WAVES

Waves are due to vibrations resulting in movement energy which transfer from its source to places around it.

Or

A wave is a means of transfer of energy by a vibrating medium.

Class of Waves

Waves can also be classified as mechanical waves and electromagnetic waves.

Mechanical waves

These are wave which require a material medium for transmission. Mechanical waves include: Sound waves, water waves, waves on strings etc.

Electromagnetic waves

These are wave which do not require a material medium for transmission. Electromagnetic waves include: light waves, radio waves, X-ray, ultraviolet etc.

Differences between mechanical and electromagnetic waves

Mechanical Waves	**Electromagnetic waves**
Need a medium for transmission.	Do not need a medium for transmission.
Cannot travel through vacuum.	Can travel through a vacuum.
Relatively slow	Very fast

Kinds of waves

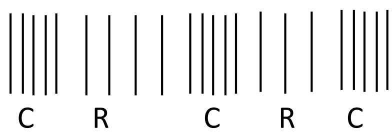
There are two kinds of waves namely:

(i) Longitudinal waves.

(ii) Transverse waves.

Longitudinal waves
A longitudinal wave is one in which the direction of the wave motion in the same direction as the vibration.
OR
A longitudinal wave is one in which particles vibrate in direction parallel to wave motion.

Examples of longitudinal waves are sound waves, waves produced by pipes and string instruments. A longitudinal wave has two regions namely: compression and rare faction regions.
Diagram showing motion of particles for longitudinal wave.



C is compression region, **R** is rare faction region.

Compression region
Compression region is a region in the longitudinal wave where the vibrating particles are very close together. A particle at the centre of compression region moves from the rest position in same direction as the wave.

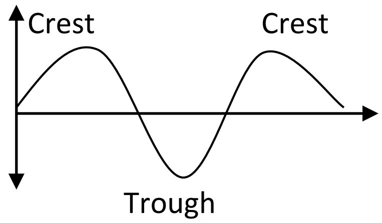
Rare-faction region
Rare-faction region is a region in the longitudinal wave where the vibrating particles are further apart. A particle at the centre of rare-faction moves from rest position in the opposite direction to that of the wave.

Differences between compression and rare faction regions of longitudinal wave.

Compression	**Rare-faction**
Vibrating particles are very close together.	Vibrating particles are further apart.
A particle at the centre moves from rest position in a direction the same as that of the wave motion.	A particle al the centre moves from rest position in opposite direction to that of the wave motion.

Transverse waves
Transverse wave is one in which particles vibrate perpendicular to the direction of wave motion.
Example: Water waves, light waves, all electromagnet waves.

A transverse wave has two main regions namely: Crest and Trough.

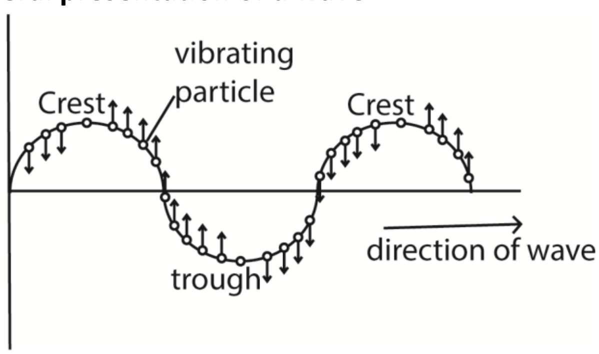


Crest is a region of maximum upward displacement of particles in a transverse wave.
Trough is a region of maximum downward displacement of particles in a transverse wave.

Differences between a transverse wave and longitudinal wave

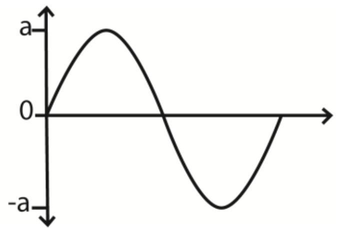
Transverse	**Longitudinal wave**
Is one in which particles vibrate perpendicular to the direction of wave motion	is one in which particles vibrate in a direction parallel to wave motion
Has 2 regions crest and trough	It has 2 regions, compression region and rare faction

General presentation of a wave



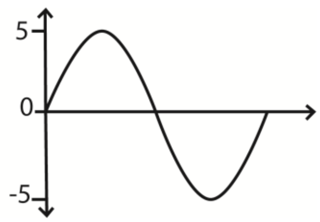
Definition of terms
Amplitude is a maximum displacement of a particle from its rest position on a wave.
S.I unit of amplitude is metre (m).

All diagram amplitude to be drawn



Amplitude = a-0 = a or Amplitude = 0-(-a) = a

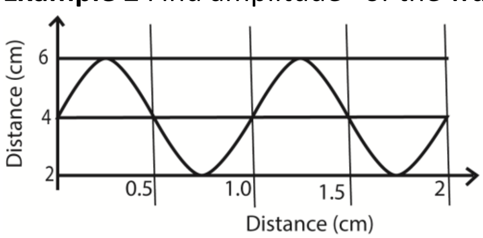
Example 1: Find the amplitude of the wave below



Amplitude = 5 -0

= 5m

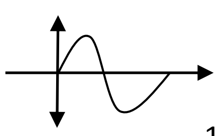
Example 2 Find amplitude of the wave below



Amplitude = 6 - 4=2m

A cycle of a wave

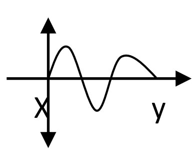
Cycle is one complete to and from motion of a wave.



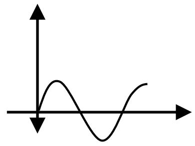
1 cycle

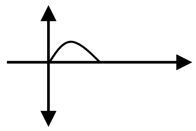
For each of the following find the number of cycles

(a)



1 ½ cycle

(b)  1 ¼ cycle

(c)  ½ cycle

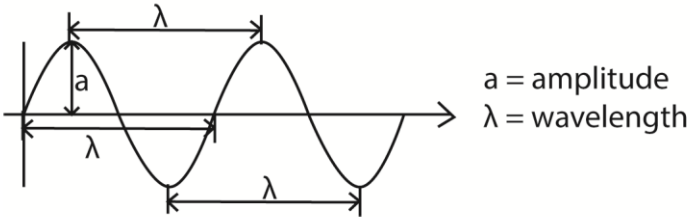
Wave length (λ)

Wave length is the distance between successive particles of the medium that are in phase.

For transverse waves, **wave length** is the distance between two successive crests or troughs.

For longitudinal waves, **wave length** is the distance between two successive compressions or rare-factions.

The S.I unit of wave length is metre **(m)**



Example 3:

The Period

A Period of a wave is the time to taken to complete one cycle of wave or time taken for a wave to travel a distance of wave length. S. I unit is seconds.

In general for n cycles completed in time t

$$\text{Period } T = \frac{t}{n}$$

Example 3: Find the period of a wave which makes 10cycles in 40s

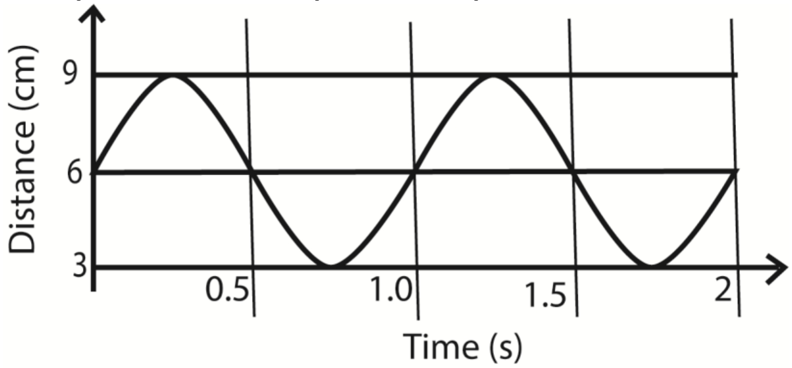
n = 10cycles

t = 40s

$$T = \frac{t}{n}$$

$$T = \frac{40}{10} = 4s$$

Example 4: Find the amplitude and period of wave below



Amplitude = 9 – 3 = 3cm
Period = 1.0cm

Frequency
Frequency is the number of vibrations per second.
Frequency is also the number of complete cycles made by a wave in 1 second.
Frequency is also the number of wave length that passes a fixed point per second.
The S.I unit for frequency is Hertz (Hz).

Hertz is one complete oscillation per second e.g. 60Hertz means 60 oscillations per second or 60 vibrations per second.
Note: 1Hz = 1s^{-1}
Bigger units
1 kHz = 1000 Hz
E.g. 4 kHz = 4 x 1000
= 4000Hz
1 MHz = 10^6 = 1000000Hz

In general for calculation
Frequency (f) = $\frac{\textbf{number of oscillation (n)}}{\textbf{time taken (t)}}$

Where **n** is the number of oscillation or cycles or vibrations made in time **t**.

