5.5 Diffraction of Waves

Photograph 5.12 shows the embankment built in Marang, Terengganu. What causes the wavefront of the seawater in region *A* and region *B* to have different shapes?

The wavefront of the seawater changes from plane wavefront in region *A* to circular wavefront in region *B*. This shows that sea waves spread out while propagating through the gap in the embankment.

Photograph 5.12 shows the phenomenon of **diffraction of waves**. Diffraction of waves can happen to water, light and sound waves.

Photograph 5.12 *Embankment at Marang, Terengganu*

(***Source:*** *Image ©2019 TerraMetrics*
Image ©2019 Maxar Technologies)

Activity 5.15

Aim: To show diffraction of water, light and sound waves

A Diffraction of water waves

Apparatus: Ripple tank and its accessories, digital xenon stroboscope and barriers

Materials: Distilled water

Instructions:

1. Set up the apparatus as shown in Figure 5.45.
2. Adjust the speed of the ripple generator so that waves can be seen clearly on the screen using the stroboscope.
3. Place the barriers to form a gap with size almost similar to the wavelength of the wave produced.
4. Switch off the ripple generator and wait until the water in the ripple tank becomes calm.
5. Switch on the ripple generator again.
6. Observe the shape of the wavefront before and after passing through the gap.
7. Draw the shape of the wavefront after passing through the gap and record the characteristics of the wavefront before and after passing through the gap in Table 5.4.

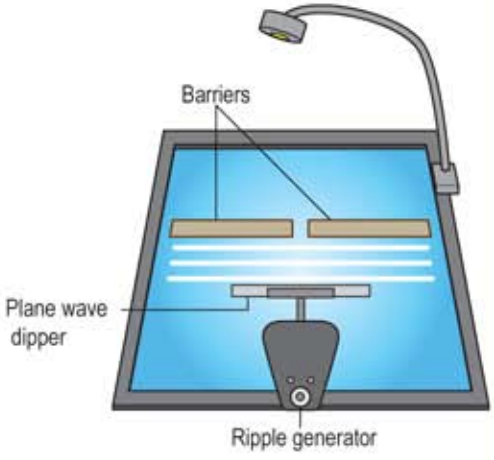


Figure 5.45

Results:

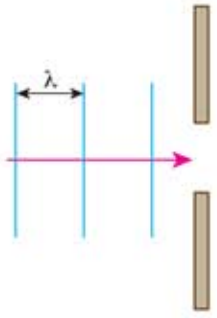


Figure 5.46

Table 5.4

Characteristic of wave	Comparison before and after the gap
Wavelength	
Frequency	
Wave speed	
Amplitude	
Direction of propagation	

Discussion:

Compare the shape of the incident wavefront with the wavefront that has passed through the gap.

B Diffraction of light waves

Apparatus: Laser pen, retort stand, single narrow slit, single wide slit, small sized pin hole, large sized pin hole and white screen

Instructions:

1. Set up the apparatus as shown in Figure 5.47. Use a single wide slit.

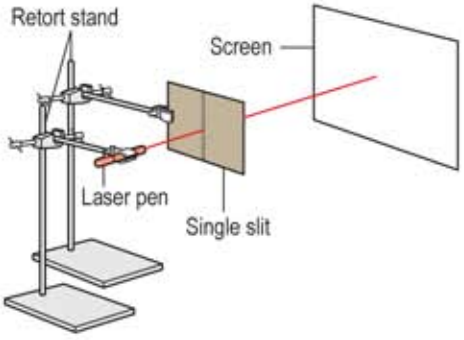


Figure 5.47

2. Direct the laser light ray through the single slit. Observe the pattern formed on the screen and draw the pattern in Table 5.5.
3. Repeat steps 1 and 2 using:
   (a) a single narrow slit
   (b) a large pin hole
   (c) a small pin hole

DIY

You can also carry out this activity using a self-made adjustable single slit as shown below.

Demonstration using self-made adjustable single slit

http://bt.sasbadi.com/p4203

Results:

Table 5.5

Wide slit	Narrow slit
Large pin hole	**Small pin hole**

Discussion:

1. What is the difference in the image formed by the single wide slit and single narrow slit?
2. Compare the image formed by the small pin hole with the large pin hole.

Sound generator application

http://bt.sasbadi.com/p4204

C Diffraction of sound waves

Apparatus: Tablet, small loudspeaker that can be connected to tablet

Instructions:

1. Set up the apparatus as shown in Figure 5.48 at a corner of a building.
2. Scan the QR code to download the sound generator application from the website given.
3. Generate a sound of frequency of 500 Hz from the application.
4. Stand at position *X* as shown in Figure 5.48 and listen to the sound from the loudspeaker.
5. Repeat step 4 by standing at position *Y*.
6. Record your observations in Table 5.6.

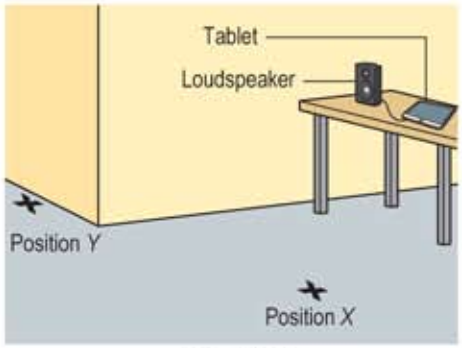


Figure 5.48

Results:

Table 5.6

Position	Sound heard
X	
Y	

Discussion:

1. Can the sound from the loudspeaker be heard at positions *X* and *Y*?
2. Explain why sound can be heard at position *Y* even though the loudspeaker cannot be seen.

Diffraction of waves is the spreading of waves when the waves propagate through a slit or side of a barrier. The effects of diffraction on the characteristics of waves are summarized in Table 5.7.

SMART INFO

The larger the amplitude, the larger the energy carried by the wave.

Table 5.7 Effects of the diffraction on characteristics of waves

Characteristic of wave	Change caused by diffraction	Explanation
Wavelength	No change	Wave speed does not change.
Frequency	No change	No change to source of frequency.
Speed	No change	No change in medium before and after diffraction.
Amplitude	Decreased	Wave energy diverges and spread out to a wider region
Direction of propagation	From one direction to many directions	Wavefront spreads.

The figures below show the pattern of diffraction of water, light and sound waves.

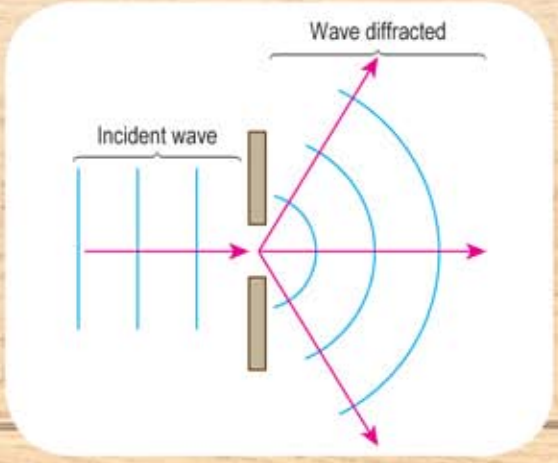


Figure 5.49 Diffraction pattern of water wave

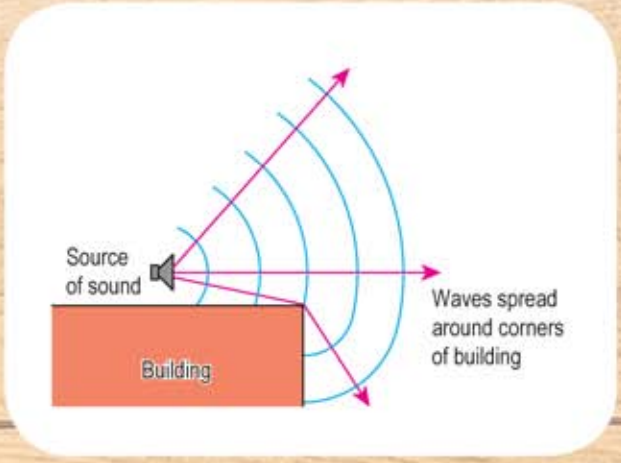
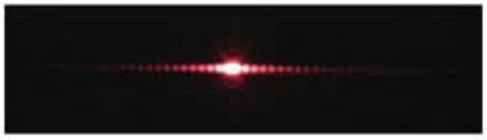


