# WAVES

A wave is a disturbance which travels through a medium and transfer energy from one point to another without causing any permanent displacement of the medium itself e.g. water waves, sound waves, waves formed when a string is plucked

**WAVE MOTION**

When a wave is set up on the medium, the particles of the medium from about a mean position as the wave passes. The vibrates are passed from one particle to the next until the final destination is reached

**TYPES OFWAVES**

Two broad types -:

a) progressive waves (stationary waves)
b) mechanical and electromagnetic waves).

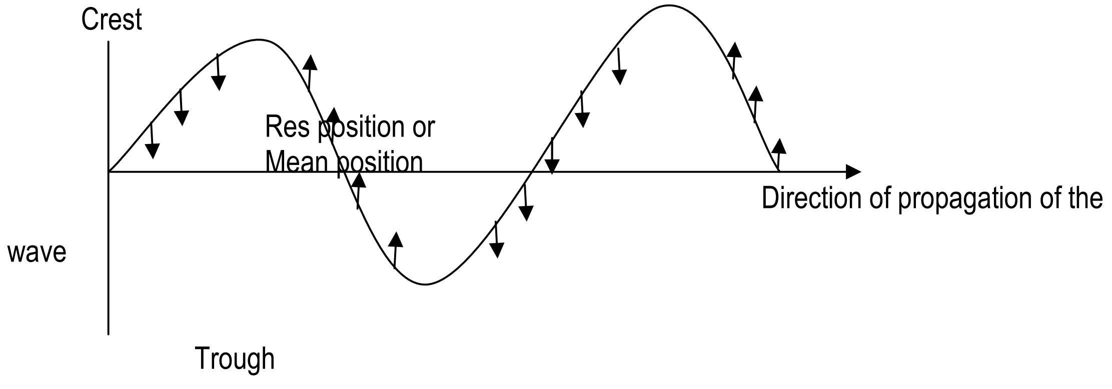
**PROGRESSIVE WAVES**

Is a wave which moves away from its source through a medium and spreads out continuously? There are two kinds of progressive waves namely:

i) Transverse waves
ii) Longitudinal waves

**i) TRANSVERSE WAVES**

These are waves in which particles vibrate perpendicular to the direction of propagation of the wave, e.g. water waves, light waves, waves formed when a rope is moved up and down.



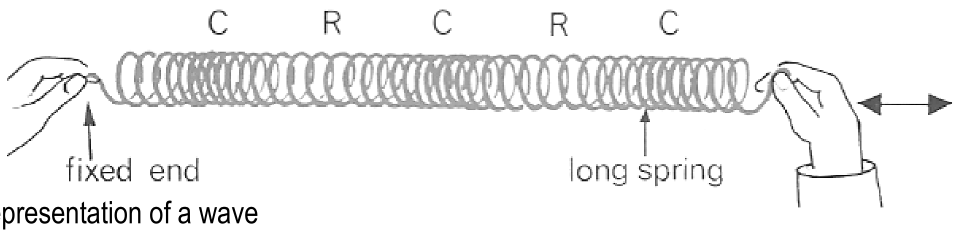
**ii) LONGITUDINAL WAVES**

These are waves in which the particles of media vibrate in the same direction as wave

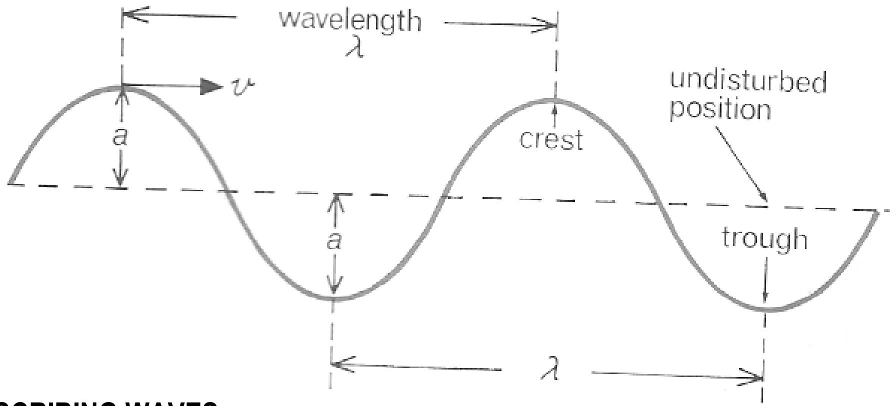
**OR**

These are waves in which the particles of the media vibrate parallel to wave motion e.g. sound waves, waves from a slinky spring.

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.




General representation of a wave




**TERMS USED IN DESCRIBING WAVES**

**1 <u>Rest position (Mean position)</u>**

This is the line OQ where particles are stationary or displacement of a particle is 0

**2 <u>Amplitude (a)</u>**

This is the maximum displacement of a particle from the rest position.

**3 <u>Cycle</u>**

This is one complete oscillation of the wave.

4 **Wave length (λ)**

- This is the distance between two successive crests or two successive troughs. (Transverse wave)
- This is the distance covered by one complete cycle of a wave.
- This is the distance between two particles of a wave vibrating in phase e.g. x$ y or p $ Q.
- This is the distance between two successive compressions or rare factions.

