CHAPTER - 11
WAVES

SYNOPSIS

When a disturbance is made in an elastic medium the particles of the medium are disturbed successively and put into SHM. At any instant the disturbed particles are in different states of SHM. A line joining all the disturbed particles at an instant will form a wave.

The length of a full wave is called wave length (λ) λ is defined as the distance between two successive particles on a wave having the same state of vibration.

λ is also defined as the distance moved by the wave in the time taken for one SHM, called the time period (T).

Two particles on a wave separated by λ distance have a difference of one SHM, equivalent to a difference of (2π) radians or 360°.

ie, if the distance between two particles on a wave is λ. they have a phase difference of (2π) radians.

A transverse wave is produced by alternate crest and trough. Distance between successive crests or successive troughs is λ.

Distance from a crest to next trough = $\lambda/2$

Any vibrating body is a source of sound. The sound energy produced by the source moves in any medium in the form of a longitudinal wave and it will be a progressive wave. To move, a sound wave requires a material medium and sound wave does not move in vacuum.

If ν is the frequency of the source and λ is the wave length, velocity of the sound wave is given by

$\boxed{V = \nu \times \lambda}$

Depending upon the frequency of the source sound produced is divided into three groups namely.

1. Infrasonic sound
2. Audible sound
3. Ultrasonic sound

If ν of the source is in the range, 0 - 20 Hz. Sound is called infrasonic and it cannot be heard.

If ν of the source is in the range 20 - 20000 Hz, sound is called audible sound and it can be heard

If ν of the source is larger than 20000 Hz, sound is ultrasonic and it cannot be heard.

In the same medium all the sound wave move with same velocity, but ν and λ are different.

If ν is minimum λ is maximum and vice versa

Factors affecting velocity of sound wave in a medium

1. Bulk modulus (B) or Elasticity

As elasticity of a medium increases velocity of wave in the medium increases and vice versa

2. Density (ρ)

As density of medium increases velocity of wave in the medium decreases and vice versa

Velocity of a sound wave in a medium of bulk modulus (B) and density (ρ) is given by

$$\boxed{v = \sqrt{\frac{B}{\rho}}}$$

According to Newton a sound wave moves through a medium isothermally. Then elasticity of the medium is isothermal = Pressure (P) of the medium

Then $v = \sqrt{\frac{P}{\rho}}$, called Newton's equation. But v calculated from Newtons eqn. is not the same as in experiment. Therefore Newton's eqn. is wrong, means sound wave is not moving isothermally in a medium.

According to Laplace a sound wave moves through a medium adiabatically. Then elasticity of the medium is adiabatic = γ x P, where $\gamma = \frac{C_P}{C_V} > 1$

Then $v = \sqrt{\frac{E(\text{adiabatic})}{\rho}} = \sqrt{\frac{\gamma P}{\rho}}$, called Laplace's eqn. v calculated from Laplace's eqn. is the same as in expt.

$\therefore$ Laplace's eqn is correct, means sound wave moves through a medium adiabatically.

3. Pressure (P)

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

As the pressure P changes, density ρ proportionately changes. Then $\left(\frac{P}{\rho}\right)$ will be a constant. For a medium γ is a constant. Therefore v is a constant. It means at all pressures of a medium, velocity of the wave is same or velocity is independent of pressure of the medium.

4. Temperature (T)

As temperature of the medium increases, velocity of the wave in the medium increases and vice versa.

$\boxed{v \propto \sqrt{T}}$ where T is the absolute temperature.

5. Humidity $v = \sqrt{\frac{\gamma \rho}{\rho}}$

As humidity in air increases density of air decrease and velocity of wave in air increases and vice versa.

