
ULTIMATE KCET
CRASH COURSE 2026
PHYSICS
Lecture - 01
Waves
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Recap

of previous lecture

1. SIMPLE HARMONIC MOTION
2. EQUATION OF SIMPLE HARMONIC MOTION
3. POSITION, VELOCITY AND ACCELERATION IN SHM
4. QUESTIONS ON OSCILLATION

Topics *to be covered*

1. TYPES OF WAVES AND ITS PARAMETER
2. WAVE EQUATION & STANDING WAVES
3. VIBRATIONS OF STRETCHED STRITCHED STRING
4. MODES OF VIBRATIONS OF AIR COLUMN

WAVE

Energy can be propagated from one point to another point by two different modes.

1. Particle motion
2. Wave motion

Wave is a sort of disturbance or the disturbance set up in medium is called wave and the propagation of disturbance from one point another is called wave motion. Wave motion is one of the means of transporting energy without the transfer of material particles. Waves transport both energy and momentum.

TYPES OF WAVES

CLASSIFICATION

NECESSITY OF MEDIUM

1. Mechanical wave
2. Non-mechanical "

DIRECTION OF PROPOGATION

1. Transverse wave
2. Longitudinal wave

DIMENSION

↳ 1D
↳ 2D
→ 3D

VIBRATION OF PARTICLE

NECESSITY MEDIUM

Mechanical wave :

Waves which require a material medium for their propagation are called mechanical waves. They are also called elastic waves, because the medium through which they propagate must be elastic in nature.

Ex:- Sound waves, Seismic waves, waves on stretched string, waves on the surface of water etc.

Non-Mechanical Wave :

Waves which do not require a material medium for their propagation are called non-mechanical waves (electromagnetic waves). These waves travel in vacuum as well as in a material medium.

Ex:- Light waves, radio wave, heat wave, X-rays, UV-rays, Infrared rays etc.

MODE OF PROPOGATION

Depending upon the mode of propagation waves are classified into 3 types.

1. Waves along a straight line are called one dimensional wave
Ex:- Waves along a stretched string.

2. Waves travelling in a plane are called two dimensional waves.
Ex:- Waves on the surface of water (Ripples).

3. Waves travelling in space are called three dimensional waves.
Ex:- Sound waves and light waves etc.

BASED ON VIBRATION OF PARTICLE

1. Transverse waves :

If the particles of the medium vibrate about their position at right angles to the direction of propagation of the wave then the waves are called transverse waves.
Ex: Light waves, radio waves etc.

2. Longitudinal waves:

If the particles of the medium vibrate about their mean position along the direction of propagation of the wave then the waves are called longitudinal waves.
Ex: - Sound waves, Seismic waves etc.