Example 5: A vibrator produces 10 vibrations in 4 seconds, find the frequency
n= 10 oscillations
t = 4s
f = $\frac{n}{t}$ = $\frac{10}{4}$
= 2.5Hz

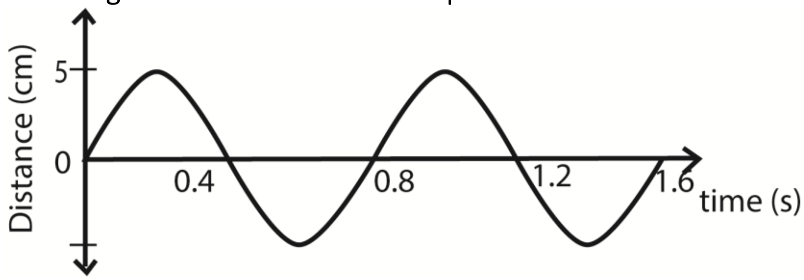
Example 6: A vibrate vibrating at 10Hz for 4s, find the no of vibrations made

$f = \frac{n}{t}$ f = 10 Hzt = 4s

$10 = \frac{n}{4}$

n= 40 vibrations

Example 7: The figure below shows a wave profile of a radio wave



(i) Determine the amplitude of the wave

5 -0 = 5cm

(ii) Find the frequency of the wave

0.8 second are required for 1wave cycle

1.0 second are equal to $\frac{1.0}{0.8}$ = 1.25Hz

Wave velocity (V)

Wave velocity is the distance a wave travels in 1 second.

Or

Velocity, v = wavelength in meters x number of cycles per second

= wavelength in meters x frequency of a wave

= fλ

S.I unit is **ms^{-1}**

For calculations

If a wave covers a distance **X** in time **t**, then wave velocity **V** = $\frac{x}{t}$

Example 8: A vibrator produces wave which travels a distance of 35m in 2 seconds

Calculate the wave velocity

X = 35m t = 2s

$V = \frac{x}{t} = \frac{35}{2} =$ **$17.5ms^{-1}$**

Example 9: A vibrator produces waves which travel 60m in 0.1minutes if the frequency of vibration is 5 vibrations per second. Find the wave length

X = 60m

t= 0.1 minute = 0.1 x 60 = **6s**

f = 5 vibrations per second = **5Hz**

$V = \frac{x}{t} = \frac{60}{6} = 10ms^{-1}$

$V = \lambda f$

$10 = \lambda \times 5$

$\lambda = \frac{10}{5} = \mathbf{2m}$

Example 10: A wave of wave length 0.5m moves at $5ms^{-1}$. Find

(i) Frequency

Frequency, $f = \frac{velocity}{wave\ length} = \frac{5}{0.5} = 10Hz$

(ii) Period

$T = \frac{I}{f} = \frac{1}{10} = \mathbf{0.1s}$

Example 11: A wave vibrating at 10Hz makes 4cycles covering 20cm. calculate a wave velocity.

f = 10Hzn= 4 cycles X = 20m

$\lambda = \frac{x}{n} = \frac{20}{4} = 5m$

$\mathbf{V = \lambda f} = 5 \times 10 = \mathbf{50ms^{-1}}$

Note: for electromagnetic waves which include Gamma rays, x-rays, light, radio waves all move at a speed of $\mathbf{3x\ 10^8ms^{-1}}$. When handling calculations involving electromagnetic waves, speed of $\mathbf{3x\ 10^8ms^{-1}}$ should be used.

Example 12: The wavelength of electromagnetic wave is 10m. Calculate frequency and period.

$V = 3 \times 10^8 ms^{-1}$ $\lambda = 10m$

(i) $V = \lambda f$

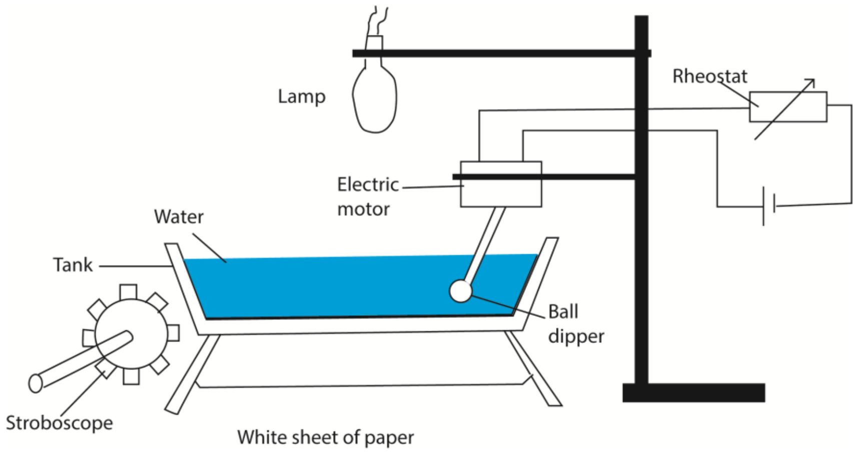
$\mathbf{3 \times 10^8 = 10 \times f}$

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

$\mathbf{f = 3 \times 10^7 Hz}$

(ii). Period $T = \frac{1}{f} = \frac{1}{3 \times 10^7} \cong \mathbf{3.3 \times 10^{-8}s}$

The ripple tank



The properties of waves can be obtained by studying the behavior of water waves in the ripple tank.

The ripple tank consists of a tray whose bottom is transparent so that light can shine upwards or downwards.

The sides are sloppy and lined with a sheet of sponge in order to:

(i) Absorb the energy of the ripples.

(ii) Prevent reflection by the sides.

The lamp above the tank casts the shadow of the wave on the white sheet of paper placed underneath.

How waves are produced on the ripple tank?

Straight waves

These are produced by dipping a straight edged object like ruler in the water surface.
Continuous straight waves are produced when a straight edged object is attached to a bar using vibrations generated by an electric motor.

Circular waves

These are produced by dipping a small spherical balls attached to bars using
Vibrations generated by an electric motor.

Stroboscope

This is used in the making of waves to appear stationary so that they can be studied.
Stroboscope is a disc with equally spaced slits.

How the Stroboscope is used to freeze or slow down movement of water waves set up in the ripple tank

This is done by varying the speed of rotation of the Stroboscope until the waves appear to be stationary when viewed on the screen through the discs of the stroboscope.

How frequency may be measured by ripple tank?

In short the frequency can be measured by the following ways:

Varying speed of rotation
The speed of rotation of the Stroboscope is varied until the waves appear stationary on viewing through the slits of the Stroboscope.

Measuring the periodic T
When the waves appear stationary, the time taken for successive slits to cross the line of sight is measured. This is the period "T" of the wave. So frequency f = 1/T

Description of how the wave length may be measured from ripple tank experiment
Varying the speed of rotation
The speed of rotation of the stroboscope is varied until the waves appear stationary on viewing through the slits.

Casting the shadow
Then the lamp above casts the shadow of the waves on the white paper below the tray. The wavelength is measured directly.

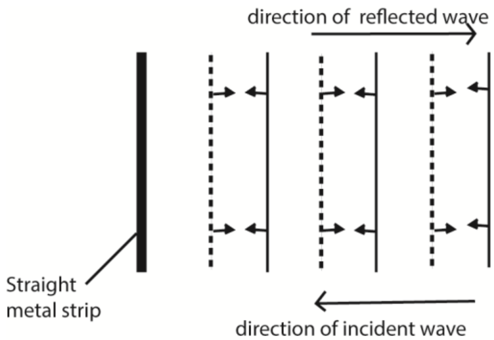
Points to note when drawing wave diagrams

a) In water of constant depth, the waves travel at constant speed so the wavelength is the same. Therefore draw wave fronts that are equally spaced.
b) The direction of travel of the waves should be shown at right angle to wave fronts.
c) Sources of circular wave and their images formed by reflection should be labeled.

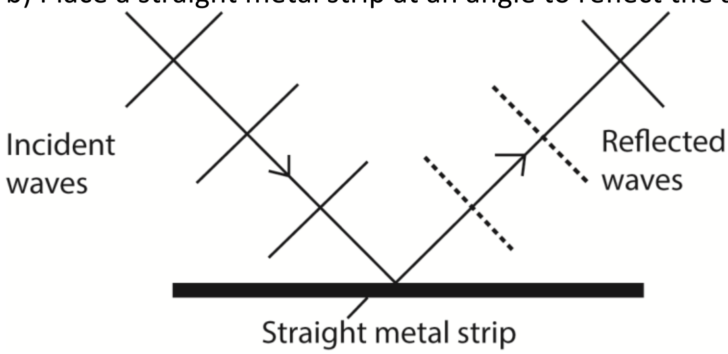
Reflection of waves
This is the bouncing back of waves from an obstacle

Reflection can be shown by standing a straight metal strip as a plane reflector and curved metal strip as concave and convex reflector in water

Reflection of waves at plane surface
A straight metal strip attached to a vibrator using vibrations generated by electric motor, is placed in water and another straight metal strip is placed in water parallel to the vibrator. Then the electric motor is switched on and the straight waves are incident normally reflected along the same path as plane waves.



b) Place a straight metal strip at an angle to reflect the approaching wave.



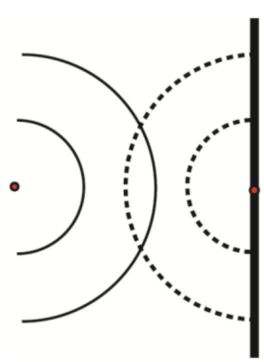
For reflection at plane surface both the incident and reflected waves are straight and have equal spacing because the incident and reflected waves have the same speed and wavelength as the wave is travelling in water of same depth.