5 **Period**

Is the time taken by a wave to perform one complete cycle, i.e. T= $\frac{t}{n}$ where n is number of cycle.

6 **Frequency**

This is the number of cycles a wave completes in one second i.e. F= $\frac{n}{t}$ S.I. unit = Hertz ($H_z$)

7 **Wave front**

Is any line or section taken through an adversing wave in which all the particles are in the same phase.

8 **Crest**

It is the maximum displaced point a above the line of 0 (zero) disturbance.

9 **Trough**

It is the maximum displaced point below line of zero disturbance.

10 **Wave velocity**

It is the distance which the wave travels in one second in a given direction. S.I unit m/s.

**THE WAVE EQUATION**

From the wave speed v= $\frac{d}{t}$ .....(i)

If the wave describes n cycles in time $t_1$

Then the distance covered d= nλ.... (ii)

Substituting for d in … (i) ⟶ v= $\frac{d}{t}$

$$V=\frac{n\lambda}{t}$$

But f= $\frac{n}{t}$ hence v= fλ   wave equation

**Examples**

A radio station produces waves of wave length 10m. 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 $10^8$

(i) λ = 10m , v= $3\times10^8$ m/s   t= 10s

v = f λ ⟶ f = $\frac{v}{\lambda}$

= $\frac{3\times 10^8}{10}$

= $3\times10^{-1}$ $H_z$

(ii) period T = $\frac{1}{f}$ = $\frac{1}{3\times10^{-1}}$

= $\underline{3.3\times10^{-8}}$

(iii) Number of cycles ⟶ f = $\frac{n}{t}$ ⟶ n = f t

= $3\times10^{-1}\times 10$

= $\underline{3\times10^8 \text{ cycles}}$

2 The distance between 10 consecutive crests is 36cm. Calculate the velocity of the wave. If the frequency of the wave is $12H_z$.

V= f λ but d = ( n – 1 ) λ

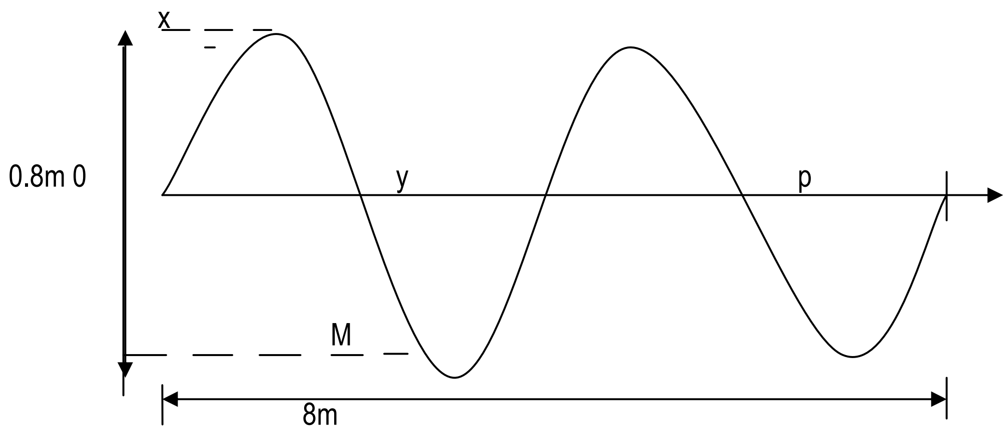
= 12×0.04 = (10- 1) λ

= 0.48m/s 0.36 = 9 λ

$\lambda = \frac{0.36}{9}$

= <u>0.04m</u>

3. The diagram below shows a wave travelling in water.




(a) Name (i) Any two points on the wave which are in phase

(ii) Labeled m and x

(b) ( i) Determine the amplitude of the wave.

(ii) If the speed of the wave is 80m/s. Determine the frequency of the wave.

*Questions*

A vibrator produces waves which travel 35 m in 2 seconds. If the waves produced are 5cm from each other, calculate;

(i) the wave velocity

(ii) wave frequency

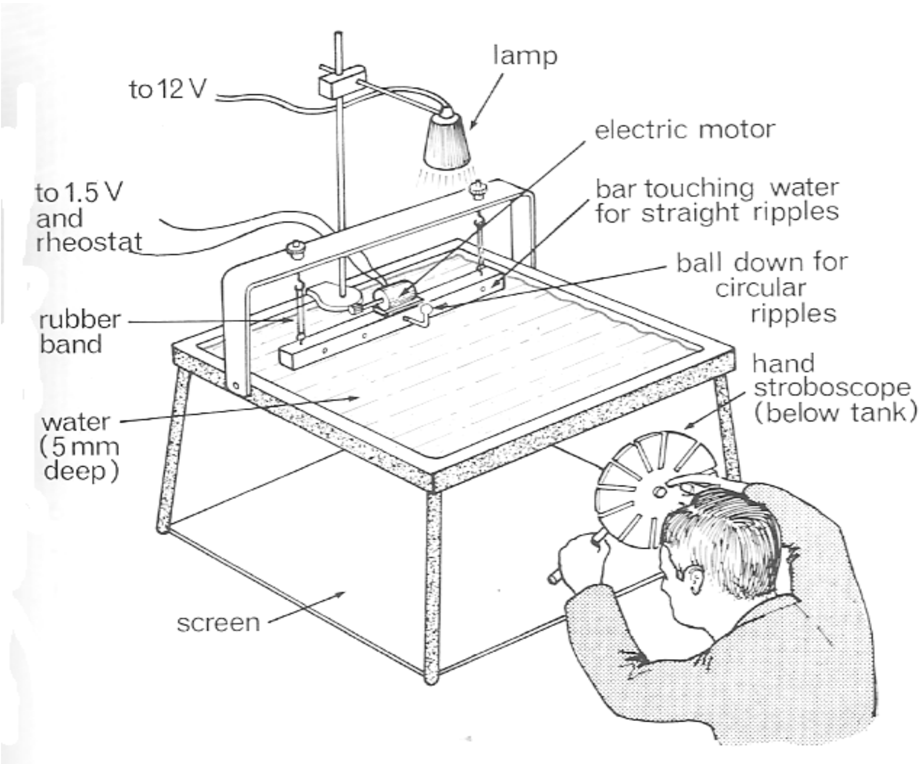
(i) v= f λ $\longrightarrow$ f = $\frac{v}{\lambda}$ = $\frac{35}{2}$