Figure 5.50 Diffraction pattern of sound wave

Diffraction pattern through single slit



Diffraction pattern through pin hole

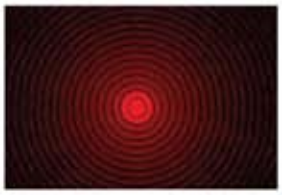


Figure 5.51 Diffraction patterns of light waves

Factors that Influence Diffraction of Waves

Activity 5.16

Aim: To study the factors which influence diffraction of water waves

Apparatus: Ripple tank and its accessories, digital xenon stroboscope and barriers

Materials: Distilled water

Instructions:

Computer simulation of diffraction of waves

http://bt.sasbadi.com/p4206

The following simulation can only be seen using a computer
http://bt.sasbadi.com/p4206a

A Effect of size of slit on diffraction of water waves

1. Prepare the ripple tank and switch on the ripple generator.
2. Observe the wavelength on the glass screen.
3. Adjust the size of the slit so that it is larger than the wavelength.
4. Observe the diffracted wave and draw the pattern in Table 5.8.
5. Repeat steps 3 and 4 with a slit size that is almost the same as the wavelength.

B Effect of wavelength on diffraction of water waves

1. Adjust the size of the slit to about 1 cm.
2. Adjust the frequency of the ripple generator to produce a wavelength shorter than the size of the slit.
3. Observe the diffracted wave and draw the pattern in Table 5.9.
4. Repeat steps 2 and 3 using a wavelength that is almost the same as the size of the slit.

Results:

Table 5.8

Size of slit	Pattern of diffraction
Wide slit	
Narrow slit	

Table 5.9

Wavelength	Pattern of diffraction
Short	
Long	

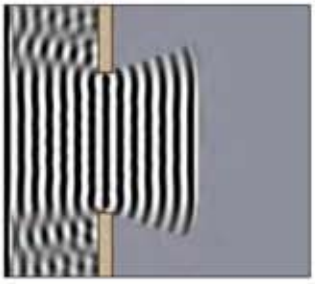
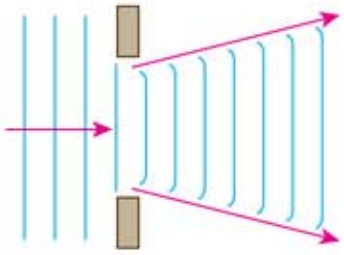
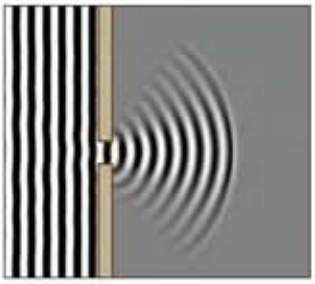
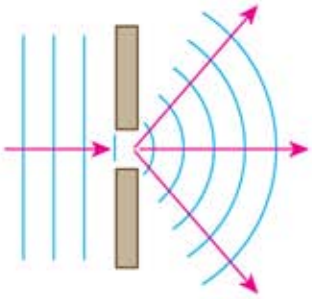
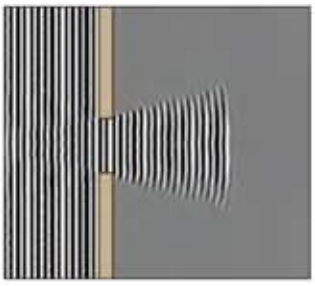
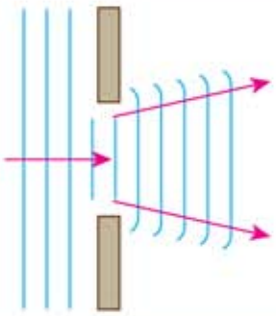
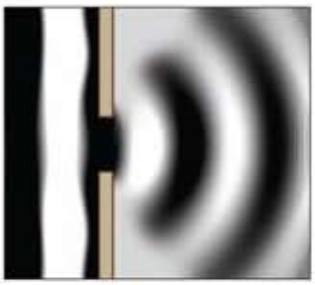
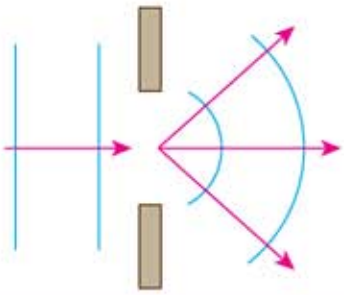
Discussion:

1. Compare the patterns of diffracted waves through a wide slit and a narrow slit.
2. Compare the patterns of diffracted waves of short and long wavelengths passing through a slit.

Patterns of Diffracted Water Waves

Table 5.10 shows the patterns of diffracted water waves in a simulated ripple tank and sketches of the wavefront. Study the effects of the size of slit and wavelength on the diffraction of water waves.

Table 5.10 *Effects of size of slit and wavelength on pattern of diffracted waves*

Factor	Pattern of diffraction	Sketch of wavefront	Notes
Wide slit			Fixed wavelength
Narrow slit			
Short wavelength			Fixed slit size
Long wavelength			

Diffraction of waves is influenced by the size of slit and wavelength. Figure 5.52 presents the effects of diffraction of waves.

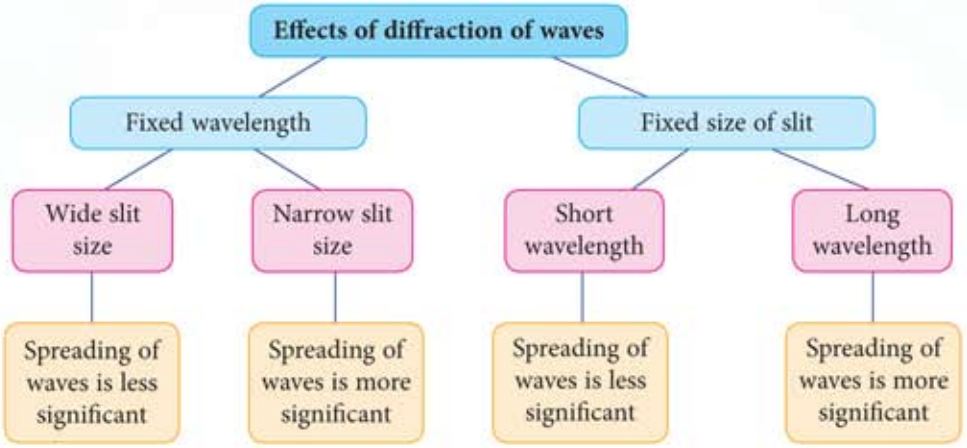


Figure 5.52 *Factors which influence diffraction of waves and their effects*

Diffraction of Waves in Daily Life

Figure 5.53 provides examples of diffraction of water, light and sound waves.

Diffractions of Waves

Water waves	Light waves	Sound waves
Diffraction of water waves produces calm of water regions suitable for docking of ships and water recreational activities.	Holograms produced by effects of diffraction of light are used as safety features on bank cards such as debit cards and credit cards	Infrasonic waves produced by elephants have long wavelength to facilitate long distance communication between elephants.

Kok Beach in Langkawi | *Hologram on a bank card* | *Elephant producing infrasonic waves*

Figure 5.53 *Diffraction of water, light and sound waves*

Activity 5.17

ISS ICS

Aim: To gather information on applications of diffraction of water, light and sound waves in daily life

Instructions:

1. Work in groups.
2. Surf websites to search for information on the applications of diffraction of water, light and sound waves in daily life that benefit mankind.
3. Present your findings in the form of an interesting multimedia presentation.