Laws of reflection of waves

i) The angle of incidence of waves is equal to the angle of reflection of the wave,

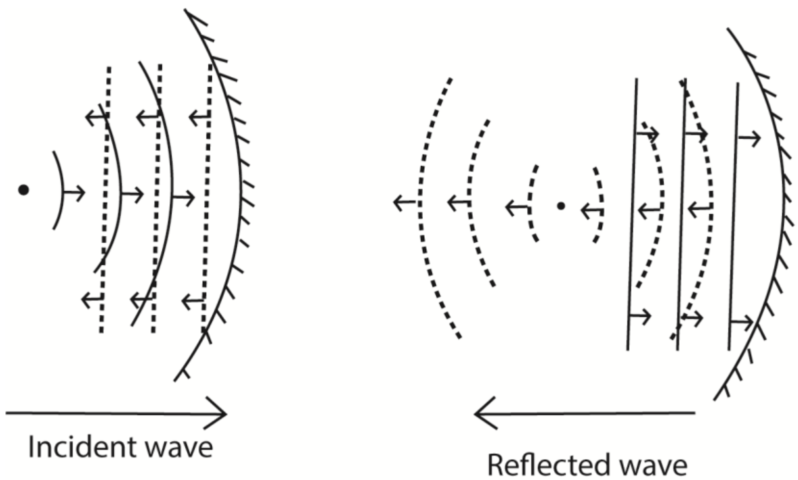
ii) The incident wave, reflected wave and the normal at the point of incidence all lie in the same plane.

Circular waves Incident on straight reflector the source "S" corresponds to the object and T corresponds to virtual source of the reflected waves,
The distance SM = MI. "MI" and "SM" are at right angles to the reflector.

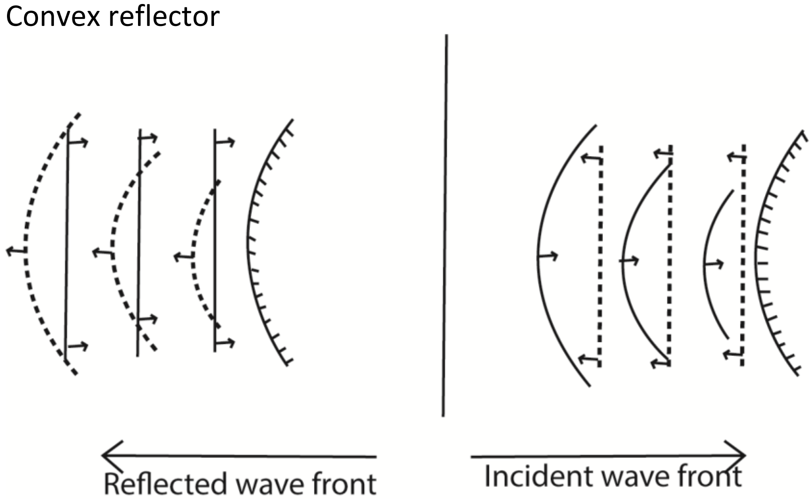


Reflection of straight waves

<u>Concave reflector</u>



Convex reflector



The reflected wave-fronts are circular, converging towards and passing through the principal focus F.

Points to consider when drawing

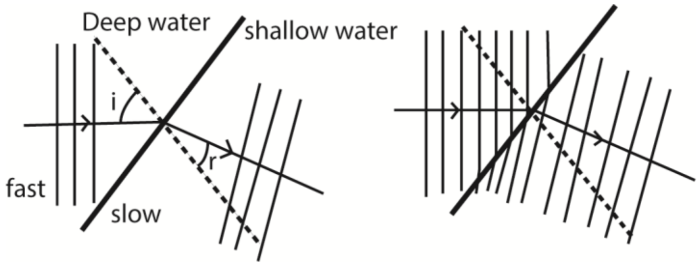
(a) The focal point F becomes the centre of the circular waves.

(b) The circular waves should be equally spaced. The distance of spacing should be the wavelength.

(c) The spacing for the circular waves should be the same as that for the straight waves.

REFRACTION OF WAVES

Waves formed in ripple tanks can be refracted by placing a sheet of glass in water to make it shallow. The continuous straight waves in the shallow water are found to be closer to one another than in deep water. This implies that the wavelength of the wave is less in shallow water than in deep water. In short the wavelength of a wave in shallow water is shorter even though the frequency is the same.



1. The direction of the wave when it strikes shallow water at a right angle does not change.
2. The wave speed is reduced in shallow water hence wavelength decreases. So when drawing the refracted waves are closely spaced
3. The frequency of the wave motion does not change.

Since speed "V" = fλ. In shallow water the wavelength decreases yet the frequency remains constant, so the speed of the wave decreases in shallow water. The wave travels faster in deep water because the wave length increase yet the frequency remains constant.

Refraction results in a wave slowing down the speed and changing direction as the wave enters shallow water.

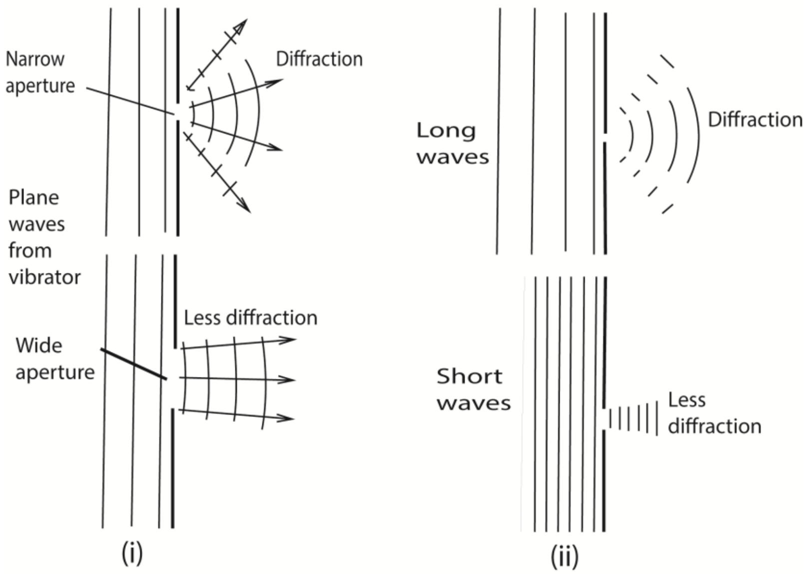
DIFFRACTION OF WAVES

Diffraction is the spreading of waves when they pass through apertures or around obstacles. The general phenomenon of diffraction may be illustrated by using water waves in a ripple tank.

For diffraction to occur the dimension/size of aperture or obstacle must be of the order of the wavelength of the wave; i.e. the width of the aperture must be of the same order as the diffracted wave.

The diffraction of Plane waves through a narrow and wide aperture is illustrated below

Diffraction of waves



Generally, the smaller the width of the aperture in relation to the wavelength, the greater is the spreading or diffraction of the waves

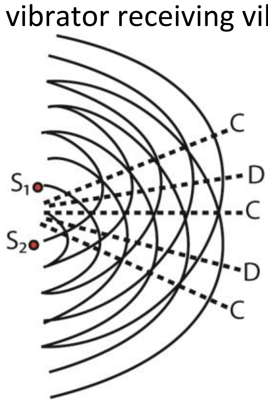
Secondary, the longer the wavelength of the wave to be diffracted the greater the diffraction or spreading.

Light waves have very short wavelengths that diffraction around obstacles of normal size is negligible that we unable to see around corners while sound waves of longer wavelength are reasonably diffracted that we are able to hear around corner.

INTERFERENCE

Interference is when two identical waves moving in the same direction are superposed on one another. Waves are superposed when one wave is placed on top of the other. For this to occur the amplitudes and frequencies of the two waves should be the same.

In the ripple tank, the two waves are produced by two ball ended dippers attached to the vibrator receiving vibration from the electric motor.

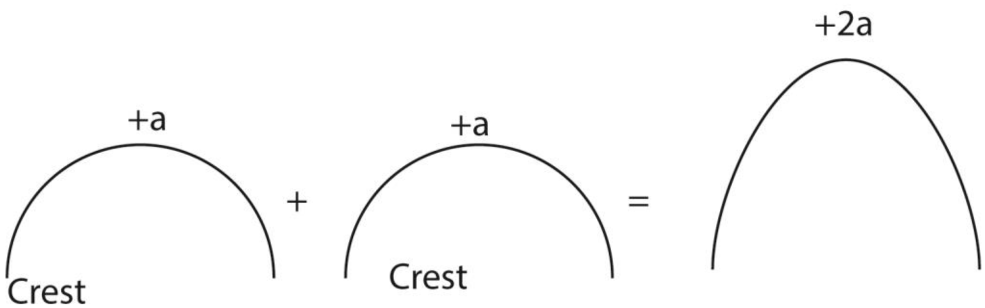


Where:
"C" is constructive interference

"D" is Destructive interference
"S_1" and S_2 are sources of vibration
Where the two waves are superposed in the same phase e.g. crests m one wave fall on the crests of another constructive interference occurs.