$PV = nRT$

For 1 mole of medium

n = 1

$\therefore$ PV = RT, where V, is the molar volume = 22.4 liters, same for all gases.
If molar mass = M and molar volume = V

density $(\rho)=\frac{M}{V}$

$$V=\sqrt{\frac{\gamma P}{\rho}}=\sqrt{\frac{\gamma P}{M/V}}=\sqrt{\frac{\gamma(PV)}{M}} \qquad \boxed{\because V=\sqrt{\frac{\gamma RT}{M}}}$$

Progressive wave

A progressive wave moving in the positive direction is represented by the equation

$$\boxed{y=A\sin\frac{2\pi}{\lambda}(vt-x)}$$

ie $y=A\sin\left[2\pi\frac{v}{\lambda}.t-\frac{2\pi}{\lambda}.x\right]=A\sin\left[(2\pi v)t-\frac{2\pi}{\lambda}.x\right]$

ie $\boxed{y=A\sin(\omega t-Vx)}$ Where $\omega=2\pi v$ and $k=\frac{2\pi}{\lambda}$.

A progressive wave moving in the negative direction is represented by the equation.

$$\boxed{y=A\sin\frac{2\pi}{\lambda}(vt+x) \text{ or } y=A\sin(\omega t+kx)}$$

Characteristics of Sound

A musical sound has three characteristics namely

1. Pitch of sound
2. Loudness of sound
3. Quality or Timbre

Intensity of a Wave

$\boxed{I\,\alpha\,A^2}$ A $\rightarrow$ Amplitude

I also depends upon the distance (d) between source and listener. As d increases I decreases and vice versa.

$\therefore I\propto 1/d^2$

The SI unit of intensity is w/m^2. However as human ear respond to sound intensities over a wide range, ie from 10^{-12} W/m^2 to 1 W/m^2. So instead of specifying intensity of sound in W/m^2, we use a logarithmic scale of intesity called sound level defined as

$$SL=10\log\left[\frac{I}{I_0}\right]$$

Where I_0 is the threshold of human ear. ie 10^{-12} W/m^2

We also use dB as a relative measure to compare different sounds with one another, rather than with reference intensity.

What is the intensity of a 60 dB sound

$$N = 10\log_{10} {}^{I}\!/\!_{I_0} \Rightarrow 60 = 10\log_{10} {}^{I}\!/\!_{I_0}$$

$$\log_{10} {}^{I}\!/\!_{I_0} = 6 \qquad \text{or} \qquad \frac{I}{I_0} = 10^6$$

$I_0 = 10^{-12}$ w/m²

$I = 10^6\, I_0 = 10^6 \times 10^{-12} = 10^{-6}$ W/m²

Two sound waves have intensities 5×10^{-10} W/m² and 1×10^{-6} W/m². By how many decibels is the louder sound above the other?

$I_1 = 5 \times 10^{-10}$ w/m²

$I_2 = 1 \times 10^{-6}$ w/m²

it is obvious that I_2 is louder than I_1

$$N_1 = 10\log_{10} {}^{I_1}\!/\!_{I_0} \qquad N_2 = 10\log_{10} {}^{I_2}\!/\!_{I_0}$$

$$N_2 - N_1 = 10\log_{10} {}^{I_2}\!/\!_{I_0} - 10\log_{10} {}^{I_1}\!/\!_{I_0}$$

$$= 10\left[\log_{10} I_2 - \log I_0\right] - (\log_{10} I_1 - \log I_0)]$$

$$= 10\left[\log_{10} I_2 - \log_{10} I_1\right]$$

$$= 10\log_{10} {}^{I_2}\!/\!_{I_1}$$

$$= 10\log_{10}\frac{10^{-6}}{5\times10^{-10}} = 10\log_{10}\left[2\times10^3\right]$$

$$= 10\left[\log_{10} 2 + 3\right]$$

= 10[.3010 + 3] = 10 × 3.301

= 33 dB

Superposition of waves

When two waves are produced simultaneously in the same medium they superpose each other producing a resultant wave.

If A_1 and A_2 are the amplitudes and ϕ is the phase difference of the two superposing waves, the resultant amplitude A of the resultant wave is given by

$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$

If $\phi = 0$, $A = A_1 + A_2$, the maximum amplitude

$\boxed{\text{ie, } A_{max} = A1 + A2}$

If $\phi = 180$, $A = A_1 - A_2$, the minimum amplitude

$\boxed{\text{ie, } A_{min} = A1 - A2}$

Beats

When two vibrating bodies having nearly equal frequencies υ_1 and υ_2 are put into vibration together the intensity of the resultant sound increases to a maximum called waxing, decreases to a minimum called wanning. The variation in intensity between maximum and minimum produces beats.

