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# **WAVES**

#### **INTRODUCTION OF WAVES What is wave motion?**

- When a particle moves through space, it carries KE with itself. Wherever the particle goes, the energy goes with it. (one way of transport energy from one place to another place)
- There is another way (wave motion) to transport energy from one part of space to other without any bulk motion of material together with it. Sound is transmitted in air in this manner.

When you say "Namaste" to your friend no material particle is ejected from your lips to falls on your friends ear. Basically you create some disturbance in the part of the air close to

**CLASSIFICATION OFWAVES**

your lips. Energy is transfered to these air particles either by pushing them ahead or pulling them back. The density of the air in this part temporarily increases or decreases. These disturbed particles exert force on the next layer of air, transferring the disturbance to that layer. In this way, the disturbance proceeds in air and finally the air near the ear of the listener gets disturbed.

**Note :** In the above example air itself does not move.

A wave is a disturbance that propagates in space, transports energy and momentum from one point to another without the transport of matter.

**Few examples of waves :** The ripples on a pond(water waves), the sound we hear, visible light, radio and TV signals etc.



**1. Based on medium necessity :** A wave mayor may not **3** require a medium for its propagation. The waves which do not require medium for their propagation are called nonmechanical, e.g. light, heat (infrared), radio waves etc. On the other hand the waves which require medium for their propagation are called mechanical waves. In the propagation of mechanical waves elasticity and density of the medium play an important role therefore mechanical waves are also known as elastic waves.

**Example :** Sound waves in water, seismic waves in earth's crust.

**2. Based on energy propagation:** Waves can be divided into two parts on the basis of energy propagation

(i) Progressive wave (ii) Stationary waves.

The progressive wave propagates with fixed velocity in a  $\frac{D \text{Urection}}{D \text{I} \cdot \text{S} \cdot \text{O}}$ medium. In stationary waves particles of the medium vibrate with different amplitude but energy does not propagate.

**3. Based on direction of propagation :** Waves can be one, two or three dimensional according to the number of dimensions in which they propagate energy. Waves moving along strings are one-dimensional. Surface waves or ripples on water are two dimensional , while sound or light waves from a point source are three dimensional.

**4. Based on the motion of particles of medium :** Waves are of two types on the basis of motion of particles of the medium. (i) Longitudinal waves (ii) Transverse waves In the transverse wave the direction associated with the disturbance (i.e. motion of particles of the medium) is at right angle to the direction of propagation of wave.



In the longitudinal wave the direction of disturbance is along the direction of propagation.



#### **TRANSVERSE WAVE MOTION**

Mechanical transverse waves produce in such type of medium which have shearing property, so they are known as shear wave or S-wave.

**Note :** Shearing is the property of a body by which it changes its shape on application of force.

Mechanical transverse waves are generated only in solids & surface of liquid.

In this individual particles of the medium execute SHM about their mean position in direction  $\perp^r$  to the direction o of propagation of wave motion.



A **crest** is a portion of the medium, which is raised temporarily above the normal position of rest of particles of the medium , when a transverse wave passes.

A **trough** is a portion of the medium, which is depressed temporarily below the normal position of rest of particles of the medium , when a transverse wave passes.

#### **LONGITUDINAL WAVE MOTION**

In this type of waves, oscillatory motion of the medium particles produces regions of compression (high pressure) and rarafaction (low pressure) which propagated in space with time (see figure)



**Note:** The regions of high particle density are called compressions and regions of low particle density are called rarefactions.

The propagation of sound waves in air is visualised as the propagation of pressure or density fluctuations. The pressure fluctuations are of the order of 1 Pa, whereas atmospheric pressure is 10<sup>5</sup> Pa.

#### **MECHANICALWAVES IN DIFFERENT MEDIA**

A mechanical wave will be transverse or longitudinal depends on the nature of medium and mode of excitation. In strings mechanical waves are always transverse that too when string is under a tension. In gases and liquids mechanical waves are always longitudinal, .e.g., sound waves in air or water. This is because fluids cannot sustain shear. In solids mechanical waves (may be sound) can be either transverse or longitudinal depending on the mode of excitation. The speed of the two waves in the same solid are different. (longitudinal waves travels faster than transverse waves). e.g., if we struck a rod at an angle the waves in the rod will be transverse while if the rod is struck at the side or is rubbed with a cloth the waves in the rod will be longitudinal. In case of vibrating tuning fork waves in the prongs are transverse while in the stem are longitudinal. Further more in case of seismic waves produced by earth-quakes both S (shear) and P (pressure) waves are produced simultaneously which travel through the rock in the crust at different speeds ( $V_S \approx 5$  km/s while  $V_p \approx 9$  km/s] S-waves are transverse while P-waves longitudinal. Some waves in nature are neither transverse nor longitudinal but a combination of the two. These waves are called ripple and waves on the surface of a liquid are of this type. In these waves particles of the medium vibrate up and down and back and forth simultaneously describing ellipses in a vertical plane.

#### **CHARACTERISTICS OF WAVE MOTION**

Some of the important characteristics of wave motion are as follows:

- (i) In a wave motion, the disturbance travels through the medium due to repeated periodic oscillations of the particles of the medium about their mean positions.
- The energy is transferred from place to another without any actual transfer of the particles of the medium.
- (iii) Each particle receives disturbance a little later than its preceding particle i.e., there is a regular phase difference between one particle and the next.
- (iv) The velocity with which a wave travels is different from the velocity of the particles with which they vibrate about their mean positions.
- (v) The wave velocity remains constant in a given medium while the particle velocity changes continuously during its vibration about the mean position. It is maximum at the mean position and zero at the extreme position.
- (vi) For the propagation of a mechanical wave, the medium must possess the properties of inertia, elasticity and minimum friction amongst its particles.

#### **SOME IMPORTANT TERMS CONNECTED WITH WAVE MOTION**

**Wavelength () [length of one wave] :** Distance travelled by the wave during the time, anyone particle of the medium completes one vibration about its mean position. We may also define wavelength as the distance between any two nearest particles of the medium, vibrating in the same phase.

### **WAVES**



equal to one wavelength.

**Amplitude (A) :** maximum displacement of vibrating particle W from its equilibrium position.

**Angular frequency (** $\omega$ **) :** It is defined as  $\omega = \frac{2\pi}{T} = 2\pi n$   $\qquad \qquad \frac{\omega y}{\partial x} = -Ak \cos{(\omega t - kx)} = -\frac{2\pi}{6}$ 

**Phase :** Phase is a quantity which contains all information related to any vibrating particle in a wave.

For equation  $y = y = A \sin(\omega t - kx)$ ,  $(\omega t - kx) =$  phase.

**Angular wave number (k)**: It is defined as 
$$
k = \frac{2\pi}{\lambda}
$$

**Wave number**  $(\kappa)$ **: It is defined as** 

 $\kappa = \frac{1}{\lambda} = \frac{k}{2\pi}$  = number of waves in a unit length of the wave

pattern.

#### **Particle velocity, wave velocity and particle's acceleration**

In plane progressive harmonic wave particles of the medium oscillate simple harmonically about their mean position. Therefore, all the formulae in SHM apply to the particles here also. For example, maximum particle velocity is  $\pm(A\omega)$ at mean position and it is zero at extreme positions etc. Similarly maximum particle acceleration is  $\pm \omega^2 A$  at extreme positions and zero at mean position.

However the wave velocity is different from the particle velocity. This depends on certain characteristics of the medium. Unlike the particle velocity which oscillates simple harmonically (between  $+A\omega$  and  $-A\omega$ ) the wave velocity is constant for given characteristics of the medium.

**Particle velocity in wave motion :** The individual particles which make up the medium do not travel through the medium with the waves. They simply oscillate about their equilibrium positions. The instantaneous velocity of an oscillating particle of the medium, through which a wave is travelling, is known as "Particle velocity".



Direction of propagation of wave

**Wave velocity :** The velocity with which the disturbance, or planes of equal phase (wave front), travel through the medium is called wave (or phase) velocity.

#### **Relation between particle velocity and wave velocity :**

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

$$
Particle velocity = \frac{\partial y}{\partial t} = A\omega \cos(\omega t - kx) = v
$$

Wave velocity = 
$$
v_p = \frac{\lambda}{T} = \lambda \frac{\omega}{2\pi} = \frac{\omega}{K}
$$

$$
\frac{\partial y}{\partial x} = A\omega \cos{(\omega t - kx)} = v
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$$
\frac{\partial y}{\partial t} = A\omega \cos{(\omega t - kx)} = v
$$
\n
$$
\frac{\partial y}{\partial t} = 2\pi n
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$$
\frac{\partial y}{\partial x} = -Ak \cos{(\omega t - kx)} = -\frac{A}{\omega} \omega k \cos{(\omega t - kx)}
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$$
= -\frac{1}{v_p} \frac{\partial y}{\partial t} \Rightarrow \frac{\partial y}{\partial x} = -\frac{1}{v_p} \frac{\partial y}{\partial t}
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 $2\pi$   $\partial y$   $\partial y$ **Note:**  $\frac{\partial y}{\partial x}$  represent the slope of the string (wav  $\partial y$  and  $\partial y$  and  $\partial y$  and  $\partial y$ represent the slope of the string (wave) at the  $\frac{\partial x}{\partial x}$ 

point x.

 $\Rightarrow$ 

Particle velocity at a given position and time is equal to negative of the product of wave velocity with slope of the wave at that point at that instant.

**Differential equation of harmonic progressive waves:**

$$
a\text{v} = \text{velocity} = \text{v}_{\text{p}} = \frac{\lambda}{T} = \lambda \frac{\omega}{2\pi} = \frac{\omega}{K}
$$
\n
$$
\frac{V}{s} = -\text{Ak} \cos{(\omega t - kx)} = -\frac{A}{\omega} \text{c} \text{K} \cos{(\omega t - kx)}
$$
\n
$$
-\frac{1}{v_{\text{p}}} \frac{\partial y}{\partial t} \Rightarrow \frac{\partial y}{\partial x} = -\frac{1}{v_{\text{p}}} \frac{\partial y}{\partial t}
$$
\nthe:  $\frac{\partial y}{\partial x}$  represent the slope of the string (wave) at the  
\nint x.

\ntricle velocity at a given position and time is equal to  
\ngative of the product of wave velocity with slope of the  
\nwe at that point at that instant.

\nfferrential equation of harmonic progressive waves:

\n
$$
\frac{\partial^2 y}{\partial t^2} = -A\omega^2 \sin{(\omega t - kx)}; \frac{\partial^2 y}{\partial x^2} = -Ak^2 \sin{(\omega t - kx)}
$$
\n
$$
\frac{\partial^2 y}{\partial x^2} = \frac{1}{v_y^2} \frac{\partial^2 y}{\partial t^2}
$$
\ntrticle velocity (v<sub>p</sub>) and acceleration (a<sub>p</sub>) in a sinusoidal  
\nwe: The acceleration of the particle is the second partial  
\nrivative of y(x, t) with respect to t,  
\n∴  $\frac{\partial^2 y(x, t)}{\partial t^2} = \omega^2 A \sin{(kx - \omega t)} = -\omega^2 y(x, t)$   
\n∴ the acceleration of the particle equals  $-\omega^2$  times its  
\nphacement, which is the result we obtained for SHM.  
\nthus,  
\n $a_p = -\omega^2$  (displacement)

\nPlase (φ) 0  $\frac{\pi}{2} \pi \frac{3\pi}{2} 2\pi \frac{5\pi}{2} 3\pi$   
\n $\frac{\pi}{2}$  (a)  $\frac{\lambda}{2} \frac{\lambda}{4} \frac{3\lambda}{2} \frac{\lambda}{4} \frac{3\lambda}{2}$   
\n $\frac{\lambda}{2}$  (a)  $\frac{\lambda}{2}$  (b)  $\frac{\lambda}{2}$  (c)  $\frac{\lambda}{2}$  (d)  $\frac{\lambda}{2}$  (e)  $\frac{\lambda$ 

**Particle velocity (v<sup>p</sup> ) and acceleration (a<sup>p</sup> ) in a sinusoidal wave:** The acceleration of the particle is the second partial derivative of  $y(x, t)$  with respect to t,

$$
\therefore \quad \frac{\partial^2 y(x,t)}{\partial t^2} = \omega^2 A \sin(kx - \omega t) = -\omega^2 y(x,t)
$$

i.e., the acceleration of the particle equals  $-\omega^2$  times its displacement, which is the result we obtained for SHM. Thus,

$$
a_p = -\omega^2 \text{ (displacement)}
$$

**Relation between Phase difference, Path difference & Time difference :**







#### **Example 1 :**

A progressive wave of frequency 500 Hz is travelling with a velocity of 360 m/s. How far apart are two points 60° out of phase.

**Sol.** We known that for a wave  $v = f \lambda$ 

So 
$$
\lambda = \frac{v}{f} = \frac{360}{500} = 0.72 \text{ m}
$$

Now as in a wave path difference is related to phase difference by the relation

#### **THE GENERAL EQUATION OF WAVE MOTION**

Some physical quantity (say y) is made to oscillate at one place and these oscillations of y propagate to other places. The y may be,

- (i) Displacement of particles from their mean position in case of transverse wave in a rope or longitudinal sound wave in a gas.
- (ii) Pressure difference  $(dP)$  or density difference  $(dp)$  in case of sound wave or
- (iii) Electric and magnetic fields in case of electromagnetic waves.

The oscillations of y may or may not be simple harmonic in nature.

Consider one-dimensional wave travelling along x-axis. In this case y is a function of x and t. i.e.  $y = f(x, t)$ But only those function of  $x \& t$ , represent a wave motion which satisfy the differential equation. and these oscillations of y propagate to other places.<br>
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of y may or may not be si

$$
\frac{\partial^2 y}{\partial t^2} = v^2 \frac{\partial^2 y}{\partial x^2}
$$
 ......(i)

The general solution of this equation is of the form

**ERALEQUATION OF WAVEMOTION**<br>
sphysical quantity (say y) is made to oscillate at one<br>
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spectred of particles from their mean position in case<br>
were wave in  $y(x,t) = f(ax \pm bt)$  .....(ii) Thus, any function of x and t and which satisfies equation (i) or which can be written as equation (ii) represents a wave. The only condition is that it should be finite everywhere and at all times, Further, if these conditions are satx vt  $\partial t^2$   $\partial x^2$   $\partial x$   $\partial x$   $\partial y$   $\partial z$   $\partial z$ 

$$
v = \frac{\text{coefficient of t}}{\text{coefficient of x}} = \frac{b}{a}
$$

isfied, then speed of wave (v) is given by,

#### **Example 2 :**

Which of the following functions represent a travelling wave

(a) 
$$
(x - vt)^2
$$
  
\n(b)  $\ln(x + vt)$   
\n(c)  $e^{-(x - vt)^2}$   
\n(d)  $\frac{1}{x + vt}$ 

**Sol. (c).** Although all the four functions are written in the form  $f(ax \pm bt)$ , only (c) among the four functions is finite everywhere at all times. Hence only (c) represents a travelling wave.

#### **EQUATION OFA PLANE PROGRESSIVEWAVE**

If on the propagation of wave in a medium, the particles of the medium perform simple harmonic motion then the wave is called a simple harmonic progressive wave.

Suppose, a simple harmonic progressive wave is advancing in a medium along the positive direction of the x-axis (from left to right). In Fig. (a) are shown the equilibrium positions of the particles 1, 2, 3.



When the wave propagates, these particles oscillate about their equilibrium positions. In Fig. (b) are shown the instantaneous positions of these particles at a particular instant. The curve joining these positions represents the wave.

Let the time be counted from the instant when the particle 1 situated at the origin starts oscillating. If y be the displacement of this particle after t seconds, then

 $y = a \sin \omega t$  .....(1) where a is the amplitude of oscillation and  $\omega = 2\pi n$ , where

n is the frequency. As the wave reaches the particles beyond the particle 1, the particles start oscillating. If the speed of the wave be v, then it will reach particle 6, distant x from the particle 1, in

x/v sec. Therefore, the particle 6 will , start oscillating x/v sec after the particle 1. It means that the displacement of the particle 6 at a time t will be the same as that of the particle 1 at a time  $x/v$  sec earlier i.e. at time t -  $(x/v)$ . The displacement of particle 1 at time  $t - (x/v)$  can be the particle 6, distant x from the origin (particle 1), at time t is agates, these particles oscillate about<br>solitions. In Fig. (b) are shown the<br>positions. In Fig. (b) are shown the<br>positions of these particles at a particular<br>ining these positions represents the<br>ed from the instant when

coefficient of t b coefficient of x a 1 x vt given by y = a sin x t v y = a sin (t – kx) k v .......(2) y = a sin 2 2 t x T .......(3) y = a sin 2 t x T ......(4)

This is the equation of a simple harmonic wave travelling along  $+x$  direction. If the wave is travelling along the  $-x$ direction then inside the brackets in the above equations, instead of minus sign there will be plus sign.



For example, equation (4) will be of the following form :

$$
y = a \sin 2\pi \left(\frac{t}{T} + \frac{x}{\lambda}\right)
$$

If  $\phi$  be the phase difference between the above wave  $\theta$ travelling along the +x direction and an other wave, then

the equation of that wave will be  $y = a \sin \left\{ 2\pi \left( \frac{t}{T} - \frac{x}{\lambda} \right) \pm \phi \right\}$ 

#### **Example 3 :**

The equation of a wave is,

$$
y(x, t) = 0.05 \sin \left[\frac{\pi}{2}(10x - 40t) - \frac{\pi}{4}\right]m
$$

Find: (a) The wavelength, the frequency and the wave velocity

(b) The particle velocity and acceleration at  $x = 0.5$  m and  $t = 0.05$  s

**Sol.** (a) The equation may be rewritten as,

$$
y(x,t) = 0.05 \sin \left(5\pi x - 20\pi t - \frac{\pi}{4}\right)
$$
 m

Comparing this with equation of plane progressive harmonic wave,  $u(x, t) = A \sin(kx - \omega t + \phi)$ 

wave number 
$$
k = \frac{2\pi}{\lambda} = 5\pi
$$
 rad/m  $\therefore \lambda = 0.4$  m

The angular frequency is,  $\omega = 2\pi f = 20\pi$  rad /s  $\therefore$  f = 10 Hz The wave velocity is,

$$
v = f\lambda = \frac{\omega}{k} = 4 \text{ ms}^{-1} \text{ in} + x \text{ direction}
$$

(b) The particle velocity and acceleration are,

$$
v_p = \frac{\partial y}{\partial t} = -(20\pi) (0.05) \cos \left(\frac{5\pi}{2} - \pi - \frac{\pi}{4}\right) = 2.22 \text{ m/s}
$$

$$
a_p = \frac{\partial^2 y}{\partial t^2} = -(20\pi)^2 (0.05) \sin\left(\frac{5\pi}{2} - \pi - \frac{\pi}{4}\right) = 140 \text{ m/s}^2
$$

#### **INTENSITY OF WAVE**

The amount of energy flowing per unit area and per unit time is called the intensity of wave. It is represented by I. Interference Its units are  $J/m<sup>2</sup>s$  or watt/metre<sup>2</sup>.

$$
I = 2\pi^2 f^2 A^2 \rho v
$$
 i.e.  $I \propto f^2$  and  $I \propto A^2$ 

If P is the power of an isotropic point source, intensity at a distance r is given by,

$$
I = \frac{P}{4\pi r^2}
$$
 or  $I \propto \frac{1}{r^2}$  (for a point source)

If P is the power of a line source, then intensity at a distance r is given by,

$$
I = \frac{P}{2\pi r\ell} \quad \text{or} \quad I \propto \frac{1}{r} \qquad \text{(for a line source)} \qquad \text{INTERFERENC}
$$
\nWhen two

As, I  $\propto$  A<sup>2</sup>

$$
ext{Equation (4) will be of the following form:}
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\left(\frac{t}{T} + \frac{x}{\lambda}\right)
$$
\n
$$
\left(\frac{t}{T} + \frac{x}{\lambda}\right) = a \sin \left\{2\pi \left(\frac{t}{T} - \frac{x}{\lambda}\right) \pm \phi\right\}
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\text{Two or more waves can traverse the same medium without}
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and A 
$$
\propto \frac{1}{\sqrt{r}}
$$
 (for a line source)

#### **SUPERPOSITION PRINCIPLE**

Solution of the reaction of the medium of the method  $T \lambda$   $\left( \begin{array}{c} T \lambda \end{array} \right)$  Two or more waves can traverse the same medium without Broman is equal to the above wave<br>  $\left\{\begin{array}{ll}\text{SVDMADWANNEED LEARINING}\end{array}\right\}$ <br>
the above wave<br>  $\left\{2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) \pm \phi\right\}$ <br>
SUPERPOSITION PRINCIPLE<br>
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Sometion (4) will be of the following form:<br>  $y = a \sin 2\pi \left(\frac{1}{1} + \frac{x}{\lambda}\right)$ <br>
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Therefore,  $A \propto \frac{1}{r}$  (for a point source)<br>
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Therefore,  $A \propto \frac{1}{\sqrt{r}}$  (for a point source)<br>  $\frac{1}{\lambda}$ <br>  $\frac{1}{\lambda}$  (for a line source)<br>  $\frac{1}{\lambda}$ <br>  $\frac{1}{\lambda}$ example, equation (4) will be of the following form:<br>  $y = a \sin 2\pi \left( \frac{t}{1} + \frac{x}{\lambda} \right)$ <br>
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difference between the above wave<br>  $+\frac{x}{\lambda}$ <br>  $+\frac{x}{\lambda}$  (for a point source)<br>  $+\frac{x}{\lambda}$  difference between the above wave<br> affecting the motion of one another. If several waves propagate in a medium simultaneously, then the resultant displacement of any particle of the medium at any instant is equal to the vector sum of the displacements produced by individual wave. The phenomenon of intermixing of two or more waves to produce a new wave is called Superposition of waves. Therefore according to superposition principle Therefore,  $A \propto \frac{1}{r}$  (for a point source)<br>
and  $A \propto \frac{1}{\sqrt{r}}$  (for a line source)<br>
ERPOSITION PRINCIPLE<br>
Two or more waves can traverse the same medium without<br>
affecting the motion of one another. If several waves<br> Therefore,  $A \propto \frac{1}{r}$  (for a point source)<br>
and  $A \propto \frac{1}{\sqrt{r}}$  (for a line source)<br> **ERPOSITION PRINCIPLE**<br>
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The resultant displacement of a particle at any point of the<br>
medium, at any instant of time is the vector sum of t The resultant displacement of a particle at any point of the medium, at any instant of time is the vector sum of the displacements caused to the particle by the individual a particular time due to individual waves, then the resultant

Principle of superposition holds for all types of waves, i.e., mechanical as well as electromagnetic waves. But this principle is not applicable to the waves of very large amplitude. Due to superposition of waves the following phenomenon can be seen

- **1. Interference :** Superposition of two waves having equal frequency and nearly equal amplitude.
- **2. Beats :** Superposition of two waves of nearly equal frequency in same direction.
- $\sigma(\pi)$  **3. Stationary waves :** Superposition of equal wave from opposite direction.
	- **4. Lissajous figure :** Superposition of perpendicular waves.



#### **INTERFERENCE OF WAVES**

When two waves of equal frequency and nearly equal amplitude travelling in same direction having same state of polarisation in medium superimpose, then intensity is



different at different points. At some points intensity is large, whereas at other points it is nearly zero. Consider two waves For points. At some points intensity is<br>
at other points it is nearly zero. (2) If tension is T theorem<br>
waves<br>  $(6x - kx)$  and  $y_2 = A_2 \sin (cot - kx + \phi)$ <br>  $y = A \sin (\omega t - kx + \delta)$ <br>  $y = A \sin (\omega t - kx + \delta)$ <br>  $y = A \sin (\omega t - kx + \delta)$ <br>  $y = A \sin (\omega t - kx + \delta)$ Ferent points. At some points intensity is<br>
at other points it is nearly zero. (2) If tension is T then  $v \propto \sqrt{\frac{1}{m}} \leftarrow$ <br>
vaves<br>
vaves<br>
superposition<br>
= A sin (ot - kx + δ)<br>
3) A since  $\frac{1}{2}$  + A<sub>2</sub><sup>2</sup> + 2<sub>A1</sub>A<sub>2</sub> co STUDYM<br>
SETUDYM<br>
SETUDYM<br>
SETUDYM<br>
SETUDYM<br>
SERUDYM<br>
SERUDYM<br>
O waves<br>
in (ot-kx) and  $y_2 = A_2 \sin (\omega t - kx + \phi)$ <br>  $y_2 = A \sin (\omega t - kx + \phi)$ <br>  $A_1^2 + A_2^2 + 2A_1A_2 \cos \phi$ ,<br>  $A_2 \sin \phi$ <br>  $A_1 + A_2 \cos \phi$ <br>  $\vec{a} = \frac{1}{1} + \frac{1}{2} + 2\sqrt{\frac{1}{12}} \$ EXERIBING<br>
LEARNING<br>
at different points. At some points intensity is<br>
trevo waves<br>
trevo waves<br>  $A_1 \sin (\omega t - kx)$  and  $y_2 = A_2 \sin (\omega t - kx + \phi)$ <br>  $y_1 + y_2 = A_1 \sin (\omega t - kx + \delta)$ <br>  $y_1 + y_2 = A_1 \sin (\omega t - kx + \delta)$ <br>  $y_2 = A_1^2 + A_2^2 + 2A_1A_2 \cos \$ From points. At some points intensity is<br>
are to the points it is nearly zero.<br>  $\frac{d^2}{dx^2}$  and  $\frac{dy}{dx} = A_2 \sin (\omega t - kx + \phi)$ <br>  $\Rightarrow A_2^2 + 2A_1A_2 \cos \phi$ ,<br>  $\Rightarrow A_2 \sin (\omega t - kx + \phi)$ <br>  $\Rightarrow A_2 \sin (\omega t - kx + \phi)$ <br>  $\Rightarrow A_2 \sin (\omega t - kx + \phi)$ <br>  $\Rightarrow A_2 \cos$ 

 $y_1 = A_1 \sin(\omega t - kx)$  and  $y_2 = A_2 \sin(\omega t - kx + \phi)$ By principle of superposition

 $y = y_1 + y_2 = A \sin (\omega t - kx + \delta)$ where  $A^2 = A_1^2 + A_2^2 + 2A_1A_2 \cos \phi$ ,

and 
$$
\tan \delta = \frac{A_2 \sin \phi}{A_1 + A_2 \cos \phi}
$$

As intensity  $I \propto A^2$  so  $I = I_1 + I_2 + 2\sqrt{I_1}$ 

#### **Constructive interference (maximum intensity) :**

Phase difference,  $\phi = 2n\pi$  or path difference =  $n\lambda$ where  $n = 0, 1, 2, 3, ...$ 

$$
\Rightarrow \mathbf{A}_{\text{max}} = \mathbf{A}_1 + \mathbf{A}_2 \text{ and } \mathbf{I}_{\text{max}} = \mathbf{I}_1 + \mathbf{I}_2 + 2\sqrt{\mathbf{I}_1 \mathbf{I}_2}
$$

**Destructive interference (minimum intensity) :** Phase difference =  $\phi = (2n + 1)\pi$ ,

 $(-1)^{\lambda}$ ; where n = 0, 1, 2, 3, ... pulse b  $\Rightarrow$  A<sub>max</sub> = A<sub>1</sub> - A<sub>2</sub> and I<sub>max</sub> = I<sub>1</sub> + I<sub>2</sub> - 2 $\sqrt{I_1}$ 

#### **Results :**

(1) Maximum and minimum intensities in any interference wave

form. 
$$
\frac{I_{\text{max}}}{I_{\text{min}}} = \left(\frac{\sqrt{I_1} + \sqrt{I_2}}{\sqrt{I_1} - \sqrt{I_2}}\right)^2 = \left(\frac{a_1 + a_2}{a_1 - a_2}\right)^2
$$

(2) Average intensity of interference wave form :

$$
or Iav = \frac{Imax + Imin}{2}
$$

Put the value of  $I_{\text{max}} \& I_{\text{min}}$ or  $I_{av} = I_1 + I_2$ If  $a = a_1 = a_2$  and  $I_1 = I_2 = I$ 

then  $I_{max} = 4I$ ,  $I_{min} = 0$  and  $I_{AV} = 2I$ 

(3) Condition of maximum contrast in interference wave form  $a_1 = a_2$  and  $I_1 = I_2$ then  $I_{max} = 4I$ ;  $I_{min} = 0$ 

For perfect destructive interference we have a maximum contrast in interference wave form.

#### **VELOCITY OF TRANSVERSE WAVE**

Velocity of transverse Wave in any wire  $v = \sqrt{\frac{T}{m}}$ 

where m = mass per unit length  $m = \frac{m \sqrt{m}}{g}$ ,  $\ell$  described ,  $m = \pi r^2 d$ .

where  $d =$  Density of matter

$$
V = \sqrt{\frac{T}{\pi r^2 d}} = \sqrt{\frac{T}{Ad}} \quad \because \quad \pi r^2 = A
$$

(1) If m is constant then,  $V \propto \sqrt{T}$  it is called tension law.

(2) If tension is T then  $v \propto \sqrt{\frac{1}{m}} \leftarrow$  it is called law of mass.

(3) If T is constant  $&$  take wire of different radius for same

material then  $v \propto \frac{1}{r}$   $\leftarrow$  it is called law of radius

(4) If T is constant  $&$  take wire of same radius for different

material. Then  $V \propto \sqrt{\frac{1}{d}} \leftarrow$  law of density

#### **REFLECTION FROM RIGID END**

**STUDY MATERIAL: PHYSICS**<br>
ome points intensity is<br>
nearly zero. (2) If tension is T then  $v \propto \sqrt{\frac{1}{m}} \leftarrow$  it is called law of mass.<br>
(3) If T is constant & take wire of different radius for same<br>
material then  $v \propto \frac{$ **STUDY MATERIAL: PHYSICS**<br>
points intensity is<br>
(2) If fension is T then  $v \propto \sqrt{\frac{1}{m}}$   $\leftarrow$  it is called law of mass.<br>
(3) If T is constant & take wire of different radius for same<br>
material then  $v \propto \frac{1}{r} \leftarrow$  it is Consider two waves<br>
By principle of superposition<br>
where  $A^2 = A_1 +$ material then  $v \propto \frac{1}{r} \leftarrow i t$  is called law of radius<br>
(4) If T is constant & take wire of same radius for different<br>  $\sqrt{I_1 I_2}$  cos  $\phi$  material. Then  $V \propto \sqrt{\frac{1}{d}} \leftarrow \text{ law of density}$ <br> **IREFLECTION FROM RIGID END**<br> **IREFL**  $\frac{2}{(2 \times 10^{-12} \text{ m})^2}$  is being reflected, can be found by adding an inverted etive interference (maximum intensity):<br>
When the pulse reaches the right end therefore,  $\phi = 2n\pi$  or path difference = n).<br>  $= A_1 + A_2$  and  $I_{\text{max}} = I_1 + I_2 + 2\sqrt{I_1 I_2}$ <br>
the element. The element at he right end the rig Firence,  $\phi = 2n\pi$  or path difference = n).<br>
the wall. The element at the right end e<br>  $= 0, 1, 2, 3, ...$ <br>
the wall. The element at the right end end<br>  $= A_1 + A_2$  and  $I_{\text{max}} = I_1 + I_2 + 2\sqrt{I_1 I_2}$ <br>
the element. The element I a  $\frac{1}{\sqrt{1 + \lambda_2 \cos \phi}}$  material. Then  $\sqrt{\alpha} \sqrt{\frac{1}{4}}$   $\left(-\frac{1}{\sqrt{1 + \lambda_2 \cos \phi}}\right)$  material. Then  $\sqrt{\alpha} \sqrt{\frac{1}{4}}$   $\left(-\frac{1}{\sqrt{1 + \lambda_2 \cos \phi}}\right)$  material. Then  $\sqrt{\alpha} \sqrt{\frac{1}{4}}$   $\left(-\frac{1}{\sqrt{1 + \lambda_2 \cos \phi}}\right)$  material. Then sity I  $\propto A^2$  so  $I = I_1 + I_2 + 2\sqrt{I_1 I_2}$  cos  $\phi$ <br>
ifference,  $\phi = 2n\pi$  or path difference  $= \pi\lambda$ .<br>
When the pulse reaches the right end which is clamp<br>
ifference,  $\phi = 2n\pi$  or path difference  $= \pi\lambda$ .<br>  $x = A_1 + A_2$   $\Delta_2 \sin \phi$ <br>  $\Delta_2 \sin \phi$ <br>  $\Delta_3 \cos \phi$ <br>  $\Delta_4 \sin \phi$ <br>  $\Delta_5 \sin \phi$ <br>  $\Delta_6 \sin \phi$ <br>  $\Delta_7 \sin \phi$ <br>  $\Delta_8 \cos \phi$  = 1-1<sub>1</sub> + 1<sub>2</sub> + 2  $\sqrt{1_1 1_2} \cos \phi$ <br> **REFELECTION FROM RIGIDEND**<br> **REFELECTION FROM RIGIDEND**<br> **REFELECTION FROM RIGIDEND**<br>  $\frac{A_2 \sin \phi}{A_1 + A_2 \cos \phi}$ (4) If T is constant & take wire of same radius for difference  $\frac{A_2 \sin \phi}{A_1 + A_2 \cos \phi}$  (4) If T is constant & take wire of same radius for difference in  $x \times \sqrt{\frac{1}{14}}$   $\leftarrow \ln x$  of density WeBL structive interference (maximum intensity):<br>
See difference,  $\phi = 2n\pi$  or pank difference = n).<br>
the will. The element at the right end the sight and<br>
the clamp exerts equal and<br>
tructive interference (minimum intensity) When the pulse reaches the right end which is clamped at the wall. The element at the right end exerts a force on the clamp and the clamp exerts equal and opposite force on the element. The element at the right end is thus acted upon by the force from the clamp. As this end remains fixed, the two forces are opposite to each other. The force from the left part of the string transmits the forward wave pulse and hence, the force exerted by the clamp sends a return pulse on the string whose shape is similar to a return pulse but is inverted. The original pulse tries to pull the element at the fixed end up and the return pulse sent by the clamp tries to pull it down. The resultant displacement is zero. Thus, the wave is reflected from the fixed end and the reflected wave is inverted with respect to the original wave. The shape of the string at any time, while the pulse image pulse to the incident pulse.

Equation of wave propagating in  $+ve$  x-axis Incident wave :  $y_1 = a \sin(\omega t - kx)$ 



reflected wave :  $y_2 = a \sin(\omega t + kx + \pi)$ or  $y_2 = -a \sin(\omega t + kx)$ 

$$
\underbrace{\qquad \qquad }%
$$

#### **REFLECTION FROM FREE END**

T vertical force on the ring. As a result, the right end is m displaced in upward direction more than the height of the <sup>24</sup><br>
<sup>24</sup> *Equation of wave propagating in* +ve x-axis<br>
lincident wave:  $y_1 = a \sin (\omega t - kx)$ <br>
<br>
22 **Example 12** reflected wave:  $y_2 = a \sin (\omega t + kx + \pi)$ <br>
or  $y_2 = -a \sin (\omega t + kx)$ <br>
<br> **Example 12 Example 12 Example 12 Example 12** value of I<sub>max</sub> & I<sub>min</sub><br>  $= a_1 + 1_2$ <br>  $= a_2$  and  $1_1 = 1_2 = 1$ <br>  $= 2$  and  $1_1 = 1_2 = 1$ <br>  $= 2$  and  $1_1 = 1_2$ <br>  $= 41$ , I<sub>min</sub> = 0 and I<sub>AV</sub> = 21<br>  $= 41$ , I<sub>min</sub> = 0 and I<sub>AV</sub> = 21<br>  $= 41$ , I<sub>min</sub> = 0 and I<sub>AV</sub> = 21<br>  $= 4$ The right end of the string is attached to a light frictionless ring which can freely move on a vertical rod. A wave pulse is sent on the string from left. When the wave reaches the right end, the element at this end is acted on by the force from the left to go up. However, there is no corresponding restoring force from the right as the rod does not exert a pulse i.e., it overshoots the normal maximum displacement. The lack of restoring force from right can be equivalent described in the following way. An extra force acts from right which sends a wave from right to left with its shape identical to the original one.

 $\frac{1}{\text{Ad}}$  :  $\pi r^2 = \text{A}$  <br>and the reflected wave and the displacements add. Thus, The element at the end is acted upon by both the incident a wave is reflected by the free end without inversion.



Incident wave



Reflected wave  $y_2 = a \sin (\omega t + kx)$ 

#### **Example 4 :**

A uniform rope of length 12 meter and mass 6kg, is swinging vertically from rigid base. From its free end, one 2kg mass is attached. At its bottom end one transverse wave is produced of wavelength 0.06 meter. At upper end of rope, wavelength will be -

 $(1) 1.2 m$   $(2) 0.12 m$   $(3) 0.12 cm$   $(4) 1.12 cm$ 

**Sol.** (2). Tension at bottom end of rope =  $T_1 = 2 \times 9.8$  N  $\therefore$  weight of rope acts on gravity center

Therefore, tension at upper end of rope,

 $T_2 = (6+2) \times 9.8 = 8 \times 9.8$  N. Thus,  $T_2 = 4T_1$ if  $v_1$  and  $v_2$  are respective velocity at bottom and upper

end, then 
$$
\sqrt{\frac{T_1}{m}}
$$
 and  $v_2 = \sqrt{\frac{T_2}{m}}$   $\therefore v_2 = 2v_1(\because T_2 = 4T_1)$   
After reflection from free end  $y_2 =$   
By Principle of superposition.

Frequency n does not depend on medium, therefore  $v \alpha \lambda$ 

If  $\lambda_1$  and  $\lambda_2$  are respective wavelength at bottom and upper end of rope  $\lambda_2 = 2\lambda_1 = 2 \times 0.06 = 0.12 \text{ m}$ 

#### **STATIONARY WAVES**

The wave propagating in such a medium will be reflected at the boundary and produce a wave of the same kind travelling in the opposite direction. The superposition of the two waves will give rise to a stationary wave.

Formation of stationary wave is possible only in bounded medium.

#### **ANALYTICAL METHOD FOR STATIONARY WAVES**

**(i) From rigid end :** We know equation for progressive wave in positive x-direction  $y_1 = a \sin(\omega t - kx)$ After reflection from rigid end  $y_2 = a \sin(\omega t + kx + \pi)$ 

$$
y_2 = -a \sin(\omega t + kx)
$$

By principle of super position.

 $y = y_1 + y_2$  $y = a \sin (\omega t - kx) - a \sin (\omega t + kx)$  $y = -2a \sin kx \cos \omega t$ 

This is equation of stationary wave reflected from rigid end

Amplitude =  $2a \sin kx$  ...(1) Velocity of particle

$$
V_{pa} = \frac{dy}{dt} = 2a \omega \sin kx \sin \omega t \qquad \qquad \dots (2)
$$



Strain, 
$$
\frac{dy}{dx} = -2ak \cos kx \cos \omega t
$$
 ....(3)

Elasticity 
$$
E = \frac{\text{stress}}{\text{strain}} = \frac{dp}{dy}
$$

Change in pressure, 
$$
dp = E \frac{dy}{dx}
$$
 ....(4)

$$
\frac{dy}{dx} \qquad \qquad \dots (4)
$$

(1) Node : 
$$
x = 0
$$
,  $\frac{\lambda}{2}$ ,  $\lambda$  .........;  $A = 0$ ;  $V_{pa} = 0$ 

strain  $\rightarrow$  max ; change in pressure  $\rightarrow$  max This point is known as node.

 $\frac{\lambda}{2}$ ,  $\lambda$  ........

Strain,  $\frac{dy}{dx} = -2ak \cos kx \cos \omega t$  ....(3)<br>
Elasticity E =  $\frac{\text{stress}}{\text{strain}} = \frac{dp}{\frac{dy}{dx}}$ <br>
Change in pressure,  $dp = E \frac{dy}{dx}$  .....(4)<br>
(1) Node:  $x = 0$ ,  $\frac{\lambda}{2}$ ,  $\lambda$ ..........;  $A = 0$ ;  $V_{pa} = 0$ <br>
strain  $\rightarrow$  max; change in pre (2) Antinode  $x = \frac{1}{4}, \frac{1}{4}, \dots, A \rightarrow \max; V_{pa} \rightarrow \max$  $\frac{\lambda}{4}$ ,  $\frac{3\lambda}{4}$  ........; A  $\rightarrow$  max ; V<sub>pa</sub>  $\rightarrow$  max  $\frac{\lambda}{\lambda}$  ......... ; **A**  $\rightarrow$  max ;  $V_{pa}$   $\rightarrow$  max

Strain =  $0$ ; Change in pressure =  $0$ This point is known as antinode.

Position of Antinodes 
$$
\rightarrow \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}
$$
 ......

 $\frac{dy}{dx}$  ......(4)<br>
...; A = 0; V<sub>pa</sub> = 0<br>
ssure → max<br>
........<br>
........<br>
...; A → max; V<sub>pa</sub> → max<br>
essure = 0<br>
ode.<br>
........<br>
ow equation for progressive<br>
y<sub>1</sub> = a sin (ot - kx)<br>  $y_2$  = a sin (ot + kx)<br>
1.  $\frac{dy}{dx}$  ....... <br>  $\therefore$   $A = 0$ ;  $V_{pa} = 0$ <br>
oressure  $\rightarrow$  max<br>  $\therefore$   $A \rightarrow$  max;  $V_{pa} \rightarrow$  max<br>  $\therefore$   $\therefore$   $\therefore$   $A \rightarrow$  max;  $V_{pa} \rightarrow$  max<br>  $\therefore$  pressure  $= 0$ <br>
tinode.<br>  $\frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$  ......<br>
know equation fo x cos ot ....(3)<br>  $\frac{1}{2}$ <br>
E  $\frac{dy}{dx}$  .....(4)<br>
.......; A = 0; V<sub>pa</sub> = 0<br>
oressure  $\rightarrow$  max<br>
de.<br>
.........<br>
.......; A  $\rightarrow$  max; V<sub>pa</sub>  $\rightarrow$  max<br>
n pressure = 0<br>
tinode.<br>  $\frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$  ......<br>
know equat **(ii) From free end :** We know equation for progressive wave in positive x-direction  $y_1 = a \sin(\omega t - kx)$ After reflection from free end  $y_2 = a \sin(\omega t + kx)$ 

$$
y = y_1 + y_2
$$
  
y = a sin (cot – kx) + a sin (cot + kx)  
y = 2 a sin ot cos kx  
Amplitude = 2a cos kx

Velocity of particle =  $\frac{dy}{dt}$  = 2a $\omega$  cos  $\omega$  cos kx Strain =  $\frac{dy}{dt}$  = -2ak sin  $\omega t$  sin kx

Change in pressure dp =  $E \frac{dy}{dx}$ dx and the contract of the con

(1) Antinode :  $0, \frac{\lambda}{2}, \lambda, \dots; A \rightarrow \text{Max}; V_{pa} \rightarrow \frac{dy}{dt} \rightarrow \text{Max}$ strain =  $0$ ; dp = 0

This point is known as antinode.

Position of antinode  $\rightarrow 0, \frac{\lambda}{2} \lambda$  ....

(2) Node :

$$
x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}
$$
 .....;  $A = 0$ ;  $\frac{dy}{dt} = 0$ 

strain  $\rightarrow$  Max; dp  $\rightarrow$  Max This point is known as node.

Position of node 
$$
\frac{\lambda}{4}
$$
,  $\frac{3\lambda}{4}$ ,  $\frac{5\lambda}{4}$  .........



#### **PROPERTIES OF STATIONARY WAVES**

The stationary waves are formed due to the superposition of two identical simple harmonic waves travelling in opposite direction with the same speed. Important characteristics of stationary waves are :

- (i) Stationary waves are produced in the bounded medium and the boundaries of bounded medium may be rigid or free.
- (ii) In stationary waves nodes and antinodes are formed alternately. Nodes are the points which are always in rest having maximum strain. Antinodes are the points where the particles vibrate with maximum amplitude having minimum strain.
- (iii) All the particles except at the nodes vibrate simple harmonically with the same period.
- (iv) The distance between any two successive nodes or

antinodes is  $\frac{\lambda}{2}$  $\lambda$ .

