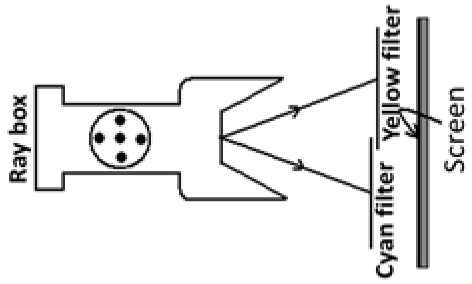
Mixing Coloured Filters and Pigments



When a yellow filter and cyan filter are placed at some distance from a ray box such that half of their portions overlap.

Observation: Green light is seen where white light passes through both filters

Explanation:
For the overlap of yellow and cyan, cyan filters absorb the red
Light and transmit green and blue, but yellow filter absorbs blue light and transmits green and red (which is absorbed by Cyan filter) so only green light is transmitted.

Note: White light is separated into seven colours by a prism because the prism has different refractive index for the different colours of white lights.

Exercise:

1993 Qn.4	**1996 Qn.16**	**2000 Qn.32**	**2001 Qn. 37**	**2003 Qn.**

Section C
UNEB 1994 Qn. .4 PII;
UNEB 1994 Qn. .4 PII;

4. WAVES

4. 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

CLASSIFICATION AND GENERAL PROPERTIES OF WAVES

A wave is a periodic disturbance which travels with finite velocity through a medium and remains unchanged in type as it travels. Or it is a disturbance which travels through a medium, and transfers energy from one location (point) to another without transferring matter.

Waves may be classified as mechanical or electromagnetic waves.
Mechanical waves: These are waves produced by a vibrating body. They are transmitted by particles of the medium vibrating to and fro.
They require a material medium for their propagation.
These include water waves, sound waves, waves on stretched strings and waves on vibrating springs., e.t.c.

Electromagnetic waves: These are waves produced by a disturbance in form of a varying electric or magnetic fields. These are waves that don't require a material medium for their propagation. Electromagnetic waves travel in a vacuum.
They include radio, infra red, light, Ultraviolet, X-rays, Gamma rays.

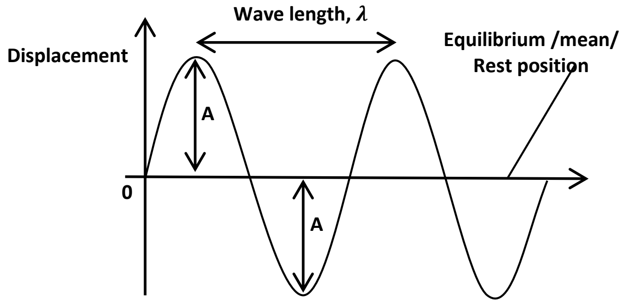
If the disturbance of the source of waves is simple harmonic, the displacement in a given time varies with distance from the source as shown below.

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 vibrations are passed from one particle to the next until the final destination is reached

Generation and Propagation of mechanical waves.
Waves are generated when particles of a transmitting medium at any point are disturbed and start vibrating.
As they vibrate, they cause the neighboring particles to vibrate in turn, hence causing the vibrations to continue from the source to other regions in the transmitting medium.
The disturbance thus spreads the source outwards and it constitutes the wave.

Graphical representation of a wave.



Terms used in describing waves,

Amplitude: This is the greatest displacement of any wave particle from its equilibrium position.

Wave length (λ): Is the distance between two successive particles in a wave profile that are in phase.
It is the distance covered in a complete cycle of a wave.
It is the distance between two successive crests or troughs.
It is the distance between two successive compressions or rare factions.

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

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

Wave front. Is a line or surface that joins points of the same phase in a wave travelling through a medium.. OR: It is the imaginary line joining the set of particles that are in the same state of motion (in phase).

Particles are in phase if they are in the same point in their path at the same time and are moving in the same direction.
The direction of travel of the wave is always at right angles to the wave front.

Cycle or Oscillation: is a complete to and fro motion of a wave. It is equivalent to moving from O to B.

Period (T): The time taken for any particle to undergo a complete oscillation. $T = \frac{t}{n}$.
Frequency (f): The number of oscillations per second.
$f = \frac{n}{t}$.

Velocity (v): The distance covered by a wave particle per second in a given direction.

Phase: Is a fraction of a cycle which has elapsed after a particle passing a fixed point.

Relationship between f and T
If a wave completes n cycles in time t, then frequency, f is given by:
Frequency, $f = \frac{n}{t}$……………………………..(i)
Period, $T = \frac{t}{n}$. ....(ii)
Eqn (i) x eqn (ii) gives;

$$fT = \left(\frac{n}{t}\right) \times \left(\frac{t}{n}\right) = 1 \Leftrightarrow f = \frac{1}{T}$$

Relationship between v, λ and f
If a wave of wavelength λ completes n cycles in time t, then the frequency, f is given by;

Each cycle is a wavelength, $\boldsymbol{\lambda}$**:**
Total distance covered in n-cycles = $n\lambda$

$$Speed, v = \frac{Distance}{Time} = \frac{n\lambda}{t} = \left(\frac{n}{t}\right)\lambda, \qquad But\ \frac{n}{t} = f$$
$$\Leftrightarrow \qquad \boldsymbol{v = f\lambda}$$

Alternatively,
If a wave covers a distance, λ, the wavelength, then the time taken is T, the period. Hence speed,
$$Speed, v = \frac{\lambda}{T} = \left(\frac{1}{T}\right)\lambda\,, \qquad But, \frac{1}{T} = f$$
$$\Leftrightarrow \qquad \boldsymbol{v = f\lambda}$$

Types of waves

There are wo broad types -:

a) progressive waves and
b) stationary waves

PROGRESSIVE WAVES

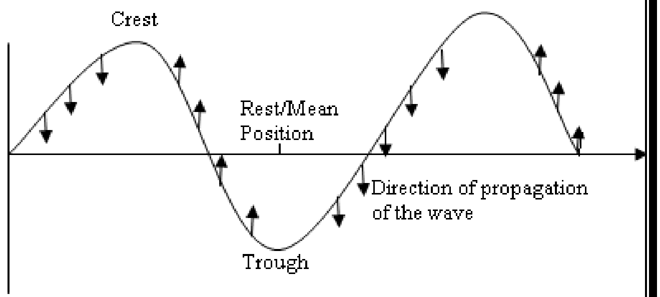
Is a wave which moves away from its source through a medium and spreads out continuously? There are two kinds of progressive waves namely:

i) Transverse waves
ii) Longitudinal waves

i) Transverse waves

These are waves in which particles vibrate perpendicularly to the direction of propagation of the wave.
Examples

- ✓ water waves,
- ✓ Electromagnetic waves
- ✓ waves formed when a rope is moved up and down.

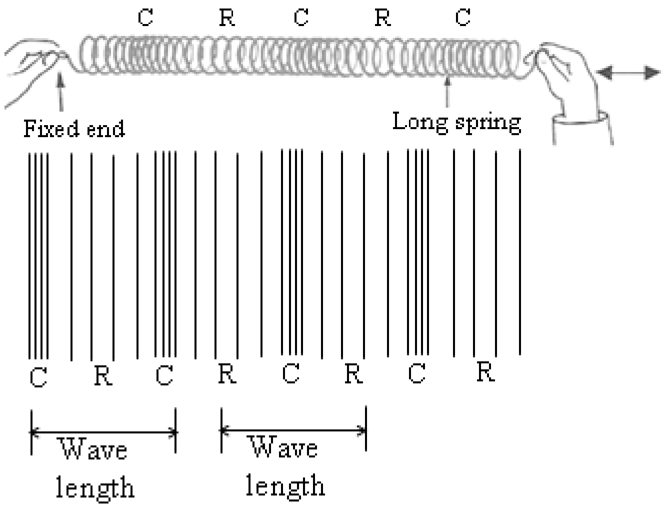


ii) Longitudinal waves

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 in pipes, 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.



Compression (C) is a region in a longitudinal where the vibrating particles are very close together.
A wave faction (R) Is a region in a longitudinal where the vibrating particles are further apart (distanced).
Wave length; of the longitudinal is the distance between two successive compressions or rare factions.

