TOPIC 1 Waves

SQ 7.1.1 How is energy transferred through a medium?

Answer

In a medium, energy is transferred due to the regular and repeated disturbances that travel through the medium, making its particles move up and down or back and forth.

SQ 7.1.2 Explain wave motion using the example of a stone thrown into a pond.

Explanation

The stone produces a disturbance, that is a ripple, which travels through the water.

The water particles move up and down about their mean positions, creating a repeating pattern known as a wave that spreads out.

SQ 7.1.3 Define the displacement of a particle of a wave.

Definition

The displacement of a particle of a wave is its distance in a specified direction from its rest or equilibrium position.

SQ 7.1.4 How is a waveform obtained graphically?

Answer

If the displacement is plotted along the y-axis and the time in the direction of energy travel along the x-axis, we get a waveform.

SQ 7.1.5 Define amplitude of a wave.

Definition

Amplitude is the maximum displacement of the wave, or of the particles of the medium, from its equilibrium position.

SQ 7.1.6 Define frequency of a wave.

Definition

Frequency is the number of oscillations or vibrations or cycles per second.

SQ 7.1.7 Define wavelength of a wave.

Definition

Wavelength is the distance between two consecutive similar points on the wave that are in phase.

SQ 7.1.8 Define time period of a wave.

Definition

The period is the time taken by the wave to complete one oscillation or cycle. It is the reciprocal of the frequency.

Formula

$$T = \frac{1}{f}$$

SQ 7.1.9 Derive the wave speed equation.

Derivation

If a wave crest moves one wavelength in one period of oscillation T, then

$$v = \frac{\lambda}{T}$$

Since

$$\frac{1}{T} = f$$

Result

$$v = f\lambda$$

SQ 7.1.10 Define the phase of a wave.

Definition

Phase is the relative position of a point on the wave at a given time.

SQ 7.1.11 What are mechanical waves? Give examples.

Definition

Mechanical waves require a physical medium, that is a solid, liquid or gas, to propagate.

Examples

Water waves, sound waves and seismic waves are mechanical waves.

SQ 7.1.12 What are electromagnetic waves? Give examples.

Definition

Electromagnetic waves do not require a medium to propagate, and therefore can travel through vacuum.

Examples

Radio waves, microwaves, infrared waves, visible light, ultraviolet waves, X-rays and gamma rays.

SQ 7.1.13 What are quantum waves? Give examples.

Definition

Quantum waves are associated with particles like electrons and photons.

Examples

Matter waves or de-Broglie waves, such as electron waves in atoms, and photon waves.

SQ 7.1.14 What are surface waves? Give examples.

Definition

Surface waves propagate along surfaces or interfaces between two mediums.

Examples

Ocean surface waves driven by wind, and seismic surface waves.

SQ 7.1.15 Define a transverse wave.

Definition

A transverse wave is one in which the vibrations of the particles are at right angles to the direction in which the energy of the wave is travelling.

SQ 7.1.16 **Define a longitudinal wave.**

Definition

A longitudinal wave is one in which the direction of vibration of the particles is along or parallel to the direction in which the energy of the wave is travelling.

SQ 7.1.17 **Distinguish between longitudinal and transverse waves.**

Longitudinal Waves	Transverse Waves
The particles vibrate parallel to the direction of energy travel.	The particles vibrate at right angles to the direction of energy travel.
They consist of compressions and rarefactions.	They consist of crests and troughs.
Sound waves are an example.	Light waves are an example.

TOPIC 2 Principle of Superposition of Waves

SQ 7.2.1 **State the principle of superposition of waves.**

Statement

If a particle of the medium is simultaneously acted upon by two waves, then the resultant displacement of the particle is the algebraic sum of their individual displacements.

SQ 7.2.2 **Write the principle of superposition for n waves.**

Formula

$y = y_1 + y_2 + \cdots + y_n$

This is the algebraic sum of all the displacements of the individual waves.