- (v) The amplitude of vibration gradually increases from zero to maximum value from node to antinode.
- (vi) All the particles in one particular segment vibrate in the same phase, but the particle of two adjacent segments differ in phase by 180°.
- (vii) All points of the medium pass through their mean position simultaneously twice in each period.
- (viii) Velocity of the particles while crossing mean position varies from maximum at antinodes to zero at nodes.
- (ix) In a standing wave the medium is splited into segments and each segment is vibrating up and down as a whole.
- (x) In longitudinal stationary waves, condensation (compression) and rarefactions don't travel forward as in progressive waves but they appear and disappear alternately at the same place.
- (xi) These waves do not transfer energy in the medium.

Transmission of energy is not possible in a stationary wave

#### **TRANSMISSION OF WAVES**

We may have a situation in which the boundary is intermediate between these two extreme cases, that is, one in which the boundary is neither rigid nor free. In this case, part of the incident energy is transmitted and part is reflected. For instance, suppose a light string is attached to a heavier string as in (figure). When a pulse travelling on the light reaches the knot, part of it is reflected and inverted and part of it is transmitted to the heavier string. As one would expect, the reflected pulse has a smaller amplitude than the incident pulse, since part of the incident energy is transferred to the pulse in the heavier string. The inversion in the reflected wave is similar to the behavior of a pulse meeting a rigid boundary, when it is totally reflected.



Where a pulse travelling on a heavy string strikes the boundary of a lighter string, as in (figure), again part is reflected and part is transmitted. However, in this case the reflected pulse is not inverted. In either case, the relative height of the reflected and transmitted pulses depend on the relative .densities of the two string.



The speed of a wave on a string increases as the density of the string decreases. That is, a pulse travels more slowly on a heavy string than on a light string, if both are under the same tension. The following general rules apply to reflected waves. When a wave pulse travels from medium A to medium B and  $v_A > v_B$  (that is, when B is denser than A), the pulse will be inverted upon reflection. When a wave pulse travels from medium A to medium B  $&v_A < v_B$ (A is denser than B), it will not be inverted upon reflection. itted pulse<br>as the density<br>Is more slowly<br>both are under<br>rules apply to<br>if from medium<br>is denser than<br> $\lim B \& v_A < v_B$ <br>pon reflection.<br> $= \ell \Rightarrow \lambda = 2\ell$ s the density<br>s more slowly<br>oth are under<br>ules apply to<br>from medium<br>is denser than<br>ion. When a<br>n B &v<sub>A</sub> < v<sub>B</sub><br>on reflection.<br> $\ell \Rightarrow \lambda = 2\ell$ <br> $\ell \Rightarrow \lambda = \ell$ <br> $\ell \Rightarrow \lambda = \frac{2\ell}{3}$ So from medium<br>
B is denser than<br>
ction. When a<br>
um B & v<sub>A</sub> < v<sub>B</sub><br>
upon reflection.<br>  $= \ell \Rightarrow \lambda = 2\ell$ <br>  $\frac{\lambda}{\ell} = \ell \Rightarrow \lambda = \ell$ <br>  $= \ell \Rightarrow \lambda = \frac{2\ell}{3}$ 

## **STATIONARYWAVE**

Stationary wave are of two types –

- (I) Transverse st. wave (stretched string)
- (II) Longitudinal st. wave (organ pipes)

**Transverse stationary wave :**

First Harmonic  
\n
$$
\begin{array}{ccc}\n & \lambda & \lambda = \ell \Rightarrow \lambda = 2\ell \\
\hline\n & \downarrow & \downarrow \\
 & \downarrow & \downarrow \\
 & & \downarrow \\
 & & & \downarrow\n\end{array}
$$

Second Harmonic 
$$
\frac{N \cancel{\overbrace{A} \cdot \overbrace{A} \
$$

A to medium B and v<sub>A</sub> > v<sub>B</sub> (that is, when B is denser than  
A), the pulse will be inverted upon reflection. When a  
wave pulse travels from medium A to medium B & v<sub>A</sub> < v<sub>B</sub>  
(A is denser than B), it will not be inverted upon reflection.  
ITONARYWAVE  
Stationary wave are of two types –  
(1) Transverse st. wave (stretched string)  
(II) Longitudinal st. wave (organ pipes)  
Transverse stationary wave:  
First Harmonic  

$$
rac{A}{L}
$$

$$
rac{
$$

p th harmonic

$$
\frac{p\lambda}{2} = \ell \Longrightarrow \lambda = \frac{2\ell}{p}
$$



 **(i) Law of length:** For a given string, under a given tension, the fundamental frequency of vibration is inversely proportional to the length of the string, i.e,

$$
n \propto \frac{1}{\ell} \text{ (T and m are constant)}
$$

**(ii) Law of tension :** The fundamental frequency of vibration of stretched string is directly proportional to the square root of the tension in the string, provided that length and mass per unit length of the string are kept constant.

 $n \propto \sqrt{T}$  ( $\ell$  and m are constant)

**(iii) Law of mass :** The fundamental frequency of vibration of a stretched string is inversely proportional to the square root of its mass per unit length provided that length of the string and tension in the string are kept constant, i.e.,

$$
n \propto \frac{1}{\sqrt{m}} \text{ } (\ell \text{ and } T \text{ are constant)}
$$

#### **(1) Melde's experiment:**

In Melde's experiment, one end of a flexible piece of thread is tied to the end of a tuning fork. The other end passed over a smooth pulley carries a pan which can be suitable loaded.,

#### **Transverse arrangement :**

**Case 1 :** In a vibrating string of fixed length, the product of number of loops in a vibrating string and square root of

**Case 2 :** When the tuning fork is set vibrating such that the prong vibrates at right angles to the thread. As a result the thread is set into motion. The frequency of vibration of the thread (string) is equal to the frequency of the tuning fork. If length and tension are properly adjusted then, standing waves are formed in the string. (This happens when frequency of one of the normal modes of the string matched with the frequency of the tuning fork). Then, if p loops are formed in the thread, then the frequency of the

tuning fork is given by 
$$
n = \frac{p}{2\ell} \sqrt{\frac{T}{m}}
$$

**Case 3 :** If the tuning fork is turned through a right angle, so that the prong vibrates along the length of the thread, then the string performs only a half oscillation for each complete vibrations of the prong. This is because the thread sags only when the prong moves towards the pulley i.e. only once in a vibration.

**Longitudinal arrangement :** The thread performs sustained oscillations when the natural frequency of the given length of the thread under tension is half that of the fork. Thus if p loops are formed in the thread, then the

frequency of the tuning fork is 
$$
n = \frac{2p}{2\ell} \sqrt{\frac{T}{m}}
$$

#### **SONOMETER**

Sonometer consists of a hollow rectangular box of light wood. One end of the experimental wire is fastened to one end of the box. The wire passes over a frictionless pulley at the other end of the box. The wire is stretched by a tension T.



The box serves the purpose of increasing the loudness of the sound produced by the vibrating wire. If the length the wire between the two bridges is  $\ell$ , then the frequency

of vibration is, 
$$
n = \frac{1}{2\ell} \sqrt{\frac{T}{m}}
$$

For the stretched by a tension T.<br>
Excellent the value is stretched by a tension T.<br>
Bridge<br>  $\sum_{\text{Dox}}$ <br>
Transion<br>
Trans To test the tension of a tuning fork and string, a small paper rider is placed on the string. When a vibrating tuning fork is placed on the box, and if the length between the bridges is properly adjusted, then when the two frequencies are exactly equal, the string quickly picks up the vibrations of the fork and the rider is thrown off the wire. There are three laws of vibration of a wire.

#### **SOUND WAVES**

#### **Displacement and pressure waves**

of streethed string is directly proportional to the square to the the threat as so that the same of the same of the same of the same of mare constant.<br>
The box serves the purpose of increasing the same of mass per unit le A sound wave (i.e. longitudinal mechanical wave) can be described either in terms of the longitudinal displacement suffered by the particles of the medium (called displacementwave) or in terms of the excess pressure generated due to compression and rarefaction (called pressure-wave). Consider a sound wave travelling in the x-direction in a medium. Suppose at time t, the particle at the undisturbed position x suffers a displacement y in the x-direction. The displacement wave then will be described by **AVES**<br> **AVES**<br> **CONTEXT AND** WAVE (i.e. longitudinal mechanical wave) can be<br>
bed either in terms of the longitudinal displacement<br>
of d by the particles of the medium (called displacement-<br>
or in terms of the excess pre acement and pressure waves<br>
and wave (i.e. longitudinal mechanical wave) can be<br>
bibel either in terms of the longitudinal displacement<br>
bibel of the princiles of the medium (called displacement-<br>
or in terms of the exces There are three laws of vibration of a wire.<br> **NAVES**<br> **IACTES**<br> **IACTES**<br> **IACTES**<br> **IACTES**<br> **IACTES**<br> **IACTES**<br> **I** the particles of the medium (called displacement-<br>  $\frac{1}{2}$ <br>  $\frac{1}{2}$  or in terms of the excess pres ....(2) we (i.e. longitudinal mechanical wave) can be<br>ther in terms of the longitudinal displacement<br>en particles of the medium (called displacement<br>ensures of the excess pressure generated due to<br>and rarefaction (called pressure ngitudinal mechanical wave) can be<br>ms of the longitudinal displacement<br>so fthe medium (called displacement-<br>he excess pressure generated due to<br>action (called pressure-wave).<br>eve travelling in the x-direction in a<br>ime t, ignoses the mediator of the longitudinal displacement<br>ans of the longitudinal displacement<br>so fthe medium (called displacement<br>he excess pressure generated due to<br>action (called pressure-wave).<br>we travelling in the x-dire

 $\overline{T}$  cross-section, the volume element in undisturbed state will m<br>displaced by amount y and  $y + \Delta y$  so that increase in  $y = A \sin(\omega t - kx)$  .....(1) Now consider the element of medium which is confined with in x and  $x + \Delta x$  in the undisturbed state. If S is the be  $V = S\Delta x$ . As the wave passes the ends at x and  $x + \Delta x$  are volume of the element will be  $\Delta V = S \Delta y$ . This in turn implies that volume strain for the element under consideration ther in terms of the longitudinal displacement<br>
e particles of the medium (called displacement-<br>
terms of the excess pressure generated due to<br>
and rarefaction (called pressure generated due to<br>
sound wave travelling in t so of the mediatural displacement-<br>of the medium (called displacement-<br>e excess pressure generated due to<br>ction (called pressure-wave).<br>travelling in the x-direction in a<br>met, the particle at the undisturbed<br>placement y i ssure generated due to<br>
I pressure-wave).<br>
in the x-direction in a<br>
icle at the undisturbed<br>
in the x-direction. The<br>
cribed by<br>
.....(1)<br>
um which is confined<br>
urbed state. If S is the<br>
undisturbed state will<br>
ends at x consider the element of medium which is confined<br>in x and x +  $\Delta x$  in the undisturbed state. If S is the<br>s-section, the volume element in undisturbed state will<br> $=$  SAx. As the wave passes the ends at x and x +  $\Delta x$  are y in the x-direction. The<br>escribed by<br>......(1)<br>ddium which is confined<br>sturbed state. If S is the<br>in undisturbed state will<br>be ends at x and x +  $\Delta x$  are<br> $\Delta y$  so that increase in<br> $= S \Delta y$ . This in turn implies<br>t under c

$$
\frac{\Delta V}{V} = \frac{S \Delta y}{S \Delta x} = \frac{\Delta y}{\Delta x}
$$
 ....(2)

So, corresponding stress, i.e. excess pressure

$$
p = B = \left[\frac{-\Delta V}{V}\right] \left[ \text{as } B = -V \frac{\Delta P}{\Delta V} = -V \frac{P}{\Delta V} \right]
$$

$$
\frac{1}{T}
$$
 or  $p = -B \frac{\Delta y}{\Delta x}$  [from eqn. 2] ....(3)

 $2\ell \quad V$  m **Note:** For a harmonic progressive waveform

$$
\frac{dy}{dx} = \frac{v_{pa}}{v}, \ p = -B \frac{dy}{dx} = B \left(\frac{v_{Pa}}{v}\right)
$$

i.e. pressure in a sound wave is equal to the product of elasticity of gas with the ratio of particle speed to wave

speed. 
$$
\frac{\Delta y}{\Delta x} = -Ak \cos (\omega t - kx)
$$
  
so  $p = AkB \cos (\omega t - kx)$  i.e.  $p = p_0 \cos (\omega t - kx)$ 

 $p_0 \cos(\omega t - kx)$ with  $p_0 = ABk$  ....(4) From eqn. (1) and (4) is clear that



(1) A sound wave may be considered as either a displacement wave  $y = A \sin(\omega t - kx)$  or a pressure wave  $p = p_0 \cos(\omega t - kx)$ 

(2) The pressure wave is 90° out of phase with respect to displacement wave, i.e, displacement will

be maximum when pressure is minimum and vice-versa. This is shown in fig.

(3) The amplitude of pressure wave

$$
p_0 = ABk = Akpv^2
$$
 [as v =  $\sqrt{B/\rho}$ ]  
 
$$
p_0 = pvA\omega
$$
 [as v =  $\omega/k$ ] ....(5)

(4) As sound-sensors (e.g., ear or mic) detects pressure changes, description of sound as pressure-wave is preferred over displacement wave.

#### **Ultrasonic, Infrasonic and Audible Sound**

Sound waves can be classified in three groups according to their range of frequencies.

**Infrasonic Waves :** Longitudinal waves having frequencies below 20 Hz are called infrasonic waves. They cannot be heard by human beings. They are produced during earthquakes. Infrasonic waves can be heard by snakes.

**Audible Waves :** Longitudinal waves having frequencies lying between 20-20,000 Hz are called audible waves.

**Ultrasonic Waves :** Longitudinal waves having frequencies above 20,000 Hz are called ultrasonic waves. They are produced and heard by bats. They have a large energy content.

**Applications of Ultrasonic Waves :** Ultrasonic waves have a large range of application. Some of them are :

(i) The fine internal cracks in metal can be detected by ultrasonic waves. .

- Ultrasonic waves can be used for determining the depth of the sea, lakes etc.
- (iii) Ultrasonic waves can be used to detect submarines, icebergs etc.
- (iv) Ultrasonic waves can be used to clean clothes, fine machinery parts etc.
- (v) Ultrasonic waves can be used to kill smaller animals like rates, fish and frogs etc.

**Shock Waves :** If the speed of the body in air is greater than the speed of the sound, then it is called supersonic speed. Such a body leaves behind a conical region of disturbance which spreads continuously such a disturbance is called a Shock Waves.

This wave carries huge energy. If it strikes a building, then the building may be damage.

#### **Sound intensity in decibels :**

This wave carries huge energy. If it strikes a building, then<br>the building may be damage.<br>Sound intensity in decisies:<br>The physiological sensation of loudness is closely related<br>to the intensity of wave producing the soun The physiological sensation of loudness is closely related to the intensity of wave producing the sound. At a frequency of 1 kHz people are able to detect sounds with intensities as low as  $10^{-12}$  W/m<sup>2</sup>. On the other hand an intensity of 1 W/m<sup>2</sup> can cause pain, and prolonged exposure to sound at this level will damage a person's ears. Because the range in intensities over which people hear is so large, it is convenient to use a logarithmic scale to specify intensities. Les as tow as 10 w/nit. On the under land and<br>y of 1 W/m<sup>2</sup> can cause pain, and prolonged exposure<br>d at this level will damage a person's ears. Because<br>ge in intensities over which people hear is so large,<br>nowenient to us the as low as 10<sup>-12</sup> W/m<sup>2</sup>. On the other band a ring<br>ties as low as 10<sup>-12</sup> W/m<sup>2</sup>. On the other hand an<br>ty of 1 W/m<sup>2</sup> can cause pain, and prolonged exposure<br>dd at this level will damage a person's ears. Because<br>gen i

If the intensity of sound in watts per square meter is I, then  $\beta$  in decibels (dB) is given by,

$$
\beta = 10 \log \frac{I}{I_0}
$$

where the base of the logarithm is 10, and  $I_0 = 10^{-12} W/m^2$ (roughly the minimum intensity that can be heard).

On the decibel scale, the pain threshold of  $1 \text{ W/m}^2$  is then

$$
\beta = 10 \log \frac{1}{10^{-12}} = 120 \text{dB}
$$

**Example 5 :**

Calculate the change in intensity level when the intensity of sound increases by  $10^6$  times its original intensity.

**Sol.** Here, 
$$
\frac{I}{I_0} = \frac{\text{Final intensity}}{\text{Initial intensity}} = 10^6
$$

Increase in intensity level, 
$$
L = 10 \log_{10} (I/I_0)
$$

$$
= 10 \log_{10} (10^6) = 10 \times \log_{10} 10 = 10 \times 6 \times 1
$$

$$
\Rightarrow L = 60 \text{ decibal}
$$

#### **CHARACTERISTICS OF SOUND**

Sound is characterised by the following three parameters : **Loudness:** It is the sensation received by the ear due to intensity of sound. Experimentally Weber-Fechner established that  $L \propto K \log I$ 

i.e., greater the amplitude of vibration, greater will be the intensity I ( $\propto$  A<sup>2</sup>) and so louder will be the sound as in about and lesser then intensity, feeble will be the sound as in whispering.

**WAVES**



The unit of loudness is phon which is equal to the intensity level in dB of equally loud sound of a kHz [for which the ear is mot sensitive].

**Pitch** : It is the sensation received by the ear due to frequency and is the characteristic which distinguishes a shrill (or sharp) sound from a grave (or flat) sound. As pitch depends on frequency, higher the frequency higher will be the pitch and shriller will be the sound. Regarding pitch it is worth noting that:

(1) The buzzing of a bee or humming of a mosquito has high pitch but low loudness while the roar of a lion has large loudness but low pitch.

(2) Due to more harmonics usually the pitch of female voice is higher than male.

**Quality (or timbre) :** It is the sensation received by the ear due to 'waveform'. Two sounds of same intensity and frequency will produce different sensation on the ear if their waveforms are different. Now as waveform depends on overtones present, quality of sound depends on number of overtones, i,e., harmonics present and their relative intensities.

**Musical Scale :** The arrangement of notes having definite ratio in respective fundamental frequencies is called a musical scale. Musical scales are of two types.

**(a) Diatonic scale :** It is known as 'Sargam' in Indian system. It contains eight notes with definite ratio in their frequencies. The note of lowest frequency is called key note and the highest (which is double of first) is called an octave. Harmonium, piano etc. are based on this scale.

**(b) Tempered Scale :** It contains 13 notes. the ratio of frequencies of successive notes is  $2^{1/12}$ .

**Musical Interval :** The ratio between the frequencies of two notes is called the musical interval. Following are the names of some musical intervals.

(i) Unison 
$$
\frac{n_2}{n_1} = 1
$$
 (ii) Octave  $\frac{n_2}{n_1} = 2$  by New air ten

(iii) Major tone 
$$
\frac{n_2}{n_1} = \frac{9}{8}
$$
 (iv) Minor tone  $\frac{n_2}{n_1} = \frac{10}{9}$   $\therefore$   $v_{air} = \sqrt{ }$ 

(v) Semi tone 
$$
\frac{n_2}{n_1} = \frac{16}{15}
$$
 (vi) Fifth tone  $\frac{n_2}{n_1} = \frac{3}{2}$  So,  $V_{air} =$ 

**Reverberation :** If a loud sound wave is produced in a ordinary room with good reflecting walls, the wave undergoes a large number of reflections at the walls. The repeated reflections produce persistence of sound, this phenomenon is called reverberation. In an auditorium or class room excessive reverberation is not desirable. However, some reverberation is necessary in a concert hall. **Time of reverberation :** It is the time required by the energy density to fall to the minimum audibility value (E) from an initial steady value  $10<sup>6</sup>E$  (i.e. million times minimum audibility) when the source of the sound wave is removed. The optimum time of reverberation is about 0.5s for a medium sized room, 0.8s to 1.5s for an auditorium, 1s to 2s for a music room and greater than 2s for a temple.

#### **ECHO**

Multiple reflection of sound is called an echo. If the distance of reflector from the source is d then,  $2d = vt$ 

Hence,  $v = speed of sound and t$ , the time of echo.

$$
\therefore d = \frac{vt}{2}
$$

Since, the effect of ordinary sound remains on our ear for 1/10 second, therefore, if the sound returns to the starting point before 1/10 second, then it will not be distinguished from the original sound and no echo will be heard. Therefore, the minimum distance of the reflector is, **EXECUTE 10**<br> **EXECUTE:**<br> **EX SOURCE AGAINET CONSTRUCT CONTROLLER CONTROLLER CONTROLLER CONTROLLER CONTROLLER CONTROLLER (SUIT) (SOURCE 1)** or the source is d then, 2d = vt or fore, if the sound remains on our ear for origin, if the sound returns to **EDIMADVANCED LEARNING**<br>
is called an echo. If the distance<br>
is d then,  $2d = vt$ <br>
and t, the time of echo.<br>
y sound remains on our ear for<br>
personal returns to the starting<br>
then it will not be distinguished<br>
no echo will b

$$
d_{\min} = \frac{v \times t}{2} = \left(\frac{330}{2}\right) \left(\frac{1}{10}\right) = 16.5 m
$$

#### **SPEED OF LONGITUDINAL (SOUND) WAVES**

**Newton Formula :** Use for every medium

$$
V_{\text{medium}} = \sqrt{\frac{E}{\rho}}
$$
, Where, E = Elasticity coefficient of

medium,  $\rho$  = Density of medium **(a) For solid medium :**

$$
V_{solid} = \sqrt{\frac{y}{\rho}}
$$
  $E = y = Young's modulus$ 

for soft iron  $V_{\text{soft iron}} = 5150 \text{ m/s}$ 

**(b) For liquid Medium :** 
$$
V_{liquid} = \sqrt{\frac{B}{\rho}}
$$

 $E = B$ , where  $B =$  volume elasticity coefficient of liquid for water  $V_{\text{Water}} = 1450 \text{ m/s}$ 

**(c) For gas medium :**

 $n_1$  air temperature remains constt. (i.e. the process is  $n<sub>2</sub>$  by Newton. He assumed that sound propagates through The formula for velocity of sound in air was first obtained isothermal) So, Isothermal Elasticity = P V<sub>medium</sub> =  $\sqrt{\frac{E}{\rho}}$ , Where, E = Elasticity coefficient of<br>
medium,  $\rho$  = Density of medium<br>
(a) For solid medium:<br>
V<sub>solid</sub> =  $\sqrt{\frac{y}{\rho}}$  E = y = Young's modulus<br>
for soft iron V<sub>soft iron</sub> = 5150 m/s<br>
(b) For liqu

$$
\frac{n_2}{n_1} = \frac{10}{9}
$$
  $\therefore$   $v_{air} = \sqrt{(P/\rho)}$   
At NTP for air, P = 1.01 × 10<sup>5</sup> N/m<sup>2</sup> and p = 1.3 kg/m<sup>3</sup>

$$
\frac{n_2}{n_1} = \frac{3}{2}
$$
  
So,  $V_{air} = \sqrt{\frac{1.01 \times 10^5}{1.3}} = 279 \text{ m/s}$ 

However, the experimental value of sound in air is 332 m/s which is much higher than given by Newton's formula

**Laplace Correction :** In order to remove the discrepancy between theoretical and experimental values of velocity of sound, Laplace modified Newton's formula assuming that propagation of sound in air is adiabatic process, i.e. Adiabatic Elasticity =  $\gamma$  P for water V<sub>Water</sub> = 1450 m/s<br>
(c) For gas medium :<br>
(c) For gas medium :<br>
The formula for velocity of sound in air was first obtained<br>
they held the velocity of sound in air was first obtained<br>
by Newton. He assumed that

so that 
$$
v = \sqrt{(\gamma P/\rho)}
$$
 .....(3)  
i.e.,  $v = \sqrt{1.41} \times 279 = 331.3$  m/s [as  $\gamma_{air} = 1.41$ ]



Which is in good agreement with the experimental value (3) (332 m/s). This in turn establishes that sound propagates adiabatically through gases.

The velocity of sound in air at NTP is 332 m/s which is much lesser than that of light & radio-waves  $(3 \times 10^8 \text{m/s})$ In case of gases

v<sup>s</sup> i.e. v<sup>s</sup> <sup>=</sup> PV mass as or v = RT [as PV = RT] <sup>V</sup>rms<sup>=</sup> 3RT / M<sup>W</sup>

or 
$$
v_s = \sqrt{\frac{\gamma RT}{M_w}}
$$
 as  $\mu = \frac{mass}{M_W} = \frac{M}{M_W}$  ...(4)

$$
M_w
$$
 = Molecular weight

And from kinetic-theory of gases

$$
V_{\rm rms} = \sqrt{(3RT/M_{\rm w})}
$$
So  
so  

$$
V_{\rm rms} = \sqrt{\frac{\gamma}{3}}
$$
. i.e.  $v_{\rm s} = \left[\frac{\gamma}{3}\right]^{1/2} v_{\rm rms}$ 

i.e., velocity of sound in a gas is of the order of rms speed of gas molecules ( $v \sim v_{rms}$ )

As velocity of sound in a according to Eqn. (4) is -

$$
\sqrt{\frac{\gamma RT}{M_w}}
$$
g/m/cc, densi

Velocity of sound in case of gases at constant temperature depends on the nature of gas i.e., its atomicity  $(y)$  and molecular weight.

#### **Effect of Various Quantities**

### **(1) Effect of temp.**

For a gas  $\gamma \& M_W$  is constant

And from kinetic-theory of gases  
\n
$$
V_{rms} = \sqrt{3RT/M_w}
$$
  
\nSo,  $\frac{v_s}{v_{rms}} = \sqrt{\frac{y}{3}}$ , i.e.  $v_s = \left[\frac{\gamma}{3}\right]^{1/2}$   
\nAs velocity of sound in a gas is of the order of rms speed  
\nof gas molecules (v ~ v<sub>rms</sub>)  
\nAs velocity of sound in a according to Eqn. (4) is -  
\n $\sqrt{\frac{YRT}{M_w}}$   
\nAs velocity of sound in a according to Eqn. (4) is -  
\n $\sqrt{\frac{YRT}{M_w}}$   
\n $\sqrt{\frac{YRT}{M_w}}$   
\nSolving 600 m/s  
\nthe nature of gas is of the order of rms speed  
\nof gas molecules (v ~ v<sub>rms</sub>)  
\n $\sqrt{\frac{YRT}{M_w}}$   
\n<

By applying Binomial theorem.

(i) For any gas medium  $v_t = v_0 \left| 1 + \frac{t}{546} \right|$  amplituding any superposition

(ii) For air  $v_0 = 332$  m/sec.;  $v_t = v_0 + 0.61$ t m/sec

#### **(2) Effect of Relative Humidity :**

With increase in humidity, density decreases so in the light 1.

of 
$$
v = \sqrt{\gamma P / \rho}
$$

We conclude that with rise in humidity velocity of sound increases. This is why sound travels faster in humid air (rainy season) than in dry air (summer) at same temperature.

## **(3) Effect of Pressure :**

As velocity of sound

$$
v = \sqrt{\frac{E}{\rho}} = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}
$$

**STUDYMATE**<br>
is in good agreement with the experimental value (3) Effect of Pressure:<br>
is in turn establishes that sound propagates<br>
tically through gases.<br>
elocity of sound in air at NTP is 332 m/s which is<br>
estar than t **STUDYMATE**<br>
This in turn establishes that sound propagates<br>
The structure of **Pressure**:<br>
STUDYMATE<br>
IT is in turn establishes that sound propagates<br>
(y of sound in air at NTP is 332 m/s which is<br>
than that of light & ra **STUDYMATERIAL: PHYSIC**<br>
This in turn establishes that sound propagates<br>
This in turn establishes that sound propagates<br>
ty of sound in air at NTP is 332 m/s which is<br>
ty of sound in air at NTP is 332 m/s which is<br>  $\frac{F}{$ **STUDY MATERIAL: PHYSIC**<br>
shes that sound propagates<br>
the experimental value (3) Effect of Pressure:<br>
As velocity of sound<br>
the action experimental value (3) Effect of Pressure is compared to the action of the statio-wave **STUDYMATERIAL: PHYSICS**<br>
entablishes that sound propagates<br>
in air at NTP is 332 m/s which is<br>  $\sqrt{\frac{p}{p}} = \sqrt{\frac{p}{p}} = \sqrt{\frac{p}{p}} = \sqrt{\frac{N}{M}}$ <br>
So pressure has no effect on velocity of sound in a gas as<br>  $\sqrt{\frac{p}{p}}$ <br>  $\approx \sqrt{\frac{p$ **STUDYMATERIAL: PHYSICS**<br>
entent with the experimental value (3) Effect of Pressure :<br>
As velocity of sound<br>
in air at NTP is 332 m/s which is<br>
or  $\sqrt{P}$ <br>
in air at NTP is 332 m/s which is<br>
So pressure has no effect on v I NTP is 332 m/s which is<br>
so radio-waves  $(3 \times 10^8 \text{m/s})$ <br>
So pressure has no effect on velocity of sound in<br>
long as temperature remain constant. This is why<br>
up in the atmosphere, through both pressure and<br>
decreases, EVENT P is 332 m/s which is<br>
v =  $\sqrt{\frac{P}{P}} = \sqrt{\frac{P \times P}{P}} = \sqrt{\frac{P \times P}{M}}$ <br>
So pressure has no effect on velocity of sound in<br>
long as temperature remain constant. This is why<br>
up in the atmosphere, through both pressure has So pressure has no effect on velocity of sound in a gas as long as temperature remain constant. This is why in going up in the atmosphere, through both pressure and density decreases, velocity of sound remains constant as long as temperature remains constant. Further more it has also been established that all other factors such as amplitude, frequency, phase, loudness pitch, quality etc. has practically no effect on velocity of sound.

#### **(4) Effect of Motion of Air :**

M If air is blowing then the speed of sound changes. If the  $\frac{M_{\text{w}}}{M_{\text{w}}}$  as  $\mu = \frac{M_{\text{w}}}{M_{\text{w}}}$  ...(4) and in the opposite direction it will be  $M_{\text{right}}$  the speed of sound in the direction in which air is blowing actual speed of sound is v and the speed of air is w, then  $(v - w)$ .

#### **(5) Effect of Frequency :**

theory of gases<br>
theory of gases<br>
theory of gases<br>  $\Gamma/M_w$ )<br>
i.e.  $v_s = \left[\frac{\gamma}{3}\right]^{1/2}$  V<sub>ms</sub><br>
i.e.  $v_s = \left[\frac{\gamma}{3}\right]^{1/2}$  V<sub>ms</sub><br>
i.e.  $v_s = \left[\frac{\gamma}{3}\right]^{1/2}$  V<sub>ms</sub><br>
then speed of sound waves of different frequencies transpec From is an effect of frequency on the<br>
unity  $\frac{1}{2}$  and the speed in air although their vavelength in<br>
und in a gas is of the order of mas speed<br>
where we could not have enjoyed orches<br>
und in a according to Eqn. (4) i (5) Effect of Frequency :<br>
There is no effect of frequency on the speed of sound<br>
Sound waves of different frequencies travel with the same<br>
speed in air although their wavelength in air are different<br>
If the speed of sou Fince is no elected frequencies travel by on the speed of inequal<br>sound waves of different frequencies travel with the sample of<br>the speed in air although their wavelength in air are different<br>frequencies travel with the There is no effect of frequency on the speed of sound. Sound waves of different frequencies travel with the same speed in air although their wavelength in air are different. If the speed of sound were dependent on the frequency, then we could not have enjoyed orchestra. tically no effect on velocity of sound.<br>
ct of Motion of Air:<br>
r is blowing then the speed of sound changes. If the<br>
r is blowing then the speed of sound changes. If the<br>
al speed of sound in the direction in which air is which an is blowing<br>
ection it will be<br>
the speed of sound.<br>
travel with the same<br>
in air are different.<br>
at on the frequency,<br>
estra.<br>
itres of alcohol if the<br>
ig to 75 cm. [velocity<br>
tiy of alcohol = 0.81<br>
d g = 9.81 m/ o erect or rrequency on the speed or solution.<br>
eves of different frequencies travel with the same<br>
railhough their wavelength in air are different.<br>
railhough their wavelength in air are different.<br>
d of sound were depen

# **Example 6 :**<br>**Example 6 :**

**Example 6:**<br>
The order of rms speed<br>
Determine the change in volume of 6 litres of alcohol if<br>
the order of ms speed<br>
the pressure is decreased from 200 cm of Hig to 75 cm. [veloc<br>
of sound in alcohol is 1280 m/s, Densit Determine the change in volume of 6 litres of alcohol if the pressure is decreased from 200 cm of Hg to 75 cm. [velocity of sound in alcohol is  $1280$  m/s, Density of alcohol =  $0.81$ gm/cc, density of Hg = 13.6 gm/ cc and g = 9.81 m/s<sup>2</sup>] hange in volume of 6 litres of alcohol if the<br>
sased from 200 cm of Hg to 75 cm. [velocity<br>
nol is 1280 m/s, Density of alcohol = 0.81<br>
f Hg = 13.6 gm/cc and g = 9.81 m/s<sup>2</sup>]<br>
of sound in liquid<br>
, i.e. B = v<sup>2</sup>  $\rho$ <br>
1B ir although their wavelength in air are different.<br>
ed of sound were dependent on the frequency,<br>
ould not have enjoyed orchestra.<br>
e the change in volume of 6 litres of alcohol if the<br>
decreased from 200 cm of Hg to 75 c hough their wavelength in air are different.<br>
Sound were dependent on the frequency,<br>
not have enjoyed orchestra.<br>
change in volume of 6 litres of alcohol if the<br>
eased from 200 cm of Hg to 75 cm. [velocity<br>
ohol is 1280

**Sol.** For propagation of sound in liquid

$$
v\,{=}\,\sqrt{\left(B\,/\,\rho\right)}\,,\,i.e.\ B\,{=}\,v^2\,\rho
$$

But by definition B = – V  $\frac{\Delta P}{\Delta V}$ P V  $\Delta P$  $\Delta V$ 

So, 
$$
-V \frac{\Delta P}{\Delta V} = v^2 \rho
$$
 i.e.  $\Delta V = \frac{V(-\Delta P)}{\rho v^2}$ 

 $Here \Delta P = H_2 \rho g - H_1 \rho g = (75 - 200) \times 13.6 \times 981$ <br>=  $\sqrt{\frac{1}{250}}$  Here  $\Delta P = H_2 \rho g - H_1 \rho g = (75 - 200) \times 13.6 \times 981$  $=-1.667\times10^{6}$  dynes/cm<sup>2</sup>

So, 
$$
\Delta V = \frac{(6 \times 10^3) (1.667 \times 10^6)}{0.81 \times (1.280 \times 10^5)^2} = 0.75
$$
cc.

#### **VIBRATION IN ORGAN PIPES**

546 superposition, standing waves are produced. 00 cm of Hg to 75 cm. [velocity<br>
m/s, Density of alcohol = 0.81<br>
gm/cc and g = 9.81 m/s<sup>2</sup>]<br>
1 liquid<br>
P<br>  $\Delta V = \frac{V(-\Delta P)}{\rho v^2}$ <br>  $5-200 \times 13.6 \times 981$ <br>
es/cm<sup>2</sup><br>
(0<sup>6</sup>)<br>  $\frac{10^6}{5^2} = 0.75$ cc.<br>
aves of same frequency and<br> When two longitudinal waves of same frequency and amplitude travel in a medium in opposite directions then by

> These waves are produced in air columns in cylindrical tube of uniform diameter. These sound producing tubes are called organ pipes.

#### **1. Vibration of air column in closed organ pipe :**

The tube which is closed at one end and open at the other end is called organ pipe. On blowing air at the open end, a wave travels towards closed end from where it is reflected towards open end. As the waves reaches open end, it is



reflected again. So two longitudinal waves travel in opposite directions to superpose and produce stationary waves. At the closed end there is a node since particles does not have freedom to vibrate whereas at open end there is an antinode because particles have greatest freedom to vibrate.



Hence on blowing air at the open end, the column vibrates forming antinode at free end and node at closed end. If  $\ell$  is length of pipe and  $\lambda$  be the wavelength and v be the velocity of sound in organ pipe then

Case (a) 
$$
\ell = \frac{\lambda}{4} \Rightarrow \lambda = 4\ell \Rightarrow n_1 = \frac{v}{\lambda} = \frac{v}{4\ell}
$$
  $\ell = (m+1)$   
Fundamental frequency.

Case (b)  $\ell = \frac{3\lambda}{4} \Rightarrow \lambda = \frac{4\ell}{3} \Rightarrow n_2 = \frac{v}{\lambda} = \frac{3v}{4\ell}$  $\frac{\lambda}{4}$   $\Rightarrow$   $\lambda = \frac{4\ell}{3}$   $\Rightarrow$   $n_2 = \frac{v}{\lambda} = \frac{3v}{4\ell}$  1  $\frac{\ell}{\ell} \Rightarrow n_2 = \frac{v}{\lambda} = \frac{3v}{4\ell}$  Due to finit First overtone frequency.

Case (c) 
$$
\ell = \frac{5\lambda}{5} \implies \lambda = \frac{4\ell}{5} \implies n_3 = \frac{v}{\lambda} = \frac{5v}{4\ell}
$$

Second overtone frequency.

When closed organ pipe vibrate in  $m<sup>th</sup>$  overtone then

$$
\ell = (2m+1)\frac{\lambda}{4} \quad \text{So} \quad \lambda = \frac{4\ell}{(2m+1)} \Rightarrow n = (2m+1)\frac{\nu}{4\ell} \tag{f_C}
$$

Hence frequency of overtones is given by

 $n_1 : n_2 : n_3 ... = 1 : 3 : 5 ...$ 

#### **2. Vibration of air columns in open organ pipe :**

The tube which is open at both ends is called an open organ pipe. On blowing air at the open end, a wave travel towards the other end from waves travel in opposite direction to superpose and produce stationary wave. Now the pipe is open at both ends by which an antinode is formed at open end. Hence on blowing air at the open end antinodes are formed at each end and nodes in the middle. If  $\ell$  is length of the pipe and  $\lambda$  be the wavelength and v is velocity of sound in organ pipe.



Case (a)

e (a)  
\n
$$
\ell = \frac{\lambda}{2} \Rightarrow \lambda = 2\ell \Rightarrow n_1 = \frac{v}{\lambda} = \frac{v}{2\ell}
$$
\n
$$
\text{Fundamental frequency.}
$$
\ne (b)  
\n
$$
2\lambda = 2\ell \qquad v = 2v
$$

Case (b)

$$
\ell = \frac{2\lambda}{2} \Rightarrow \lambda = \frac{2\ell}{2} \Rightarrow n_2 = \frac{v}{\lambda} = \frac{2v}{2\ell}
$$

First overtone frequency.

Fundamental frequency.

Case (c)

$$
\ell = \frac{3\lambda}{2} \Rightarrow \lambda = \frac{2\ell}{3} \Rightarrow n_3 = \frac{v}{\lambda} = \frac{3v}{2\ell}
$$

Second overtone frequency

Hence frequency of overtones are given by the relation

$$
n_1 : n_2 : n_3 \dots \dots \dots = 1 : 2 : 3 \dots \dots
$$

When open organ pipe vibrate in m<sup>th</sup> overtone then

$$
\ell = (m+1)\frac{\lambda}{4}
$$
 so,  $\lambda = \frac{4\ell}{m+1} \Rightarrow n = (m+1)\frac{v}{2\ell}$ 

#### **End correction :**

 $\lambda$  4 $\ell$  reflection takes place not exactly at open end but some  $=\frac{3v}{4\ell}$  Due to finite momentum of air molecular in organ pipes<br>reflection takes place not exactly at open and but some  $=\frac{v}{\lambda} = \frac{5v}{4\ell}$  correction or Rayleigh correction) with r being the radius  $\lambda$  4 $\ell$  of pipe. So for closed organ pipe L  $\rightarrow$  L + 0.6r while for 1. These transmisted in the set of =  $\frac{v}{\lambda} = \frac{v}{2\ell}$ <br>
Fundamental frequency.<br>
=  $\frac{v}{\lambda} = \frac{2v}{2\ell}$ <br>
First overtone frequency.<br>  $a_3 = \frac{v}{\lambda} = \frac{3v}{2\ell}$ <br>
dovertone frequency<br>
sa are given by the relation<br>  $b: 3$ .........<br>
te in m<sup>th</sup> overtone then<br> what it so in an organ pipe antinode is not formed exactly at free-end but above it at a distance  $e = 0.6r$  (called end open 4 L 0.6r ertone frequency<br>
e given by the relation<br>  $\frac{1}{1} \Rightarrow n = (m + 1) \frac{v}{2\ell}$ <br>
molecular in organ pipes<br>
y at open end but some<br>
le is not formed exactly at<br>
nce e = 0.6r (called end<br>
n) with r being the radius<br>  $\frac{1}{2} \Rightarrow L + 0.$ 

 $L \rightarrow L + 2 \times 0.6r$  (as both ends are open) so that

$$
f_C = \frac{v}{4(L + 0.6r)}
$$
 while  $f_0 = \frac{v}{2(L + 1.2r)}$ 

This is why for a given v and L narrower the pipe higher will the frequency or pitch and shriller will be the sound.

#### **Example 7 :**

For a certain organ pipe, three successive resonance frequencies are observed at 425, 595 and 765 Hz respectively. Taking the speed for sound in air to be 340 m/s (a) Explain whether the pipe is closed at one end or open at both ends (b) determine the fundamental frequency and length of the pipe. narrower the pipe higher<br>hriller will be the sound.<br>ee successive resonance<br>95 and 765 Hz respectively.<br>to be 340 m/s (a) Explain<br>e end or open at both ends<br>equency and length of the<br>the ratio<br>egers so the given pipe is<br>f

**Sol.** (a) The given frequencies are in the ratio

425 : 595 : 765 i.e., 5 : 7 : 9

And as clearly these are odd integers so the given pipe is closed end.

(b) From part (b) it is clear that the frequency of 5th harmonic (which is third overtone) is 425 Hz

so 
$$
425 = 5f_C
$$
 or  $f_C = 85 \, \text{Hz}$ 

Further as 
$$
f_C = \frac{v}{4L}
$$
,  $L = \frac{v}{4f_C} = \frac{340}{4 \times 85} = 1m$ 

#### **Example 8 :**

AB is a cylinder of length 1 m fitted with a thin flexible diaphragm C at middle and two other thin flexible diaphragm A and B at the ends. The portions AC and BC contain hydrogen and oxygen gases respectively. The diaphragms A and B are set into vibrations of the same frequency. What is the minimum frequency of these vibrations for which diaphragm C is a node? Under the condition of the  $\overline{2}$ . experiment the velocity of sound in hydrogen is 1100 m/s and oxygen 300 m/s.

**Sol.** As diaphragm C is a node, A and B will be antinode (as in a organ pipe either both ends are antinode or one end node and the other antinode), i.e., each part will behave as closed end organ pipe so that

$$
f_{\rm H} = \frac{V_{\rm H}}{4L_{\rm H}} = \frac{1100}{4 \times 0.5} = 550 \text{ Hz}
$$
\n
$$
f_0 = \frac{v_0}{4L_0} = \frac{300}{4 \times 0.5} = 150 \text{ Hz}
$$
\nand\n
$$
\frac{n_{\rm H}}{n_0} = \frac{f_0}{f_{\rm H}} = \frac{150}{550} = \frac{3}{11}
$$
\n
$$
v_0 = 150 \text{ Hz}
$$

As the two fundamental frequencies are different, the system will vibrate with a common frequency f such that

$$
f = n_H f_H = n_0 f_0
$$
 i.e.,  $\frac{n_H}{n_0} = \frac{f_0}{f_H} = \frac{150}{550} = \frac{3}{11}$  Let n is

i.e., the third harmonic of hydrogen and 6th harmonic of oxygen or 6th harmonic of hydrogen and 22nd harmonic of oxygen will have same frequency. So the minimum common frequency  $f = 3 \times 550$  or  $11 \times 150 = 1650$  Hz

#### **APPARATUS FOR DETERMINING SPEED OF SOUND**

**1. Quinck's Tube :** It consists of two U shaped metal tubes. Sound waves with the help of tuning fork are produced at A which travel through B  $&$  C and T) comes out at D where a sensitive flame is present. Now the two waves coming through different path interfere and flame flares up. But if they are not in phase destructive interference occurs and flame remains undisturbed.



