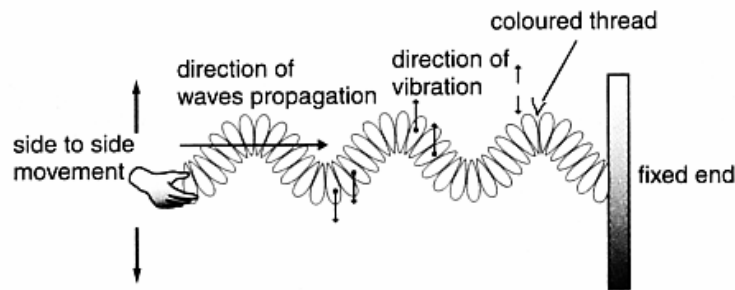


## 6.1 WAVES

What is waves?	Process of transferring energy from one location to another which is produced by an oscillating or vibrating motion.
Examples of waves	<p><u>Light waves</u> are produced as a result of vibrations of electrons in an atom</p> <p><u>Sound waves</u> are produced by vibrating mechanical bodies such as a guitar strings or a tuning fork.</p> <p><u>Water waves</u> are produced by a disturbance on a still water surface.</p>
How do waves transfer energy?	<p>When energy is transferred by a wave from a vibrating source to a distant receiver, there is no transfer of matter between the two points.</p> <div data-bbox="203 877 618 1108" data-label="Image"> </div> <p>When the string is shaken up and down, a <u>disturbance</u> moves along the length of the string. It is the disturbance that moves along the length of the string, not parts of the string itself.</p> <p>Drop a stone in a quite pond. It will produce a wave that moves out from the center in expanding circles. It is the disturbance that moves, not the water. After the disturbance passes, the water is where it was before the wave was produced .</p> <div data-bbox="609 1409 1490 1606" data-label="Image"> </div> <p>The string and water is the <u>medium</u> through which wave energy travels.</p>
What is Transverse Wave?	A <u>transverse wave</u> is a wave in which the <u>vibration of particles</u> in the medium is at <u>right angle</u> to the <u>direction of propagation of the wave</u> .

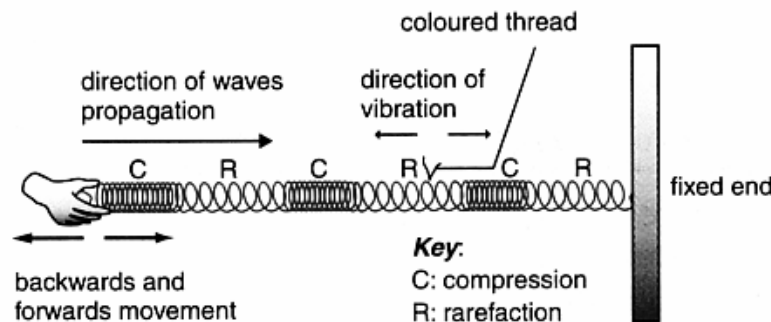


The spring is moved sideways. The motion of the particles medium (spring) is at right angles to the direction in which the wave travels.

Examples: water waves, light waves

**What is Longitudinal Waves?**

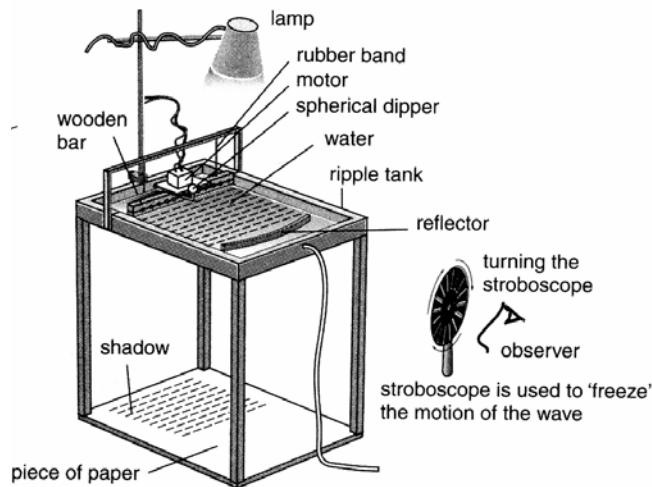
A longitudinal wave is a wave which the vibration of particles in the medium is along (parallel to) the direction of propagation of the wave.



The slinky spring moves backwards and forwards to produce a transverse wave. The particles of the medium (spring) move along the direction of the wave. The wave that travels along the spring consists of a series of compression and rarefaction.

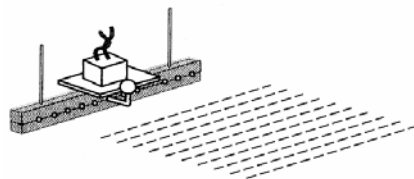
Examples: sounds waves.

## What is a ripple tank?

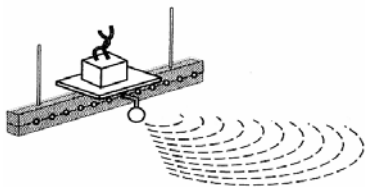


The phenomenon of water waves can be investigated using a ripple tank. The water waves are produced by a vibrating bar on the water surface.

The tank is leveled so that the depth of water in the tank is uniform to ensure water waves propagate with uniform speed.

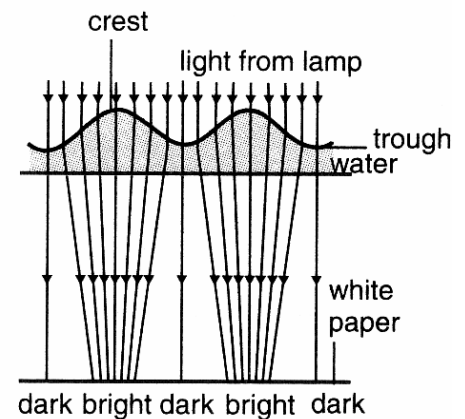


(a) plane waves



(b) circular waves

white piec



The water acts as a lens to produce a pattern of bright and dark regions on a piece of white paper placed under the tank when light passes through it.

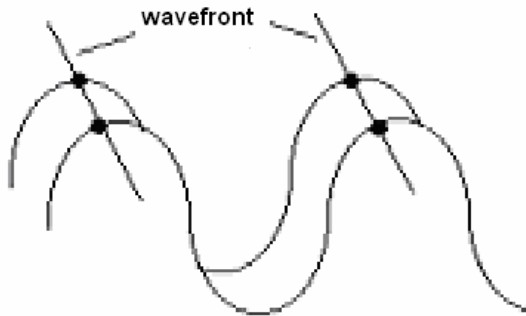
Water waves have crests and troughs.

A crest is the highest position of the wave acts as a convex lens, whereas a trough is the lowest position acts as a concave lens.

Light rays from the lamp on top will focus onto the white screen below. The bright lines correspond to the crests, and the dark lines correspond to the troughs.

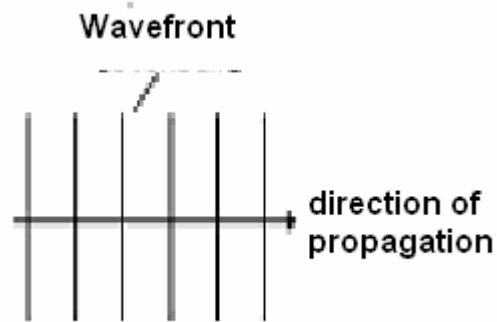
What is meant by a wavefront?

Lines joining all the points of the same phase are called wavefronts.

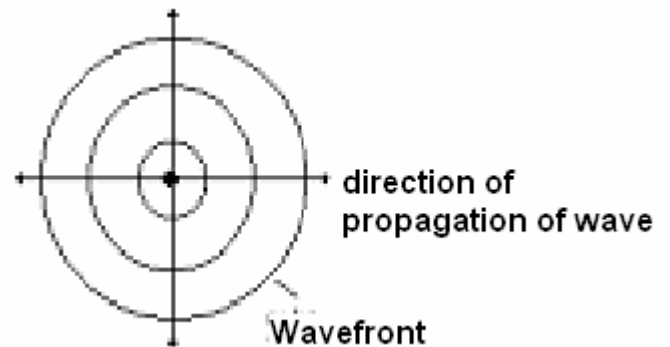


*The wavefronts of a transverse wave and longitudinal wave are perpendicular to the direction of propagation of the waves.*

## 1. Plane wavefronts



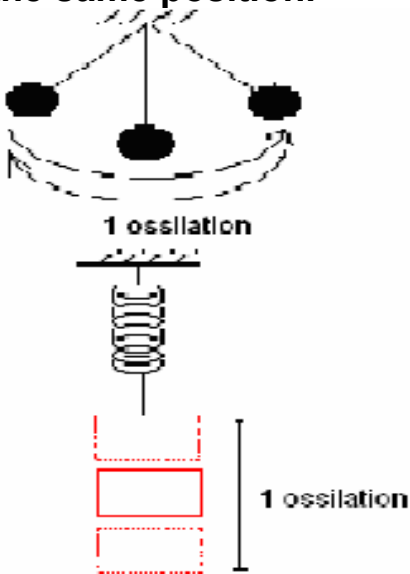
## 2. Circular wavefronts



## Describing Waves

### Vibration/Oscillation

The movement from one extreme position to the other and back to the same position.