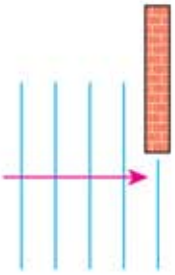
Diffraction of waves

http://bt.sasbadi.com/p4209

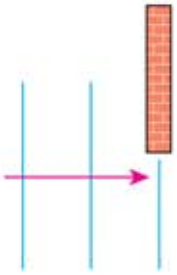
Formative Practice 5.5

1. Complete the following diagrams by drawing the patterns of diffracted waves.

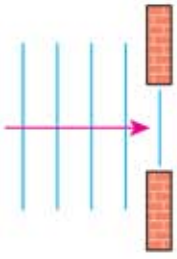
(a)



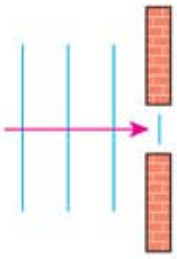
(b)



(c)



(d)



2. Figure 5.54 shows a plan of the living room and bedroom. A child lying on the bed cannot see the television in the living room but can still hear the sound from the television.
   (a) By drawing wavefronts, explain how the phenomenon of diffraction enables the child to hear sound from the television.
   (b) State another phenomenon which causes sound to propagate from the television to the child.

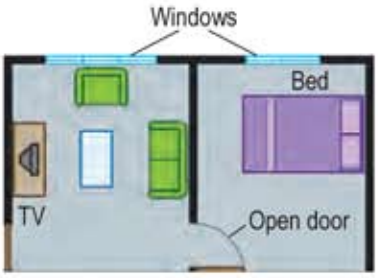


Figure 5.54

5.6 Interference of Waves

Principle of Superposition of Waves

DIY

Try to vibrate two small balls such as tennis balls on the surface of water. Can you see the pattern produced when the two waves overlap?

Photograph 5.13 *Superposition of two circular waves*

Photograph 5.13 shows two circular waves on the surface of water are in superposition. What happens when the two waves are in superposition?

Activity 5.18

ICS

Aim: To study superposition of waves using computer simulation

Instructions:

1. Work in pairs.
2. Scan the first QR code given to read about wave interference.
3. Scan the second QR code to carry out simulation to superposition as follows:
   (a) crest and crest with the same displacement
   (b) trough and trough with the same displacement
   (c) crest and trough with the same displacement
4. Draw the wave profiles before, during and after superposition for each simulation in step 3.
5. Record your observations in the form of a tree map.

Computer simulation of superposition of waves

http://bt.sasbadi.com/p4210a

http://bt.sasbadi.com/p4210b

Discussion:

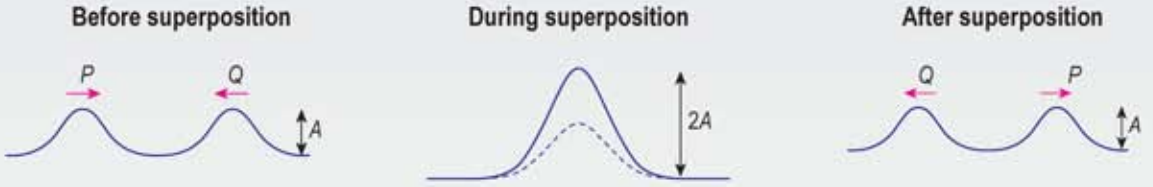
1. Which superposition produces a larger displacement?
2. Which superposition produces zero displacement?

The **principle of superposition** states that when two waves overlap, the resultant displacement is the sum of the individual displacements of the two waves.

Interference with Coherent Source of Waves

Interference of waves is the superposition of two or more waves from a **coherent** source of waves. Two sources of waves are coherent when the **frequency of both waves is the same** and the **phase difference is constant**. Superposition of waves produces constructive interference and destructive interference.

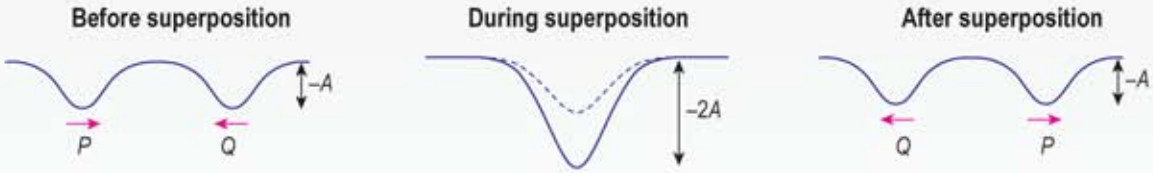
Constructive interference occurs when two **crests** are in superposition.



Combined displacement = $A + A = 2A$

Figure 5.55 *Constructive interference between two crests*

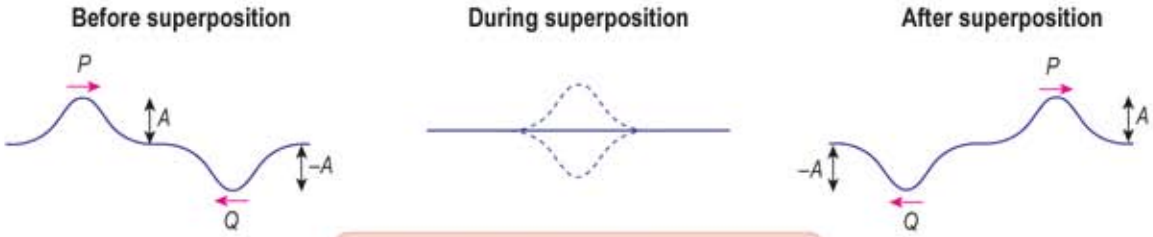
Constructive interference also occurs when two **troughs** are in superposition.



Combined displacement = $(-A) + (-A) = -2A$

Figure 5.56 *Constructive interference between two troughs*

Destructive interference occurs when a **crest** and a **trough** are in superposition to produce zero combined displacement.



Combined displacement = $A + (-A) = 0$

Figure 5.57 *Destructive interference between a crest and a trough*

Activity 5.19

Aim: To show interference with two coherent sources of waves

(A) Pattern of interference for water waves

Apparatus: Ripple tank and its accessories and digital xenon stroboscope

Materials: Distilled water

Instructions:

1. Prepare the ripple tank and attach a pair of spherical dippers as in Photograph 5.14.
2. Adjust the frequency of the ripple generator so that a clear pattern can be seen on the glass screen.
3. Observe the pattern of interference formed on the screen.
4. Repeat steps 1 and 2 using two spherical dippers which have a smaller gap between the two dippers. Observe the change in the interference pattern.
5. Adjust the ripple generator to obtain a lower wave frequency. Observe the change in the interference pattern.

Photograph 5.14

Discussion:

1. Why must the base of the ripple tank be on a horizontal plane?
2. What causes the formation of bright and dark regions in the interference pattern?
3. Suggest an alternative way to produce two coherent circular water waves.

(B) Pattern of interference for light waves

Apparatus: Laser pen, retort stand, two pieces of double-slit with different distance of separation and white screen

Instructions:

1. Set up the apparatus as shown in Figure 5.58.
2. Direct the laser light ray through the double-slit. Observe the pattern formed on the screen.
3. Repeat step 2 with a double-slit with a larger distance of separation between the slits.

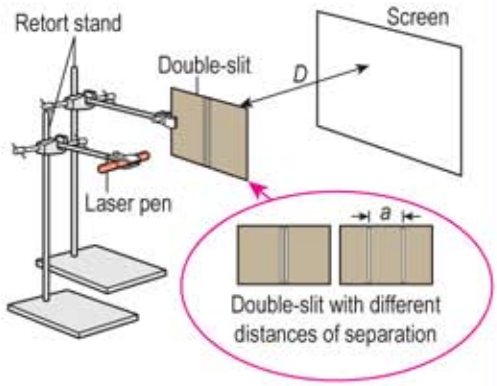


Figure 5.58

Discussion:

1. What phenomenon occurs when light passes through each slit?
2. What pattern is formed on the screen when two light rays superpose after passing through the double-slit?
3. Explain the formation of dark fringes in the interference pattern.