= $\frac{14.7}{1} = \frac{v}{5}$

14.7 × 5 = v

$7^3$ .5m/s = v

**THE RIPPLE TANK**



A ripple tank is an instrument used to study water wave properties. It is a shallow glass trough which is transparent. The images of the wave are projected on the screen which is placed below it.

The waves are produced by means of a dipper which is either a strip of a metal or a sphere. When the dipper is moved up and down by vibration of a small electric motor attached to it. The sphere produces circular wave fronts and the metal strip is used to produce plain waves.

A stroboscope helps to make the waves appear stationery and therefore allows the wave to be studied in detail.

**N.B** Therefore 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 sped of waves is that wave length of water reduces but frequency does not. The frequency can only be changed by the source of wave.

**WAVE PROPERTIES**

The wave produced in a ripple tank can undergo.

(a) Refraction
(b) Reflection
(c) Defraction
(d) Interference

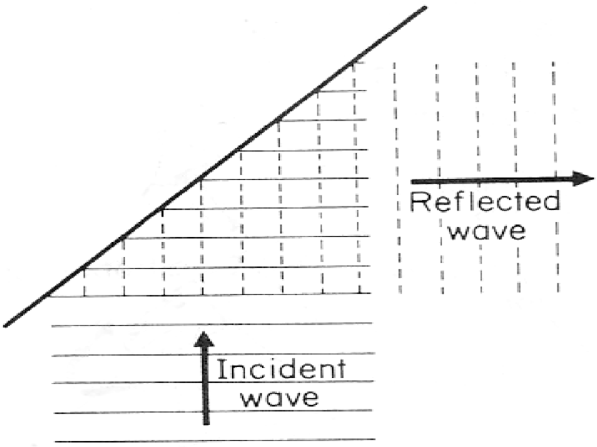
## REFLECTION OF WAVES

A wave is reflected when a barrier is placed in its path. The shape of the reflected wave depends on the shape of the barrier.

The laws of reflection of waves are similar to the laws of reflection of light.

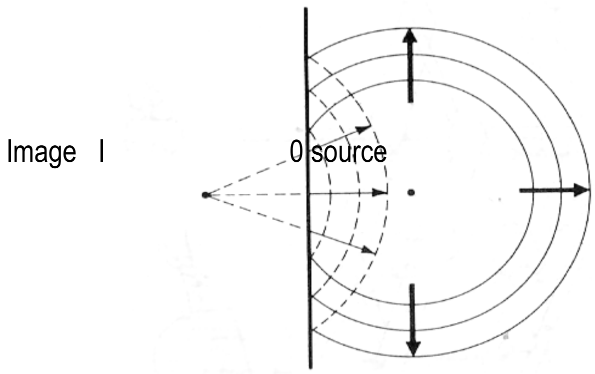
(i) <u>Reflection of plane wave</u>

(a) On a plane surface.