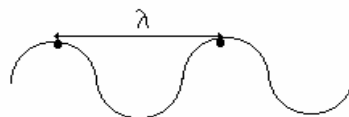
### Amplitude (a)

The maximum displacement from its equilibrium position.

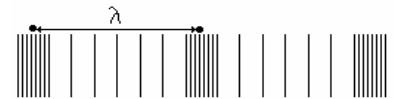
Amplitude relates to loudness in sound and brightness in light. SI unit: meter, m

### Wavelength ( $\lambda$ )

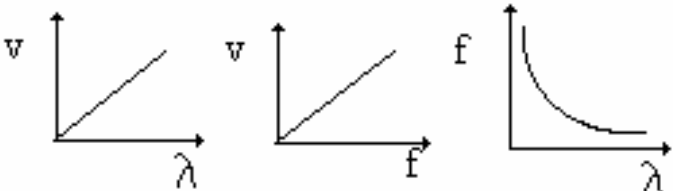
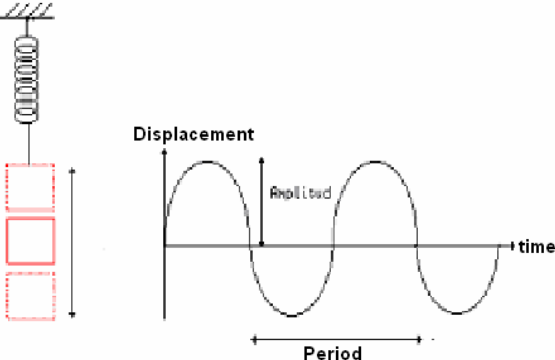
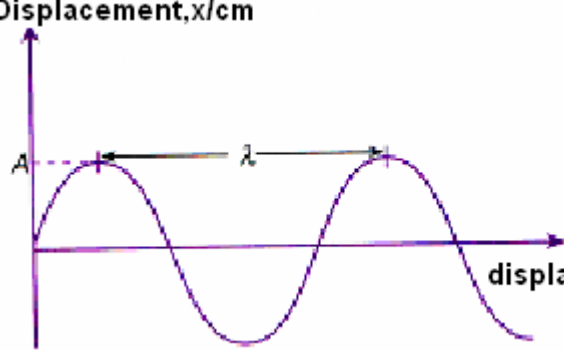
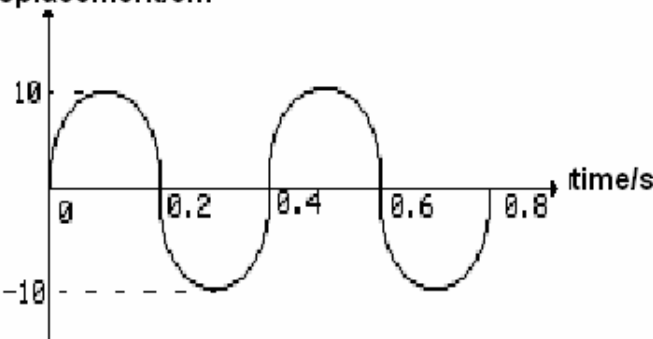
The distance between two adjacent points of the same phase on a wave.



The distance between two successive crests or two successive troughs

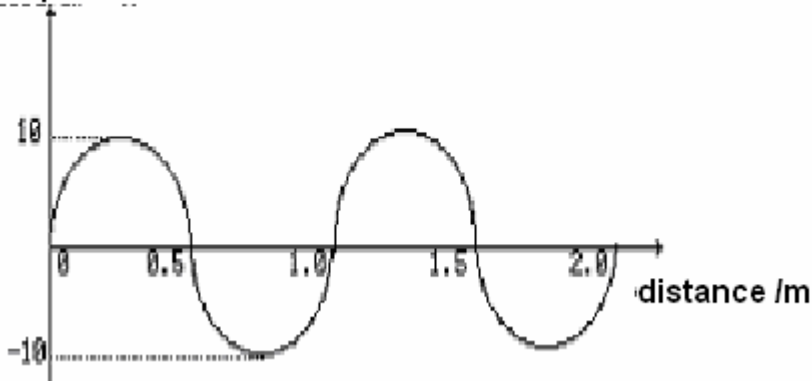


The distance between two successive compressions or two successive rarefactions in a sound wave.

<p><b><u>Period (T)</u></b> The time taken for an oscillation to complete one cycle. SI unit is second (s).</p>	<p><b><u>Frequency, f</u></b> The number of waves produced in one second. SI unit is Hertz (Hz)</p>	<p><b>Relation between frequency and period:</b></p> $f = \frac{1}{T}$
<p><b><u>Wave Speed (v)</u></b> The speed of a wave is <u>the measurement of how fast a crest is moving from a fixed point.</u> SI unit is <math>\text{ms}^{-1}</math>.</p>	<p>The relationship between speed, wavelength and frequency</p> <p>Velocity = wavelength x frequency  <math>v = f\lambda</math></p> 	
<p><b>Displacement-time graph</b></p> 	<p><b>Displacement-distance graph</b></p>  <p>Velocity , <math>v = f\lambda</math></p>	
<p><b><u>Example 1</u></b></p> <p>Displacement/cm</p> 	<p>From the graph, calculate:</p> <p>(a) Amplitude</p> <p>(b) Period,</p> <p>(c) Frequency</p>	

### Example 2

displacement/cm

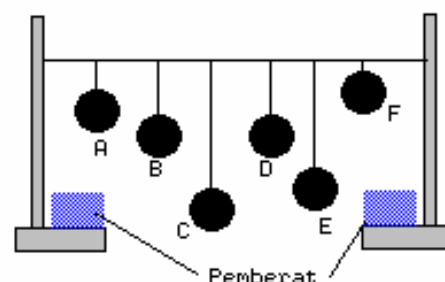


A graph shows a wave produced by a slinky spring vibrating at frequency 8 Hz. What is:

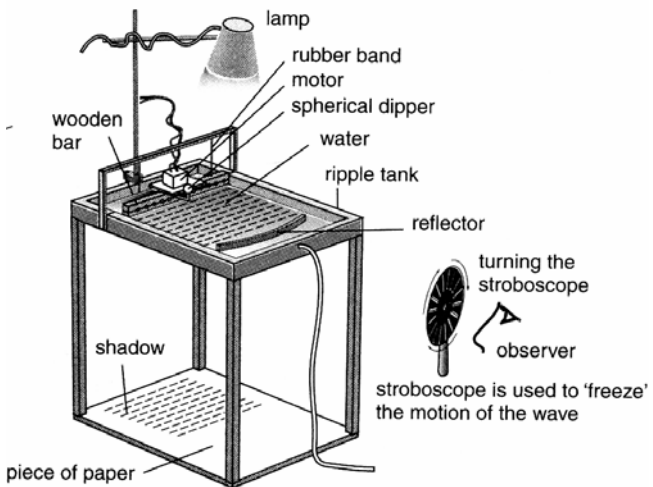
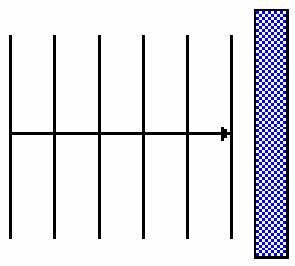
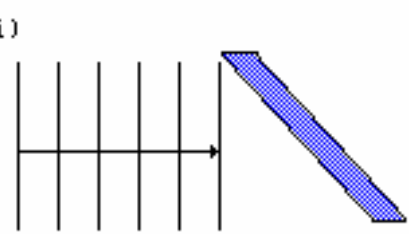
- (a) amplitude
- (b) wavelength
- (c) wave speed

What is damping?	<b><u>Damping</u> is the <u>decrease</u> in the <u>amplitude</u> of an oscillating system when its energy is drained out as <u>heat energy</u>. The amplitude of an oscillating system will gradually decrease and become zero when the oscillation stops.</b>
What causes damping?	<ol style="list-style-type: none"> <li><b><u>External damping</u> of the system is the <u>loss of energy</u> to overcome <u>frictional forces</u> or air resistance.</b></li> <li><b><u>Internal damping</u> is the <u>loss of energy</u> due to the <u>extension</u> and <u>compression</u> of the molecules in the system.</b></li> </ol>
A graph to show damping	<p>Displacement</p> <p>time</p>
External Force	➤ To enable an oscillating system to go on continuously, an <b><u>external force</u></b> must be applied to the system.
Force oscillation	➤ The external force supplies energy to the system. Such a motion is called a <b><u>forced oscillation</u></b>
Natural frequency	➤ The frequency of a system which oscillates freely without the action of an external force is called the <b><u>natural frequency</u></b> .