Differences between longitudinal and transverse waves

Transverse Waves	**Longitudinal waves**
- Particles vibrate perpendicular to the direction of wave	Particles vibrate parallel to the direction of wave
-Consists of crests & troughs	Consists of compression & refraction
-Can be polarized	Cannot be polarized

1. State two differences between waves and light waves.

Examples

1. A radio station produces waves of wave length 10m. If the wave speed is 3×10^8 m/s, calculate
   (i) Frequency of radio wave.
   (ii) period time, T
   (iii) Number of cycles completed in $10^8\ s$

Solution:

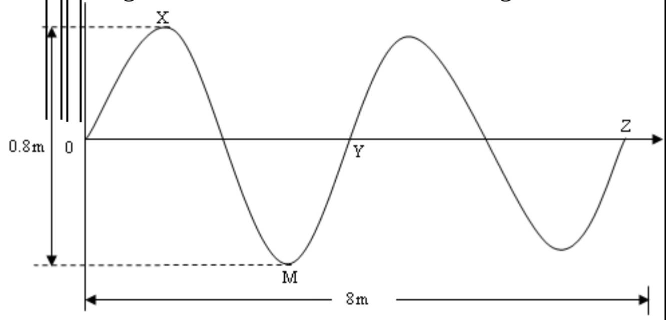
(i) Frequency of radio wave ; λ = 10m, v=3×10^8 m/s $v = f\lambda$ $3\times10^8 = f\times10$ $f = \frac{3\times10^8}{10}$ $f = 3\times10^7$Hz	(ii) Period ,T $\text{Period}, T = \frac{1}{f}$ $T = \frac{1}{3\times10^7}$ $T = 3.3\times10^{-7}$s	(ii) Number of cycles $\text{Frequency}, f = \frac{n}{t}$ $n = ft$ $n = 3\times10^7\times10$ $n = 3\times10^8$cycles

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

Solution:

The distance between n-successive crests or troughs is given by; $\mathbf{d = (n-1)\lambda}$	$v = f\lambda$ $v = 12\times0.04$ $v = 0.48\ ms^{-1}$
$\lambda = \frac{d}{n-1}$ $\lambda = \frac{36}{10-1} = \frac{36}{9} = 0.04$m $\lambda = 0.04$ m	

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



(a) Name;
   (i) Any two points on the wave which are in phase
   (ii) The points Labeled m and x

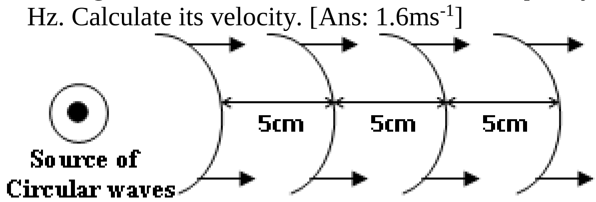
(b) (i) Determine the amplitude of the wave.
   (ii) If the speed of the wave is 8000cm/s. Determine the frequency of the wave.

Questions

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

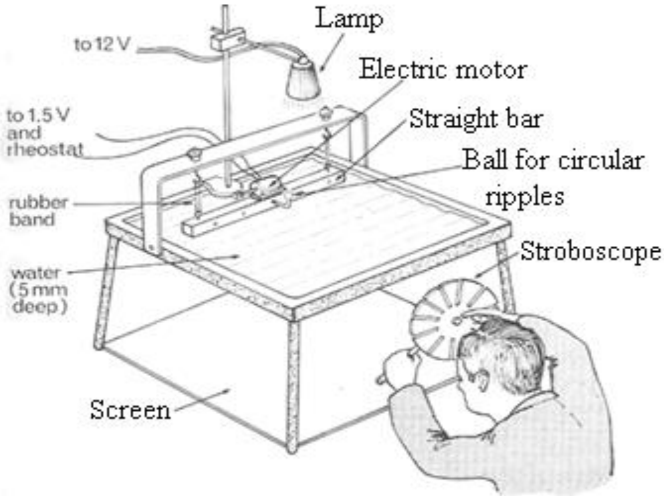
(i) wave velocity $d = 35m, t = 2s$ $v = \frac{d}{t} = \frac{35}{2} = 17.5ms^{-1}$ $v = 17.5ms^{-1}$	(ii) wave frequency $v = f\lambda$ $f = \frac{v}{\lambda} = \frac{17.5}{5} = 3.5$Hz $f = 3.5$Hz

2. The figure below shows circular waves of frequency 32 Hz. Calculate its velocity. [Ans: $1.6ms^{-1}$]



3. A source produces waves which travel a distance of 140cm in 0.08s. If the distance between successive crests is 20cm, find the frequency of the source. [Ans: 87.5Hz].
4. 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 [$320ms^{-1}$]
5. See **UNEB 1992** Qn. 7

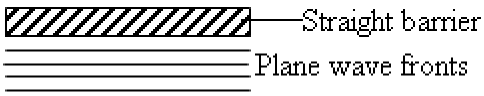
THE RIPPLE TANK



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

Straight waves (plane waves): These are produced by dipping a straight edged object e.g. a ruler on the water surface.

Continuous straight waves: These are produced by fixing a straight dipper (horizontal bar) suspended by rubber bands. The whole bar is dipped in water and is made to vibrate by the vibrations generated by an electric motor.



Continuous circular waves: These are produced by attaching small total balls (using rubber bands) to metal bars and using the vibration from an electric motor.
As the bar vibrates, the vibrations cause the dipper to move up and down producing continuous circular waves.

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 the speed of waves is that the wave length of water reduces but frequency does not. The frequency can only be changed by the source of the wave.
Qn: 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 ms^{-1}]

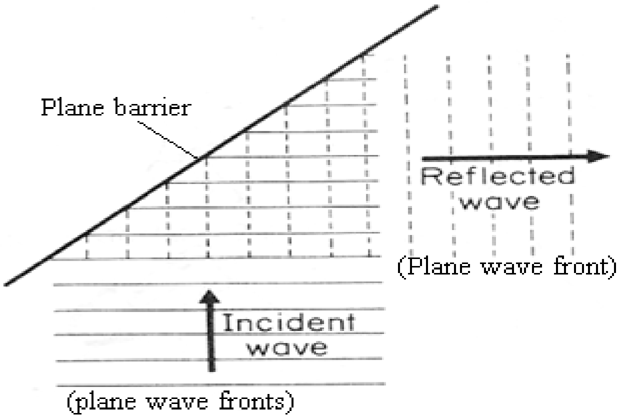
WAVE PROPERTIES
The wave produced in a ripple tank can undergo.

(a) Reflection	(b) Refraction	(c) Diffraction
(d) Interference	(e) Polarization	

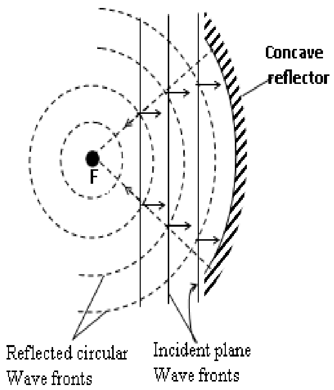
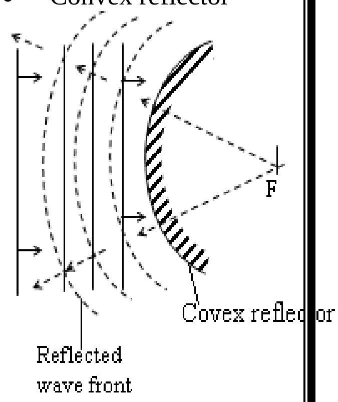
(a) REFLECTION OF WAVES
A wave is reflected when a barrier is placed in its path. The shape of the reflected wave depends on the shape of the barrier.
The laws of reflection of waves are similar to the laws of reflection of light.

- **Reflection of plane wave**

(i) On a plane surface.

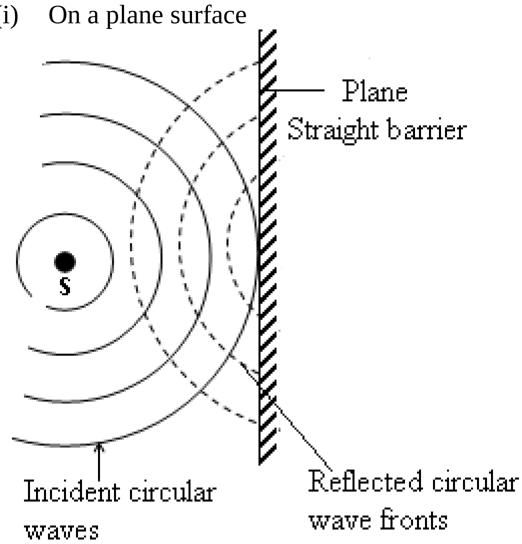


(ii) On a curved surface

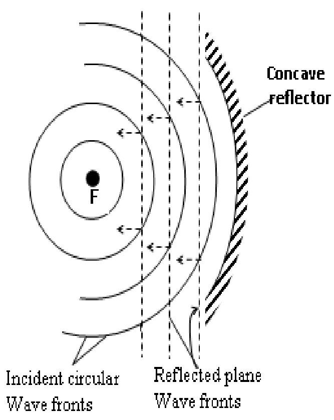
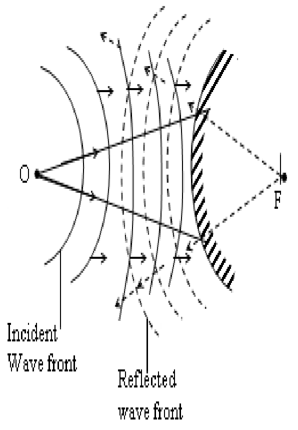
• Concave reflector	• Convex reflector
	

- **Reflection of circular waves**

(i) On a plane surface



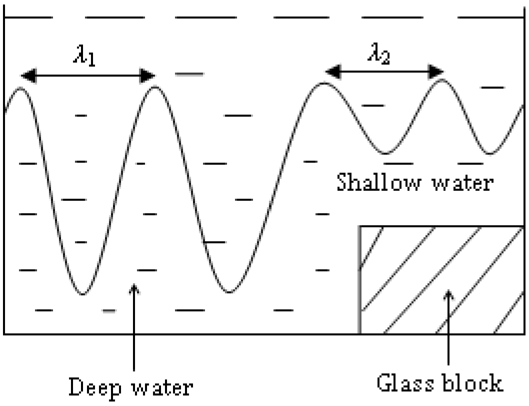
(ii) On a curved surface

• Concave reflector	• Convex reflector
	

Note: During reflection of water waves, the frequency and velocity of the wave do not change.