TRANSVERSE AND LONGITUDINAL WAVE

$v = f\lambda$

$\omega = \frac{2\pi}{T}$

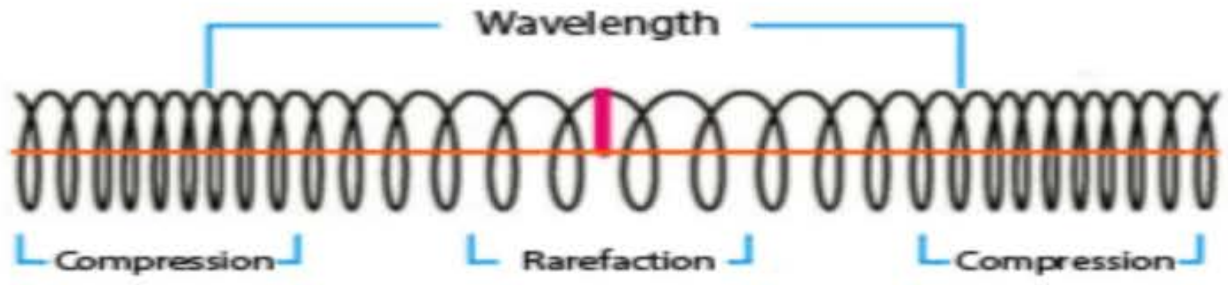
$k = \frac{2\pi}{\lambda}$

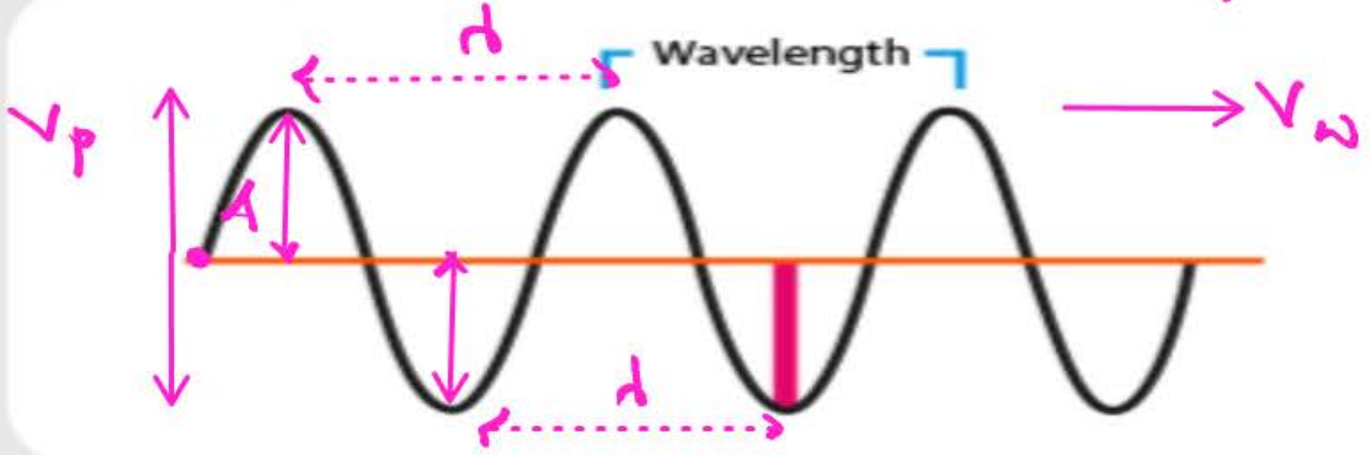
LONGITUDINAL WAVE AND TRANSVERSE WAVE

$v_p = \omega\sqrt{A^2 - x^2}$

$v_p = (-\text{slope})\, v_w$

$v_w = \frac{\omega}{k}$





LONGITUDINAL WAVE

Longitudinal waves are those waves in which the particles of the medium move parallel to the propagation of the wave. For example, sound waves are longitudinal waves.

TRANSVERSE WAVE

Transverse waves are those waves in which the particles of the medium move perpendicular to the direction of the propagation of the wave. For example, ripples formed on the surface of the water are transverse waves.

PARAMETERS OF WAVE REPRESENTATION

Amplitude (A) : The maximum displacement of a particle from either side of mean position.
Unit : metre (m)

Wave length : The distance between two consecutive points which are in same phase is called wave length.
Unit: metre (m)

Time period : Time required to set up one complete wave is known as wave period.
Unit: Second (s)

Wave frequency: Number of wave's setup in the medium in one second is called wave frequency.
Unit: Hz

PARAMETERS OF WAVE REPRESENTATION

Wave velocity: The distance travelled by a wave in a given direction in one second is called wave velocity.

Unit : m/s

Phase: The physical quantity which represents the position and direction of motion of a vibrating particle with respect to mean position is defined as the phase. Phase is expressed in terms of fraction of period or fraction of angle. $(\omega t \pm kx)$

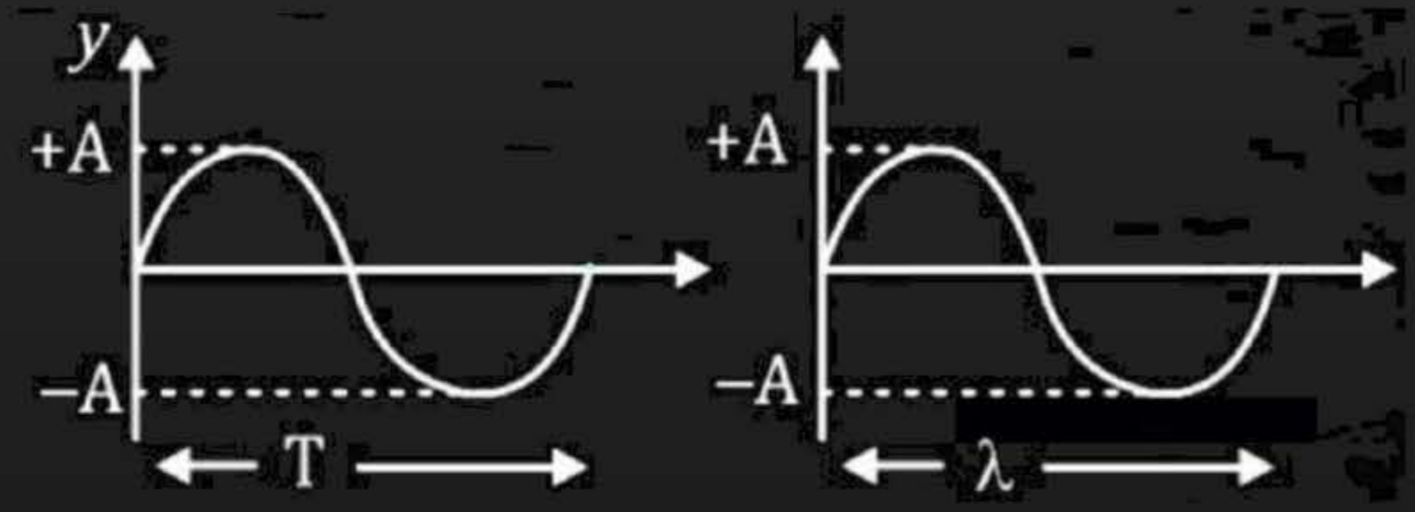
ϕ

Phase difference: The difference of phase angles of two vibrating particles is known as phase difference.

$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$

Path difference: The difference between distances covered by two vibrating particles is known as path difference.

WAVE EQUATION



$$y = A\sin(wt - kx + \phi)$$

$$T = \frac{2\pi}{\omega}, k = \frac{2\pi}{\lambda}$$

$$V_{\omega} = \frac{\omega}{k} = \frac{\text{cofecient of } 't'}{\text{cofecient of } 'x'}$$

$$V_p = -V_w \, (\text{slope})$$

$$V_p = w\sqrt{A^2 - y^2}$$

$$V_{p(wax)} = AW$$

$$V = \lambda f$$

DIRECTION OF WAVE

$\omega = \frac{2\pi}{T}$ $\quad V_p = \omega\sqrt{A^2 - y^2}$

$K = \frac{2\pi}{\lambda}$ $\quad V_\omega = \frac{\omega}{K}$

$y = A\sin(at \pm bx)$: $y = A\sin(\omega t \pm Kx) \Rightarrow y = A\sin(\omega t - Kx)$

$y = A\sin(Kx - \omega t)$

y = Direction of oscillation of particles

x = axis along which wave is travelling

1. If coefficient of time & position have opposite sign. Then wave will travel along + ve axis. (+, –) or (– , +) → Positive Axis.