<b>Resonance</b>	<p>➤ <u>Resonance</u> occurs when a system is made to <u>oscillate</u> at a <u>frequency equivalent</u> to its <u>natural frequency</u> <u>by an external force</u>. The resonating system oscillates at its <u>maximum amplitude</u>.</p>
<b>Experiment in Barton's pendulum</b>          <b>How does resonance occur in the two pendulum of equal length?</b>	<p>➤ The frequency of a simple pendulum depends on the length of the pendulum.</p> <p>➤ In Barton's pendulum experiment, there are many pendulums tied to the rope. Two of the pendulum are of the same length</p> <p>➤ When pendulum B oscillates, all the other pendulums are forced to oscillate.</p> <p>➤ But pendulum D oscillates with the largest amplitude, ie, pendulum D resonates</p> <p>➤ Pendulum B and pendulum D are of the same length.</p> <p>➤ Frequency B = Frequency D</p> <p>➤ Therefore, pendulum B causes pendulum D to oscillate at its natural frequency.</p>
<b>Good effects of resonance</b>	<p>1. The tuner in a radio or television enables us to select the programmes we are interested. The circuit in the tuner is adjusted until resonance is achieved, at the frequency transmitted by a particular station selected. Hence a strong electrical signal is produced.</p> <p>2. The loudness of music produced by musical instruments such as the trumpet and flute is the result of resonance in the air.</p>
<b>Bad effects of resonance</b>	<p>3. A bridge can collapse when the amplitude of its vibration increases as a result of resonance.</p>

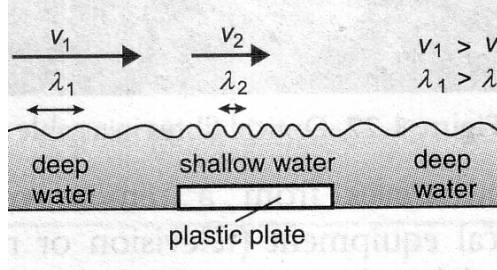
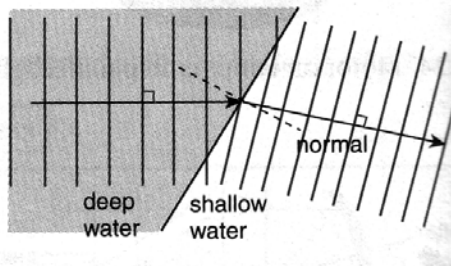
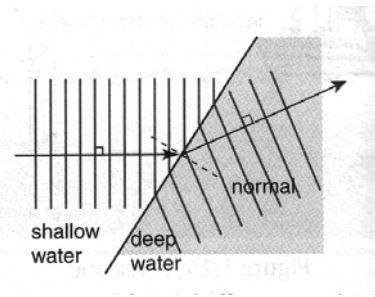


## 6.2 REFLECTION OF WAVES

<b>Reflection of wave</b>	<ul style="list-style-type: none"> <li>➤ Occurs when a wave strikes an obstacle.</li> <li>➤ The wave undergoes a <u>change in direction</u> of propagation when it is reflected.</li> <li>➤ The value of frequency (<math>f</math>), wavelength (<math>\lambda</math>) and speed (<math>v</math>) remain the same after reflection.</li> </ul>
<p><b><u>Incident wave</u></b> : the wave before it strikes the obstacle</p> <p><b><u>Reflected wave</u></b>: the wave which has undergone a change in direction of propagation after reflection.</p> <p><math>i</math> = angle of incident – the angle between the direction of propagation of incident wave and the normal</p> <p><math>r</math> = angle of reflection – the angle between the direction of propagation of reflected wave and the normal.</p>	<p><b>Law of Reflection:</b></p> <p>The angle of incidence, <math>i</math> is <u>equal</u> to the angle of reflection, <math>r</math>.</p>
<p><b><u>Reflection of plane water waves in a ripple tank</u></b></p> <ol style="list-style-type: none"> <li>1. Set up a ripple tank.</li> <li>2. Switch on the motor to set the vibrating. Increase the frequency of the waves by increasing the voltage power supply to the motor.</li> <li>3. Observe the reflected wave by using a stroboscope.</li> </ol>	 <p>Labels in diagram: lamp, rubber band, motor, spherical dipper, water, ripple tank, reflector, shadow, piece of paper, turning the stroboscope, observer, stroboscope is used to 'freeze' the motion of the wave.</p>
<p><b>Draw a diagram to show reflection of waves.</b></p>	<div style="display: flex; justify-content: space-around;"> <div data-bbox="414 1659 971 1946"> <p>(i)</p>  </div> <div data-bbox="976 1659 1533 1946"> <p>(ii)</p>  </div> </div>

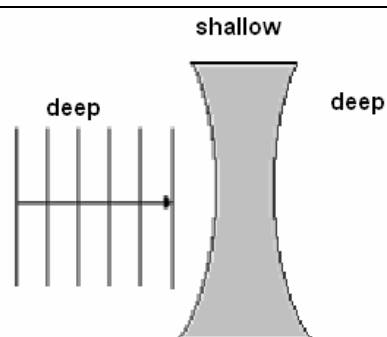
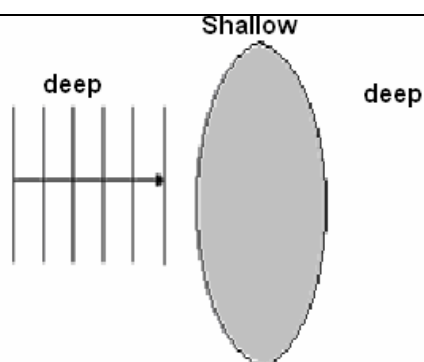
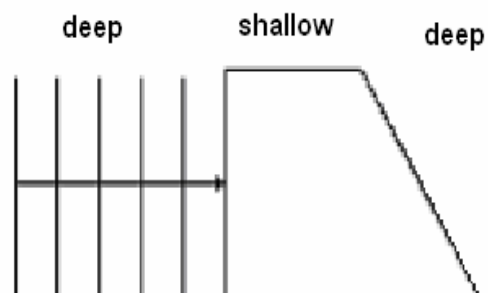
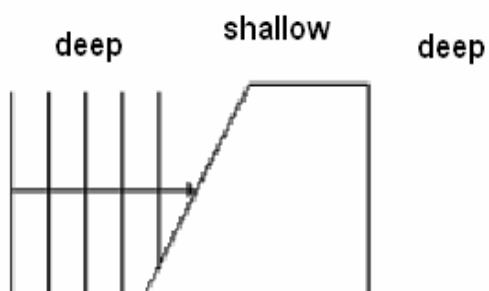
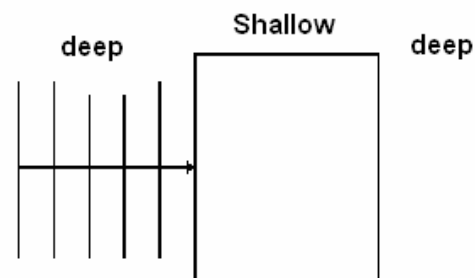
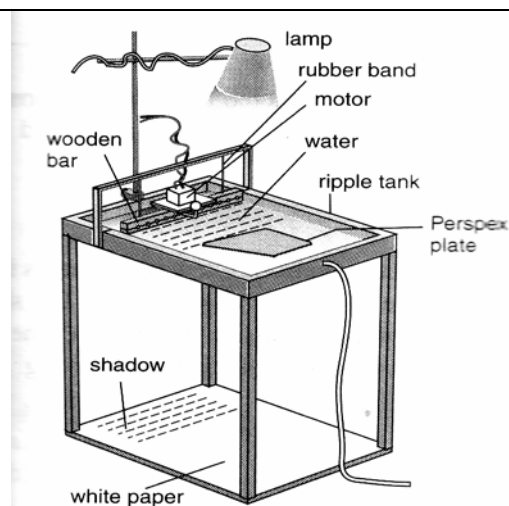