SQ 7.2.3 **Write the resultant displacement of two waves having the same phase.**

Formula

$y = y_1 + y_2$

If

$y_1 = y_2$

then the resultant displacement is

$y = 2y_1$

SQ 7.2.4 **Write the resultant displacement of two waves having opposite phase.**

Formula

$y = y_1 - y_2$

If

$y_1 = y_2$

then the resultant displacement is

$y = 0$

SQ 7.2.5 **What does the wave function y(x,t) represent?**

Answer

In the context of waves, $y(x, t)$ represents the wave displacement at a given point x and time t. It describes the shape of the wave and its evolution over time.

SQ 7.2.6 **To which type of waves does the principle of superposition apply?**

Answer

The principle of superposition applies to linear waves or small amplitude waves.

SQ 7.2.7 **Which three phenomena arise from the principle of superposition?**

Interference

Two waves having the same frequency and travelling in the same direction.

Beats

Two waves of slightly different frequencies travelling in the same direction.

Stationary Waves

Two waves of equal frequency travelling in opposite directions.

SQ 7.2.8 **How do noise-cancelling headphones work?**

Working

The headphones contain microphones that capture ambient noise and send the signals to a processing unit.
The processing unit generates an “anti-noise” signal, which is the exact opposite of the ambient noise in amplitude and phase.

Result

When the anti-noise signal meets the ambient noise, the two waves cancel each other out, resulting in a much quieter listening experience.

TOPIC 3 Interference and Its Types

SQ 7.3.1 **Define interference of waves.**

Definition

Superposition of two waves having the same frequency and travelling in the same direction results in a phenomenon called interference.

SQ 7.3.2 **Describe the experimental setup to observe interference of sound waves.**

Setup

Two loud speakers act as two sources of harmonic sound waves of a fixed frequency produced by an Audio Generator. A microphone attached to a sensitive Cathode Ray Oscilloscope acts as a detector of sound waves.

SQ 7.3.3 **What are coherent sources?**

Definition

Since the two speakers are driven from the same generator, they vibrate in phase. Such sources of waves are called coherent sources.

SQ 7.3.4 **What is a CRO used for in the interference experiment?**

Answer

The CRO is a device to display the input signal as a waveform on its screen.

SQ 7.3.5 **Define constructive interference.**

Definition

Whenever the path difference is an integral multiple of wavelength, the two waves are added up. This effect is called constructive interference.

SQ 7.3.6 **Write the condition for constructive interference.**

Formula
$\Delta S = n\lambda$
Here
$n = 0, \pm1, \pm2, \pm3, \ldots$

SQ 7.3.7 **What is observed on the CRO screen during constructive interference?**

Answer
A compression meets a compression and a rarefaction meets a rarefaction, so the displacements are added up and a large resultant displacement is seen on the CRO screen.

SQ 7.3.8 **Define destructive interference.**

Definition
At points where the displacements of two waves cancel each other's effect, the path difference is an odd integral multiple of half the wavelength. This effect is called destructive interference.

SQ 7.3.9 **Write the condition for destructive interference.**

Formula
$$\Delta S = (2n+1)\frac{\lambda}{2}$$
Here
$n = 0, \pm1, \pm2, \pm3, \ldots$

SQ 7.3.10 **What is observed on the CRO screen during destructive interference?**

Answer
A compression meets a rarefaction, so they cancel each other's effect and the resultant displacement becomes zero on the CRO screen.

SQ 7.3.11 **Differentiate between constructive and destructive interference.**

Constructive Interference	Destructive Interference
The path difference is an integral multiple of the wavelength.	The path difference is an odd integral multiple of half the wavelength.
A compression meets a compression.	A compression meets a rarefaction.
A large resultant displacement is produced.	The resultant displacement becomes zero.

SQ 7.3.12 **What are the conditions for interference to occur?**

Conditions
The two waves must have the same frequency and must travel in the same direction.
The sources must be coherent, that is they must vibrate in phase.

