves from deep water to shallow water its wave length and its speed decrease but the frequency does not change. The wave fronts are therefore close to one another in shallow waters than in deep waters as shown below;





$$Refractive\ index, n = \frac{Velocity\ of\ the\ wave\ within\ the\ first\ medium, v_1}{Velocity\ within\ the\ second\ medium. v_2}$$

$$n = \frac{f\lambda_1}{f\lambda_2}$$

$$n = \frac{\lambda_1}{\lambda_2}$$

Note that $v_1 > v_2$ and $\lambda_1 > \lambda_2$

(c) **DIFFRACTION OF WAVES**

This is the spreading of waves of the same wave length and frequency around the corner or barrier. In a ripple tank diffraction can be achieved by placing two barriers with a gap between them and plane wave fronts made to pass through the gap. If the gap is made smaller the plane wave fronts emerge with a circular shape and spread out in all directions and if the gap is made wide plane wave fronts emerge bent slightly at the edges as shown below;

NOTE: 1. The speed of the wave in a ripple tank can be reduced by reducing the depth of water in the tank. The effect of reducing the speed of waves is that the wave length of wave reduces but frequency does not. The frequency can only be changed by the source of the wave.

2. A wave front is the surface of the wave form on which every particle transmitting the wave is at the same distance from source of the wave and in the same state of disturbance. Wave fronts are either circular or plane wave fronts as shown below;



3. The distance between two successive wave fronts is equal to the wave length, λ

Question

A vibrator in a ripple tank has a period of 0.2 seconds and the distance between 10 successive crests is 38.8cm.

Calculate the ;

(i)wavelength of the wave [4.31cm]

(ii)velocity of the wave [0.22 m/s]

WAVE PROPERTIES

The wave produced in a ripple tank can undergo,

(a) Reflection

(b) Refraction

(c) Diffraction

(d) Interference

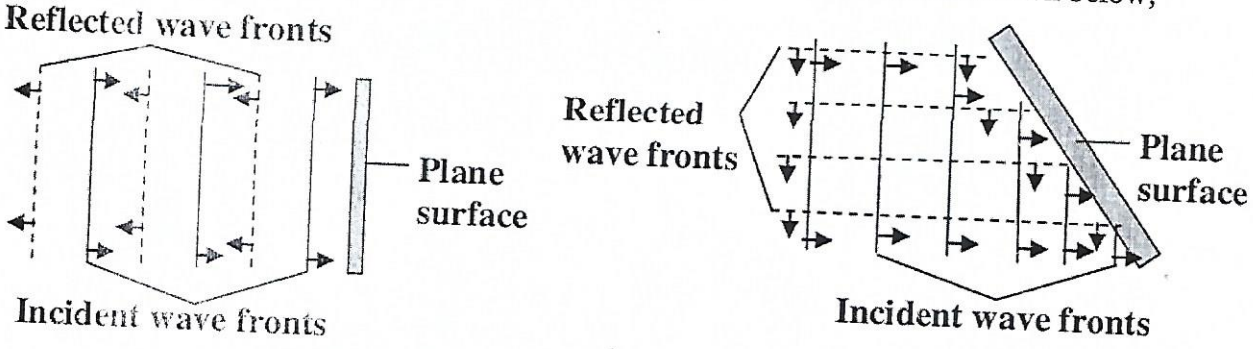
(e) Polarization

(a) REFLECTION OF WAVES

This is the bouncing off of waves when they meet a barrier. The waves produced in a ripple tank are reflected when a barrier is placed in their path.