Suppose destructive interference occurs at D for some position of C. If now the tube C is moved so that interference condition is disturbed and again by moving a distance x,

destructive interference occurs so that  $2x = \lambda$ . Similarly if the distance moved between successive constructive and

destructive interference is x then 
$$
2x = \frac{\lambda}{2}
$$

Now by having value of x, speed of sound is given by  $v = n \lambda$ 

**STUDYM**<br>
of length 1 m fitted with a thin flexible<br>
deleard two other thin flexible diaghram<br>
destructive interference occurs so the<br>
dideand two other thin flexible diaghram<br>
or which as the portions AC and BC contain<br> **EXERCISION FORM I** m fitted with a bim lexible the distance moved between successive destructive interference occurs so that 2x<br>
BE:<br>
Si a cylinder of length 1 m fitted with fitchilde faightness<br>
dd B at the ends. The po **EXERCISE STODYMAT**<br> **EXERCISE TO ALL AND THE CONDUMNAT**<br> **EXERCISE TO AL 2. Kundt's tube :** It is the used to determine speed of sound in different gases. It consists of a glass tube in which a small quantity of lycopodium powder is spread. The tube is rotated so that powder starts slipping. Now rod is rubbed at end so that stationary waves form. The disc vibrates so that air column also vibrates with the frequency of the rod. The piston is adjusted so that frequency of air column become same as that of rod. So resonance occurs and column is thrown into stationary waves. The powder sets into oscillations at antinodes while heaps of powder are formed at nodes.



 $=\frac{150}{550}=\frac{3}{11}$  Let n is the frequency of vibration of the rod then, this is 11 also the frequency of sound wave in the air column in the tube.

For rod: 
$$
\frac{\lambda_{\text{rod}}}{2} = \ell_{\text{rod}}
$$
; For air:  $\frac{\lambda_{\text{air}}}{2} = \ell_{\text{air}}$ 

Where  $\ell_{\text{air}}$  is the distance between two heaps of powder in the tube (i.e. distance between two nodes). if  $v_{air}$  and  $v_{rod}$ are velocity of sound waves in the air and rod respectively,

then 
$$
\frac{v_{air}}{v_{rod}} = \frac{\lambda_{air}}{\lambda_{rod}} = \frac{\ell_{air}}{\ell_{rod}}
$$

Thus knowledge of v<sub>rod</sub> determines v<sub>air</sub>

#### **3. Resonance tube**

**Construction :** The resonance tube is a tube T (Fig.) made of brass or glass, about 1 meter long and 5 cm in diameter and fixed on a vertical stand. Its lower end is connected to a water reservoir B by means of a flexible rubber tube. The rubber tube carries a pinch-cock P. The level of water in T can be raised or lowered by water adjusting the height of the reservoir B and controlling the flow of water from B to T or from T to B by means of the pinch-cock P. Thus the length of the air-column in T can be changed. The position of the water level in T can be read by means of a side tube C and a scale S.





**Determination of the speed of sound in air by resonance tube :** First of all the water reservoir B is raised until the water level in the tube T rises almost to the top of the tube. Then the pinch-cock P is tightened and the reservoir B is lowered. The water level in T stays at the top. Now a tuning fork is sounded and held over the mouth of tube . The pinch-cock P is opened slowly so that the water level in T falls and the length of the air-column increases. At a particular length of air-column in T, a loud sound is heard. This is the first state of resonance. In this position the following phenomenon takes place inside the tube.

(i) For first resonance  $\ell_1 = \lambda/4$  .....(1) (ii) For second resonance  $\ell_2 = 3\lambda/4$  .....(2) Substract Eq. (2) from Eq. (1)

 $\ell_2 - \ell_1 = \lambda/2$ ;  $\lambda = 2(\ell_2 - \ell_1)$ 

If the frequency of the fork be n and the temperature of the air-column be t°C, then the speed of sound at t°C is given by  $v_t = n\lambda = 2n (\ell_2 - \ell_1)$ 

The speed of sound wave at  $0^{\circ}$ C;  $v_0 = (v_t - 0.61 t)$  m/s. **End Correction :** In the resonance tube, the antinode is not formed exactly at the open but slightly outside at a distance x. Hence the length of the air -column in the first and second states of resonance are  $(\ell_1 + x)$  and  $(\ell_2 + x)$  then



#### **BEATS**

When two sound waves of same amplitude travelling in same direction with different frequency superimpose, then intensity varies periodically with time. This effect is called Beats. Suppose two waves of frequencies  $f_1$  and  $f_2$  (  $\leq f_1$  ) are meeting at some point in space. The corresponding periods are  $T_1$  and  $T_2$  ( $>T_1$ ). If the two waves are in phase at  $t = 0$ , they will again be in phase when the first wave has gone through exactly one more cycle than the second. This will happen at a time  $t = T$ , the period of the beat. Let n be the number of cycles of the first wave in time T, then the number of cycles of the second wave in the same time is  $(n-1)$ . Hence,  $T = nT_1 = (n-1)T_2$ sound waves of same amplitude travelling in<br>ion with different frequency superimpose, then<br>ries periodically with time. This effect is called<br>oose two waves of frequencies  $f_1$  and  $f_2$  (<  $f_1$ )<br> $g$  at some point in sp Example 11 and the method of the same of  $\frac{1}{T_1}$  and  $\frac{1}{T_2}$  and  $\frac{1}{T_1}$  and  $\frac{1}{T_2}$  and  $\frac{1}{T_1}$  and  $\frac{1}{T_2}$  and  $\frac{1}{T_2}$  and  $\frac{1}{T_2}$  and  $\frac{1}{T_2}$  and  $\frac{1}{T_2}$  and  $\frac{1}{T_2}$  and  $\frac{$ butcarly with time. This effect is called<br>waves of frequencies  $f_1$  and  $f_2$  ( <  $f_1$ )<br>e point in space. The corresponding<br> $2$  ( > T<sub>1</sub>). If the two waves are in phase<br>in be in phase when the first wave has<br>v one more T T 1 1 <sup>T</sup> **SPECIES 10**<br> **EVALUATE:**<br> We provide the same application of the same of the same application of the same application of the properties of frequencies  $f_1$  and  $f_2$  ( $\langle f_1$ ) are point in space. The corresponding  $T_2$  ( $\langle f_1$ ). If the two wave **SOMADVANCED LEARNING**<br> **EDEMADVANCED LEARNING**<br> **EDEMADVANCED LEARNING**<br> **EDEMADVANCED LEARNING**<br> **EDEMADV** varies periodically with time. This effect is called<br>
Suppose two waves of frequencies  $f_1$  and  $f_2$  ( $\lt f_1$ ) **SOMAGE DESCRIPED ASSESS AND**<br> **SOMAGE DEARVING**<br>
SOUND WANCED LEARVING<br>
SOUND ONCE TO THE STONE OF THE SCRIP (5 FOR THE SCRIP (1 of the script of the carrier is called<br>
a st some point in space. The corresponding<br>  $\Gamma_1$ 

Eliminating n we have



The reciprocal of the beat period is the beat frequency

$$
f = \frac{1}{T} = f_1 - f_2
$$

#### **Waves Interference on the bases of beats:**

**Conditions:** Two equal frequency wave travel in same direction. Mathematical analysis If displacement of first wave

 $y_1 = a \sin \omega_1 t \rightarrow (N_1, a)$  $(a)$   $I \propto N^2 a^2$ Displac

 $y_2 = a \sin \omega_2 t \rightarrow (N_2, a)$ By superposition

$$
y = y_1 + y_2
$$

Eq. of resulting wave

$$
y = a \left(\sin 2\pi N_1 t + \sin 2\pi N_2 t\right)
$$

The reciprocal of the beat period is the beat frequency  
\n
$$
f = \frac{1}{T} = f_1 - f_2
$$
  
\nWaves Interference on the bases of beats:  
\nConditions: Two equal frequency wave travel in same direction. Mathematical analysis  
\nIf displacement of first wave  
\n $y_1 = a \sin \omega_1 t \rightarrow (N_1, a)$   $I \propto N^2 a^2$   
\nDisplacement of second wave  
\n $y_2 = a \sin \omega_2 t \rightarrow (N_2, a)$   
\nBy superposition  
\n $y = y_1 + y_2$   
\nEq. of resulting wave  
\n $y = a (\sin 2\pi N_1 t + \sin 2\pi N_2 t)$   
\n $y = a \left\{ 2 \sin 2\pi t \frac{(N_1 + N_2)}{2} \cos 2\pi t \frac{(N_1 - N_2)}{2} \right\}$   
\nor  $y = \left\{ 2a \cos 2\pi t \frac{(N_1 + N_2)}{2} \right\} \sin 2\pi t \frac{(N_1 - N_2)}{2}$   
\nor  $y = A \sin 2\pi N^t t$   
\nAmplitude  $A = 2a \cos 2\pi t \frac{(N_1 - N_2)}{2}$   
\n $A = 2a \cos 2\pi t (N_1 - N_2)$   
\nFrequency  $N^t = \frac{N_1 + N_2}{2}$ 

or 
$$
y = \left\{ 2a \cos 2\pi t \frac{(N_1 + N_2)}{2} \right\} \sin 2\pi t \frac{(N_1 - N_2)}{2}
$$

or  $y = A \sin 2\pi N'$ t

Amplitude 
$$
A = 2a \cos 2\pi t \left(\frac{N_1 - N_2}{2}\right)
$$
  
 $A = 2a \cos 2\pi t (N_1 - N_2)$ 

Frequency 
$$
N' = \frac{N_1 + N_2}{2}
$$

**225**



**(1) For max Intensity:**  $A = \pm 2a$ If  $\cos \pi (N_1-N_2)t = \pm 1$  $\cos \pi (N_1-N_2) = \cos n\pi$ ; n=0, 1, 2.......... 1 2 **EXERIBING**<br>
(N<sub>T</sub>-N<sub>2</sub>) t = 1<br>
(N<sub>T</sub>-N<sub>2</sub>) t = 0<br>
(N<sub>T</sub>-N<sub>2</sub>) t = 0<br>
(N<sub>T</sub>-N<sub>2</sub>) t = 0<br>

$$
\pi(N_1 - N_2)t = n\pi; t = \frac{n}{N_1 - N_2}; t = 0, \frac{1}{\Delta N}, \frac{2}{\Delta N}, \frac{3}{\Delta N}, \dots, \text{Example 9:}
$$
 A tuning fork having n

**(2) For Minimum Intensity:**  $A=0$  $\cos \pi (N_1 - N_2) t = 0$ 

cos  $(N_1 - N_2)t = \cos(2n + 1) \frac{\pi}{2}$   $n = 0, 1, 2, \dots$  **Sol.** The frequency

$$
\pi (N_1-N_2)t = (2n+1)\frac{\pi}{2}
$$
;  $t = \frac{2n+1}{2(N_1-N_2)}$ 

$$
t = \frac{1}{2\Delta N}, \frac{3}{2\Delta N}, \frac{5}{2\Delta N}, \dots
$$
 Ex

#### **TUNING FORK**

When tuning fork is sounded by striking its one end on rubber pad, then:

- (a) The ends of prongs vibrate in and out while the stem Vibrates up and down or vibrations of the prongs are transverse and that of the stem is longitudinal. Generally tuning fork produces fundamental note.
- (b) At the free end of a fork antinodes are formed. At the place where stem is fixed antinode is formed. In between these antinodes, nodes are formed.

(c) Frequency of tuning fork 
$$
n \propto \left(\frac{t}{\ell^2}\right) \sqrt{\frac{E}{d}}
$$
 Q.1 Water waves prod are

 $t =$  thickness of tuning fork

 $\ell$  = length of arm of fork

 $E =$  coefficient of elasticity for the material of fork

 $d =$  density of the material of a fork.

(d) Frequency of tuning fork decrease with increase in  $Q.2$ temperature.

(e) increasing the weight, the frequency of a tuning fork decreases while on filling the prongs near stem the frequency decreases.

#### **PRACTICAL APPLICATIONS OF BEATS**

 **Determination of Frequency :** If we know the frequency  $n_1$  of a tuning fork, then we can determine the exact frequency of another fork of nearly equal frequency by the<br>
shows means of last a Familia had the trains for a second  $Q.4$ phenomenon of beats. For this, both the tuning forks are sounded together and the beats are heard. Suppose, x beats are heard in 1 second. Then the frequency of the second fork will be either  $(n_1 + x)$  or  $(n_1 - x)$ . Now one prong of this fork is loaded with a small wax so that its frequency is slightly lowered. Again, the two forks are sounded together  $\overline{0.5}$ and beats are heard. If the number of beats per second decreases then it means that the new (lowered) frequency of the second tuning forks is more nearer to the frequency of the first tuning fork. This would happen if the frequency of the second tuning fork is higher than the frequency of the first fork. Hence the frequency of the second fork is

 $(n_1 + x)$ . On the other hand, if on loading with wax, the number of beats per second increases, then the frequency of the second fork is  $(n_1 - x)$ .

N N  $\Delta N$   $\Delta N$   $\Delta N$   $\Delta N$   $\Delta N$   $\Delta N$   $\Delta M$   $\Delta N$   $\Delta N$  ; t = 1 2 **STUDY MATERIAL: PHYSICS**<br>
(n<sub>1</sub> + x). On the other hand, if on loading with wax, the<br>
number of beats per second increases, then the frequency<br>
of the second fork is  $(n_1 - x)$ .<br>  $\frac{2}{N}$ ,  $\frac{3}{\Delta N}$  .................... **STUDY MATERIAL: PHYSICS**<br>
(n<sub>1</sub> + x). On the other hand, if on loading with wax, the<br>
number of beats per second increases, then the frequency<br>
of the second fork is (n<sub>1</sub> - x).<br>  $\frac{1}{\Delta N}$ ,  $\frac{2}{\Delta N}$ ,  $\frac{3}{\Delta N}$  ... 2 N 2 N another tuning fork. If impurity (wax) is added on the arm of known tuning fork, the number of beats decreases then calculate the frequency of unknown tuning fork.

**Sol.** The frequency of unknown tuning fork should be  $300 \pm 5 = 295$  Hz or 305 Hz.

 $\pi$  2n + 1 When wax is added, if it would be 305 Hz, beats would have  $\overline{-N_2}$  increases but with 295 Hz beats decreases so frequency of unknown tuning fork is 295 Hz.

#### **Example 10 :**

A tuning fork having  $n = 158$  Hz, produce 3 beats/s with another. As we file the arm of unknown, beats become 7 then calculate the frequency of unknown. .

**Sol.** The frequency of unknown tuning fork should be

#### $158 \pm 3 = 155$  Hz or 161 Hz.

t E After filling the number of beats = 7 so frequency of unknown tuning fork should be  $158 \pm 7 = 165$  Hz or 151 Hz. As both above frequency can be obtain by filing so frequency of unknown = 155/161 Hz.

## **TRY IT YOURSELF-1**

- d are and a set of the same se **Q.1** Water waves produced by a motor boat sailing in water are
	- (A) neither longitudinal nor transverse.
	- (B) both longitudinal and transverse.
	- (C) only longitudinal.
	- (D) only transverse.
	- Speed of sound wave in air
	- (A) is independent of temperature.
		- (B) increases with pressure.
		- (C) increases with increase in humidity.
	- (D) decreases with increase in humidity.
	- **Q.3** Change in temperature of the medium changes
		- (A) frequency of sound waves.
		- (B) amplitude of sound waves.
		- (C) wavelength of sound waves.
		- (D) loudness of sound waves.
	- String of mass 2.5 kg is under a tension of 200 N. The length of the stretched string is 20.0 m. If the transverse jerk is struck at one end of the string, the disturbance will reach the other end in
		- (A) one second (B) 0.5 second
		- (C) 2 seconds (D) data given is insufficient.
	- Speed of sound waves in a fluid depends upon
		- (A) directly on density of the medium.
		- (B) square of Bulk modulus of the medium.
		- (C) inversly on the square root of density.
		- (D) directly on the square root of bulk modulus of the medium.

## **WAVES**



- **Q.6** During propagation of a plane progressive mechanical wave
	- (A) all the particles are vibrating in the same phase.
	- (B) amplitude of all the particles is equal.
	- (C) particles of the medium executes S.H.M.
	- (D) wave velocity depends upon the nature of the medium.
- **Q.7** Which of the following statements are true for a stationary wave?
	- (A) Every particle has a fixed amplitude which is different from the amplitude of its nearest particle.
	- (B) All the particles cross their mean position at the same time.
	- (C) All the particles are oscillating with same amplitude.
- (D) There is no net transfer of energy across any plane. **Q.8** A string of length 0.4 m and mass  $10^{-2}$  kg is tightly clamped at its ends. The tension in the string is 16 N. Identical wave pulses are produced at one end at equal (ii) intervals of time  $\Delta t$ . The minimum value of  $\Delta t$ , which allows constructive interference between successive pulses, is B) amplitude of all the particles is equal.<br>
(C) particles of the medium excetters S.H.M.<br>
(D) Wave velocity depends upon the nature of the medium.<br>
(D) (D) C)<br>
(D) Wave velocity depends upon the nature of the medium.<br>
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velocity depends upon the nature of the medium.<br>
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the medium executes S.H.M. (7) (ABD) (8) (B)<br>
the medium executes S.H.M. (7) (ABD) (8) (B)<br>
the medium executes S.H.M. (10(D) (1) (B)<br>
llowing statements are true for a statio



**Q.9**  $Y(x, t) = \frac{x^2 + 5t^2 + 51}{(4x + 5t^2 + 51)}$  represents a moving pulse

where x and y are in metres and t is in second. Then

- (A) pulse is moving in positive x-direction
- (B) in 2 s it will travel a distance of 2.5 m
- (C) its maximum displacement is 0.16 m

(D) it is a symmetric pulse

**Q.10** Two vibrating strings of the same material but of lengths L and 2L have radii 2r and r respectively. They are stretched under the same tension. Both the strings vibrate in their fundamental modes, the one of length L with frequency  $v_1$  and the other with frequency  $v_2$ . The ratio  $v_1/v_2$  is

$$
(A) 2 \t (B) 4 \t (C) 8 \t (D) 1
$$

**Q.11** In the experiment for the determination of the speed of (1) sound in air using the resonance column method, the length of the air column that resonates in the fundamental mode, with a tuning fork is 0.1 m. When this length is changed to 0.35 m, the same tuning fork resonates with the first overtone. Calculate the end correction.<br>(A)  $0.012 \text{ m}$  $(A)$  0.012 m



**Q.12** A vibrating string of certain length  $\ell$  under a tension T resonates with a mode corresponding to the first overtone (third harmonic) of an air column of length 75 cm inside a tube closed at one end. The string also generates 4 beats per second when excited along with a tuning fork of frequency n. Now when the tension of the string is slightly increased the number of beats reduces 2 per second. Assuming the velocity of sound in air to be 340  $m/s$ , the frequency n of the tuning fork in Hz is –





## **DOPPLER EFFECT**

#### **Acoustic Doppler effect (Doppler effect for sound waves) :**

The apparent change in the frequency of sound when the source of sound, the observer and the medium are in relative motion is called Doppler effect.

While deriving these expressions, we make the following assumptions:

- The velocity of the source, the observer and the medium are along the line joining the positions of the source and the observer.
- The velocity of the source and the observer is less than velocity of sound.

Doppler effect takes place both in sound and light. In sound it depends on whether the source or observer or both are in motion while in light it depends on whether the distance between source and observer is increasing or decreasing. **Notations :**

- $n \rightarrow$  actual frequency
- $n' \rightarrow$  observed frequency (apparent frequency)
- $\lambda \rightarrow$  actual wave length
- $\lambda' \rightarrow$  observed (apparent) wave length
- $v \rightarrow$  velocity of sound,  $v_s \rightarrow$  velocity of source

 $v_0 \rightarrow$  velocity of observer,  $v_w \rightarrow$  wind velocity

**Case I : Source in motion, observer at rest, medium at rest** Suppose the source S and observer O are separated by distance v. Where v is the velocity of sound. Let n be the frequency of sound emitted by the source. Then n waves will be emitted by the source in one second. These n waves will be accommodated in distance v. So, wave length; of the source and the observer is less than<br>
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nency of sound emitted by the source. Then n waves

$$
\lambda = \frac{\text{total distance}}{\text{total number of waves}} = \frac{v}{n}
$$

### **(1) Source moving towards stationary observer:**

Let the source start moving towards the observer with velocity  $v_s$  After one second, the n waves will be crowded in distance  $(v - v_s)$ . Now the observer shall feel that he is listening to sound of wavelength  $\lambda$ ' and frequency n' There v is the velocity of solution. Let it be the control<br>of solution entitled by the source. Then n waves<br>commodated in distance v. So, wave length;<br>total distance in one second. These n waves<br>commodated in distance  $\frac$ commodated in distance v. So, wave length;<br>
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Now apparent wavelength

$$
\lambda' = \frac{\text{total distance}}{\text{total number of waves}} = \frac{v - v_s}{n}
$$

and changed frequency,

$$
n' = \frac{v}{\lambda} = \frac{v}{\left(\frac{v - v_s}{n}\right)} = n\left(\frac{v}{v - v_s}\right)
$$



As the source of sound approaches the observer the apparent frequency n' becomes greater than the true frequency n.

**(2) When source move away from stationary observer :** For this situation n waves will be crowded in distance  $v+v_s$ .



Stationary Observer n  $\overline{O}$ 

So, apparent wavelength, 
$$
\lambda' = \frac{V + V}{n}
$$

and apparent frequency,

$$
n' = \frac{v}{\lambda'} = \frac{v}{\left(\frac{v + v_s}{n}\right)} = n\left(\frac{v_s}{v + v_s}\right)
$$

So, n' becomes less than n.  $(n' < n)$ 

**Case II : Observer in motion, source at rest, medium at rest:** Let the source (S) and observer (O) are in rest at their respective places. Then n waves given by source S would be crossing observer O in one second and fill the space  $OA (=v)$ 

#### **(1) Observer move towards stationary source :**

When observer O moves towards S with velocity  $v_0$ , it will cover  $v_0$  distance in one second. So the observer has received not only the n waves occupying OA but also received additional number of  $\Delta n$  waves occupying the distance OO' (=  $v_0$ ). **EXECUTE SOMETHEY SURFALL SUR** Case II: Observer in notion, source at rest, medium at<br>
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So, total waves received by observer in one second i.e., apparent frequency

 $(n')$  = Actual waves  $(n)$  + Additional waves  $(\Delta n)$ 

$$
n' = \frac{v}{\lambda} + \frac{v_0}{\lambda} = \frac{v + v_0}{(v/n)} = n\left(\frac{v + v_0}{v}\right) \qquad \left(\because \lambda = \frac{v}{n}\right)
$$
  
(so, n' > n)

#### **(2) Observer move away from stationary source :**

For this situation n waves will be crowded in distance  $v - v_0$ . When observer move away from source with  $v_0$  velocity then he will get  $\Delta n$  waves less than real number of waves.

 $\rm V_{_0}$ 

Stationary Moving

S O So, total number of waves received by observer i.e., Apparent frequency =  $(n')$  = Actual waves  $(n)$ 

– reduction in number of waves  $(\Delta n)$ 

$$
n' = \frac{v}{\lambda} - \frac{v_0}{\lambda} = \frac{v - v_0}{\lambda} = \frac{v - v_0}{(v/n)} = \left(\frac{v - v_0}{v}\right)n \qquad \left(\because \lambda = \frac{v}{n}\right)
$$
  
(so, n' < n)

#### **Case III : Effect of motion of medium :**

General formula for doppler effect

n' = n 0 ..........(i)

SO, apparent wavelength,  $\lambda' = \frac{v + v_s}{h}$ <br>  $n' = \frac{v}{\lambda} = \frac{v}{(v + v_s)} = n \left(\frac{v_s}{v + v_s}\right)$ <br>  $n' = \frac{v}{\lambda} = \frac{v}{(v + v_s)} = n \left(\frac{v_s}{v + v_s}\right)$ <br>
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the crowded in distance v+v<sub>s</sub>.<br>  $n' = n \left[ \frac{v \pm v_0}{v \mp v_s} \right]$  ...........(i)<br> **STUDY MATERIAL: PHYSICS**<br> **ffect of motion of medium :**<br>
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ain) is also moving with  $v_m$  velocity in direction<br>
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rmula for doppler effect<br>  $\left[\frac{v \pm v_0}{v \mp v_s}\right]$  ..........(i)<br>
(air) is also moving with  $v_m$  velocity in direction<br>
and observer. Then velocity of sound relativ If medium (air) is also moving with  $v_m$  velocity in direction of source and observer. Then velocity of sound relative to observer will be  $v \pm v_m$  (–ve sign, if  $v_m$  is opposite to **DY MATERIAL: PHYSICS**<br>
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\text{velocity of sound relative to} \\
\text{e sign, if } v_m \text{ is opposite to} \\
\text{y} \pm v_m \pm v_0 \\
\text{y} \pm v_m \mp v_s\n\end{pmatrix}$ <br>
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 sound velocity). So,  $n' = n \left( \frac{v \pm v_m \pm v_0}{v \pm v_m \mp v_s} \right)$ 

n [On replacing v by  $v \pm v_m$  in equation (i)]

**Note :** When both S and O are in rest (i.e.  $v_s = v_0 = 0$ ) then there is no effect of frequency due to motion of air

**Case-IV :** Both source and observer are moving away from each other. Medium at rest.

<sup>s</sup> <sup>s</sup> v v <sup>v</sup> n n ' v v v v S V<sup>S</sup> O V<sup>0</sup> n' = 0 <sup>s</sup> v v v v n: Clearly, n' > n <sup>s</sup> v v n n v v <sup>s</sup> v v 

If moving towards each other  $n' = \left(\frac{v + v_0}{v - v}\right)n$ 

If source moving towards observer which is moving away

from source 
$$
n' = \left(\frac{v - v_0}{v - v_s}\right)n
$$

If observer moving towards source which is moving away

from observer 
$$
n' = \left(\frac{v + v_0}{v + v_s}\right)n
$$

#### **DOPPLER'S EFFECT IN REFLECTION OF SOUND (ECHO)**

rece (S) and observer (O) are in rest at their<br>
s. Then n waves given by source S would<br>
verve O in one second and fill the space<br>
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towards stationary source :<br>
If moving towards each other  $n'$  $v \rangle$  from the reflector. If the two frequencies are different then  $\overline{n}$  superposition of these waves result in beats and by the rest, medium at<br>
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e. If moving towards each other  $n' = \left(\frac{v + v_0}{v - v_s}\right)n$ <br>  $P = \left(\frac{v + v_0}{v - v_s}\right)n$ <br>  $P = \left(\frac{v + v_0}{v - v_s}\right)n$ <br>  $P = \left(\frac{v + v_0}{v$ bund Source Observer<br>
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So, total waves received by observer in one second<br>
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i.e., apparent frequency (n + Additional waves (Δn)<br>  $u' = \frac{v}{\lambda} + \frac{v_0}{\lambda$ from observer  $n' = \left(\frac{v+v_0}{v+v_0}\right)n$ <br>
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see waves result in beats and by the<br>
an calculate speed of the source.<br>
st and reflector is moving **NOF SOUND (ECHO)**<br>the reflector the observer<br>the source and other<br>encies are different then<br>alt in beats and by the<br>beed of the source.<br>r is moving towards the<br>nt frequency heard by<br>source so that apparent<br>source so that **NOF SOUND (ECHO)**<br>ne reflector the observer<br>m the source and other<br>encies are different then<br>let in beats and by the<br>beed of the source.<br>is moving towards the<br>nt frequency heard by<br>source so that apparent<br> $\left(\frac{v+u}{v}\right) n$ D(**ECHO**)<br>e observer<br>and other<br>ferent then<br>nd by the<br>surce.<br>wards the<br>heard by<br>t apparent<br> $\frac{v+u}{v-u}$  n<br> $\left(1+\frac{2u}{v}\right)$ 

If the source is at rest and reflector is moving towards the source with speed u, then apparent frequency heard by

$$
reflection \quad n_1 = \left(\frac{v+u}{v}\right)n
$$

Now this frequency  $n_1$  acts as a source so that apparent frequency received by observer is

$$
n_2 = \left(\frac{v}{v-u}\right) n_1 = \left(\frac{v}{v-u}\right) \times \left(\frac{v+u}{v}\right) n = \left(\frac{v+u}{v-u}\right) n
$$

If  $u \ll v$  then,

$$
\frac{v}{n} = n \left( 1 + \frac{u}{v} \right) \left( 1 - \frac{u}{v} \right)^{-1} = n \left( 1 + \frac{u}{v} \right)^{2} = n \left( 1 + \frac{2u}{v} \right)
$$

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c  $\sqrt{ }$ 

$$
\ at frequency \ \Delta n = n_2 - n = \left(\frac{2u}{v}\right)n
$$

So speed of the source  $u = \frac{v}{2} \left( \frac{\Delta n}{n} \right)$ 

#### **CONDITIONS WHEN DOPPLER'S EFFECT IS NOT OBSERVED FOR SOUND-WAVES**

- **1.** When the source of sound and observer both are at rest then doppler effect is not observed.
- **2.** When the source and observer both are moving with same velocity in same direction.
- **3.** When the source and observer are moving mutually in perpendicular directions.
- **4.** When the medium only is moving.
- **5.** When the distance between the source and observer is constant.

#### **DOPPER EFFECT IN LIGHT**

Dopper effect holds also for em waves. As speed of light is independent of relative motion between source and observer, the formulae are different from that of sound. Here when either source or observer (detector) or both are in motion, only two cases are possible (approach or recession). In case of approach same directions.<br>
source and observer are moving mutually in<br>
lar directions.<br>
distance between the source and observer is<br>
diate directions.<br>
distance between the source and observer is<br>  $\frac{7}{6} = \left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right$ source and observer are moving mutually in<br>
lardirections.<br>
medium only is moving.<br>
distance between the source and observer is<br>
distance between the source and observer is<br>  $\frac{7}{6} = \left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)^{\frac{1}{2}} \Rightarrow \frac{4$ medium only is moving.<br>
distance between the source and observer is<br>  $\frac{7}{6} = \left( \frac{1+\frac{v}{c}}{1-\frac{v}{c}} \right)^{\frac{1}{2}} \Rightarrow \frac{49}{36} = \left( \frac{1}{1-\frac{v}{c}} \right)^{\frac{1}{2}}$ <br>
exchabilised for em waves. As speed of light is<br>
ent of relative moti

$$
n' = \left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)^{\frac{1}{2}} \text{ and } \lambda' = \lambda \left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)^{\frac{1}{2}}
$$
 Q.1 A train  
frequency the direquen

In case of recession

$$
n' = n \left( \frac{1 - \frac{v}{c}}{1 + \frac{v}{c}} \right)^{\frac{1}{2}} \text{ and } \lambda' = \lambda \left( \frac{1 + \frac{v}{c}}{1 - \frac{v}{c}} \right)^{\frac{1}{2}}
$$

If v << c then in case of approach n'  $\approx$  n  $\left(1+\frac{v}{c}\right)$ 

in case of recession n' 
$$
\approx
$$
 n  $\left(1 - \frac{v}{c}\right)$ 

So at low speeds dopper effect in light and sound is governed by the same formulae,

#### **DOPPLER'S SHIFT**

When radiation coming from distance stars are analysed by radio telescopes and compared with their natural  $Q.3$ radiation wavelength focussed on mean wavelength on a visible spectrum, it is observed that coming radiation has a shift towards red or violet end.

Red shift  $\Delta \lambda = \lambda' - \lambda = \left(\frac{v}{c}\right)\lambda$ 

$$
\text{Violet shift (or blue shift)} \ \Delta \lambda = \lambda - \lambda' = \left(\frac{\text{v}}{\text{c}}\right) \lambda
$$

 $2u$ ) In case  $V \int_{0}^{H}$  decreased  $V = \frac{1}{2}$  $\left(\frac{2u}{v}\right)n$ <br>
In case of approach frequency increases while way<br>
decreases i.e. shift  $\Delta \lambda$  is towards blue end of the s<br>
while in case of recession frequency decreases<br>
wavelength increases i.e, shift is towards red e  $\left(\frac{2u}{v}\right)n$ <br>
In case of approach frequency increases while way<br>
decreases i.e. shift  $\Delta\lambda$  is towards blue end of the while in case of recession frequency decreases<br>
while in case of recession frequency decreases<br>
whi  $\frac{2u}{v}$  n<br>
In case of approach frequency increases while wave<br>
decreases i.e. shift  $\Delta \lambda$  is towards blue end of the sp<br>
while in case of recession frequency decreases<br>
wavelength increases i.e, shift is towards red e  $\frac{2u}{v}\bigg) n$ In case of approach frequency increases while wave<br>
decreases i.e. shift  $\Delta \lambda$  is towards blue end of the sp<br>
while in case of recession frequency decreases<br>
wavelength increases i.e., shift is towards red In case of approach frequency increases while wavelength decreases i.e. shift  $\Delta\lambda$  is towards blue end of the spectrum while in case of recession frequency decreases and wavelength increases i.e, shift is towards red end.

#### **Example 11 :**

How fast one must move to see a red light signal as a green  $R = 4.8 \times 10^{14}$  Hz &  $n_G = 5.6 \times 10^{14}$  Hz

$$
\text{[uency }\Delta n = n_2 - n = \left(\frac{2u}{v}\right)n
$$
\nIn case of approach frequency increases while wavelength decreases with the end of the spectrum  
\nwhich in case of necessary decreases as the x, is towards blue end of the spectrum  
\nfor the source  $u = \frac{v}{2}\left(\frac{\Delta n}{n}\right)$ \n**EXAMPLE N DOPE LERE-TECT IS NOT**\n
$$
\text{[10]} \quad \text{[11]} \quad \text{[12]} \quad \text{[13]} \quad \text{[14]} \quad \text{[15]} \quad \text{[16]} \quad \text{[16]} \quad \text{[16]} \quad \text{[17]} \quad \text{[18]} \quad \text{[19]} \quad \text{[10]} \quad \text{[10]} \quad \text{[10]} \quad \text{[11]} \quad \text{[12]} \quad \text{[13]} \quad \text{[14]} \quad \text{[16]} \quad \text{[17]} \quad \text{[18]} \quad \text{[19]} \quad \text{[10]} \quad \text{[10]} \quad \text{[10]} \quad \text{[16]} \quad \text{[16]} \quad \text{[17]} \quad \text{[18]} \quad \text{[19]} \quad \text{[19]} \quad \text{[10]} \quad \text{[10]} \quad \text{[10]} \quad \text{[11]} \quad \text{[12]} \quad \text{[16]} \quad \text{[16]} \quad \text{[17]} \quad \text{[18]} \quad \text{[19]} \quad \text{[19]} \quad \text{[10]} \quad \text{[10]} \quad \text{[10]} \quad \text{[11]} \quad \text{[12]} \quad \text{[16]} \quad \text{[16]} \quad \text{[17]} \quad \text{[18]} \quad \text{[19]} \quad \text{[19]} \quad \text{[10]} \quad \text{[10]} \quad \text{[10]} \quad \text{[11]} \quad \text{[12]} \quad \text{[16]} \quad \text{[16]} \quad \text{[17]} \quad \text{[18]} \quad \text{[19]} \quad \text{[19]} \quad \text{[10]} \quad \text{[10]} \quad \text{[10]} \quad \text{[10]} \quad \text{[11]} \quad \text{[10
$$

g.   
\nsource and observer is  
\nwaves. As speed of light is  
\non between source and  
\nrent from that of sound.  
\n
$$
\Rightarrow \frac{7}{6} = \left( \frac{1+\frac{v}{c}}{1-\frac{v}{c}} \right)^{\frac{1}{2}} \Rightarrow \frac{49}{36} = \left( \frac{1+\frac{v}{c}}{1-\frac{v}{c}} \right)
$$
\n
$$
\Rightarrow 49-49 \left( \frac{v}{c} \right) = 36+36 \left( \frac{v}{c} \right) \Rightarrow 85 \left( \frac{v}{c} \right) = 13
$$
\n
$$
\Rightarrow v = \frac{13}{85} \times 3 \times 10^8 = \frac{39}{85} \times 10^8 = 4.59 \times 10^7 \text{ ms}^{-1}
$$
\n
$$
\Rightarrow \frac{v}{c} \bigg|_{\frac{v}{c}}^{\frac{1}{2}}
$$
\nQ.1 A train, standing in a station yard, blows a white of  
\nfrequency 400 Hz in still air. The wind starts blowing in  
\nthe direction from the yard to the station with a speed of  
\n10m/s. Given that the speed of sound in still air is 340m/s,  
\n(A) the frequency of sound as heard by an observer  
\nstanding on the platform is 400 Hz.  
\n
$$
\left( \frac{1+\frac{v}{c}}{1-\frac{v}{c}} \right)^{\frac{1}{2}}
$$
\n(B) the speed of sound for the observer standing on the  
\nplafform is 350m/s.  
\n(c) the frequency of sound as heard by the observer  
\nstanding on the platform will increase.  
\nh n' ≈ n  $\left( 1+\frac{v}{c} \right)$   
\nQ.2 A train moves towards a stationary observer with speed  
\n34 mincos towards a unitary observer with speed  
\n34 mincos towards a unitary observer with speed

## **TRY IT YOURSELF-2**

- $Q.1$ v frequency 400 Hz in still air. The wind starts blowing in  $c \angle$  the  $+\frac{v}{c}$   $\left| \frac{1}{2} + \frac{1}{2} \right|$ **Q.1** A train, standing in a station yard, blows a whistle of the direction from the yard to the station with a speed of 10m/s.Given that the speed of sound in still air is 340m/s,
	- 1 (A) the frequency of sound as heard by an observer standing on the platform is 400Hz.
- $(1 + \frac{v}{c})^2$  (B) the speed of sound for the observer standing on the  $\begin{array}{c|c}\n c & \n \hline\n \end{array}$  $V$  platform platform is 350m/s.
- $1-\frac{1}{s}$  (c) the frequency of sound as heard by the observer  $c$ ) (c)  $c$  standing on the platform will increase.
	- $(v)$  (d) the frequency of sound as heard by the observer  $1+\frac{1}{c}$  standing on the platform will decrease.

 $\Rightarrow \frac{7}{6} = \frac{1}{1-\frac{v}{c}}$   $\Rightarrow \frac{4}{36} = \frac{1}{1-\frac{v}{c}}$ <br>
spend of light is<br>
then source and<br>
that of sound.<br>  $\Rightarrow 49-49(\frac{v}{c}) = 36+36(\frac{v}{c}) \Rightarrow 85(\frac{v}{c}) = 13$ <br>
(approach or<br>  $\Rightarrow v = \frac{13}{85} \times 3 \times 10^8 = \frac{39}{85} \times 10^8 = 4.59 \times$ v  $\vert$  34 m/s. The train sounds a whistle and its frequency  $1-\frac{1}{\cdot}$ c  $\left( \begin{array}{ccc} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 &$ notion between source and<br>
different from that of sound.<br>  $\Rightarrow 49-49\left(\frac{v}{c}\right) = 36+36\left(\frac{v}{c}\right) \Rightarrow 85\left(\frac{v}{c}\right)$ <br>
as are possible (approach or<br>  $\Rightarrow v = \frac{13}{85} \times 3 \times 10^8 = \frac{39}{85} \times 10^8 = 4.59 \times 10^7$  ms<br>  $\therefore$  The strat **Q.2** A train moves towards a stationary observer with speed registered by the observer is  $f_1$ . If the train's speed is reduced to 17 m/s, the frequency registered is  $f_2$ . If the speed of sound is 340 m/s then the ratio  $f_1/f_2$  is

(A) 18/19 (B) 1/2 (C) 2 (D) 19/18

c  $\int_0^\infty$ (A) the frequency of sound as heard by<br>  $\frac{1+\frac{v}{c}}{1-\frac{v}{c}}$  (A) the prequency of sound as heard by<br>  $\frac{1+\frac{v}{c}}{1-\frac{v}{c}}$  (B) the speed of sound for the observer st<br>
parading on the platform is 350m/s.<br>
(c) the freque (B) the speed of sound for the observer standing on the pharmon is 350m/s.<br>
(c) the frequency of sound as heard by the observer<br>
standing on the platform will increase.<br>
(d) the frequency of sound as heard by the observer **Q.3** A siren placed at a railway platform is emitting sound of frequency 5 kHz. A passenger sitting in a moving train A records a frequency of 5.5 kHz, while the train approaches the siren. During his return journey in a different train B he records a frequency of 6 kHz while approaching the same siren. The ratio of the velocity of train B to that train A is

$$
\left(\begin{array}{c}\n\mathbf{v} \\
\mathbf{c}\n\end{array}\right)\lambda
$$
\n(A) 242/252\n(B) 2\n(D) 11/6



**Q.4** A police car moving at 22 m/s chases a motorcyclist. The police man sounds his horn at 176 Hz, while both of them move towards a stationary siren of frequency 165 Hz. Calculate the speed of the motorcycle. If it is given that the motorcyclist does not observe any beats.



 $(C)$  zero  $(D)$  11 m/s

**Q.5** A source of sound of frequency 600 Hz is placed inside water. The speed of sound in water is 1500 m/s and in air it is 300 m/s. The frequency of sound recorded by an observer who is standing in air is –



- **Q.6** An observer standing on a railway crossing receives frequency of 2.2 kHz and 1.8 kHz when the train approaches and recedes from the observer. Find the velocity of the train. [The speed of the sound in air is 300 m/s]
- **Q.7** A police car with a siren of frequency 8 kHz is moving with uniform velocity 36 km/hr towards a tall building which reflects the sound waves. The speed of sound in air is 320m/s. Frequency of the siren heard by the car driver (A) 8.50 kHz (B) 8.25 kHz (C) 7.75 kHz (D) 7.50 kHz
- **Q.8** Two vehicles, each moving with speed u on the same horizontal straight road, are approaching each other. Wind blows along the road with velocity w. One of these vehicles blows a whistle of frequency  $f_1$ . An observer in the other vehicle hears the frequency of the whistle to be  $f_2$ . The **Exam** speed of sound in still air is V. The correct statement(s) is  $(are)$  –
	- (A) If the wind blows from the observer to the source,  $f_2 > f_1$ .
	- (B) If the wind blows from the source to the observer,  $f_2 > f_1$ . Sol. .<br>. **.**
	- (C) If the wind blows from observer to the source,  $f_2 < f_1$ .
	- (D) If the wind blows from the source to the observer,  $f_2 < f_1$ . .

#### **ANSWERS**



## **ADDITIONAL EXAMPLES**

#### **Example 1 :**

The length of a wire between the two ends of a sonometer is 105cm. Where should the two bridges be placed so that the fundamental frequencies of the three segments are in the ratio of 1 : 3 : 15.