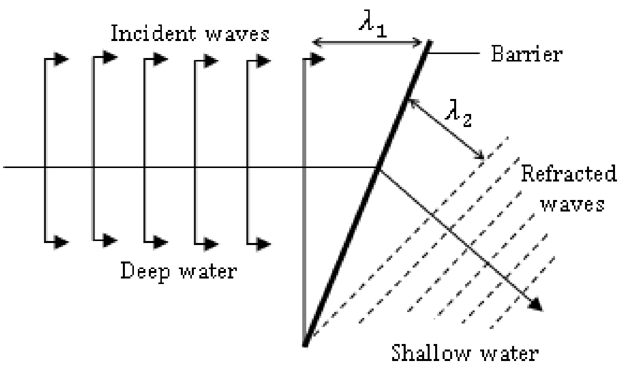
(b) REFRACTION

This is the change of in direction of wave travel as it moves from one medium to another of different depth. It is caused by the 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.



When waves are incident on a shallow water boundary at an angle;

- ✓ Wave length decreases in shallow waters
- ✓ Speed decreases in shallow water
- ✓ Frequency and period remain the same.



λ_1= wave length in deep water
λ_2 = wave length in shallow water
Note:

(i) $\lambda_1 > \lambda_2$

(ii) $v_1 = f\lambda_1$ *and* $v_2 = f\lambda_2$

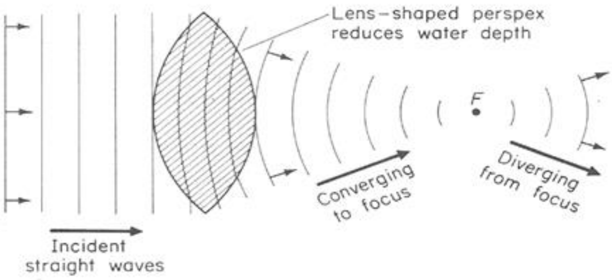
(iii) $v_1 > v_2$; When f – is constant.

Refractive index n $= \frac{\text{velocity in deepwater}}{\text{velocity in shallowwater}}$

Refractive index $n = \frac{v_1}{v_2} = \frac{f\lambda_1}{f\lambda_2}$

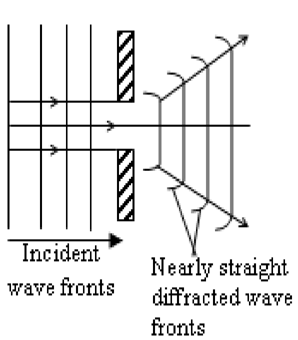
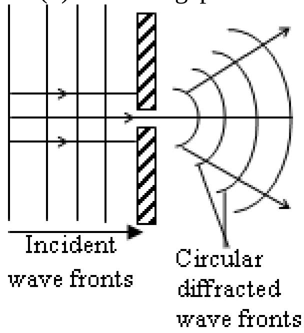
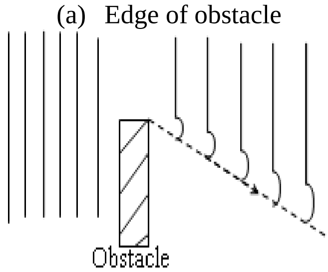
Refractive index $n = \frac{\lambda_1}{\lambda_2} = \frac{\text{Wave length in deep water}}{\text{Wave length in shallow water}}$

Refraction of plane waves by a convex lens



(c) DIFFRACTION

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 diffraction as shown below.

(a) Wide gap	(b) Narrow gap
 The ripples emerge straight and curve at the ends.	 The ripples emerge in a semi-circular pattern.
-Waves spread out more (i.e greatly diffracted) when the wave length is longer. -The wave length does not change when waves pass through the slit. -Diffraction (spreading) increases with decrease in the width of the slit. Wider gaps produce less diffraction. -When the width of the gap is less than the wave length of the of the incident waves, the emerging waves are circular. At this width, the slit may be considered to act as a separate point source of waves.	
(a) Edge of obstacle 	

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

(d) INTERFERENCE

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).

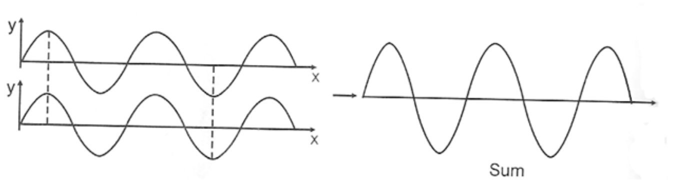
Conditions necessary for producing interference:

1. The two waves must have coherent sources.
2. The two waves must have the same amplitude and the same frequency.
3. The distance between the sources must be very small.

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.
E.g.

$\cap + \cap = \cap$ OR $\cup + \cup = \cup$

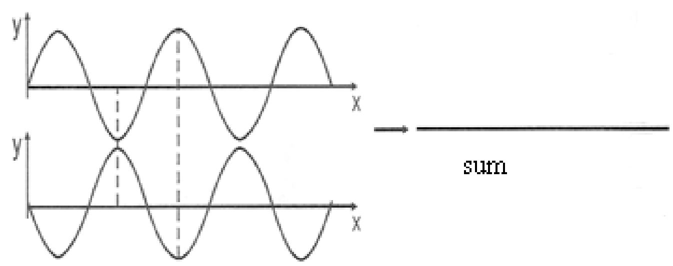


- **For Light,** constructive Interference would give **increased brightness.**
- **For sound,** constructive Interference would give **increased loudness.**

Destructive interference

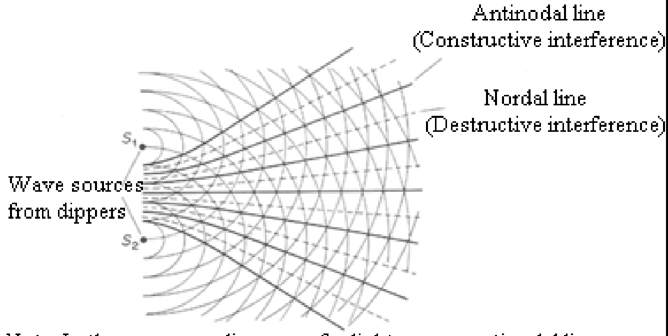
This occurs when the crest of one wave meets a trough of another wave resulting in wave cancelling i.e.
If waves are out of phase, they cancel each other to give an area of zero resultant. This is called destructive interference.
e.g.

$\cap + \cup =$ ……………………………………………

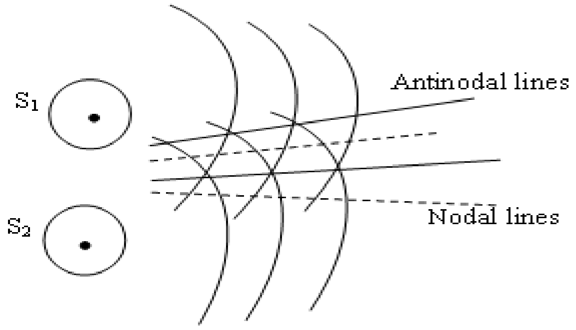


For Light, constructive Interference would give **reduced brightness or darkness.**
For sound, constructive Interference would give **reduced loudness or no sound at all.**

Note:
The interference pattern caused by two sources placed close together – give nodal and antinodal lines that are spread widely. When the two sources are placed far apart, the nodal and anti-nodal lines are closer together making the pattern more difficult to see.



Note: In the corresponding case for light waves, antinodal lines are **bright fringes** and nodal lines are **dark fringes**.



Lines joining points of constructive interference are called **antinodal lines** while these lines joining points of destructive interference are called **nodal lines**.

Trial Questions:

(a) With the aid of a diagram, describe how an interference patter (Interference fringes) can be produced in a ripple tank.
(b) What are the conditions necessary for interference to occur?