## 6.3 REFRACTION OF WAVES

What is Refraction of waves?	<b>Refraction of waves</b> is a <u>change</u> in its <u>direction</u> as the waves pass from one medium to another. It occurs when there is a <u>difference</u> in the <u>speed</u> of the wave at the boundary of two mediums.																		
What happens to frequency, speed, wavelength & direction?	<b>After refraction, the wave has the <u>same frequency</u>, but a <u>different speed, wavelength and direction of propagation</u>.</b>		<b>The relationship between <math>v</math> and <math>\lambda</math> of a water wave in deep and shallow water:</b> $v = f\lambda$ $f$ is constant $\therefore v \propto \lambda$ $v$ is directly proportional to $\lambda$ $f = \frac{v}{\lambda} = \text{constant} \therefore \frac{v_1}{f_1} = \frac{v_2}{f_2}$																
																			
Use the words, 'increase', 'decrease' or 'unchanged'	<table><tr><td>Characteristics</td><td>Water waves passes from deep water to shallow water</td></tr><tr><td>Speed</td><td>Decrease</td></tr><tr><td>Wavelength</td><td>Decrease</td></tr><tr><td>Frequency</td><td>unchanged</td></tr></table>	Characteristics	Water waves passes from deep water to shallow water	Speed	Decrease	Wavelength	Decrease	Frequency	unchanged	<table><tr><td>Characteristics</td><td>Water waves passes from shallow water to deep water</td></tr><tr><td>Speed</td><td>increase</td></tr><tr><td>Wavelength</td><td>Increase</td></tr><tr><td>Frequency</td><td>unchanged</td></tr></table>	Characteristics	Water waves passes from shallow water to deep water	Speed	increase	Wavelength	Increase	Frequency	unchanged	
	Characteristics	Water waves passes from deep water to shallow water																	
Speed	Decrease																		
Wavelength	Decrease																		
Frequency	unchanged																		
Characteristics	Water waves passes from shallow water to deep water																		
Speed	increase																		
Wavelength	Increase																		
Frequency	unchanged																		
How does the direction of waves change when:	<b>Water passing from the deep region to the shallow region, the water wave is refracted toward the normal.</b> 	<b>Water passing from the shallow region to the deep region, the water wave is refracted away from the normal.</b> 																	

Use a ripple tank

Draw a ray diagram to show refraction of waves.



### Example 1

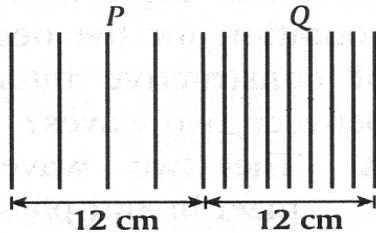
A plane wave has a wavelength of 2 cm and a velocity of  $8 \text{ cm s}^{-1}$  as it moves over the surface of shallow water. When the plane wave moves into an area of greater depth, its velocity becomes  $12 \text{ cm s}^{-1}$ . What is

(a) the wavelength

(b) the frequency of the wave in the area of greater depth?

### **Example 2**

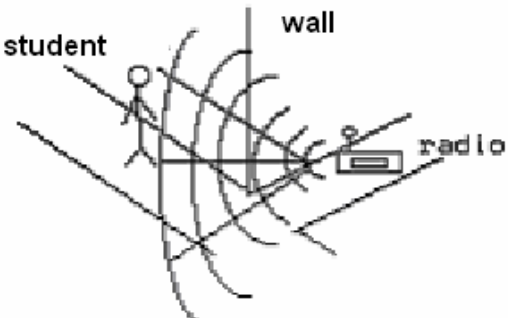
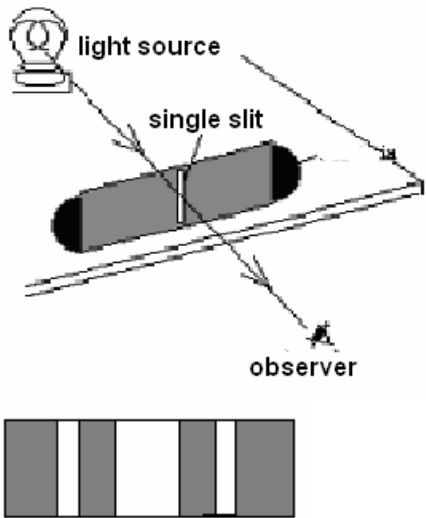
The diagram shows a plane water wave moving from one area P to another area Q of different depth.

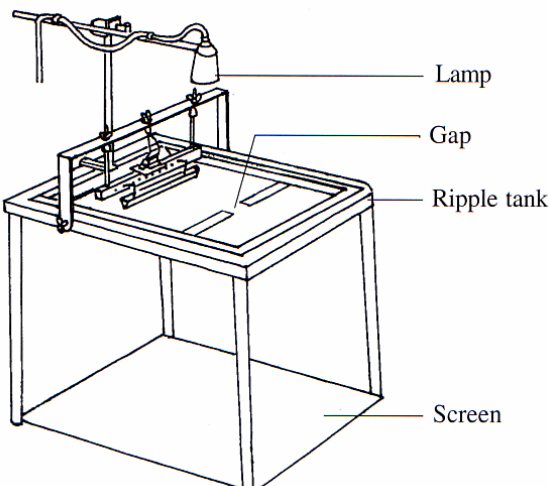


If the speed of water wave in P is  $18 \text{ cm s}^{-1}$ , what is the speed of water wave in Q?

## **6.4 DIFFRACTION OF WAVES**

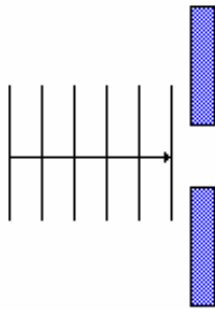
What is diffraction of waves?	<b><u>Diffraction</u> of waves is a phenomenon in which waves <u>spread out</u> as they pass through a <u>gap</u> or round a small <u>obstacle</u>.</b>
What are Characteristics of diffracted waves?	<b>1. Frequency, wavelength and speed of waves <u>do not change</u>.</b> <b>2. Changes in the direction of propagation and the pattern of the waves.</b> <b>3. The amplitude of the diffraction wave decreases so its energy decrease.</b>
What are the factors that influence the effect of diffraction?	<b>The effect of diffraction is <u>obvious</u> if:</b> <b>1. the <u>size</u> of the <u>gap</u> or <u>obstacle</u> is <u>small</u> enough</b> <b>2. the <u>wavelength</u> is <u>large</u> enough.</b>  <b>The effect of diffraction is obvious if the shape of the diffracted waves more spread out or more circular</b>

<b>Diffraction of sound</b>	<b>Sound diffracting around corners so allowing us to hear others who are speaking to us from adjacent rooms.</b>	 <p>The diagram illustrates sound diffraction. A radio is positioned behind a wall. Sound waves, represented by curved lines, emanate from the radio and bend around the corner of the wall. A student is shown on the other side of the wall, with lines indicating they can hear the radio because the sound waves have diffracted around the corner.</p>
<b>Diffraction of light</b>	<b>Light is diffracted if it passes through a <u>narrow slit</u> comparable in size to its wavelength. However, the effect is not obvious as the size of the slit increases. This is because the wavelengths of light are very short.</b>	 <p>The diagram shows a single-slit diffraction experiment. A light source (a lamp) emits light that passes through a single slit in a barrier. An observer is positioned to receive the diffracted light. Below the barrier, a series of vertical bars of varying heights represent the intensity of the light, showing a central maximum and several smaller side maxima and minima, characteristic of diffraction.</p>
<b>We can hear the sound of a radio placed nearby a corner of a wall but we cannot see the radio. Why?</b>	<b>Sound waves are more easily diffracted in comparison to light waves because the wavelength of sound waves is much longer than the wavelength of light waves.</b>	

<p><b><u>Procedure</u></b></p> <ul style="list-style-type: none"> <li>➤ <b>A ripple tank is filled with water and set up as shown.</b></li> <li>➤ <b>Switch on the power pack.</b></li> <li>➤ <b>Use a barrier to block the incident straight water waves. Observe the wave pattern beyond the barrier.</b></li> <li>➤ <b>Send a straight water waves to pass through a gap. Observe the pattern of diffracted waves beyond the gap.</b></li> <li>➤ <b>Send straight water waves towards a small gap. Observe the wave pattern beyond the small gap.</b></li> </ul>	 <p>The diagram shows a ripple tank setup. A lamp is mounted on a stand above the tank, illuminating the water surface. A barrier with a gap is placed in the tank. A screen is positioned at the bottom of the tank to observe the wave pattern. Labels point to the Lamp, Gap, Ripple tank, and Screen.</p>
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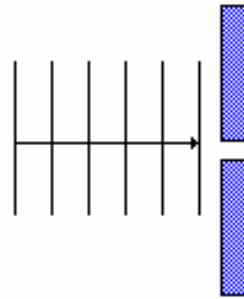
## Observation

**(a) Wide gap**



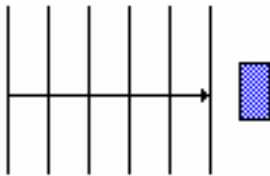
The waves are bend only at the edges after passing through the gap.  
The effect of diffraction is not obvious