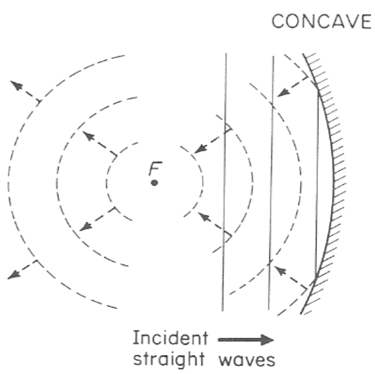

**<u>Reflection of circular wave</u>**

**(a) <u>On a plane surface</u>**



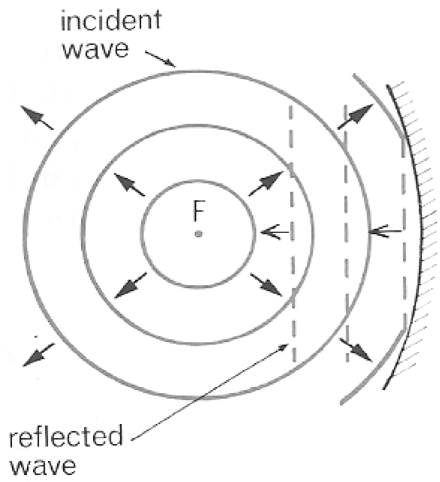

**(i) Reflection of plane wave**

(b) Concave reflector



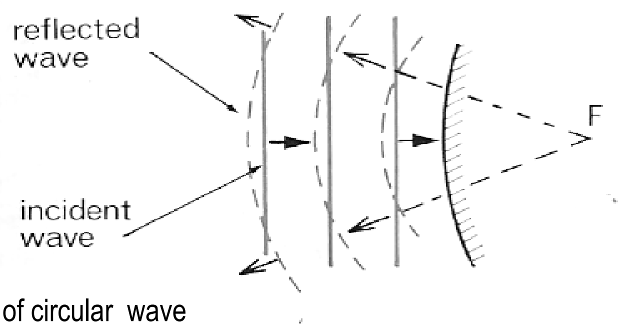
**(ii) Reflection of circular wave**

(b) Concave reflector



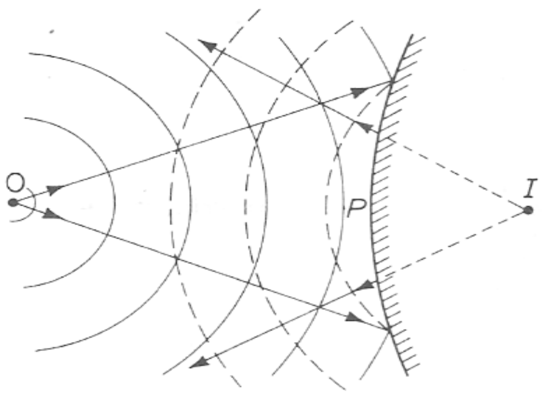

**(i) Reflection of plane wave**

(a) Convex reflector




(ii) Reflection of circular wave

(b) Convex reflector

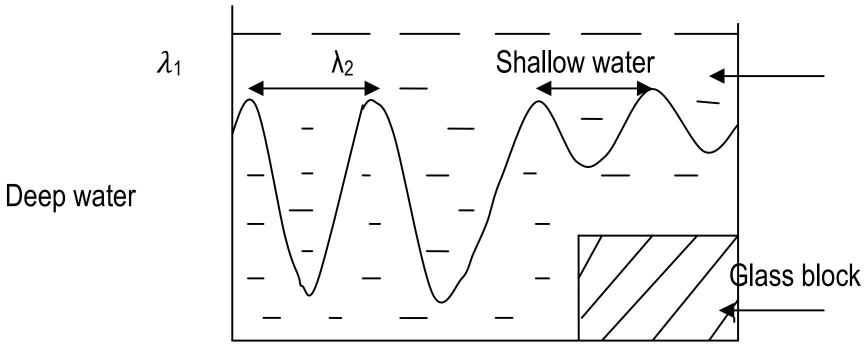


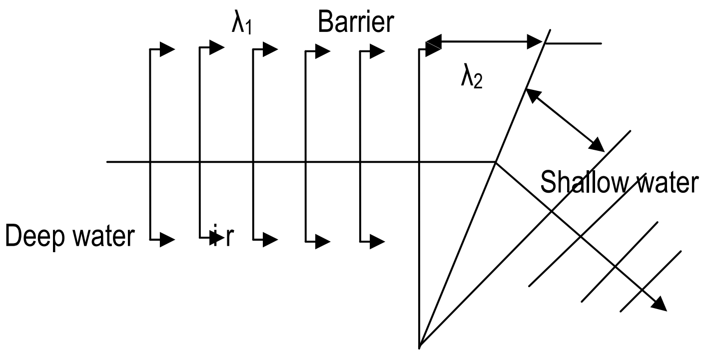
**Note**

During reflection of water waves, the frequency and velocity of the wave does not change.

# REFRACTION OF WAVE

This is the change of in direction of wave travel as it moves from one medium to another of different depth. It is caused in change of wave length and velocity of the wave. However, the frequency and the period are not affected. In a ripple tank, the change in direction is brought about by the change in water depth.




$\lambda_1$ = wave length in deep water

$\lambda_2$ = wave length in shallow water

Note (i) $\lambda_1 > \lambda_2$

(ii) $v_1 = f\lambda$ and $v_2 = f\lambda_2$

(iii) $v_1 > v_2$ When f – is constant.

Refractive index n = $\frac{velocity\ in\ deep\ water}{velocity\ in\ shallow\ water}$

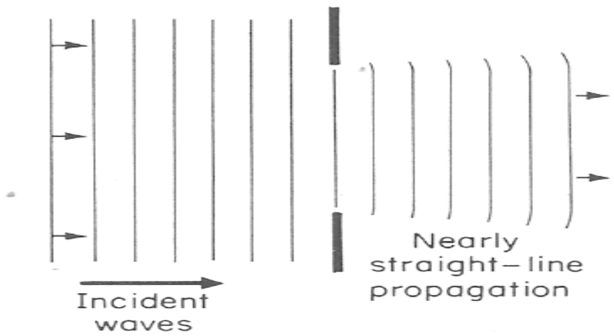
$= \frac{v_1}{v_2} = \frac{f\lambda_1}{f\lambda_2}$

n = $\frac{\lambda_1}{\lambda_2} = \frac{wave\ length\ in\ deep\ water}{wave\ length\ in\ shallow\ water}$