SQ 7.3.13 **Two speakers 3.0 m apart emit 344 Hz. A microphone moves along a line 4.0 m away. Find the path difference at the first maximum.**

Solution
By Pythagoras' theorem
$S_2P_1 = \sqrt{(3)^2 + (4)^2} = 5\,\text{m}$
The path difference is $S_2P_1 - S_1P_1$.
Result
$\lambda = 5\,\text{m} - 4\,\text{m} = 1\,\text{m}$

SQ 7.3.14 **For a 344 Hz tone with wavelength 1 m, find the speed of sound.**

Solution
$v = f\lambda = 344 \times 1$
Result
$v = 344\,\text{m}\,\text{s}^{-1}$

SQ 7.3.15 **A radio signal has λ = 1500 m at 200 kHz. Find the speed of radio waves.**

Solution
$v = f_1\lambda_1 = 2.0 \times 10^5 \times 1500$
Result
$v = 3.0 \times 10^8\,\text{m}\,\text{s}^{-1}$

SQ 7.3.16 **Find the wavelength of a transmitter operating at 1000 kHz.**

Solution
$$\lambda_2 = \frac{v}{f_2} = \frac{3 \times 10^8}{1 \times 10^6}$$
Result
$\lambda_2 = 3 \times 10^2\,\text{m}$

TOPIC 4 Stationary Waves and Their Formation

SQ 7.4.1 **What are stationary waves?**

Definition
Stationary waves, also known as standing waves, are waves that oscillate in a fixed position without moving or propagating.

SQ 7.4.2 **How are stationary waves formed?**

Formation
They are formed by the superposition of two waves with the same frequency and amplitude, travelling in opposite directions.

SQ 7.4.3 **What is meant by the term standing wave?**

Answer
The term standing wave describes that the wave pattern remains fixed in space, oscillating between positive and negative values, without moving forward or backward.

SQ 7.4.4 **Define nodes.**

Definition
Nodes are the points of the medium whose resultant displacement is always zero.

SQ 7.4.5 **Define antinodes.**

Definition

Antinodes are the points which move with an amplitude that is the sum of the amplitudes of the component waves. They are situated midway between the nodes.

SQ 7.4.6 **What is the distance between two consecutive nodes?**

Answer

The distance between two consecutive nodes is $\frac{\lambda}{2}$.

SQ 7.4.7 **What is the distance between a node and the next antinode?**

Answer

The distance between a node and the next antinode is $\frac{\lambda}{4}$.

SQ 7.4.8 **Why can energy not flow past the nodes of a stationary wave?**

Reason

Energy in a wave transfers because of the motion of the particles of the medium. The nodes always remain at rest, so energy cannot flow past these points.

SQ 7.4.9 **How does energy alternate in a stationary wave?**

Answer

Energy remains standing in the medium between nodes, although it alternates between potential and kinetic forms at the antinodes.

Detail

When the antinodes are at their extreme displacements the energy is wholly potential, and when they pass through their equilibrium positions the energy is wholly kinetic.

SQ 7.4.10 **Give examples of stationary waves.**

Examples

Waves on a string, and sound waves in a pipe.

TOPIC 5 Stationary Waves on a Stretched String

SQ 7.5.1 **How are stationary waves produced on a string plucked at its middle point?**

Formation

Two transverse waves originate from the plucked point, one moving towards each end of the string. When these waves reach the clamped ends they are reflected back, thus giving rise to stationary waves.

SQ 7.5.2 **Why are nodes formed at the two ends of a stretched string?**

Reason

As the two ends of the string are clamped, no motion can take place there, so nodes are formed at the two ends.

SQ 7.5.3 **Write the wavelength for the first mode of vibration of a stretched string.**

Derivation

In the first mode the string vibrates in one loop, so

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

Result

$$\lambda_1 = 2\ell$$

SQ 7.5.4 **On what does the speed of waves in a stretched string depend?**

Answer

The speed depends upon the tension F of the string and the mass per unit length m. It is independent of the point from where the string is plucked.

Formula

$$v = \sqrt{\frac{F}{m}}$$

SQ 7.5.5 **Write the fundamental frequency of a stretched string.**

Derivation

Since

$$f_1 = \frac{v}{\lambda_1}$$

and

$$\lambda_1 = 2\ell$$

therefore

Result

$$f_1 = \frac{1}{2\ell}\sqrt{\frac{F}{m}}$$

SQ 7.5.6 **What happens when a string is plucked at one quarter of its length?**

Answer

Stationary waves are again set up, but now the string vibrates in two loops. This configuration develops because the string was plucked from the position of an antinode.