Number of beats/second = $|\upsilon_1 - \upsilon_2|$.

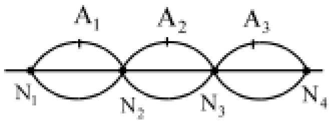
The time interval between successive maximum or successive minimum = $\left|\frac{1}{\upsilon_1 - \upsilon_2}\right|$.

Time interval between a maximum and next minimum = $\frac{1}{2} \times \frac{1}{|\upsilon_1 - \upsilon_2|}$

Stationary or Standing wave

When two similar waves are simultaneously produced along the same line in opposite directions they superpose each other producing a resultant wave. The resultant wave does not move in the medium and hence it is called a stationary wave.

The amplitude of particles on a stationary wave varies from zero at a point called node to a maximum at a point called antinode.



Distance between successive nodes or antinodes = $\frac{\lambda}{2}$.

Distance from a node to the next antinode = $\frac{\lambda}{4}$.

Usually a stationary wave is produced by superposing a progressive wave and its own reflected wave. If progressive wave is represented by

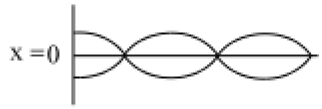
$y_1 = A\sin(\omega t - kx)$ its reflected wave is $y = +A\sin(\omega t + kx)$

Since amplitude of each superposing wave is A, maximum amplitude at an antinode = $A_1 + A_2 = A + A = 2A$.

Then stationary wave is represented by the equation, $y = y_1 + y_2$.

ie, $y = 2A\left(\cos\left(\frac{2\pi x}{\lambda}\right).\sin\omega t\right)$

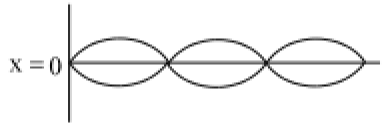
The stationary wave represented by this equation has an antinode at x = 0.



A stationary wave may also be represented by the equation,

$$y = 2A\sin\left(\frac{2\pi x}{\lambda}\right).\cos\omega t$$

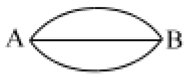
The stationary wave represented by this equation has a node at x = 0.



Vibration of a stretched wire

Fundamental vibration or 1st mode

AB is a stretched wire of length l m, tension T newton and mass per unit length or linear density μ.



When it is put into vibration as shown, it produces a sound. The velocity of the sound wave is given by $v = \sqrt{\frac{T}{\mu}}$.

The whole length of the wire vibrates in one segment. Then A and B are successive nodes.

Therefore, $AB = l = \frac{\lambda}{2}$ $\qquad \lambda = 2l \qquad v = \upsilon\lambda$ or $\upsilon = \frac{v}{\lambda}$

$\boxed{\upsilon = \frac{v}{2l}}$ Frequency υ is called the fundamental frequency or 1st Harmonic.

or $\boxed{\upsilon = \frac{1}{2l}\sqrt{\frac{T}{\mu}}}$

2nd mode

There are two segments in the wire. The frequency of vibration is given by, $\underline{\underline{\upsilon_1 = 2\times\upsilon.}}$

υ_1 is called the 1st overtone and $(2\times\upsilon)$ is called 2nd harmonic.

$\therefore$ 1st overtone = 2nd harmonic

3rd mode

There are three segments in the wire.

The frequency of vibration is given by $\nu_2 = 3\times\nu$.

$\therefore$ 2nd overtone = 3rd harmonic

[NB: The number of segments in the wire give the number of mode of vibration. The frequency of nth mode of vibration is nth harmonic, where n = 1, 2, 3, etc.

n^{th} overtone = (n + 1) harmonic

In a stretched wire all the harmonics can be heard and hence the quality of sound is rich.]

$$\upsilon = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

From the above equation the three laws of transverse vibration of a string are concluded.