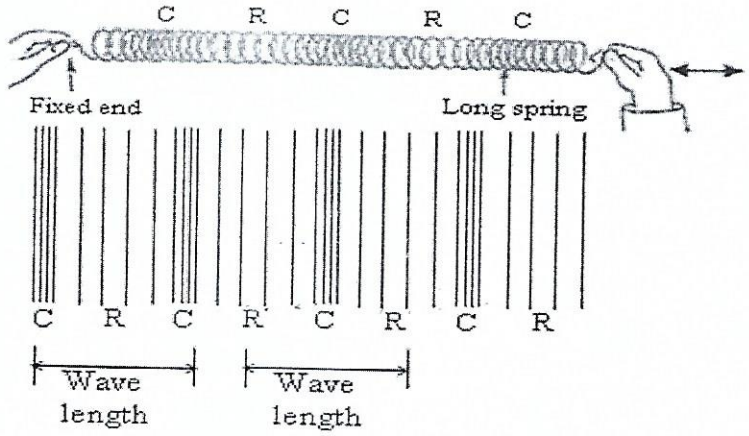
i) Reflection on a plane surface

A plane wave front incident on a plane surface is reflected as a plane wave front and if the plane surface is inclined at an angle of 45° to the waves, the waves are reflected as shown below;



Circular convex wave fronts incident on a plane surface are reflected as circular concave wave fronts and circular concave wave fronts are reflected as convex circular wave fronts as shown below;

Longitudinal waves travel by formation of compressions and rare factions. Regions where particles crowd together are called **compressions** and regions where particles are further apart are called **rare factions** as shown below;



Compression (C) is a region in a longitudinal where the vibrating particles are very close together.
A rare faction (R) is a region in a longitudinal where the vibrating particles are further apart (distanced).

NB: Note that the distance between two successive compressions or rare factions is equal to the wave length of the wave.

Differences between longitudinal and transverse waves.

Transverse Waves

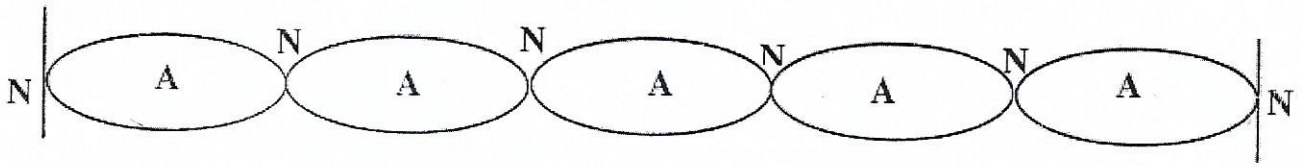
- Particles vibrate perpendicular to the direction of the wave
- Consists of crests and troughs
- Can be polarized

Longitudinal waves

- Particles vibrate parallel to the direction of the wave
- Consists of compressions and rare factions
- Cannot be polarized

(b) STATIONARY (STANDING) WAVES.

This is a wave formed when two transverse waves of the same speed, frequency, wave length and amplitude traveling in opposite direction meet.
It has points which are permanently at rest called **Nodes** and points which vibrate with maximum displacement called **Anti-nodes** as shown below;



Conditions for a stationary wave to be formed.

The following conditions are necessary to form a stationary wave;

- The waves have the same frequency.
- The waves have the same speed.
- The waves have the same wave length.
- The waves have the same amplitude.
- The waves are moving in opposite directions.

NOTE: The distance between two successive nodes or anti-nodes is equal to a half wave length ($\frac{1}{2}\lambda$).

Example:

The distance between two successive nodes is 12cm. Find the wave length of the wave

(c) velocity of the wave

$$v = \frac{Distance}{Time} = \frac{18}{0.45} = 40\,m\,s^{-1}$$

Alternatively;

$$v = f\lambda = 10 \times 4$$
$$= 40\ ms^{-1}$$

(d) frequency

The frequency can be obtained in two ways

4.5 waves are made in 0.45 s

1 wave is made in $\frac{0.45}{4.5}$ s

$\therefore \quad T = 0.1$

From $f = \frac{1}{T} = \frac{1}{0.1}$

$f = 10$ Hz

Alternatively; In 0.45 s, 4.5 waves are made,

In 1 s $\frac{4.5}{0.45}$ waves are made = 10 Hz

2. A vibrator produces waves which travel a distance of 35cm in 2s. If the distance between two successive crests is 5cm, what is the frequency of the vibrator?