SQ 7.5.7 **Write the wavelength for the second mode of vibration of a string.**

Derivation

Since the string vibrates in two loops,

$$\ell = \frac{\lambda_2}{2} + \frac{\lambda_2}{2}$$

Result

$$\lambda_2 = \ell$$

SQ 7.5.8 **Show that the second harmonic frequency is double the fundamental.**

Derivation

Since

$$f_2 = \frac{v}{\lambda_2} = \frac{v}{\ell}$$

multiplying and dividing by 2 gives

$$f_2 = 2\left(\frac{v}{2\ell}\right)$$

Result

$$f_2 = 2f_1$$

SQ 7.5.9 Write the frequency when a string vibrates in n loops.

Formula

$f_n = n\left(\frac{v}{2\ell}\right) = nf_1$

Here

$n = 1, 2, 3, \ldots$

SQ 7.5.10 Write the wavelength when a string vibrates in n loops.

Formula

$\lambda_n = \frac{2\ell}{n}$

SQ 7.5.11 What happens to frequency and wavelength as the number of loops increases?

Answer

As the string vibrates in more than one loop, its frequency goes on increasing and the wavelength gets correspondingly shorter. However, the product $f\lambda$ is always equal to v.

SQ 7.5.12 What is a harmonic series?

Definition

The stationary waves have a discrete set of frequencies $f_1, 2f_1, 3f_1, \ldots, nf_1$, which is known as the harmonic series.

SQ 7.5.13 Define fundamental frequency and harmonics.

Fundamental Frequency

The lowest characteristic frequency of vibration f_1 corresponds to the first harmonic.

Harmonics

The frequency

$f_2 = 2f_1$

corresponds to the second harmonic, and so on.

SQ 7.5.14 What is meant by quantization of frequencies?

Definition

Quantum jumps in frequency exist between the resonance frequencies. This phenomenon is known as the quantization of frequencies, and it means

$f_n = nf_1$

where n is an integer.

SQ 7.5.15 What happens to waves which are not in the harmonic series?

Answer

Waves which are not in the harmonic series are quickly damped out.

SQ 7.5.16 How can the frequency of a string on a musical instrument be changed?

Answer

The frequency can be changed either by varying the tension or by changing the length.

Example

The tension in guitar and violin strings is varied by tightening the pegs on the neck. Once tuned, musicians vary the frequency by moving their fingers along the neck.

SQ 7.5.17 A 120 cm string fixed at both ends vibrates in four segments. Find its wavelength.

Solution

Since

$\ell = \frac{n\lambda_n}{2}$

with

$n = 4$

therefore

$\lambda_n = \frac{2\ell}{n} = \frac{2 \times 1.2}{4}.$

Result

$\lambda_n = 0.6\,\text{m}$

SQ 7.5.18 A string vibrating in four segments has a frequency of 120 Hz. Find its fundamental frequency.

Solution

Since

$f_n = nf_1$

with

$n = 4$

therefore

$f_1 = \frac{120}{4}.$

Result

$f_1 = 30\,\text{Hz}$

TOPIC 6 Stationary Waves in Air Columns

SQ 7.6.1 What is an organ pipe?

Definition

An organ pipe is a wind instrument in which sound is produced due to the setting up of stationary waves in an air column. It consists of a hollow long tube with both ends open, or with one end open and the other closed.

SQ 7.6.2 Why does an open end of a pipe behave as an antinode?

Reason

If the reflecting end is open, the air molecules have complete freedom of motion, and this behaves as an antinode.

SQ 7.6.3 Why does a closed end of a pipe behave as a node?

Reason

If the reflecting end is closed, it behaves as a node because the movement of the molecules is restricted.

SQ 7.6.4 Describe the fundamental mode of an organ pipe open at both ends.

Description

There is only one node at the middle of the pipe, and since both ends are open there are two antinodes at the ends.