C Pattern of interference for sound waves

Apparatus: Audio generator, two identical loudspeakers, metre rule, microphone and cathode ray oscilloscope (C.R.O)

Instructions:

1. Set up the apparatus as shown in Figure 5.59. Two loudspeakers are placed 1.0 m apart from each other.

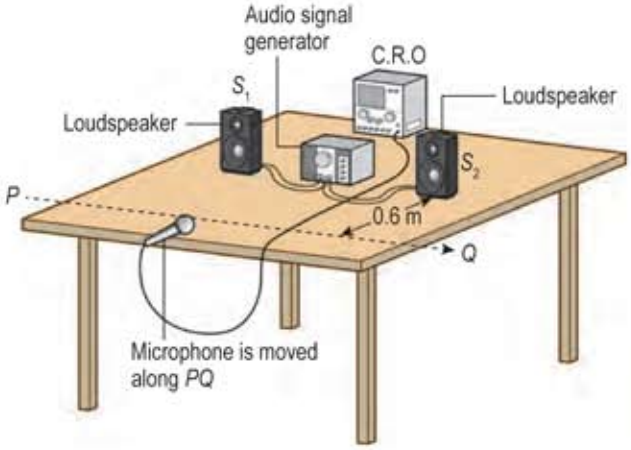


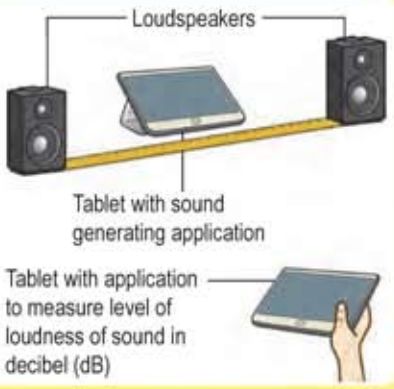
Figure 5.59

2. Adjust the audio generator to a frequency of 1 000 Hz.
3. Switch on the audio generator. Adjust the C.R.O. until a clear waveform is displayed on the screen.
4. Move the microphone slowly along the straight line *PQ* which is at a perpendicular distance of 0.6 m from the loudspeakers.
5. Observe the waveform on the C.R.O. screen when loud sound and soft sounds are detected.
6. Repeat steps 4 and 5 with the loudspeakers placed 0.5 m apart.

Discussion:

1. Why do the two loudspeakers need to be connected to the same audio generator?
2. Relate the waveform displayed on the C.R.O. screen with the sound heard when you walk in front of the loudspeakers.

You can also use 2 tablets for this activity with the following apparatus setup:



DIY

Interference of sound waves using tuning fork

Tuning fork is struck and then rotated slowly near the ear.

In Activity 5.19, can you identify the constructive and destructive interferences for water, light and sound waves?

Interference of water waves

Figure 5.60 shows the pattern of interference of water waves produced by two coherent sources S_1 and S_2 in a ripple tank.

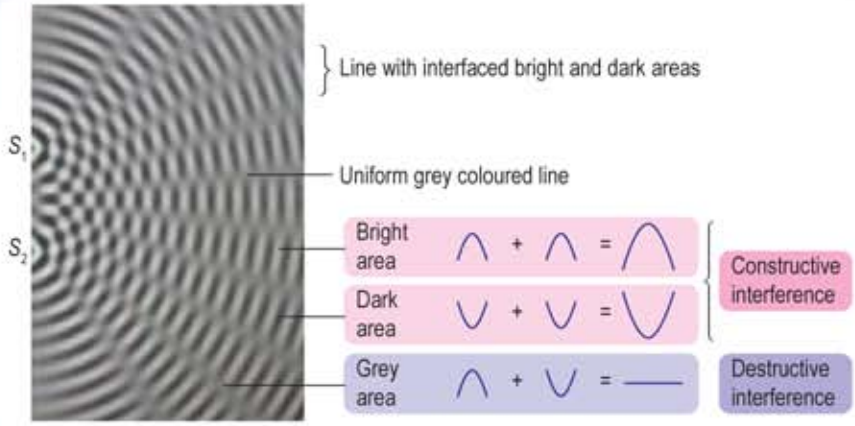


Figure 5.60 *Interference pattern for water waves*

Interference of light waves

Figure 5.61 shows the interference pattern formed on the screen with light from a laser pen. Diffracted light waves that appear from the double-slit are coherent. Superposition of waves from the double-slit produces a pattern made up of bright fringes and dark fringes. Constructive interference produces bright fringes while destructive interference produces dark fringes.

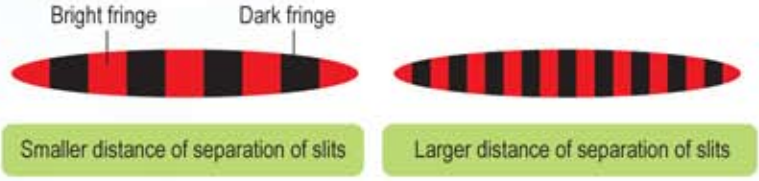


Figure 5.61 *Interference pattern for light waves*

INTEGRATION OF HISTORY

Activity on interference of light waves is also known as Young's double-slit experiment after the name of a physicist, Thomas Young. He successfully showed that light has wave characteristics through experiments which produce bright and dark fringes.

Interference of sound waves

Sound waves cannot be seen. Observer can only hear loud sounds in constructive interference regions and soft sound in destructive interference regions. Figure 5.62 shows a waveform displayed on a C.R.O. screen.

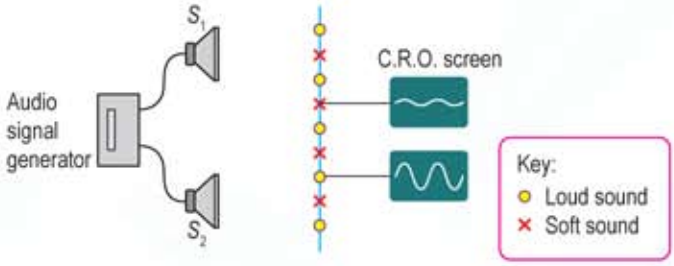


Figure 5.62 *Pattern of interference for sound waves*

Drawing Patterns of Wave Interference

Interference of water, light and sound waves can be analysed by drawing their patterns of interference as shown in Figure 5.63. Points P and Q are antinodes, the points where constructive interference occurs. Point R is a node, the point where destructive interference occurs.