Speed, v of the wave is given by

$v = \frac{d}{t}$ where, d, is the distance moved and t the time taken.

$v = \frac{35}{2}$ $\quad v = 17.5\ cms^{-1}$

Using $v = f\lambda$

$f = \frac{v}{\lambda}$

$f = \frac{17.5}{5}$ $\quad f = 3.5$ Hz

NB: The distance, d between n successive crests or troughs is given by; $\mathbf{d = (n-1)\lambda}$

EXERCISE

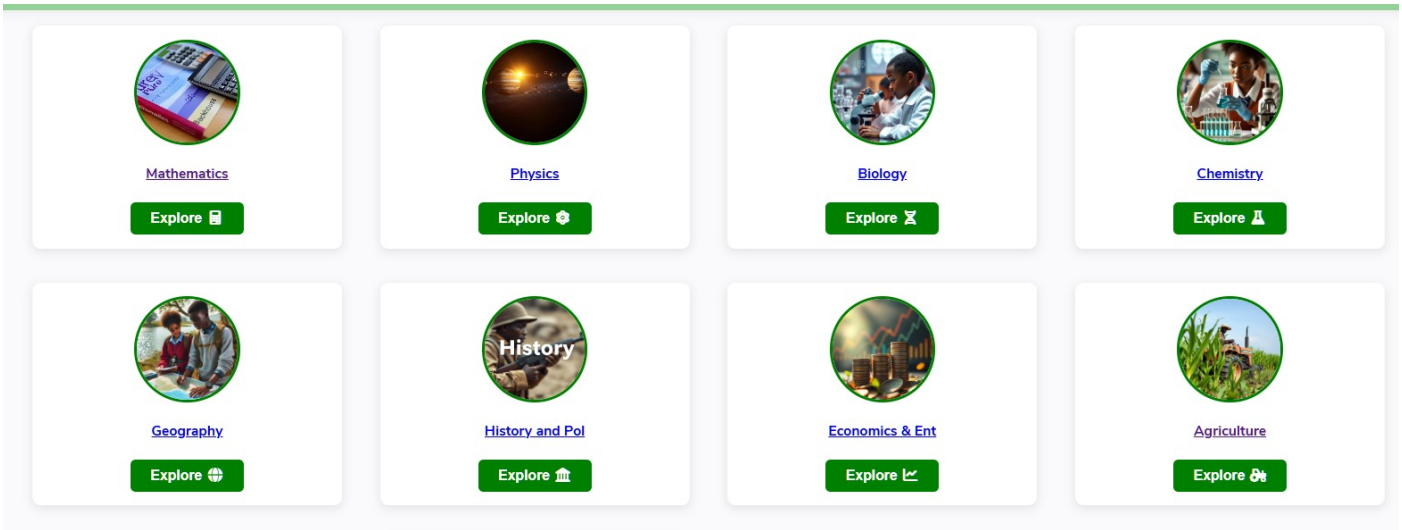
1. A radio station produces waves of wave length $10\,m$. If the wave speed is $3\times10^{8}\,m/s$, calculate;
   (i)Frequency of radio wave.
   (ii)Period, T
   (iii)Number of cycles completed in $10^{8}\,s$
2. A vibrator of 5Hz produces plane waves in a ripple tank. If the distance between ten successive crests is 37.8cm, calculate the speed of the wave.
3. Plane water ripples are produced in a ripple tank. The distance between 2 successive crests is 2.5cm and the wave travels 20cm in 125s. Calculate the speed and the frequency of the wave,
4. Water enters a beach at a rate of 45 crests per minute. A boy watches a particular wave crest passing two poles which are 6m apart along the direction of travel of the waves. The time taken from one pole to another is 2s. Calculate the;

(a) frequency of the wave motion.
(b) wavelength of the wave motion.

5. A sound source produces 160 compressions in 10s. The distance between successive compressions is 20m. Calculate the;

(i)frequency of sound(16Hz). (ii)wave speed(320m/s)

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