**Sol. (3).** From the law of length of stretched string, we have  $n_1 \ell_1 = n_2 \ell_2 = n_3 \ell_3$ Here  $n_1 : n_2 : n_3 = 1 : 3 : 15$ 

**STUDY MATERIAL: PHYSICS**  
\n
$$
\frac{\ell_1}{\ell_2} = \frac{n_2}{n_1} = \frac{3}{1}
$$
 and  $\frac{\ell_1}{\ell_3} = \frac{n_3}{n_1} = \frac{15}{1}$ ;  $\ell_2 = \frac{\ell_1}{3}$  and  $\ell_3 = \frac{\ell_1}{15}$   
\nThe total length of the wire is 105 cm  
\nTherefore,  $\ell_1 + \ell_2 + \ell_3 = 105$   
\nor  $\ell_1 + \frac{\ell_1}{3} + \frac{\ell_1}{15} = 105$  or  $\frac{21\ell_1}{15} = 105$ 

The total length of the wire is 105 cm Therefore,  $\ell_1 + \ell_2 + \ell_3 = 105$ 

**STUDY MATERIAL: PHYSICS**  
\n
$$
\frac{\ell_1}{\ell_2} = \frac{n_2}{n_1} = \frac{3}{1} \text{ and } \frac{\ell_1}{\ell_3} = \frac{n_3}{n_1} = \frac{15}{1}; \ell_2 = \frac{\ell_1}{3} \text{ and } \ell_3 = \frac{\ell_1}{15}
$$
\nThe total length of the wire is 105 cm  
\nTherefore,  $\ell_1 + \ell_2 + \ell_3 = 105$   
\nor  $\ell_1 + \frac{\ell_1}{3} + \frac{\ell_1}{15} = 105$  or  $\frac{21\ell_1}{15} = 105$   
\n
$$
\ell_1 = \frac{105 \times 15}{15} = 75 \text{ cm } \therefore \ell_2 = \frac{\ell_1}{3} = \frac{75}{3} = 25 \text{ cm}
$$
\nHence the bridge should be placed at 75 cm and  
\n(75 + 25) = 100 cm from one end.  
\n**101e2:**  
\n(a) Compute the fundamental frequency of a sonometer wire of the length 20.0 cm, T = 20 N, m = 5.2 × 10<sup>-3</sup> kg/m.  
\n(b) A resonance air column resonates with a turning fork of the frequency 512 Hz at the length 17.4cm Neglecting the end correction, deduce the speed of the sound in air is  
\n(a) The fundamental frequency of a sonometer wire is given  
\n(1a) The fundamental frequency of a sonometer wire is given by n =  $\frac{1}{2\ell} \sqrt{\frac{T}{m}}$   
\nHere,  $\ell = 20$  cm = 0.2m, T = 20N, m = 5.2 × 10<sup>-3</sup> kg/m  
\nHence, n =  $\frac{1}{2 \times 0.2} \sqrt{\frac{20}{5.2 \times 10^{-3}}} = 155$  Hz  
\n(b) Speed of sound in air is given by, y = n 4  $\ell$  = 512 × 4 × 0 174 = 356 35 ms<sup>-1</sup>

Hence the bridge should be placed at 75 cm and  $(75 + 25) = 100$  cm from one end.

#### **Example 2 :**

(a) Compute the fundamental frequency of a sonometer wire of the length 20.0 cm,  $T = 20$  N,  $m = 5.2 \times 10^{-3}$  kg/m. (b) A resonance air column resonates with a turning fork of the frequency 512 Hz at the length 17.4cm Neglecting the end correction, deduce the speed of the sound in air is your answer unique for the given data.  $\frac{15}{15}$  = 75 cm  $\therefore$   $\ell_2 = \frac{\ell_1}{3} = \frac{75}{3}$  = 25 cm<br>ge should be placed at 75 cm and<br>cm from one end.<br>he fundamental frequency of a sonometer<br>th 20.0 cm, T = 20 N, m = 5.2 × 10<sup>-3</sup>kg/m.<br>a ir column resonates with  $\frac{15}{15}$  - 75 cm ...  $t_2 - \frac{1}{3} - \frac{1}{3}$  - 25 cm<br>  $\frac{15}{15}$  = 5 cm<br>  $\frac{15}{15}$  = 5 cm<br>
ordge should be placed at 75 cm and<br>
00 cm from one end.<br>
e the fundamental frequency of a sonometer<br>
ength 20.0 cm, T = 20 N,

**Sol.** (a) The fundamental frequency of a sonometer wire is given

by 
$$
n = \frac{1}{2\ell} \sqrt{\frac{T}{m}}
$$

Here,  $\ell = 20$  cm = 0.2m, T = 20N, m = 5.2 × 10<sup>-3</sup>kg/m

Hence, n = 
$$
\frac{1}{2 \times 0.2} \sqrt{\frac{20}{5.2 \times 10^{-3}}} = 155
$$
 Hz

(b) Speed of sound in air is given by,

 $v = n 4 \ell = 512 \times 4 \times 0.174 = 356.35$  ms<sup>-1</sup>

This answer is unique for the fundamental mode.

#### **Example 3 :**

A piezo electric quartz plate of thickness 0.005m is vibrating in resonant conditions. Calculate its fundamental frequency if for quartz Y = 8  $\times$  10<sup>10</sup>N/m<sup>2</sup> &  $\rho$  = 2.65  $\times$  10<sup>3</sup> kg/m<sup>3</sup> at the length 17.4cm Neglecting the<br>
ce the speed of the sound in air is<br>
or the given data.<br>
a, T = 20N, m = 5 . 2 × 10<sup>-3</sup>kg/m<br>  $\frac{20}{5.2 \times 10^{-3}}$  = 155 Hz<br>
air is given by,<br>  $\frac{20}{5.2 \times 10^{-3}}$  = 155 Hz<br>
for the funda the difference of the solid in an is<br>
for the given data.<br>
frequency of a sonometer wire is given<br>  $m, T = 20N, m = 5.2 \times 10^{-3} \text{kg/m}$ <br>  $\frac{20}{5.2 \times 10^{-3}} = 155 \text{ Hz}$ <br>
n air is given by,<br>  $4 \times 0.174 = 356.35 \text{ ms}^{-1}$ <br>
le for th

. **Sol.** We know that for longitudinal waves in solids

$$
v = \sqrt{\frac{Y}{\rho}}
$$
, so  $v = \sqrt{\frac{8 \times 10^{10}}{2.65 \times 10^3}} = 5.5 \times 10^3$  m/s

Further more for fundamental mode of plate

$$
(\lambda/2) = L \text{ so } \lambda = 2 \times 5 \times 10^{-3} = 10^{-2} \text{m}
$$
  
v = f\lambda, i.e, f = (v/\lambda)  
So, f = [5.5 \times 10^3/10^{-2}] = 5.5 \times 10^5 \text{ Hz} = 550 \text{ kHz}

**Example 4 :**

A 5 watt source sends out waves in air at frequency  $1000s^{-1}$ . Deduce the intensity at a 100 meter distance, assuming spherical distribution. If  $v = 350 \text{ ms}^{-1}$  and  $\rho = 1.3 \text{ kg/m}^3$ , deduce the displacement amplitude.  $\sqrt{\rho}$ , so  $v - \sqrt{2.65 \times 10^3 - 3.3 \times 10^{10}}$  in the more for fundamental mode of plate<br>
her more for fundamental mode of plate<br>  $(\lambda/2) = L$  so  $\lambda = 2 \times 5 \times 10^{-3} = 10^{-2}$  m<br>  $\lambda$ , i.e,  $f = (v/\lambda)$ <br>  $f = [5.5 \times 10^3/10^{-2}] = 5.5 \times$ electric quartz plate of thickness 0.005m is vibrating<br>ant conditions. Calculate its fundamental frequency<br>artz Y = 8 × 10<sup>10</sup>N/m<sup>2</sup> &  $\rho$  = 2.65 × 10<sup>3</sup> kg/m<sup>3</sup><br>w that for longitudinal waves in solids<br> $\frac{8 \times 10^{10}}{2.6$ electric quariz piate of uncessies 0.000m is vibrating<br>that conditions. Calculate its fundamental frequency<br>trtz Y = 8 × 10<sup>10</sup>N/m<sup>2</sup> & p = 2.65 × 10<sup>3</sup> kg/m<sup>3</sup><br>v that for longitudinal waves in solids<br>5. so  $v = \sqrt{\frac{8 \times 10$ 

**Sol.** We know that intensity is given by,

$$
I = \frac{Power}{Area} = \frac{5Watt}{4\pi(100)^2 m^2}
$$



ANSS	Answer 1000 s. $1 = 2\rho \text{yr}^2$ m <sup>2</sup> $\frac{2}{2}$	The standard equation of harmonic wave is dynamboxwise theorem 250 ms <sup>-1</sup>	
180, $1 = 2\rho \text{yr}^2$ m <sup>2</sup> $\frac{2}{2}$	180 s. $\frac{1}{2} = \frac{1}{2\rho \text{yr}} \frac{1}{\sqrt{2\rho \text{yr}}}$	181 s. $\rho = 3.6 \text{ m}$ (1) and (2), and $\rho = 350 \text{ ms}^{-1}$	250 ms <sup>-1</sup> $\frac{2\pi}{\lambda} = 0.0080$ or $\lambda = \frac{2\pi}{0.0080}$ cm = $\frac{2\pi}{0.0080 \text{ cm}} = \frac{2\pi}{0.0080 \text{ cm}} = \frac{$

#### **Example 5 :**

The equation of plane progressive wave motion is  $y = a \sin 2\pi / \lambda$  (vt – x). Velocity of particle is -

22×1000 V2×1.3×350  
\n**aple 5:**  
\nThe equation of plane progressive wave motion is  
\n
$$
y = a \sin 2\pi / \lambda (vt - x)
$$
. Velocity of particle is  
\n(1) y  $\frac{dv}{dx}$   
\n(2) v  $\frac{dy}{dx}$   
\n(3) - y  $\frac{dv}{dx}$   
\n(4). Velocity of particle  
\n $\frac{dy}{dt} = a \cos \left\{ \frac{2\pi}{\lambda} (vt - x) \right\} \frac{2\pi v}{\lambda}$   
\nSlope of curve,  
\nBy equation (1) and (2)  
\n $\frac{dy/dt}{dx} = -v$   $\therefore \frac{dy}{dt} = -v \frac{dy}{dx}$   
\n $\frac{dy}{dt} = -$ 

**Sol. (4).** Velocity of particle

$$
\frac{dy}{dt} = a \cos \left\{ \frac{2\pi}{\lambda} (vt - x) \right\} \frac{2\pi v}{\lambda}
$$
 (iv) Phase d (iv)

Slope of curve,

$$
\frac{dy}{dx} = a \cos \left\{ \frac{2\pi}{\lambda} (vt - x) \right\} \left\{ \frac{-2\pi}{\lambda} \right\} \qquad \qquad \dots \dots \dots (2) \qquad \text{Wa}
$$

By equation (1) and (2)

$$
\frac{dy/dt}{dy/dx} = -v \qquad \therefore \quad \frac{dy}{dt} = -v \frac{dy}{dx}
$$
 Sol. G

#### **Example 6 :**

If equation of transverse wave is  $y = x_0 \cos 2\pi \left( \frac{nt - \overline{x}}{\lambda} \right)$ . .

Maximum velocity of particle is twice of wave velocity, if  $\lambda$ is-

(1) 
$$
\pi/2x_0
$$
  
(3)  $\pi x$   
(4)  $\pi x_0$ 

Slope of curve,  
\n
$$
\frac{dy}{dx} = a \cos \left\{ \frac{2\pi}{\lambda} (v-x) \right\} \left\{ \frac{-2\pi}{\lambda} \right\}
$$
\n
$$
\frac{dy}{dx} = -v \quad \therefore \quad \frac{dy}{dt} = -v \frac{dy}{dx}
$$
\n
$$
\frac{dy/dt}{dy/dx} = -v \quad \therefore \quad \frac{dy}{dt} = -v \frac{dy}{dx}
$$
\n
$$
\frac{ds}{dx} = -v \quad \therefore \quad \frac{dy}{dt} = -v \frac{dy}{dx}
$$
\n
$$
\frac{ds}{dx} = -v \quad \therefore \quad \frac{dy}{dt} = -v \frac{dy}{dx}
$$
\n
$$
\frac{ds}{dx} = -v \quad \therefore \quad \frac{ds}{dt} = -v \frac{dy}{dx}
$$
\n
$$
\frac{ds}{dx} = -v \quad \frac{ds}{dx}
$$

$$
\left(\frac{dy}{dt}\right)_{max} = x_0 \times \frac{2\pi}{\lambda} v = 2v \text{ (given)} \qquad \therefore \lambda = \pi x_0
$$

#### **Example 7 :**

For the travelling harmonic wave

 $y = 2.0 \cos (10t - 0.0080x + 0.35)$ . Where x and y are in cm and t in sec. What is the phase difference between oscillatory motion at two points separated by a distance of  $(i)$  4m,  $(ii)$  0.5m  $(iii)$  A/2  $(iv)$  3 $\lambda$ /4

**Sol.** The given equation of harmonic wave is  $y = 2.0 \cos(10t - 0.0080x + 0.35)$  .......(1) The standard equation of harmonic wave is

$$
\begin{array}{c}\n\text{CDMADVANCGED LEARNING} \\
\text{CDIMADVANCGED LEARNING} \\
\text{We have:}\n\end{array}
$$
\n
$$
y = a \cos \left[ 2\pi \left( \frac{1}{T} - \frac{x}{\lambda} \right) + \phi \right] \qquad \qquad \dots \dots (2)
$$
\n
$$
\text{mparing equations (1) and (2),}
$$
\n
$$
\frac{2\pi}{\lambda} = 0.0080 \text{ or } \lambda = \frac{2\pi}{0.0080} \text{ cm} = \frac{2\pi}{0.0080 \times 100}
$$

Comparing equations (1) and (2),

$$
\frac{2\pi}{\lambda} = 0.0080 \text{ or } \lambda = \frac{2\pi}{0.0080} \text{ cm} = \frac{2\pi}{0.0080 \times 100}
$$

$$
\tan \frac{\pi}{1000 \text{ s}^{-1}} = 1.3 \text{ kg m}^{-3}
$$
\n
$$
\frac{2\pi}{\lambda} = 0.0080 \text{ or } \lambda = \frac{2\pi}{0.0080} \text{ cm} = \frac{2\pi}{0.0080 \times 100}
$$
\n
$$
\frac{4 \times 10^{-5}}{2 \times 1.3 \times 350} = 6.67 \times 10^{-8} \text{m}
$$
\n(ii) Phase difference  $= \frac{2\pi}{\lambda} \times \text{path difference}$   
\n
$$
= \frac{2\pi}{2\pi} \times .00080 \times 100 \times 4 = 3.2 \text{ rad}
$$
\n
$$
= \frac{2\pi}{\lambda} \times \text{path difference}
$$
\n
$$
= \frac{2\pi}{\lambda} \times \text{path difference}
$$
\n(iii) Phase difference  $= \frac{2\pi}{\lambda} \times \text{path difference}$   
\n
$$
= \frac{2\pi}{\lambda} \times \text{path difference}
$$
\n
$$
= \frac{
$$

(ii) Phase difference = 
$$
\frac{2\pi}{\lambda}
$$
 × path difference

$$
\frac{dy}{dx} = \frac{2\pi}{2\pi} \times .00080 \times 100 \times 0.5 = 0.40 \text{ rad}
$$

$$
\frac{dy}{dx}
$$
 (iii) Phase difference =  $\frac{2\pi}{\lambda}$  × path diff =  $\frac{2\pi}{\lambda}$  ×  $\frac{\lambda}{2}$  =  $\pi$  rad

(iv) Phase difference = 
$$
\frac{2\pi}{\lambda}
$$
 × path diff. =  $\frac{2\pi}{\lambda}$  ×  $\frac{3\lambda}{4}$  =  $\frac{3\pi}{2}$  rad

#### **Example 8 :**

Wavelength of two notes in air are (80/195) m and (80/195) m. Each note produces five beats per second with a note of a fixed frequency. Calculate the velocity of sound in air.  $\times 100 \times 4 = 3.2$  rad<br>  $e = \frac{2\pi}{\lambda} \times$  path difference<br>  $\times 100 \times 0.5 = 0.40$  rad<br>  $e = \frac{2\pi}{\lambda} \times$  path diff.  $= \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$  rad<br>  $e = \frac{2\pi}{\lambda} \times$  path diff.  $= \frac{2\pi}{\lambda} \times \frac{3\lambda}{4} = \frac{3\pi}{2}$  rad<br>
notes in ai mce<br>  $\frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$  rad<br>  $\frac{2\pi}{\lambda} \times \frac{3\lambda}{4} = \frac{3\pi}{2}$  rad<br>
5) m and (80/195)<br>
bnd with a note of<br>
of sound in air.<br>  $\frac{v}{v_2} = \frac{193}{80}$ 

$$
\frac{dy}{dx}
$$
 **Sol.** Given that  $\lambda_1 = \frac{v}{\lambda_1} = \frac{195v}{80}$  and  $n_2 = \frac{v}{\lambda_2} = \frac{193}{80}$ 

This show that,  $n_1 > n_2$ 

(i) Phase difference = 
$$
\frac{2\pi}{\lambda}
$$
 × path difference  
\n
$$
= \frac{2\pi}{2\pi} \times .00080 \times 100 \times 0.5 = 0.40 \text{ rad}
$$
\n(iii) Phase difference =  $\frac{2\pi}{\lambda}$  × path diff =  $\frac{2\pi}{\lambda}$  ×  $\frac{\lambda}{2}$  = π rad  
\n........(1)  
\n(iv) Phase difference =  $\frac{2\pi}{\lambda}$  × path diff =  $\frac{2\pi}{\lambda}$  ×  $\frac{3\lambda}{4}$  =  $\frac{3\pi}{2}$  rad  
\nExample 8:  
\nWavelength of two notes in air are (80/195) m and (80/195)  
\nm. Each note produces five beats per second with a note of  
\na fixed frequency. Calculate the velocity of sound in air.  
\nSol. Given that  $\lambda_1 = \frac{v}{\lambda_1} = \frac{195v}{80}$  and  $n_2 = \frac{v}{\lambda_2} = \frac{193}{80}$   
\nThis show that,  $n_1 > n_2$   
\nLet the frequency of third note be n, then  
\n $n_1 - n_1 = 5$  and  $n_1 - n_2 = 5$   
\n∴  $n_1 - n_2 = 10$   
\nlocity, if λ  $\frac{195v}{80} - \frac{193v}{80} = 10$   
\n $2v = 80 \times 10 = 800$ ;  $v = 400$  m/sec  
\nExample 9:  
\n- x)  
\nTuning fork A has frequency 1% greater than that of  
\nstandard for the number of students and the original work of the average 2%  
\nsmaller than that of R. When Δ and C are rounded together

$$
2v = 80 \times 10 = 800 \; ; \; v = 400 \; \text{m/sec}
$$

#### **Example 9 :**

ricle<br>  $\left(\frac{2\pi}{\lambda}(vt-x)\right)\left\{\frac{2\pi v}{\lambda}\right\}$  (iv) Phase difference =  $\frac{2\pi}{\lambda}$  routh diff. =  $\frac{2\pi}{\lambda}(vt-x)\left\{\frac{-2\pi}{\lambda}\right\}$  Example 8:<br>
Wavelength of two notes in air are (80/19<br>
an. Each note produces five beats per sec  $\left(\pi - \frac{x}{\lambda}\right)$  (iv) Phase difference =  $\frac{2\pi}{\lambda}$  spath diff. =  $\frac{2\pi}{\lambda}$  (vt - x)  $\left\{\frac{-2\pi}{\lambda}\right\}$  (2π)<br>
(2π)<br>
(vt) - 2π)<br>
(2π)<br>
(2) (xt - x)  $\left\{\frac{-2\pi}{\lambda}\right\}$  (3π)<br>
(3π)<br>
(3π)<br>
(3π)<br>
(3π)<br>
(3π)<br>
(3π)<br>
(3π)<br>  $\frac{2\pi}{\text{(vt-x)}}$  Tuning fork A has frequency 1% greater than that of  $\lambda$  standard fork B while tuning fork C has frequency 2% smaller than that of B. When A and C are sounded together, the number of beats heard per second is 5. What is the frequency of each fork.

**Sol.** Let the frequencies of forks be  $n_1$ ,  $n_2$  &  $n_3$  respectively. Then,  $n_1 = n_2(1 + 0.01) = 1.01 n_2$ 

and  $n_3 = n_2(1 - 0.02) = 0.98 n_2$ Further,  $n_1 - n_3 = 5$ 

Substituting the values, we get
$$
(1.01n_2 - 0.98n_2) = 5
$$
  
n<sub>2</sub> = 166.7 Hz. Now, n<sub>1</sub> = 1.01 × 166.7 = 168.3 Hz

and 
$$
n_3 = 0.98 \times 166.7 = 163.3
$$
 Hz



#### **Example 10 :**

A metal rod 1.5m length is clamped at the center. When it is set with longitudinal vibrations it emits a note of 1KHz. If the density of the material is  $8 \times 10^3$ , then determine the Young's modulus.

**Sol.** For longitudinal waves in a rod the velocity of sound is

$$
v = \sqrt{\frac{Y}{\rho}}
$$
, where Y is Young's modulus and  $\rho$  density.

Also for a clamped rod in the middle, the frequency of

For longitudinal waves in a rod the velocity of sound is  
\n
$$
V = \sqrt{\frac{Y}{\rho}}
$$
, where Y is Young's modulus and  $\rho$  density.  
\nAlso for a clamped rod in the middle, the frequency of  
\nfundamental note is  $n = \frac{v}{2\ell}$   
\nfundamental note is  $n = \frac{v}{2\ell}$   
\n
$$
V = 4 \times (10^3)^2 \times (1.5)^2 \times 8 \times 10^3 = 7.2 \times 10^{10} \text{ N/m}^2
$$
\n
$$
= 8.64 \times 10^{-2} = 0.087 \text{ W/r}
$$
\n
$$
= 8.66 \times 10^{-2} = 0.087 \text{ W/r}
$$
\n
$$
= 8.64 \times 10^{-2} = 0.087 \text{ W/r}
$$
\n
$$
= 8.64 \times 10^{-2} = 0.087 \text{ W/r}
$$
\n
$$
= 8.64 \times 10^{-2} = 0.087 \text{ W/r}
$$
\n
$$
= 100 \text{ hydrogen are in the ratio 16 : 1}
$$
\n
$$
= 100 \text{ hydrogen per}
$$
\n
$$
= 100 \text{ hydrogen per}
$$
\n
$$
= 100 \text{ hydrogen per}
$$
\n
$$
= 100 \text{ N/m}^2
$$
\n
$$
= 100 \text{ m}
$$
\n
$$
= 100
$$

Substituting the data from question  
\n
$$
Y = 4 \times (10^3)^2 \times (1.5)^2 \times 8 \times 10^3 = 7.2 \times 10^{10} \text{ N/m}^2
$$

#### **Example 11 :**

The ratio in the densities of oxygen and nitrogen is 16 : 14. At what temperature the speed of sound will be the same which is in nitrogen at 15ºC.

**Sol.** If M be the molecular weight of the gas and T be the absolute temperature, then speed of sound in a gas.

$$
v = \sqrt{\left(\frac{\gamma RT}{M}\right)} \qquad \qquad \left(\because \frac{P}{d} = \frac{RT}{M}\right) \qquad \qquad Ex
$$

Where R is universal gas constant. Velocity of sound in

oxygen at t°C = 
$$
\sqrt{\left[\frac{\gamma R(273+t)}{M_0}\right]}
$$

Velocity of sound in nitrogen at 15°C =  $\sqrt{\frac{\gamma R(273+15)}{M_N}}$ 

According to the given problem

0 N R(273 t) R(273 15) M M 0 <sup>n</sup> <sup>M</sup> 273 t M 288 ; 16 273 t 0 

Solving we get,  $t = 56.1$ °C

#### **Example 12 :**

What is the intensity level of sound in dB for (i) threshold of hearing and (ii) threshold of pain.

oxygen at t<sup>o</sup>C = 
$$
\sqrt{\frac{\gamma R(273+t)}{M_0}}
$$

\nis closed, then the fundamental frequency (1) 350, 700 (2) 700, 350 (3) 175, 350 (4) 350, 175 (3) 175, 350 (4) 350, 175 (4) 350,

#### **Example 13 :**

- A trumpet player plays a note of frequency 400Hz with an  $\frac{1}{3}$  mm. If the density of air is taken as 1.3kg/m<sup>3</sup> , and the speed of sound 330 m/s, find the intensity of the sound wave.
- **Sol.** The intensity of sound wave is given by,

1.3 kg/m<sup>3</sup>, and the speed of sound 330 m/s, find the intensity  
\nof the sound wave.  
\nThe intensity of sound wave is given by,  
\n
$$
I = 2\pi^2 \rho v n^2 a^2
$$
  
\n $= 2 \times (3.14)^2 \times 1.3 \times 330 \times (400)^2 \times (8 \times 10^{-6})^2$   
\n $= 2 \times 9.86 \times 1.3 \times 330 \times 16 \times 64 \times 10^{-8}$   
\n $= 8.66 \times 10^{-2} = 0.087 \text{ W/m}^2$   
\n**ample 14 :**  
\nAt what temperature will the speed of sound in hydrogen  
\nbe the same as in oxygen at 100°C. Densityes of oxygen and  
\nhydrogen are in the ratio 16 : 1 -  
\n(1)-250°C (2)249.7°C  
\n(3)250° (4)-249.7°C  
\n(4). Velocity  $v = \sqrt{\frac{\gamma RT}{M}}$   
\nFor oxygen and hydrogen  $\gamma = 1.4$  and R is constant  
\n $\therefore \sqrt{\frac{T}{M_H}} = \sqrt{\frac{T_{100}}{M_0}} \Rightarrow \frac{T}{T_{100}} = \frac{M_H}{M_0}$   
\n $\Rightarrow \frac{273+t}{273+100} = \frac{273+t}{273+100} = \frac{1}{16}$ ; t=-249.7°C  
\n**nple 15 :**  
\nThe length of an organ pipe open of both ends is 0.5 meter.  
\nCalculate the fundamental frequency of the pipe, if the  
\nvelocity of sound in air be 350 m/sec. If one end of the pipe

**Example 14 :**

At what temperature will the speed of sound in hydrogen be the same as in oxygen at 100ºC. Densities of oxygen and hydrogen are in the ratio 16 : 1 -  $66 \times 10^{-2} = 0.087 \text{ W/m}^2$ <br>temperature will the speed of sound in hydrogen<br>me as in oxygen at 100°C. Densities of oxygen and<br>are in the ratio 16 : 1 -<br>(2) 249.7°C<br>(4) - 249.7°C<br>city  $v = \sqrt{\frac{\gamma RT}{M}}$ <br>en and hydrogen  $\gamma = 1.$ A 10  $\approx$  04  $\approx$  10<br>W/m<sup>2</sup><br>the speed of sound in hydrogen<br>100°C. Densities of oxygen and<br>6 : 1 -<br>(2) 249.7°C<br>(4) – 249.7°C<br> $\gamma = 1.4$  and R is constant<br> $\frac{T}{N_{100}} = \frac{M_H}{M_0}$ <br> $T = \frac{1}{16}$ ; t = - 249.7°C In. If the density of air is taken as<br>
f sound 330 m/s, find the intensity<br>
ave is given by,<br>  $330 \times (400)^2 \times (8 \times 10^{-6})^2$ <br>  $> 16 \times 64 \times 10^{-8}$ <br>
T W/m<sup>2</sup><br>
the speed of sound in hydrogen<br>  $1100^{\circ}$ C. Densities of oxygen an

$$
(1) -250^{\circ}\text{C} \qquad (2) 249.7^{\circ}\text{C} (3) 250^{\circ} \qquad (4) -249.7^{\circ}\text{C}
$$

**Sol.** (4). Velocity  $v = \sqrt{\frac{v}{M}}$ RT and the state of the sta M  $\gamma RT$ 

For oxygen and hydrogen  $\gamma = 1.4$  and R is constant

$$
\therefore \quad \sqrt{\frac{T}{M_H}} = \sqrt{\frac{T_{100}}{M_0}} \Rightarrow \frac{T}{T_{100}} = \frac{M_H}{M_0}
$$

$$
\Rightarrow \frac{273 + t}{273 + 100} = \frac{273 + t}{273 + 100} = \frac{1}{16} \text{ ; } t = -249.7^{\circ}\text{C}
$$

**Example 15 :**

 $M / U$  d  $M / U$  The length of an organ pipe open of both ends is 0.5 meter. modulus and  $\rho$  density.<br>  $= 2\pi^2 \times 3.14)^2 \times 1.3 \times 330 \times (400)^2 \times (8 \times 10^{-6})^2$ <br>  $= 2 \times 9.86 \times 1.3 \times 330 \times 16 \times 64 \times 10^{-8}$ <br>
ddle, the frequency of<br> **Example 14:**<br>
At what temperature will the speed of sound in hydro<br>
At modulus and p density.<br>  $= 2 \times 9.86 \times 1.3 \times 330 \times (400)^2 \times (8 \times 10^{-9})$ <br>
ddle, the frequency of<br>  $= 2 \times 9.86 \times 1.3 \times 330 \times (400)^2 \times (8 \times 10^{-9})$ <br>
Adde, the frequency of<br>
Example 14:<br>
At what temperature will the speed of sound the velocity of sound is<br>  $I = 2x^2e^{2\rho}$ <br>  $= 2x^2e^{2\rho}$ <br>
and  $\rho$  density.<br>  $= 2 \times 9.86 \times 1.3 \times 330 \times (400)^2 \times (8 \times 10^{-6})^2$ <br>  $= 2 \times 9.86 \times 1.3 \times 330 \times 16 \times 64 \times 10^{-8}$ <br>
and dle, the frequency of<br>  $= 8.66 \times 10^{-2} = 0.087$  2's modulus and ρ density.<br>  $1 = 2\pi^2 \text{p} \text{v} \text{m}^2$ <br>  $= 2 \times (3.14)^2 \times 1.3 \times 330 \times (400)^2 \times (8 \times 10^{-6})^2$ <br>  $= 2 \times 9.86 \times 1.3 \times 330 \times 16 \times 64 \times 10^{-8}$ <br>
middle, the frequency of<br> **Example 14:**<br> **Example 14:**<br>
At what temp n =  $\frac{v}{2\ell}$ <br>  $n\ell = \sqrt{\frac{Y}{p}}$  or  $Y = 4n^2\ell^2p$ <br>  $(1)-250^\circ C$  (1)-250°C (2) 249.7°C<br>
from question<br>
from question<br>  $1.5\ell^2 \times 8 \times 10^{3} = 7.2 \times 10^{10} \text{ N/m}^2$ <br>
Sol. (4). Velocity  $v = \sqrt{\frac{rRT}{M}}$ <br>
For oxygen and nitrogen and rod in the middle, the frequency of<br>
is  $n = \frac{v}{2\ell}$ <br>  $2n\ell = \sqrt{\frac{v}{p}}$  or  $Y = 4n^2\ell^2p$ <br>  $2n\ell = \sqrt{\frac{v}{p}}$  or  $Y = 4n^2\ell^2p$ <br>  $\approx (1.5)^2 \times 8 \times 10^3 = 7.2 \times 10^{10} \text{ N/m}^2$ <br>  $\approx (1.5)^2 \times 8 \times 10^3 = 7.2 \times 10^{10} \text{ N/m}^2$ <br> 4m<sup>2</sup> $\ell^2$ ρ (1)-250°C (2)249.7°C (2)249.7°C (3)250° (4)-249.7°C (4)<br>
II be the same  $\therefore \sqrt{\frac{T}{M_H}} = \$  $x = 4n^2\ell^2p$  by drogen are in the ratio 16:1 -<br>
(1)-250°C (2)249.7°C<br>  $\times 10^{10}$  N/m<sup>2</sup> **Sol. (4).** Velocity  $v = \sqrt{\frac{rRT}{M}}$ <br>
For oxygen and hydrogen  $\gamma = 1.4$  and R is constant<br>
trogen is 16:14.<br>
Will be the associate trogen is 16:14<br>
will be the same<br>  $\frac{17}{N_H} = \sqrt{\frac{T_{100}}{M_0}} \Rightarrow \frac{T}{T_{100}} = \frac{M_H}{M_0}$ <br>
The the absolute<br>  $\Rightarrow \frac{273 + 10}{273 + 100} = \frac{1}{273 + 100} = \frac{1}{16}$ ;  $t = -249.7^{\circ}\text{C}$ <br>
Example 15:<br>
The length of an organ pipe open sound wave.<br>  $2^2$ Pyn<sup>2</sup>a<sup>2</sup><br>  $2^2$   $\sqrt{2}$  a<sup>2</sup><br>  $2 \times (3.14)^2 \times 1.3 \times 330 \times (400)^2 \times (8 \times 10^{-6})^2$ <br>  $2 \times 9.86 \times 1.3 \times 330 \times 16 \times 64 \times 10^{-8}$ <br>  $8.66 \times 10^{-2} = 0.087$  W/m<sup>2</sup><br>
4:<br> **4:**<br> **4:**<br> **4:**<br> **4:**<br> **4:**<br> **4:**<br> **4:**<br> **4:**<br> intensity of sound wave is given by,<br>  $\pi^2$ ovn<sup>2</sup>a<sup>2</sup><br>  $= 2 \times (3.14)^2 \times 1.3 \times 330 \times (400)^2 \times (8 \times 10^{-6})^2$ <br>  $= 2 \times 9.86 \times 1.3 \times 330 \times 16 \times 64 \times 10^{-8}$ <br>  $= 8.66 \times 10^{-2} = 0.087 \text{ W/m}^2$ <br>
44 :<br>
44 the metal temperature will th und wave.<br>
sity of sound wave is given by,<br>  $\text{var}^2$ <br>  $\times (3.14)^2 \times 1.3 \times 330 \times (400)^2 \times (8 \times 10^{-6})^2$ <br>  $\times 9.86 \times 1.3 \times 330 \times 16 \times 64 \times 10^{-8}$ <br>  $\times 9.86 \times 1.3 \times 330 \times 16 \times 64 \times 10^{-8}$ <br>
temperature will the speed of sound i Calculate the fundamental frequency of the pipe, if the velocity of sound in air be 350 m/sec. If one end of the pipe is closed, then the fundamental frequency will be - Eny  $v = \sqrt[3]{M}$ <br>
en and hydrogen  $\gamma = 1.4$  and R is constant<br>  $\frac{v}{H} = \sqrt{\frac{T_{100}}{M_0}} \Rightarrow \frac{T}{T_{100}} = \frac{M_H}{M_0}$ <br>  $\frac{3+t}{1100} = \frac{273+t}{273+100} = \frac{1}{16}$ ;  $t = -249.7^{\circ}\text{C}$ <br>
th of an organ pipe open of both ends is 0.5 met gen and hydrogen  $\gamma = 1.4$  and R is constant<br>  $\frac{1}{10}$ <br>  $\frac{1}{10}$ <br>  $\frac{1}{100}$ <br>  $\frac{3+t}{100}$   $\Rightarrow \frac{T}{T_{100}} = \frac{M_H}{M_0}$ <br>  $\frac{3+t}{100} = \frac{273+t}{273+100} = \frac{1}{16}$ ;  $t = -249.7^{\circ}\text{C}$ <br>
(th of an organ pipe open of both ends  $\frac{3+1}{100} = \frac{273+1}{273+100} = \frac{1}{16}$ ;  $t = -249.7^{\circ}\text{C}$ <br>the of an organ pipe open of both ends is 0.5 meter.<br>the final magnitude of the pipe open of both ends is 0.5 meter.<br>the final in air be 350 m/sec. If one end o

$$
\left[\frac{(1)350,700}{M_0}\right] \tag{2) 700, 350(3) 175, 350(4) 350, 175
$$

**Sol.** (4). Speed of sound  $v = 350$  m/sec

length of pipe  $\ell = 0.5$  m

 $M_N$   $\Box$  The frequency of the fundamental tone of a pipe open at both end is given by

$$
n = \frac{v}{2\ell} = \frac{350}{2 \times 0.5} = 350 \text{ sec}^{-1}
$$

The frequency of the fundamental tone of a pipe open at one end is given by

$$
\frac{M_0}{M_N} = \frac{16}{14}
$$
\n
$$
n = \frac{v}{4\ell} = \frac{350}{4 \times 0.5} = 175 \text{ sec}^{-1}.
$$

**Example 16 :**

eight of the gas and T be the absolute<br>  $\frac{16}{273+100} = \frac{273+1}{273+100} = \frac{273+1}{273+100} = \frac{1}{16}$ ;  $t = -249$ .<br>  $\therefore \frac{P}{d} = \frac{RT}{M}$ <br>  $\therefore \frac{P}{d} = \frac{RT}{M}$ <br>  $\Rightarrow \frac{P}{d} = \frac{1}{273+100} = \frac{1}{273+100} = \frac{1}{16}$ ;  $t = -249$ .<br>
Th be the absolute<br>  $\frac{273+1}{273+100} = \frac{273+1}{273+100} = \frac{1}{16}$ ;  $t = -249.7^{\circ}\text{C}$ <br> **Example 15:**<br>
The length of an organ pipe open of both ends is 0.5 meter.<br>
The length of an organ pipe open of both ends is 0.5 meter.<br>  $\frac{3+t}{+100} = \frac{273+t}{273+100} = \frac{1}{16}$ ;  $t = -249.7^{\circ}\text{C}$ <br>th of an organ pipe open of both ends is 0.5 meter.<br>e the fundamental frequency of the pipe, if the<br>of sound in air be 350 m/sec. If one end of the pipe<br>t, then The length of a pipe open at both ends is 48cm and its fundamental frequency is 320 Hz. If the speed of sound be 320 m/sec, then determine the diameter of the pipe. If one end of the pipe be closed, then what will be the fundamental frequency ? cy of the fundamental tone of a pipe open at<br>given by<br> $= \frac{350}{2 \times 0.5} = 350 \text{ sec}^{-1}$ <br>cy of the fundamental tone of a pipe open at<br>tiven by<br> $= \frac{350}{4 \times 0.5} = 175 \text{ sec}^{-1}$ .<br>of a pipe open at both ends is 48cm and its<br>freq  $\frac{v}{2\ell} = \frac{350}{2 \times 0.5} = 350 \text{ sec}^{-1}$ <br>
uency of the fundamental tone of a pipe open at<br>
is given by<br>  $\frac{v}{4\ell} = \frac{350}{4 \times 0.5} = 175 \text{ sec}^{-1}$ .<br>
gth of a pipe open at both ends is 48cm and its<br>
retal frequency is 320 Hz ency of the fundamental tone of a pipe open at<br>
s given by<br>  $= \frac{350}{2 \times 0.5} = 350 \text{ sec}^{-1}$ <br>
mey of the fundamental tone of a pipe open at<br>
given by<br>  $= \frac{350}{4 \times 0.5} = 175 \text{ sec}^{-1}$ .<br>
of a pipe open at both ends is 48cm a



**Sol. (4).** Fundamental frequency of the pipe of diameter D, open at both ends, is

$$
n = \frac{v}{2(\ell + 2e)} = \frac{v}{2(\ell + 2x0.3D)}
$$



$$
\Rightarrow 320 = \frac{32000}{2(48 + 2 \times 0.3D)} \Rightarrow D = 3.33 \text{ cm}
$$

For a pipe closed at one end,

**Example 19:**  
\n
$$
320 = \frac{32000}{2(48 + 2x0.3D)} \Rightarrow D = 3.33 \text{ cm}
$$
\nA column of air and a tuning f second when sounded together.  
\nA column of air and a tuning f second when sounded together.  
\nlower note. The temperature of temperature falls to 10°C, the two  
\ntemperature falls to 10°C, the two  
\nFind the frequency of the fork  
\n(1)210 Hz  
\nA column of air and a tuning f  
\nsecond when sounded together.  
\n(1)210 Hz  
\n(A)112 Hz

#### **Example 17 :**

A tuning fork of frequency 340 Hz is allowed to vibrate just above a 120cm high tube. Water is being filled slowly in the tube. What minimum height of water will be necessary for resonance. (speed of sound in air = 340 m/s) ⇒  $3200 = \frac{32000}{2(48 + 2x0.3D)}$  ⇒  $D = 3.33 \text{ cm}$ <br>
For a pipe closed at one end,<br>  $n = \frac{v}{4(\ell + e)} = \frac{v}{4(1 + 0.3D)}$ ;  $n = \frac{32000}{4(48 + 0.3 \times 33.3)}$ <br>
Find the frequency of the temperature falls to 10°C;<br>
The the frequency of  $320 = \frac{32000}{2(48 + 2x0.3D)} \Rightarrow D = 3.33 \text{ cm}$ <br>  $\text{Example 19:}$ <br>  $\text{a point of air and a second when sounded to lower note. The temp temperature falls to 10°C.}$ <br>  $\overline{4(l+e)} = \frac{v}{4(l+0.3D)}; \quad n = \frac{32000}{4(48 + 0.3 \times 33.3)}$ <br>  $\overline{1}$  find the frequency of the temperature fills to 10°C.<br>
In the freq



**Sol.** (1). From the data  $n = 340$  Hz and  $v = 340$  m/s, we find the

at which air – column can resonate with a given frequency (wavelength) are



(i) 
$$
\ell_1 = \frac{\lambda}{4} = \frac{1}{4} = 0.25 \text{ m}
$$
 (ii)  $\ell_2 = \frac{3\lambda}{4} = \frac{3}{4} = 0.75 \text{ m}$ 

(iii) 
$$
\ell_3 = \frac{5\lambda}{4} = \frac{5}{4} = 1.25 \text{ m}
$$
 and so on

Thus for the tube of length 1.20m only two possibilities occur. When water is filled slowly in the tube then the available length of air column starts decreasing from value 1.20m, and when it reaches a value 0.75m, resonance occurs. The minimum height of water should be  $120 - 0.75 = 0.45$ m 4 4 missec, determine the ring<br>
Sol. Given that  $n_1 - n_2 = 5$ <br>
Sol. Given that  $n_1 - n_2 = 5$ <br>
Sol. Given that  $n_1 - n_2 = 5$ <br>
When water is filled slowly in the tube then the<br>
length of air column starts decreasing from value 2.5 m and so on<br>
81. Civen that  $n_1 - n_2 = 5$ <br>
1.20m only two possibilities<br>
is filled slowly in the tube then the<br>
trace content at  $n_1 - n_2 = 5$ <br>
1.20m only two possibilities<br>
1.20m only two possibilities<br>
1.20m only two

#### **Example 18 :**

What should be the length of a closed organ pipe to produce  $(3)$  40 m/s a fundamental frequency of 512Hz at 0ºC.

**Sol.** 
$$
n_1 = \frac{v}{4\ell}
$$
 or  $\ell = \frac{v}{4n_1}$   

$$
\ell = \frac{332}{2}m = \frac{33200}{2}m = 16.2 \text{ cm}
$$

$$
\ell = \frac{332}{4 \times 512} \text{ m} = \frac{33200}{4 \times 512} \text{ cm} = 16.2 \text{ cm}
$$

#### **Example 19 :**

32000<br>  $\frac{1}{2}$ <br>  $\frac{32000}{(48 + 2x0.3D)} \Rightarrow D = 3.33 \text{ cm}$ <br>  $\frac{1}{2}$ <br>  $\frac{1}{4(1 + 0.3D)}$ ;  $n = \frac{32000}{4(48 + 0.3 \times 33.3)}$ <br>  $\frac{33 \text{ Hz}}{4 \text{ km/s} + \text{ s}} = \frac{32000}{4(1 + 0.3D)}$ ;  $n = \frac{32000}{4(48 + 0.3 \times 33.3)}$ <br>  $\frac{1}{3}$ <br>  $\frac{1}{3}$ <br>  $\frac{32000}{2(48 + 2x0.3D)}$   $\Rightarrow$  D=3.33 cm<br>  $\frac{4(2 + e)}{4(1 + 0.3D)}$ ; n =  $\frac{32000}{4(48 + 0.3 \times 33.3)}$ <br>  $\frac{32000}{4(4 \times 10^{-10} \text{ kg})}$ <br>  $\frac{32000}{2(11111 \text{ kg})}$ <br>  $\frac{63.3 \text{ Hz}}{2(11111 \text{ kg})}$ <br>  $\frac{63.3 \text{ Hz}}{2(11111 \text{ kg})}$ <br>  $\frac{6$  $\frac{32000}{2(48 + 2x0.3D)}$   $\Rightarrow$  D=3.33 cm<br>  $\frac{1}{2(48 + 0.3D)}$ ;  $n = \frac{32000}{4(48 + 0.3 \times 33.3)}$ <br>  $\frac{32000}{1}$ <br>  $\$  $\frac{32000}{60000}$  Find the frequency of the fork **Example 19:**<br> **Example 19:**<br>
A column of air and a tuning fork produce 4 beats per<br>
second when sounded together. The tuning fork gives the<br>
lower note. The temperature of air is 15°C. When the<br>
democrature falls to 10°C A column of air and a tuning fork produce 4 beats per second when sounded together. The tuning fork gives the lower note. The temperature of air is 15ºC. When the temperature falls to 10ºC, the two produce 3 beats per second. **SPARE 1997**<br> **SPARE 10**<br> **EQUEDED**<br> **EQUEDED**<br> **EQUEDED**<br> **EQUEDED**<br> **EQUEDE EXERCUADE IDENTIFY**<br> **EXERCUADE IT AND IDENTIFY**<br>
on sounded together. The tuning fork gives the<br>
The temperature of air is 15°C. When the<br>
falls to 10°C, the two produce 3 beats per second.<br>
quency of the fork<br>
(2) 113



**Sol. (4).** Let the frequency of the tuning fork be n Hz Then frequency of air column at  $15^{\circ}C = n + 4$ 

Frequency of air column at  $10^{\circ}C = n + 3$ 

According to  $v = n\lambda$ , we have

 $v_{15} = (n + 4)\lambda$  and  $v_{10} = (n + 3)\lambda$ 

$$
\therefore \quad \frac{v_{15}}{v_{10}} = \frac{n+4}{n+3}
$$

The speed of sound is directly proportional to the squareroot of the absolute temperature.