Result

$\ell = \frac{\lambda_1}{2} \quad \text{so} \quad \lambda_1 = 2\ell$

SQ 7.6.5 **Write the fundamental frequency of an organ pipe open at both ends.**

Formula

$$f_1 = \frac{v}{2\ell}$$

SQ 7.6.6 **Describe the second mode of vibration of an open organ pipe.**

Description

In the second mode of vibration there are three antinodes and two nodes.

Result

$$\lambda_2 = \ell \quad \text{and} \quad f_2 = \frac{v}{\ell} = 2f_1$$

SQ 7.6.7 **Write the frequency and wavelength for the nth mode of an open organ pipe.**

Formulas

$$f_n = n\left(\frac{v}{2\ell}\right) = nf_1$$

$$\lambda_n = \frac{2\ell}{n}$$

Here

$n = 1, 2, 3, \ldots$

SQ 7.6.8 **Describe the fundamental mode of an organ pipe closed at one end.**

Description

At the closed end there is a node and at the open end an antinode, so the fundamental mode has one node and one antinode.

Result

$$\ell = \frac{\lambda_1}{4} \quad \text{so} \quad \lambda_1 = 4\ell$$

SQ 7.6.9 **Write the fundamental frequency of an organ pipe closed at one end.**

Formula

$$f_1 = \frac{v}{4\ell}$$

SQ 7.6.10 **Describe the second mode of vibration of a closed organ pipe.**

Description

The second mode of vibration contains two nodes and two antinodes.

Result

$$\lambda_2 = \frac{4\ell}{3} \quad \text{and} \quad f_2 = \frac{3v}{4\ell} = 3f_1$$

SQ 7.6.11 **Write the frequency and wavelength for the nth mode of a closed organ pipe.**

Formulas

$$f_n = n\left(\frac{v}{4\ell}\right) = nf_1$$

$$\lambda_n = \frac{4\ell}{n}$$

Here

$n = 1, 3, 5, \ldots$

SQ 7.6.12 **Which organ pipe is richer in harmonics and why?**

Answer

The pipe which is open at both ends is richer in harmonics than the pipe closed at one end.

Reason

In an open pipe all the harmonics are present, while in a closed pipe only the odd harmonics are present.

SQ 7.6.13 **What is the primary driving mechanism in an organ pipe?**

Answer

In an organ pipe the primary driving mechanism is a wavering, sheet-like jet of air from a flue-slit, which interacts with the upper lip and the air column in the pipe to maintain a steady oscillation.

TOPIC 7 Experiment Demonstrating Stationary Waves Using Microwaves

SQ 7.7.1 **What are microwaves and why are they so called?**

Definition

Microwaves are a form of electromagnetic radiation. They are called “micro” waves because their wavelengths are typically of the order of millimetres or centimetres, much shorter than radio waves.

SQ 7.7.2 **How are stationary waves produced by microwaves?**

Answer

Stationary waves can be produced when microwaves are confined to a specific region or cavity, such as a wave guide or a resonant chamber. In these structures microwaves bounce back and forth, creating a standing wave pattern with nodes and antinodes.

SQ 7.7.3 **When does a stationary microwave pattern occur in a cavity?**

Answer

It occurs when the microwave frequency matches the resonant frequency of the cavity.

SQ 7.7.4 **Name the apparatus used to demonstrate stationary waves using microwaves.**

Apparatus

The experimental setup consists of a microwave source or transmitter, a probe detector, and a metal reflector for the reflection of microwaves. All three are placed in line.

SQ 7.7.5 **Explain the working of the microwave stationary wave experiment.**

Working

The waves coming out of the microwave source move towards the metal plate and are then reflected back. The reflected wave and the incident wave superpose and create a stationary wave pattern.

Detection

This is detected by the probe detector placed between the transmitter and the metallic plate.

SQ 7.7.6 How is the wavelength found in the microwave stationary wave experiment?

Method

The plate or the detector is moved to observe the antinodes and nodes. By finding the distance from one antinode to the next antinode, the wavelength of the stationary wave can be found.

TOPIC 8 Diffraction of Waves

SQ 7.8.1 Define diffraction of waves.

Definition

Diffraction of waves is the bending of waves around the sharp edges or corners of obstacles, or the spreading of waves beyond a barrier.