2. If coefficient of time & position have same sign. then wave will travel Along. –ve axis. (+, +) or (–, –) Negative axis

$y = A\sin(\omega t + Kx)$

$y = A\sin(Kx + \omega t)$

EXAMPLE

$$y = A\sin(20t - 4x)$$

Find $y = A\sin(\omega t - kx)$

(i) Direction of Propagation of wave → +ve direction

(ii) Wave Velocity → $v_w = \frac{\omega}{k} = \frac{20}{4} = 5\ m/s$

(iii) Wave length → $k = \frac{2\pi}{\lambda}$

$\lambda = \frac{2\pi}{k} = \frac{2\pi}{4} = \frac{\pi}{2} = \frac{3.14}{2} \Rightarrow \boxed{\lambda = 1.57\ m}$

(iv) Time period → $\omega = \frac{2\pi}{T}$

$T = \frac{2\pi}{\omega} = \frac{2\pi}{20} = \frac{\pi}{10} = 0.314 \Rightarrow \boxed{T = 0.314\ s}$

(v) Frequency → $\omega = 2\pi f$

$f = \frac{\omega}{2\pi} = \frac{20}{2\pi} = \frac{10}{3.14} = \boxed{3.18\ Hz}$

VELOCITY OF PARTICLE

Particles of medium performs SHM

1. Velocity of the particle, $v_p = \omega\sqrt{A^2 - y^2}$

2. Maximum Velocity of the particle

   ↳ $v_{max} = \omega A$

RELATIONSHIP BETWEEN VELOCITY OF PARTICLE AND WAVE

Particles of medium performs SHM

$$v_p = (-\text{slope})\, v_w$$

QUESTION

$y = A\sin(\omega t - kx)$

The equation of a progressive wave for a wire is $Y = 4\sin\left[\frac{\pi}{2}\left(8t - \frac{x}{8}\right)\right]$. If x and y are measured in cm then velocity of wave is

$A = 4$ cm. $\omega = \frac{\pi 8}{2} = 4\pi$

$k = \frac{\pi}{2} \cdot \frac{1}{8} = \frac{\pi}{16}$

$v_w = \frac{\omega}{k} = \frac{4\pi}{\frac{\pi}{16}} = 4 \times 16$

$v_w = 64$ cm/s

(A) 64 cm/s along $-x$ direction

(B) 32 cm/s along $-x$ direction

(C) 32 cm/s along $+x$ direction

(D) 64 cm/s along $+x$ direction

QUESTION

The equation of progressive wave is $Y = 4\sin\left\{\pi\left(\frac{t}{5} - \frac{x}{9}\right) + \frac{\pi}{6}\right\}$ where x and y are in cm. Which of the following statement is true?

(A) $\lambda = 18$ cm

$k = \frac{2\pi}{\lambda}$, $\lambda = \frac{2\pi}{\pi/9} = 18$ cm

$y = 4\sin\left[\left(\frac{\pi}{5}t - \frac{\pi}{9}x\right) + \frac{\pi}{6}\right]$

$A = 4$ cm, $\omega = \frac{\pi}{5}$, $k = \frac{\pi}{9}$, $\phi = \frac{\pi}{6}$

(B) amplitude = 0.04 cm ✗

(C) velocity $v = 50$ cm/s ✗, $v_w = \frac{\omega}{k} = \frac{\pi}{5} \times \frac{9}{\pi} = 1.8$ cm/s

(D) Frequency $f = 20$ Hz ✗ $f = \frac{\omega}{2\pi} = \frac{\pi}{5 \times 2\pi} = \frac{1}{10} = 0.1$ Hz

QUESTION

$y = A\cos(kx - \omega t - \phi)$

A plane is described by the equation $y = 3\cos\left(\frac{x}{4} - 10t - \frac{\pi}{2}\right)$. The maximum velocity of the particles of the medium due to this wave is

$k = \frac{1}{4}$ $\omega = 10$

$v_p = \omega A$

$v_p = 10 \times 3$

$v_p = 30$

A) 30

B) $3\pi/2$

C) $3/4$

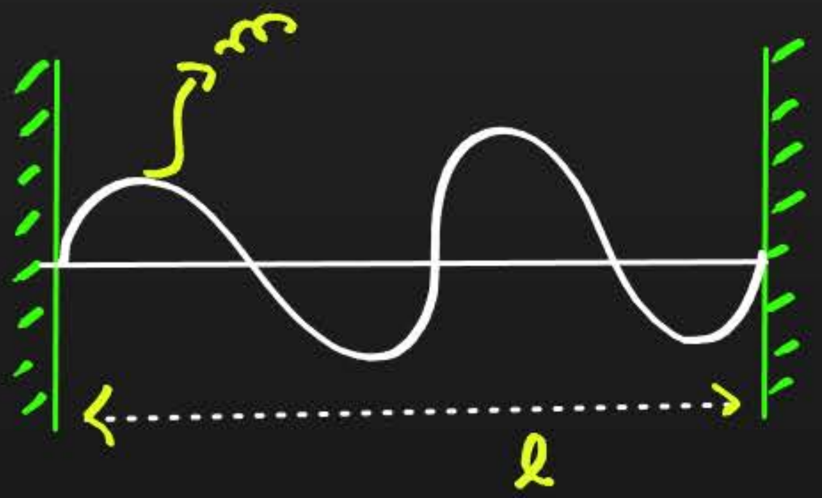
D) 40

SPEED OF A TRANSVERSE WAVE ON STRETCHING STRING

The speed of transverse waves in a stretched string is given by

$$v = \sqrt{\frac{T}{\mu}}, \quad \mu = \frac{m}{l}$$

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



Velocity of wave on string

$$V_{sound} = \sqrt{\frac{\text{Modulus of Elasticity}}{\text{Density of Medium}(\rho)}}$$