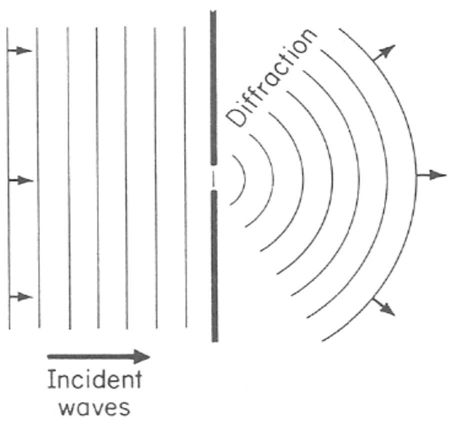
## DEFRACTION OF WAVES

This is the spreading of waves as they pass through holes, round corners or edges of obstacle. It takes place when the diameter of the whole is in the order of wave length of the wave i.e. the smaller the gap the greater the degree of defraction as shown below.

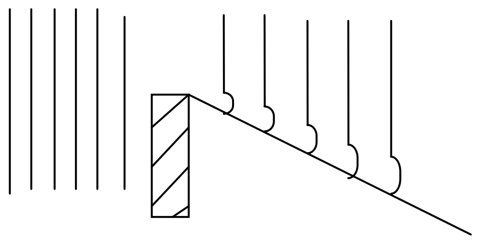
**(a) Wide gap**




**(b) Narrow gap**



**(c) Edge of obstacle**



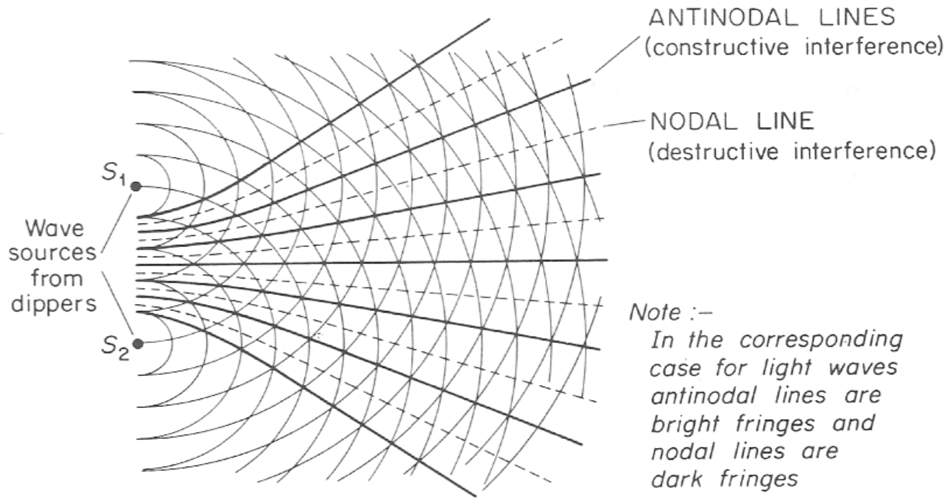
Sound waves are more defrosted than light waves because the wave length is greater than that of light. Therefore sound can be heard in hidden corners.

**N.B -** When waves undergo defraction, wave length and velocity remain constant.

## INTERFERENCE OF WAVES

This is the super imposition of two identical waves travelling in the same direction to form a single wave with a larger amplitude or smaller amplitude.

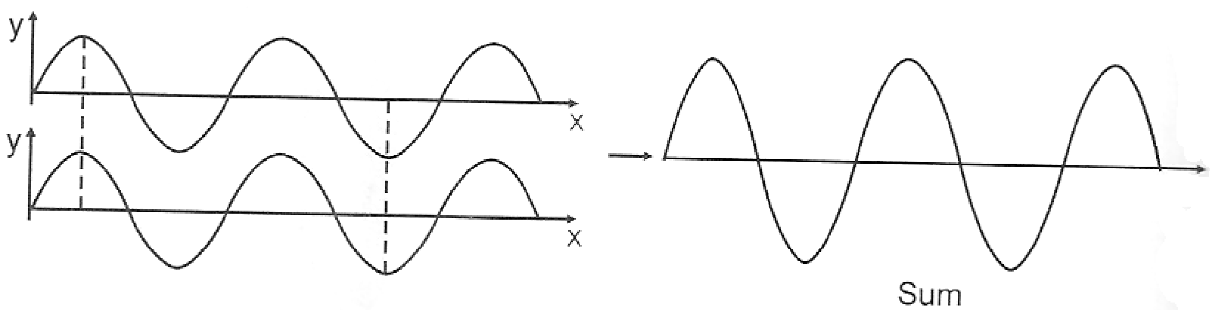
The two waves should be in phase (matching).