SQ 7.8.2 When does diffraction occur?

Condition

It occurs when a wave encounters a physical barrier or an opening that is comparable in size to the wavelength of the wave.

SQ 7.8.3 How does wavelength affect the amount of diffraction?

Answer

The longer the wavelength, the greater the spreading, and vice versa.

SQ 7.8.4 In which types of waves can diffraction be observed?

Answer

Diffraction can be observed in various types of waves, including water waves, sound waves, light waves and electromagnetic waves.

SQ 7.8.5 Give two examples of diffraction.

Examples

Hearing of sound waves around corners or through a doorway, as sound waves bend around the corners.
Diffraction of X-rays by crystals, as the spacing between the regular arrays of atoms is of the order of the X-ray wavelength.

SQ 7.8.6 What is a ripple tank used for?

Answer

A ripple tank is a very useful apparatus not only to generate water waves, but also to demonstrate wave properties such as reflection, diffraction and refraction.

SQ 7.8.7 What does a ripple tank contain?

Contents

A ripple tank contains water, a vibrator such as a motorized oscillating needle, obstacles such as a small rectangular block or semicircular barrier, and gap widths of different sizes.

SQ 7.8.8 What is observed when the gap width is small compared to the wavelength?

Observation

When the gap width is small compared to the wavelength, diffraction is significant and the waves bend around the obstacle, creating a semicircular pattern.

SQ 7.8.9 What is observed when the gap width is large compared to the wavelength?

Observation

As the gap width increases relative to the wavelength, diffraction decreases and the waves pass through the gap with less bending.

SQ 7.8.10 A wave generator produces 500 pulses in 10 s. Find the frequency and time period.

Solution

$$f = \frac{\text{Number of pulses}}{\text{Time}} = \frac{500}{10}$$

Result

$$f = 50\,\text{Hz} \qquad T = \frac{1}{50} = 0.02\,\text{s}$$

TOPIC 9 Beats

SQ 7.9.1 Define beats.

Definition

Beats are produced by the superposition of two waves of slightly different frequencies travelling in the same direction, resulting in a periodic rise and fall in the loudness of sound.

SQ 7.9.2 Explain the formation of beats using two tuning forks.

Explanation

At some instant the displacements of the two waves are in the same direction, so the resultant displacement is large and a loud sound is heard.
A quarter of a second later the displacements are opposite, giving a minimum displacement, so a faint sound or no sound is heard.

SQ 7.9.3 Write the relation for the number of beats per second.

Statement

The number of beats per second is equal to the difference between the frequencies of the two tuning forks.

Formula

$$f_b = f_1 - f_2$$

SQ 7.9.4 Two tuning forks of 32 Hz and 30 Hz are sounded together. Find the number of beats.

Solution

$$f_b = f_1 - f_2 = 32 - 30$$

Result

$$f_b = 2\,\text{Hz}$$

SQ 7.9.5 **Why is it difficult to recognize beats when the frequency difference is large?**

Reason
When the difference between the frequencies of the two sounds is more than 10 Hz, it becomes difficult to recognize the beats.

SQ 7.9.6 **Define beat frequency.**

Definition
The difference between the frequencies of the two waves is termed as the beat frequency.

SQ 7.9.7 **How are beats used to tune a string instrument?**

Method
One can use beats to tune a string instrument, such as a piano or violin, by beating a note against a note of known frequency. The string is then adjusted by tightening or loosening it until no beats are heard.

SQ 7.9.8 **How are beats generated in a guitar and a piano?**

Guitar
When playing two strings with slightly different tunings, beats are created.
Piano
Playing two keys adjacent to each other creates beats.

SQ 7.9.9 **How are beats generated in a violin and in drums?**

Violin
When playing two strings with slightly different bow pressures or speeds, beats are generated.
Drums
When two drums with slightly different tunings are played simultaneously, beats are created.

SQ 7.9.10 **Why do musicians sometimes use beats intentionally?**

Answer
Musicians often use beats intentionally to create interesting rhythmic effects, add texture, or produce a sense of tension and release.