**(b) Narrow gap**



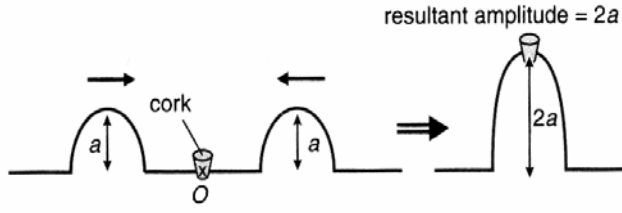
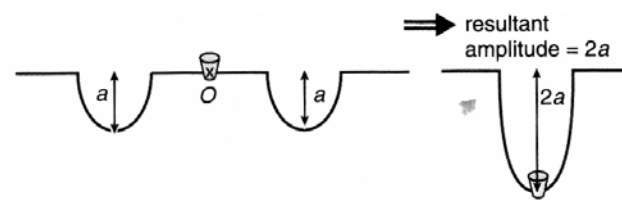
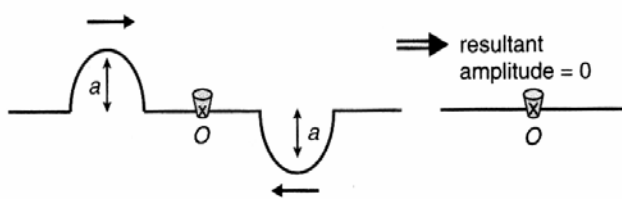
The waves are circular and appear to originated from the small gap.  
The effect of diffraction is obvious

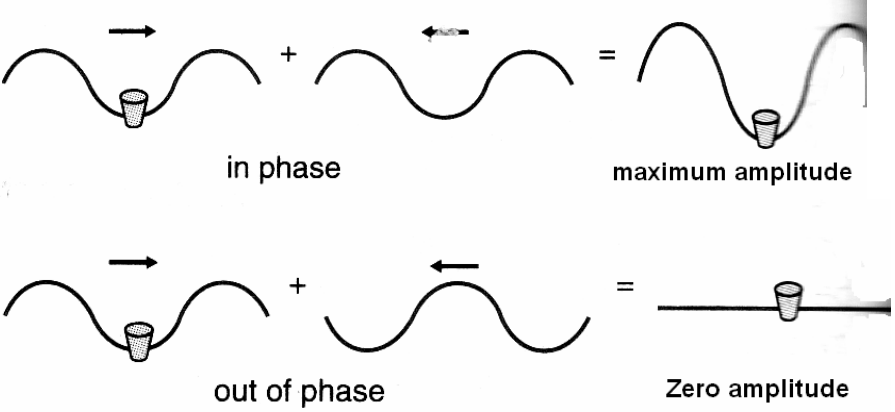
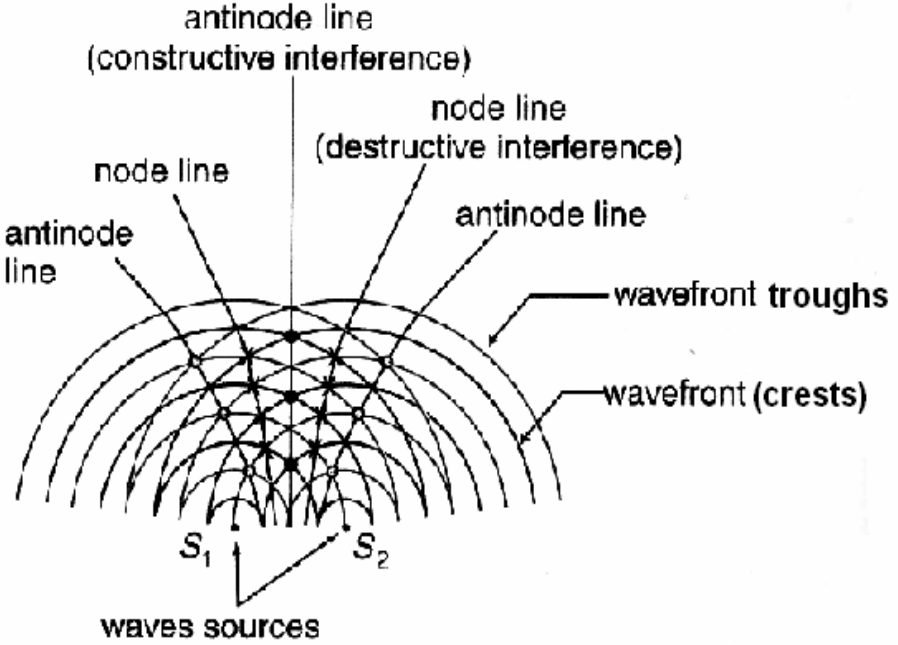
**Straight water wave propagate towards an obstacle.**



**As the size of the gap or obstacle is smaller , the effect of diffraction becomes obvious.**

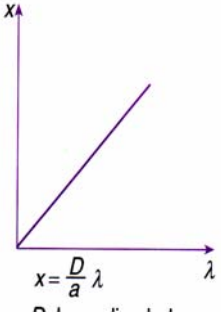
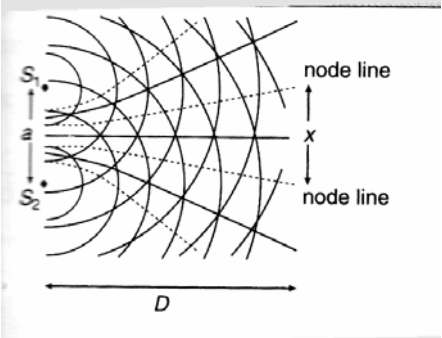
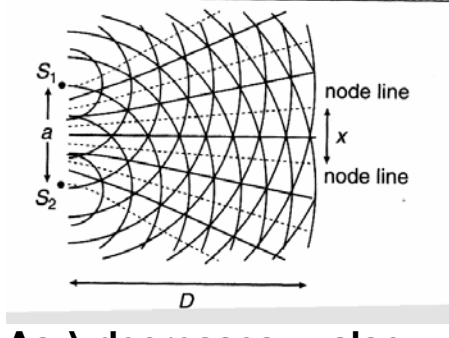
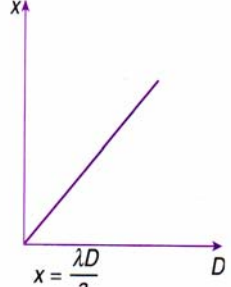
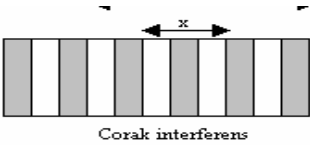
## 6.5 INTERFERENCE OF WAVES

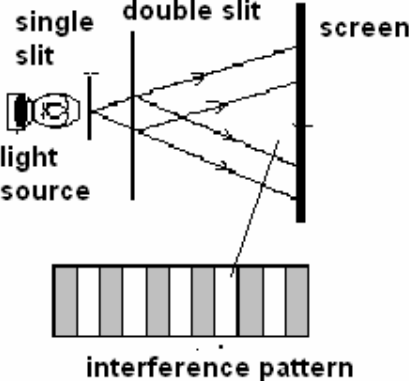
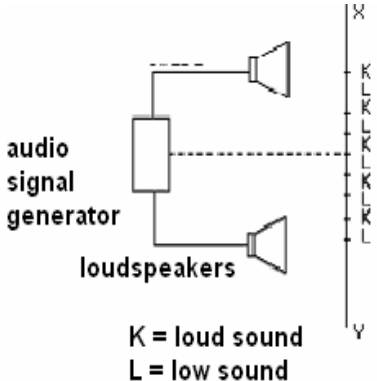
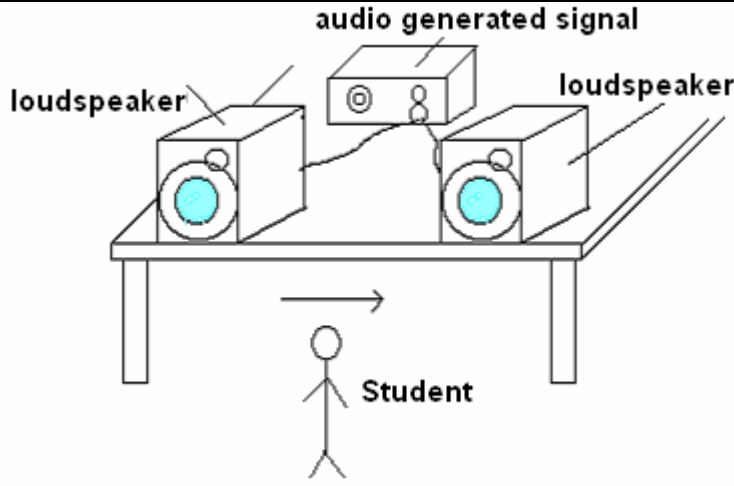
State the Principle of superposition of Waves	When two waves interfered, the resulting displacement of the medium at any location is the algebraic sum of the displacements of the individual waves.	
(a) Superposition of two crests		<u>Constructive Interference</u>
(b) Superposition of two troughs		<u>Constructive Interference</u>
(c) Superposition of a crest and a trough		<u>Destructive Interference</u>
What is Interference of Waves?	➤ <u>Interference</u> is the <u>superposition</u> of two waves originating from two <u>coherent sources</u> .	
What is coherent sources?	➤ The waves from coherent sources have the same frequency ( $f$ ), same wavelength and constant phase difference.	
How does interference occur?	➤ Wave interference occurs when two waves meet while propagating along the same medium. ➤ When the two waves are superposed, interference will occur either constructive interference or destructive interference.	