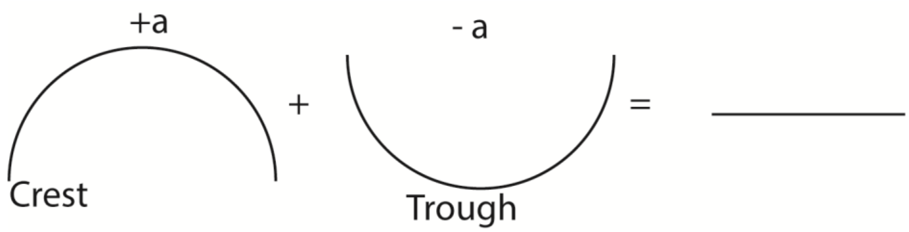
Where the two waves are superposed such that they are exactly out nr phase e.g. crests of one wave are superposed on the troughs of the other identical wave, no disturbance is obtained. These positions are called destructive interference.

Constructive interference



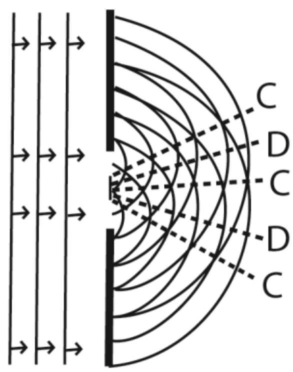
$\cap^{+a} + \cap^{+a} = \cap^{+2a}$ displacement (+a) + (+a) = +2a occurs when the displacement due to two waves combine to produce larger displacement This happens when the wave crests overlap. The wave is in phase.

Destructive interference



Occurs when, the crest of one wave falls in the trough of another. This produces an effect of no displacement such waves are in antiphase.

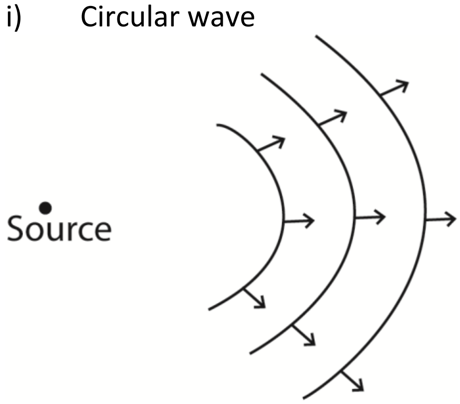
Double-slit interference



C - Constructive interference
D - Destructive interference
When straight wave fronts reach two gaps, circular waves emerge.
Where these two sets of waves are superposed, the same interference effects are produced.

Wave fronts
A wave front is a surface of a waveform on which every particle is in the same state of disturbance and transmitting the wave at the same distance from the source of the wave.

A wave front may be;
i) Circular wave



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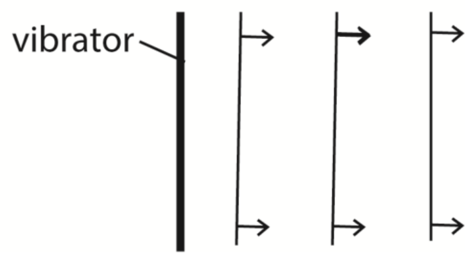
(ii) Plane waves



The distance between two consecutive wave fronts equal to one wave length.
For "n" crest or troughs covering a distance X
Then wave length λ can be calculated from

$$\lambda = \frac{x}{n-1}$$

Example 13
Calculate the wavelength if the distance between 6 successive crests is 20cm
Solution
λ = ?   n = 6 crests   x = 20cm

$\lambda = \frac{x}{n-1}$

$= \frac{20}{(6-1)} = \frac{20}{5}$ = 4cm.

If the frequency of the vibrator is 5Hz calculate the velocity of the wave.
= 4cm = 0.04m   f = 5Hz

V= λf
= 0.04 x 5
= 0.20m/s

Example 14
A vibrator in a ripple tank vibrates at 5Hz. If the distance between 10 successive crests is 37.8 cm Calculate:
i) The wave length of the waves

x = 37.8cm   n = 10 crest

$\lambda = \frac{x}{n-1}$

$= \frac{37.8}{10-1} = \frac{37.8}{9}$

= 4.2cm = 0.042m

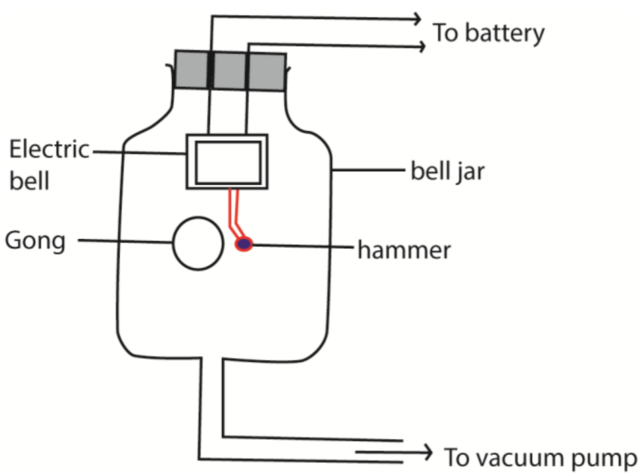
(ii) The velocity of the waves

V = f λ   f= 5Hz
V= 0.042 x 5
= 0.21m/s

Sound waves
Sound is a form of energy produced by vibrating objects. It travels as a longitudinal wave through a material medium.

Production
Sound is produced by vibrating objects. Vibrating objects cause nearby surrounding air molecules to vibrate. When these vibrating air molecules reach our ear, sensation of sound is produced. A sound wave is a longitudinal wave

Propagation of sound
Sound waves need a material medium for transmission so that the vibrating objects cause the nearby molecules of the medium to vibrate
Experiment to show that sound needs a material medium for the transmission



Switch on the electric bell
Switching on the electric bell, a loud sound is heard

Removal of air gradually
On gradually removing the air by a vacuum pump, the loudness of sound gradually dies away.

No sound is heard when all the air has been completely removed though the hammer is seen hitting the gong.

This shows sound waves need material medium like air, liquid or solid for transmission.

The speed of sound waves depends on:-
(i) Temperature.
(ii) Density and elasticity of the medium.
(iii) Wind in the case of air.

How each factor affects the speed of sound waves?

Density: The speed of sound waves is higher in denser medium than in less denser medium in that the speed of sound is higher in solids than in liquids and gases because solids are generally more denser. In a steel rod the speed of sound is about $5000ms^{-1}$ yet in water the speed of sound is $1500ms^{-1}$ because steel is denser than water.

In daily life, an approaching train can easily be detected by human ears positioned close to the rails than in air. This is explained from the fact that sound waves travel faster through solids than through air as solids are generally denser than air. So sound waves from an approaching train travel faster and over longer distances before dying away in solid like rails than air.

Temperature: Increasing the temperature, increases the speed of sound in air greatly because the speed of vibrating air molecules increases with temperature.
However in solids and liquids, increasing the temperature, decreases the speed of sound waves because solids and liquids become less dense.

Wind in the case of air: The speed of sound waves increases if the direction of sound wave travel is the same as that of the wind. If the direction of sound waves travel is opposite that of wind, the speed decreases.

Note: Pressure change in air (gases) does not affect the speed of sound wave because density of air is not affected by change in pressure,

a) Experiment to measure the speed of sound (echo method) Two people one claps and the other records the time, while standing at a known distance from a high wall. The time taken for the sound wave to travel to and from the wall is recorded.

The exercise is repeated many times so that the average time is obtained.

$$\text{Speed of sound} = \frac{2 \text{ x distance}}{\text{Average time}}$$

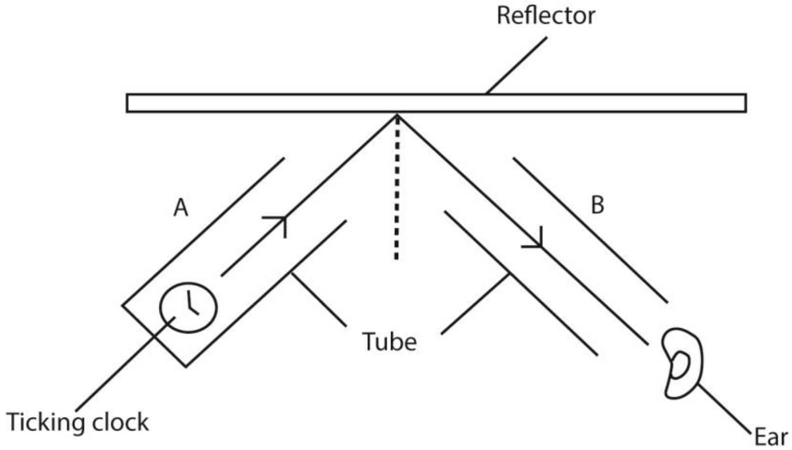
Reflection

Laws of reflection of sound waves state:-

i) Incident sound wave, reflected sound wave and the normal at the point of incidence all He in the same plane,

ii) The angle of incidence of sound waves is equal to angle of reflection of sound waves.