- Solid → $Y = \frac{FL}{A\Delta L}$
- Liq → $B = \frac{-PV}{\Delta V}$
- Gas → γP

$$V_{gas} = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{Mw}} = \sqrt{\frac{\gamma PV}{M}}$$

$$\left(\gamma = 1 + \frac{2}{f}\right)$$

$$V_{solid} = \sqrt{\frac{Y}{\rho}}$$

$$Vliq = \sqrt{\frac{B}{\rho}}$$

- Effect of Temperature: $V_s \propto \sqrt{T}$
- Effect of Relative Humidity: H↑ ρ ↓ Vs↑
- Effect of pressure: if Temperature is constant then speed of sound is Independ of Pressure.

QUESTION

The velocities of sound at the same pressure in two monoatomic gases of densities ρ_1 and ρ_2 are v_1 and v_2 respectively. If $\rho_1/\rho_2 = 4$, then the value of v_1/v_2

$$v = \sqrt{\frac{\gamma P}{\rho}} \qquad \frac{\rho_1}{\rho_2} = 4$$

$$v \propto \frac{1}{\sqrt{\rho}} \qquad \frac{\rho_2}{\rho_1} = \frac{1}{4}$$

$$\frac{v_1}{v_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

$$\boxed{\frac{v_1}{v_2} = \frac{1}{2}}$$

A. 1/4

B. 1/2

C. 2

D. 4

QUESTION

Velocity of sound in medium is V. if the density of the medium is doubled, what will be the new velocity of sound?

$V \propto \frac{1}{\sqrt{\rho}}$ $\rho' = 2\rho$

$V' \propto \frac{1}{\sqrt{2\rho}} = \frac{1}{\sqrt{2}} \frac{1}{\sqrt{\rho}} = \frac{V}{\sqrt{2}}$

A $\sqrt{2}V$

B V

C $V/\sqrt{2}$

D 2V

THE PRINCIPLE OF SUPERPOSITION OF WAVES

Statement:

When two or more waves of same nature are superposed, the resultant displacement at the point of superposition is equal to vector sum of the individual displacement.

$y = y_1 + y_2 = R\sin(\omega t + \phi)$

$= R\sin(\omega t \pm kx + \phi)$

Example for superposition of waves is the formation of

a. Stationary waves.

b. Beats.

c. Interference etc.

Interference: Superposition of two waves having equal frequency and nearly equal amplitude

Beats : Superposition of two waves having nearly equal frequency in same direction

Superposition of two waves

Super position of Two waves

Slightly Different frequency

$\Delta f = 10\,Hz$

$f_b = f_1 \sim f_2$

$f_b = f_A - f_B$

Same Frequency

↳ Interference

Beats

Beats with Two sources

Q. 1 (A) 504 Hz

(B) 499 Hz

$$f_b = f_A - f_B$$

$$= 504 - 499$$

$$\boxed{f_b = 5\,Hz}$$

Beats

$y = A\sin(\omega t \pm kx)$

Q. 2 (A) Asin (206 πt – kx)

(B) Asin (200 πt + kx + ϕ)

$\omega = 2\pi f$

$f = \frac{\omega}{2\pi}$

$\omega_1 = 206\pi$

$\omega_2 = 200\pi$

$f_1 = \frac{206\pi}{2\pi} = 103\,Hz$

$f_2 = \frac{200\pi}{2\pi} = 100\,Hz$

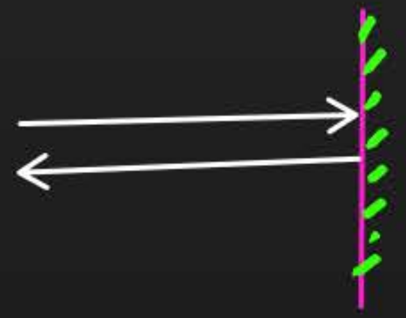
$f_b = f_1 - f_2$

$= 103 - 100$

$f_b = 3\,Hz$

REFLECTION OF WAVES

When a wave meets a boundary it gets reflected. If the boundary is rigid then almost entire wave is reflected by the boundary.



Ex:

- Phenomenon of echo ✓
- Stethoscope and ear trumpet work on reflection of sound waves
- reflection of ripples by walls of water tank

If the boundary is not rigid then a part of incident wave is reflected and a part is transmitted.

Ex:

- reflection of waves in an open pipe.