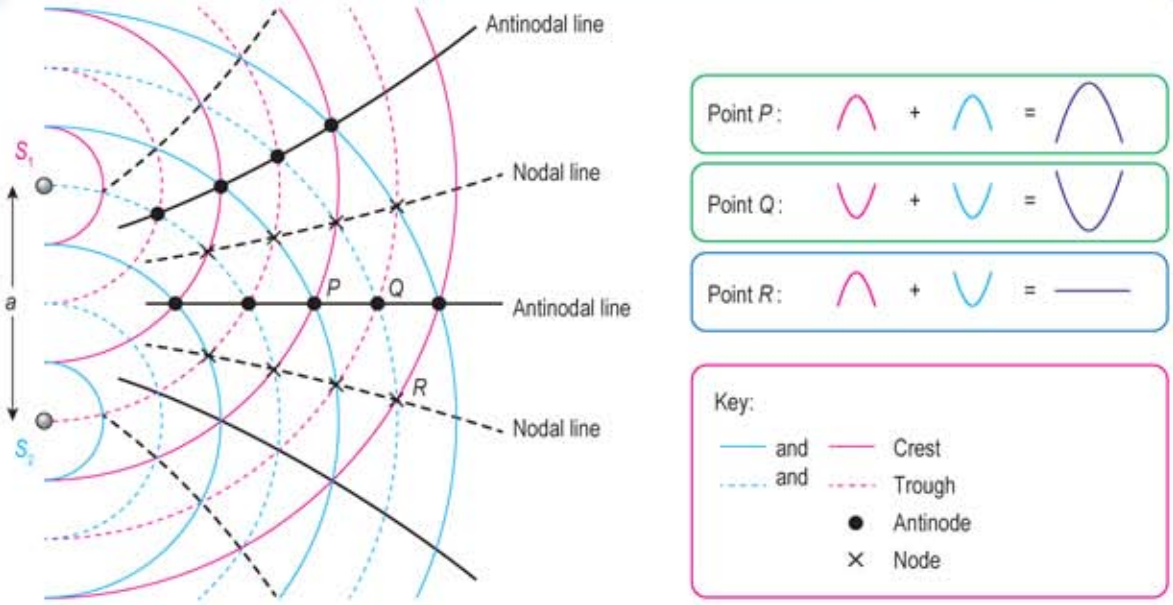


Figure 5.63 *Interference pattern of waves*

Activity 5.20

Aim: To draw pattern of interference of waves

Materials: A4 size white paper, compass, colour pencil and ruler

Instructions:

1. Work in groups.
2. Draw the pattern of interference *A* as shown in Figure 5.63.
   Use the following measurements:
   (a) Distance between coherent sources, a = 4 cm.
   (b) Wavefronts of radii 1 cm, 2 cm, 3 cm, 4 cm, 5 cm, 6 cm and 7 cm.
3. On the diagram that you have drawn in step 2:
   (a) Mark all the antinodes and nodes
   (b) Draw three antinodal lines and two nodal lines
4. Draw the pattern of interference *B* with the following measurements:
   (a) Distance between coherent sources, a = 6 cm.
   (b) Wavefronts of radii 1 cm, 2 cm, 3 cm, 4 cm, 5 cm, 6 cm and 7 cm.
5. Draw the pattern of interference *C* with the following measurements:
   (a) Distance between coherent sources, a = 4 cm.
   (b) Wavefronts of radii 1.5 cm, 3.0 cm, 4.5 cm, 6.0 cm and 7.5 cm.

6. On the diagrams that you have drawn in steps 4 and 5, draw three antinodal lines and two nodal lines.

Discussion:

1. Based on the patterns of interference *A* and *B*, describe the difference in the pattern of interference when the distance of separation between sources increases.
2. Based on the patterns of interference *A* and *C*, describe the difference in the pattern of interference when wavelength increases.
3. How does the distance between antinodal lines change at positions further from the coherent sources?

Relationship between Variables of Interference of Waves

In the pattern of interference of waves, there are four variables namely λ, a, x and D which are related to the interference pattern of waves.

λ = wavelength
a = distance of separation between two coherent sources
x = distance of separation between two adjacent antinodal lines or two adjacent nodal lines
D = the perpendicular distance from the sources and the position where the value of x is measured

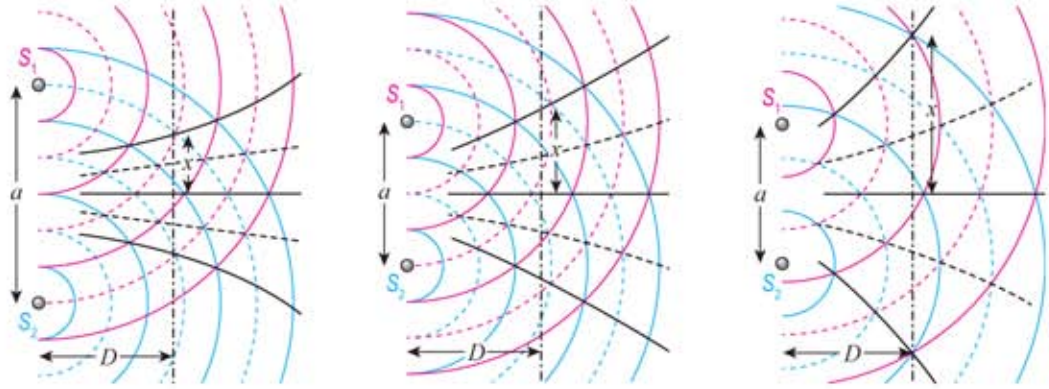
Activity 5.21

Algorithms ICS

Aim: To study the relationship between λ, a, x and D

Instructions:

1. Work in pairs.
2. You are given three patterns of interference of waves in Figure 5.64.



Pattern 1 Pattern 2 Pattern 3

Figure 5.64 *Pattern of interference of waves*

3. From Pattern 1 and Pattern 2:
   (a) Determine the constant variable.
   (b) What is the relationship between x and a?
4. From Pattern 2 and Pattern 3:
   (a) Determine the constant variable.
   (b) Compare the wavelength, λ.
   (c) What is the relationship between x and λ?
5. From Pattern 3, determine the relationship between x and D.

In the pattern of interference of water, sound and light waves, variables λ, a, x and D are mutually dependent on one another. Through Activity 5.21, we can interrelate the four variables as $x = \frac{\lambda D}{a}$. From the formula, we can determine the wavelength, λ as follows:

$$\lambda = \frac{ax}{D}$$

Solving Problems Involving Interference of Waves

Example 1

Figure 5.65 shows Young's double-slit experiment which produces interference pattern on the screen. The distance between adjacent bright fringes is 4.5 mm. What is the wavelength of the light used?

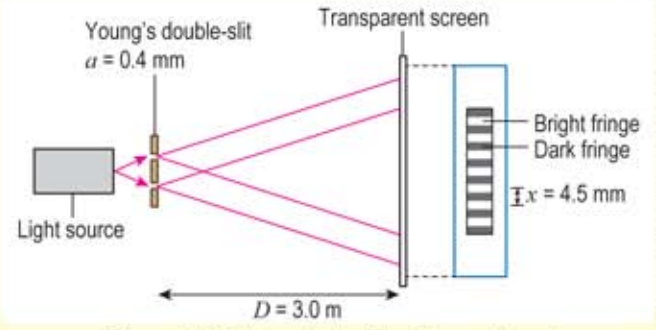


Figure 5.65 Young's double-slit experiment

Solution:

Separation of slit, $a = 0.4$ mm
$= 0.4 \times 10^{-3}$ m

Distance between adjacent bright fringes, $x = 4.5$ mm
$= 4.5 \times 10^{-3}$ m

Distance between screen and double slit, $D = 3.0$ m

Wavelength, $\lambda = \frac{ax}{D}$

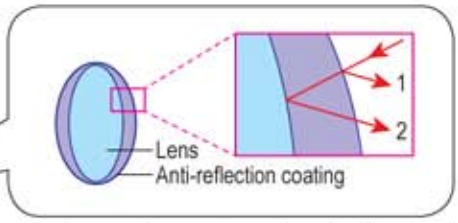
$$= \frac{(0.4 \times 10^{-3})(4.5 \times 10^{-3})}{3.0}$$

$$= 6.0 \times 10^{-7} \text{ m}$$

Applications of Interference of Waves in Daily Life

Knowledge on interference of waves is widely used in our daily life. Figure 5.66 shows examples of applications of interference of water, light and sound waves.

Bulbous bow generates water waves which interfere destructively with the water waves around the hull. This causes the water around the ship to become calmer and thus, reduces water drag.



Coating on the surface of anti-reflection lens causes reflected light to interfere destructively. This helps to improve vision.

Microphone and transmitter system in head phones used on aeroplanes produces sound waves which interfere destructively with the surrounding noise.