1. $\upsilon \propto \frac{1}{l}$, when T and m are constants.

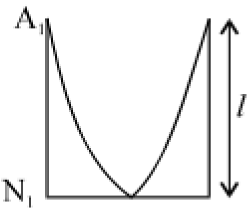
2. $\upsilon \propto \sqrt{T}$, when *l* and m are constants.

3. $\upsilon \propto \frac{1}{\sqrt{\mu}}$, when *l* and T are constants.

VIBRATION OF AIR COLUMNS

The air inside an empty pipe is called air column. The length of air column is equal to the length of empty pipe. When the air column in a pipe is put into vibration a stationary wave is formed inside the pipe, with a node at the closed end and an antinode at the open end of the pipe

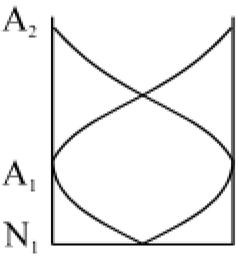
Closed Pipe: Ist Mode



$\ell = \lambda/4$; $\lambda = 4\ell$; v = $\nu\lambda$; or $\upsilon = \frac{v}{\lambda}$

$\boxed{\therefore \upsilon = \frac{v}{4\ell}}$. ν is called the 1st harmonic or fundamental frequency

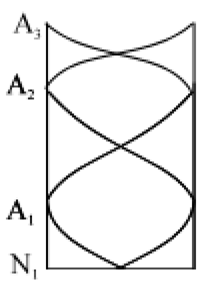
2nd mode



Frequency of vibration is υ_1 = 3× ν

ie 1st overtone = 3rd Harmonic

3rd mode



Frequency of vibration is,

υ_2 = 5 ×ν

ie 2nd overtone = 5th Harmonic

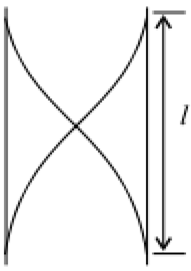
NB: Number of nodes inside the pipe gives the number of mode of vibration

The frequency of n^{th} mode of vibration is (2n – 1) harmonic where n = 1, 2, 3.....

n^{th} overtone is equal to (2n + 1) Harmonic

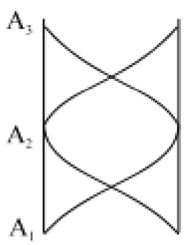
In a closed pipe only the odd multiples of harmonics can be heard, no even multiples are heard. Therefore quality of sound is poor

Open pipe: Ist mode



$\ell = \lambda/2$; $\lambda = 2\ell$; $\nu = v/\lambda$; $\boxed{\therefore \nu = \frac{v}{2\ell}}$. ν is called 1st Harmonic or fundamental frequency

2nd Mode

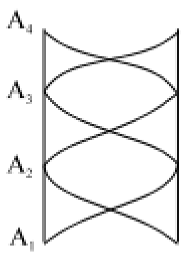


Frequency of vibration

$\nu_1 = 2 \times \nu$

ie, 1st overtone = 2nd Harmonic

3rd Mode



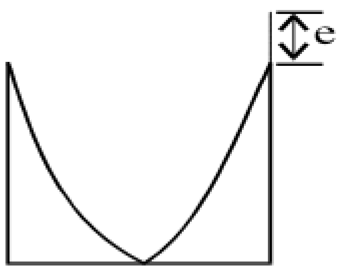
Frequency of vibration

$\nu_2 = 3 \times \nu$

ie, 2nd overtone = 3rd Harmonic

[NB : Number of nodes inside the pipe gives the number of mode of vibration.
The frequency of n^{th} mode of vibration is n^{th} Harmonic, where n = 1, 2, 3 etc
n^{th} overtone = (n + 1) harmonic
In an open pipe all the harmonics can be heard and hence the quality of sound is rich]

End correction (e)



When the air column in a pipe is put into vibration the antinode is forming not exactly at the open end, but a little above the open end. The distance of antinode from the open end is called end correction given by [e = 0.3 $\times$ d], where d is the diameter of the tube

Resonance experiment

When the two vibrating bodies vibrate with same frequency, resonance takes place and at resonance intensity of sound will be maximum.