Reflection of Wave

Rarer to denser

Before reflection

After reflection

$|V_i| = |V_R| > |V_T|$

Phase difference b/w

- Incident and reflected $\rightarrow \pi$
- Incident and transmitted $\rightarrow 0$
- Frequency of wave do not change in any conditions

Denser to Rarer

Before reflection

After reflection

$|V_i| = |V_R| < |V_T|$

Phase difference b/w

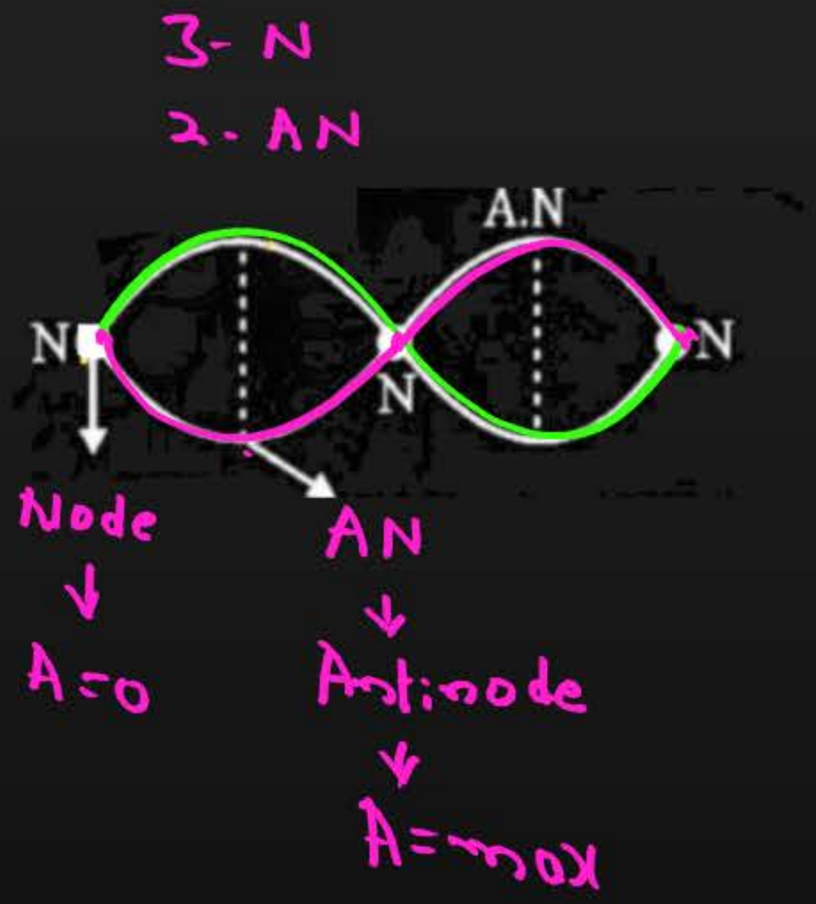
Incident and reflected $\rightarrow 0$

Incident and transmitted $\rightarrow 0$

Standing wave

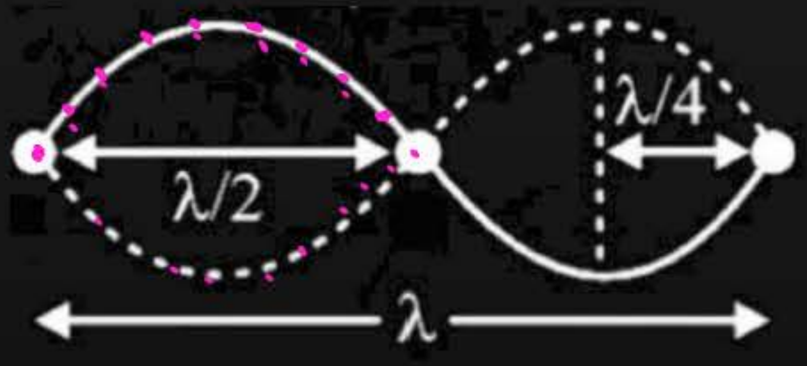
Stationary Waves:

Super position of two identical progressive waves travelling in opposite directions along a straight line gives rise to the phenomenon of stationary waves or standing waves.



Properties of standing wave

- All particles performs S.H.M of Different Amplitude
- No transfer of Energy from one lobe to other
- All particles of one lobe are in same phase. They attain Maxima together, Minima together & Crosses Mean Position together.
- Particle of two Adjacent lobe have phase difference of π.



Fundamental/Harmonics/overtone

n=1 n n+1

The mode of vibration of air column with the lowest possible frequency is called fundamental mode or 1st harmonic.

The other modes of vibration which produce notes of higher frequency or frequencies greater than fundamental frequency with which a body can vibrates are called overtones (notes).

If the frequency of the overtone (notes) are integral multiples of the fundamental then they are called harmonics.

VIBRATIONS OF AIR COLUMN

When a source of sound is held at the mouth of a tube, the wave travels through the pipe, gets reflected and the reflected, incident waves travelling in opposite directions are superposed. This leads to the formation of stationary longitudinal waves inside the pipe. A cylindrical tube produces sound is known as an organ pipe.

The pipe is said to be closed pipe. if one end is closed and other end is opened
Ex: jalatharang.

The pipe is said to be open pipe if both ends are opened
Ex: flute

A column of air enclosed in a pipe is called air column.

VIBRATIONS OF STRETCHED STRING

Consider a uniform string of length ‘l’ stretched between 2 fixed points A and B. Let ‘M’ be the mass of the string and ‘m’ it’s mass per unit length. Let the string be plucked at the centre. Transverse vibrations setup on the string and they travel along the string with a velocity.