Figure 5.66 *Applications of interference of waves in daily life*

Activity 5.22

ICS ISS

Aim: To search for information related to application of interference of waves in daily life

Instructions:

1. Work in groups.
2. Surf the Internet to search for information related to applications of interference of waves in daily life.
3. Present your findings in the form of an interesting multimedia presentation.

Formative Practice 5.6

1. Figure 5.67 shows Young's double-slit experiment.

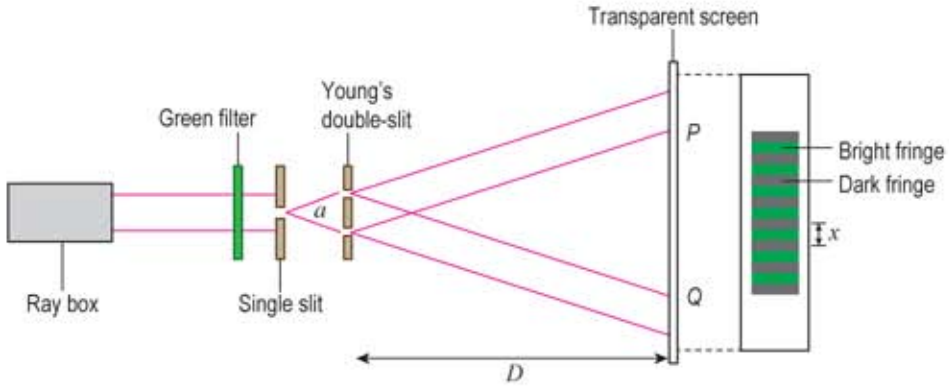


Figure 5.67

(a) State the phenomenon that occurs when light passes through the single slit.

(b) What will happen to the two light rays in the area PQ on the screen?

(c) Describe the formation of bright fringes and dark fringes.

(d) In the apparatus set up of this experiment, $a = 0.30$ mm, $D = 2.5$ m and $x = 4.6$ mm. Calculate the wavelength, λ of the green light.

5.7 Electromagnetic Waves

Characteristics of Electromagnetic Waves

Figure 5.68 shows briefly the history of early scientific discoveries which brought about the present knowledge regarding electromagnetic waves.

1801	1862	1887	Early 20th century
Thomas Young showed that light is a wave through experiments on interference of light.	James Maxwell put forth the theory that light is an electromagnetic wave.	Heinrich Hertz generated a different kind of electromagnetic wave, that is radio wave.	Electromagnetic waves are made up of: 1. Gamma ray 2. X-ray 3. Ultraviolet ray 4. Visible light 5. Infrared ray 6. Microwave 7. Radio wave

Figure 5.68 *History of electromagnetic waves*

Electromagnetic waves are made up of an electric field and a magnetic field that oscillate perpendicularly to one another, as shown in Figure 5.69. What are the characteristics of electromagnetic waves?

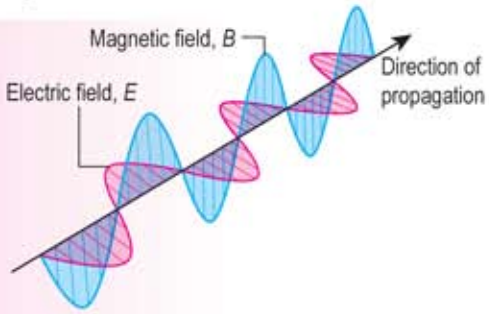


Figure 5.69 *Electromagnetic waves*

Activity 5.23

ICS

Aim: To search for information related to the characteristics of electromagnetic waves

Instructions:

1. Work in groups.
2. Search for information related to the characteristics of electromagnetic waves for the following aspects:
   (a) types of waves
   (b) requirement of medium for propagation
   (c) speed in vacuum
   (d) speed in medium
   (e) wave phenomena
3. Present your findings using a suitable mind map and put up on a notice board for information sharing.

Electromagnetic waves:
- are transverse waves
- do not need medium for propagation
- can propagate through vacuum
- have speed in vacuum, $c = 3.00 \times 10^8$ m s^{-1}, and move with lower speed in any medium.
- show phenomena of reflection, refraction, diffraction and interference under suitable conditions

Info File

- For electromagnetic waves, the formula $v = f\lambda$ is rewritten as $c = f\lambda$.
- Continuous spectrum means no specific boundary which separates two adjacent types of waves.

Electromagnetic Spectrum

Seven types of electromagnetic waves form a continuous spectrum known as electromagnetic spectrum. Figure 5.70 shows the electromagnetic spectrum.

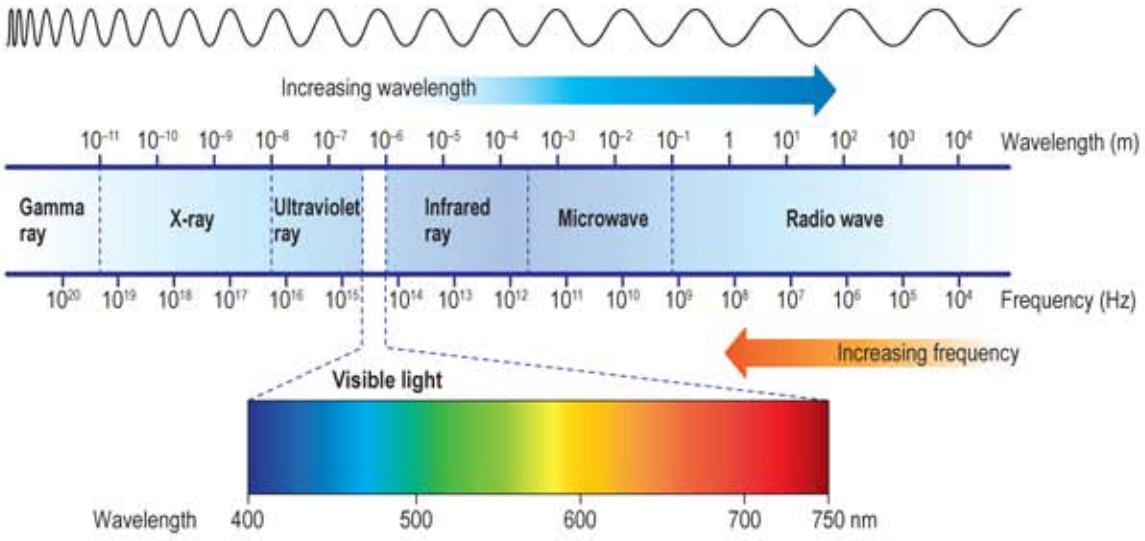


Figure 5.70 *Electromagnetic spectrum*

The energy carried by electromagnetic waves is directly proportional to its frequency. This means gamma ray and X-ray carry large amount of energy. These waves need to be handled properly as not to endanger the users.

DIY

Smartphone as a remote control device

Surf the Internet to get guidelines on how to configure smartphones to function as television or air conditioner remote control.

Applications of Electromagnetic Waves

Electromagnetic spectrum is made up of seven types of electromagnetic waves and covers a very wide range of wavelengths. As such, applications of electromagnetic waves encompass various fields. With the rapid advancements in science and technology, new applications are discovered from time to time. What applications of electromagnetic waves do you know?