(e) POLARISATION OF WAVES

It only occurs with transverse waves like other transverse waves, water waves can be polarized.
Polarization: is the effect in which vibration are in only a vertical plane.
Differences between water and sound waves;

Water waves	**Sound waves**
-Transverse	Longitudinal
-Low speed	High speed
-Short wave length	Long water length
-Can be polarized	Cannot be polarised
-Possible only in liquid (.e.g water)	Possible in solids, liquids and gases.

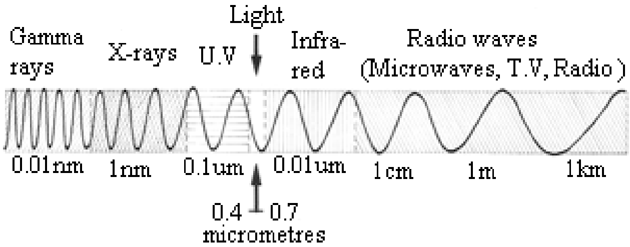
State three differences between sound and light waves.

Wave motion 1992 Qn7 1989 Qn30 1990 Qn21	1994 Qn23 1998 Qn23 1998 Qn26 2001 Qn18	1992 Qn1 2006 Qn22 2007Qn35 2007Qn39	2008 Qn31 1989 Qn6 1993 Qn4 2006 Qn5

ELECTRO MAGNETIC WAVES

This is a family of waves which is made by electric and magnetic vibrations of very high frequency.
Electromagnetic waves do not need a material medium for transformation i.e. they can pass through a vacuum.

Spectrum of electromagnetic waves
In decreasing frequency



Properties of electromagnetic 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, diffracted and undergo interference.
- They posses energy.

Effects of electromagnetic 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 leakages 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	Radioactive substance
X- rays	Electrons hitting a metal target	X – ray tube
Ultra- violet	Fairly high energy changes in atoms	Very hot bodies Electron discharge Through gases especially mercury 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 Oscillating electric current Very low energy changes in electronic structures of atoms.	Radio transmission aerials.

Red Sun set and Blue sky
Effect of long and short wave lengths.
(i) Long wavelength: Waves of long wavelength are less scattered than waves of short wavelength. This explains why the sun appears red when rising or setting.
Explanation: At sun rise or sun set, the light rays from the sun travel through greater thickness of earth's atmosphere. So the longer wavelength passes through.
(ii) Short wavelength: Waves of short wavelength are highly scattered. This explains why the sky appears blue, since the primary colour, blue has the shortest wavelength in the spectrum.
Note: Beyond the atmosphere, the sky appears black and the astronauts are able to see the stars and the moon.

Electromagnetic waves	2001 Qn21
1987 Qn30	2006 Qn31
1989 Qn16	2007 Qn13

SOUNDS 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.

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

SPECTRUM SOUND WAVES

Frequency	$0H_Z$	$20H_Z$	$20{,}000H_Z$
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 KH_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.

Example: 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. [$3.0\ \times 10^{8}$]

(ii) Wave length of another station that broad casts at a frequency of 250 Hz. [$\lambda = 1.2 \times 10^{6}$ m.]

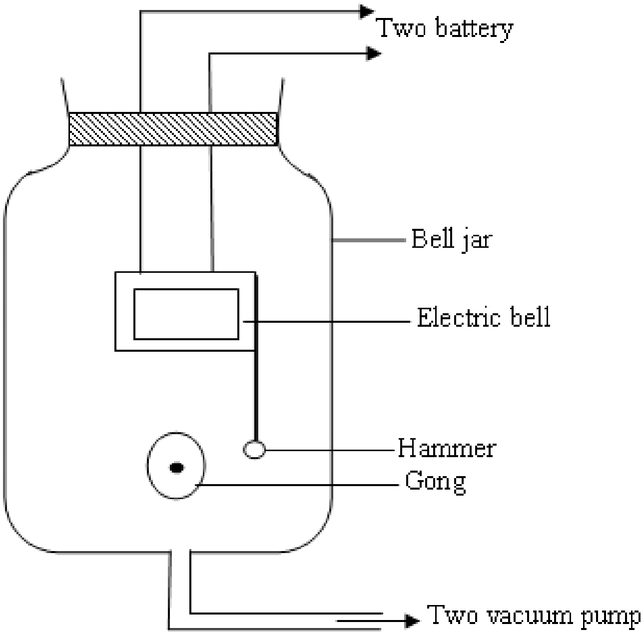
Example: 2

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

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 cannot pass through a vaccum.



Procedures:

- 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.

Observation:

- 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 cannot travel through vacuum.

Conclusion:

- Sound waves require a material medium for their transmission.

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

The speed of sound depends on;

(i) Temperature

Increase in temperature increases the speed of sound i.e. sound travels faster in hot air than in cold air.

(ii) Wind

Speed of sound is increased if sound travels in the same direction as wind.

(iii) Attitude

Sound travels faster on a low altitude and slower on higher altitude.

(iv) Humidity:

The higher the humidity, the higher the speed of sound and velocity.

(v) Density of the medium.

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

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

Sound travels fastest in solids than liquids and gases because. In solids the particles in solids are very close together and they produce vibration easily i.e. solids are more dense. Also speed of sound is faster in liquids than in gases.

In solids and liquids, increasing the temperature decreases the speed of sound because solids are denser. Also speed of sound is faster in liquids than in gases.

Some media and the speed of sound

Medium	**Speed of sound (ms^{-1})**
Air	330
Steer	600
Water	1500
Glass	5600

Some explanations

- If a person places his ear near the ground and another person taps along a metal which is some distance away the sound will be heard clearly than when standing since sound travels faster in solids than in gases.

- A sound made by a turning fork, sounds, louder when placed on a table than when held in the hand. This is because a larger mass of air is set in vibration thereby increasing the sound.

Qn. Explain why sound travels faster in solids than in liquids.

- Sound waves of frequency 3.3 KHz travel in air. Find the wavelength (Take speed of sound in air = $330ms^{-1}$)

$$V = f\lambda \Rightarrow \lambda = \frac{V}{f} = \frac{330}{3.3 \times 1000} = \frac{330}{3300} = 0.1m$$

Example:

Two men stand a distance apart besides a long metal rail on a sill day. 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 $330ms^{-1}$, and that in the metal rail is $5280ms^{-1}$, find the distance between the men.

Solution:

$t_1 - t_2 = 0.5$

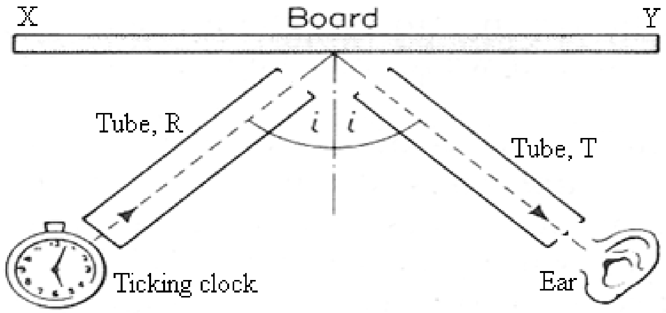
$\frac{x}{330} - \frac{x}{5280} = 0.5$

$x = 176 \text{ m}$

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 particle are so made to vibrate and in doing so, they transfer their energy particles which also vibrate.

Experiment to verify the laws of reflection of sound.



XY is a hard plane surface, R is a closed tube and T is an 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 angles i and r which are the angles of incidence and reflection respectively.
- 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.

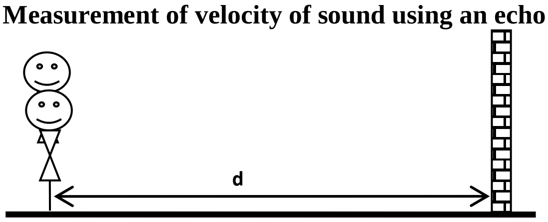
Note: Hard surfaces reflect sound waves while soft surface absorb sound wave.

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 standing at a distance, **d** from a reflecting surface to hear the echo; sound travels a distance of **2d**.

Measurement of velocity of sound using an echo method



- Two experimenters stand at a certain distance **d** from a tall reflecting surface
- One experimenter claps pieces of wood **n times**, while the other starts the stop clock when the first sound is heard and stops it when the last sound is heard.
- The time taken, t for the n claps is recorded and the speed of sound in air is calculated from;

$$\textbf{Speed} = \frac{\mathbf{2(distance)}}{\mathbf{time}} = \frac{\mathbf{2nd}}{\mathbf{t}}$$

For an echo; Speed $= \frac{2(\text{distance})}{\text{time}} = \frac{2d}{\left(\frac{t}{n}\right)} = \frac{2nd}{t}$

Where n is the number of claps (or sounds) made.

Example: 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.

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

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

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

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

Example: 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.

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

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

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

Example: 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?

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

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

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

$2d = 340 \times 8$

$2d = 2720$

$d = 1360 \text{ m}$

Example: 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.