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{Tl}{m}}$$

In general, When the string vibrates n-segment – It is said to be in n^{th} harmonic frequency.

$$f_n = \frac{nv}{2L} = \frac{n}{2L}\sqrt{\frac{TL}{M}} \quad n = 1, 2, 3, 4 \ldots$$

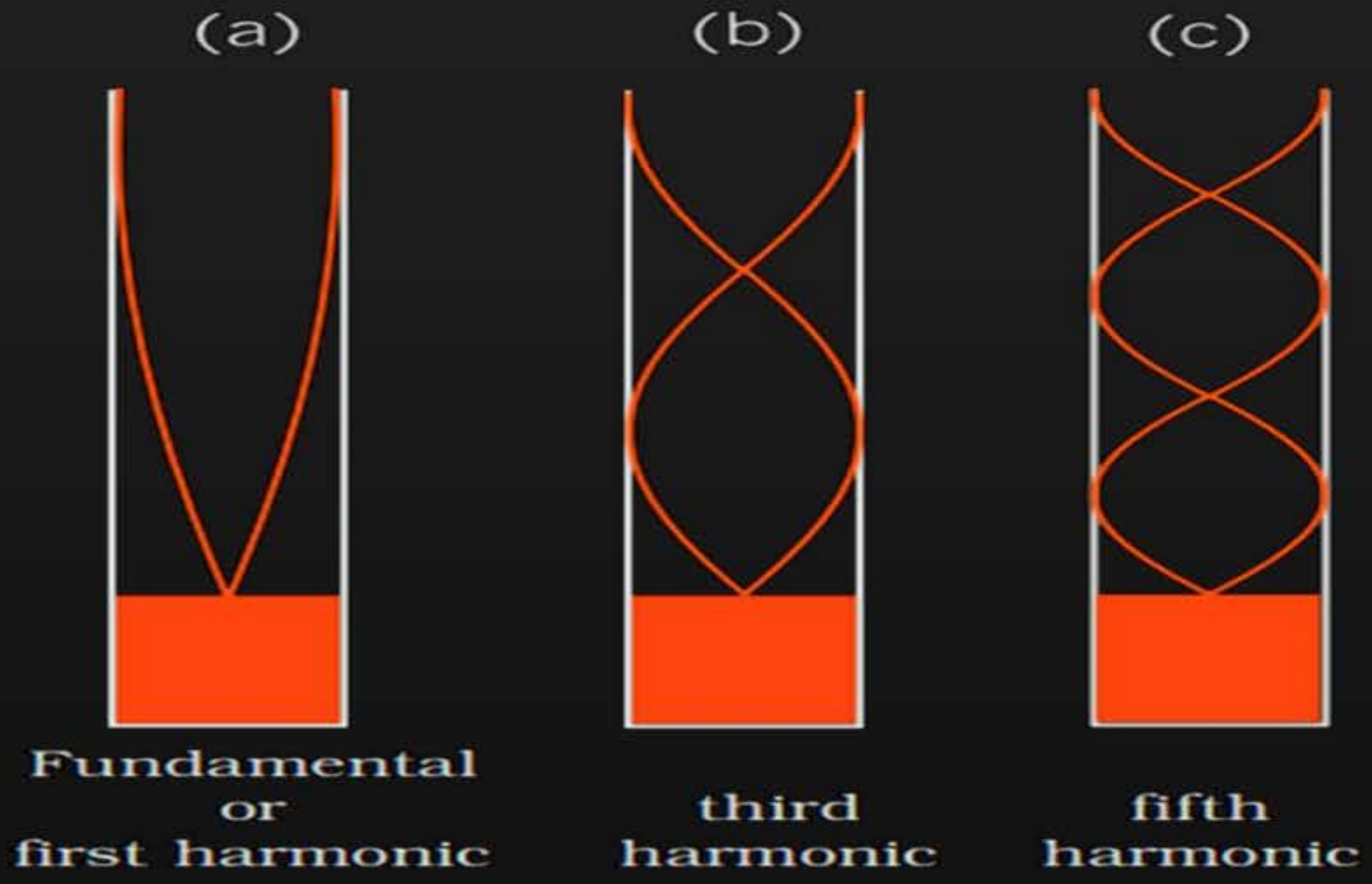
MODES OF VIBRATIONS OF AIR COLUMN IN A CLOSED PIPE

Consider a narrow tube of length l closed at one end and open at the other end. When the air molecules are set into vibration, in the simplest mode of vibration an anti node is formed at the open end and the next node is formed at the closed end.

The 'n^{th}' modes mode of vibrations

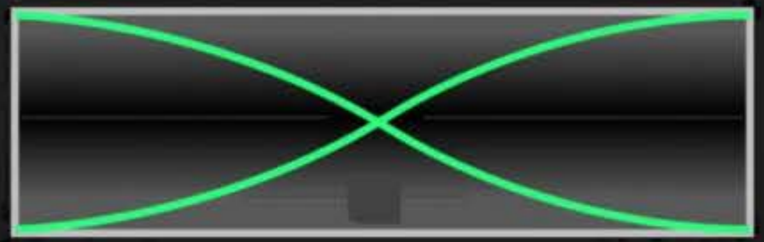
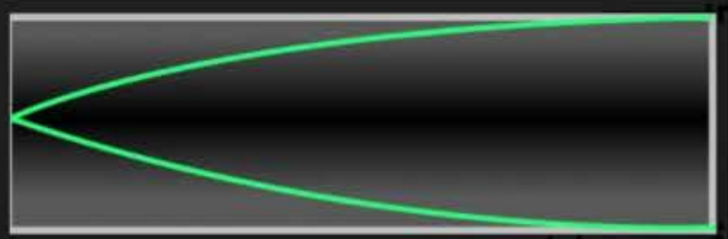
$$f_o = \frac{nv}{2L} = \frac{n}{2L}\sqrt{\frac{TL}{m}}$$

$$f_c = \frac{(2n-1)v}{2L} = \frac{(2n-1)}{2L}\sqrt{\frac{TL}{m}}$$



Organ Pipe

Organ Pipe

Closed Organ Pipe	Open Organ Pipe
	
Same as string one end free	same as string both end fixed (sonometer)