In resonance experiment the frequency of the tunning fork and the frequency of vibrating air column are same, when resonance taken place.

Let ν be the frequency of the tunning fork. If l_1 and l_2 are the 1st and 2nd resonating lengths of air coulmns, the wave length of the wave forming inside the tube is given by

$\lambda = 2(\ell_2 - \ell_1)$. Where $\lambda/2$ = distance between successive antinodes.

Then velocity of sound wave is given by

$v = \nu \times \lambda$

i.e. $\boxed{u = \nu \times 2(\ell_2 - \ell_1)}$

The end correction at the open end of pipe is given by

$$\boxed{e = \frac{\ell_2 - 3\ell_1}{2}}$$

Doppler effect

When the source and the listner approach each other or recede each other there is a relative motion between them.

Due to the relative motion between the source and the listner the frequency ν_1 of the sound heard by the listener is appeared either to increase or to decrease from the frequency n of the source. This apparent change in frequency ν_1 is called Doppler effect.

If the source and the listner approach each other ν_1 is appeared to increase. Then $\nu_l > \nu$.

If the source and the listner recede each other ν_1 is appeared to decrease. Then $\nu_l > \nu$

$\therefore$ When there is Doppler effect, $\nu_1 \neq \nu$

If u is the velocity of sound, u_s is velocity of the source and u_l is velocity of the listner,

$\boxed{\nu_1 = \frac{u \pm u_\ell}{u \pm u_s} \times \nu}$, called general equation of Doppler effect

Interval - implies the ratio of two frequencies. If the interval is 1, the two vibrating bodies are said to exist in unison ($n_2 = n_1$). If the interval is 2, n_2 is said to be an octave higher and so if interval is 2^n, n_2 will be n octave higher.

Acoustics of Buildings

Acoustics is the branch of physics that deals with the generation, propagation and reception of sound.

Reverberation

Phenomenon of persistence or prolongation of sound in the auditorium is called reverberation.

Reverberation time

The time gap between the initial direct note and reflected note upto minimum audibility level is called reverberation time.

Sabine law

Sabine derived an expression of reverberation time which is $t = K\alpha\frac{V}{s}$, where K is constant V = volume of the hall, s = surface area exposed to the sound, α = coefficient of absorption.

PART - I (JEEMAIN)

SECTION-I - Straight objective type questions

1. A simple harmonic wave is represented as

$$y = 5\sin\frac{\pi}{2}(100t - 2x)$$

x, y are in metres, t in seconds
The ratio of wave velocity to maximum particle velocity will be
1) $1 : 2\pi$
2) $1 : 3\pi$
3) $1 : 4\pi$
4) $1 : 5\pi$

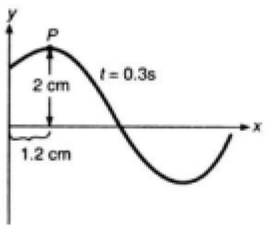
2. Two waves traveling in a medium in the x - direction are represented by $y_1 = A\sin(\alpha t - \beta x)$ and $y_2 = A\cos\left(\beta x + \alpha t - \frac{\pi}{4}\right)$, where y_1 and y_2 are the displacements of the particles of the medium, t is time, and α and β are constants. The two waves have different

1) speeds 2) directions of propagation
3) wavelengths 4) frequencies

3. The displacement of particles in a string stretched in the x - direction is represented by y. Among the following expressions for y, which can possibly represent travelling wave is

1) $\cos kx \sin \omega t$ 2) $(x-vt)^2$ 3) $\log\left(\frac{x+vt}{x_o}\right)$ 4) None of these