Experiment to show reflection of sound waves



(a) Producing sound waves
Sound waves produced by the clock at the end of tube A are reflected at the hard surface reflector.

b) Moving tube B
The ear is put at the end of the tube B and the tube B is moved until the ticks of the clock are loudest. This is the direction of reflected sound wave.

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

ECHOES
An echo is reflected sound waves

Echoes are produced by the reflection of sound from a hard surface. Echoes are often heard in the neighborhoods of large houses, high walls, cliffs etc.

I echoes are often heard in the big churches, halls etc. They are not heard in a small room or class-room because the reflected sound waves return very quickly and mix up with the original sound wave.

Echoes are troublesome in lecture halls, cinema etc. To reduce echoes in such places, the walls are covered with soft thick porous materials.

Furniture and people in halls also reduce echoes. So many echoes are produced in empty halls compared to one filled with people because bodies of people are soft so they absorb some of the sound.

Reverberation
If the reflecting surface is nearer, the echo joins the original sound which then seems to become prolonged. This is called reverberation.

To some degree, reverberation is desirable in concert halls to stop the hall sounding dead so that hearing in such places is improved.

However, too much reverberation causes confusion.

The time taken by
II particular intensity of sound to die away is the reverberation time.

For echo
Velocity $= \frac{\text{2xdistance}}{\text{time taken}}$

Example 15
A man stands at a distance of 990m away from a tall building and makes a loud sound. He hears the echo after 6 seconds. Calculate the speed of sound.

For echo: **Speed =** $\frac{\text{2xdistance}}{\text{time taken}} = \frac{2x990}{6}$ = **330ms^{-1}**

Example 16
A man stands between two walls, but nearer one of them and makes a loud sound. If he hears the third echo after 6 seconds, calculate the distance between the two walls, (speed of sound in air is 330ms^{-1}.

V =330 **ms^{-1}** d = ? t = 6 seconds

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

$330 = \frac{2xd}{6}$

d =330x3 =**990m**

Example 17
A sound of frequency 150Hz is produced 45m away from a cliff. Calculate the
(i). wavelength
From V =λ f

$\lambda = \frac{v}{f} = \frac{330}{150} = 2.3\text{m}$

(ii). Time it takes the sound wave to travel to and from the cliff
(speed of sound in air=300ms^{-1}**).**

Time = $\frac{\textit{distance to and fro}}{\textit{speed}} = \frac{45 \times 2}{330}$ **= 0.27s**

Example 18

A man stands between two cliffs and makes a loud sound. If he hears the first echo after 1.5s and second echo after 2s, find the distance between the two cliffs. Speed of sound in air is 300ms^{-1}.

Diagram to be drawn

Using Velocity $= \frac{2\text{xdistance}}{\text{time taken}}$

First echo

t = 1.5s

V = 300ms^{-1}

X =?

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

$300 = \frac{2X}{1.5}$ $300 = \frac{2Y}{2}$

$X = \frac{300 \text{x} 1.5}{2}$ = 225m

Second echo

t = 2s

V = 300ms^{-1}

Y =?

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

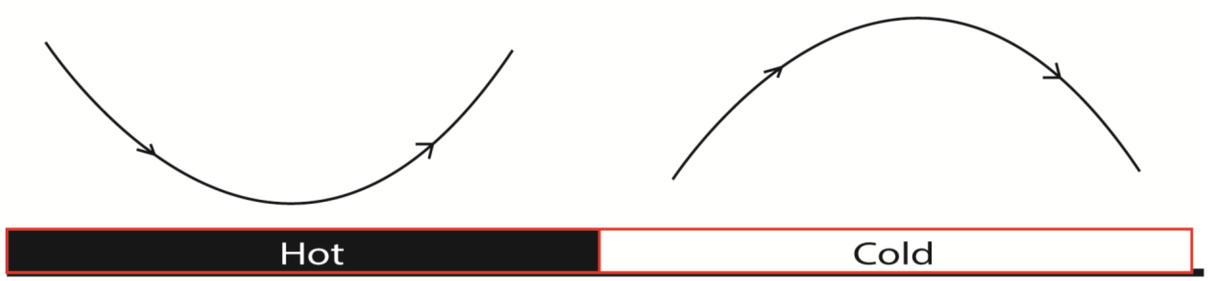
$Y = \frac{300\text{x}2}{2}$ =300m

Distance between the two cliffs = 225 + 300 = 525m

REFRACTION OF SOUND WAVES

Refraction of sound waves occurs when the speed of the wave changes as it moves from one medium to another of different density. The speed of sound waves in air is affected by the air temperature. When sound waves pass through layers of air at different temperature they are refracted i.e. turned into another direction. On a hot day sound waved are bent upwards away from the earth where they otherwise travel faster.

During day sound waves bend away from hot earth At night sound waves bend toward colder earth

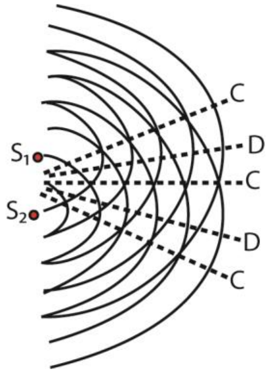


Earth

In the evening when the air near the ground becomes cool, refraction of sound is towards the earth, making it easier to hear distant sound as the range of sound is more.

Radios are clearer at night than during day because at night the sound waves are bent down towards the cool earth making the range of sound more.

INTERFERENCE OF SOUND WAVES



C - Constructive interference

D - Destructive interference

Overlapping sound waves produce regions of louder sound by constructive interference and regions of quiet sound by destructive interference.

If two loud speakers are connected to the same audio frequency generator, they produce sound waves of identical frequency and similar amplitude.
A louder sound is produced when the waves from the two speakers arrive in phase and interfere constructively.
A quiet sound is produced when destructive interference occurs.
If the speakers are moved closer together, the distance between the places where loud sound is heard is increased.

Ultrasonic

Sound waves with frequencies above 20 kHz are called ultrasonic waves. They are emitted by bats. Sound of high frequency that human ear cannot detect is described as ultrasonic.

APPLICATIONS OF ULTRASONICS

1. Ultrasonic enable bats to judge the distance of an object from the time taken by the reflected wave to return.
2. Ultrasonic are used in spectacles for blind to judge distances of an object from the time taken by reflected waves to return. Such spectacles contain ultrasonic sender and receiver.
3. In sonar (echo-sounding system) of ships use ultrasonic wave to measure the depth of sea and to detect shoals of fish.
4. In industry, ultrasonic waves are used to reveal flaws in welded joints and also holes are cut in glass and steel by ultrasonic drills.

Note:

In an echo sounder (sonar, ultrasonic waves are used because they:-

(i) Cannot be confused with engine sound and other sound made ship,

(ii) Can penetrate sea water to a large distance without undue loss of energy.

(iii) They are not much detracted.

Frequency and audio frequency range.

The human ear has a range of sound frequencies which it can hear. The lowest limit of audibility is about 30Hz and the upper limit audibility for most people is between 20 kHz and 30 kHz.

In daily life, a dog is more able than a human being to detect the presence of a thief tiptoeing at night. A thief tiptoeing at night produces sound of low frequency that can only be detected by dog ears not human being ears because the dog has wider ears than human being ears.

MUSICAL NOTES

Musical notes are regular vibrations of sound waves.

Properties of musical notes

Musical notes have three properties namely:
Pitch, loudness and quality

PITCH

A pitch is the sharpness or mildness of the soft musical note. A pitch is directly proportional to the frequency in that high frequency gives high pitch (sharper note).

A high pitched note has high frequency and short wavelength.

A pitch Produced by a string instrument depends on the nature of the string, length and tension acting of the string.

Shorter strings and high tension produce sound of higher frequency than long strings of low tension

LOUDNESS AND INTENSITY

The intensity or loudness of sound depends on the amplitude of the vibration in that a loud note has a large amplitude while a quiet note has a small amplitude.

A mother and child may both shout a note of the same frequency but the note from a mother is louder because the amplitude of the sound wave made by the mother is larger so a greater mass of air is set into vibration.

In general, the greater the mass of air which can be set into vibration the louder will be the sound. The prongs of a vibrating tuning fork, make a small mass of air vibrate. So the sound is soft. However if the end of the fork is placed on a table the sound is much louder because a large mass of air in contact with surface of the table is set into vibration.

A violin string directly produces soft sound because very little air is sot into vibration as the violin has small surface area.

When the same violin string is attached to a sounding box a much louder sound is produced because the large surface area of the sounding box results in large mass of air to vibrate as the box vibrates,

The sound from a telephone earpiece is heard distinctly only when the ear is placed close to the earpiece because the vibrating circular metal plate inside has a small area so only a small mass of air is set into vibration.

A loud sound may be heard from a small transistor set or a television set because the loud speaker has a vibrating cone with relatively large surface area so a large mass of air in contact is set into vibration.

INTENSITY OF SOUND
The intensity of sound is the rate of flow of energy per unit area perpendicular to the direction of sound. Intensity is proportional to;

i) The square of the amplitude,
ii) The square of the frequency
iii) The density of the medium

LOUDNESS OF SOUND
Loudness depends on;-

i) The varying pressure exerted on the eardrum by the sound,
ii) The sensitivity of the ear to the different frequencies,
iii) The sound intensity.