$f = (2n-1)\frac{v}{4L}$ → closed $f = \frac{nv}{2L}$ → open

$L = (2n-1)\frac{\lambda}{4}$ $L = \frac{n\lambda}{2}$

Closed end: Displacement node (min) and pressure antinode (max)

Open end : Displacement antinode (max) and pressure node (min)

QUESTION

Stationary waves are so called because in them

A. The particles of the medium are not disturbed at all

B. The particles of one medium do not execute S.H.M

C. There occur no flow of energy along the wave

D. The interference effect can't be observed

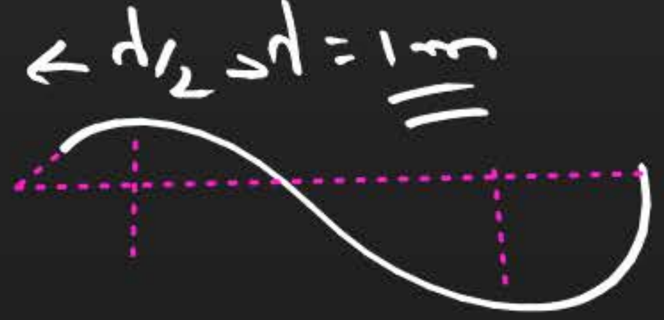
QUESTION

A string is rigid by two ends and its equation is given by $y = \cos 2\pi t \sin 2\pi x$. Then minimum length of string is

$k = 2\pi$

$k = \frac{2\pi}{\lambda}$

$\lambda = \frac{2\pi}{k} = \frac{2\pi}{2\pi} = 1 m$



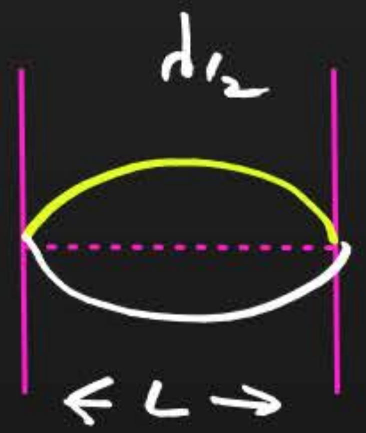
(A) 1 m

(B) 1/2 m

(C) 5 m

(D) 2 πm

$l = \frac{\lambda}{2} = \frac{1}{2} m$



QUESTION

Stationary wave is represented by $y = A\sin(100\,t)\cos(0.01\,x)$ where y and A are in mm, t in the velocity of the wave:

ωt $\quad$ kx

$\omega = 100$ rad/s

$k = 0.01$

$V_w = \frac{\omega}{k} = \frac{100}{0.01} = \frac{100}{1\times10^{-2}}$

$V_w = 10^4$ m/s

(A) 1 m/s

(B) 10^2 m/s

(C) 10^4 m/s

(D) zero

QUESTION

A uniform string of length L and mass M is fixed at both ends under tension T, then it can vibrate with frequency given by the formula.

(A) $f = \frac{1}{2}\sqrt{\frac{T}{ML}}$

(B) $f = \frac{1}{2L}\sqrt{\frac{T}{M}}$

(C) $f = \frac{1}{2}\sqrt{\frac{T}{M}}$

(D) $f = \frac{1}{2}\sqrt{\frac{M}{LT}}$

$n = 1$

$f_n = \frac{nv}{2L} \Rightarrow f_1 = \frac{v}{2L} = \frac{1}{2L}\sqrt{\frac{TL}{M}}$

$= \frac{1}{2}\sqrt{\frac{TL}{ML^2}} = \frac{1}{2}\sqrt{\frac{T}{ML}}$

QUESTION

The speed of transverse waves in a stretched string is 700 cm/s. If the string is 2m long, the frequency with which it resonates in fundamental mode is:

(A) (7/2) Hz

(B) (7/4) Hz

(C) (14) Hz

(D) (2/7) Hz

$f_n = \frac{nv}{2L} \Rightarrow f_1 = \frac{1 \times 700 \times 10^{-2}}{2 \times 2} = \left(\frac{7}{4}\right) Hz$

QUESTION

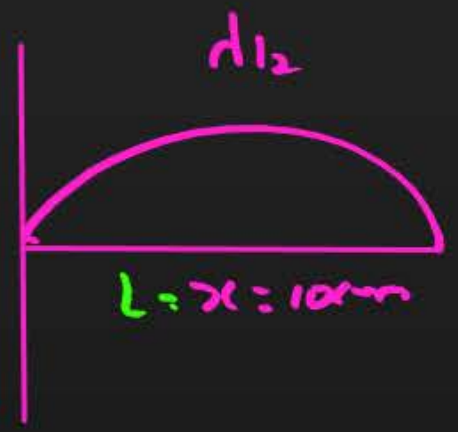
A wave of frequency 100 Hz travels along a string towards its fixed end. When this wave travels back, after reflection, a node is formed at a distance of 10 cm from the fixed end. The speed of the wave (incident and reflected) is:

(A) 5 m/s

(B) 10 m/s

(C) 20 m/s

(D) 40 m/s



$L = \frac{\lambda}{2}$

$\lambda = 2L = 2 \times 10\ cm$

$\lambda = 20\ cm.$

$v = f\lambda = 100 \times 20 \times 10^{-2}$

$V = 20\ m/s$

QUESTION

A tube closed at one end and containing air produces, when excited, the fundamental note of frequency 512 Hz. If the tube is open at both ends, the fundamental frequency that can be excited is (in Hz)