**CONSTRUCTIVE INTERFERENCE**

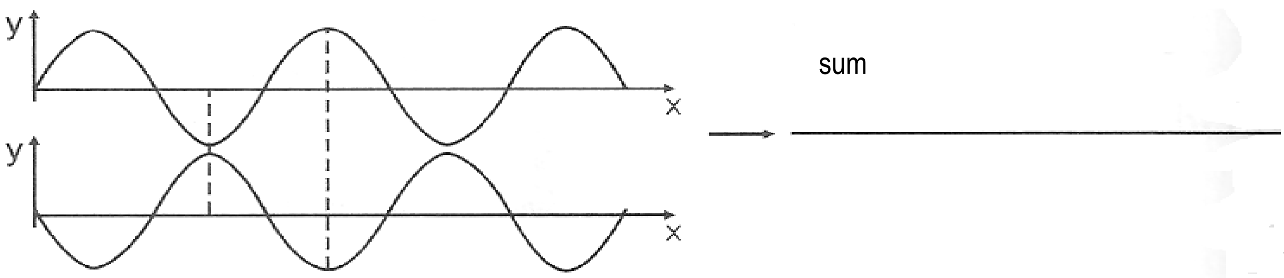
This constructive interference occurs when a crest from one wave source meets a crest from another source or a trough from one source causing reinforcement of the wave i.e. increased disturbance is obtained.

The resulting amplitude is the sum of the individual amplitudes.




**DESTRUCTIVE INTERFERENCE**

This occurs when the crest of one wave meets a trough of another wave resulting in wave cancelling i.e.



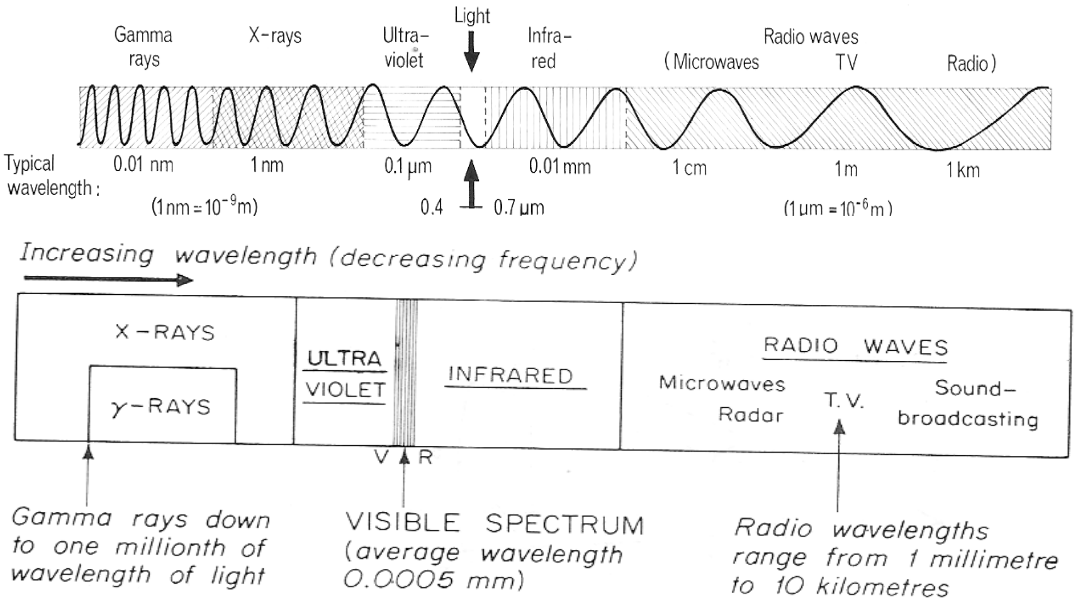

**ELECTRO MAGNETIC WAVES**

This is a family of waves which is made by electric and magnetic vibrations of very high frequency.

Electro magnetic waves do not need a material medium for transformation i.e. they can pass through a vacuum.

**SPECTRUM OF ELECTRO MAGNETIC WAVES**

In decreasing frequency




**PROPERTIES OF ELECTRO MAGNETIC WAVES**

- They are transverse waves.
- They can travel through vacuum.
- They travel at a speed of light ( 3.0 × $10^8$ m/s).
- They can be reflected, refracted, defracted and undergo interference.
- They posses energy.

**EFFECTS OF ELECTRO MAGNETIC WAVES ON METER**

**(a) Gamma rays.**

- They destroy body tissues if exposed for a long time.
- They harden rubber solutions and lubricate oil to thickness.

**(b) X- rays**

- Causes curtains to give off electrons.
- Destroys body tissues if exposed for a long time.
- Used in industries to detect lickages in pipes and in hospitals to detect fractures of bones.

**(c) Ultra violet**

- Causes sun burn
- Causes metals to give off electrons by the process called photoelectric emission.
- Causes blindness.

**(d) Visible light**

- Enables us to see.
- Changes the apparent color of an object.
- Makes objects appear bent to refraction.

**(e) Infrared**

- Causes the body temperature of an object to rise.
- It is a source of vitamin D.