5.7.1 5.7.2 5.7.3

Table 5.11 Application for each type of electromagnetic wave in daily life

Type of wave	Application
Radio wave	• Long distance radio communication • Local radio and TV broadcasting • Wireless communication (*Bluetooth, Wifi, Zigbee and Z-Wave*) • Millimeter-wave machine to scan body of passengers at airport 
Microwave	• International communication through use of satellite • Mobile phone framework • Communication between electronic devices: *Wifi*, *Bluetooth*, *Zigbee*, *Z-Wave* • Detection of plane radar and speed trap • Cooking using microwave oven 
Infrared ray	• For cooking (oven, grill and toaster) • For night vision (infrared camera and infrared binoculars) • Drying paint on car • Treatment of muscle pain • Remote control device for television and DVD player 
Visible light	• Enables living things to see • Photography • Photosynthesis in green plants • Laser light used in cutting of metal, measurement of land and sending of information through optical fibres 
Ultraviolet ray	• Hardens tooth filling material • Determines authenticity of currency notes • Treatment of jaundice in babies • Purification of drinking water • Sterilising surgical instruments and food • Insect traps 
X-ray	• Detects fractures or broken bones and examines internal organs • Checking of welding connections • Baggage scanning at airport • Determines authenticity of paintings 
Gamma ray	• Kills cancer cells in radiotherapy • Sterilisation of surgical and medical equipment in bulk • Used in food processing industry so that food can last longer 

Activity 5.24

Evaluation CPS ICS STEM

Aim: To gather information regarding application of each component of the electromagnetic spectrum in daily life to raise awareness through STEM approach

Instructions:

1. Work in groups.
2. By referring to Table 5.11 on page 222, gather more detailed information regarding applications of electromagnetic waves.
3. Choose the electromagnetic wave that is used widely by each group of society and gather the following information:
   (a) factors that cause over-exposure to the electromagnetic wave that you have chosen
   (b) potential harmful effects to users due to exposure to the electromagnetic wave
   (c) steps to be taken to reduce exposure to the electromagnetic wave
4. Discuss information that is needed and complete the K-W-L Chart.
5. Present the information in the forms of a printed and an electronic pamphlets.
6. Get feedback from friends and teachers regarding the pamphlet prepared. Then, improve the pamphlet before distribution.

Download K-W-L Chart

http://bt.sasbadi.com/p4223

Formative Practice 5.7

1. Figure 5.71 shows an electromagnetic spectrum.

A	X-ray	*B*	Visible light	Infrared ray	*C*	Radio wave

Figure 5.71

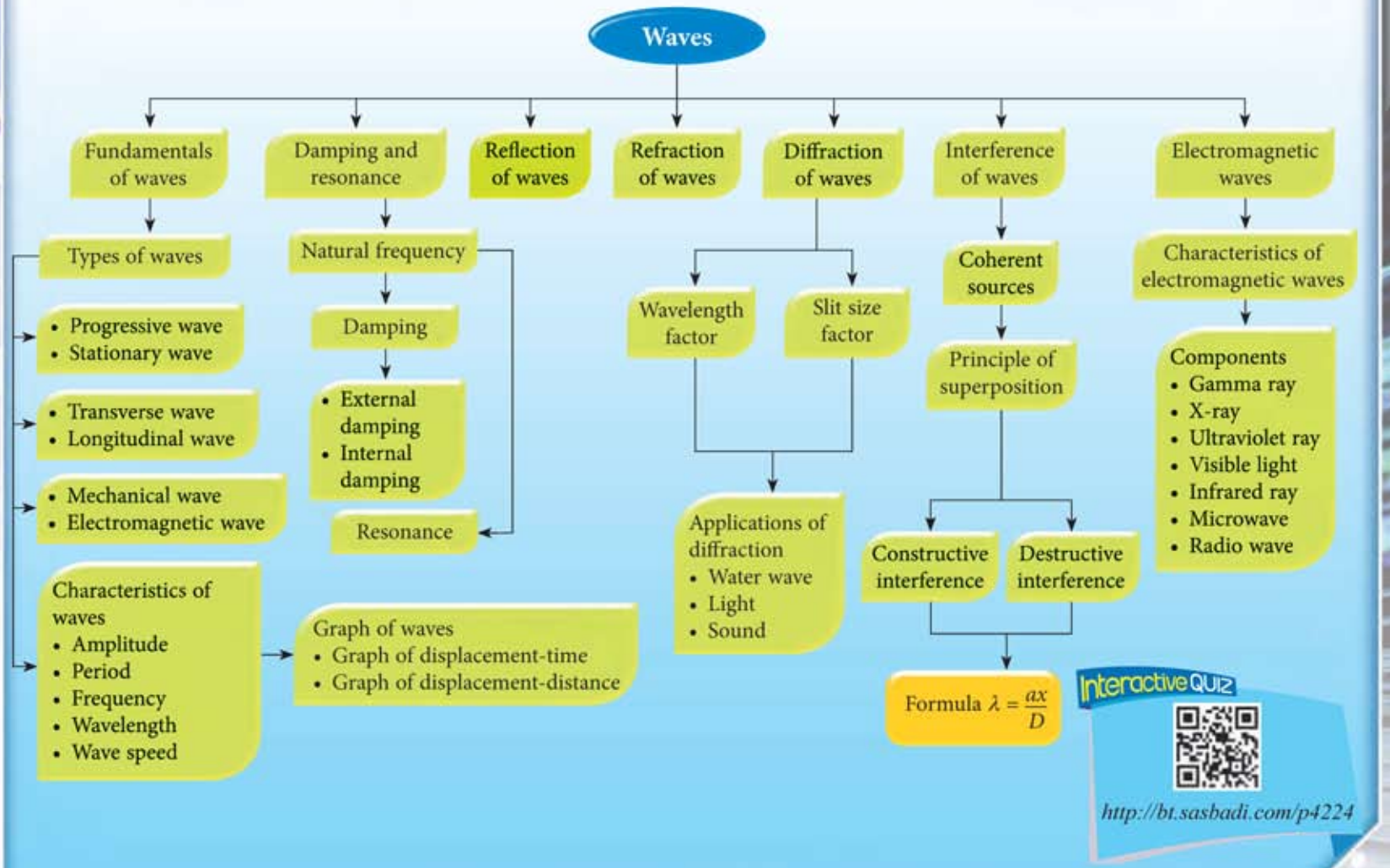
What are waves *A*, *B* and *C*?

2. Arrange the electromagnetic waves below according to the order of increasing frequency.

Infrared ray	X-ray	Microwave	Gamma ray	Radio wave

3. In the air, blue light with a wavelength of 420 nm moves at a speed of 3.00×10^8 m s^{-1}. The speed of the blue light reduces to 2.25×10^8 m s^{-1} when passing through a liquid. What is the wavelength of the blue light in the liquid?

Conceptual Framework



SELF-REFLECTION

1. New things I learnt in the chapter on waves are _____.
2. The most interesting thing I learnt in the chapter on waves is _____.
3. Things I still do not fully understand or comprehend are _____.
4. My performance in this chapter,

   Poor | 1 | 2 | 3 | 4 | 5 | Excellent

5. I need to _____ to improve my performance in this chapter.

Download and print Self-reflection Chapter 5

http://bt.sasbadi.com/p4225

Performance Evaluation

1. Figure 1 shows a port and the area around it.
   (a) State the wave phenomena that occur when sea waves
      (i) collide with the embankment of the port at *A*,
      (ii) move towards the beach at *B*, and
      (iii) pass through the entrance of the port at *C*.
   (b) Draw the wavefronts after the waves pass *C*.
   (c) What is the effect on the waves if the entrance of the port is widened?

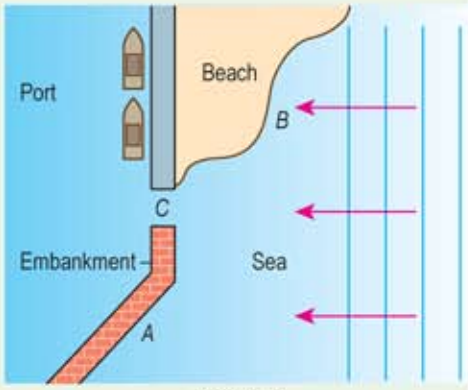


Figure 1

2. Figure 2 shows the wavefront of water waves approaching a barrier. Complete Figure 2 by sketching the wavefront after passing around the barrier.