A. 1024

B. 512

C. 253

D. 128

f_c, f_0

$f_c = \frac{(2n-1)v}{4L}$, $n = 1$, $f_1 = \frac{v}{4L} \Rightarrow 512 = \frac{v}{4L}$

$f_0 = \frac{nv}{2L} = \frac{1 \times v}{2L} = \frac{v}{2L}$

$f_0 = 2\left(\frac{v}{4L}\right) = 2 \times 512$

$f_0 = 1024\ Hz$

QUESTION

An air column in pipe, which is closed at one end will be in resonance with a vibrating tuning fork of frequency 264 Hz if the length of the column in cm is: (v = 330 m/s)

(A) 31.25

(B) 62.50

(C) 110

(D) 125

$f_c = (2n-1)\frac{v}{4L}$

$264 = \frac{v}{4L}$

$L = \frac{v}{264 \times 4} = \frac{330}{264 \times 4}$

$L = 0.3125\ m$

$L = 31.25\ cm$

QUESTION

The angle between the particle velocity and wave velocity in a transverse wave is (except when the particle passes through the mean position)

A. π radian

B. π/2 radian

C. Zero radian

D. π/4 radian

QUESTION

To propagate both longitudinal and transverse waves, a material must have

A. Bulk and shear moduli

B. Bulk modulus

C. Shear modulus

D. Young's and bulk modulus

QUESTION

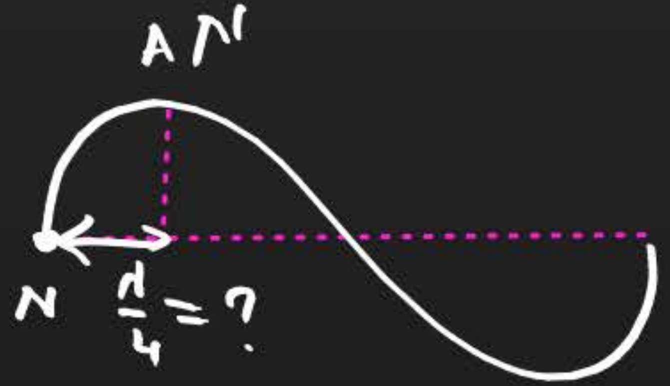
The equations of a stationary between a node and $y = 2\sin\left(\frac{\pi x}{15}\right)\cos(48\pi t)$. The distance a node and its next antinode is

A 7.5 Units

B 1.5 Units

C 22.5 Units

D 30 Units



$k = \frac{\pi}{15}$

$k = \frac{2\pi}{\lambda}$

$\lambda = \frac{2\pi}{k} = \frac{2\pi}{\frac{\pi}{15}}$

$\lambda = 30\,m$

$\frac{\lambda}{4} = \frac{30}{4} = 7.5\,m$

QUESTION

First Overtone frequency of a closed pipe of length l_1 is equal to the second harmonic frequency of an open pipe of length l_2. The ratio $\frac{l_1}{l_2}$ is equal to

(A) $\frac{3}{4}$

(B) $\frac{4}{3}$

(C) $\frac{3}{2}$

(D) $\frac{2}{3}$

$n = 2$

$f_c = (2n-1)\frac{v}{4L_1} = \frac{3}{4}\frac{v}{L_1}$

$f_0 = \frac{nv}{2L_2} = \frac{2v}{2L_2}$

$f_c = f_0$

$\frac{3v}{4L_1} = \frac{v}{L_2}$

$\frac{L_1}{L_2} = \frac{3}{4}$

QUESTION

The waves set up in a closed pipe are

A. Longitudinal and progressive

B. Transverse and progressive

C. Transverse and stationary

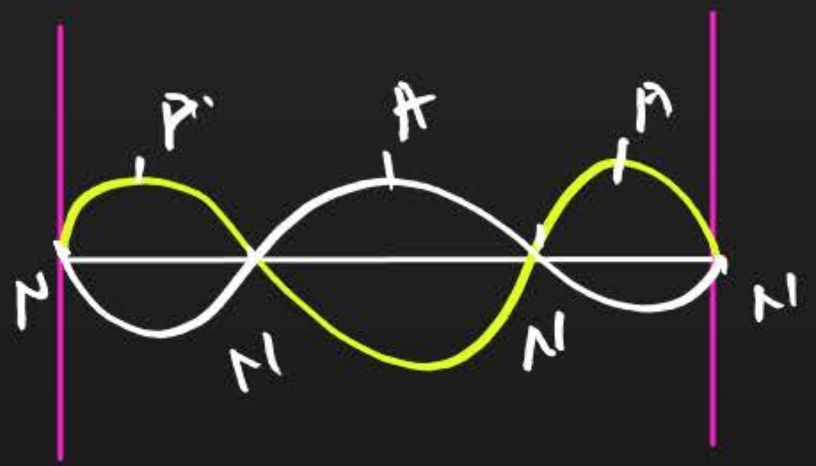
D. Longitudinal and stationary

QUESTION

A stretched string is vibrating in the second overtone. then the number of nodes and anti-nodes between the ends of the string are respectively

A 3 and 4

B 4 and 3



C 2 and 3

D 3 and 2

QUESTION

When two tuning forks A and B are sounded together, 4 beats per second are heard. The frequency of the of B is 384 Hz. When one of the prongs of the fork A is filled and sounded with B, the beat frequency increase then the frequency of the fork A is

(A) 379 Hz

(B) 380 Hz

(C) 389 Hz

(D) 388 Hz

$$f_b = f_A - f_B$$

$$4 = f_A - 384$$

$$f_A = 384 + 4$$

$$f_A = 388 \text{ Hz}$$

Thank You