<table>
<tr><td>$V = \frac{2d_1}{t_1}$

$330 = \frac{2d_1}{2} \Rightarrow 2d_1 = 660$

$d_1 = 330 \text{ m}$</td><td>$V = \frac{2d_2}{t_2}$

$330 = \frac{2d_2}{5} \Rightarrow 2d_2 = 1650$

$d_2 = 825 \text{ m}$</td></tr>
<tr><td colspan="2">$d = d_1 + d_2$

$d = 330 + 825$

$d = 1155\text{m}$</td></tr>
</table>

Example: 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)

$V = \frac{2d_1}{t_1}$ $330 = \frac{2d_1}{3} \Rightarrow 2d_1 = 990$ $d_1 = 495$ m	Since the man is mid way between the cliffs, $d_2 = d_1 = 495$m $d = d_1 + d_2$ $d = 495 + 495$ $d = 990$m

Example: 6

A student made 50 claps in one minute. If the velocity of sound is 330s, find the distance between the student and the wall.

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

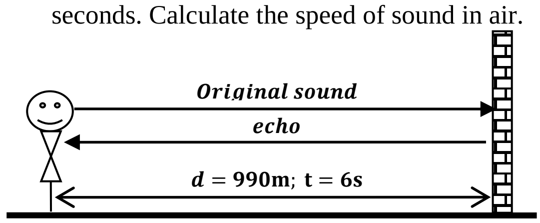
$V = \frac{2nd}{t}$

$330 = \frac{2 \times 50 \times d}{60}$

$100d = 330 \times 60$

$d = 198$

1. A boy stands at a distance of 990m from a tall building and makes a loud sound. He hears the echo after 6 seconds. Calculate the speed of sound in air.



$$V = \frac{2d}{t} = \frac{2 \times 990}{6} = 330ms^{-1}$$

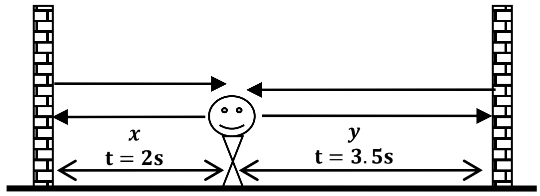
2. A sound wave of frequency 200Hz is produced 300m away from a high wall. If the echo is received after 2 seconds. Find the wave length of sound wave.

$$V = \frac{2d}{t} = \frac{2 \times 300}{2} = 3000ms^{-1}$$

$$f\lambda \Rightarrow \lambda = \frac{v}{f} = \frac{300}{200} = 1.5m$$

3. A man stands between two cliffs and fires a gun. He hears the 1st echo after 2seconds and the second echo after 3 ½ seconds. Calculate the distance between two cliffs and speed of sound in air = 330ms^{-1}.

Solutions:



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

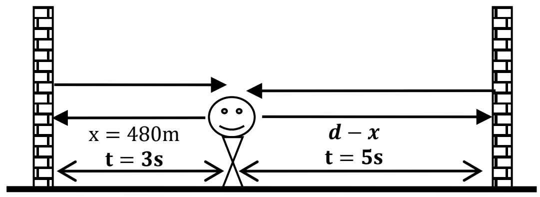
4. A student, standing between two vertical cliffs and 480m from the nearest cliff shouted. She heard the 1st echo after 3 seconds and the second echo 2 seconds later. Calculate;

(i) The velocity of sound in air.

(ii) The distance between the cliff.

Solutions:

Let distance between cliffs = **d**



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

Questions

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 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

(ii) The time taken for the sound wave to travel to the wall and back to the source and speed of sound in air = 330ms^{-1}.

4. A man standing between two vertical walls and 170m from the nearest wall shouted. He heard the 1st echo after 4s and the 2nd echo 2 seconds later. Find the distance between the walls.

5. A boy standing 150m from a high cliff claps his hands and hears an echo. If the velocity of sound in air is $320ms^{-1}$. Find the time taken for the sound to travel to the wall and back to the source.

6. A man stands at a distance of 340m from a high cliff and produces sound. He hears the sound Again after 2 seconds. Calculate the speed of sound.

7. A child stands between 2 cliffs and makes sound. If it hears the 1st echo after 1.5 seconds and the 2nd echo after 2.0 seconds. Find the distance between the 2 cliffs. (Speed of sound in air = $320ms^{-1}$).
8. A man sees the flash from a gun fired 1020m away and then hears a bang. How long does the bang take to reach him? [Ans: 330x1020 s].

9. The echo sounder on a boat sends down the sea, a pulse and receives its echo 0.3 seconds later. Find the depth of the sea. (speed of sound in water is $1445ms^{-1}$)
[Ans: 216.8m].

10. A girl at A clapped her hands once and a boy at B heard two claps in an interval of 1 second between the two sounds. Find the distance AB. [Ans: 330m].

11. Two people X and Y stand in a straight line at distances of 330m and 660m respectively from a high wall. Find the time interval taken for X to hear the first and second sounds when Y makes a loud sound. [Ans: 2.0 s].

Reverberation
In a large hall where there are many reflecting walls, multiple reflections occur and cause or create an impression that sound lasts for a longer time such that when somebody makes a sound; it appears as if it is prolonged. This is called reverberation.

Definition of Reverberation
Reverberation is the effect of the original sound being prolonged due to multiple reflections.

Advantages of reverberation
In grammar, reverberation is used in producing sound. Complete absence of reverberation makes speeches inaudible.
Disadvantages of reverberation
During speeches, there is a nuisance because the sound becomes unclear.

Prevention of reverberation
The internal surfaces of a hall should be covering the sound absorbing material called acoustic materials.

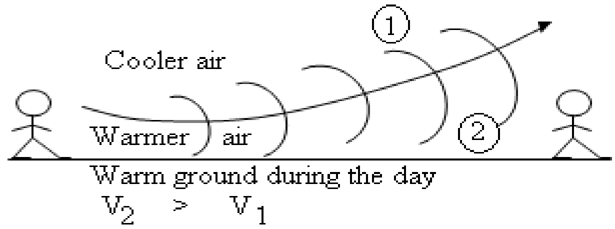
Why echoes are not heard in small rooms?
This is because the distance between the source and reflected sound is so small such that the incident sound mixes up with the reflected sound making it harder for the ear to differentiate between the two.

Questions:
(a) Outline four properties of electromagnetic waves.
(b) Distinguish between:
(i) Sound waves and light waves.
(ii) Sound waves and water waves.

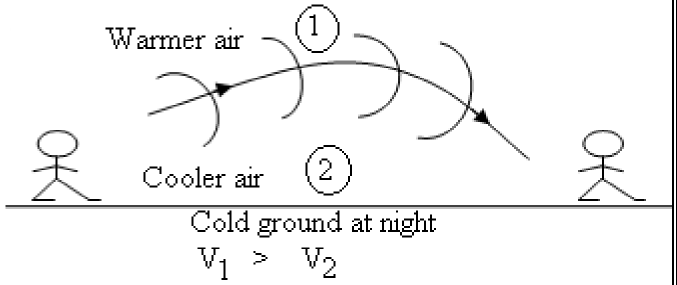
1. A man standing midway between two cliffs makes a sound. He hears the first echo after 3s. Calculate the distance between the two cliffs (Velocity of sound in air = 330m/s)

Refraction of sound waves
Refraction occurs when speed of sound waves changes as it crosses the boundary between two media. The speed of sound in air is affected by temperature.
Sound waves are refracted when they are passed through areas of different temperatures. 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.
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.

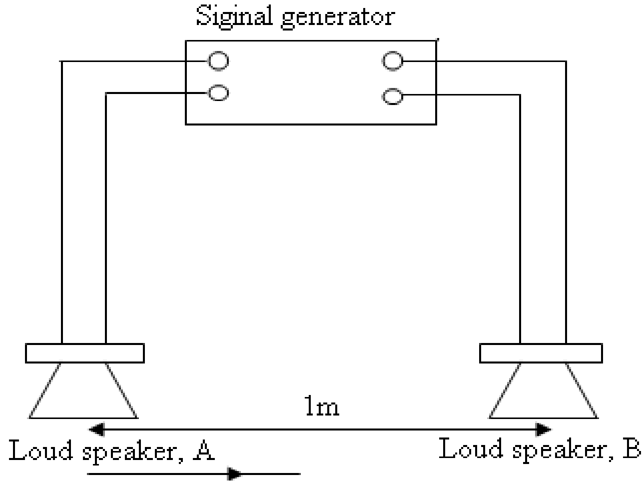
A person in one room can be heard by another person in the next room because of diffraction of sound waves.
The mouth acts as a gap and the waves from mouth spread and the person is able to hear the sound.
If you are sitting in a room and the door is open, you can hear music from a radio in the next 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.

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.

An experiment to show interference of sound waves.



Two loud speakers A and B are connected to the same signal generator so that sound waves from each are in phase and are of the same frequency. Interference of waves from A and B occurs

An observer moving in front of the loud along AB hears alternating **loud** and **soft** sound as he moves which corresponds to **constructive** and **destructive** interferences respectively.