Loudness of sound is the sensation of a note in the mind of an individual.

Quality or tone (timbre) of a musical note
The same note on different instruments sounds different, the notes are said to differ in quality or timbre. The difference arises because no instruments except a tuning fork and single generator can emit a pure note i.e. of one frequency but they produced notes consisting of main or fundamental frequency mixed with overtones.

Overtones have frequencies that are exact multiples of the fundamental. The number and strength of overtones determines the quality of a note.

A violin has more and stronger higher overtones than a piano.

WAVES IN STRINGS AND PIPES

Factors on which the frequency of a wave in a vibrating string depend

- Length of the string.
- Tension in the string.
- Mass per unit length of the string.

A stationary wave can be set up in a string which has both ends fixed.

RESONANCE

Resonance occurs when a body or system is set into vibrations with its own natural frequency by a nearby body or system vibrating with the same frequency.

The vibrations combine to produce a larger vibration with a larger amplitude.

Thus, resonance occurs when a body is set into vibration with its own natural frequency by another nearby body which vibrates with the same frequency.

Exercise

1. A vibrator produces waves which travel a distance of 12m in 4s. If the frequency of the vibrator is 2Hz, what is the wave length of the wave?

   A. 1.5m B. 3m C. 6m D. 24

   $V = d/t = 12/4 = 3ms^{-1}$

   $V = f\lambda$

   $\lambda = v/f = 3/2 = 1.5m$

2. Which of the following statement is true?
   A. Light wave, radio waves and sound waves will all travel through a vacuum.
   B. Light waves and radio waves will travel through vacuum, sound waves will not.
   C. Light waves and sound waves will travel through vacuum, radio waves will not
   D. Sound waves and radio waves will travel through vacuum, light waves will not
3. Sound waves
   A. Do not pass through vacuum
   B. Travel through solids at lower speed than in air
   C. Do not travel through liquids
   D. Travel in at the highest speed in air
4. Which one of the following does not change when waves travel from deep to shallow water?
   A. Frequency
   B. Amplitude
   C. Velocity
   D. Wavelength
5. Which of the following statements is true about the wave travelling from one medium to another
   (i) Its frequency and wavelength change

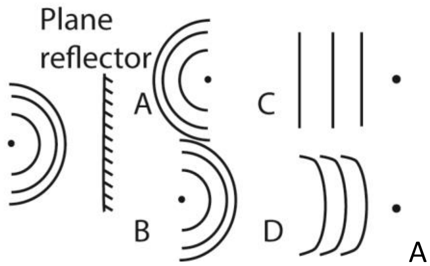
(ii) Its frequency and velocity change
(iii) Its velocity and wavelength change
(iv) Only its frequency remain unchanged

A. (i) only B. (i) and (ii)only C. (i), (ii), (iii) only D. (iii) and (iv) only

6. Which of the following statements is true about sound waves?
(i) They are longitudinal
(ii) They are transverse
(iii) They are produced by vibration
(iv) They can travel in empty space

A. (ii) and (iv) only B. (i) and (iii) only C. (i), (ii) and (iii) only D. (iv) only

7. The figure below shows a circular waves incident on plane reflector. Which of the following represent reflected wave?



8. Which of the following are not electromagnetic wave?
   A. X-ray
   B. Radar waves
   C. Microwaves
   D. Sound waves
9. Which of the following are transverse waves only?
   A. Radio waves, sound waves, ultraviolet
   B. Ultra violet, x-ray, water
   C. Infrared, sound and gamma
   D. Sound waves, ultraviolet, x-ray
10. A boy standing 150m from a vertical cliff claps his hand and hears an echo 0.85 seconds later. Find the speed of sound in air.
   A. $128ms^{-1}$ B. $176ms^{-1}$ C. $255ms^{-1}$ D. $353ms^{-1}$

   $v = \frac{D}{t} = \frac{150 \, x \, 2}{0.85} = 353ms^{-1}$
11. In sound waves the particles of the medium
   A. Are stationary
   B. Move along with the wave
   C. Vibrate in the same direction as the wave
   D. Vibrate at right angle to the direction of a wave

12. Plants inside a greenhouse emit radiations which cannot pass through green house because the radiations are
    A. Of short wavelength
    B. Of long wave length
    C. Used to warm up a greenhouse
    D. Absorbed by the glass
13. What would occur when a body is made to vibrate with its natural frequency due to external vibration?
    A. Echo
    B. Resonance
    C. Refraction
    D. reverberation
14. A man standing 85m from a tall walls fires a gun and hears and echo from the wall after 0.5s. calculate the speed of sound in the air
    A. 340ms^{-1} B. 170ms^{-1} C. 85ms^{-1} D. 43ms^{-1}
    V = $\frac{D}{t} = \frac{85 \, x \, 2}{0.5}$
15. 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.
    A. 0.875Hz B. 8.750Hz C. 87.500Hz D. 8750Hz
    V = $\frac{D}{t} = \frac{1.4}{0.08} = 17.5 ms^{-1}$
    f = $\frac{v}{\lambda} = \frac{17.5}{0.2} = 87.5 Hz$
16. A man sees the flash from a gun fired 1020m away and then later hears a bang. How long does the bang take to reach him? (Take the speed of sound as 340ms^{-1})
    A $\frac{1020s}{340 \, x \, 10}$ B. $\frac{340 \, s}{1020}$ C. $\frac{1020s}{340}$ D. (340 x 1020)s
    Time = $\frac{Distance}{speed}$
17. The velocity of sound in air at constant pressure
    A. increases with loudness
    B. Decreases with loudness
    C. Increases with temperature
    D. Decreases with temperature

18. Points on stationary line which are permanently at rest are called
    A. Node
    B. Crest
    C. Trough
    D. antinode

19. sound is produced by a source vibrator at a frequency of 50Hz. Given that the speed is $330ms^{-1}$ in air, its wavelength is

A. 0.15m B. 6.6m C. 380m D. 16500m

$\lambda = \frac{v}{f} = \frac{330}{50} = 6.6m$

20. In force vibration, resonance occurs

A. Frequency is equal to the natural velocity

B. Velocity is equal to natural velocity

C. Frequency is equal to natural frequency

D. Frequency exceeds natural frequency

21. A man standing in front of a tall wall makes a loud sound and hears the echo after 1 ½ s. how far is he from the wall if the velocity of sound in air is $330ms^{-1}$.

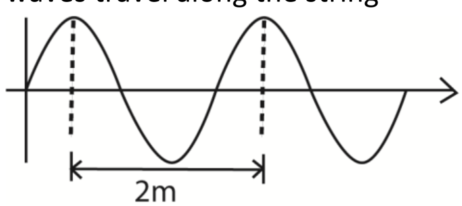
A. 110m B. 247.5m C. 440m D 990m

Distance = (velocity x time)/2 = (330 x 1 ½)/2

22. The number of vibrations a wave makes per second is the

A. frequency B. wavelength C. period D. amplitude

23. The figure shows a wave produced in a string. If the frequency is 2Hz, at what speed do waves travel along the string



A. $0.5ms^{-1}$ B. $1.0ms^{-1}$ C. $2.0ms^{-1}$ D. $4.0ms^{-1}$

Velocity v = fλ = 2 x2 = 4.0ms-1

24. A vibrator produces a sound that travels 900m in 3 seconds. If the wavelength of the wave is 10m, find the frequency of vibrator.

A. 30Hz B. 270Hz C. 300Hz D. 3000Hz

Velocity = $\frac{distance}{time} = \frac{900}{3} = 300ms^{-1}$

Frequency, f = $\frac{velocity}{wavelength} = \frac{300}{10} = 30Hz$

25. A longitudinal wave is one in which the

A. Direction of propagation is parallel to that of vibration producing it

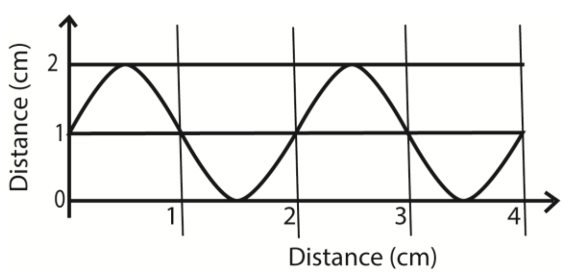
B. Particles of a medium through which it travels move in opposite direction to the direction of propagation

C. Direction of propagation is perpendicular to that of vibration producing it.

D. Particles of the medium through which it travels move together with it.

26. The basic difference between transverse and longitudinal waves is in
   A. Amplitude
   B. Wavelength
   C. Direction of vibration
   D. Medium through which the waves travel
27. The sound waves produced by a vibrating tuning fork is longitudinal because the air vibrates
   A. The same direction as that in which the prongs vibrate
   B. A direction opposite to that in which the wave is travelling
   C. The same direction as that in which the wave is travelling
   D. The opposite direction to that in which the prongs vibrate
   A
28. An echo sounder in a boat emits a pulse of sound which returns 0.2s later after reflection from the sea bed. If sound travels at $1500ms^{-1}$ is sea water, how deep is water?
   A. 7500m B. 600m C. 300m D. 150m

   Depth = $\frac{Speed\ x\ time}{2} = \frac{1500\ x\ 0.2}{2}$ = 150m
29. All electromagnetic waves
   A. Highly penetrate matter
   B. Produce ionization in gases
   C. Cause heating effect when absorbed by matter
   D. Do not require any material medium for transmission.
30.