SQ 7.9.11 **Two tuning forks give 3 beats per second and one has frequency 256 Hz. What are the possible frequencies of the other?**

Solution
Since
$f_2 = f_1 \pm f_b$
therefore
$f_2 = 256 \pm 3.$
Result
$f_2 = 259\,\mathrm{Hz} \quad \text{or} \quad 253\,\mathrm{Hz}$

SQ 7.9.12 **On loading the 256 Hz fork with wax the beat frequency falls to 1 Hz. Find the frequency of the other fork.**

Reasoning
If the second fork were 259 Hz, loading the first fork would lower its frequency below 256 Hz and the number of beats would increase.

Result
Since the beats decreased, the correct frequency is $f_2 = 253\,\mathrm{Hz}$.

TOPIC 10 Intensity of a Wave

SQ 7.10.1 **Define intensity of a wave.**

Definition
Intensity is the amount of energy transmitted per unit area per unit time in the direction of propagation of a progressive wave.

SQ 7.10.2 **Write the formula and unit of intensity.**

Formula
$I = \frac{E}{At} = \frac{P}{A}$
SI Unit
It is measured in watts per square metre $(\mathrm{W\,m^{-2}})$.

SQ 7.10.3 **Define a progressive wave.**

Definition
A progressive or travelling wave is one that travels through a medium in a consistent direction, transferring energy from one point to another. It propagates or moves forward, as opposed to a stationary wave.

SQ 7.10.4 **How is energy stored in mechanical waves?**

Answer
In mechanical waves, such as sound waves, water waves or waves on a vibrating string, energy is stored as the kinetic energy and potential energy of the medium's particles.

SQ 7.10.5 **On what does the stored energy of a wave depend?**

Answer
How much energy is stored depends upon the displacement or amplitude of the particles from the mean position.

SQ 7.10.6 **Write the relation between intensity and amplitude.**

Formula
$I \propto A^2$
$I = kA^2$
Here k is a constant of proportionality which depends upon the physical properties of the wave and the medium.

SQ 7.10.7 **A wave has intensity 0.5 W m⁻² at 3.0 m from the source. Find the power of the wave.**

Solution
Since
$I = \frac{P}{4\pi r^2}$
therefore
$P = I \times 4\pi r^2$
Calculation
$P = 0.5 \times 4 \times 3.14 \times (3.0)^2$
Result
$P = 56.5\,\mathrm{W}$

SQ 7.10.8 **Two progressive waves have intensities 0.5 W m^{-2} and 0.25 W m^{-2}. Find the total intensity.**

Solution

$I = I_1 + I_2 = 0.5 + 0.25$

Result

$I = 0.75\,\mathrm{W\,m^{-2}}$

SQ 7.10.9 **A speaker emits 50 W of sound spreading over an area of 314 m^2. Find the intensity.**

Solution

$I = \frac{P}{A} = \frac{50}{314}$

Result

$I = 0.159\,\mathrm{W\,m^{-2}}$

SQ 7.10.10 **Are the frequency and amplitude of a travelling wave related?**

Answer

No. The frequency and amplitude of a travelling wave are independent of each other. That is why the volume of a song can be turned up without changing its pitch.

TOPIC 11 Doppler Effect

SQ 7.11.1 **Define the Doppler effect.**

Definition

The apparent change in the frequency or pitch of waves due to the relative motion between the source and the observer is called the Doppler effect.

SQ 7.11.2 **Who first observed the Doppler effect and how?**

Answer

This effect was first observed by John Doppler while observing the frequency of light emitted from a star. He found that the frequency of emitted light was slightly different from that of a similar source on the Earth, and that the change depends on the motion of the star relative to the Earth.

SQ 7.11.3 **Give an everyday example of the Doppler effect with sound.**

Example

The pitch of the whistle of an engine coming towards a platform appears to become higher to an observer standing on the platform, while the pitch of a whistle going away appears to become lower.

SQ 7.11.4 **Write the frequency heard by a stationary observer from a stationary source.**

Formula

$f = \frac{v}{\lambda}$

Here v is the speed of sound and λ is the wavelength.