**(f) Radio waves**

- Induces the voltage on a conductor and it enables its presence to be detected.

| Wave band | Origin | Source |
| --- | --- | --- |
| Gamma rays | Energy changes in modes of atoms | Radio active substance |
| X- rays | Electrons hitting a metal target | X – ray tube |
| Ultra- violet | Fairly high energy changes in atoms | Very hot bodies<br>Electron discharge<br>Through gases especially mercury<br>Vapour |
| Visible light | Energy changes in electron structure of atoms | Lamps, flames etc |
| Infrared radiation | Low energy changes in electrons of atoms | All matter over a wide range of temperature from absolute zero onwards. |
| Radio waves | High frequency<br>Oscillating electric current<br>Very low energy changes in electronic structures of atoms. | Radio transmission aerials. |

# SOUNDS WAVES (LONGTUDINAL WAVES)

Is a form of energy which is produced by vibrating objects e.g. when a tuning fork is struck on a desk and dipped in water, the water is splashed showing that the prongs are vibrating or when a guitar string is struck.

**SPECTRUM SOUND WAVES**

| **Frequency** | $\mathbf{0H_Z}$ | $\mathbf{20H_Z}$ | $\mathbf{20{,}000H_Z}$ |
|---|---|---|---|
| Type of sound | Subsonic sound | Audible sound waves | Ultra sonic sound wave. |

**SUBSONIC SOUND WAVES**

These are not audible to human ear because of very low frequency of less than $20H_Z$.

**AUDIBLE SOUND WAVES**

These are audible to human ear. This frequency ranges from

$20H_Z$- 20 K$H_Z$.

**ULTRA SONIC SOUND WAVES**

These are sound waves whose frequencies are above $20H_Z$. 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 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.

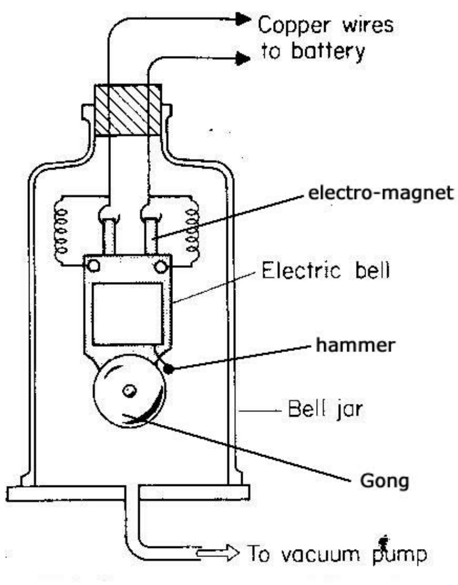
**PROPERTIES OF SOUND WAVES**

- Cannot travel in a vacuum because there is no metal needed.
- Can cause interference.
- Can be reflected, refracted, defracted, planes polarized and undergo interference.
- Travels with a speed V= 330m/s in air.

**TRANSMISSION OF SOUND**.

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

**EXPERIMENT TO SHOW THAT SOUNDS CAN NOT PASS THROUGH A VACCUM.**




- Arrange the apparatus as in the diagram with air, in the jar.
- Switch on the electric bell, the hammer is seen striking the gong and sound is heard.
- Gently withdraw air from the jar by means of a vacuum pump to create a vacuum in the jar.
- The sound produced begins to fade until it is heard no more yet the hammer is seen striking the gong.

- Gently allow air back into the jar, as the air returns, the sound is once again heard showing that sound can not travel through vacuum.

**Note:** The moon is sometimes referred to as a silent planet because no transmission of sound can occur due to lack of air (metal medium).

The speed of sound depends on;

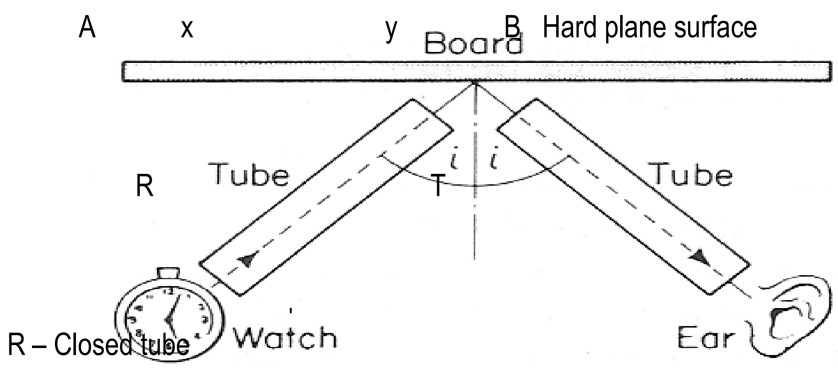
(i) Temperature
(ii) Wind
(iii) Density of medium.

Speed of sound is more in denser medium than in less dense.

Increase in temperature increases the speed of sound i.e. sound travels faster in hot air than in cold air. Speed of sound is increased if sound travels in the same direction as wind.

Change in pressure of air does not affect speed of sound because density is not affected by change in pressure.

**EXPERIMENT TO VERIFY THE LAWS OF REFLECTION OF SOUND**




T – Open tube

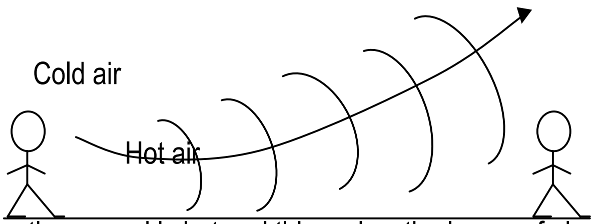
- Put a ticking clock in tube R on a table and make it to face a hard plane surface e.g. a wall.
- Put tube T near your ear and move it on either sides until the ticking sound of the sound is heard loudly.
- Measure angle i and r which are the angles of incidence and reflected.