   The above figure shows a transverse wave. What is the wave length?
   A. 4cm B. 3cm C. 2cm D. 1cm
31. Which of the following affects the frequency of vibrating string
   A. Tension and length
   B. Length and mass of the string
   C. Mass per length of string and temperature
   D. Tension and velocity of sound

32. Sound waves travel a distance of 48cm in 8s. If the separation between successive compressions is 3.0cm, find the frequency of the waves.

A. 0.5Hz B. 2.0Hz C. 18.0Hz D. 128.0Hz

Velocity = $\frac{Distance}{time} = \frac{48}{8} = 6.0cms^{-1}$

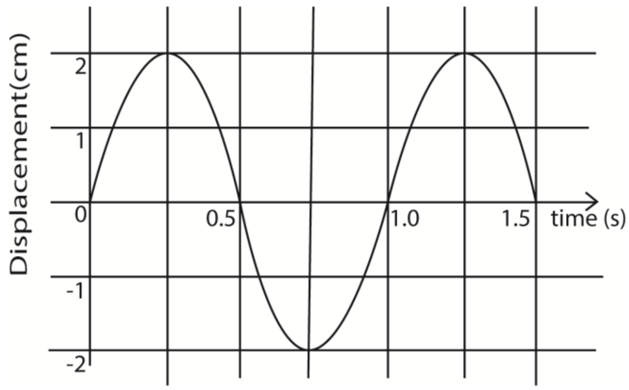
Wavelength = 3.0cm

$\lambda = \frac{velocity}{wavelength} = \frac{6}{3} = 2Hz$

33.

Section B

34.



The diagram above shows a section of a transverse wave of wavelength 4.0cm

Find its

(i) Frequency

Frequency = $\frac{1}{T} = \frac{1}{1} = 1Hz$

(ii) Amplitude

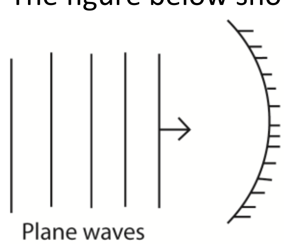
2cm

(iii) Velocity

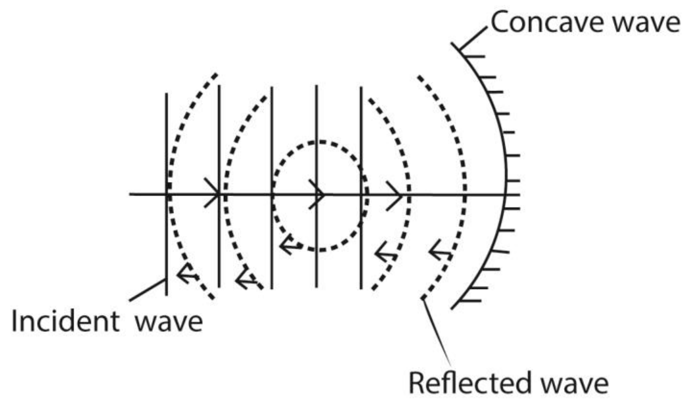
Velocity = fλ = 1 x $\frac{4}{100} = 0.04ms^{-1}$

35. (a) list three differences between sound and radio waves

(b) The figure below shows waves propagating towards a concave reflector.



(i) Draw a diagram to show how the wave will be reflected.



(ii) State what happen to the wave if the concave surface was removed and the depth of water reduced.

- Waves are refracted
- Wavelength is reduced
- Velocity decrease
- Amplitude decrease.

(iii) If the velocity of the wave is 320ms^{-1} and the distance between two successive crests is 10cm, find the period of the waves

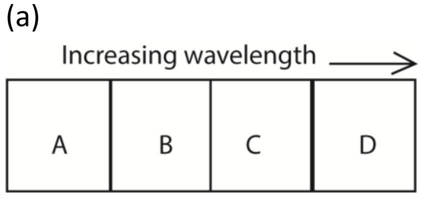
Wavelength = 10cm = 0.1m

Frequency, f = $\frac{v}{\lambda} = \frac{320}{0.1} = 3200ms^{-1}$

(iv) Describe a simple echo method of determining the speed of sound in air.

- ✓ Clap at such a rate that each clap coincides with the echo from a tall wall a distance D from the experimenter.
- ✓ Using a stop clock, measure the time, t, for a given number of claps, n.
- ✓ Average time for one clap = $\frac{t}{n}$ is the time taken for the wave to travel from experimenter to the wall and back
- ✓ The velocity of sound in air = $\frac{2D}{t/n}$ = $\frac{2nD}{t}$

36. (a)



The figure above shows part of the electromagnetic spectrum consisting of gamma rays, radio waves, infrared and visible light. Identify the bands to which these radiations belong

A: …………………………… gamma rays

B: ……………………….. visible light

C: …………………………. Infrared
D: ………………………… Radio waves

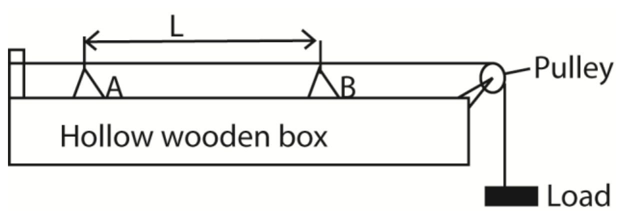
(c) State the application of radiations
   (i) B and A …………………destroy cancerous cell
   (ii) B and C …………………. Used in photocells to provide current

37. (a) What is an echo?
   Echo is reflected sound

(b) (i) Describe an experiment to measure the speed of sound in air.
- Measure a distance X in meters from a point of experiment to a tall wall more than 17.5m
- Make a sharp clapping sound by bringing two blocks of wood together at such an interval that each clap coincides with its echo.
- Using a stop clock determine time, t, for 20 claps
- Velocity of light v = $\frac{2x}{\frac{t}{20}} = \frac{40x}{t}$ ms-1
-

(iii) State the probable source of error in this experiment.
- From timing
- Variation of speed of sound with change in temperature, humidity and wind

(c) Describe an experiment to determine how the frequency of a vibrating string depends on the length of the string.
   A Sonometer is used

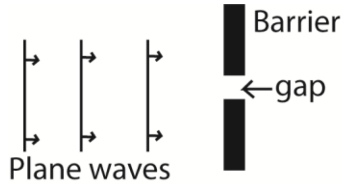


- The wooden bridges A and B vary the effective length of the wire, L.
- Constant tension in the wire is maintained by the fixed mass/load
- A paper rider is place on the wire in the middle of AB and a sounding fork placed near it.
- The position of the bridge B is varied until sound is heard.
- The distance between the bridges L and the frequency, **f**, of the tuning fork is noted.
- The procedure is repeated for various tuning forks and values of L, **f** and $\frac{1}{L}$ are tabulated
- A plot of **f** against $\frac{1}{L}$ gives a straight line showing that the frequency of vibration of the wire is inversely proportional to length.

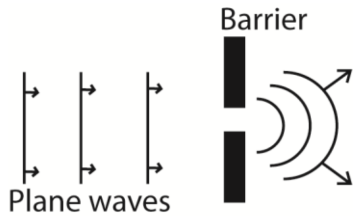
38. (a)What is meant by standing wave?

Standing waves is one which is formed as a result of the two waves moving in opposite direction with the same speed, amplitude and superpose on each other.

(b) The figure below shows plane wave approaching a gap in barrier



(i) Show on the diagram, the appearance of the wave after the barrier.



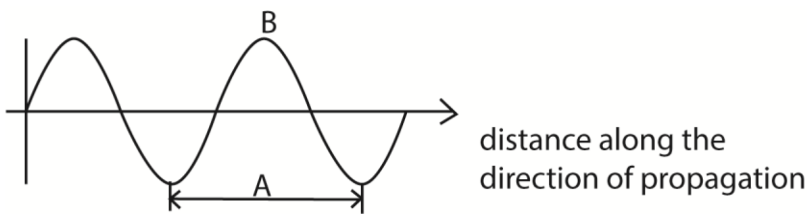
(ii) What is the effect of reducing the size of the gap?

The waves become more circular.

39. (a) What is meant by a transverse wave?

Is one in which particles in a medium vibrate perpendicular to the direction of travel of the wave.

(b) the diagram below represents a wave travelling in water



(i) Name part labelled B

crest

(ii) If distance represented by A is 20cm and the speed of the wave is $8.0ms^{-1}$. What is the speed of a wave?

f = $\frac{v}{\lambda} = \frac{8}{0.2} = 40Hz$

40. (a) state three differences between sound and light waves

Sound wave	Light waves
- Need material medium for propagation - Propagate at relatively low speed - Have longer wavelength - Particles vibrate in direction is same direction as that of a wave	- Can propagate in vacuum - Propagate as very high speed - Shorter wavelength - Particles vibrate perpendicular to the direction of travel of the wave.