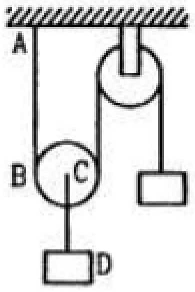
4. Figure shows a snap shot of a sincisoidal travelling wave taken at t = 0.3s. The wavelength is 7.5 cm and the amplitude is 2 cm. If the crest P was at x = 0 at t = 0, then the equation of travelling wave is



1) 2 cos (0.84 x- 3.36t) 2) 2 cos (0.84x + 3.36t)
3) 2 sin (0.84 x - 3.36 t) 4) 2 sin (o.84 x + 3.36 t)

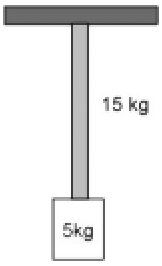
5. Both the strings shown in figure are made of same material and have same cross section. The pulleys are light. The wavespeed of transverse wave in the string AB is V_1 and in CD is V_2

Then $\frac{V_1}{V_2}$ is



1) 1 2) 2 3) $\sqrt{2}$ 4) $\frac{1}{\sqrt{2}}$

6. A uniform rope of length 10m and mass 15 kg hangs vertically from a rigid support. A block of mass 5 kg is attached to the free end of the rope. A transverse pulse of wavelength 0.08 m is produced at lower end of the rope. The wavelength of the pulse when it reaches the top of the rope will be



1) 0.08 m 2) 0.04 m 3) 0.16 m 4) 0m

7. Two waves

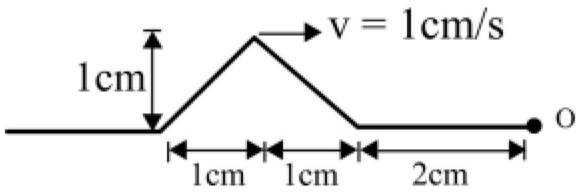
$X_1 = A\sin(wt - 0.1\,x)$ and

$X_2 = A\sin(wt - 0.1\,x - \frac{\phi}{2})$

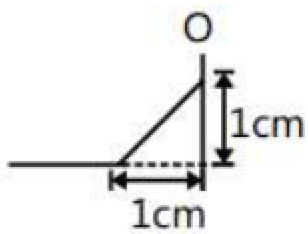
Super imposes. Resultant amplitude of combined wave is

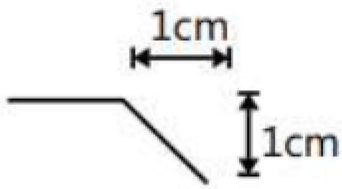
1) $2A\cos\left(\frac{\phi}{4}\right)$ 2) $A\sqrt{2\cos\left(\frac{\phi}{4}\right)}$ 3) $2A\cos\frac{\phi}{2}$ 4) $A\sqrt{2(1+\cos\frac{\phi}{2})}$

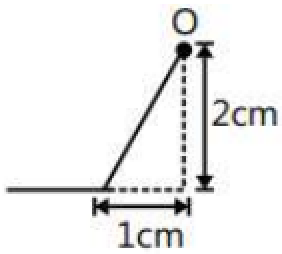
8. A wave pulse on a string has the dimension shown in figure. The wave speed is V = 1 cm/s. If point o is a free end. The shape of wave at time t = 3s is

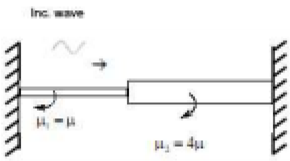


1) 

2) 

3) 

4) 

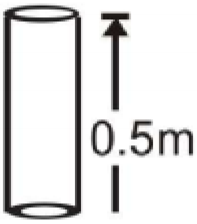
9. 