With the sound set at a lower frequency (long wave length) the interference pattern becomes widely spread.

Qn. Describe an experiment to show interference of sound waves.

MUSICAL NOTES OR TONES:

A musical note or a tone is a single sound of a a definite pitch and quality made by a musical instrument or voice.

Music: This is an organized sound produced by regular vibrations.

Noise: This is a disorganized sound produced by irregular vibrations.

Characteristics of musical notes

(i) Pitch

This is the loudness or softness of sound. It depends on the frequency of sound produced, the higher the frequency the higher the pitch.

(ii) Loudness

This depends on the amplitude of sound waves and sensitivity of the ear.

- Amplitude; This is the measure of energy transmitted by the wave. The bigger the amplitude, the more energy transmitted by the wave and the louder sounder sound produced.
- Sensitivity of the ear. If the ear is sensitive, then soft sound will be loud enough to be detected and yet it will not be detected by the ear which is insensitive.

(iii) Timber (Quality)

This is the characteristic of a note which allows the ear to distinguish sounds of the same pitch and loudness it depends on the number of overtones produced, the more the number of overtones, the richer and the sweeter the music and therefore the better the quality.

Overtone

This is a sound whose frequency is a multiple of a fundamental frequency of the musical note.

Pure and impure musical notes.

Pure refers to a note without overtones. It is very boring and only produced by a tuning fork.

Impure refers to a note with overtones. It is sweet to the ear and produced by all musical instruments.

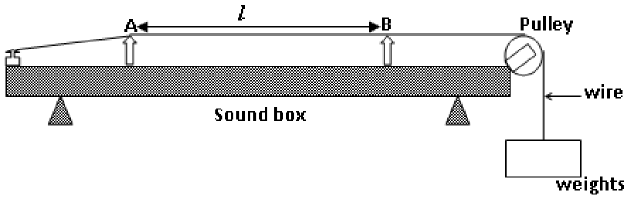
Beats

A beat refers to the periodic rise and fall in the amplitude of the resultant note.

VIBRATION IN STRINGS

Many musical instruments use stretched strings to produce sound. A string can be made to vibrate plucking it like in a guitar or in a harp putting it in pianos. Different instruments produce sounds of different qualities even if they are of the same note.

Factors affecting the frequency of the stretched string.



A. =Fixed bridge; B.=Movable bridge

(a) Length

For a given tension of the string, the length of the string is inverse the proportion to the frequency of sound produced. This can be demonstrated by an instrument called sonometer as shown above.

By moving bridgeB, higher frequency can be obtained for a short length AB and lower frequency for a long length. The relation can be expressed as ;

$f \propto \frac{1}{l} \Rightarrow fl = k \Rightarrow \boldsymbol{f_1 l_1 = f_2 l_2}$

(b) Tension

Adding weights or removing them from its ends at load R the tension of the higher sonometer wire. It will be noted that the higher the tension, the higher the frequency of the note produced.

$$f \propto \sqrt{T} \Rightarrow \frac{f}{\sqrt{T}} = k \Rightarrow \frac{\boldsymbol{f_1}}{\boldsymbol{f_2}} = \sqrt{\frac{\boldsymbol{T_1}}{\boldsymbol{T_2}}}$$

(c) Mass per unit length (μ)

Keeping length (l) and tension (t) constant, the frequency of sound produced depends on the mass per unit length of the string. Heavy strings produce low frequency sounds. This is seen in instruments such as guitar, base strings are thicker than solo strings. If the tension and length are kept constant, the frequency of sound is inversely proportional to the mass of the strings thus a thin short and taut string produces high frequency sound.

$f \propto \frac{1}{\sqrt{\mu}} \Rightarrow f\sqrt{\mu} = k \Rightarrow \boldsymbol{f_1\sqrt{\mu_1} = f_2\sqrt{\mu_2}}$

Where, $\mu = mass\ per\ unit\ length = \frac{mass}{length}$

<u>The three factors can be combined into a single formula to give the expression for frequency of a stretched string (wire) as:</u>

$$\boldsymbol{f = \frac{1}{l}\sqrt{\frac{T}{\mu}}}$$

Where, ***l*** is the length in m, **T** is the tension in N and μ is mass per unit length in kgm^{-1}

Example: 1

A musical note has frequency of $420H_z$ and length (l), if the length of the string is reduced by $\frac{1}{2}$, find the new frequency.

$f_1 l_1 = f_2 l_2$

But, $\quad l_2 = \frac{1}{2} l_1$

$420 \times l_1 = f_2\left(\frac{1}{2} l_1\right)$

$f_2 = 840$ Hz

A stationary wave is a wave formed when two progressive waves of the same frequency and wave length travelling in opposite direction meet producing nodes and antinodes.

Progressive wave is a wave in which energy is transmitted from one place to another and is not stores.

Vibrating strings

The ways in which a string vibrates are called harmonics. The sound is produced when notes are performed at both ends of a stationary wave.

Modes of vibration

The ends of a stretched string are fixed and therefore the ends of the string must be the displacement nodes.

If the string is displaced in the middle, a stationary wave is formed.

<u>**Fundamental note:**</u>

- Is a note with the lowest audible frequency.
- It is the note produced at the first position of resonance.

<u>**Overtones:**</u>

- Is a note whose frequency is higher than the fundamental frequency.
-

<u>Uses of overtones:</u>

-Determining the overall quality of sound

-Describing sound systems in pipes or plucked strings.

<u>**Harmonics:**</u>

- Is a note whose frequency is an integral multiple of the fundamental frequency.

Musical Interval:

- This is the ratio of the frequencies of two notes.

Name of musical note	Tone ratio
Octave tone	2:1
Minor tone	5:4
Major tone	9:8
Semi tone	16:5

Octave:

- This is the span of notes between one pitch and another that it is twice or a half its frequency.

Note: Two notes with fundamental frequencies in a ratio of any power of two (e.g half, twice, four times e.t.c) will sound similar. Because of that, all notes with these kinds of relations can be grouped under the same pitch class.

Note: In calculations involving octave use the formula;

$$\boldsymbol{\frac{f_2}{f_1} = \left(\frac{2}{1}\right)^n}$$

Where, $f_2 =$ Higher frequency

$f_1 =$ Lower frequency

$n =$ Number of octaves above or below f_1

Example: 1

Find the frequency of a note four octave above a note of frequency 20Hz.

Solution: $f_1 = 20Hz, n = 2\ (above);\ f_2 = ?$
$\frac{f_2}{f_1} = \left(\frac{2}{1}\right)^n \Rightarrow \frac{f_2}{20} = \left(\frac{2}{1}\right)^2 \Rightarrow f_2 = 2^2 \times 20 = 80Hz$

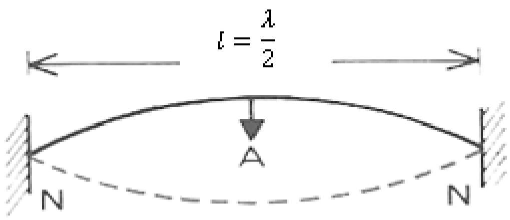
Example: 1

Find the frequency of a note of four octaves below a note of frequency 512Hz.

Solution: $f_2 = 512Hz, n = 4\ (below);\ f_1 = ?$
$\frac{f_2}{f_1} = \left(\frac{2}{1}\right)^n \Rightarrow \frac{512}{f_1} = \left(\frac{2}{1}\right)^4 \Rightarrow f_1 = 2^4 \times 20 = 32Hz$

(i) First Position of resonance (fundamental note)

1st harmonic vibration



The wave formed in this case is the simplest form of vibration and is called the fundamental note .

The frequency at which it vibrates is called the fundamental frequency.

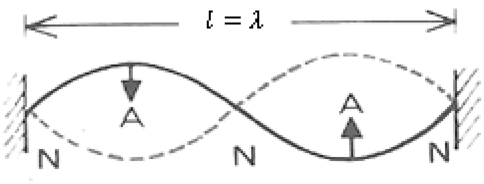
If f is the frequency (Fundamental frequency). Then

$f_1 = \left(\frac{v}{\lambda}\right)$, But $\lambda = 2l$

$f_1 = \left(\frac{v}{2l}\right)$, Where v is the speed of the wave.

(ii) Second Position of resonance (first Overtone).

When the wave is plucked quarter way from one end, the wave formed is shown below.

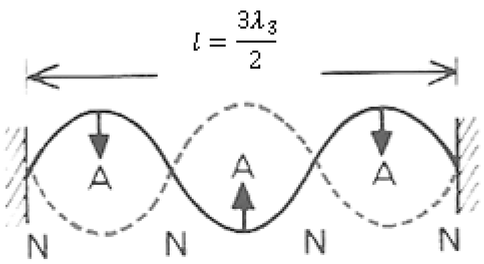


If f_2 is the frequency of the wave, then;

$$f_2 = \frac{v}{\lambda_2} = \frac{v}{l} = \frac{2}{2} \times \frac{v}{l} = 2 \times \left(\frac{v}{2l}\right) = 2f_1$$

Thus, it is also called the **second harmonic.**

(iii) ***Third Position of resonance (2nd overstone***)



$$f_3 = \frac{v}{\lambda_3} = \frac{v}{\left(\frac{2}{3}l\right)} = 3 \times \frac{v}{2l} = 3f_1$$

Thus, it is also called the **third harmonic.**

Therefore in a stretched string all the harmonics are possible and their frequencies are; $f_{1,} 2f_{1,} 3f_1, 4f_1$ ..