- From the experiment, sound is heard distinctly due to reflection.
- Angle of incidence (i) and angle of reflection (r) are equal and lie along XY in the same plane.
- This verifies the laws of reflection.

**REFRACTION OF SOUND WAVES**

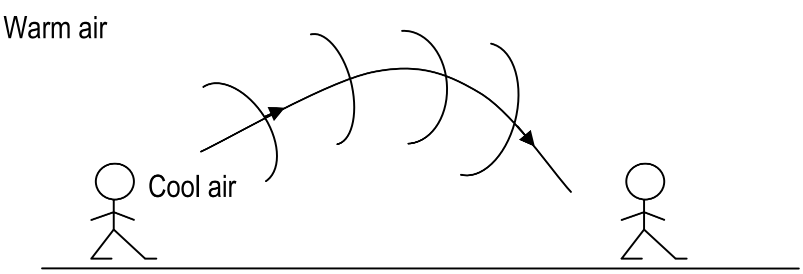
Refraction occurs when speed of sound waves changes. The speed of sound in air is affected by temperature. Sound waves are refracted when they are passed through areas of different temperature. This explains why it is easy to hear sound waves from distant sources at night than during day.

**REFRACTION OF SOUND DURING DAY.**




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.

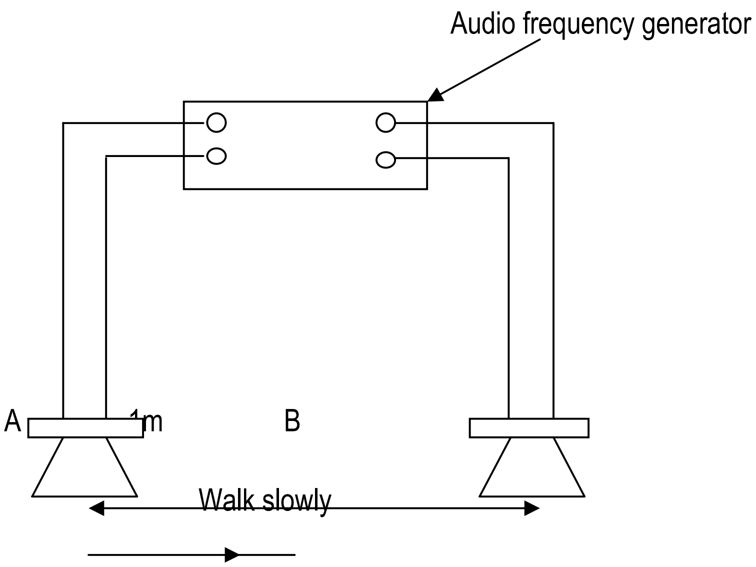
**DEFRACTION OF SOUND**

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 defracted most. It is due to refraction that a person behind the house can hear sound from inside.

**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.

**EXPERIMENT TO SHOW INTERFERENCE OF SOUND**




**ECHOES**

An echo is a reflected sound. Echoes are produced when sound moves to and fro from a reflecting surface e.g. a cliff wall. The time taken before an echo arrives depends on the distance away from the reflecting surface.

In order for a girl to hear the echo; sound travels a distance of 2d.

Velocity = $\frac{distance}{time}$

For an echo; velocity of sound = $\frac{2d}{t}$

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

**Examples**

1 A girl stands 34m away from a reflecting wall. She makes sound and hears an echo after 0.2 seconds. Find the velocity of sound.

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

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

$$= 340 m/s$$

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.

$$V = \frac{2d}{t} = \frac{2 \times 99}{0.6} = \frac{198}{0.6} = \underline{330 m/s}$$

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?

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

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

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

$$1360 = d$$

$$d = 1360 m$$

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.

$V = \frac{2d_1}{t}$ $\quad$ $V = \frac{2d_2}{t}$ $\quad$ $\frac{distance\ btn\ walls}{d_1 + d_2}$

$330 = \frac{2\times d_1}{2}$ $5 \times 330 = \frac{2\times d_2}{5} \times 5$ $= 330 + 825$

$d_1 = 330m$ $\frac{5\times 330}{2} = \frac{2d_2}{2}$ $= 1155m$

$= 825$ m

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)

$V = \frac{2d_1}{t}$ $d_1 = d_2$

$3 \times 330 = \frac{2d_1}{3} \times 3$ $d_1 + d_2 = 495 + 495$

$\frac{3\times 330}{2} = \frac{2d_1}{2}$ $= 990m$

$3\times 165 = d_1$

$495 = d_1$

$d_1 = 495m$

**MEASUREMENT OF VELOCITY OF SOUND USING AN ECHO METHOD**

**Method;**

A person stands a certain distance d from the reflecting surface, then measure that distance.

Make a sharp clapping sound by banging two blocks of wood together.

Report the sound at regular time intervals to coincide exactly with the echo.

Count the number of claps in a given time t

Find the time taken for one clap i.e. $\frac{t}{N}$

$$\text{Velocity} = \frac{2\times distance}{time}$$