<sup>=</sup> 3 3 4 4 15 10 v v <sup>=</sup> 15 273 10 273 <sup>=</sup> <sup>288</sup> <sup>283</sup> n 4 n 3 <sup>=</sup> <sup>288</sup> <sup>283</sup><sup>=</sup> 1/2 <sup>5</sup> 1 283 1 + 1 n 3 = 1 + 1/2 × 5 <sup>283</sup> = 1 + 5 566 1 n 3 <sup>=</sup> <sup>5</sup> <sup>566</sup> n + 3 = 113 n = 110 Hz 320 320 <sup>5</sup> 4 0.25 4 

**Example 20 :**

 $\lambda = 3$  organ pipe is 25 cm in length and the speed of sound is 320 5 beat per second are produced by simultaneously blowing two closed organ pipes of different lengths. If the shorter m/sec., determine the length of the other organ pipe. second are produced by simultaneously blowing<br>d organ pipes of different lengths. If the shorter<br>e is 25 cm in length and the speed of sound is 320<br>etermine the length of the other organ pipe.<br>tt  $n_1 - n_2 = 5$ <br> $\frac{0}{4 \times \ell}$ and the shorter<br>
engths. If the shorter<br>
peed of sound is 320<br>
her organ pipe.<br>
<br>
<br>  $e$  get,  $\ell = 25.4$  cm<br>
<br>
appears to be  $(4/5)^{\text{th}}$ <br>
stationary observer.<br>
<br>
n the speed of engine<br>
<br>
6 m/s<br>  $0 \text{ m/s}$ <br>  $0 \text{ m/s}$ <br>  $0 \text{$ 

**Sol.** Given that  $n_1 - n_2 = 5$ 

$$
\therefore \quad \frac{320}{4 \times 0.25} - \frac{320}{4 \times \ell} = 5 \quad ; \text{ Solving we get, } \ell = 25.4 \text{ cm}
$$

#### **Example 21 :**

The frequency of whistle of an engine appears to be  $(4/5)$ <sup>th</sup> of initial frequency when it crosses a stationary observer. If the velocity of sound is 330 m/s, then the speed of engine will be in priparities of different lengths. If the shorter<br>pipes of different lengths. If the shorter<br>in in length and the speed of sound is 320<br>the length of the other organ pipe.<br>= 5<br>0<br> $\frac{0}{\ell} = 5$ ; Solving we get,  $\ell = 25.4$ m in length and the speed of sound is 320<br>the length of the other organ pipe.<br> $\frac{100}{\epsilon} = 5$ ; Solving we get,  $\ell = 25.4$  cm<br>whistle of an engine appears to be  $(4/5)^{\text{th}}$ <br>y when it crosses a stationary observer.<br>ound is e produced by simulated by interactively browing<br>tipes of different lengths. If the shorter<br>in length and the speed of sound is 320<br>the length of the other organ pipe.<br>= 5<br> $\frac{1}{e}$  = 5 ; Solving we get,  $\ell$  = 25.4 cm<br>th

(1) 30 m/s (2) 36.6 m/s (3) 40 m/s (4) 330 m/s

**Sol.** (2). 
$$
n' = {nv \over v - v_s}
$$
 ......(1);  $n'' = {nv \over v + v_s}$  ......(2)

From (1) and (2) 
$$
\frac{n'}{n''} = \frac{v + v_s}{v - v_s}
$$
 ......(3)



According to question 
$$
\frac{n'}{n''} = \frac{5}{4}
$$
;  $v_s = ? v = 330$  m/s .......(4) A so

From eq.  $(3)$  and  $(4)$ 

$$
\frac{5}{4} = \left[ \frac{330 + v_s}{330 - v_s} \right] ; 9v_s = 330 \quad \therefore \quad v_s = 36.6 \text{ m/s}
$$

#### **Example 22 :**

**EXAMPLE 330**<br>
STUT<br>
STUT<br>
ording to question  $\frac{n'}{n'} = \frac{5}{4}$ ;  $v_s = ? v = 330$  m/s .......(4)<br>
a source of sound of frequence<br>
towards a wall with a velocity of<br>
second will be heard if sound<br>  $\frac{5}{4} = \left[\frac{330 + v_s}{330 - v_s}\right$ **EXAMPLE 24:**<br>
STUT<br>
ording to question  $\frac{n'}{n'} = \frac{5}{4}$ ;  $v_s = ? v = 330 \text{ m/s}......(4)$ <br>
Let a source of sound of frequence<br>  $\frac{5}{4} = \left[\frac{330 + v_s}{330 - v_s}\right]$ ;  $9v_s = 330 \therefore v_s = 36.6 \text{ m/s}$ <br>  $\frac{5}{4} = \left[\frac{330 + v_s}{330 - v_s}\right]$ ;  $9v_s = 3$ **EXAMPLE 24:**<br>
ling to question  $\frac{n'}{n'} = \frac{5}{4}$ ;  $v_s = ? v = 330 \text{ m/s}.$  Example 24:<br>
4. (3) and (4)<br>  $= \left[\frac{330 + v_s}{330 - v_s}\right]$ ;  $9v_s = 330$   $\therefore$   $v_s = 36.6 \text{ m/s}$ <br>  $\therefore$ <br>  $v_s$  and the source S is between the vector of fight r The wavelength of light received from a milky way is 0.4% higher than that from the same source on earth. The velocity of milky way with respect to earth will be -



**Sol.** (2). 
$$
\Delta \lambda = \frac{v_s}{c} \lambda
$$
;  $\frac{\Delta \lambda}{\lambda} = \frac{v_s}{c}$   
  
 $\frac{\Delta \lambda}{\lambda} \times 100 = \frac{v_s}{c} \times 100$   
  
 $v_s = \frac{0.4}{100} \times 3 \times 10^8 = 1.2 \times 10^6 \text{ m/s}$ 

#### **Example 23 :**

A train approaching a hill at a speed of 40km/hr sounds a whistle of frequency 580 Hz when it is at a distance of 1km from a hill. A wind with a speed of 40Km/hr is blowing in the direction of motion of the train. Find the frequency of the (3) 510 whistle as heard by an observer on the hill.  $\frac{100}{c} \times 100$ <br>  $\frac{0.4}{c} \times 100$ <br>  $\frac{0.4}{100} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{0.4}{100} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{0.4}{100} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{0.4}{100} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{0.4}{100} \times$ x 100 =  $\frac{3}{2}$  x 3 x 10<sup>8</sup> = 1.2 x 10<sup>6</sup> m/s<br>
A siren is fitted on a car going tow<br>  $\frac{0.4}{100} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{0.4}{100} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{0.4}{100} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{0.4}{$ Number of beats/sec = n' – n' =<br>
00 =  $\frac{v_s}{c}$  × 100<br>  $\frac{4}{0} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{4}{0} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{4}{0} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{1}{0} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{1}{0} \times$  $A = 200$ <br>  $\frac{V_s}{C} \times 100$ <br>  $\frac{V_s}{C} \times 100$ <br>  $\frac{4}{V} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{4}{V} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{4}{V} \times 3 \times 10^8 = 1.2 \times 10^6$  m/s<br>  $\frac{10}{V} \times 10^6$  m/s<br>  $\frac{10}{V} \times 10^6$  m/s<br>  $\frac{10}{V} \times 10^$ 200 No  $\gamma$  source as well as that coming at<br>
source as well as that coming at<br>
froaching a hill at a speed of 40km/hr sounds a<br>
directly from the siren it frequency<br>
source as well as that coming at<br>
metrough of the tra proaching a hill at a speed of 40km/hr sounds a<br>
calculate the apparent frequency<br>
frequency 580 Hz when it is at a distance of Ikm<br>
reflection. Take the speed of sound<br>
conformon of the train. Find the frequency of the<br>  $\frac{1}{10} \times 3 \times 10^6 = 1.2 \times 10^9$  m/s<br>
succe as well as that coming a<br>
foraching a hill at a speed of 40km/hr sounds a<br>
equency 580 Hz when it is at a distance of 1km<br>
wind with a speed of 40Km/hr solowing in the<br>
equency

(velocity of sound in air = 1200 km/hr)



**Sol. (3).** According to Doppler's effect, the apparent frequency when both source and observer move along the same direction is direction of motion of the train. Find the frequency of the<br>
whistle as head by an observer on the hill.<br>
(velocity of sound in air = 1200 km/hr)<br>
(1) S80 Hz<br>
(a) 600 Hz<br>
(a) 600 Hz<br>
(a) 720 Hz<br>
(a) 720 Hz<br>
(a) According Sheard by an observer on the hull.<br>
Sol. (2). Here the observer is at rest with ro<br>
of Sound in air = 1200 km/hr<br>
z (4) 720 Hz<br>
d (4) 720 Hz<br>
(4) 720 Hz<br>
(4) 720 Hz<br>
(4) 720 Hz<br>
is<br>
is<br>
(y + w) – v<sub>0</sub><br>
(y + w) – v<sub>0</sub><br>
(y otion of the train. Find the frequency of the<br>
dd by an observer on the hill.<br>
and in air = 1200 km/hr)<br>
(2) 620 Hz<br>
(4) 200 Hz<br>
(3) 510

$$
n' = \frac{(v+w) - v_0}{(v+w) - v_s}
$$

Velocity of observer  $v_0 = 0$ 

$$
\therefore \quad n' = \frac{(v+w)}{v+w-v_s}n
$$

Given  $v = 1200$  km/hr,  $w = 40$  km/hr,  $v_s = 40$  km/hr. and  $n = 580$  Hz

$$
\therefore n' = \frac{1200 + 40}{(1200 + 40) - 40} \times 580 = 599.33 \text{ Hz} = 600 \text{ Hz}
$$

#### **Example 24 :**

**STUDYMATERL**<br>  $\frac{n'}{n'} = \frac{5}{4}$ ;  $v_s = ? v = 330$  m/s ........(4)<br> **Example 24 :**<br>
A source of sound of frequency 256Hz is n<br>
towards a wall with a velocity of 5m/s. How i<br>
second will be heard if sound travels at a spe<br>
by **STUDYMATERL**<br>  $\frac{n'}{n'} = \frac{5}{4}$ ;  $v_s = ? v = 330$  m/s ........(4)<br> **Example 24 :**<br>
A source of sound of frequency 256Hz is n<br>
towards a wall with a velocity of 5m/s. How i<br>
second will be heard if sound travels at a spe<br>
by Example 24:<br>
Example 24:<br>
g to question  $\frac{n'}{n'} = \frac{5}{4}$ ;  $v_s = ? v = 330 \text{ m/s}$ ........(4)<br>
(3) and (4)<br>  $\left[\frac{330 + v_s}{330 - v_s}\right]$ ;  $9v_s = 330$   $\therefore$   $v_s = 36.6 \text{ m/s}$ <br>
Sol. When the source S is between the vectors<br>
(0) For dir A source of sound of frequency 256Hz is moving rapidly towards a wall with a velocity of 5m/s. How many beats per second will be heard if sound travels at a speed of 330 m/s by an observer behind the source. **STUDY MATERIAL: PHYSICS**<br>
of sound of frequency 256Hz is moving rapidly<br>
wall with a velocity of 5m/s. How many beats per<br>
II be heard if sound travels at a speed of 330 m/s<br>
erver behind the source.<br>
source S is between **STUDY MATERIAL: PHYSICS**<br>
frequency 256Hz is moving rapidly<br>
velocity of 5m/s. How many beats per<br>
if sound travels at a speed of 330 m/s<br>
and the source.<br>
between the wall (W) and the observer<br>
the source is moving away **STUDY MATERIAL: PHYSICS**<br>
of sound of frequency 256Hz is moving rapidly<br>
wall with a velocity of 5m/s. How many beats per<br>
fill be heard if sound travels at a speed of 330 m/s<br>
server behind the source.<br>
source S is betw **STUDY MATERIAL: PHYSICS**<br>
of frequency 256Hz is moving rapidly<br>
a velocity of 5m/s. How many beats per<br>
if sound travels at a speed of 330 m/s<br>
ind the source.<br>
between the wall (W) and the observer<br>
the source is moving

**Sol.** When the source S is between the wall (W) and the observer (O) For direct sound the source is moving away from the observer, therefore the apparent frequency

$$
n'' = \frac{v}{v + v_s} \ n = \frac{330}{330 + 5} \times 256
$$

and frequency of reflected sound

$$
n' = \frac{v}{v - v_s} n = \frac{330}{330 - 3} \times 256 = 259.9
$$

Number of beats/sec =  $n' - n'' = 259 - 252.2 = 7.7$ 

#### **Example 25 :**

s and for a second will be heard if sound or indeed by a not of requency  $5$ <br>
second will be heard if sound travel<br>  $\frac{5}{4} = \left[\frac{330 + v_s}{330 - v_s}\right]$ ;  $9v_s = 330$   $\therefore$   $v_s = 36.6$  m/s<br>
where beind the sound the survey betwee ing to question  $\frac{n'}{n''} = \frac{5}{4}$ ;  $v_s = ?v = 330$  m/s .........(4)<br>
1. (3) and (4)<br>
1. (3) and (4)<br>  $\left[\frac{330 + v_s}{330 - v_s}\right]$ ;  $9v_s = 330$   $\therefore$   $v_s = 36.6$  m/s<br>
by an observer behind the source of<br>
1. When the source  $V_s$  is A siren is fitted on a car going towards a vertical wall at a speed of 36 km/hr A person standing on the ground, behind the car, listens to the siren sound coming directly from the source as well as that coming after reflection from the wall. Calculate the apparent frequency of the wave (a) coming directly from the siren to the person and (b) coming after reflection. Take the speed of sound to be 340 m/s.  $\frac{v}{v - v_s}$  n =  $\frac{330}{330-3} \times 256 = 259.9$ <br>
of beats/sec = n' - n'' = 259 - 252.2 = 7.7<br>
fitted on a car going towards a vertical wall at a<br>
66 km/h person standing on the ground, behind<br>
of km/h person standing on the  $330 - 3 \times 256 = 259.9$ <br>  $=n' - n'' = 259 - 252.2 = 7.7$ <br>
car going towards a vertical wall at a<br>
serson standing on the ground, behind<br>
siren sound coming directly from the<br>
coming after reflection from the wall.<br>
the frequency o 6 km/hr A person standing on the ground, behind<br>tens to the siren sound coming directly from the<br>well as that coming affer reflection from the wall.<br>the apparent frequency of the wave (a) coming<br>tom the siren to the perso berson standing on the ground, behind<br>siren sound coming directly from the<br>coming after reflection from the wall.<br>therefore, the wave (a) coming<br>n to the person and (b) coming after<br>peed of sound to be 340 m/s.<br>(2) 486 Hz



**Sol. (2).** Here the observer is at rest with respect to the medium and the source is going away from the observer. The apparent frequency heard by the observer is, therefore,

$$
v' = \frac{v}{v + v_s} v = \frac{340}{340 + 10} \times 500 \,\text{Hz}
$$

 $v' = 486$  Hz

(b) The frequency received by the wall is

$$
v'' = \frac{v}{v - v_s} \quad v = \frac{340}{340 - 10} \times 500 = 515 \text{ Hz}
$$

The wall reflects this sound without changing the frequency. Thus, the frequency of the reflected wave as heard by the ground observer is 515 Hz.





(D) None of the above

(A) 30  
(B) 
$$
3\pi/2
$$
  
(C) 3/4  
(D) 40

 $(A)$  a  $(C)$  2a<sup>2</sup>

**Q.18** Two monoatomic ideal gases 1 and 2 of molecular masses  $m_1$  and  $m_2$  respectively are enclosed in separate containers kept at the same temperature. The ratio of the speed of sound in gas 1 to that in gas 2 is given by

(A) 
$$
\sqrt{\frac{m_1}{m_2}}
$$
 (B)  $\sqrt{\frac{m_2}{m_1}}$  (C)2  
\n(D)  $\frac{m_1}{m_2}$  (E)

(C) 
$$
\frac{1}{m_2}
$$
 (D)  $\frac{2}{m_1}$  y<sub>1</sub>

**Q.19** Velocity of sound in air

I. Increases with temperature

- II. Decreases with temperature
- III. Increase with pressure

IV. Is independent of pressure

V. Is independent of temperature

Choose the correct answer –

(A) Only I and II are true (B) Only I and III are true (C) Only II and III are true (D) Only I and IV are true

## **PART - 3 : SPEED OF TRANSVERSE WAVE**

**Q.20** A string of 7 m length has a mass of 0.035 kg. If tension in the string is 60.5 N, then speed of a wave on the string is



**Q.21** A string is producing transverse vibration whose equation is  $y = 0.0021 \sin(x + 30t)$ , where x and y are in meters and t is in seconds. If the linear density of the string is  $1.3 \times 10^{-4}$  kg/m, then the tension in the string in N will be<br> $(A)$  10



**Q.22** The speed of longitudinal wave in a wire is 100 times the speed of transverse wave. If Young's modulus of the wire material is  $1 \times 10^{11}$  N/m<sup>2</sup> then the stress in the wire is –



## **PART - 4 : INTERFERENCE**

**Q.23** When two sound waves with a phase difference of  $\pi/2$ , and each having amplitude A and frequency  $\omega$ , are superimposed on each other, then the maximum amplitude and frequency of resultant wave is –

(A) 
$$
\frac{A}{\sqrt{2}} : \frac{\omega}{2}
$$
 (B)  $\frac{A}{\sqrt{2}} : \omega$  (C)  $\sqrt{2} A : \frac{\omega}{2}$  (D)  $\sqrt{2} A : \omega$  (C) 24  
Q.34 A source of s

- **Q.24** If the phase difference between the two wave is  $2\pi$  during superposition, then the resultant amplitude is – (A) Maximum (B) Minimum (C) Maximum or minimum (D) None of these
- **Q.25** The superposition takes place between two waves of frequency f and amplitude a. The total intensity is directly proportional to –



 $(A) 5I, I$  $m_1$  (C) 2I, I (D)  $m_2$  (A) 5I I (R) **Q.26** Consider interference between waves from two sources of intensities I and 4I. Find the intensities at points where the phase difference is (i)  $\pi/2$  (ii)  $\pi$ .  $(B)$  4I, I/2  $(D) 8I, I$ **STUDY MATERIAL: PHYSICS**<br>
(B) 2a<br>
(D) 4a<sup>2</sup><br>
(D) 4a<sup>2</sup><br>
intensities I and 41. Find the intensities at points where<br>
intensities I and 41. Find the intensities at points where<br>  $\frac{1}{2}$  phase difference is<br>
(i)  $\pi/2$  (i **MATERIAL: PHYSICS**<br>
(3) 2a<br>
(3) 4a<sup>2</sup><br>
waves from two sources<br>
ntensities at points where<br>  $\pi/2$  (ii)  $\pi$ .<br>
(ii)  $\pi$ .<br>
(3) 4I, I/2<br>
(3) 8I, I<br>
ring light waves are<br>
( $\omega t + \frac{\pi}{2}$ ). What is the<br>
e **TUDY MATERIAL: PHYSICS**<br>
(B) 2a<br>
(D) 4a<sup>2</sup><br>
ttween waves from two sources<br>
and the intensities at points where<br>
(i)  $\pi/2$  (ii)  $\pi$ .<br>
(B) 4I, I/2<br>
(D) 8I, I<br>
interfering light waves are<br>
= 3 sin  $\left(\omega t + \frac{\pi}{2}\right)$ . What 1 2 y a sin1000 t, y a sin 998 t . The number of beats

**Q.27** The displacement of the interfering light waves are

$$
\frac{m_2}{m_1}
$$
  $y_1 = 4 \sin \omega t$  and  $y_2 = 3\sin\left(\omega t + \frac{\pi}{2}\right)$ . What is the

amplitude of the resultant wave  $(A) 5$  (B) 7  $(C) 1$  (D) 0

## **PART - 5 : BEATS**

**Q.28** Two tuning forks have frequencies 450 Hz and 454 Hz respectively. On sounding these forks together, the time interval between successive maximum intensities will be  $(A) 1/4$  sec  $(B) 1/2$  sec



**Q.29** Beats are produced by two waves

heard/sec is –



**Q.30** Maximum number of beats frequency heard by a human being is –



- **Q.31** Two waves of lengths 50 cm and 51 cm produced 12 beats per second. The velocity of sound is  $(A) 306 \text{ m/s}$  (B) 331 m/s (C) 340 m/s (D) 360 m/s
- (A) 10<br>
is. If the linear density of the<br>
(A) 10<br>
then the tension in the string in<br>
(C)20<br>
(B) 0.17<br>
(B) 0.17<br>
(D) -117<br>
(D) -117<br>
(D) -117<br>
(D) -117<br>
(D) -117<br>
(D) -117<br>
wave in a wire is 100 times the<br>
vave in a wire i lensity of the comparison (A) 10 (B) 4<br>
in the string in (C) 20 (D) 6<br> **(A) 10** (B) 10<br>
beats per second. The velocity of sound is<br>
(A) 306 m/s<br>
(A) 306 m/s<br>
(B) 331 m/s<br>
100 times the (A) 234 m/s<br>
dulus of the Q.32 When **Q.32** When a tuning fork of frequency 341 is sounded with another tuning fork, six beats per second are heard. When the second tuning fork is loaded with wax and sounded with the first tuning fork, the number of beats is two per second. The natural frequency of the second tuning fork is –
	- (A) 334 (B) 339 (C) 343 (D) 347
	- **Q.33** The wavelengths of two waves are 50 and 51 cm respectively. If the temperature of the room is  $20^{\circ}$ C, then what will be the no. of beats produced per second by these waves, when the speed of sound at  $0^{\circ}$ C is 332m/sec (A) 14 (B) 10  $(D)$  None of these
	- $\frac{\omega}{2}$  (D)  $\sqrt{2}$  A :  $\omega$  (C) 24 (D) None of these<br> **Q.34** A source of sound gives five beats per second when sounded with another source of frequency  $100s^{-1}$ . The second harmonic of the source together with a source of frequency  $205s^{-1}$  gives five beats per second. What is the frequency of the source

(A) 
$$
105 \text{ s}^{-1}
$$
  
\n(B)  $205 \text{ s}^{-1}$   
\n(C)  $95 \text{ s}^{-1}$   
\n(D)  $100 \text{ s}^{-1}$ 



**Q.35** The frequency of tuning forks A and B are respectively 3% more and 2% less than the frequency of tuning fork C. When A and B are simultaneously excited, 5 beats per second are produced. Then the frequency of the tuning fork  $'A'$  (in Hz) is  $(A) 98$  (B) 100



## **PART - 6 : STANDING WAVES IN STRINGS**

- **Q.36** At a certain instant a stationary transverse wave is found to have maximum kinetic energy. The appearance of string at that instant is –
	- (A) Sinusoidal shape with amplitude A/3
	- (B) Sinusoidal shape with amplitude A/2
	- (C) Sinusoidal shape with amplitude A
	- (D) Straight line
- **Q.37** The distance between the nearest node and antinode in a stationary wave is



- **Q.38** In stationary wave
	- (A) Strain is maximum at nodes
	- (B) Strain is maximum at antinodes
	- (C) Strain is minimum at nodes
	- (D) Amplitude is zero at all the points
- **Q.39** The phase difference between the two particles situated on both the sides of a node is –  $(A) 0^{\circ}$  (B) 90°  $(C) 180^{\circ}$   $(D) 360^{\circ}$
- **Q.40** Frequency of a sonometer wire is n. Now its tension is increased 4 times and its length is doubled then new frequency will be –  $(A) n/2$  (B) 4n



**Q.41** A string on a musical instrument is 50 cm long and its fundamental frequency is 270 Hz. If the desired frequency of 1000 Hz is to be produced, the required length of the string is (A) 13.5 cm (B) 2.7 cm



**Q.42** The first overtone of a stretched wire of given length is 320Hz. The first harmonic is –  $(A)$  320 Hz (B) 160 Hz



- **Q.43** In a stationary wave all the particles
	- (A) On either side of a node vibrate in same phase
	- (B) In the region between two nodes vibrate in same phase
	- (C) In the region between two antinodes vibrate in same phase
	- (D) Of the medium vibrate in same phase
- **Q.44** The stationary wave produced on a string is represented y are in cm and t is in seconds. The distance between

consecutive nodes is



**Q.45** A tuning fork of frequency 392 Hz, resonates with 50 cm length of a string under tension (T). If length of the string is decreased by 2%, keeping the tension constant, the number of beats heard when the string and the tuning fork made to vibrate simultaneously is –



**Q.46** A tuning fork and a sonometer wire were sounded together and produce 4 beats per second. When the length of sonometer wire is 95 cm or 100 cm, the frequency of the tuning fork is



- **Q.47** A piece of wire is cut into two pieces A and B, and stretched to the same tension and mounted between two rigid walls. Segment A is longer than segment B. Which of the following quantities will always be larger for waves on A than for waves on B. **Q.48** The equation y experimental mode<br> **Q.48** The equation of Solution Solution CO and B and Solution Solution Solution (and B and Street wite is 95 cm or 100 cm, the frequency 152Hz<br>
160Hz<br>
160Hz<br>
2 pieces A and B, and<br>
160Hz<br>
2 pieces A and B, and<br>
160Hz<br>
2 mg<br>
160Hz<br>
1 r second. When the<br>100 cm, the frequency<br>52 Hz<br>60 Hz<br>60 Hz<br>bieces A and B, and<br>d mounted between<br>ger than segment B.<br>will always be larger<br>B.<br>mode<br>1 mode<br>300t, describes a<br>f the stationary wave<br>256 metres<br>628 metres<br>628 m
	- (A) amplitude of the wave
	- (B) frequency of the fundamental mode
	- (C) wave velocity
	- (D) wavelength of the fundamental mode
- stationary wave. The wavelength of the stationary wave



- **Q.49** Equation of a stationary wave is  $y = 10 \sin \frac{\pi x}{4} \cos 20 \pi t$ . Distance between two consecutive nodes is
	- $(A)$  4 (B) 2
	- $(C) 1$  (D) 8

## **PART - 7 : STANDING WAVES IN ORGAN PIPES**

- **Q.50** If the velocity of sound in air is 350 m/s. Then the fundamental frequency of an open organ pipe of length 50cm, will be –
	- (A) 350 Hz (B) 175 Hz (C) 900 Hz (D) 750 Hz
- increased 4 innear manual wave a streathed in the same of the consecutive noise is  $(X)$  and the equation of streathed and the equation of  $(X)$  and  $(X)$  is the equation of streathed frequency is  $20$  Hz (fine describe the **Q.51** An open pipe is suddenly closed at one end with the result that the frequency of third harmonic of the closed pipe is found to be higher by 100 Hz, then the fundamental frequency of open pipe is (A) 480 Hz (B) 300 Hz
	- (C) 240 Hz (D) 200 Hz
	- **Q.52** If fundamental frequency of closed pipe is 50Hz then frequency of  $2<sup>nd</sup>$  overtone is – (A) 100 Hz (B) 50 Hz
		- (C) 250 Hz (D) 150 Hz
	- **Q.53** What should be the length of a closed organ pipe to produce a fundamental frequency of 512Hz at 0ºC. (A) 16.2 cm. (B) 15.2 cm. (C) 18.2 cm. (D) 19.2 cm.



**Q.54** The first overtone of an open pipe has the same frequency as the first overtone of a closed pipe 3m long. What is the length of the open pipe.



**Q.55** An organ pipe emits fundamental tone of frequency 320Hz at 47ºC. What would be the fundamental tone emitted by pipe at 27ºC.  $(A) 310 \text{ Hz}$  (B) 720 Hz



**Q.56** Two closed pipes, one filled with  $O_2$  and the other with  $H_2$ , have the same fundamental frequency. Find the ratio of their lengths.



**Q.57** An air column in a pipe, which is closed at one end, will be in resonance with a vibrating body of frequency 166Hz, if the length of the air column is –<br> $(4)$  2.00 m  $(A)$  2.00



**Q.58** If the length of a closed organ pipe is 1m and velocity of sound is 330 m/s, then the frequency for the second note is

(A) <sup>330</sup> 4 Hz <sup>4</sup> (B) (C) <sup>4</sup> (D)

- the dypipe at 27°C.<br>
(B) 720Hz<br>
20.65 A source of sound emitting<br>
1312Hz<br>
(D) 440Hz<br>
moves towards an observer<br>
1312Hz<br>
(D) 440Hz<br>
moves towards an observer<br>
11:0<br>
1:3<br>
1:5<br>
(B) 1:4<br>
(A) 50Hz<br>
1:6<br>
(C) 150Hz<br>
1:5<br>
(B) 1:4 **Q.59** The frequency of fundamental tone in an open organ pipe of length 0.48 m is 320 Hz. Speed of sound is 320 m/sec. Frequency of fundamental tone in closed organ pipe will be – (A) 153.8 Hz (B) 160.0 Hz (C) 320.0 Hz (D) 143.2 Hz
- **Q.60** A resonance air column of length 20 cm resonates with a  $Q.69$ tuning fork of frequency 250 Hz. The speed of sound in air is



**Q.61** Two closed pipe produce 10 beats per second when emitting their fundamental nodes. If their length are in ratio of 25 : 26. Then their fundamental frequency in Hz,  $(A)$  270, 280 (B) 260, 270



### **PART - 8 : DOPPLER EFFECT**

**Q.62** The frequency of a whistle of an engine is 600 cycles/ sec is moving with the speed of 30 m/sec towards an observer. The apparent frequency will be – (Velocity of sound  $= 330$ m/s)



**Q.63** An observer is moving away from source of sound of frequency 100 Hz. His speed is 33 m/s. If speed of sound is 330 m/s, then the observed frequency is (A) 90 Hz (B) 100 Hz (C) 91 Hz (D) 110 Hz

- **Q.64** With what velocity an observer should move relative to a stationary source so that he hears a sound of double the frequency of source –
	- (A) Velocity of sound towards the source.
	- (B) Velocity of sound away from the source.
	- (C) Half the velocity of sound towards the source.
	- (D) Double the velocity of sound towards the source.
- **Q.65** A source of sound emitting a note of frequency 200 Hz moves towards an observer with a velocity v equal to the velocity of sound. If the observer also moves away from the source with the same velocity v, the apparent frequency heard by the observer is –

(A) 50 Hz (B) 100 Hz (C) 150 Hz (D) 200 Hz

**Q.66** A source of sound is travelling towards a stationary observer. The frequency of sound heard by the observer is of three times the original frequency. The velocity of sound is v m/sec. The speed of source will be

$$
(A) (2/3) v \t\t (B) v\n(C) (3/2) v \t\t (D) 3v
$$

- 431<br>
and tone of frequency<br>
(B) Velocity of sound away from the source.<br>
the fundamental tone<br>
(D) Double the velocity of sound towards the source.<br>
720 Hz<br> **Q.65** A source of sound emitting a note of frequency 200 Hz<br>
44  $\times \frac{330}{4}$  Hz m/s. The apparent frequency in cps heard by the observer 22 2001<br>
22 2012<br>
22 2012<br>
22 2012<br>
22 23<br>
22 24 25 202 2001 2000 11<br>
22 25 26 2012<br>
2 **Q.67** The speed of sound in air at a given temperature is 350m/s. An engine blows whistle at a frequency of 1200cps. It is approaching the observer with velocity 50 will be
	- $(A) 600$  $\times \frac{4}{330}$  Hz (A) 000 (C) 1400  $(B) 1050$ (C) 1400 (D) 2400
		- **Q.68** A source of frequency 150 Hz is moving in the direction of a person with a velocity of 110 m/s. The frequency heard by the person will be

(Speed of sound in medium = 
$$
330 \text{ m/s}
$$
)  
(A) 225 Hz (B) 200 Hz

- (C) 150 Hz (D) 100 Hz
- **Q.69** A source of sound of frequency 500 Hz is moving towards an observer with velocity 30 m/s. The speed of sound is 330 m/s. the frequency heard by the observer will be (A) 550 Hz (B) 458.3 Hz (C) 530 Hz (D) 545.5 Hz  $n/s$ <br>
0 Hz<br>
0 Hz<br>
20 Hz<br>
22 is moving towards<br>
he speed of sound is<br>
e observer will be<br>
28.3 Hz<br>
5.5 Hz<br>
n a circle of radius R<br>
ratio of largest and<br>
etector D at rest at a<br>
e as shown in figure<br>  $\frac{1}{2} \left( \frac{c + v}{c - v} \$ z<br>
z<br>
s moving towards<br>
speed of sound is<br>
sserver will be<br>
Hz<br>
Hz<br>
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io of largest and<br>
tor D at rest at a<br>
s shown in figure<br>  $\frac{c + v}{c - v}$ v/s. The frequency<br>
S)<br>
Hz<br>
Hz<br>
Hz<br>
is moving towards<br>
e speed of sound is<br>
bbserver will be<br>
3 Hz<br>
5 Hz<br>
a circle of radius R<br>
atio of largest and<br>
ector D at rest at a<br>
as shown in figure<br>  $\left(\frac{c+v}{c-v}\right)$ <br>  $\frac{-v}{\sqrt{2}}$ B)<br>Hz<br>Hz<br>is moving towards<br>e speed of sound is<br>3 Hz<br>5 Hz<br>a circle of radius R<br>attio of largest and<br>ector D at rest at a<br>as shown in figure<br>as shown in figure<br> $\left(\frac{c+v}{c-v}\right)$ <br> $\frac{v}{\sqrt{2}}$
- **Q.70** A whistle S of frequency f revolves in a circle of radius R at a constant speed v. What is the ratio of largest and smallest frequency detected by a detector D at rest at a distance 2R from the centre of circle as shown in figure (take c as speed of sound) Fiz is moving towards<br>the speed of sound is<br>the speed of sound is<br>8.3 Hz<br>45.5 Hz<br>and a circle of radius R<br>ratio of largest and<br>etector D at rest at a<br>le as shown in figure<br> $\frac{1}{2} \left( \frac{c + v}{c - v} \right)$ <br> $\frac{c + v}{c\sqrt{2}}$

of a person with a velocity of 110 m/s. The frequency  
hearted by the person will be  
(Speed of sound in medium = 330 m/s)  
(A)225 Hz (B)200 Hz  
(C) 150 Hz (D) 100 Hz  
A source of sound of frequency 500 Hz is moving towards  
an observer with velocity 30 m/s. The speed of sound is  
330 m/s. the frequency heard by the observer will be  
(A)550 Hz (B)458.3 Hz  
(C)530 Hz (D)545.5 Hz  
A whistle S of frequency frevolves in a circle of radius R  
at a constant speed v. What is the ratio of largest and  
smallest frequency detected by a detector D at rest at a  
distance 2R from the centre of circle as shown in figure  
(take c as speed of sound)  
D  
(A) 
$$
\frac{c + v}{c - v}
$$
  
(B)  $\sqrt{2} \left(\frac{c + v}{c - v}\right)$   
(C)  $\sqrt{2}$  (D)  $\frac{(c + v)}{c\sqrt{2}}$ 



## **PART - 9 : MISCELLANEOUS**

- **Q.71** A tube of length  $L_1$  is open at both ends. A second tube of length  $L_2$  is closed at one end and open at the other end. Both tubes have the same fundamental frequency of vibration of air in it. What is the value of  $L_2$  ?  $(A) 4L_1$  $(B) 2L_1$ **COUESTION BANK**<br> **COUE EXECUTE:**<br> **EXECUTE:**<br> **EXEC PART - 9 : MISCELLANEOUS** 0.78 Equation of a stationary<br>
be of length L<sub>1</sub> is open at both ends. A second tube<br>
follows  $y_1$  = a sin kx cos of<br>
Both tubes have the same fundamental frequency<br>
Both tubes have the same fu **ART - 9: MISCELLANEOUS**<br> **OUBSTION BANK**<br> **COUBSTION BANK**<br>
cof length L<sub>1</sub> is open at both ends. A second tube<br>
to flow s<sub>N</sub> = a sin kx coss<br>
Both tubes have the same fundamental frequency<br>
Both tubes have the same fund **(OUESTION BANK**<br> **COUESTION BANK**<br> **COUE PART - 9 : MISCELLANEOUS**<br>
De of length L<sub>1</sub> is open at both ends. A second tube<br>
the of length L<sub>1</sub> is open at both ends. A second tube<br>
The of length L<sub>2</sub> is closed at one end and open at the other<br>
both tubes have the **PART - 9: MISCELLANEOUS**<br>
Dealer and both ends. A second tube<br>
ment L<sub>1</sub> is open at both ends. A second tube<br>
Both tubes have the same fundamental frequency<br>
Both tubes have the same fundamental frequency<br>
libration of a
	- $(C) L_1/2$  $(1) L_1/4$
- **Q.72** In a standing wave formed as a result of reflection from a surface, the ratio of the amplitude at an antinode to that at node is x. The fraction of energy that is reflected is –

(A) 
$$
\left[\frac{x-1}{x}\right]^2
$$
  
\n(B)  $\left[\frac{x}{x+1}\right]^2$   
\n(C)  $\left[\frac{x-1}{x+1}\right]^2$   
\n(D)  $\left[\frac{1}{x}\right]^2$ 

**Q.73** A sound wave of frequency 440 Hz is passing through air. An O<sub>2</sub> molecule (mass =  $5.3 \times 10^{-26}$  kg) is set in oscillation with an amplitude of  $10^{-6}$  m. Its speed at the centre of its oscillation is –<br>(A)  $1.70 \times 10^{-5}$  m/s

(A)  $1.70 \times 10^{-5}$  m/s<br>
(C)  $2.76 \times 10^{-3}$  m/s<br>
(D)  $2.77 \times 10^{-5}$  m/s  $(D) 2.77 \times 10^{-5}$  m/s

**Q.74** A siren placed at a railway platform is emitting sound of frequency 5kHz. A passenger sitting in a moving train A records a frequency of 5.5 kHz while the train approaches the siren. During his return journey in a different train B be records a frequency of 6.0 kHz while approaching the same siren. The ratio of the velocity of train B to that of train A is :



**Q.75** A string fixed at both ends has consecutive standing wave modes for which the distances between adjacent nodes are 18cm. and 16cm respectively. The minimum possible length of the string is –



**Q.76** The extension in a string, obeying Hooke's law, is x. The speed of sound in the stretched string is v. If the extension in the string is increased to 1.5x, the speed of sound will be  $(A) 1.22 v$  (B) 0.61 v



**Q.77** If the source is moving towards right, wave front of Q.83 sound waves get modified to –



**Q.78** Equation of a stationary and travelling waves are as follows  $y_1 = a \sin kx \cos \omega t$  and  $y_2 = a \sin (\omega t - kx)$ . The phase difference between two points

$$
x_1 = \frac{\pi}{3k}
$$
 and  $x_2 = \frac{3\pi}{2k}$  is  $\phi_1$  in the standing wave  $(y_1)$ 

and is  $\phi_2$  in travelling wave (y<sub>2</sub>) then ratio  $\frac{\phi_1}{\phi_2}$  is-2  $\phi_1$  $\frac{1}{\phi_2}$  is-

(A) 1 (B) 5/6 (C) 3/4 (D) 6/7

2 **Q.79** The beat frequency produced by two tuning forks when  $\frac{x}{x+2}$  sounded together is observed to be 4 Hz. One of the **EXECUTS**<br> **EXEQUIS CONSTION BANK**<br> **EXECUIS**<br> **EXECUIS**<br> **EXECUIS**<br> **C.78** Equation of a stationary and travelling waves are as<br>
and open at the other<br>
indamental frequency<br>
wave difference between two points<br>
wave (y<sub>1</sub>) and  $x_2 =$ **EXECUTE:**<br> **EXEC**  $\frac{1}{2}$  1<sup>2</sup> disappear 1<sup>st</sup>. The frequency of the second tuning fork  $x \perp$  is **(OUESTION BANK EXECUTE ANTIST AND CONSTANT CONSTANT CONSTANT CONSTANT CONSTANT CONSTANT AND A SEXEMBEND AND A SEXEMBEND AND A SEXEMPTION BANK THANGED TO A SEXEMPTION BANK CONSTANT CONSTANT CONSTANT CONSTANT CONSTANT CO EXECUTE:**<br> **EXECUTE:**<br> **EXEC** forks makes 384 vibrations per second. When the other fork is loaded with a small piece of wax, the beats is and is  $\phi_2$  in travelling wave  $(y_2)$  then ratio  $\frac{w_1}{\phi_2}$  is-<br>
(A) 1 (B) 5/6<br>
(C) 3/4 (D) 6/7<br>
The beat frequency produced by two tuning forks when<br>
sounded together is observed to be 4 Hz. One of the<br>
forks makes



**Q.80** In the resonance tube experiment, the first resonance is heard when length of air column is  $\ell_1$  and second resonance is heard when length of air column is  $\ell_2$ . What should be the minimum length of the tube so that third resonance can also be heard –



**Q.81** A stationary observer receives sonic oscillations from two tuning forks, one of which approaches and the other recedes with same speed. As this takes place the observer hears the beat frequency of 2 Hz. Find the speed of each tuning fork, if their oscillation frequency is 680 Hz and the velocity of sound in air is 340 m/s –



**Q.82** The average density of earth's crust 10 km beneath the surface is  $2.7 \text{ gm/cm}^3$ . The speed of longitudinal seismic waves at that depth is 5.4 km/s. The bulk modulus of earth's crust considering its behaviour as fluid at that depth is–



**Q.83** A note has a frequency of 128 Hz. The frequency of a note which is two octave higher than this is



**Q.84** Two coherent sources of different intensities send waves which interfere. The ratio of the maximum intensity to the minimum intensity is 25. The intensities are in the ratio –





## **EXERCISE - 2 [LEVEL-2]**

#### **ONLY ONE OPTION IS CORRECT**

**Q.1**  $S_1$  and  $S_2$  are two coherent sources of sound having no initial phase difference. The velocity of sound is 330m/s. No minima will be formed on the line passing through  $S_2$  and perpendicular to the line joining  $S_1$  and  $S_2$ , if the frequency of both the sources is



**Q.2** Figure shows a stretched string of length L and pipes of length L, 2L,  $L/2$  and  $L/2$  in options  $(A)$ ,  $(B)$ ,  $(C)$  and  $(D)$ respectively. The string's tension is adjusted until the speed of waves on the string equals the speed of sound  $\qquad 0.8$ speed of waves on the string equals the speed of sound waves in air. The fundamental mode of oscillation is then set up on the string. In which pipe will the sound produced by the string cause resonance.



- **Q.3** The speed of sound wave in a mixture of 1 mole of helium and 2 moles of oxygen at 27° C is  $(A)$  400 m/s (B) 600 m/s (C)  $800 \text{ m/s}$  (D)  $1200 \text{ m/s}$ .
- **Q.4** In resonance tube experiment, if 400 Hz tuning fork is used, the first resonance occurs when length of air columns is 19 cm. If the 400 Hz tuning fork is replaced by 1600 Hz tuning fork then to get resonance, the water level in the tube should be further lowered by (take end  $correct = 1$  cm.)



**Q.5** Three coherent sonic sources emitting sound of single wavelength ' $\lambda$ ' are placed on the x-axis at points

same value  $I_0$ . Then the resultant intensity at this point  $\mathbf 0$ due to the interference of the three waves will be :



(D)  $5I_0$ **Q.6** Two identical pulses move in opposite directions with same uniform speeds on a stretched string. The width and kinetic energy of each pulse is L and k respectively. At the instant they completely overlap, the kinetic energy of the width L of the string where they overlap is –



**Q.7** Two vibrating strings of the same material but length L and 2L have radii 2r and r respectively. They are stretched under the same tension. Both the strings vibrate in their fundamental modes, the one of length L with frequency  $v_1$  and the other with frequency  $v_2$ . The ratio  $v_1/v_2$  is given by :

(A) 
$$
\hat{2}
$$
 (B) 4  
(C) 8 (D) 1

String  $# 1$  is connected with string  $# 2$ . The mass per unit length in string  $\# 1$  is  $\mu_1$  and the mass per unit length in string # 2 is 4  $\mu_1$ . The tension in the strings is T. A travelling wave is coming from the left. What fraction of the energy in the incident wave goes into string  $# 2$  ?