Thus harmonics obtained from vibrating strings are f_1,$2f_1$,$3f_1$ etc. hence both even and odd harmonics are obtained.

A- Antinodes- these are points that are permanently at rest. No disturbance occurs at these points.

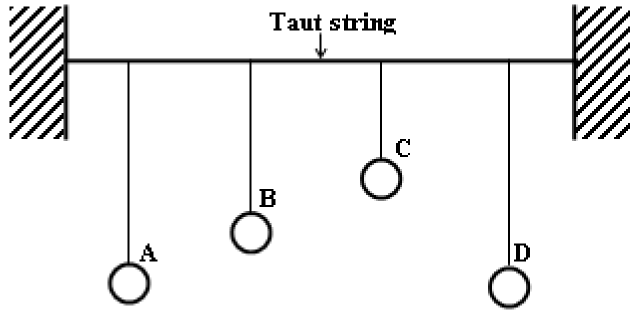
RESONANCE

This is when a body is set into vibrations with its own natural frequency by another nearby body vibrating at the same frequency.

The final amplitude of the resonating system builds up to a much greater value than that of the driving system.

An experiment to demonstrate Resonance using a coupled pendulum and tubes.

Procedures:



Hang four pendulum bobs on the same taut string such that pendulum, A has variable length while B, C and D have different fixed lengths.

Set pendulum A to the same length as D. Make it swing and observe the mode of swinging of the pendulums.

Set pendulum A to the same length as B. Make it swing and observe the mode of swinging of the pendulums.

Observation:

When length of A is equal to length of D, B and C vibrate with smaller amplitudes while D swings with larger amplitudes.

When length of A is equal to length of B, the motion of A will be transferred to B in greater amplitude and B will start to swing with appreciable amplitude while C and D will jiggle a little but they will not swing appreciably.

Common consequences of resonance:

(i) A playground swing can be made to swing high by someone pushing in time with the free swing.

(ii) Soldiers need to break a step when crossing a bridge.

(iii) Vibrations of the sounding box of a violin.

(iv) A column of air in a tube resonates to a particular note.

(v) A diver on a spring board builds up the amplitude of oscillation of the body by bouncing on it at its natural frequency.

(vi) Singers who can produce very high frequency notes can cause wineglasses to break when the notes have the same frequency as the natural frequency of the glass. [Opera singers]

Applications of Resonance:

- In determining the speed of sound in air using a tuning fork and the resonance tube.
- In tuning strings of a musical instrument e.g a guitar and tuning electrical circuits which include indicators.

Dangers of Resonance

- Causes bridges to collapse as soldiers match across them. This can be prevented by stopping the matching.
- Causes buildings to collapse due to earthquake.
- Chimneys can also collapse due to strong resonance.

Vibrations of air in pipes.

(a) When a wave of a particular wave length and frequency is set into a closed pipe, reflection of the wave occurs at the bottom of the pipe. The reflected wave will interfere with the incidence when the length of the wave is adjacent so that a node is reflected at the reflected surface, a standing wave is produced.

The air column is now forced to vibrate at the same frequency as that of the source of the wave which is a natural frequency of the air column.

(a) Closed pipes.

This consist essentially of a metal pipes closed at one end and open at the other.

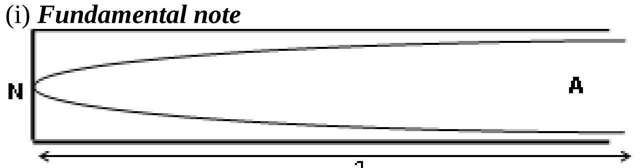
Closed pipes boundary conditions.

At the closed end, there is a displacement node.

At the open end here is displacement antinode.

The allowed oscillation modes or standing wave patterns are:-

(i) ***Fundamental note***



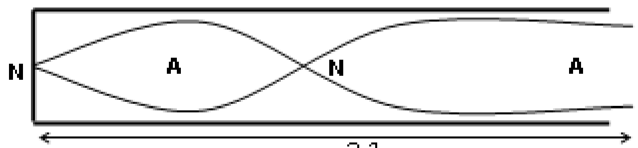
$$l = \frac{\lambda_1}{4}$$

Fundamental frequency, $f_1 = \frac{v}{\lambda_1} = \frac{v}{4l}$ ……………….(i)

Fundamental or lowest audible frequency (f_1)

It is obtained when the simplest stationary wave form is obtained.

(ii) ***First overtone*** (3^{rd}harmonic)

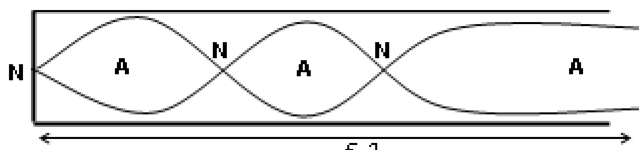


$$l = \frac{3\lambda_1}{4}$$

Frequency of first overtone f_3 is given by;

$$f_2 = \frac{v}{\lambda_2} = \frac{v}{\left(\frac{4l}{3}\right)} = \frac{3v}{4l} = 3 \times \left(\frac{v}{4l}\right) = 3f_1$$

(iii) ***Second overtone*** (5^{th}harmonic)



$$l = \frac{5\lambda_3}{4}$$

$$f_3 = \frac{v}{\lambda_3} = \frac{v}{\left(\frac{4l}{5}\right)} = \frac{5v}{4l} = 5f_1$$

The frequencies obtained with a closed pipe are f_1, $3f_1$, $5f_1$, $7f_1$ $9f_1$, etc i.e. only odd harmonics' are obtainable. Because of the presence of only odd harmonics, closed pipes are not as rich as open pipes.

In closed pipes, nodes are formed at closed ends and antinodes at open end.

(b) Open pipes

These are Pipes which are open at both ends.

In open pipes, standing waves resulting into resonance are created when the incident waves are reflected by the air molecules at the other end. Possible ways in which waves travel are shown below:

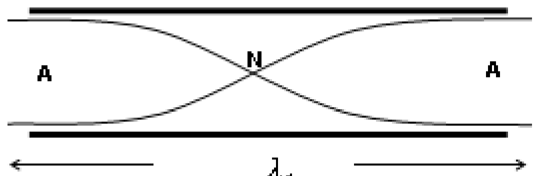
In open pipes, the sound nodes are produced when antinodes are formed at both ends.

Open pipes boundary conditions:

Antinodes are at both ends.

The allowed oscillation modes or standing wave patter are:-

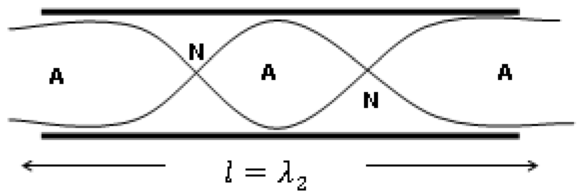
(i) ***Fundamental note.(1st harmonic)***



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

Fundamental frequency; $f_1 = \frac{v}{\lambda_1} = \frac{v}{2l}$

(ii) ***First overtone (second harmonic)***



$$l = \lambda_2$$

$$f_2 = \frac{v}{\lambda_2} = \frac{v}{l} = \frac{2}{2} \times \frac{v}{l} = 2 \times \left(\frac{v}{2l}\right)$$

$$f_2 = 2f_1$$

Thus frequencies for notes produced by open pipes are $f_1, 2f_1, 3f_1, 4f_1$……….

So an open pipe can produce both odd and even harmonics. Therefore, open pipes produce a richer note than that from a similar closed pipe, due to the extra harmonics.

In general;

- For a **closed pipe:** $f_n = n\left(\frac{v}{4l}\right) = nf_1$, Where, **n** = 1, 3, 5, 7………
- For an **open pipe:** ;$f_n = n\left(\frac{v}{2l}\right) = nf_1$, Where, **n** = 1, 2, 3, 4………

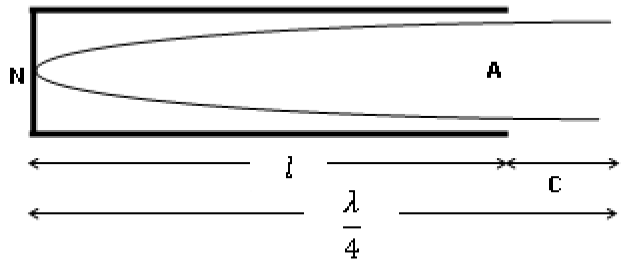
End correction

Then, at the open end of the pipe is free to move and hence the vibration at this end of the sounding pipe extend a little into the air outside.