<b>Constructive Interference</b>	<p>➤ Occurs when the crests or troughs of both waves coincide to produce a wave with crests and troughs of <u>maximum amplitude</u>.</p>
<b>Destructive interference</b>	<p>➤ Occurs when crest of one wave coincide with the trough of the other wave, thus canceling each other with the result that the <u>resultant amplitude is zero</u></p>
<p><b>The occurrence of constructive interference</b></p> <p><b>and</b></p> <p><b>destructive interference</b></p>	 <p>in phase                      maximum amplitude</p> <p>out of phase                      Zero amplitude</p>
<p><b>Antinode</b></p> <p><b>Node</b></p> <p><b>Keys:</b></p> <ul style="list-style-type: none"> <li>■ Maximum crest wave (2 crests meet)</li> <li>× Zero amplitude (trough meets crest)</li> <li>○ Maximum trough wave (2 troughs meet)</li> </ul>	<p>➤ A point where <u>constructive interference</u> occurs</p> <p>➤ A point where <u>destructive interference</u> occurs.</p>  <p>antinode line (constructive interference)</p> <p>node line (destructive interference)</p> <p>antinode line</p> <p>node line</p> <p>antinode line</p> <p>wavefront troughs</p> <p>wavefront (crests)</p> <p>S<sub>1</sub> S<sub>2</sub></p> <p>WAVES SOURCES</p>

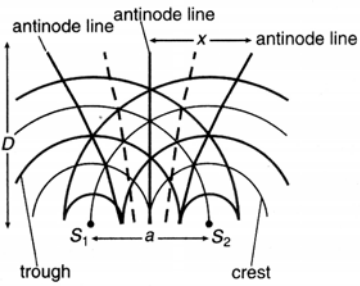
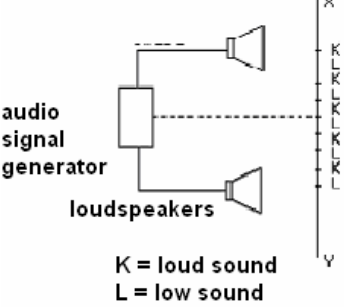
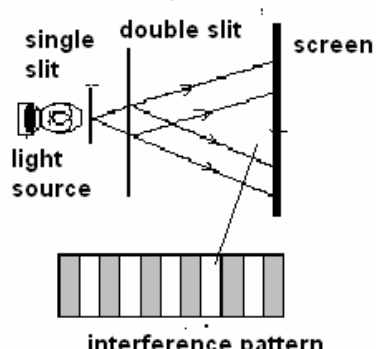




<p>2. <math>x \propto \lambda</math></p> <p>where <math>a</math> &amp; <math>D</math> are constant</p> 	<p>The distance between two consecutive node lines or antinode lines, <math>x</math> increases is directly proportional to the wavelength of the wave, <math>\lambda</math></p> <div style="display: flex; justify-content: space-around;"> <div data-bbox="513 363 1008 867"> <p>Low frequency (large <math>\lambda</math>)</p>  <p>As <math>\lambda</math> increases, <math>x</math> increases</p> </div> <div data-bbox="1008 363 1515 867"> <p>High frequency (small <math>\lambda</math>)</p>  <p>As <math>\lambda</math> decreases, <math>x</math> also decreases.</p> </div> </div>	
<p>3. <math>x \propto D</math></p> <p><math>x</math> directly proportional to <math>D</math></p> <p>where <math>a</math> &amp; <math>\lambda</math> are constant</p>	<p>The distance between two consecutive node lines or antinode lines, <math>x</math> is directly proportional to the distance from the two sources to the point of measurement of <math>x</math>, <math>D</math></p>	
<p><b>Interference of lights</b></p> 	<p>Occurs when an incident light wave passes through a double slit.</p> <p>An interference pattern is produced as a result of the superposition of two emerging light waves from the double slit.</p>	
<p><b>Young's double-slit experiment</b></p>	<ul style="list-style-type: none"> <li>➤ Use monochromatic light (light which has one colour and one wavelength)</li> <li>➤ The double slit must be very narrow (about 0.5 mm) to produce a clear interference pattern because the wavelength of light is very small.</li> <li>➤ When light from monochromatic source passes through a double slit, two sources of coherent light are produced.</li> </ul>	

 <p style="text-align: center;">interference pattern</p> $\lambda = \frac{ax}{D}$	<p>➤ The interference pattern consists of alternate bright and dark fringes that can be seen on a distant screen.</p> <p>➤ Bright fringes: constructive interference</p> <p>➤ Dark fringes: destructive interference.</p> <p><math>a</math> = Distance between the two slits on the double slit plate</p> <p><math>D</math> = Distance between the double-slit plate and the screen</p> <p><math>\lambda</math> = The wavelength of light depends on its <u>color</u>.</p> <p><math>x</math> = Distance between two consecutive bright fringes or dark fringes.</p>
<p><b>Interference of Sound Waves</b></p>	<p>Occurs when two coherent sound waves interact on the basis of the principle of superposition to produce a pattern of</p>
 <p><math>a</math> = the distance between the two loudspeakers</p> <p><math>D</math> = Distance between the loudspeakers and the path along which interference can be detected</p> <p><math>\lambda</math> = The wavelength of sound waves is</p>	 <p>The two loud speakers are the sources of the two coherent sound waves as they are connected to the same audio signal generator.</p> <p>A student is requested to walk in a straight path at a distance of <math>D</math> from the loudspeakers.</p> <p>The student hears alternating loud and soft sounds as he walks along the straight path.</p>

<p>influenced by the frequency of the <u>audio signal generator</u>.</p> <p><math>x</math> = Distance between two consecutive positions where loud sound is heard</p>	<p>The alternating loud and soft sounds is caused by interference of the sound waves.</p> <p>The loud sound: constructive interference</p> <p>The soft sound : destructive interference.</p> $\lambda = \frac{ax}{D}$
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	Water wave	Sound wave	Light wave
		 <p>K = loud sound L = low sound</p>	 <p>interference pattern</p>
$\lambda$	The wavelength of water waves is influenced by the frequency of the <u>vibrator</u>	The wavelength of sound waves is influenced by the frequency of the <u>audio signal generator</u> .	The wavelength of light depends on its <u>color</u> .
D	Distance between the spherical dippers and the position marked x is measured	Distance between the loudspeakers and the path along which interference can be detected	Distance between the double-slit plate and the screen
a	Distance between the two spherical dippers	Distance between the two loudspeakers	Distance between the two slits on the double slit plate
x	Distance between two consecutive antinode lines or two consecutive node lines	Distance between two consecutive positions where loud sound is heard	Distance between two consecutive bright fringes or dark fringes.
	High amplitude of water Calm water	Loud sound Soft sound	Bright fringes Dark fringes

**Example 1**

In the interference of two coherent sources of waves, the separation between two spherical dippers is 3 cm and the distance between two consecutive node lines is 4 cm measured at a distance of 15 cm from the two coherent sources of waves. Calculate the wavelength of the water waves originating from the sources.

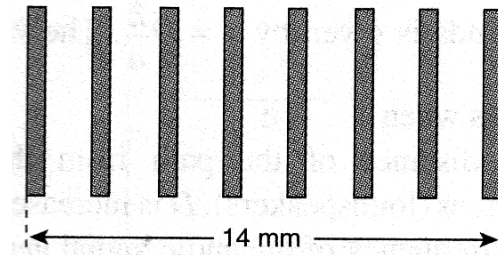
**Example 2**

In a Young's double slit experiment, the distance between the double slit and the screen is 4.0 m and the separation of the two slits is 0.5 mm. Calculate the distance between two consecutive bright fringes for violet light with a wavelength of  $4.0 \times 10^{-7}$  m

**Example 3**

The wavelength of light can be determined with a double-slit plate. The diagram shows the pattern of interference fringes obtained in a Young's double-slit experiment. The separation of distance of the two slits is 0.25 mm and the distance between the screen and the double slit plate is 3.0 m.