(A)  $\frac{1}{2}$ <br>
(B)  $\frac{1}{2}$ <br>
(C)  $\frac{1}{2}$ <br>
(C)  $\frac{1}{2}$ <br>
(C)  $\frac{1}{2}$ <br>
(D)  $\frac{1}{2}$ <br>
(A)  $\frac{1}{2}$ <br>
(B)  $\frac{1}{2$ **Q.9** In the system shown, the wire connecting two masses has linear mass density of 1/20 kg/m. A tuning fork of 50Hz is found to be in resonance with the horizontal part of wire between pulley and block A. (Assuming nodes at block A and pulley). Now at  $t = 0$  system is released from rest. The ratio of time gap between successive resonance with the same tuning fork starting from  $t = 0$ (Take  $g = 10 \text{ m/s}^2$ ) In the system shown, the wire connecting two masses<br>has linear mass density of 1/20 kg/m. A tuning fork of<br>50Hz is found to be in resonance with the horizontal part<br>of wire between pulley). Now at t = 0 system is relased<br>





**Q.10** The displacement y of a particle executing periodic motion is given by  $y = 4 \cos^2(t) \sin(t) = 1000t$ . This expression may be considered to be a result of the superposition of waves :





- **Q.11** When beats are produced by two progressive waves of nearly the same frequency, which one of the following is correct –
	- (A) The particles vibrate simple harmonically, with the frequency equal to the difference in the component frequencies.
	- (B) The amplitude of vibration at any point changes simple harmonically with a frequency equal to the difference in the frequencies of the two waves.
	- (C) The frequency of beats depends upon the position, where the observer is.
	- (D) The frequency of beats changes as the time progresses.
- **Q.12** Sound waves of frequency 16 kHz are emitted by two coherent point sources of sound placed 2m apart at the centre of a circular train track of large radius. A person riding the train observes 2 maxima per second when the train is running at a speed of 36 km/h. Calculate the radius of the track. [Velocity of sound in air 320 m/s]

(A) 
$$
\frac{1000}{\pi}
$$
m  
\n(B)  $\frac{500}{\pi}$ m  
\n(C)  $\frac{250}{\pi}$ m  
\n(D)  $\frac{700}{\pi}$ m  
\n(m)  $\frac{700}{\pi}$ m

- **Q.13** A composite string is made up by joining two strings of different masses per unit length  $\rightarrow \mu$  and 4 $\mu$ . The composite string is under the same tension. A transverse wave pulse  $Y = (6 \text{ mm}) \sin (5 t + 40 x)$ , where 't' is in seconds and 'x' is in metres, is sent along the lighter string towards the joint. The joint is at  $x = 0$ . The equation of the wave pulse reflected from the joint is :
	- (A)  $(2 \text{ mm}) \sin (5t 40 \text{ x})$  (B)  $(4 \text{ mm}) \sin (40 \text{ x} 5 \text{ t})$ (C) – (2 mm)  $\sin(5t - 40x)$  (D) (2 mm)  $\sin(5t - 10x)$
- **Q.14** A pipe open at the top end is held vertically with some of its lower portion dipped in water. At a certain depth of immersion, the air column of length (3/8) m in the pipe resonates with a tuning fork of frequency 680 Hz. The speed of sound in air is 340 m/s. The pipe is now raised up by a distance 'a' until it resonates in the "next overtone" with the same tuning fork. The value of 'x' is:



**Q.15** A source of sound is moving with velocity  $u/2$  and two observers A and B are moving with velocity 'u' as shown. Find ratio of wavelength received by A and B. Given that velocity of sound is 10 u .



**Q.16** A closed organ pipe has length  $\ell$ . The air it is vibrating in 3rd overtone with maximum amplitude 'a'. The amplitude at a distance of  $\ell/7$  from closed end of the pipe is equal to –

(A) a  
\n(B) a/2  
\n(C) 
$$
\frac{a\sqrt{3}}{2}
$$
  
\n(D) zero

500 travels along the left part of the string, as shown in the  $\frac{30}{\pi}$  m figure, what is the amplitude of the wave that is **EXERENT ASSESS**<br> **EXER Q.17** A string consists of two parts attached at  $x = 0$ . The right part of the string  $(x > 0)$  has mass  $\mu_r$  per unit length and the left part of the string  $(x < 0)$  has mass  $\mu_{\ell}$  per unit length. The string tension is T. If a wave of unit amplitude transmitted to the right part of the string. 17/23<br>
The air it is vibrating<br>
amplitude 'a'. The<br>
om closed end of the<br>
a/2<br>
zero<br>
thed at x = 0. The right<br>  $\mu_r$  per unit length and<br>
has mass  $\mu_\ell$  per unit<br>
wave of unit amplitude<br>
tring, as shown in the<br>
of the wa <sup>r</sup> 2 / (B) a/2<br>
a  $\frac{\text{a}\sqrt{3}}{2}$  (D) zero<br>
cing consists of two parts attached at x = 0. The right<br>
of the string (x > 0) has mass  $\mu_r$  per unit length and<br>
teleft part of the string (x < 0) has mass  $\mu_r$  per unit<br>
th. The s by evertone with maximum amplitude 'a'. The wind rise voltione.<br>
vertone with maximum amplitude 'a'. The<br>
le at a distance of  $\ell/7$  from closed end of the<br>
qual to –<br>
(B) a/2<br>
(D) zero<br>
consists of two parts attached at tude at a distance of  $\ell/7$  from closed end of the<br>
s equal to –<br>
(B) a/2<br>  $\frac{\sqrt{3}}{2}$  (D) zero<br>
mg consists of two parts attached at x = 0. The right<br>
of the string (x > 0) has mass  $\mu_r$  per unit length and<br>
ft part o <sup>r</sup> / 1 / 1 in closed end of the<br>
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2<br>
composition and as mass  $\mu_{\ell}$  per unit<br>
inve of unit amplitude<br>
ng, as shown in the<br>
f the wave that is<br>
tring.<br>
2<br>
2<br>
2<br>  $\frac{2}{\sqrt{\mu_{\ell}/\mu_r}}$ <br>  $\frac{2}{\sqrt{\mu_{\ell}/\mu_r}}$ <br>  $\frac{1}{\sqrt{\mu$ 

$$
\frac{\partial \phi}{\partial \pi} \text{m}
$$
\njoining two strings of

\n
$$
\rightarrow \mu \text{ and } 4\mu. \text{ The}
$$
\n(A) 1

\n
$$
\text{(B) } \frac{2}{1 + \sqrt{\mu_\ell / \mu_r}}
$$
\nrension A transverse

(C) 
$$
\frac{2\sqrt{\mu_{\ell}/\mu_{\rm r}}}{1+\sqrt{\mu_{\ell}/\mu_{\rm r}}} \qquad \qquad (D) \frac{\sqrt{\mu_{\ell}/\mu_{\rm r}}-1}{\sqrt{\mu_{\ell}/\mu_{\rm r}}+1}
$$

**Q.18** A parachutist jumps from the top of a very high tower with a siren of frequency 800 Hz on his back. Assume his initial velocity to be zero. After falling freely for 12s, he observes that the frequency of sound heard by him reflected from level ground below him is differing by 700Hz w.r.t. the original frequency. What was the height of tower. Velocity of sound in air is 330 m/s, and

$$
g=10 \text{ m/s}^2.
$$

(A) 511.5m. (B) 1057.5m. (C) 757.5m. (D) 1215.5m.

## **EXERCISE - 3 (NUMERICAL VALUE BASED QUESTIONS)**

## **NOTE : The answer to each question is a NUMERICAL VALUE.**

- **Q.1** A glass tube of 1.0 meter length is filled with water. The water can be drained out slowly at the bottom of the tube. If a vibrating tuning fork of frequency 500Hz is brought at the upper end of the tube and the velocity of sound is 330m/s then the total number of resonances  $0.5$ obtained will be –
- **Q.2** In the figure shown a source of sound of frequency 510 Hz moves with constant velocity  $v_s = 20$  m/s in the direction shown. The wind is blowing at a constant velocity  $v_w = 20$  m/s towards an observer who is at rest at point B. Find the frequency (in Hz) detected by the observer corresponding to the sound emitted by the source at initial position A.

[ Speed of sound relative to air = 330 m/s ]



**Q.3** A straight line source of sound of length  $L = 10$ m, emits a pulse of sound that travels radially outward from the source. What sound energy (in mW) is intercepted by an acoustic cylindrical detector of surface area 2.4 cm<sup>2</sup>, 0.8 located at a perpendicular distance 7m from the source. The waves reach perpendicularly at the surface of the detector. The total power (in mW) emitted by the source in the form of sound is  $2.2 \times 10^4$  W (Use  $\pi = 22/7$ )

- A wire of length  $\ell$  having tension T and radius r vibrates with fundamental frequency f. Another wire of the same metal with length  $2\ell$  having tension  $2T$  and radius  $2r$  will **E BASED QUESTIONS)**<br>
A wire of length  $\ell$  having tension T and radius r vibrates<br>
with fundamental frequency f. Another wire of the same<br>
metal with length 2 $\ell$  having tension 2T and radius 2r will<br>
vibrate with fundam the value of a.
- Two vibrating strings of same length, same cross section area and stretched to same tension is made of materials with densities  $\rho \& 2\rho$ . Each string is fixed at both ends. If v<sub>1</sub> represents the fundamental mode of vibration of the one made with density  $\rho$  and  $v_2$  for another, then

 $v_1/v_2$  is  $\sqrt{x}$  then find the value of x.

- **Q.6** A bat emits ultrasonic sound of frequency 1000 kHz in air. If the sound meets a water surface, it gets partially reflected back and partially refracted (transmitted) in water. Difference of wavelength transmitted to wavelength reflected is  $117/x$  (in m). Find the value of x. (speed of sound in air  $=$  330 m/sec, Bulk modulus of water =  $2.25 \times 10^9$ ,  $\rho_{\text{water}} = 1000 \text{ kg/m}^3$ ).
- **Q.7** A 40 cm long wire having a mass 3.2 gm and area of cross section 1 mm<sup>2</sup> is stretched between the support 40.05 cm apart. In its fundamental mode. It vibrate with a frequency 1000/64 Hz then Young's modulus the wire =  $10^{\text{a}}$  N/m<sup>2</sup>. Find the value of a.
- **Q.8** A wall is moving with velocity u and a source of sound moves with velocity u/2 in the same direction as shown in the figure. Assuming that the sound travels with velocity 10u. The ratio of incident sound wavelength on the wall to the reflected sound wavelength by the wall, is equal to A/11. Find the value of A.

 $(A) 1050 Hz$ 



## **EXERCISE - 4 [PREVIOUS YEARS AIEEE / JEE MAIN QUESTIONS]**

**Q.1** A wire of length 40 cm is taut at both ends. The maximum wavelength of standing waves generated in the wire will be – **[AIEEE-2002]** Q.9



- **Q.2** A wave  $y = a \sin(\omega t kx)$  on a string meets with another wave producing a node at  $x = 0$ . Then the equation of the unknown wave is – **[AIEEE-2002]** (A)  $y = a \sin(\omega t + kx)$  (B)  $y = -a \sin(\omega t + kx)$  $(C)$  y = a sin ( $\omega t - kx$ ) (D) y = – a sin ( $\omega t - kx$ )
- **Q.3** A metal wire of linear mass density of 9.8 g/m is stretched with a tension of 10 kg-wt between two rigid supports 1 metre apart. The wire passes at its middle point between the poles of a permanent magnet and it vibrates in resonance when carrying an alternating current of frequency n. Frequency n of the alternating source is – (A) 100 Hz (B) 200 Hz **[AIEEE-2003]** (C) 25 Hz (D) 50 Hz
- **Q.4** A tuning fork of known frequency 256 Hz makes 5 beats per second with the vibrating string of a piano. The beat frequency decreases to 2 beats per second when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was – **[AIEEE-2003]**  $(A)$  256 – 2 Hz (B) 256 – 5 Hz  $(C)$  256 + 5 Hz (D) 256 + 2 Hz
- **Q.5** When two tuning forks (fork 1 and fork 2) are sounded simultaneously, 4 beats per second are heard. Now, some tape is attached on the prong of the fork 2. When the tuning forks are sounded again, 6 beats per seconds are heard. If the frequency of fork 1 is 200 Hz, then what was the original frequency of fork 2? **[AIEEE-2005]** (A) 200 Hz (B) 202 Hz (C) 196 Hz (D) 204 Hz simultaneously, 4 beats per second are heard Now, some<br>
temperator and 19 km per second are temperator over the second and the second stress of the same temperator of the distance of the distance of the distance of the se
- **Q.6** An observer moves towards a stationary source of sound, with a velocity one fifth of the velocity of sound. What is the percentage increase in the apparent frequency?



**Q.7** A whistle producing sound waves of frequencies 9500 Hz and above is approaching a stationary person with speed v ms<sup>-1</sup>. The velocity of sound in air is  $300 \text{ ms}^{-1}$ . If the person can hear frequencies upto a maximum of 10,000 Hz, the maximum value of v upto which he can hear the whistle is – **[AIEEE-2006]** the migral frequencies (A) 49 m<br>
tuning forks are sounded again, 6 beats per seconds are<br>
tuning forks are sounded again, 6 beats per seconds are<br>
the original frequency of fork 1 is 200 Hz, then what was<br>
(A) 200 Hz<br>
(C)

(D)  $15 \text{ ms}^{-1}$ 

**Q.8** A string is stretched between fixed points separated by 75.0 cm. It is observed to have resonant frequencies of 420Hz and 315Hz. There are no other resonant frequencies between these two. Then, the lowest resonant frequency for this string is – **[AIEEE 2006]**



- **Q.9** A sound absorber attenuates the sound level by 20 dB. The intensity decreases by a factor of – **[AIEEE 2007]** (A) 1000 (B) 10000  $(C) 10$   $(D) 100$
- **Q.10** A wave travelling along the x- axis is described by the equation  $y(x,t) = 0.005 \cos(\alpha x - \beta t)$ . If the wavelength and the time period of the wave are 0.08 m and 2.0 s, respectively, then  $\alpha$  and  $\beta$  in appropriate units are

 **[AIEEE 2008]**

(A) 
$$
\alpha = \frac{0.08}{\pi}, \beta = \frac{2.0}{\pi}
$$
 (B)  $\alpha = \frac{0.04}{\pi}, \beta = \frac{1.0}{\pi}$   
(C)  $\alpha = 12.50 \pi, \beta = \frac{\pi}{2.0}$  (D)  $\alpha = 25.00\pi, \beta = \pi$ 

**Q.11** Three sound waves of equal amplitudes have frequencies  $(v - 1)$ ,  $v$ ,  $(v + 1)$ . They superpose to give beats. The number of beats produced per second will be –

**[AIEEE 2009]**

(A) 4 (B) 3 (C) 2 (D) 1

- **Q.12** A motor cycle starts from rest and accelerates along a straight path at 2 m/s<sup>2</sup>. At the starting point of the motor cycle there is a stationary electric siren. How far has the motor cycle gone when the driver hears the frequency of the siren at 94% of its value when the motor cycle was at rest ? (Speed of sound =  $330 \text{ ms}^{-1}$ ) [AIEEE-2009] (A) 49 m (B) 98 m (C) 147 m (D) 196 m (C)  $\alpha = 12.50 \pi$ ,  $\beta = \frac{\pi}{2.0}$  (D)  $\alpha = 25.00\pi$ ,  $\beta = \pi$ <br>
Three sound waves of equal amplitudes have frequencies<br>
(v - 1), v, (v + 1). They superpose to give beats. The<br>
number of beats produced per second will be -<br> <sup>1</sup>O. (D) α=25.00π, β = π<br>equal amplitudes have frequencies<br>ney superpose to give beats. The<br>uced per second will be –<br>[AIEEE 2009]<br>(B) 3<br>(D) 1<br>from rest and accelerates along a<br>. At the starting point of the motor<br>ary e =  $\frac{\pi}{\pi}$  (B) α =  $\frac{1}{\pi}$ , β =  $\frac{1}{\pi}$ <br>
B =  $\frac{\pi}{2.0}$  (D) α = 25.00π, β = π<br>
es of equal amplitudes have frequencies<br>
1). They superpose to give beats. The<br>
produced per second will b – [AIEEE 2009]<br>
(B) 3<br>
(D mary electric siren. How far has the<br>
een the driver hears the frequency<br>
its value when the motor cycle was<br>
und = 330 ms<sup>-1</sup>) [AIEEE-2009]<br>
(B) 98 m<br>
(D) 196 m<br>
ve on a string of linear mass density<br>
by<br>
(B) 12.5 N<br>
(B) At the starting point of the motor<br>ry electric siren. How far has the<br>n the driver hears the frequency<br>s value when the motor cycle was<br>id = 330 ms<sup>-1</sup>) [AIEEE-2009]<br>(B) 98 m<br>on a string of linear mass density<br>(D) 196 m<br>o
- **Q.13** The equation of a wave on a string of linear mass density 0.04 kg m<sup>-1</sup> is given by

$$
r = 0.02 \text{ (m) } \sin \left[ 2\pi \left( \frac{t}{0.04 \text{(s)}} - \frac{x}{0.50 \text{(m)}} \right) \right].
$$



**Q.14** The transverse displacement  $y(x, t)$  of a wave on a string

is given by y (x, t) = 
$$
e^{(-ax^2 + bt^2 + 2\sqrt{ab}xt)}
$$
  
This represents a – [AIEEE 2011]

- (A) wave moving in +x.direction with speed  $(a/b)^{1/2}$
- (B) wave moving in  $-x$ -direction with speed  $(b/a)^{1/2}$
- (C) standing wave of frequency  $(b)^{1/2}$
- 
- of the siren at 94% of its value when the motor cycle was<br>
at rest? (Speed of sound = 330 ms<sup>-1</sup>) [AIEEE-2009]<br>
(A) 49 m<br>
(C) 147 m (B) 98 m<br>
(C) 147 m (D) 196 m<br>
The equation of a wave on a string of linear mass density<br> **Q.15** A cylindrical tube, open at both ends, has a fundamental frequency, f, in air. The tube is dipped vertically in water so that half of it is in water. The fundamental frequency of the air-column is now – **[AIEEE 2012]**  $(A) f (B) f/2$



- **Q.16** A sonometer wire of length 1.5 m is made of steel. The tension in it produces an elastic strain of 1%. What is the fundamental frequency of steel if density and elasticity of steel are 7.7  $\times$  10<sup>3</sup> kg/m<sup>3</sup> and 2.2  $\times$  10<sup>11</sup> N/m<sup>2</sup> respectively? **[JEE MAIN 2013]** (A) 188.5 Hz (B) 178.2 Hz (C) 200.5 Hz (D) 770 Hz
- **Q.17** A pipe of length 85cm is closed from one end. Find the number of possible natural oscillations of air column in the pipe whose frequencies lie below 1250 Hz. The velocity of sound in air is 340 m/s. **[JEE MAIN 2014]**  $(A) 6$  (B) 4  $(C) 12$  (D) 8
- **Q.18** A train is moving on a straight track with speed  $20 \text{ ms}^{-1}$ . . It is blowing its whistle at the frequency of 1000 Hz. The percentage change in the frequency heard by a person standing near the track as the train passes him is (Speed of sound =  $320 \text{ ms}^{-1}$ ) close to **[JEE MAIN 2015]**  $(A) 12\%$  (B) 18%  $(C) 24\%$   $(D) 6\%$ (C) 200.5 Hz<br>
(C) 200.5 Hz<br>
Al pipe of length 85cm is closed from one end. Find the<br>
number of possible natural oscillations of air column in<br>
the pipe whose frequencies lie below 1250 Hz. The Q.25 A wire of length 21, is A prior toregal oscientistics the behavior since the sphere of the
- **Q.19** A uniform string of length 20m 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: (Take  $g=10 \text{ ms}^{-2}$ )

**[JEE MAIN 2015]**

- **Q.20** A pipe open at both ends has a fundamental frequency f in air. The pipe is dipped vertically in water so that half of it is in water. The fundamental frequency of the air column in now : **[JEE MAIN 2016]**  $(A) 3f/4$  (B) 2f (C) f (D) f/2
- **Q.21** An observer is moving with half the speed of light towards a stationary microwave source emitting waves at frequency 10 GHz. What is the frequency of the microwave measured by the observer?

(Speed of light =  $3 \times 10^8$  m/s) **[JEE MAIN 2017]** (A) 12.1 GHz (B) 17.3 GHz (C) 15.3 GHz (D) 10.1 GHz

- **Q.22** A granite rod of 60 cm length is clamped at its middle point and is set into longitudinal vibrations. The density Q.29 of granite is  $2.7 \times 10^3$  kg / m<sup>3</sup> and its Young's modulus is  $9.27 \times 10^{10}$  Pa. What will be the fundamental frequency of the longitudinal vibrations? **[JEE MAIN 2018]** (A) 10 kHz (B) 7.5 kHz (C) 5 kHz (D) 2.5 kHz
- **Q.23** Two coherent sources produce waves of different intensities which interfere. After interference, the ratio of the maximum intensity to the minimum intensity is 16. The intensity of the waves are in the ratio:

#### **[JEE MAIN 2019]**



**Q.24** A heavy ball of mass M is suspended from the ceiling of a car by a light string of mass  $m (m << M)$ . When the car is at rest, the speed of transverse waves in the string is  $60 \text{ ms}^{-1}$ . When the car has acceleration a, the wavespeed increases to  $60.5 \text{ms}^{-1}$ . The value of a, in terms of gravitational acceleration g, is closest to :

#### **[JEE MAIN 2019 (JAN)]**



**Q.25** A wire of length 2L, is made by joining two wires A and B of same length but different radii r and 2r and made of the same material. It is vibrating at a frequency such that the joint of the two wires forms a node. If the number of antinodes in wire A is p and that in B is q then the ratio p : q is : **[JEE MAIN 2019 (APRIL)] STUDY MATERIAL: PHYSICS**<br>
SM is suspended from the ceiling of<br>
g of mass m (m<<M). When the car<br>
of transverse waves in the string is<br>
car has acceleration a, the wave-<br>
0.5ms<sup>-1</sup>. The value of a, in terms of<br>
ration g,

$$
(A)4:9 \qquad L \longrightarrow \begin{array}{c} B \\ \hline L \\ (C)1:4 \end{array}
$$

**Q.26** In an interference experiment the ratio of amplitudes of

coherent waves is  $\frac{a_1}{a_2} = \frac{1}{3}$ . The ratio of maximum and

minimum intensities of fringes will be



**Q.27** A string of length 60 cm, mass 6gm and area of cross section 1mm<sup>2</sup> and velocity of wave 90m/s. Given Young's modulus is  $Y = 16 \times 10^{11}$  N/m<sup>2</sup>. Find extension in string

### **[JEE MAIN 2020 (JAN)]**



- **Q.28** A stationary observer receives sound from two identical tuning forks, one of which approaches and the other one recedes with the same speed (much less than the speed of sound). The observer hears 2 beats/sec. The oscillation frequency of each tuning fork is  $v_0 = 1400 \text{ Hz}$ and the velocity of sound in air is 350 m/s. The speed of each tuning fork is close to : **[JEE MAIN 2020 (JAN)]**  $(A)$  (1/4) m/s (B) 4 m/s (C)  $2 \text{ m/s}$  (D) (1/2) m/s
- **Q.29** A one metre long (both ends open) organ pipe is kept in a gas that has double the density of air at STP. Assuming the speed of sound in air at STP is 300 m/s, the frequency difference between the fundamental and second harmonic of this pipe is Hz.

**[JEE MAIN 2020 (JAN)]**

**Q.30** Three harmonic waves having equal frequency v and same intensity I<sub>0</sub>, have phase angles 0,  $\pi/4$  and  $-\pi/4$ respectively. When they are superimposed the intensity of the resultant wave is close to :



 $(C) I_0$ 



## **EXERCISE - 5 (PREVIOUS YEARS AIPMT/NEET EXAM QUESTIONS)**

**Q.1** Atransverse wave is represented by  $y = Asin (\omega t - kx)$ . For what value of the wavelength is the wave velocity equal to the maximum particle velocity? **[AIPMT (PRE) 2010]**



**Q.2** A tuning fork of frequency 512 Hz makes 4 beats per second with the vibrating string of a piano. The beat<br>frequency decreases to 2 beats ner sec when the tension  $Q.9$ frequency decreases to 2 beats per sec when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was



**Q.3** Two waves are represented by the equations  $y_1 = a \sin(\omega t + kx + 0.57)$  m and

 $y_2$  = acos ( $\omega t$  + kx) m, where x is in meter and t in s. The phase difference between them is**[AIPMT (PRE) 2011]** (A) 0.57 radian (B) 1.0 radian (C) 1.25 radian (D) 1.57 radian

**Q.4** Sound waves travel at 350 m/s through a warm air and at 3500 m/s through brass. The wavelength of a 700 Hz acoustic wave as it enters brass from warm air

**[AIPMT (PRE) 2011]**

(A) Decreases by a factor 20(B) Decreases by a factor 10 (C) Increases by a factor 20 (D) Increases by a factor 10

- **Q.5** Two identical piano wires kept under the same tension T have a fundamental frequency of 600Hz. The fractional increase in the tension of one of the wires which will lead to occurrence of 6 beats/s when both the wires oscillate together would be – **[AIPMT (MAINS) 2011]**  $(A) 0.02$  (B) 0.03  $(C) 0.04$  (D) 0.01 acoustic wave as it enters brass from warm and<br>
(A) Decreases by a factor 20(B) Decreases by a factor 10<br>
(A) Decreases by a factor 10<br>
(C) Increases by a factor 10<br>
(C) Increases by a factor 10<br>
(C) Moreon and will be an second of thexe means in inner and time and they also that is now in Figure 200 Hz.<br>
Equilibration continuous continuous continuous continuous continuous continuous continuous of the source of unknown frequency is 25 radi
- **Q.6** When a string is divided into three segments of length  $\ell_1$ ,  $\ell_2$  and  $\ell_3$  the fundamental frequencies of these three segments are  $v_1$ ,  $v_2$  and  $v_3$  respectively. The original fundamental frequency  $(v)$  of the string is

**[AIPMT (PRE) 2012]**

(A) 
$$
\sqrt{v} = \sqrt{v_1} + \sqrt{v_2} + \sqrt{v_3}
$$
 (B)  $v = v_1 + v_2 + v_3$   
(C)  $\frac{1}{v} = \frac{1}{v_1} + \frac{1}{v_2} + \frac{1}{v_3}$  (D)  $\frac{1}{\sqrt{v}} = \frac{1}{\sqrt{v_1}} + \frac{1}{\sqrt{v_2}} + \frac{1}{\sqrt{v_3}}$ 

**Q.7** Two sources of sound placed close to each other are emitting progressive waves given by  $y_1 = 4 \sin 600 \pi t$  and  $y_2 = 5 \sin 608 \pi t$ .

An observer located near these two sources of sound will hear : **[AIPMT (PRE) 2012]**

- (A) 4 beats per second with intensity ratio 25 : 16 between waxing and waning.
- (B) 8 beats per second with intensity ratio 25 : 16 between waxing and waning
- (C) 8 beats per second with intensity ratio 81 : 1 between waxing and waning
- (D) 4 beats per second with intensity ratio 81 : 1 between waxing and waning
- **Q.8** A train moving at a speed of 220ms–1 towards a stationary object, emits a sound of frequency 1000 Hz. Some of the sound reaching the object gets reflected back to the train as echo. The frequency of the echo as detected by the driver of the train is (Speed of sound in air is 330 m/s) **[AIPMT (MAINS) 2012]** (A) 3500 Hz (B) 4000 Hz (C) 5000 Hz (D) 3000 Hz
- **Q.9** A wave travelling in the +ve x-direction having displacement along y-direction as 1m, wavelength  $2\pi$  m and frequency of  $1/\pi$  Hz is represented by –**[NEET 2013]** (A)  $y = \sin(2\pi x + 2\pi t)$

$$
(B) y = sin(x - 2t)
$$

(C)  $y = \sin(2\pi x - 2\pi t)$ 

(D)  $y = \sin(10\pi x - 20\pi t)$ 

- (C)  $\sqrt{AB} = 1$ <br>
(D)  $\sqrt{AB} = 1$ in (or + kx + 0.57) m and<br>
in (or + kx + 0.57) m and<br>
or (st + kx) m, where x is in meter and t in s. The<br>
sounded with a source of known frequency 250 E<br>
if fibrence between them is [AIPM1T (PRE) 2011]<br>
7 radian<br>
(B) 1.0 ISN (We set  $x = 0.1$  If the study the sum of the study of the stu **Q.10** A source of unknown frequency gives 4beats<sup>1</sup>s, when<br>
meter and tin s. The<br>
IFMT (PRE) 2011] second harmonic of the source of unknown frequency<br>
or adian<br>
gives  $\pi$  beats preserve contour frequency 251 Hz, The<br>
S7 in meter and tin s. The<br>
in meter and tin s. The<br>
sounded with a source of known frequency 250 Hz, The<br>
1.0 radian<br>
1.0 radia **Q.10** A source of unknown frequency gives 4 beats/s, when sounded with a source of known frequency 250 Hz, The second harmonic of the source of unknown frequency gives five beats per second, when sounded with a source of frequency 513 Hz, The unknown frequency is – (A) 260 Hz (B) 254 Hz **[NEET 2013]** (C) 246 Hz (D) 240 Hz
	- **Q.11** If we study the vibration of a pipe open at both ends, then the following statement is not true –**[NEET 2013]** (A) Pressure change will be maximum at both ends.
		- (B) Open end will be antinode.
		- (C) Odd harmonics of the fundamental frequency will be generated.
		- (D) All harmonics of the fundamental frequency will be generated.
	- in meter and tin s. The<br>
	independential sound with sound contour frequency 250 Hz, The<br>
	1AIPMT (PRE) 2011J<br>
	13 second harmonic of the source of unknown frequency<br>
	1.0 radian<br>
	2011J<br>
	11 57 malan<br>
	2011 if ve study the vibra **Q.12** The number of possible natural oscillations of air column in a pipe closed at one end of length 85 cm whose frequencies lie below 1250 Hz are (Velocity of sound = 340 ms–1) **[AIPMT 2014]**  $(A)$  4 (B) 5 (C) Odd harmonics of the fundamental frequency will<br>be generated.<br>(D) All harmonics of the fundamental frequency will be<br>generated.<br>The number of possible natural oscillations of air column<br>in a pipe closed at one end of 46 Hz (D) 240 Hz<br>
	tudy the vibration of a pipe open at both ends,<br>
	the following statement is not true -[NEET 2013]<br>
	Pheressure change will be maximum at both ends.<br>
	Open end will be antimode.<br>
	Odd harmonics of the fundam (6) Hz<br>
	(B) 254 Hz<br>
	(D) 240 Hz<br>
	(D) 240 Hz<br>
	study the vibration of a pipe open at both ends,<br>
	the following statement is not true  $-$ [NEET 2013]<br>
	Pressure change will be maximum at both ends.<br>
	Open end will be antinode.<br> 9) 240 Hz<br>pipe open at both ends,<br>not true -[NEET 2013]<br>not true -[NEET 2013]<br>aximum at both ends.<br>amental frequency will be<br>oscillations of air column<br>of length 85 cm whose<br>are (Velocity of sound =<br>[AIPMT 2014]<br>3) 5<br>b) 6 2014 Hz [NEET 2013]<br>
	(240 Hz<br>
	(240 Hds)<br>
	(240 Hds)<br>
	(240 Hds)<br>
	(240 Hds)<br>
	(261 Here (2013)<br>
	(261 Here (261 Here (261 Having 1914)<br>
	(261 Here (261 Here (261 Ha
		- $(C) 7$  (D) 6 **Q.13** If  $n_1$ ,  $n_2$  and  $n_3$  are the fundamental frequencies of three segments into which a string is divided, then the original fundamental frequency n of the string is given by –

**[AIPMT 2014]**

(A) 
$$
\frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3}
$$
 (B)  $\frac{1}{\sqrt{n}} = \frac{1}{\sqrt{n_1}} + \frac{1}{\sqrt{n_2}} + \frac{1}{\sqrt{n_3}}$   
(C)  $\sqrt{n} = \sqrt{n_1} + \sqrt{n_2} + \sqrt{n_3}$  (D)  $n = n_1 + n_2 + n_3$ 

If we study the vibration of a pipe open at both ends,<br>
then the following statement is not true -[NEET 2013]<br>
(A) Pressure change will be maximum at both ends.<br>
(B) Open end will be antinode.<br>
(C) Odd harmonics of the fu **Q.14** A speeding motorcyclist sees traffic jam ahead of him. He slows down to 36 km/hour. He finds that traffic has eased and a car moving ahead of him at 18 km/hour is honking at a frequency of 1392 Hz. If the speed of sound is 343 m/s, the frequency of the honk as heard by him will be **[AIPMT 2014]** 



 $(A)$  L  $(C) L/2$ 

- **Q.15** The fundamental frequency of a closed organ pipe of length 20 cm is equal to the second overtone of an organ pipe open at both the ends. The length of organ pipe open at both the ends is – **[AIPMT 2015]** (A) 100 cm (B) 120 cm (C) 140 cm (D) 80 cm
- **Q.16** A source of sound S emitting waves of frequency 100 Hz and an observer O are located at some distance from each other. The source is moving with a speed of 19.4  $\text{ms}^{-1}$  at an angle of 60 $\degree$  with the source observer line as shown in the figure. The observer is at rest. The apparent frequency observed by the observer

(Velocity of sound in air  $330 \text{ ms}^{-1}$ ) is  $-$ **[RE-AIPMT 2015]**  $(A) 97 Hz$  (B) 100 Hz (C) 103 Hz (D) 106 Hz  $\sqrt{60^\circ}$  0  $\blacktriangleright$  Vs

- **Q.17** A string is stretched between fixed points separated by 75.0 cm. It is observed to have resonant frequencies of 420 Hz and 315 Hz. There are no other resonant frequencies between these two. The lowest resonant Q.23 frequencies for this string is **[RE-AIPMT 2015]** (A) 105 Hz (B) 155 Hz (C) 205 Hz (D) 10.5 Hz
- **Q.18** A siren emitting a sound of frequency 800 Hz moves away from an observer towards a cliff at a speed of  $15 \text{ m}$  Q.24 s. Then, the frequency of sound that the observer hears in the echo reflected from the cliff is (Take velocity of sound in air = 330 m/s) **[NEET 2016 PHASE 1]** (A) 765 Hz (B) 800 Hz (C) 838 Hz (D) 885 Hz
- **Q.19** A uniform rope of length L and mass  $m_1$  hangs vertically<br>from a rigid support. A block of mass  $m_2$  is attached to Q.25 from a rigid support. A block of mass  $m_2$  is attached to Q.25 the free end of the rope. A transverse pulse of wavelength  $\lambda_1$  is produced at the lower end of the rope. The wavelength of the pulse when it reaches the top of the rope is  $\lambda_2$ . The ratio  $\lambda_2/\lambda_1$  is [NEET 2016 PHASE 1]

(A) 
$$
\sqrt{\frac{m_1}{m_2}}
$$
  
\n(B)  $\sqrt{\frac{m_1 + m_2}{m_2}}$   
\n(C)  $\sqrt{\frac{m_2}{m_1}}$   
\n(B)  $\sqrt{\frac{m_1 + m_2}{m_2}}$   
\n(C)  $\sqrt{\frac{m_2}{m_1}}$   
\n(D)  $\sqrt{\frac{m_1 + m_2}{m_1}}$   
\n(D)  $\sqrt{\frac{m_1 + m_2}{m_1}}$   
\n1.

**Q.20** An air column, closed at one end and open at the other, resonates with a tuning fork when the smallest length of the column is 50 cm. The next larger length of the column resonating with the same tuning fork is –

## **[NEET 2016 PHASE 1]**



**Q.21** The second overtone of an open organ pipe has the same frequency as the first overtone of a closed pipe L metre long. The length of the open pipe will be



 $(n-1)$ , n,  $(n + 1)$ . They superimpose to give beats. The number of beats produced per second will be

#### **[NEET 2016 PHASE 2]**  $(A) 1$  (B) 4



- **Q.23** The two nearest harmonics of a tube closed at one end and open at other end are 220 Hz and 260 Hz. What is the fundamental frequency of the system? **[NEET 2017]**  $(A) 20 Hz$  (B) 30 Hz (C) 40 Hz (D) 10 Hz
- Two cars moving in opposite directions approach each other with speed of 22 m/s and 16.5 m/s respectively. The driver of the first car blows a horn having a a frequency 400 Hz. The frequency heard by the driver of the second car is [Velocity of sound 340 m/s] (A) 361 Hz (B) 411 Hz **[NEET 2017]** (C) 448 Hz (D) 350 Hz
- The fundamental frequency in an open organ pipe is equal to the third harmonic of a closed organ pipe. If the length of the closed organ pipe is 20cm, the length of the open organ pipe is **[NEET 2018]** (A) 12.5 cm (B) 8 cm (C) 13.2 cm (D) 16 cm
- Hz<br>
Fig. (A) 20 Hz<br>
(B) 30 Hz<br>
covers (C140 Hz<br>
covers (C140 Hz<br>
covers (D16) Hz<br>
covers and the observer hears<br>
the observer hears<br>
of Take velocity of<br>
Take velocity of<br>
The driver of the first car blows a horn<br>
frequen m<sub>2</sub> adjusted by a variable piston. At room temperature of mant frequencies of<br>
(A) 1<br>
no other resonant<br>
(C)3<br>
he lowest resonant<br>
(C)3<br>
he lowest resonant<br>
(Q)3<br>
and open at other end are 220 Hz and 260 Hz. What is the<br>
fundamental frequency of the system?<br>
(B) 30 Hz<br>
(B) 30 Hz  $+\frac{m_2}{m_1}$  tube. The length of the air column in this tube can be at a speece of 15 min and speece of the cost of the disk of the disk elections and the section of the first car blows a horn **F2016 PHASE 1** (Take velocity of the diriver of the first car blows a horn **F2016 PHASE 1** (A)  $m_1$  tuning fork is 320Hz, the velocity of sound in air at 27<sup>o</sup>C **EXECTIVAT 2015**<br>
EVERT 2015 and open at other end are 220 Hz and 260 Hz. What is the<br>
fundamental frequency of the system? (B) 30 Hz<br>
fundamental frequency of the system? (B) 30 Hz<br>
(C) 40 Hz<br>
(C) 40 Hz<br>
(C) 40 Hz<br>
(C) 1  $+m_2$  and 73 cm of column length. If the frequency of the **Q.26** A tuning fork is used to produce resonance in a glass 27ºC two successive resonances are produced at 20 cm is **[NEET 2018]**





# **ANSWER KEY**





## **EXERCISE - 3**









## **WAVES TRY IT YOURSELF-1**

- **(1)** (B)
- **(2)** (C)
- **(3)** (C)
- **(4)** (B) **(5)** (CD)
- **(6)** (BCD)
- **(7)** (ABD)
- **(8) (B).** Mass per unit length of the string,

$$
m = \frac{10^{-2}}{0.4} = 2.5 \times 10^{-2} kg/m
$$

 $\therefore$  Velocity of wave in the string,

$$
v = \sqrt{\frac{T}{m}} = \sqrt{\frac{1.6}{2.5 \times 10^{-2}}} = 8 \text{ m/s}
$$
 The

For constructive interference between successive

pulses: 
$$
\Delta t_{min} = \frac{2\ell}{v} = \frac{(2)(0.4)}{8} = 0.10s
$$

(After two reflections, the wave pulse is in same phase as it was produced, since in one reflection its phase changes by  $\pi$ , and if at this moment next identical pulse is produced, then constructive interference will be obtained.)

#### **(9) (BCD).**

The shape of pulse at  $x = 0$  and  $t = 0$  would be as shown in figure (a).





From the figure it is clear that  $y_{\text{max}} = 0.16$ m.

Pulse will be symmetric (Symmetry is checked about  $y_{max}$ ) (11) if at  $t = 0$ .

$$
y(x) = y(-x)
$$

From the given equation,

$$
y(x) = \frac{0.8}{16x^2 + 5}
$$
 and  $y(-x) = \frac{0.8}{16x^2 + 5}$  at  $t = 0$ 

or  $y(x) = y(-x)$ 

Therefore, pulse is symmetric.

**Speed of pulse :** At  $t = 1s$  and  $x = -1.25m$ 



= 2.3 × 10 kg/m<br>
of 1.25m in 1s in negative x-direction or we can say<br>
spect of plube is 1.25 m is sin the structure<br>
direction. Therefore, it will travel a distance of 2.5<br>
The above statement can be better understood fr 10<sup>-2</sup> kg/m<br>
Value of y is again 0.16m, i.e., pulse has travelled<br>
of 1.25m in 1s in negative x-direction or we can s<br>
speed of pluse is 1.25 m/s and it is travelling in n<br>
direction. Therefore, it will travel a distanc Value of y is again 0.16m, i.e., pulse has travelled a distance of 1.25m in 1s in negative x-direction or we can say that the speed of pulse is 1.25 m/s and it is travelling in negative xdirection. Therefore, it will travel a distance of 2.5m in 2s. The above statement can be better understood from figure (b).  $x = -1.25m$   $t = 1s$  (b)  $t = 0$ <br>  $t = 1s$  (c)  $t = 0$ <br>  $t = 1s$  (d)  $t = 0$ <br>  $t = 1s$  is again 0.16m, i.e., pulse has travelled a distance<br>
in 1s in negative x-direction or we can say that the<br>
sulse is 1.25 m/s and it is travel x = -1.25m<br>  $x = -1.25m$ <br>  $t = 1s$  (b)  $t = 0$ <br>
e of y is again 0.16m, i.e., pulse has travelled a distance<br>
25m in 1s in negative x-direction or we can say that the<br>
d of pulse is 1.25 m/s and it is travelling in negative x-25m in 1s in negative x-direction or we can say that the<br>
dof pulse is 1.25 m/s and it is travelling in negative x-<br>
tion. Therefore, it will travel a distance of 2.5m in 2s.<br>
above statement can be better understood from

**Alternate :** If equation of a wave pulse is  $y = f(ax \pm bt)$ 

The speed of wave is b/a in negative x direction for

 $y = f(ax + bt)$  and positive x direction for  $y = f(ax - bt)$ .

Comparing this from given equation we can find that speed of wave is  $5/4 = 1.25$  m/s and it is travelling in negative xdirection. Externate: it equation of a wave puise is  $y = 1$  (ax=bt)<br>
The speed of wave is b/a in negative x direction for<br>  $y = f (ax + bt)$  and positive x direction for  $y = f (ax - bt)$ .<br>
Comparing this from given equation we can find that spee uation of a wave puise is y = f (ax=bt)<br>ve is b/a in negative x direction for<br>d positive x direction for y = f (ax – bt).<br>from given equation we can find that speed<br>1.25 m/s and it is travelling in negative x-<br>1 frequenc g this from given equation we can find that speed<br>
5/4 = 1.25 m/s and it is travelling in negative x-<br>
mental frequency is given by<br>  $\frac{1}{\ell} \sqrt{\frac{T}{\mu}}$  (with both the ends fixed)<br>
mental frequency<br>
[for same tension in b f (ax + bt) and positive x direction for  $y = f (ax - bt)$ .<br>
mparing this from given equation we can find that speed<br>
vave is  $5/4 = 1.25$  m/s and it is travelling in negative x-<br>
cetion.<br>
Fundamental frequency is given by<br>  $v = \frac$ 

**(10) (D).** Fundamental frequency is given by

$$
v = \frac{1}{2\ell} \sqrt{\frac{T}{\mu}}
$$
 (with both the ends fixed)

: Fundamental frequency

we is 5/4 = 1.25 m/s and it is travelling in negative x-

\nIt is that it is that it is that it is not a real number.