Two strings connected as shown in the figure. Find the fraction of incident power transmitted

1) $\frac{1}{9}$ 2) $\frac{4}{9}$ 3) $\frac{7}{9}$ 4) $\frac{8}{9}$

10. In each of four situation of column 1 a strethed string or an organ pipe is given along with required data. In case of strings the tension in the string is T = 102.4 N mass per unit length is 1g/m. Speed of sound in air is 320 m/s. The frequencies of resonance are given in column II

Match the following

Column I	Column II
i) 	a) 320 Hz
ii) 	b) 480 Hz
iii) 	c) 640 Hz
iv) 	d) 800 Hz

1) i - a, c ii-d iii-a iv - c
2) i - a, c ii-b, d iii - a, c iv - b, d
3) i -c ii - b iii-a iv - c
4) i - a, c ii - d iii - a iv - d

11. Stationary waves are produced in 10m long stretched string. If the string vibrates in 5 segments and wave velocity 20m/s then the frequency is

1) 10Hz
2) 5Hz
3) 4Hz
4) 2Hz

12. The length of a sonometer wire between two fixed end is 1.10 m. Where should the two bridges be placed to divide the wire into three segments whose fundamental frequencies are in the ratio 1 : 2: 3

1) 0.6 m and 0.9 m
2) 0.2 m and 0.4 m
3) 0.6 m and 0.8 m
4) 0.3 ma and 0.6 m

13. Two open pipes of length 25 cm and 25.5cm produced 0.1 beat/second. The velocity of sound will be:-

1) 255cm/s
2) 250cm/s
3) 350cm/s
4) None of these

14. The maximum length of a closed pipe that would produce a just audible sound is (v_{sound} = 336m/s):-

1) 4.2cm
2) 4.2m
3) 4.2mm
4) 1.0cm

15. How many times more intense is 90 d B sound than 40 d B sound

1) 5
2) 50
3) 500
4) 10^5

16. 1) Both assertion and reason are true and reason is correct explanation of assertion
2) Both assertion and reason are correct but reason is not the correct explanation of assertion
3) Assertion is incorrect but reason is correct
4) Assertion is correct and reason is incorrect

Assertion : Two longitudanals waves given by equations y_1 = 2 a sin (wt - kx) and y_2 = a sin (2 wt - 2 Kx) will have equal intensity

Reason : Intensity of waves of given frequency in same medium is propotional to square of amplitude only

17. Two sound waves represented by $y_1 = 4\sin 200\pi t$ and $y_2 = 3\sin 208\pi t$ super impose each other. The beat frequency and ratio of maximum to minimum intensity are

1) $8 \text{ and } \frac{7}{1}$ 2) $4 \text{ and } \frac{49}{1}$ 3) $4 \text{ and } \frac{4}{3}$ 4) $8 \text{ and } \frac{16}{9}$

SECTION - II (NUMERICAL TYPE QUESTIONS)

18. A uniform string of length 20 m is suspended from a rigid support. A short wave pulse is introduced at its lowest end. It starts moving up the string. The time taken to reach the support is $\sqrt{n}\text{ sec}$. Then value of n is _______

19. The speed of sound in hydrogen is X × 3 32 m/s at NTP if density of hydrogen is $\frac{1}{4}\text{th}$ of that of air. Find value of x if speed of sound in air is 332 m/s at NTP

20. A tuning of frequency 200 Hz is in unison with a sonometer wire. the number of beats are heared in 30s if the tension is increased by 1% is 10 n. Then n is equal to

PART - II (JEE ADVANCED)

SECTION - III (Only one option correct type)

21. In an organ pipe whose one end is at x = 0, the pressure is expressed by $p = p_0 \cos\left(\frac{3\pi x}{2}\right)\sin 300\pi t$, where x is in meter and t in sec. The organ pipe can be;

A) closed at one end, open at another with length = 0.5m

B) open at both ends, length = 1m

C) closed at both ends, length = 2m

D) closed at one end,m open at another with length $= \frac{2}{3}\text{m}$

22. The shape of a wave propagating in the positive x or negative x -direction is given $y=\frac{1}{\sqrt{1+x^2}}$ at t = 0 and $y=\frac{1}{\sqrt{2-2x+x^2}}$ at t = 1s where x and y are in meters. The shape the wave disturbance does not change during propagation. Find the velocity of the wave.

A) 1 m/s in positive x direction
B) 1 m/s in negative x direction
C) $\frac{1}{2}m/s$ in positive x direction
D) $\frac{1}{2}m/s$ in negative x direction

23. A car moves towards a hill with speed v_c. It blows a horn of frequency f which is heard by an observer following the car with speed v_0. The speed of sound in air is v.