SQ 7.11.5 **What happens to the waves when the source moves towards a stationary observer?**

Answer

The waves are compressed and their wavelength is decreased, because the same number of waves are contained in a shorter space.

SQ 7.11.6 **What is Doppler shift?**

Definition

The decrease in wavelength in one second,

$\Delta\lambda = \frac{u_s}{f}$

is called the Doppler shift.

SQ 7.11.7 **Write the apparent frequency when the source moves towards a stationary observer.**

Derivation

The observed wavelength is

$\lambda_A = \frac{v - u_s}{f}$

so the apparent frequency is

$f_A = \frac{v}{\lambda_A}$

Result

$f_A = \left(\frac{v}{v - u_s}\right) f$

SQ 7.11.8 **What happens to the pitch when the source approaches the observer?**

Answer

The apparent frequency of sound heard by the observer increases, which in turn increases the pitch of the sound.

SQ 7.11.9 **Write the apparent frequency when the source moves away from a stationary observer.**

Explanation

When the source moves away, the waves are expanded and their wavelength is increased.

Result

$f_B = \left(\frac{v}{v + u_s}\right) f$

SQ 7.11.10 **A train sounding a 1200 Hz whistle is heard at 1140 Hz. Find its speed if v = 340 m s^{-1}.**

Solution

Using

$f_B = \left(\frac{v}{v + u_s}\right) f$

for a receding source.

Calculation

$1140 = \frac{340}{340 + u_s} \times 1200$

Result

$u_s = 17.89\,\mathrm{m\,s^{-1}}$

SQ 7.11.11 **A train moving at 17.89 m s^{-1} travels for 50 s. Find the distance covered.**

Solution

$S = u_s t = 17.89 \times 50$

Result

$S = 894\,\mathrm{m}$

TOPIC 12 Applications of Doppler Effect

SQ 7.12.1 Is the Doppler effect applicable to electromagnetic waves?

Answer

Yes. The Doppler effect is also applicable to electromagnetic waves, and one of its important applications is the radar system.

SQ 7.12.2 What is RADAR and what does it do?

Definition

RADAR stands for RAdio Detection And Ranging. It is a device which transmits and receives radio waves, and it uses radio waves to determine the elevation and speed of an aeroplane.

SQ 7.12.3 How does radar detect an approaching or receding aeroplane?

Answer

If an aeroplane approaches the radar, the wavelength of the wave reflected from it is shorter. If it moves away, the wavelength is larger.

Application

The speed of satellites moving around the Earth can also be determined by the same principle.

SQ 7.12.4 What is SONAR?

Definition

SONAR is an acronym derived from Sound Navigation And Ranging. It is the general name for sonic or ultrasonic underwater echo-ranging and echo-sounding systems.

SQ 7.12.5 How does Doppler detection work in sonar?

Answer

In sonar, Doppler detection relies upon the relative speed of the target and the detector to provide an indication of the target speed. It employs the Doppler effect, in which an apparent change in frequency occurs when the source and observer are in relative motion.

SQ 7.12.6 Give the military applications of sonar.

Applications

Its known military applications include the detection and location of submarines, control of antisubmarine weapons, mine hunting and depth measurement of the sea.

SQ 7.12.7 How is the Doppler effect used in astronomy?

Method

Astronomers use the Doppler effect to calculate the speeds of distant stars and galaxies. By comparing the line spectrum of light from the star with light from a laboratory source, the Doppler shift of the star's light can be measured and the speed calculated.

SQ 7.12.8 What is red shift?

Definition

Stars moving away from the Earth show a red shift. The emitted waves have a longer wavelength than if the star had been at rest, so the spectrum is shifted towards the red end of the spectrum.

SQ 7.12.9 What is blue shift?

Definition

Stars moving towards the Earth show a blue shift. The wavelengths of light emitted by the star are shorter than if the star had been at rest, so the spectrum is shifted towards the blue end of the spectrum.

SQ 7.12.10 What have astronomers discovered from red shifts of distant galaxies?

Answer

Astronomers have discovered that all the distant galaxies are moving away from us, and by measuring their red shifts they have estimated their speeds.