(b) (i) explain how stationary wave is formed

When two waves of the same frequency, equal wavelength and equal amplitude are propagating in the same medium in opposite direction they meet and superpose; the resultant displacement of particles in medium at any point is the sum of displacements due to each of the waves at that point.

(ii) State three main characteristics of a wave

- Amplitude of a wave varies from place to place along the profile.
- Wave energy is not transmitted along the profile.
- At certain points called nodes, the particles are permanently at rest
- Has nodes and antinodes.

(c) (i) Define the terms frequency and wavelength as applied to sound.

(ii) Describe an experiment to demonstrate resonance in sound.

(d) The velocity and frequency of sound in air at a certain time were 320ms^{-1} and 200Hz respectively. At later time, the air temperature changed and velocity of sound in air was found to be 340ms^{-1}. Determine the change in wavelength of sound.

41. (a) By use of a diagram, explain what is you understand by the term amplitude and wavelength as applied in wave motion.

Amplitude is the maximum displacement of a particle from its equilibrium position while wavelength is the distance covered by a wave after one complete oscillation or it is the distance between two successive crests or troughs.

42. (a) What is meant by sound?

Sound is a form of energy that travels in form of longitudinal waves from one point to another than enable us to hear.

(b) Describe an experiment to show that sound waves require a material medium for transmission.

Electric bell hung from rubber bands inside a bell jar is used.

- A loud sound is heard when the bell is switched on
- When air is removed, the sound disappear

(c) Explain the following

(i) A dog is more able than human beings to detect the presence of a thief tiptoeing at night

A tip toeing thief produced low frequency (ultrasonic) sound which cannot be detected by human but can be detected by dog’s ears

(ii) An approaching train can easily be detected by human ears placed close to the rail.

Because sound travels faster in solids than in air.

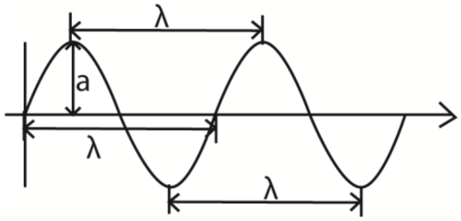
(d) A sound of frequency 250Hz is produced 120m away from a high wall.

Calculate

(i) Wavelength

(ii) Time it takes sound wave to travel to and from the wall (speed of sound in air = $320ms^{-1}$)

43.



(b) Derive an equation relating velocity, V, frequency, F, and wavelength, W, of a wave.

Wave speed, V = $\frac{wavelength}{periodic\ time} = \frac{W}{T}$

But T = $\frac{1}{F}$

Thus, V = $\frac{W}{\frac{1}{F}}$ = FW

(c) A radio wave is transmitted at a frequency of 150MHz. calculate its wavelength, velocity of electromagnetic wave is $3 \times 10^8 ms^{-1}$.

V = fλ

λ = $\frac{v}{f} = \frac{3\ x\ 10^8}{150\ x\ 10^6}$ =2m

(d) (i) List four properties of electromagnetic waves.

They undergo

- Reflection
- Refraction
- Interference
- Diffraction
- Travel in straight

(ii) A long open tube is partially immersed in water in water and a tuning fork of frequency 425Hz is sounded, and held above it. If the tube is gradually raised, find the length of the air column when resonance first occur. (speed of sound in air = $240ms^{-1}$)

$L_0 = \frac{\lambda_0}{4}$; but v = λf or λ = $\frac{v}{f}$

$LO = \frac{V}{4f} = \frac{340}{4 \, x \, 425} = 0.2m$

44. (a) (i) How can the speed of waves in ripple tank be reduced

By placing (or dipping) thin glass in the tank making water shallower.

(ii) What is the effect of decreasing the speed of waves in the ripple tank above on frequency?

No change in frequency since frequency depends on the vibrator not depth.

(b) What is the effect of the size of a gap on diffraction of a wave?

When the gap is small the diffracted wave are more circular than when the gap is big

(c) (i) Give two reasons why sound is louder at night than during the day?

- At night air has lower temperature and thus denser increasing speed of sound
- also the air above the earth is less dense causing refraction of sound towards the earth

(ii) An echo sounding equipment on a ship receives sound pulse reflected from sea bed 0.03s after they have sent out from it. Is the speed of sound in water is 1450ms^{-1}. Calculate the depth of water under the ship.

Depth = velocity x time/2 = $\frac{1450 \, x \, 0.03}{2}$ = 21.75m

(d) Give the differences between water and sound waves

Water waves	Sound waves
Particles vibrate perpendicular to the direction of wave/transverse	Particles vibrate in the same direction as that of a wave/longitudinal
Slow	Fast
Polarized	Unpolarized

45. (a) What is reverberation?

Reverberation is when echo joins up with original sound which seems a prolonged sound and occurs when the reflecting surface is less than 15m from the source.

(c) State two factors which affect frequency of a vibrating string

Length of string

Tension of string

(d) A sound wave of frequency 440Hz has a velocity 330Hz. Calculate its wavelength.

$\lambda = \frac{v}{f} = \frac{330}{44o} = 0.75m$

46. (a) (i) Define an echo?

An echo is reflected sound

(ii) State one application of echoes

- Measurement of velocity of sound in air
- In medicine field to give an image of internal structure of the body
- In speaking tubes to send messages from one point to another
- In Radar aerials to send out radio waves into space

(iii) State the conditions required for a standing wave to be formed.

The two waves should have the same frequency and nearly equal amplitude moving in opposite direction

(a) List the factors on which the frequency of vibrating string depends

- Tension in string
- Length of string

(b) A child stands between two cliffs and makes loud sound. If he hears the first echo after 1.5s and the second echo after 2.0s. find the distance between the two cliffs (speed of sound in air =320ms^{-1})

Distance = (velocity x time)/2 = (320 x 1.5 + 320 x 2)/2 =560m

47. (a) What is an echo?

Echo is reflected sound.

(b) An echo sounder on a boat send down a pulse through the water and receives its echo 0.9s later. Calculate the water depth. (speed of sound in water = 1450ms^{-1})

Depth = $\frac{1}{2}$vt = $\frac{1}{2}\ x\ 1450\ x\ 0.9$ = 652.5m

(c) State two factors which determine the frequency of a note produced when a guitar string vibrates. (1mark)

- Tension in string
- Length of the string

48. (a) State any two difference between sound and light waves.

Sound waves	Light waves
Are longitudinal	Are transverse
Slow	Fast
Do not travel n vacuum	Travel in vacuum

(b)(i) Describe a simple experiment to determine the velocity of sound in air.

- A long glass tube is filled with water.

- A tuning fork of frequency f is sounded and held close to the open end of the tube.
- Water is the tube is slowly drained until a loud sound is heard.
- Length, L, of the air column is measured
- The velocity of sound v = 4Lf.

(ii) Explain why the speed of sound is higher in solids than air.

The molecules of solids are closely packed, hence vibrations are easily transmitted from one atom to another, than in air.

(c) Two people X and Y, stand in a line at a distances of 330m, and 660m respectively from high wall. Find the time interval taken for X to hear the first and second sounds when y makes a loud sound. (speed of sound in air = $330ms^{-1}$)

Time taken to hear first sound = $\frac{distance}{velocity} = \frac{330}{300} = 1s$

The second sound is an echo is heard when travel 660m or 330 to and fro

Time = $\frac{distance}{velocity} = \frac{660}{300} = 2s$

(d) (i) What is meant by stationary waves?

Stationary wave is formed when two equal progressive waves meet when travelling in opposite direction.

(ii) Give any two conditions for it to be produced.

- Waves must be travelling in opposite direction
- Waves must have equal frequency
- Waves must have equal frequency

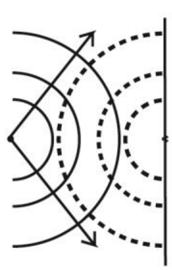
(iii) Name one instrument which produces stationary waves.

Guitar and flute

49. (a) (i) What is meant by interference of waves?

Occurs when two coherent waves are superposed on one another giving regions of maximum and/or minimum amplitudes.

(ii) Using a labelled diagram, show how circular water waves are reflected from a straight barrier.



50. (a) State the changes detected when listening to sound note if the

(i) Amplitude is raised

A louder note is heard

(ii) Frequency is increased

A higher note is heard

(b) Give three differences between light waves and sound waves (03marks)

Light wave	Sound wave
Transverse wave	Longitudinal wave
Can travel through vacuum	Cannot travel through vacuum
Very fast	slow

(c) The distance between two successive antinodes on standing wave is 3.0cm. if the distance between the source of wave and reflector is 24.ocm, find the

(i) Number of loops

Number of loops = $\frac{24}{3} = 8lops$

(ii) Wavelength

Wavelength (λ) = distance corresponding to 2 loops = 2 x 3 = 6 cm

(d) Explain how sound waves travel though air

When a source vibrates causes, it causes nearby air molecules to vibrate to and fro about their mean position. The vibration of the nearby air molecules also causes the next air molecules to vibrate.

This causes regions of compression and refraction which transfer sound from one point to another.

Thank you so much