Calculate the wavelength of light used in the experiment.

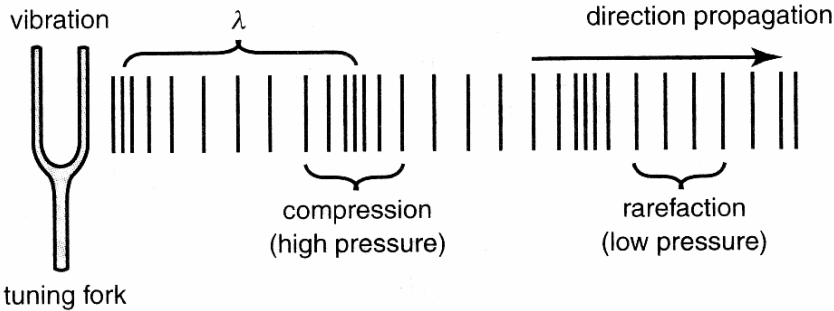
**Example 4**

In an experiment on the interference of waves, two loudspeakers are placed at a distance of 1.5 m from each other. They are connected to an audio signal generator to produce coherent sound waves at a frequency of 0.5 kHz.

Calculate

- the wavelength of the sound wave if the speed of sound is  $300 \text{ ms}^{-1}$
- the distance between two consecutive soft sounds at a perpendicular distance of 5 m from the source of the sound.

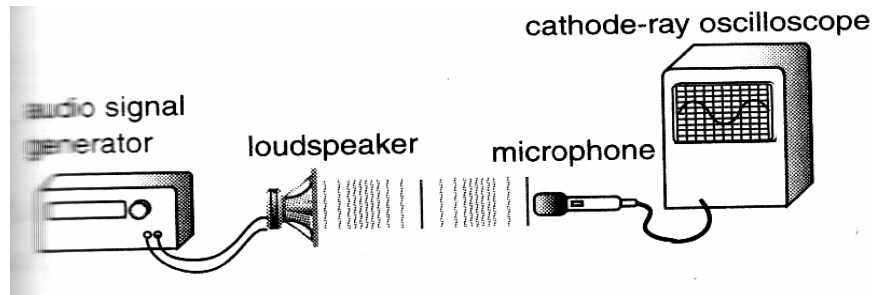
## 6.6 ANALYSING SOUND WAVES

What is sound waves?	<p>Sound is a form of <u>energy</u> propagated as <u>waves</u> that make our eardrums <u>vibrate</u>.</p> <p>Sound waves are caused by <u>vibrating</u> objects.</p> <p>Sound waves are <u>longitudinal</u> waves.</p>
How is sound produced by a vibrating objects?	<ul style="list-style-type: none"> <li>Sound waves are produced when a vibrating object causes the air molecules around it to <u>vibrate</u>.</li> </ul>  <ul style="list-style-type: none"> <li>When a tuning fork vibrates, layers of air vibrate and the sound energy is propagated through the air around it in the form of waves.</li> <li>When the tuning fork moves forwards, the air is <u>compressed</u>.</li> <li>When the tuning fork moves backwards, the air layers are pulled apart and cause a <u>rarefaction</u>.</li> <li>Therefore, a series of <u>compression</u> and <u>rarefactions</u> will produce sound.</li> </ul>
Why does sound waves is a longitudinal waves?	<ul style="list-style-type: none"> <li>The air particles vibrate backward and forward in the direction parallel to the direction of propagation of the sound wave.</li> <li>Wavelength of sound, <math>\lambda</math> = the distance between two successive regions of compression or two successive regions of rarefaction.</li> </ul>
Explain how the loudness relates to amplitude?	<ul style="list-style-type: none"> <li>The loudness of the sound depends on its amplitude.</li> <li>If the amplitude is increased, the loudness increases.</li> </ul>
Explain how	<ul style="list-style-type: none"> <li>A high pitch sound corresponds to a high frequency and</li> </ul>

the pitch  
relates to  
frequency

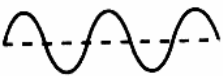

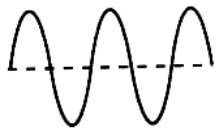
a low pitch sound corresponds to a low frequency of vibration.

**To investigate the relationship between the amplitude and the loudness of sound**



The audio signal generator is switched on and the frequency of the sound wave is adjusted to a suitable level. The loudness of the sound is varied from a lot to a high level gradually. Observe the shape of the sound wave displayed on the screen of oscilloscope.


Write: low / medium / high



Wave form	Amplitude of sound wave	Loudness of sound
		
		
		

**The relation between the pitch and the frequency of sound**

The audio signal is switched on and the loudness is adjusted to a suitable level. The frequency of the sound is varied from low to high gradually. The pitch of the sound that is heard and the form of the wave displayed on the screen of the oscilloscope is observed.

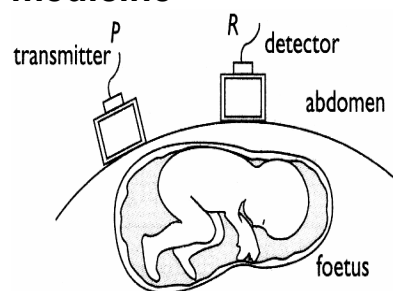
Write: low / medium / high

Wave form	Frequency of sound wave	Pitch of sound
		

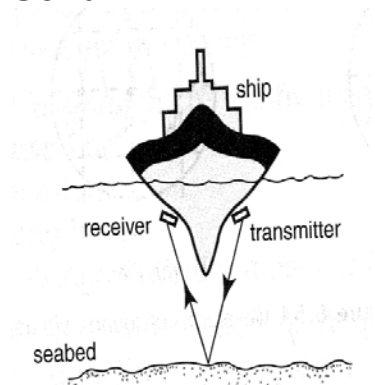
			
			

describe applications of reflection of sound waves.

### Ultrasound in medicine



### Sonar

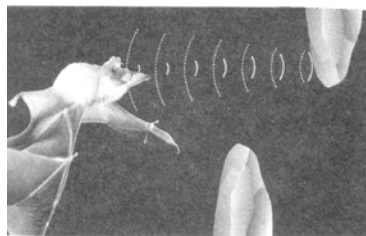


The reflection of sound is called echoes.

Infrasound	Normal audible range	Ultrasound
Less than 20 Hz	20 Hz to 20 000 Hz	Higher than 20 000 Hz.

- Ultrasound waves is used to scan and capture the image of a fetus in a mother's womb and the image of internal organ in a body.
- Transmitter P emits ultrasound downwards to the fetus.
- Detector R receives the ultrasound (echoes) reflected by the various parts of the fetus.
- The soft tissues of the fetus absorb most of the incident ultrasound, reflect very little. The bony parts will absorb very little, but reflect most of the ultrasound. The reflected ultrasound will produce an image of contrasting brightness.
- Sonar is the technique of using ultrasound to locate underwater objects or to measure the depth of a seabed.
- Ultrasound signal is sent out from a transmitter.
- Its echo from the seabed is detected by a receiver which is connected to an electrical recording circuit.
- The time interval,  $t$  between the sending and receiving of the ultrasound signal after reflection from the seabed is measured.

**A bat can navigate in darkness**



- The depth of the seabed,  $d = v \times \frac{t}{2}$  where  $v$  is the velocity of sound in water.
- When ultrasonic waves emitted by the bat hit an object, they are reflected back and received by the bat.
- The time between the emission of the sound waves and reception of the reflected waves enables the bat to estimate the position of the object accurately.
- This enables the bat to adjust its direction to avoid knocking at the object.