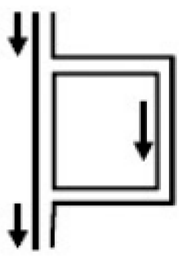
A) the wavelength of sound reaching the hill is $\frac{v}{f}$

B) the wavelength of sound reaching the hill is $\frac{v-v_c}{f}$

C) the beat frequency observed by the observer is $\left(\frac{v+v_0}{v-v_c}\right)f$

D) the beat frequency observed by the observer is $\frac{2v_c\left(v+v_0\right)f}{v^2-v_c^e}$

24. A sound consists of four frequencies $\rightarrow 300Hz$, 900 Hz, 2400 Hz and 4500 Hz. A sound 'filter's is made by passing this sound through a bifurcated pipe as shown. The sound waves have to travel a distance of 50 cm more in the right branch-pipe than in the straight pipe. The speed of sound in air is 300 m/s. Then, which of the following frequencies will be almost completely muffled or "silenced" at the outlet?



A) 300Hz
B) 900 Hz
C) 2400Hz
D) 4500 Hz

25. An string has resonant frequencies given by 1001 Hz and 2639 Hz

A) If the string is fixed at one end only, 910 Hz can be a resonance frequency

B) If the string is fixed at one end only, 1911 Hz can be a resonance frequency

C) If the string is fixed at both the ends, 364 Hz can be one of the resonant frequency.

D) 1001 Hz is definitely not the fundamental frequency of the string.

26. A horizontal stretched string, fixed at two ends, is vibrating in its fifth harmonic according to the equation, $y(x,t)=(0.01\,m)\sin\left[\left(62.8\,m^{-1}\right)x\right]\cos\left[\left(628\,s^{-2}\right)t\right]$.

Assuming $\pi = 3.14$, the correct statement(s) is (are)

A) The number of nodes is 5

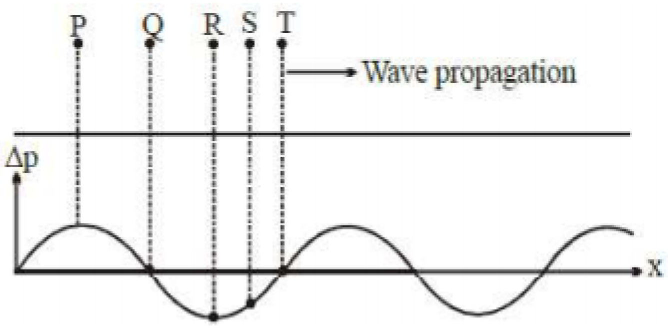
B) The length of the string is 0.25 m

C) The maximum displacement of the midpoint of the string, from its equilibrium position is 0.01 m

D) The fundamental frequency is 100Hz.

Matrix Match type

27. Sound is travelling in a long tube towards right and the graph of excess pressure variation versus position (at some instant) is given below.
Match velocities in column-I with column -II . P,Q,R,S,T are medium particles inside the tube.



Column -I	Column-II
A) Velocity is towards right	P) P
B) Velocity is towards left	Q) Q
C) Velocity is zero	R) R
D) Speed is maximum	S) S
	T) T

28. In a string a standing wave is set up whose equation is given as $y = 2A\sin kx\cos\omega t$. The mass per unit length of the string is μ.

Column-I	**Column-II**
A) AT t = 0	P) Total energy per unit length at x = 0 is $2\mu A^2\omega^2$
B) At $t = \frac{T}{8}$	Q) Total energy per unit length at $x = \lambda/4$ is $2\mu A^2\omega^2$
C) At $t = \frac{T}{4}$	R) Total energy per unit length at $x = \lambda$ is $2\mu A^2\omega^2$
D) At $t = \frac{T}{2}$	S) Power transmitted through a point at $x = \lambda$ is 0
	T) Power transmitted through a point at $x = \lambda/4$ is 0.