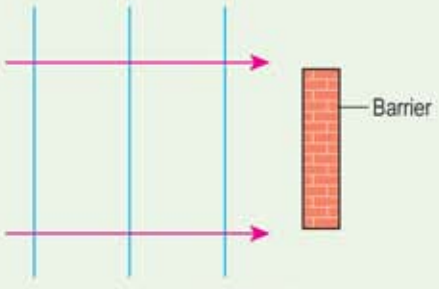


Figure 2

3. Figure 3 shows superposition of two coherent plane waves.

(a) What is a coherent wave?

(b) State the points where the following occur

(i) constructive interference,

(ii) destructive interference.

(c) Explain with suitable diagrams, interference at point

(i) *Q*,

(ii) *R*, and

(iii) *S*.

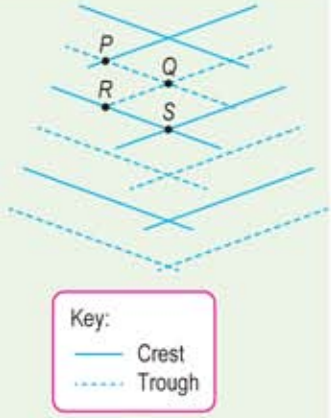


Figure 3

4. Figure 4 shows the apparatus set up of Young's double-slit experiment.

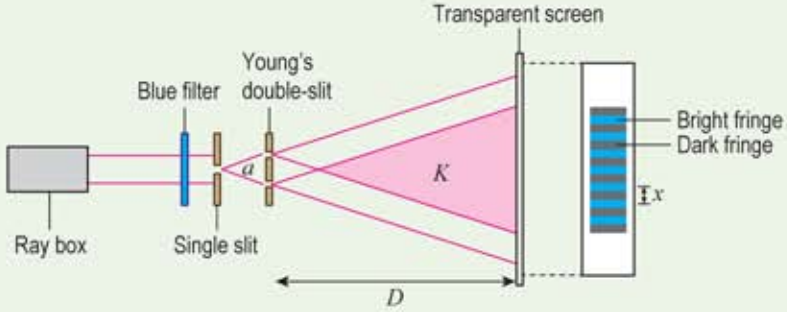


Figure 4

(a) What happens to the light rays at area *K*?

(b) Explain the formation of bright fringes and dark fringes on the screen.

(c) You are given the following information:

- Distance between double slits, $a = 0.30$ mm
- Distance between double-slits and screen, $D = 2.70$ m
- Separation distance between two adjacent bright fringes, $x = 4.0$ mm

Calculate the wavelength, λ of blue light in this experiment.

5. A student moves a slinky spring repeatedly at a frequency of 5 Hz so that a transverse wave is produced as shown in Figure 5.

(a) Determine the amplitude, period and wavelength of the wave.

(b) Calculate the wave speed along the slinky spring.

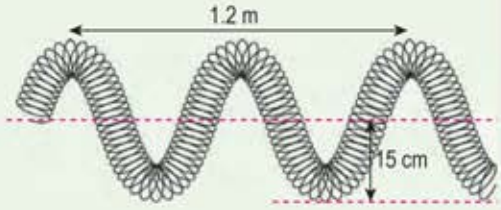


Figure 5

6. A judge blew a whistle which produced a sound of frequency 500 Hz and a wavelength of 0.67 m in the air. What is the wave speed of the sound?

7. Figure 6 shows a tuning fork vibrating and producing sound waves.

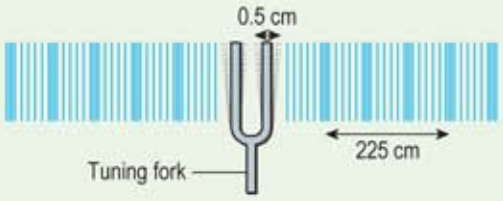


Figure 6

Based on Figure 6, determine the
(a) amplitude of the sound waves,
(b) wavelength of the sound waves,
(c) speed of the sound waves produced when the tuning fork vibrates with a frequency of 440 Hz.

8. Figure 7 shows an image of water waves moving from a deep water region to a shallow water region.

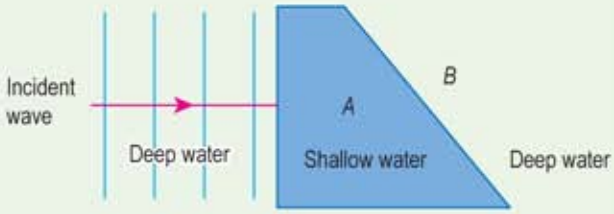


Figure 7

(a) In Figure 7, draw the pattern of wavefront in region *A* and region *B*.

(b) Given that the speed of water waves in the shallow water region and deep water region are 4.0 m s^{-1} and 9.0 m s^{-1} respectively. Wavelength of water waves in the shallow water region is 2 m. Calculate the wavelength of water waves in the deep water region.

9. Figure 8 shows the graph of displacement against time which represents the oscillation of a pendulum.

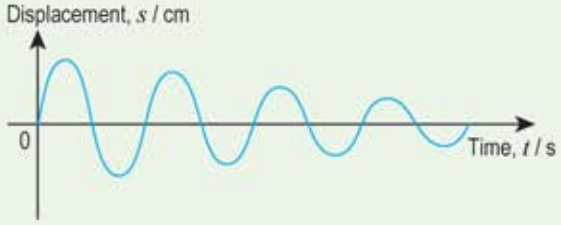


Figure 8

Based on the graph, answer the following questions:
(a) What happens to the amplitude of the oscillating pendulum?
(b) What phenomenon is experienced by the oscillating pendulum?
(c) What is the main reason for the phenomenon?
(d) How is the pendulum able to keep oscillating?

10. Figure 9 shows the pattern of interference produced by three coloured lights in an experiment.

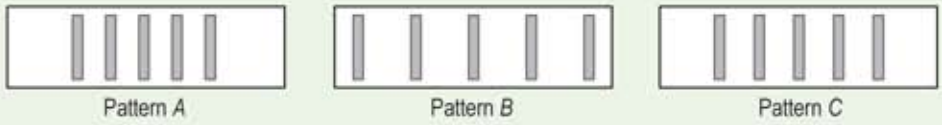


Figure 9

Table 1 shows the coloured lights used in this experiment and the values of wavelength. Complete Table 1 by matching the coloured lights with patterns *A*, *B* and *C*.

Table 1

Colour	Wavelength / nm	Pattern of interference
Blue	400	
Green	550	
Red	700	

Justify your answer.

11. Figure 10 shows a system of communication which involves direct transmission of electromagnetic wave signals from a transmitting station to a receiving station. The distance between the two distant stations and the shape of the Earth cause the receiving station to be unable to receive clear signals directly from the transmitter. You are required to give several proposals to improve the quality of transmission of signal.

Figure 10

Explain your proposal based on the following aspects:

(a) type of wave broadcasted
(b) frequency of wave
(c) method which enables the wave to propagate through a further distance
(d) locations of transmitter and receiver

Enrichment Corner

12. Kompleks Pendaratan Ikan LKIM is a place where fishermen anchor their ship and bring ashore their catch. The river estuary becomes the entrance for ships to dock at the complex. Photograph 1 shows an example of a river estuary.

Photograph 1

*(**Source**: Image ©2019 TerraMetrics, Image ©2019 Maxar Technologies)*

Assume you are an engineer who is an expert in reflection, refraction and diffraction of waves. You are required to propose characteristics of the design of the building structure to ensure the fishermen's ships can pass through the river estuary safely based on the following aspects:

(a) building structure that can reduce the height of waves
(b) characteristics of the building structure that can reduce the effects of erosion
(c) depth of the river estuary to enable ships to pass through the estuary safely

13. Your new school hall is supplied with a Public Address (PA) system which consists of two loudspeakers, a microphone and a control station made up of an amplifier equipped with USB and DVD slots. You are required to propose the installation of the PA system so that the sound can be heard clearly by the audience. Sketch the layout of the hall and explain your proposal based on the following aspects:

(a) location of loudspeakers
(b) distance between loudspeakers
(c) location of microphone
(d) location of control station