An antinode of the stationary wave due to any note is in practice a distance, c from the open end. The distance, c is known as the end correction.

For the closed pipe;-

Fundamental mode



$\frac{\lambda_1}{4} = l + c \Leftrightarrow \lambda_1 = 4(l + c)$

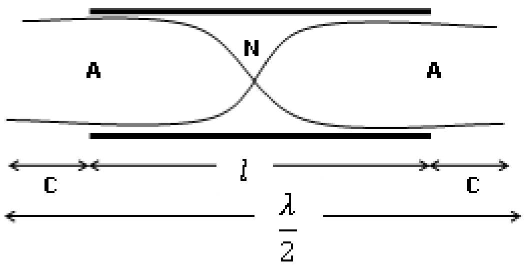
$f_1 = \frac{v}{\lambda_1} = \frac{v}{4(l + c)}$

Fundamental frequency,

$\boldsymbol{f_1 = \frac{v}{4(l + c)}}$

***For open pipe*;-**

Fundamental mode,



$\frac{\lambda_1}{2} = l + 2c \Leftrightarrow \lambda_1 = 4(l + 2c)$

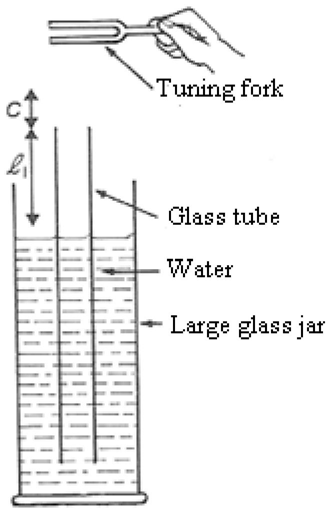
$f_1 = \frac{v}{\lambda_1} = \frac{v}{2(l + 2c)}$

Fundamental frequency,

$\boldsymbol{f_1 = \frac{v}{2(l + 2c)}}$

Open pipes are preferred to closed pipes because they give both odd and even harmonics hence better quality sound.

Determination of velocity of sound in air by Resonance method.



C = End correction, l_1, l_2 = Length of air columns.

- Assemble the apparatus as in the diagram.
- Put a vibrating tuning fork just above the resonance tube.
- Gently lower the resonance tube until the 1st resonance (loud sound) occurs.
- Measure the length $l_1$at which it occurs.

l_1 + c = $\frac{1}{4}$ λ…………………………………. (i)

- Raise the resonance tube until the 2nd resonance (loud sound) occurs.
- Measure the length l_2 at which it occurs.

l_2 + c = $\frac{3}{4}$ λ…………………………….......... (ii)

- Subtract equation (i) from (ii) to eliminate c

(l_2 - l_1) + (c-c) = $\frac{3}{4}$λ -$\frac{1}{4}$λ

l_2 - l_1 = $\frac{1}{2}$ λ

2 (l_2 - l_1) = λ

- Hence the speed or velocity of sound in air is determined from the expression. $V = f\lambda$.

$$\boldsymbol{V = 2f(l_2 - l_1)}$$

Example: 1.

In an experiment the velocity of sound in air using a resonance tube, the following results were obtained:

- Length of 1st resonance = 16.1cm
- Length of 2nd resonance = 51.1cm
- Frequency of tuning fork = 480 H_z

(i) .

(i) Calculate the wave length of sound produced. $\lambda = 2(l_2 - l_2)$ $\lambda = 2(51.1 - 16.1)$ λ = 70 cm	(ii) The end correction of the resonance tube. $l_1 + C = \frac{1}{4}\lambda$ $16.1 + C = \frac{1}{4} \times 70$ $C = 17.5 - 16.1$ $C = 14$ cm
(iii)The velocity sound in air. V = $2f(l_2 - l_1)$ V = $2 \times 480\left(\frac{51.1}{100} - \frac{16.1}{100}\right)$ V = 336ms^{-1}	

Example: 2.

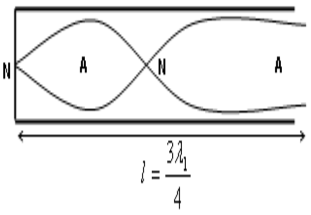
A glass tube open at the top is held vertically and filled with water. A tuning fork vibrating at 264 Hz is held above the table and water is allowed to flow out slowly .The first resonance occurs when the water level is 31.5cm from the top while the 2nd resonance occurs when the water level is 96.3cm from the top. Find the;-

Solution:

(i) Speed of sound in the air column. V = $2f(l_2 - l_1)$ V = $2 \times 264\left(\frac{96.3}{100} - \frac{31.5}{100}\right)$ V = 342.144ms^{-1}	(ii) End correction. $\lambda = 2(l_2 - l_2)$ $\lambda = 2\left(\frac{96.3}{100} - \frac{31.5}{100}\right)$ λ = 1.296 m $l_1 + C = \frac{1}{4}\lambda$ $0.315 + C = \frac{1}{4} \times 1.296$ $C = 0.324 - 0.315$ $C = 0.009$ m

Example: 3.

The frequency of the third harmonic in a closed pipe is 280 Hz. Find the length of the air column. (Speed of sound in air = 330ms^{-1})

 $\lambda = \frac{4l}{3}$ From; $v = f\lambda$ $330 = 280 \times \frac{4l}{3}$ $3 \times 330 = 280 \times 4l$ $990 = 1120l$ $l = 0.884$	**Alternatively;** For a closed pipe, the possible frequencies are; **f$_1$, 3f$_1$, 5f$_1$…..;** where $f_1 = \begin{pmatrix} frequency\ of\ the \\ fundamental\ note \end{pmatrix}$ But frequency of third harmonic = $3f_1 = 280$Hz. **Thus;** $3f_1 = 280$ $f_1 = 93.33\ Hz$ $f_1 = \frac{v}{4l}$ $93.33 = \frac{330}{4l}$ $4l \times 93.33 = 330$ $l = 0.884$ m

Example : 4.

The frequency of the 4th overtone in an open pipe is 900Hz when the length of the air column is 0.4m. Find the

(i) Frequency of the fundamental note

(ii) Speed of sound in air.

Solution:

(i)Frequency of the fundamental note **For an open pipe, the possible frequencies are;** **f$_1$, 2f$_1$, 3f$_1$, 4f$_1$, 5f$_1$…..;** **where** $f_1 = \begin{pmatrix} \text{frequency of the} \\ \text{fundamental note} \end{pmatrix}$ $f_1 = \frac{v}{2l}$ **But frequency of 4th overtone = $5f_1 = 900$Hz.**	**Thus;** $5f_1 = 900$ $f_1 = 180\ Hz$ (ii) Speed of sound in air. $f_1 = \frac{v}{2l}$ $180 = \frac{v}{2l}$ $v = 2 \times 0.4 \times 180$ $v = 144\text{ms}^{-1}$

Exercise:

1. The frequency of the 3rd overtone (4th harmonic) produced by an open pipe is $840H_z$. Given that the velocity of sound in air is 330m/s, calculate;

(i) Length of the people

(ii) Fundamental frequency

2. A pipe closed at one end has a length of 10cm, if the velocity of sound is 340m/s; calculate the frequency of the fundamental note.

3. A tuning fork produces resonance in a tube at a length of 15.0cm and also at a length of 40.0cm. Find the frequency of the tuning fork.

4. (a) A tuning fork of $256H_z$ was used to produce resonance in a closed pipe. The first resonance position was at 22cm and the 2nd resonance position was at 97cm. Find the frequency of sound waves.

(b) An open tube produced harmonics of fundamental frequency $256H_z$, what is the frequency of the 2nd harmonics.

5. A tuning fork of frequency 256 Hz was used to produce resonance in a a tube of length 32.5cm and also in one of length 95.0cm. Calculate the speed of sound in the air column. [320ms^{-1}]

6. A tuning fork of frequency 512Hz is held over a resonance tube of length 80cm. The first position of resonance is 16.3 cm from the top of the tube and the second position of resonance is 49.5cm. Find the speed of sound in air. Why is it better to use a frequency of 512Hz rather than one of 256Hz? [340ms^{-1}]

7. See UNEB

Sound waves 2001 Qn19 1990 Qn40 1995Qn22 2002 Qn17	1989 Qn27 1997 Qn23 1994Qn10 1998 Qn25 2002 Qn25	2006 Qn42 2008 Qn26 1997 Qn26 1999 Qn27	1989 Qn2 1991 Qn14 1991 Qn40 1992 Qn32 1997 Qn33

Progressive and/stationary waves 1988 Qn25 1989 Qn9 1995 Qn21	2000 Qn12 2000 Qn29 2000 Qn30 2002	Qn22 2005 Qn39 2008 Qn31 2008 Qn35 Section B	1990 Qn6 2000 Qn6 2004 Qn7 2008 Qn6