**Calculate distances using the reflection of sound waves.**

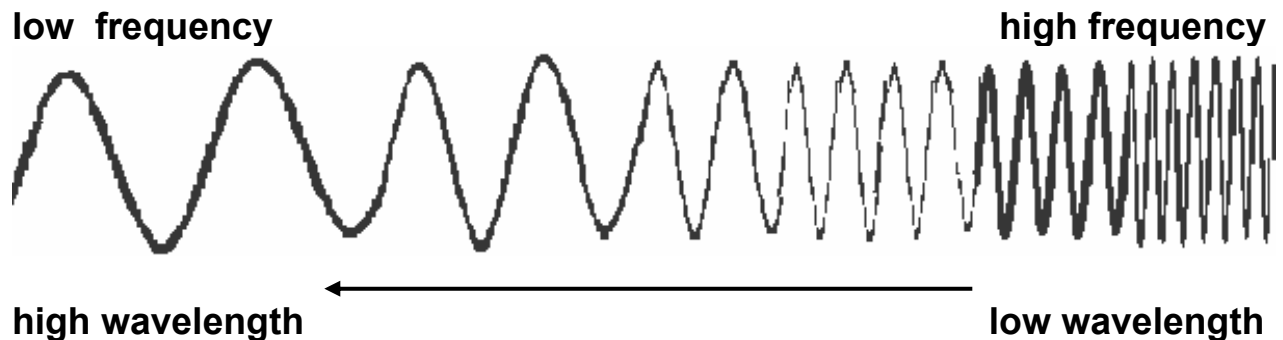
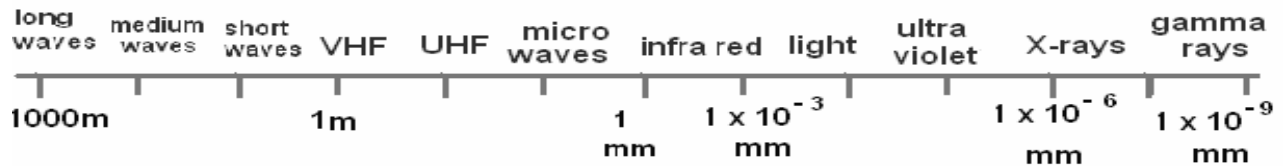
An ultrasonic wave is used to determine the depth of a seabed. A pulse of ultrasound is generated and travels to the seabed and reflected by it. The time taken by a pulse of ultrasonic wave to travel to and fro the seabed is 0.28 s. If the speed of sound in the water is  $1500 \text{ ms}^{-1}$ , calculate the depth of the seabed.



## 6.7 ANALYSING ELECTROMAGNETIC WAVES

Describe the electromagnetic spectrum

I-----Radio waves-----I

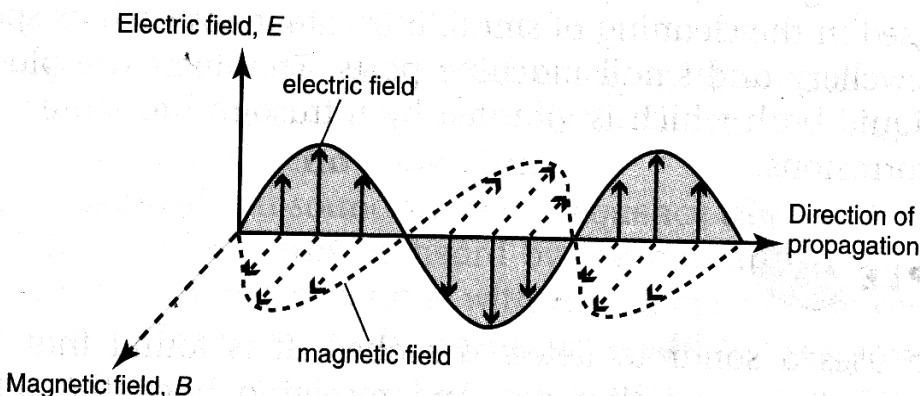


What is the electro-magnetic spectrum?

- It consists of a group of waves with similar natures.
- The members of the electromagnetic spectrum arranged in increasing frequencies and decreasing wavelengths are radio waves, microwaves, infrared rays, visible light, ultraviolet rays, X – rays and gamma rays.
- Radio waves have the longest wavelength but are of low frequency waves. They carry very little energy.
- Gamma rays have the shortest wavelength but are of high frequency waves. They carry very high energy.

What is the electro-magnetic wave?

- It is produced when electric and magnetic field vibrate at right angle to each other.
- The direction of propagation of the wave is perpendicular to both fields.

	 <p>The diagram illustrates an electromagnetic wave propagating to the right. The electric field (E) is represented by a solid sine wave with vertical arrows pointing up and down. The magnetic field (B) is represented by a dashed sine wave with horizontal arrows pointing left and right. The two fields are perpendicular to each other and to the direction of propagation.</p>	
<b>State the visible light is a part of the electro-magnetic spectrum</b>	<ul style="list-style-type: none"><li>• <b>Visible light waves are the only electromagnetic waves we can see. Light can be seen as the colours of rainbow.</b></li><li>• <b>Each colour has a different wavelength.</b></li><li>• <b>Red has the longest wavelength and violet the shortest.</b></li><li>• <b>When all the waves are seen together, they make <u>white light</u>.</b></li><li>• <b>When white light shines through a prism, the white light is broken apart into the <u>seven</u> colours of the visible light <u>spectrum</u>.</b></li><li>• <b>Red, orange, yellow, green, blue, indigo and violet.</b></li></ul>	
<b>Describe the properties of electro-magnetic waves</b>	<ol style="list-style-type: none"><li>1. They transfer <u>energy</u> from one point to another.</li><li>2. They are <u>transverse</u> waves.</li><li>3. They can travel through <u>vacuum</u>.</li><li>4. They travel at the same speed through vacuum, i.e at the speed of light , <math>c = 3 \times 10^8 \text{ ms}^{-1}</math>.</li><li>5. They all show wave properties such as <u>reflection, refraction, diffraction and interference</u>.</li><li>6. They obey the wave equation, <math>v = f\lambda</math>.</li></ol>	
<b>List sources of electro-magnetic waves and the applications.</b>		
<b>Electromagnetic wave</b>	<b>Sources</b>	<b>Applications</b>
<b>Gamma Rays</b>	<b>Radioactive substances</b>	<ul style="list-style-type: none"><li>• <b>Engineering – to detect leakages in underground pipes</b></li><li>• <b>Medicine – cancer treatment</b></li><li>• <b>Food sterilisation</b></li></ul>

<b>X- rays</b>	<b>x-ray tube</b>	<ul style="list-style-type: none"> <li>• <b>Medicine</b> <ol style="list-style-type: none"> <li>i. X-ray photograph of the internal organs of the body, e.g to locate bone fracture.</li> <li>ii. Cancer treatment</li> </ol> </li> <li>• <b>Engineering – to detect cracks in metal</b></li> <li>• <b>Checking of luggage at airports</b></li> </ul>
<b>Ultraviolet rays</b>	<b>The sun, mercury vapour lamp.</b>	<ul style="list-style-type: none"> <li>• <b>Cause sunburn</b></li> <li>• <b>Stimulates the formation of vitamin D needed for assimilation of calcium and the prevention of rickets.</b></li> <li>• <b>Detect fake notes</b></li> <li>• <b>Fluorescent lamp</b></li> <li>• <b>Sterilization of surgical tools and plant seedlings.</b></li> </ul>
<b>Visible light</b>	<b>Flames, lamps, the sun</b>	<ul style="list-style-type: none"> <li>• <b>Visual communication</b></li> <li>• <b>Photography</b></li> <li>• <b>Photosynthesis</b></li> </ul>
<b>Infrared radiation</b>	<b>Hot objects such as flames, the human body, the sun</b>	<ul style="list-style-type: none"> <li>• <b>A sensation of warmth is felt when IR falls on the skin.</b></li> <li>• <b>Thermal imaging and physiotherapy</b></li> <li>• <b>Infrared binoculars for night time vision. IR radiation emitted by a living thing can be detected.</b></li> <li>• <b>Remote control for TV / VCR</b></li> </ul>
<b>Microwaves</b>	<b>Radar transmitter Microwaves oven</b>	<ul style="list-style-type: none"> <li>• <b>Communication system with satellites</b></li> <li>• <b>Used in radar system</b></li> <li>• <b>Cooking</b></li> <li>• <b>Cellular (mobile) phone service</b></li> </ul>
<b>Radio waves</b>	<b>Electrons oscillating in aerials Radio/ television</b>	<ul style="list-style-type: none"> <li>• <b>For broadcasting and wireless communication</b></li> <li>• <b>UHF (ultra high frequency) radio waves – television and hand phones</b></li> </ul>

	transmitter	<ul style="list-style-type: none"> <li>• VHF (very high frequency) radio wave – local radio FM and wireless communication used by the police</li> </ul>	
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**Describe the detrimental effects of excessive exposure to certain components of the electromagnetic spectrum.**

<b>Radio waves</b>	<b>No evidence of hazard</b>
<b>Microwaves</b>	<b>Internal heating of body tissues when they enter our body.</b> <b>Long exposure to mobile phones can cause brain tumor and inner ear complications in children. Just SMS.</b>
<b>Infrared</b>	<b>Skin burns</b>
<b>Visible light</b>	<b>No evidence of hazard</b>
<b>Ultraviolet</b>	<b>Damage to the surface cells (including skin cancer) and blindness</b>
<b>X-rays</b>	<b>Damage to cells.</b>
<b>Gamma rays</b>	<b>Cancer, mutation</b> <b>The mutated cells may result in the abnormal growth of cancer cells.</b> <b>Pregnant mothers who are exposed to X-rays and radiations too frequently may cause abnormalities in new born babies.</b>