\nFundamental frequency is given by

\n
$$
v = \frac{1}{2\ell} \sqrt{\frac{T}{\mu}}
$$
 (with both the ends fixed)\nundamental frequency

\n
$$
v \propto \frac{1}{\ell \sqrt{\mu}}
$$
 [for same tension in both strings]\nwe have:

\n
$$
v = \rho A \quad (ρ = density) = ρ \quad (πr^2)
$$
\n
$$
\sqrt{\mu} \propto r \quad \therefore \quad v \propto \frac{1}{r\ell}
$$
\nor

\n
$$
\frac{v}{2} = \left(\frac{r_2}{r_1}\right) \left(\frac{\ell_2}{\ell_1}\right) = \left(\frac{r}{2r}\right) \left(\frac{2L}{L}\right) = 1
$$
\nLet Δ*l* be the end correction.

\nGiven that fundamental to the form of a length 0.1 m = first

\nbetween for the length 0.35 m.

\n
$$
\frac{v}{4(0.1 + \Delta l)} = \frac{3v}{4(0.35 + \Delta l)}
$$

\nSolving this equation, we get Δ*l* = 0.025 m.

where  $\mu$  = mass per unit length of wire

$$
= \rho.A
$$
 ( $\rho = density$ ) =  $\rho$  ( $\pi$ r<sup>2</sup>)

or 
$$
\sqrt{\mu} \propto r
$$
 :  $v \propto \frac{1}{r\ell}$ 

$$
\therefore \frac{\mathbf{v}_1}{\mathbf{v}_2} = \left(\frac{\mathbf{r}_2}{\mathbf{r}_1}\right) \left(\frac{\ell_2}{\ell_1}\right) = \left(\frac{\mathbf{r}}{2\mathbf{r}}\right) \left(\frac{2L}{L}\right) = 1
$$

**(B).** Let  $\Delta l$  be the end correction.

Given that fundamental tone for a length  $0.1m =$  first overtone for the length 0.35m.

$$
\frac{v}{4(0.1+\Delta l)} = \frac{3v}{4(0.35+\Delta l)}
$$

 $+5$  Solving this equation, we get  $\Delta l = 0.025$ m.



Waves		(TRY SOLUTIONS)	EXAMPLE 2
(12)	(A) $n_s = \frac{3}{4} \left( \frac{340}{0.75} \right) = n - 4$ $\therefore n = 344$ Hz	$\therefore 176 = \left( \frac{330 - v}{330 - 22} \right) = 165 \left( \frac{330 + v}{330} \right)$	
<b>TRY IT YOLIRSELF-2</b>	Solving this equation, we get		
(1)	(AB)	$v = 22m/s$	
(2)	(D) $f_1 = f \left( \frac{v}{v - v_s} \right)$ ; $f_1 = f \left( \frac{340}{340 - 34} \right) = f \left( \frac{340}{306} \right)$	(5)	(D) The frequency is a characteristic of source. It is independent of the medium.
(3)	(B) Using the formula, $f' = f \left( \frac{v + v_0}{v} \right)$	While reducing,	
$f' = f_0 \left( \frac{v}{v - v_s} \right)$ ; $2200 = f_0 \left( \frac{300}{300 - v_s} \right)$			
(3)	(B) Using the formula, $f' = f \left( \frac{v + v_0}{v} \right)$	While reducing,	
$f'' = f_0 \left( \frac{v}{v + v_s} \right)$ ; $1800 = f_0 \left( \frac{300}{300 + v_s} \right)$			
and	$6.0 = 5 \left( \frac{v + v_B}{v} \right)$	........(1)	
and	$6.0 = 5 \left( \frac{v + v_B}{v} \right)$	........(2)	
Here, v = speed of sound,	(8)		

## **TRY IT YOURSELF-2**

**(1)** (AB)

(2) **(D).** 
$$
f_1 = f\left(\frac{v}{v - v_s}\right)
$$
;  $f_1 = f\left(\frac{340}{340 - 34}\right) = f\left(\frac{340}{306}\right)$ 

**(A).** 
$$
n_{s} = \frac{3}{4} \left( \frac{340}{0.75} \right) = n - 4 \quad \therefore n = 344 \text{ Hz}
$$

\n**(A)**

\n**(b)** 
$$
f_{1} = f \left( \frac{v}{v - v_{s}} \right) \text{; } f_{1} = f \left( \frac{340}{340 - 34} \right) = f \left( \frac{340}{306} \right)
$$

\n**(b)** The frequency is a characteristic. It is independent of the medium.

\n**(b)** Using the formula, 
$$
f' = f \left( \frac{340}{340 - 17} \right) = f \left( \frac{340}{323} \right) \quad \therefore \quad \frac{f_{1}}{f_{2}} = \frac{323}{306} = \frac{19}{18}
$$

\n**(c)** While approaching, 
$$
f' = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text{; } 2200 = f_{0} \left( \frac{v}{v - v_{s}} \right) \text
$$

(3) (B). Using the formula, 
$$
f' = f\left(\frac{v + v_0}{v}\right)
$$
 While

We get, 
$$
5.5 = 5 \left( \frac{v + v_A}{v} \right)
$$
 .........(1)

and 
$$
6.0 = 5 \left( \frac{v + v_B}{v} \right)
$$
 .........(2) (7)

Here,  $v = speed of sound$ ,

$$
v_A
$$
 = speed of train A  
 $v_B$  = speed of train B

Solving eqs. (1) and (2), we get  $\frac{v_{\text{B}}}{v} = 2$  When A  $\frac{V_{\rm B}}{V_{\rm A}} = 2$  When wi

**(4) (B).** The motorcyclists observes no beats.

So, the apparent frequency observed by him from the two sources must be equal.

$$
f_1 = f_2
$$

$$
\frac{\sqrt{2}}{\sqrt{2}}\sqrt{2}} = 165\left(\frac{330 - v}{330 - 22}\right) = 165\left(\frac{330 + v}{330}\right)
$$
  
Solving this equation, we get  
 $v = 22m/s$   
The frequency is a characteristic of source.

Solving this equation, we get

$$
v = 22m/s
$$

**TRY SOLUTIONS**<br>
TRY SOLUTIONS<br>  $1-4$   $\therefore n = 344$  Hz<br>  $\therefore 176 = \left(\frac{330 - v}{330 - 22}\right) = 165 \left(\frac{330 + v}{330}\right)$ <br> **OURSELF-2**<br>
Solving this equation, we get<br>  $r = 22m/s$ <br>  $f_1 = f\left(\frac{340}{340 - 34}\right) = f\left(\frac{340}{306}\right)$ <br>
(5) (D). The **TRY SOLUTIONS**<br>  $\therefore n = 344 \text{ Hz}$ <br>  $\therefore 176 = \left(\frac{330 - v}{330 - 22}\right) = 165 \left(\frac{330 + v}{330}\right)$ <br> **SELE-2**<br>
Solving this equation, we get<br>  $v = 22 \text{ m/s}$ <br>  $\therefore 340 - 34 = f\left(\frac{340}{306}\right)$ <br> **(5) (b)**. The frequency is a characteris **EDENTIONS**<br> **EDENTION**<br>
Solving this equation, we get<br>  $v = 22m/s$ <br>
Solving thi **EXECUTIONS**<br>
FIZ<br>
FIZ<br>
FIZ<br>  $\therefore 176 = \left(\frac{330 - v}{330 - 22}\right) = 165 \left(\frac{330 + v}{330}\right)$ <br>
Solving this equation, we get<br>  $v = 22m/s$ <br>  $= f\left(\frac{340}{306}\right)$ <br>
(5) (D). The frequency is a characteristic of source.<br>
It is independent o **EXECUTIONS**<br>
Hz  $\therefore 176 = \left(\frac{330 - v}{330 - 22}\right) = 165 \left(\frac{330 + v}{330}\right)$ <br>
Solving this equation, we get<br>  $v = 22m/s$ <br>  $= f\left(\frac{340}{306}\right)$ <br>
(5) (D). The frequency is a characteristic of source.<br>
It is independent of the medium **EXECUTIONS**<br>
In = 344 Hz<br>  $\therefore$  n = 344 Hz<br>  $\therefore$  176 =  $\left(\frac{330 - v}{330 - 22}\right) = 165 \left(\frac{330 + v}{330}\right)$ <br> **SELE-2**<br>
Solving this equation, we get<br>  $v = 22m/s$ <br>  $v = 22m/s$ <br>
(5) **(D).** The frequency is a characteristic of source TRY SOLUTIONS<br>
TRY SOLUTIONS<br>  $\therefore n = 344 \text{ Hz}$ <br>  $\therefore 176 = \left(\frac{330 - v}{330 - 22}\right) = 165 \left(\frac{330 + v}{330}\right)$ <br>
SELIE-2<br>
Solving this column, we get<br>  $v = 22m/s$ <br>  $\Rightarrow v = 22m/s$ <br>
(5) (D). The frequency is a characteristic of source.<br>
I **EXECUTIONS**<br>
TRY SOLUTIONS<br>  $= n-4$  ...  $n=344$  Hz<br>  $\therefore$   $176 = \left(\frac{330-v}{330-22}\right) = 165 \left(\frac{330+v}{330-22}\right)$ <br>  $\therefore$  f<sub>1</sub> = f  $\left(\frac{340}{340-34}\right) = f\left(\frac{340}{306}\right)$ <br>
(5) (D). The frequency is a characteristic of so<br>  $\frac{1}{30$ **(5) (D).** The frequency is a characteristic of source. It is independent of the medium.

**(6)** While approaching,

$$
176 = \left(\frac{330 - v}{330 - 22}\right) = 165 \left(\frac{330 + v}{330}\right)
$$
  
Solving this equation, we get  
v = 22m/s  
The frequency is a characteristic of source.  
It is independent of the medium.  
le approaching,  
 $f' = f_0 \left(\frac{v}{v - v_s}\right)$ ; 2200 =  $f_0 \left(\frac{300}{300 - v_s}\right)$   
le reducing,

While reducing ,

v v 0 <sup>s</sup> <sup>v</sup> ; <sup>0</sup>

On solving velocity of source (train)  $v_s = 30$  m/s

**TRY SOLUTIONS**  
\n
$$
\frac{40}{75} = n - 4 \therefore n = 344 Hz
$$
\n
$$
\therefore 176 = \left(\frac{330 - v}{330 - 22}\right) = 165\left(\frac{330 + v}{330}\right)
$$
\n**YITYOLIRSEL E-2**  
\nSolving this equation, we get  
\n $v = 22m/s$   
\n $v = 22m/s$   
\nSolving this equation, we get  
\n $v = 22m/s$   
\n $v = 2m/s$   
\n $v = 2m/s$ <

**(8) (AB).** If wind blows from source to observer

$$
f_2=f_1\left(\frac{V+w+u}{V+w-u}\right)
$$

2 When wind blows from observer towards source

$$
f_2 = f_1 \left( \frac{V - w + u}{V - w - u} \right)
$$

In both cases,  $f_2 > f_1$ .



## **CHAPTER-13 :WAVES**

#### **EXERCISE-1**

- **(1) (C).** Since solid has both the properties (rigidity and elasticity).
- **(2) (B).** Water waves produced by a motor boat sailing in **(16)** water are both, longitudinal and transverse.
- **(3) (C).** Comparing with the standard equation,

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

We have v = 200cm/sec, 
$$
\lambda
$$
 = 200cm  $\therefore$  n =  $\frac{v}{\lambda}$  = 1 sec<sup>-1</sup>

- **CHAPTER-13 : WAVES**<br> **CHAPTER-13 : WAVES**<br> **CHAPTER-13 : WAVES**<br> **CHAPTER-13 : WAVES**<br>
Since solid has both the properties (rigidity and<br>
Bince solid has both the properties (rigidity and<br>
P/p remains constant so speed r **CHAPTER-13: WAVES** (O.B.- SOLUTIONS) STUDY MATERIAL: PHYSICS<br>
CHAPTER-13: WAVES (15) (D),  $v = \sqrt{\frac{T}{p}}$ ; as P changes,  $\rho$  also changes. Hence<br>
Since solid has both the properties (rigidity and<br>
destrictly).<br>
Since solid **(4) (C).** Change in temperature of the medium changes the velocity of sound waves and hence the wavelength of sound waves. This is because frequency ( $v = v/\lambda$ ) is fixed. **EXERCISE-1** (15) (D).  $v = \sqrt{\frac{1}{f}}$ ; as P changes,  $\rho$  also<br>
Since solid has both the properties (rigidity and<br>
Mater waves produced by a motor boat sailing in (16) (C). Speed of sound wave in air ince<br>
Mater waves prod **EXECUTE:**<br>
(1) **CDUSTRIMENT (1) CDUSTRIMENT (1) (B) (B) CDUSTRIMENT (B) (B) (B) CDUSTRIMENT (B)** any with the standard equation,<br>  $\sin \frac{2\pi}{\lambda} (v-x)$ ,<br>  $\sec y = 200$  cm/s  $\sec \lambda = 200$  cm  $\therefore n = \frac{v}{\lambda} = 1 \sec^{-1}$ <br>  $\sec y = 200$  cm/s  $\sec \lambda = 200$  cm  $\therefore n = \frac{v}{\lambda} = 1 \sec^{-1}$ <br>
Sound with the heard after 3.03 sec. So 1<br>
sec. slower. A sin  $\frac{2\pi}{\lambda}$  (vt - x),<br>
(17) (B). Time =  $\frac{\text{Distance}}{\text{Velocity}} = \frac{1}{2}$ <br>
we v = 200cm/sec,  $\lambda$  = 200cm  $\therefore$  n =  $\frac{v}{\lambda}$  = 1 sec<sup>-1</sup><br>
Sound will be heard after<br>
sec, slower.<br>
trivy of sound waves and hence the wavelengt water are both, longitudinal and transverse.<br>  $y = A \sin \frac{2\pi}{\lambda}(vt - x)$ ,<br>  $y = A \sin \frac{2\pi}{\lambda}(vt - x)$ ,<br>
We have  $v = 200$ cm/sec,  $\lambda = 200$ cm  $\therefore n = \frac{v}{\lambda} = 1 \sec^{-1}$ <br>
Sure, shower and hence of the medium changes the (18) (B). Speed o Change in temperature of the medium changes the medium changes the properties of the model of the medium.<br>
Evelocity of sound waves. This is because frequency  $(v = v/\lambda)$ <br>
Sinced.<br>
Sinced the propagation of longitudinal wave
- **(5) (B).** During the propagation of longitudinal wave in a medium, energy, not the matter is transmitted through (19) the medium.
- **(6) (A).** Energy is not carried by stationary waves

(7) (C). 
$$
n = \frac{54}{60}
$$
 Hz,  $\lambda = 10$  m  $\implies$  v = n $\lambda = 9$  m/s.

between them 
$$
\Delta = \frac{\lambda}{2\pi} \times \phi = \frac{\lambda}{2\pi} \times \frac{\pi}{3} = \frac{\lambda}{6} = \frac{v}{6n}
$$

$$
\Rightarrow \ \Delta = \frac{360}{6 \times 500} = 0.12 \,\mathrm{m} = 12 \,\mathrm{cm}
$$

**(9) (B).** Phase difference between two successive crest is  $2\pi$ . **(2)** 

Also, phase difference  $(\Delta \phi) = \frac{2\pi}{\pi}$  time interval  $(\Delta t)$ 

$$
\Rightarrow 2\pi = \frac{2\pi}{T} \times 0.2 \Rightarrow \frac{1}{T} = 5\sec^{-1} \Rightarrow n = 5\text{ Hz}
$$

**(10) (A).**  $v_{\text{max}} = a\omega = 3 \times 10 = 30$ 

velocity of sound waves and hence the wavelength  
\nof sound waves. This is because frequency (v = v/
$$
\lambda
$$
)  
\nis fixed.  
\n**(5)** (B). During the propagation of longitudinal wave in  
\nthe medium, energy, not the matter is transmitted through  
\nthe medium.  
\n**(6)** (A). Energy is not carried by stationary waves  
\n**(7)** (C).  $n = \frac{54}{60} Hz, \lambda = 10 m \Rightarrow v = n\lambda = 9 m/s$ .  
\n**(8)** (B). The distance between two points i.e. path difference  
\nbetween them  $\Delta = \frac{\lambda}{2\pi} \times \phi = \frac{\lambda}{2\pi} \times \frac{\pi}{3} = \frac{\lambda}{6} = \frac{v}{6n}$   
\n $\Rightarrow \Delta = \frac{360}{6 \times 500} = 0.12 \text{ m} = 12 \text{ cm}$   
\n**(9)** (B). Phase difference between two successive crest is 2π.  
\n**(10)** (A). Phase difference (A $\phi$ ) =  $\frac{2\pi}{T}$  time interval (At)  
\n $\Rightarrow 2\pi = \frac{2\pi}{T} \times 0.2 \Rightarrow \frac{1}{T} = 5 \sec^{-1} \Rightarrow n = 5 Hz$   
\n**(11)** (B).  $y_1 = a_1 \sin(\omega t - \frac{2\pi x}{\lambda}) \& y_2 = a_2 \cos(\omega t - \frac{2\pi x}{\lambda} + \phi)$   
\n**(22)** (A).  $V_{long} = 100V_{trans}$ ;  $\sqrt{\frac{Y}{d}} = 100\sqrt{\frac{stress}{ds}} = 100\sqrt{\frac{stress}{d}} = 100$   
\n $\sqrt{1 \times 10^{11}} = 100 \sqrt{stress}$ ; Stress  $\frac{8 \text{ Kress}}{10^4} = 10^7$   
\n $\Rightarrow \Delta = \frac{2\pi}{3} \times 0.2 \Rightarrow \frac{1}{T} = 5 \sec^{-1} \Rightarrow n = 5 Hz$   
\n**(19)** (A).  $v_{max} = a_0 = 3 \times 10 = 30$   
\n $\Rightarrow 2\pi = \frac{2\pi}{T} \times 0.2 \Rightarrow \frac{1}{T} = 5 \sec^{-1} \Rightarrow n = 5 Hz$   
\n**(10)** (A).  $v_{max} =$ 

So phase difference = 
$$
\phi + \frac{\pi}{2}
$$
 and  $\Delta = \frac{\lambda}{2\pi} \left( \phi + \frac{\pi}{2} \right)$  (26) (A).

**(12) (A).** Both waves are moving opposite to each other

$$
\Rightarrow \Delta = \frac{360}{6 \times 500} = 0.12 \text{ m} = 12 \text{ cm}
$$
\n(9) **(B)**. Phase difference between two successive crest is 2 $\pi$ .  
\nAlso, phase difference  $(\Delta \phi) = \frac{2\pi}{T}$  time interval (At)  
\n $\Rightarrow 2\pi = \frac{2\pi}{T} \times 0.2 \Rightarrow \frac{1}{T} = 5 \text{sec}^{-1} \Rightarrow n = 5 \text{ Hz}$   
\n(10) **(A)**.  $v_{\text{max}} = a\omega = 3 \times 10 = 30$   
\n(11) **(B)**.  $y_1 = a_1 \sin(\omega t - \frac{2\pi x}{\lambda})$  &  $y_2 = a_2 \cos(\omega t - \frac{2\pi x}{\lambda} + \phi)$   
\n $= a_2 \sin(\omega t - \frac{2\pi x}{\lambda})$  &  $y_2 = a_2 \cos(\omega t - \frac{2\pi x}{\lambda} + \phi)$   
\n(12) **(A)**. Both waves are moving opposite to each other  
\n(13) **(C)**.  $I \propto \frac{1}{t^2} \Rightarrow \frac{1}{t^2} = \frac{t^2}{1} \Rightarrow \frac{1}{2} = \frac{t^2}{1} \Rightarrow \frac{1}{2} = \frac{t^2}{1 \times 10^{-2}} = \frac{2}{100} = 4 \times 10^{-4}$  **(D)**.  $\frac{t}{100} = \frac{2t}{100} = 4 \times 10^{-4}$   
\n $\Rightarrow I_2 = \frac{4 \times 10^{-2}}{100} = 4 \times 10^{-4}$  **(D)**. The system is given by the formula of the formula. The formula of the formula is  $\Delta = \frac{2}{2\pi} \left(\phi + \frac{\pi}{2}\right)$   
\n $\Rightarrow I_2 = \frac{4 \times 10^{-2}}{100} = 4 \times 10^{-4}$  **(A)**. The time interval between successive intervals,  $\sqrt{18} = 51 + 41 \cos(\pi/2) = 51$ ;  $I_R = 51 + 41 \cos(\pi/2) = 51$ ;  $I_R = 51 + 41 \cos(\pi/2) = 51$ ;  $I$ 

**(14) (A).** Displacement of wave in x direction  $\Delta x = x - (x - 1) = 1$  m Time intervel  $\Delta t = 2 - 0 = 2$  sec.

$$
\therefore \text{ Phase velocity} = \frac{\Delta x}{\Delta t} = \frac{1}{2} \text{ m/s}
$$

(15) **(D).** 
$$
v = \sqrt{\frac{\gamma P}{\rho}}
$$
; as P changes,  $\rho$  also changes. Hence

 $P/\rho$  remains constant so speed remains constant.

**CHAPTER-13: WAVES**<br> **CHAPTER-13: WAVES** (15) (D).  $v = \sqrt{\frac{\gamma P}{p}}$ ; as P changes,  $\rho$  also changes. Hence solid has both the properties (rigidity and  $P/\rho$  remains constant so speed remains constant so speed remains const is both the properties (rigidity and<br>
produced by a motor boat sailing in<br>
conductional and transverse.<br>
Longitudinal and transverse.<br>
the standard equation,<br>
the standard equation,<br>
the standard equation,<br>
the standard e ced by a motor boat sailing in (16) (C). Speed of sound wave in air increases with<br>
intundinal and transverse.<br>
standard equation,<br>  $\sec, \lambda = 200 \text{cm}$   $\therefore n = \frac{v}{\lambda} = 1 \sec^{-1}$ <br>
Sound will be heard after 3.03 sec. So his wat **(C).** Speed of sound wave in air increases with increase in humidity. This is because presence of moisture decreases the density of air. **(15) (D).**  $v = \sqrt{\frac{\gamma P}{p}}$ ; as P changes,  $\rho$  also changes. Hence<br>  $P/\rho$  remains constant so speed remains constant.<br> **(16) (C).** Speed of sound wave in air increases with increase<br>
in humidity. This is because prese **STUDY MATERIAL: PHYSICS**<br>  $\frac{V}{\rho}$ ; as P changes,  $\rho$  also changes. Hence<br>
mains constant so speed remains constant.<br>
of sound wave in air increases with increase<br>
iidity. This is because presence of moisture<br>
ses the **STUDY MATERIAL: PHYSICS**<br>  $\sqrt{\frac{\gamma P}{\rho}}$ ; as P changes,  $\rho$  also changes. Hence<br>
remains constant so speed remains constant.<br>
eed of sound wave in air increases with increase<br>
thumidity. This is because presence of moist **SDEAD**<br>
SUDY MATERIAL: PHYSICS<br> **(D).**  $v = \sqrt{\frac{\gamma P}{\rho}}$ ; as P changes,  $\rho$  also changes. Hence<br>  $P/\rho$  remains constant so speed remains constant.<br> **(C).** Speed of sound wave in air increases with increase<br>
in lumidity. T **STUDY MATERIAL: PHYSICS**<br> **(APPE)** : as P changes, p also changes. Hence<br>  $P/\rho$  remains constant so speed remains constant.<br> **(APPE)** Framing constant so speed remains constant.<br> **(APPE)** Framing and wave in air increase p also changes. Hence<br>speed remains constant.<br>iir increases with increase<br>use presence of moisture<br>ir.<br> $\frac{0}{1} = 3.03$  second<br>3 sec. So his watch is set<br>is given by<br> $\frac{1}{2} = \sqrt{\frac{m_2}{m_1}}$ <br>and it is independent of<br> $10m/s$ **DY MATERIAL: PHYSICS**<br>
s,  $\rho$  also changes. Hence<br>
speed remains constant.<br>
air increases with increase<br>
rause presence of moisture<br>
air.<br>  $\frac{300}{0} = 3.03$  second<br>
03 sec. So his watch is set<br>
is given by<br>  $\frac{v_1}{v_2}$ DY MATERIAL: PHYSICS<br>
s,  $\rho$  also changes. Hence<br>
speed remains constant.<br>
air increases with increase<br>
cause presence of moisture<br>
air.<br>  $\frac{00}{60} = 3.03$  second<br>
03 sec. So his watch is set<br>
s is given by<br>  $\frac{v_1}{v_2}$ **(15) (D).**  $v = \sqrt{\frac{\gamma P}{p}}$ ; as P changes,  $\rho$  also changes. Hence<br>  $P/\rho$  remains constant so speed remains constant.<br> **(16) (C).** Speed of sound wave in air increases with increase in humidity. This is because presen **STUDY MATERIAL: PHYSICS**<br>
=  $\sqrt{\frac{\gamma P}{\rho}}$ ; as P changes,  $\rho$  also changes. Hence<br>  $\rho$  remains constant so speed remains constant.<br>
humidity. This is because presence of moisture<br>
rereases the density of air.<br>
lime =  $\$ **STUDY MATERIAL: PHYSICS**<br>  $\frac{1}{2}$ <br>  $\frac{1}{2}$ ; as P changes, p also changes. Hence<br>
ins constant so speed remains constant.<br>
Sound wave in air increases with increase<br>
tity. This is because presence of moisture<br>
the den peed remains constant.<br>
ir increases with increase<br>
use presence of moisture<br>
ir.<br>  $\frac{1}{3} = 3.03$  second<br>
3 sec. So his watch is set<br>
s given by<br>  $\frac{1}{2} = \sqrt{\frac{m_2}{m_1}}$ <br>
and it is independent of<br>  $10m/s$ <br>  $v = \frac{\omega}{k} = \frac{3$ Tremans constant.<br>
creases with increase<br>
presence of moisture<br>
.. So his watch is set<br>
ven by<br>  $\frac{m_2}{m_1}$ <br>
it is independent of<br>  $\sqrt{s}$ <br>  $\frac{m_2}{k} = \frac{30}{1} = 30 \text{ m/s}$ .<br>  $\frac{m_2}{k} = \frac{30}{1} = 30 \text{ m/s}$ . (**U).**  $v = \sqrt{\frac{p}{p}}$ , as P changes, p also changes. Fience<br>
P/p remains constant so speed remains constant.<br>
(**C**). Speed of sound wave in air increases with increase<br>
in humidity. This is because presence of moisture<br>
de

**(B).** Time = 
$$
\frac{\text{Distance}}{\text{Velocity}} = \frac{1000}{330} = 3.03 \text{ second}
$$

 $\lambda$  3sec, slower. Sound will be heard after 3.03 sec. So his watch is set

**(18) (B).** Speed of sound in gases is given by

$$
v = \sqrt{\frac{\gamma RT}{M}}
$$
  $\Rightarrow$   $v \propto \frac{1}{\sqrt{M}}$   $\Rightarrow$   $\frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$ 

pressure.

(20) (C). 
$$
v = \sqrt{\frac{T}{m}} = \sqrt{\frac{60.5}{(0.035/7)}} = 110 \text{m/s}
$$

(21) **(D).** 
$$
y = 0.0021 \sin(x + 30t) \Rightarrow v = \frac{\omega}{k} = \frac{30}{1} = 30 \text{ m/s}.
$$

**(B).** Time = 
$$
\frac{1}{\text{Velocity}} = \frac{1}{330} = 3.03 \text{ second}
$$
  
\nSound will be heard after 3.03 sec. So his watch is set  
\n3sec, slower.  
\n**(B).** Speed of sound in gases is given by  
\n $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$   
\n**(D).** Speed of sound  $v \propto \sqrt{T}$  and it is independent of  
\npressure.  
\n**(C).**  $v = \sqrt{\frac{T}{m}} = \sqrt{\frac{60.5}{(0.035/7)}} = 110 \text{ m/s}$   
\n**(D).**  $y = 0.0021 \sin(x + 30t) \Rightarrow v = \frac{\omega}{k} = \frac{30}{1} = 30 \text{ m/s}$ .  
\nUsing,  $v = \sqrt{\frac{T}{m}} \Rightarrow 30 = \sqrt{\frac{T}{1.3 \times 10^{-4}}} \Rightarrow T = 0.117 \text{ N}$   
\n**(A).**  $v_{long.} = 100v_{trans.}$ ;  $\sqrt{\frac{Y}{d}} = 100\sqrt{\frac{\text{stress}}{d}} = \sqrt{1.3 \times 10^{-4}} = 10^7$   
\n**(D).**  $A_{max} = \sqrt{A^2 + A^2} = A\sqrt{2}$ ,  
\nfrequency will remain same i.e.  $\omega$ .

2 2 3 6 6n ( ) <sup>T</sup> time interval (t) & 2 2 2 x y a cos t T T v 30 T 0.117N <sup>m</sup> 1.3 10 **(22) (A).** long. trans. v 100v ; <sup>11</sup> 1 10 100 stress ; Stress = **(23) (D).** 2 2 A A A A 2, max

$$
\sqrt{1 \times 10^{11}} = 100 \sqrt{\text{stress}}
$$
; Stress =  $\frac{10^{11}}{10^4} = 10^7$ 

(23) **(D).** 
$$
A_{\text{max}} = \sqrt{A^2 + A^2} = A\sqrt{2}
$$
,  
frequency will remain same i.e. ω.

- **(24) (A).** Phase difference is  $2\pi$  means constructive interference so resultant amplitude will be maximum.
- **(25) (D).** Resultant amplitude

$$
A = \sqrt{a^2 + a^2 + 2aa\cos\phi} = \sqrt{4a^2\cos^2\left(\frac{\phi}{2}\right)}
$$
  
 
$$
\therefore I \propto A^2 \implies I \propto 4a^2
$$

This is because frequency (v = v/*k*)  
\n
$$
v = \sqrt{\frac{\mu x}{M}} \Rightarrow v \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{v_2}{v_2} = \sqrt{\frac{m_2}{m_1}}
$$
  
\ngation of longitudinal wave in a  
\n $v_2 = v_1 \lambda = 9 \text{ m/s}$ .  
\n $v_1 = v_2 \ln \lambda = 9 \text{ m/s}$ .  
\n $v_1 = v_1 \lambda = 9 \text{ m/s}$ .  
\n $v_2 = \sqrt{\frac{m_1}{m}} = \sqrt{\frac{60.5}{(0.035/7)}} = 110 \text{ m/s}$   
\n $v_1 = v_2 \lambda = \frac{\lambda}{2\pi} \times \frac{\pi}{9} = \frac{\lambda}{6} = \frac{v_1}{60}$   
\n $v_2 = \sqrt{\frac{m_1}{m}} = \sqrt{\frac{60.5}{(0.035/7)}} = 110 \text{ m/s}$   
\n $v_1 = 12 \text{ cm}$   
\n $v_1 = \sqrt{\frac{m_1}{m}} \Rightarrow 30 = \sqrt{\frac{m_1}{1.3 \times 10^{-4}}} \Rightarrow T = 0.117 \text{ N}$   
\n $v_1 = 12 \text{ cm}$   
\n $v_1 = \frac{32}{(1.3 \times 10^{-4} \text{ m})} = 30 \text{ N}$   
\n $v_1 = \sqrt{\frac{m_1}{m}} = 300 = \sqrt{\frac{3 \text{ tors}}{1.1 \times 10^{-4}}} = 100 \sqrt{\frac{\text{stress}}{1.1 \times 10^{-4}}} = 10^7$   
\n $v_1 = \frac{\sqrt{m_1}}{1.1 \times 10^{-4}} = \frac{\sqrt{$ 

(27) (A). Since 
$$
\phi = \frac{\pi}{2} \implies A = \sqrt{a_1^2 + a_2^2} = \sqrt{(4)^2 + (3)^2} = 5
$$

**(28) (A).** The time interval between successive maximum

intensities will be 
$$
\frac{1}{n_1 - n_2} = \frac{1}{454 - 450} = \frac{1}{4} \text{sec.}
$$

(29) (C). 
$$
n_1 = \frac{1000\pi}{2\pi} = 500
$$
 Hz and  $n_2 = \frac{998\pi}{2\pi} = 499$  Hz  
Hence beat frequency =  $n_1 - n_2 = 1$ 

**250**

 $2^{j}$ 



**(30) (A).** Persistence of hearing is  $10 \text{ sec}^{-1}$ .

(Q.B. SOLUTIONS	
(30) (A) persistence of hearing is 10 sec <sup>-1</sup> .	(42) (B). Frequency of first overtone or second harmonic (n <sub>2</sub> )
(31) (A) $n_1 = \frac{v}{\lambda_1} = \frac{v}{0.50}$ and $n_2 = \frac{v}{\lambda_2} = \frac{v}{0.51}$	(42) (B). Frequency of first overtone or second harmonic (n <sub>2</sub> )
(31) (A) $n_1 = \frac{v}{\lambda_1} = \frac{v}{0.50}$ and $n_2 = \frac{v}{\lambda_2} = \frac{v}{0.51}$	(43) (B). In stationary wave all the particles in one particular segment (i.e., between two nodes) vibrates in the same phase.
$\Rightarrow v = \frac{12 \times 0.51 \times 0.50}{0.01} = 306$ m/s	(44) (C). On comparing the given equation with standard equation $\Rightarrow \frac{2\pi}{\lambda} = \frac{\pi}{3} \Rightarrow \lambda = 6$ cm.
(32) (D). $n_A$ = Known frequency = 341 Hz, $n_B$ = ?	(44) (C). On comparing the given equation with standard equation $\Rightarrow \frac{2\pi}{\lambda} = \frac{\pi}{3} \Rightarrow \lambda = 6$ cm.
(5a) In phys, which is decreasing (i.e. $x\downarrow$ ) after loading (from the system two consecutive nodes $\Rightarrow \lambda = 3$ cm	

$$
\Rightarrow v = \frac{12 \times 0.51 \times 0.50}{0.01} = 306 \text{m/s}
$$

- **12** Persistence of hearing is 10 sec<sup>-1</sup>.<br>  $n_1 = \frac{v}{\lambda_1} = \frac{v}{0.50}$  and  $n_2 = \frac{v}{\lambda_2} = \frac{v}{0.51}$ <br>  $\Delta n = n_1 n_2 = v \left[ \frac{1}{0.50} \frac{1}{0.51} \right] = 12$ <br>  $v = \frac{12 \times 0.51 \times 0.50}{0.01} = 306 \text{ m/s}$ <br>  $n_A = \text{Known frequency} = 341 \text{ Hz}, n_B = ?$ **(32) (D).**  $n_A =$ Known frequency = 341 Hz,  $n_B = ?$  $x = 6$  bps, which is decreasing (i.e.  $x \downarrow$ ) after loading (from equals) 6 to 1 bps) Unknown tuning fork is loaded so  $n_B \downarrow$ <br>Hence  $n_A - n_D \downarrow = x \downarrow$  ... (i) Wrong Hence  $n_A - n_B \downarrow = x \downarrow$  ... (i) Wrong  $n_B \downarrow -n_A = x \downarrow$  ... (ii) Correct  $\Rightarrow$  n<sub>B</sub> = n<sub>A</sub> + x = 341 + 6 = 347 Hz. **ES**<br>
(A). Persistence of hearing is 10 sec<sup>-1</sup>.<br>
(A).  $n_1 = \frac{v}{\lambda_1} = \frac{v}{0.50}$  and  $n_2 = \frac{v}{\lambda_2} = \frac{v}{0.51}$ <br>
(A).  $n_1 = \frac{n_2}{\lambda_1} = \frac{v}{0.50}$  and  $n_2 = \frac{v}{\lambda_2} = \frac{v}{0.51}$ <br>  $\Delta n = n_1 - n_2 = v \left[ \frac{1}{0.50} - \frac{1}{0.51}$  $\frac{1 \times 0.50}{0.50} = \frac{1}{0.51}$  = 12<br>  $\frac{1 \times 0.50}{0.1} = 306 \text{ m/s}$ <br>  $\frac{1 \times 0.50}{0.1} = 340 \text{ m/s}$ 2 of hearing is 10 sec<sup>-1</sup>.<br>
(42) (B). Frequency of first overtone or  $\frac{v}{1.50}$  and  $n_2 = \frac{v}{\lambda_2} = \frac{v}{0.51}$ <br>  $n_2 = v \left[ \frac{1}{0.50} - \frac{1}{0.51} \right] = 12$ <br>  $(43)$  (B). In stationary wave all the particularly of first<br>  $n$ Persistence of hearing is 10 sec<sup>-1</sup>.<br>  $n_1 = \frac{v}{\lambda_1} = \frac{v}{0.50}$  and  $n_2 = \frac{v}{\lambda_2} = \frac{v}{0.51}$ <br>  $\Delta n = n_1 - n_2 = v \left[ \frac{1}{0.50} - \frac{1}{0.51} \right] = 12$ <br>  $v = \frac{12 \times 0.51 \times 0.50}{0.01} = 306 \text{ m/s}$ <br>  $v = \frac{12 \times 0.51 \times 0.50}{0.01} = 3$ **1.** Persistence of hearing is 10 sec<sup>-1</sup>.<br>  $n_1 = \frac{v}{\lambda_1} = \frac{v}{0.50}$  and  $n_2 = \frac{v}{\lambda_2} = \frac{v}{0.51}$ <br>  $\Delta n = n_1 - n_2 = v \left[ \frac{1}{0.50} - \frac{1}{0.51} \right] = 12$ <br>  $\Delta n = n_1 - n_2 = v \left[ \frac{1}{0.50} - \frac{1}{0.51} \right] = 12$ <br>  $v = \frac{12 \times 0.51 \times 0.$ is 10 sec<sup>-1</sup>. **(42) (B).** Frequency of first overtone or second harmonic (n<sub>2</sub>)<br>  $\frac{1}{2} \times \frac{1}{2} = \frac{v}{0.51}$ <br>  $\frac{1}{0.51}$  = 12<br>  $\frac{1}{0.51}$  = 12<br> **(43) (B).** In stationary wave all the particles in one particular **Q.B.- SOLUTIONS**<br>
(a) (B). Frequency of first overtone or second harmonic (n<sub>2</sub>)<br>  $\frac{1}{2} = \frac{v}{\lambda_2} = \frac{v}{0.51}$ <br>  $\frac{1}{0} = \frac{1}{0.51}$ <br>  $\frac{1}{0} = \frac{1}{0.51}$ <br>  $\frac{1}{0} = \frac{1}{0.51}$ <br>  $\frac{1}{0} = \frac{1}{0.51}$ <br>  $\frac{1}{0} = \frac{1}{0.5$ bown frequency = 341 Hz,  $n_B$  = ?<br>
thich is decreasing (i.e. x, k) after loading (from<br>
uning fork is loaded so  $n_B$  b bistance between two consecut<br>
uning fork is loaded so  $n_B$  b bistance between two consecut<br>  $n_B$  k = **D).**  $n_A =$ Known frequency = 341 Hz,  $n_B = ?$ <br>  $n_B = n_A - n_B = + s \times 1$  ...(i)<br>  $n_B = n_A + s = 341 + 6 = 347$  Hz,  $n_B = 100$  and  $n_B = 100$  Hz,  $n_A = 100$  Hz,  $n_A = n + \frac{3n}{100} = 5 \Rightarrow n_B = 100$  Hz,  $n_A = \frac{1030}{100} = 103$  Hz,  $n_A = \frac{(103)(100)}{5} =$ Which is decreasing (i.e. x) after bading (from equation  $\Rightarrow \frac{2x}{\lambda} = \frac{x}{3} \Rightarrow \lambda = 6$  en<br>
tuning fork is loaded so n<sub>B</sub><sup>1</sup><br>  $\lambda = n_0 + \lambda = x$ <sup>1</sup> ....(i)<br>  $\lambda = n_0 + \lambda = x$ <sup>1</sup> ....(i)<br>  $\lambda = \frac{3}{100} + \frac{1}{100} + \frac{1}{100} + \frac{1}{100} + \frac$ v =  $\frac{1}{0.01}$  = 306m/s<br>  $\frac{1}{0.01}$  = 306m/s<br>
hps, m<sub>0</sub> = Rnown frequency = 341 Hz, n<sub>B</sub> = ?<br>
bps, which is decreasing (i.e. x<sup>1</sup>) after loading (from<br>
tuning fork is loaded so n<sub>B</sub><sup>1</sup><br>  $\frac{1}{0.01}$  =  $\frac{1}{1.01}$  is  $\frac{1}{16}$  = 7<br>
Her loading (from equation  $\Rightarrow \frac{2\pi}{\lambda} = \frac{\pi}{3} \Rightarrow \lambda = 6$  cm.<br>
Distance between two consecutive nodes  $\Rightarrow \lambda = 3$  cm<br>
Wrong<br>
Correct **(45) (C).** n  $\propto \frac{1}{\ell} \Rightarrow \frac{\Delta n}{n} = -\frac{\Delta \ell}{\ell}$ <br>
If length is decreased 341 Hz,  $n_B = ?$ <br>
(i.e. x, b) after loading (from<br>
equation  $\Rightarrow \frac{2\pi}{\lambda} = \frac{\pi}{3} \Rightarrow \lambda = 6 \text{ cm}$ .<br>
Distance between two consecutive nodes  $\Rightarrow \lambda = ?$ <br>
(ii) Correct<br>
(45) (C).  $n \propto \frac{\lambda}{\ell} \Rightarrow \frac{\Delta n}{n} = -\frac{\Delta\ell}{\ell}$ <br>
Hz,<br>
If length 5<br>
1 Hz, n<sub>B</sub> = ?<br>
1 Hz, n<sub>B</sub> = ?<br>
(44) (C). On comparing the given equation with standard<br>
contrelating (from<br>
100 n<sub>B</sub><sup>1</sup><br>
100 n<sub>B</sub><sup>1</sup><br>
100 n<sub>D</sub><sup>1</sup><br>
100 - 100 l+<br>
100 - 100 l+<br>
100 - 100 l+<br>
100 - 100 l+<br>
100 - 100 l+
- **(33) (A).**  $v_0 = 332 \text{ m/s}$ . Velocity sound at t°C is  $v_t = (v_0 + 0.61t)$

$$
\Rightarrow \Delta n = v_{20} \left( \frac{1}{\lambda_1} - \frac{1}{\lambda_2} \right) = 344.2 \left( \frac{100}{50} - \frac{100}{51} \right) = 14
$$

- **(34) (A).** Frequency of the source =  $100 \pm 5 = 105$  Hz or 95 Hz. **(46)** Second harmonic of the source = 210 Hz or 190 Hz. As the second harmonic gives 5 beats/sec with sound of frequency 205 Hz, the second harmonic should be 210Hz.  $\Rightarrow$  Frequency of the source = 105 Hz.  $v_{10} = \frac{1}{100}x^{-1}x - x \cdot v = ...$   $v_{10} = \frac{1}{100}x^{-1}x + \frac{1}{100}$ <br>  $v_{20} = v_0 + 0.61 \times 20 = 344.2 \text{ m/s}$ <br>  $v_{20} = v_0 + 0.61 \times 20 = 344.2 \text{ m/s}$ <br>  $v_{20} = v_0 + 0.61 \times 20 = 344.2 \text{ m/s}$ <br>  $v_{20} = v_0 + 0.61 \times 20 = 344.2 \text{ m/s}$ <br>  $v_{20} = v_$  $n_A - n_B \downarrow = x \downarrow$  ... (i) Wrong<br>  $n_B + n_B \downarrow = x \downarrow$  ... (ii) Correct<br>  $n_B + x = 341 + 6 = 347$  Hz.<br>  $= 332 \text{ m/s}$ . Velocity sound at  $\text{t}^{\circ}\text{C}$  is  $v_t = (v_0 + 0.61t)$ <br>  $= v_0 + 0.61 \times 20 = 344.2 \text{ m/s}$ <br>  $= \text{y}_0 \left(\frac{1}{\lambda_1} - \frac{1}{\lambda$
- **(35) (C).** Let n be the frequency of fork C then

$$
n_A = n + \frac{3n}{100} = \frac{103n}{100}
$$
 and  $n_B = n - \frac{2n}{100} = \frac{98}{100}$ 

(C). Let n be the frequency of fork C then  
\n
$$
n_A = n + \frac{3n}{100} = \frac{103n}{100}
$$
 and  $n_B = n - \frac{2n}{100} = \frac{98}{100}$  or  $95n + 380 = 100n - 400$  or  $5n = \frac{103n}{2} = \frac{103n}{2} = 5$   
\nbut  $n_A - n_B = 5 \Rightarrow \frac{5n}{100} = 5 \Rightarrow n = 100$  Hz  
\n $\therefore n_A = \frac{(103)(100)}{100} = 103$  Hz  
\n(D). Particles have kinetic energy maximum at mean position.  
\n(C). The distance between the nearest node and antinode  
\nin a stationary wave is  $\lambda/4$   
\n(a). At nodes strain is maximum.  
\n(d). At nodes strain is maximum.  
\n(e). Both the sides of a node, two antinodes are present  
\nwith separation  $\lambda/2$ . So phase difference between  
\n $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$   
\n $\Rightarrow \lambda = 8$   
\n $\Rightarrow \lambda = 8$   
\nHence distance between two con-  
\n $n_1 = \frac{v}{2\ell} = \frac{350}{2 \times 0.5} = 350$  Hz  
\n $v_1 = \frac{v}{2\ell} = \frac{350}{2 \times 0.5} = 350$  Hz  
\n $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$   
\n $\Rightarrow \lambda = \frac{3v}{4\ell} = 100 + \frac{v}{2\ell}$ ;  
\n $\Rightarrow \frac{3v}{4\ell} = \frac{2v}{4\ell} = \frac{v}{4\ell} = 100 \Rightarrow \frac{v}{2\ell} = 2$   
\n $\frac{3v}{4\ell} - \frac{2v}{4\ell} = \frac{v}{4\ell} = 100 \Rightarrow \frac{v}{2\ell} = 2$ 

- **(36) (D).** Particles have kinetic energy maximum at mean position.
- **(37) (C).** The distance between the nearest node and antinode in a stationary wave is  $\lambda$ /4



- **(38) (A).** At nodes strain is maximum.
- **(39) (C).** Both the sides of a node, two antinodes are present with separation  $\lambda/2$ . So phase difference between (51) then



(40) **(D).** 
$$
n \propto \frac{1}{\ell} \sqrt{T} \Rightarrow \frac{n'}{n} = \sqrt{\frac{T'}{T}} \times \frac{\ell}{\ell'} = \sqrt{4} \times \frac{1}{2} = 1 \Rightarrow n' = n
$$
 (52) **(C).**

(36) (D) Particles have kinetic energy maximum at mean position.  
\n(37) (C). The distance between the nearest node and antinode in a stationary wave is 
$$
\lambda/4
$$
  
\nin a stationary wave is  $\lambda/4$   
\n $\lambda$   
\nHence distance between two consecutive no  
\n(38) (A). At nodes strain is maximum.  
\n(39) (C). Both the sides of a node, two antinodes are present  
\nwith separation  $\lambda/2$ . So phase difference between  
\n $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$   
\n $\phi = \frac{3\pi}{\lambda} \times \frac{2\pi}{2} = \pi$   
\n $\phi = \frac{3\pi}{\lambda} \times \frac{2\pi}{2} = \pi$   
\n $\frac{3\pi}{4\ell} = \frac{2\gamma}{4\ell} = \frac{\gamma}{4\ell} = 100 \Rightarrow \frac{\gamma}{2\ell} = 200 \text{ Hz}$   
\n(40) (D).  $n \propto \frac{1}{\ell} \sqrt{T} \Rightarrow \frac{n'}{n} = \sqrt{\frac{T'}{T}} \times \frac{\ell}{\ell'} = \sqrt{4} \times \frac{1}{2} = 1 \Rightarrow n$ 

**(42) (B).** Frequency of first overtone or second harmonic  $(n_2)$ = 320 Hz. So, frequency of first harmonic

$$
n_1 = \frac{n_2}{2} = \frac{320}{2} = 160 \,\text{Hz}
$$

- **(Q.B.- SOLUTIONS**<br>  $0 \sec^{-1}$ .<br> **(42) (B).** Frequency of first overtone or second harmonic<br>  $\frac{v}{v_2} = \frac{v}{0.51}$ <br>  $n_1 = \frac{n_2}{2} = \frac{320}{2} = 160 \text{ Hz}$ <br> **(43) (B).** In stationary wave all the particles in one particles **(O.B.- SOLUTIONS**<br>
is 10 sec<sup>-1</sup>.<br>  $=\frac{v}{\lambda_2} = \frac{v}{0.51}$ <br>  $=\frac{1}{0.51}$ <br>
(42) (B). Frequency of first overtone or second harmonic<br>  $n_1 = \frac{n_2}{2} = \frac{320}{2} = 160 \text{ Hz}$ <br>
(43) (B). In stationary wave all the particles in on **(O.B.- SOLUTIONS**<br>
Tring is 10 sec<sup>-1</sup>.<br>
(42) (B). Frequency of first overtone or second harmonic (n<sub>2</sub>)<br>  $\frac{1}{\lambda_2} = \frac{v}{0.51}$ <br>  $\frac{1}{0.50} - \frac{1}{0.51}$ ] = 12<br>
(43) (B). In stationary wave all the particles in one part y<br>
y in 1930 Hz. So, frequency of first harmonic<br>
0.51<br>
1<sub>0</sub> =  $\frac{n_2}{2} = \frac{320}{2} = 160$ Hz<br>
1-12<br>
(43) (B). In stationary wave all the particles in one particula<br>
segment (i.e., between two nodes) vibrates in the same<br> Frequency of first overtone or second harmonic (n<sub>2</sub>)<br>
Frequency of first overtone or second harmonic (n<sub>2</sub>)<br>  $n_1 = \frac{n_2}{2} = \frac{320}{2} = 160$ Hz<br>
In stationary wave all the particles in one particular<br>
ent (i.e., between two **EDIMEDIVANCED LEARNING**<br> **EDIMEDIVANCED LEARNING**<br>
20 Hz. So, frequency of first harmonic (n<sub>2</sub>)<br>  $= \frac{n_2}{2} = \frac{320}{2} = 160$  Hz<br>
stationary wave all the particles in one particular<br>
(i.e., between two nodes) vibrates in **(43) (B).** In stationary wave all the particles in one particular segment (i.e., between two nodes) vibrates in the same phase. **SOMADVANCED LEARNING**<br> **EXECUTE:**<br> **EXEC SOMADVANCED LEARNING**<br>
oDMADVANCED LEARNING<br>
of first overtone or second harmonic (n<sub>2</sub>)<br>
o, frequency of first harmonic<br>  $\frac{320}{2} = 160$ Hz<br>
y wave all the particles in one particular<br>
etween two nodes) vibrates in the **SOMADVANGED LEARNING**<br>
Transformation of the probability of the probability<br>  $= 160$ Hz<br>
are all the particles in one particular<br>
ten two nodes) vibrates in the same<br>
the given equation with standard<br>  $\frac{t}{s} \Rightarrow \lambda = 6$  cm. = 320 Hz. So, frequency of first harmonic<br>  $n_1 = \frac{n_2}{2} = \frac{320}{2} = 160$  Hz<br> **(B).** In stationary wave all the particles in one particular<br>
segment (i.e., between two nodes) vibrates in the same<br>
phase.<br> **(C).** On compari **EXERCISE AND MONOGEDIEATERING**<br> **EXERCISE ADDED**<br>
10 Hz. So, frequency of first harmonic (n<sub>2</sub>)<br>  $\frac{n_2}{2} = \frac{320}{2} = 160$  Hz<br>
tationary wave all the particles in one particular<br>
(i.e., between two nodes) vibrates in the **EVALUATE CONTADINATION**<br>
THE SO, frequency of first harmonic (n<sub>2</sub>)<br>  $\frac{12}{2} = \frac{320}{2} = 160$ Hz<br>
ionary wave all the particles in one particular<br>
e., between two nodes) vibrates in the same<br>
mynaring the given equation **(B).** In stationary wave all the particles in one particular<br>segment (i.e., between two nodes) vibrates in the same<br>phase.<br>**(C).** On comparing the given equation with standard<br>equation  $\Rightarrow \frac{2\pi}{\lambda} = \frac{\pi}{3} \Rightarrow \lambda = 6$  cm.<br>D Frequency of first overtone or second harmonic (n<sub>2</sub>)<br>= 320 Hz. So, frequency of first harmonic<br>n<sub>1</sub> =  $\frac{n_2}{2} = \frac{320}{2} = 160$  Hz<br>In stationary wave all the particles in one particular<br>ment (i.e., between two nodes) vib equency of first overtone or second harmonic (n<sub>2</sub>)<br>
200 Hz. So, frequency of first harmonic (n<sub>2</sub>)<br>  $= \frac{n_2}{2} = \frac{320}{2} = 160$  Hz<br>
stationary wave all the particles in one particular<br>
to ti.e., between two nodes) vibrate wave an the particles in the particular<br>tween two nodes) vibrates in the same<br>ing the given equation with standard<br> $= \frac{\pi}{3} \Rightarrow \lambda = 6$  cm.<br>n two consecutive nodes  $\Rightarrow \lambda = 3$  cm<br> $= \frac{\Delta n}{n} = -\frac{\Delta \ell}{\ell}$ <br>ased by 2% then frequen
	- **(44) (C).** On comparing the given equation with standard

equation 
$$
\Rightarrow \frac{2\pi}{\lambda} = \frac{\pi}{3} \Rightarrow \lambda = 6 \text{ cm}
$$
.

Distance between two consecutive nodes  $\Rightarrow \lambda = 3$ cm

(45) (C). 
$$
n \propto \frac{1}{\ell} \Rightarrow \frac{\Delta n}{n} = -\frac{\Delta \ell}{\ell}
$$

If length is decreased by 2% then frequency increases by

$$
2\% \text{ i.e., } \frac{n_2 - n_1}{n_1} = \frac{2}{100}
$$

$$
\Rightarrow n_2 - n_1 = \frac{2}{100} \times n_1 = \frac{2}{100} \times 392 = 7.8 \approx 8.
$$

**(A).** Probable frequencies of tuning fork be  $n + 4$  or  $n - 4$ 

Frequency of sonometer wire  $n \propto \frac{1}{a}$  $\ell$ 

segment (i.e., between two nodes) vionates in the same  
phase.  
(44) (C). On comparing the given equation with standard  
equation 
$$
\Rightarrow \frac{2\pi}{\lambda} = \frac{\pi}{3} \Rightarrow \lambda = 6
$$
 cm.  
Distance between two consecutive nodes  $\Rightarrow \lambda = 3$  cm  
(45) (C). n  $\propto \frac{1}{\ell} \Rightarrow \frac{\Delta n}{n} = -\frac{\Delta \ell}{\ell}$   
If length is decreased by 2% then frequency increases by  
2% i.e.,  $\frac{n_2 - n_1}{n_1} = \frac{2}{100}$   
 $\Rightarrow n_2 - n_1 = \frac{2}{100} \times n_1 = \frac{2}{100} \times 392 = 7.8 \approx 8$ .  
(46) (A). Probable frequencies of tuning fork be n + 4 or n - 4  
Frequency of sonometer wire n  $\propto \frac{1}{\ell}$   
 $\therefore \frac{n_+4}{n_+4} = \frac{100}{95}$  or 95 (n + 4) = 100 (n - 4)  
or 95n + 380 = 100n - 400 or 5n = 780 or n = 156  
(47) (D). For fundamental mode =  $\frac{\lambda}{2} = L$ ,  $\lambda = 2L$   
High L assure high λ.  
(48) (B). On comparing the given equation with standard  
equation  $\frac{2\pi}{\lambda} = 5 \Rightarrow \lambda = \frac{6.28}{5} = 1.256m$   
(49) (A). On comparing the given equation with standard  
equation  $\frac{2\pi}{\lambda} = \frac{\pi}{4} \Rightarrow \lambda = 8$ 

2  $\overline{\phantom{a}}$  $\lambda$   $\lambda$   $\lambda$   $\lambda$   $\lambda$   $\lambda$ 

High L assure high  $\lambda$ .

**(48) (B).** On comparing the given equation with standard

equation 
$$
\frac{2\pi}{\lambda} = 5 \implies \lambda = \frac{6.28}{5} = 1.256
$$
m

**(49) (A).** On comparing the given equation with standard

equation 
$$
\frac{2\pi}{\lambda} = \frac{\pi}{4} \Rightarrow \lambda = 8
$$

 $\frac{1}{11} = \frac{2}{100}$ <br>  $= \frac{2}{100} \times n_1 = \frac{2}{100} \times 392 = 7.8 \approx 8.$ <br>
Le frequencies of tuning fork be n + 4 or n - 4<br>
of sonometer wire n  $\propto \frac{1}{\ell}$ <br>  $= \frac{100}{95}$  or 95 (n + 4) = 100 (n - 4)<br>  $= 80$ <br>  $= 100n - 400$  or  $=$ Hence distance between two consecutive nodes  $\frac{\pi}{2}$  = 4 2  $\lambda$ ,  $\lambda$  $=4$ **(50) (A).** Fundamental frequency of open pipe uency of sonometer wire n  $\alpha \frac{1}{\ell}$ <br>  $\frac{n+4}{n-4} = \frac{100}{95}$  or 95 (n+4) = 100 (n-4)<br>
55n + 380 = 100n - 400 or 5n = 780 or n = 156<br>
For fundamental mode =  $\frac{\lambda}{2}$  = L,  $\lambda$  = 2L<br>
L assure high  $\lambda$ .<br>
On comparing th

$$
_1 = \frac{v}{2\ell} = \frac{350}{2 \times 0.5} = 350 \text{ Hz}
$$

**(D).** Fundamental frequency of open organ pipe  $= v/2\ell$ Frequency of third harmonic of closed pipe =  $3v/4\ell$ 

and harmonic of the source = 210 Hz or 190 Hz  
\nwe second harmonic is two and of  
\nenergy 205 Hz, the second harmonic should be 210Hz.  
\nLet n be the frequency of fork C then  
\n
$$
= n + \frac{3}{100} = \frac{103n}{100}
$$
 and  $n_B = n - \frac{2n}{100} = \frac{98}{100}$   
\n
$$
A - n_B = 5 \Rightarrow \frac{5n}{100} = 5 \Rightarrow n = 100 Hz
$$
\n
$$
A = \frac{(103)(100)}{100} = 103 Hz
$$
\n
$$
A = \frac{(103)(100)}{100} = 103 Hz
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A = \frac{(103)(100)}{100} = 103 Hz
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A = \frac{(103)(100)}{100} = 103 Hz
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A = \frac{(103)(100)}{100} = 103 Hz
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A = \frac{(103)(100)}{100} = 103 Hz
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A = \frac{(103)(100)}{100} = 103 Hz
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A = \frac{(103)(100)}{100} = 103 Hz
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A = \frac{(48)}{100} = 104 Hz
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A = \frac{(48)}{100} = 104 Hz
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A = \frac{(48)}{100} = 104 km
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\n
$$
A = \frac{(48)}{100} = 104 km
$$
\n
$$
A = \frac{(48)}{100} = 104 km
$$
\n
$$
A = \frac{(48)}{100} = 104 km
$$
\n<

**(52) (C).** Frequency of  $2^{nd}$  overtone  $n_3 = 5n_1 = 5 \times 50 = 250$  Hz

$$
50 \times \frac{270}{1000} = 13.5
$$
 cm (53) (A).  $n_1 = \frac{v}{4\ell}$  or  $\ell = \frac{v}{4n_1}$ 

**251**



$$
\therefore \quad \ell = \frac{332}{4 \times 512} \text{ m} = \frac{33200}{4 \times 512} \text{ cm} = 16.2 \text{ cm}
$$

(54) **(D).** 
$$
\frac{2v_0}{2\ell_0} = \frac{3v}{4\ell_c} = \frac{3v}{4\times3}
$$
;  $\ell_0 = 4$  meter

ObMADVMATERL1: PHYS	STUDY MATERIAL: PHYS	
$\therefore$ $\ell = \frac{332}{4 \times 512} \text{m} = \frac{33200}{4 \times 512} \text{cm} = 16.2 \text{cm}$	(67) (C). $\text{n'} = \text{n} \left( \frac{\text{v}}{\text{v} - \text{v}_s} \right) = 1200 \times \left( \frac{350}{350 - 50} \right) = 1400 \text{cps}$	
(54) (D). $\frac{2v_0}{2\ell_0} = \frac{3v}{4\ell_c} = \frac{3v}{4 \times 3}$ ; $\ell_0 = 4 \text{ meter}$	(68) (A). $\text{n'} = \frac{\text{v}}{\text{v} - \text{v}_s} \times \text{n} = \left( \frac{330}{330 - 110} \right) \times 150 = 225 \text{ Hz}$	
(55) (A). $\text{n } \propto \sqrt{T}$ (assuming no change in length)	(69) (A). $\text{n'} = \text{n} \left( \frac{\text{v}}{\text{v} - \text{v}_s} \right) \Rightarrow \text{n'} = 500 \left( \frac{330}{330 - 30} \right) = 550 \text{Hz}$	
$\frac{\text{n}}{320} = \sqrt{\left( \frac{300}{320} \right)}$ ; $\text{n}_1 = 320 \sqrt{\left( \frac{15}{16} \right)} \approx 310 \text{Hz}$	(70) (A). $\sum_{i=1}^{\infty} \frac{\text{s}}{\sqrt{5}}$	D.

320  
\n332  
\n(54) (b) 
$$
\frac{2v_0}{2\ell_0} = \frac{3v}{4\ell_0} = \frac{3v}{4 \times 512}
$$
 (c)  $-\frac{3200}{4\ell_0} = \frac{3v}{4 \times 512}$   
\n(d) (d)  $\ln \alpha \sqrt{T}$  (assuming no change in length)  
\n(e) (b)  $\ln \alpha \sqrt{T}$  (assuming no change in length)  
\n $\frac{2v_0}{3.0} = \sqrt{\frac{3v}{4\ell_0} = \frac{3v}{4\ell_0} = \frac{3v}{4 \times 5}$   
\n $\frac{3v}{4\ell_0} = \sqrt{\frac{3v}{4\ell_0} = \frac{3v}{4\ell_0}}$   
\n $\frac{3v}{4\ell_0} = \sqrt{\frac{3v}{4\ell_0} = \frac{v_2}{4\ell_0}}$   
\n $\frac{69}{3.30 - 110} = \sqrt{8 \times \frac{8}{3.30}} = \sqrt{8 \times 10^2 \times 10^2}$   
\n $\frac{69}{3.30 - 110} = \sqrt{8 \times \frac{8}{3.30}} = \sqrt{8 \times 10^2 \times 10^2}$   
\n $\frac{69}{3.30 - 30} = \sqrt{8 \times 10^2}$   
\n

**(57) (D).** For closed pipe

$$
n_1 = \frac{v}{4\ell} \Rightarrow \ell = \frac{v}{4n} = \frac{332}{4 \times 166} = 0.5m
$$

**(58) (B).** For closed pipe  $n_1 = \frac{1}{4} = \frac{330}{4} Hz$  $\frac{1}{\ell} = \frac{24}{4}$  Hz

Second note = 
$$
3n_1 = \frac{3 \times 300}{4}
$$
 Hz.

(59) (B). 
$$
n_{\text{Closed}} = \frac{1}{2}(n_{\text{Open}}) = \frac{1}{2} \times 320 = 160 \text{ Hz}
$$

**(60) (B).** For closed pipe

$$
n_1 = \frac{v}{41} \Rightarrow 250 = \frac{v}{4 \times 0.2} \Rightarrow v = 200 \text{ m/s}
$$
  
(61) (C).  $n_1 - n_2 = 10$ 

Using  $n_1 = \frac{v}{4\ell_1}$  and  $n_2 = \frac{v}{4\ell_2} \Rightarrow \frac{n_1}{n_2} = \frac{v_2}{\ell_1} = \frac{2}{2}$  $n_1 = \frac{v}{4\ell_1}$  and  $n_2 = \frac{v}{4\ell_2} \Rightarrow \frac{n_1}{n_2} = \frac{\ell_2}{\ell_1} = \frac{26}{25}$  ....(ii)  $n_2 = {v \over 4\ell_2} \Rightarrow {n_1 \over n_2} = {\ell_2 \over \ell_1} = {26 \over 25} ..... (ii)$ …..(ii) After solving these equation  $n_1 = 260$  Hz,  $n_2 = 250$  Hz

(62) **(B).** 
$$
n' = n \left( \frac{v}{v - v_S} \right) = 600 \left( \frac{330}{300} \right) = 660 \text{ cps}
$$

(63) (A). 
$$
n' = n\left(\frac{v - v_0}{v}\right) = \left(\frac{330 - 33}{330}\right) \times 100 = 90
$$
 Hz (74) (B).  $f_A$ 

(64) (A). 
$$
2n = n\left(\frac{v - v_0}{v - 0}\right) \Rightarrow v_0 = -v = -(
$$
Speed of sound)  
Negative sign indicates that observer is moving

Negative sign indicates that observer is moving opposite to the direction of velocity of sound.

**(65) (D).** Since there is no relative motion between observer and source, therefore there is no apparent change in frequency.

(66) (A). 
$$
n' = n \left( \frac{v}{v - v_S} \right) \Rightarrow \frac{n'}{n} = \frac{v}{v - v_S} \Rightarrow \frac{v}{v - v_S} = 3 \Rightarrow v_s = \frac{2v}{3}
$$

Q.B. SOLUTIONS  
\n
$$
r = \frac{332}{4 \times 512} \text{ m} = \frac{33200}{4 \times 512} \text{ cm} = 16.2 \text{ cm}
$$
\n(Q.B. SOLUTIONS)  
\n
$$
r = n \left( \frac{v}{v - v_s} \right) = 1200 \times \left( \frac{350}{350 - 50} \right) = 1400 \text{ cps}
$$
\n
$$
\frac{2v_0}{2\ell_0} = \frac{3v}{4\ell_c} = \frac{3v}{4 \times 3}; \quad \ell_0 = 4 \text{ meter}
$$
\n(Q.B. SOLUTIONS)  
\n(Q.B. SOLUTIONS)  
\n(G7)  
\n(G9)  
\n(A).  $n' = n \left( \frac{v}{v - v_s} \right) = 1200 \times \left( \frac{350}{330 - 110} \right) \times 150 = 225 \text{ Hz}$ \n
$$
r = \frac{330}{330 - 110} \times 150 = 225 \text{ Hz}
$$
\n
$$
\frac{1}{1} = \sqrt{\left( \frac{T_1}{T} \right)} = \sqrt{\left( \frac{273 + 27}{273 + 47} \right)}
$$
\n(G9)  
\n(A).  $n' = n \left( \frac{v}{v - v_s} \right) \Rightarrow n' = 500 \left( \frac{330}{330 - 30} \right) = 550 \text{ Hz}$ 

(68) (A). 
$$
n' = \frac{v}{v - v_s} \times n = \left(\frac{330}{330 - 110}\right) \times 150 = 225 \text{ Hz}
$$

(69) (A). 
$$
n' = n \left( \frac{v}{v - v_S} \right) \Rightarrow n' = 500 \left( \frac{330}{330 - 30} \right) = 550 \text{Hz}
$$

<b>ADL</b>		CDALIIONS	STDDVMATERIAL: PHYSICS
$\therefore$ $\ell = \frac{332}{4 \times 512} \text{ m} = \frac{33200}{4 \times 512} \text{ cm} = 16.2 \text{ cm}$	(67) (C). $n' = n \left( \frac{v}{v - v_s} \right) = 1200 \times \left( \frac{350}{350 - 50} \right) = 1400 \text{ cps}$		
$\text{(D) } \frac{2v_0}{2\ell_0} = \frac{3v}{4\ell_c} = \frac{3v}{4 \times 3} \; ; \quad \ell_0 = 4 \text{ meter}$	(68) (A). $n' = \frac{v}{v - v_s} \times n = \left( \frac{330}{330 - 110} \right) \times 150 = 225 \text{ Hz}$		
(A) $n \propto \sqrt{T}$ (assuming no change in length)	(69) (A). $n' = n \left( \frac{v}{v - v_s} \right) = n' = 500 \left( \frac{330}{330 - 30} \right) = 550 \text{ Hz}$		
$\frac{n_1}{n} = \sqrt{\frac{300}{T}} \; ; \quad n_1 = 320 \sqrt{\frac{15}{16}} \approx 310 \text{ Hz}$	(70) (A). $\frac{\sqrt{5}}{100}$	24. $\frac{1}{100} \times \frac{1}{100} \times \frac{1}{$	

Largest frequency will be detected when the source approaches detector along the line joining and the smallest frequency will be detected when the source recedes the detectors along the line joining them

$$
\frac{f_1}{f_2} = \frac{\left(\frac{c}{c-v}\right)f}{\left(\frac{c}{c+v}\right)f} = \frac{c+v}{c-v}
$$

(69) (A). 
$$
n' = n\left(\frac{v}{v - v_S}\right) \Rightarrow n' = 500\left(\frac{330}{330 - 30}\right) = 550
$$
 Hz  
\n $\therefore n_1 = 320\sqrt{\frac{15}{16}} \approx 310$  Hz.  
\n(70) (A).  $\sum_{\substack{v_2 \text{Largest frequency (f_1) \text{Lowers frequency (f_2)}}}$   
\n $\sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{1}{16}} = \frac{1}{4}$   $\therefore l_1 : l_2 = 1 : 4$   
\n $\frac{v_2}{d_1} = \frac{332}{4 \times 166} = 0.5$  m  
\npipe  
\n $\frac{v_1}{d_1} = \frac{3 \times 300}{4} \text{ Hz}$   
\n $3n_1 = \frac{3 \times 300}{4} \text{ Hz}$   
\n $3n_1 = \frac{3 \times 300}{4} \text{ Hz}$   
\n $\frac{1}{2}(n_{\text{open}}) = \frac{1}{2} \times 320 = 160$  Hz  
\n $\frac{1}{2} = \frac{1}{2} \times 320 = 160$  Hz  
\n $\frac{1}{2} = \frac{1}{2} \times 320 = 160$  Hz  
\n $\frac{1}{2} = \frac{1}{2} \times 320 = 160$  Hz

(56) (B). 
$$
n = \frac{v_1}{4f_1} = \frac{v_2}{4f_2}
$$
  
\n
$$
\frac{\ell_1}{\ell_2} = \frac{v_1}{v_2} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{1}{(16)}} = \frac{1}{4}
$$
\n
$$
\therefore \frac{\ell_1}{\ell_2} = \frac{v_2}{v_2} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{1}{(16)}} = \frac{1}{4}
$$
\n
$$
\therefore \frac{\ell_1}{\ell_2} = \frac{v_1}{v_2} = \sqrt{\frac{d_2}{d_1}} = \frac{1}{4 \times 166} = 0.5m
$$
\n(58) (B). For closed apipe  
\n
$$
n_1 = \frac{v}{4f} \Rightarrow \ell = \frac{330}{4} = \frac{332}{4 \times 166} = 0.5m
$$
\n(59) (B). For closed apipe  
\n
$$
n_1 = \frac{v}{4f} \Rightarrow 250 = \frac{330}{4} = \frac{330}{4 \times 166} = 0.5m
$$
\n(50) (C). For closed apipe  
\n
$$
n_1 = \frac{v}{4f} \Rightarrow 250 = \frac{v}{4 \times 0.2} \Rightarrow v = 200 \text{ m/s}
$$
\n(61) (C).  $n_1 = n_2 = 10$  ....(i) (71) (C).  
\n(d) (D). For closed apipe  
\n
$$
n_1 = \frac{v}{4f} \Rightarrow 250 = \frac{v}{4 \times 0.2} \Rightarrow v = 200 \text{ m/s}
$$
\n(61) (D.  $n_1 = n_2 = 10$  ....(i) (72) (C).  $\frac{A_1 + A_2}{A_1 - A_2} = x$ ;  $\frac{A_2}{A_1} = \frac{x-1}{x+1}$ ; Energy  $\propto A^2$   
\nUsing  $n_1 = \frac{v}{4f} \text{ and } n_2 = \frac{v}{4\ell_2} \Rightarrow \frac{n_1}{n_2} = \frac{\ell_2}{\ell_1} = \frac{25}{25} \text{ ....(i)}$   
\n(62) (B).  $n' = n \left(\$ 

(73) (C).  $v_{max} = \omega_n A = (2\pi f) A = (2\pi) (440) (10^{-6})$ <br>= 2.76 × 10<sup>-3</sup> m/sec

(74) **(B).** 
$$
f_A - \frac{v + v_A}{v} f
$$
, or  $v_A = \frac{v}{f} (f_A - f)$ 

$$
f_B = \frac{v + v_B}{v} f, \text{ or } v_B = \frac{v}{f} (f_B - f)
$$

$$
\frac{v_B}{v_B} = \frac{f_B - f}{v_B} = \frac{6.0 - 5}{v_B} = \frac{1}{v_B} = 2
$$

$$
\therefore \frac{1}{v_A} - \frac{1}{f_A - f} = \frac{1}{5.5 - 5} - \frac{1}{0.5} - 2
$$

(75) (A). 
$$
L = \frac{m\lambda_1}{2}
$$
 and  $L(m+1)\frac{\lambda_2}{2}$ ,

where m is no. of harmonic  $m.36 = (m+1) 32 \implies m=8$ ; L=8 × 18 = 144 cm.

 $\ldots$  . (i)



**(76) (A).** Tension  $T = kx$ ,  $T' = 1.5x$ 

WES	Q.B.- SOLUTIONS	Q.B.- SOLUTIONS
(A). Tension T = kx, T' = 1.5x	(B)	$f = \frac{v}{2(2\ell)}, \frac{2v}{2(2\ell)}, \$

- **(77) (B).** Towards right wavelength gets compressed, towards left, wavelength gets expanded.
- (78) **(D).**  $x_1$  and  $x_2$  are in successive loops of std. waves.  $\phi_1 = \pi$  and

$$
\phi_2 = K (\Delta x) = K \left( \frac{3\pi}{2K} - \frac{\pi}{3K} \right) = \frac{7\pi}{6} = \frac{\phi_1}{\phi_2} = \frac{6}{7}
$$

(**Q.B. SOLUTIONS**<br>
T ..  $\frac{v'}{v} = \sqrt{\frac{\Gamma}{T}} = \sqrt{1.5} = 1.22$  or  $v' = 1.22v$ <br>
(B)  $\frac{2v}{\sqrt{2(2\ell)}} = \sqrt{2(2\ell)} \cdot \frac{3v}{2(2\ell)}$ <br>
sing the twavelength gets compressed, towards<br>
and  $x_2$  are in successive loops of std. waves.<br>  $\$ **(O.B.- SOLUTIONS** BONDADVANCED LEADING<br>
1.5x<br>  $\frac{1}{\sqrt{17}} = \sqrt{1.5} = 1.22$  or  $v' = 1.22v$ <br>  $\left(\frac{1.5x}{17}\right)^2 = \sqrt{1.5} = 1.22$  or  $v' = 1.22v$ <br>  $\frac{1.5x}{17} = \sqrt{1.5} = 1.22$  or  $v' = 1.22v$ <br>  $\frac{1.5x}{17} = \sqrt{1.5} = 1.22$  or  $v' = 1$ **(Q.B.- SOLUTIONS**<br>
SERVICUTIONS)<br>
The street of the strength and the street energies of the street energies of the strength and the street energies of the strength and the strength and the strength and the strength and **(79) (A).** Since the frequency of beats in 4 Hz, the frequency of the second tuning fork will be either  $384 + 4 = 388$ Hz, or  $384 - 4 = 380$  Hz. On loading, the frequency decreases. (3) If 388 Hz be the true frequency, the beats after loading may disappear since frequency may decrease from 388Hz to 384 Hz. The frequency 380Hz is not permissible , since if will decrease further and cannot increase to 384Hz. Hence 388 Hz is the true frequency. (**80) (A).**  $x_1$  and  $x_2$  are in successive loops of std. waves.<br>
so,  $\phi_1 = \pi$  and<br>  $\phi_2 = K (\Delta x) = K \left( \frac{3\pi}{2K} - \frac{\pi}{3K} \right) = \frac{7\pi}{6} = \frac{\phi_1}{\phi_2} = \frac{6}{7}$ <br> **(19) (A).** Since the frequency of beats in 4 12, at the f and<br>
and<br>
and<br>  $\Delta x$ ) =  $K\left(\frac{3\pi}{2K} - \frac{\pi}{3K}\right) = \frac{7\pi}{6} = \frac{\phi_1}{\phi_2} = \frac{6}{7}$ <br>
(D)<br>
f =  $\frac{v}{2(\ell/2)}, \frac{2v}{2(\ell/2)}$ <br>
cannot match with f<sub>wi</sub><br>
traguency of beats in 4 Hz, the frequency<br>
ming fork will be either 384+4 = 3 Since  $v \propto \sqrt{T}$ .  $v = \sqrt{T} - \sqrt{1.5} = 1.22$  or  $v' = 1.22v$ <br> **(B)**. Towards right wavelength gets compressed, towards<br>
(c) The matrix  $\frac{2v}{2(2\ell)}$  matches with<br>
left, wavelength gets expanded.<br>
(c)  $\frac{8}{\sqrt{1 + \left(\frac{3\pi}{2K} - \$ d  $x_2$  are in successive loops of std. waves.<br>  $x = \pi$  and<br>  $x = k$  ( $\Delta x$ ) =  $K\left(\frac{3\pi}{2K} - \frac{\pi}{3K}\right) = \frac{7\pi}{6} = \frac{6}{\phi_2} = \frac{6}{7}$ <br>  $x = \frac{6}{2K}$ <br>  $x = \frac{300 \text{ Hz}}{4 \text{ kg/m}^2}$ , the frequency of beats in 4 Hz, the frequency<br> wards right wavelength gets compressed, towards<br>
vealength gets expanded.<br>
welength gets expanded.<br>  $\phi_2 = K (\Delta x) = K \left(\frac{3\pi}{2K} - \frac{\pi}{3K}\right) = \frac{7\pi}{6} = \frac{\phi_1}{\phi_2} = \frac{6}{7}$ <br>  $\phi_2 = K (\Delta x) = K \left(\frac{3\pi}{2K} - \frac{\pi}{3K}\right) = \frac{7\pi}{6} = \frac{\phi$ 80,  $\phi_1 = \pi$  and<br>  $\phi_2 = K (\Delta x) = K \left(\frac{3\pi}{2K} - \frac{\pi}{3K}\right) = \frac{7\pi}{6} = \frac{\phi_1}{\phi_2} = \frac{6}{7}$ <br> **(79)** (A). Since the frequency of beats in 4 Hz, the frequency<br>
of the second tunning fork will be either 384 + = 388Hz.<br>
or 384

(80) (A). 
$$
\ell_1 + \varepsilon = \frac{v}{4f_0} \Rightarrow \ell_2 + \varepsilon = \frac{3v}{4f_0} \Rightarrow \ell_3 + \varepsilon = \frac{5v}{4f_0}
$$

**(81) (C).** 
$$
\left[ \left( \frac{v}{v - v_s} \right) - \left( \frac{v}{v + v_s} \right) \right] f_0 = 2 Hz
$$
;  $v_s = 0.5$  m/s

(82) (A). 
$$
V = \sqrt{\frac{B}{\rho}} \Rightarrow B = V^2 \rho
$$

$$
= (5.40 \times 10^3 \,\mathrm{m/s})^2 (2.7 \times 10^3) = 7.9 \times 10^{10} \,\mathrm{Pa}
$$

**(83) (D).** One octave higher means the note whose frequency is 2 times the given frequency. Similarly 2 octave higher means 3 times the given frequency, which is  $3 \times 128$  Hz = 384 Hz.

if will decrease in the *n*th element increase to 384Hz.  
\nHence 388 Hz is the true frequency.  
\n**(80)** (A) 
$$
\ell_1 + \epsilon = \frac{v}{4f_0} \Rightarrow \ell_2 + \epsilon = \frac{3v}{4f_0} \Rightarrow \ell_3 + \epsilon = \frac{5v}{4f_0}
$$
  
\n(b) (A)  $\left[ \left( \frac{v}{v-v_s} \right) - \left( \frac{v}{v+v_s} \right) \right] f_0 = 2Hz$ ;  $v_s = 0.5$  m/s  
\n**(82)** (A)  $V = \sqrt{\frac{B}{p}} \Rightarrow B = V^2p$   
\n**(83)** (B)  $\sqrt{2}$ ,  $\sqrt{4}$ ,  $V = \sqrt{\frac{B}{p}} \Rightarrow B = V^2p$   
\n**(84)** (C)  $\frac{a_1 + a_2}{a_1 + a_2} = 5 \Rightarrow a_1 + a_2 = 5 \text{ (a}_1 - a_2)$   
\n $= 5 \frac{a_1}{3} g/m \text{ of } \frac{1}{3} g/m$ 

The maximum possible path difference = distance between the sources  $= 3m$ .

2  $\lambda$  6  $\therefore$  If f < 55 Hz, no, minimum will occur.

**(2) (B).** Fundamental frequency of wire  $(f_{\text{wire}}) = \frac{V}{2\ell}$ 

(A) 
$$
f = \frac{v}{4\ell}, \frac{3v}{4\ell}, \frac{5v}{4\ell}
$$
 cannot match with f<sub>wire</sub>

**Q.B. SOLUTIONS**  
\n
$$
\frac{v'}{v} = \sqrt{\frac{T'}{T}} = \sqrt{1.5} = 1.22 \text{ or } v' = 1.22v
$$
\n
$$
\frac{v'}{v} = \sqrt{\frac{T'}{T}} = \sqrt{1.5} = 1.22 \text{ or } v' = 1.22v
$$
\n
$$
\frac{1.22}{v} = \sqrt{\frac{T'}{T}} = \sqrt{1.5} = 1.22 \text{ or } v' = 1.22v
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \text{ or } v' = 1.22v}
$$
\n
$$
\frac{2v}{2(2\ell)} = \sqrt{1.22 \
$$

its second harmonic  $\frac{1}{2(2\ell)}$  $2v$ matches with  $f_{wire}$ .

(C) 
$$
f = \frac{v}{2(\ell/2)}, \frac{2v}{2(\ell/2)}
$$

cannot match with  $f_{\text{wire}}$ .

$$
f = \frac{v}{2(2\ell)}, \frac{2v}{2(2\ell)}, \frac{3v}{2(2\ell)}
$$
  
second harmonic  $\frac{2v}{2(2\ell)}$  matches with f<sub>wire</sub>.  

$$
f = \frac{v}{2(\ell/2)}, \frac{2v}{2(\ell/2)}
$$
  
cannot match with f<sub>wire</sub>.  

$$
f = \frac{v}{4(\ell/2)}, \frac{3v}{4(\ell/2)}
$$
  
cannot match with f<sub>wire</sub>.  
The speed of sound wave is

cannot match with  $f_{\text{wire}}$ .<br>(A). The speed of sound wave is

(D)

$$
v = \sqrt{\frac{\gamma RT}{M}}
$$
, where  $\gamma = \left(\frac{c_p}{c_v}\right)_{mixture}$ 

The molecular weight of the mixture

Tension T = kx, T = 1.5x  
\n
$$
v \propto \sqrt{r}
$$
.  $\frac{v'}{v} = \sqrt{\frac{17}{17}} = \sqrt{1.5} = 1.22$  or  $v' = 1.22v$   
\nTo  
\n
$$
v \propto \sqrt{r}
$$
.  $\frac{v'}{v} = \sqrt{\frac{17}{17}} = \sqrt{1.5} = 1.22$  or  $v' = 1.22v$   
\nTo  
\n
$$
v \propto \sqrt{r}
$$
.  $\frac{v'}{v} = \sqrt{\frac{17}{17}} = \sqrt{1.5} = 1.22$  or  $v' = 1.22v$   
\nTo  
\n*W*<sub>1</sub> and *W*<sub>2</sub> are in successive loops of sid, waves.  
\n
$$
\Phi_1 = K
$$
 (ax) = K  $\left(\frac{3\pi}{3.5}, \frac{\pi}{3.5}\right) = \frac{7\pi}{6} = \frac{\phi_1}{6} = \frac{6}{7}$   
\nSince the frequency of beats in 4 H4 = 188 H4 = 488 H4 = 484 H4 = 480 H4x. On loading, the frequency decreases.  
\n
$$
d = 44 - 380 H2c
$$
 On loading, the frequency of the best arc from 888H2.  
\nH decrease further and cannot increase to 384H1/  
\nH decrease for the arc frequency, the between *u* and *v* are 188H4.  
\nH decrease in the arc frequency, the between *u* and *v* are 188H4 = 188 H4 = 188 H4 = 188 H4 = 188 H4 = 184 H

$$
(c_v)_{mixture} = \frac{(n_1c_v)_{He} + (n_1c_v)_{O_2}}{n_1 + n_2} = \frac{1 \times \frac{3}{2}R + 2 \times \frac{5}{2}R}{1 + 2} = \frac{13}{6}R
$$
  
\n
$$
(c_p)_{mixture} = (c_v)_{mixture} + R = \frac{19}{6}R \quad \therefore
$$
  
\n
$$
(\gamma)_{mixture} = \frac{(c_p)_{mixture}}{(c_v)_{mixture}} = \frac{19}{13}
$$
  
\nSubstituting these values, we get  
\n
$$
v = \sqrt{\frac{19}{13} \times 8.31 \times (273 + 27) / \frac{68}{3} \times 10^{-3}} = 400.93 \text{ m/s}
$$
  
\n(C). For first resonance with 400 Hz tuning fork  
\n
$$
\ell_{eq} = \frac{V}{4f_0} = \frac{V}{4(400)} = (19 + 1) = 20 \text{cm}.
$$
  
\nIf we use 1600 Hz tuning fork  
\n
$$
\frac{V}{4f_0} = \frac{V}{4 \times (1600)} = \frac{20}{4} = 5 \text{cm}.
$$
  
\nFor resonance  
\n
$$
\ell_{eq} = \frac{V}{4f_0}, \frac{3V}{4f_0}, \frac{5V}{4f_0}, \frac{7V}{4f_0}, \dots
$$

$$
(c_p)_{mixture} = (c_v)_{mixture} + R = \frac{19}{6}R
$$
  $\therefore$ 

$$
(\gamma)_{\text{mixture}} = \frac{(c_{\text{p}})_{\text{mixture}}}{(c_{\text{v}})_{\text{mixture}}} = \frac{19}{13}
$$

Substituting these values, we get

7.9 × 10<sup>10</sup> Pa  
\n(6<sub>p</sub>)<sub>mixture</sub> = (c<sub>v</sub>)<sub>mixture</sub> + R = 
$$
\frac{19}{6}
$$
 R  
\nwhose frequency  
\ntimes the given  
\n7.9 × 10<sup>10</sup> Pa  
\n6.2  
\n6.3  
\n6.3  
\n6.4  
\n7.5  
\n6.5  
\n6.5  
\n6.5  
\n6.6  
\n6.6  
\n6.7  
\n6.7  
\n6.8  
\n6.9  
\n
$$
(r)_{mixture} = \frac{(c_p)_{mixture}}{(c_v)_{mixture}} = \frac{19}{13}
$$
\n6.1  
\n6.1  
\n6.1  
\n6.1  
\n6.2  
\n6.2  
\n6.3  
\n6.3  
\n6.3  
\n6.3  
\n6.4  
\n6.5  
\n6.5  
\n6.5  
\n6.6  
\n6.6  
\n
$$
v = \sqrt{\frac{19}{13} \times 8.31 \times (273 + 27)/\frac{68}{3} \times 10^{-3}} = 400.93 \text{ m/s}
$$
\n6.4  
\n6.5  
\n6.6  
\n6.6  
\n6.7  
\n
$$
c_{eq} = \frac{V}{4f_0} = \frac{V}{4(400)} = (19 + 1) = 20 \text{ cm}.
$$
\n6.8  
\n6.9  
\n6.1  
\n

**(4) (C).** For first resonance with 400 Hz tuning fork

$$
\ell_{\text{eq}} = \frac{V}{4f_0} = \frac{V}{4(400)} = (19+1) = 20 \text{cm}.
$$

20cm

If we use 1600 Hz tuning fork

$$
\frac{V}{4f_0} = \frac{V}{4 \times (1600)} = \frac{20}{4} = 5 \text{ cm.}
$$

For resonance

$$
\frac{V}{\lambda} < \frac{330}{6} = 55
$$
\n
$$
\ell_{\text{eq}} = \frac{V}{4f_0}, \frac{3V}{4f_0}, \frac{5V}{4f_0}, \frac{7V}{4f_0}, \dots
$$

 $v = 4$ cm, 14 cm, 24 cm, 34 cm, 44 cm, ..........

 $\ell$  water level should be further lowered by,

$$
24-19=5 \text{ cm}
$$

$$
34 - 19 = 15
$$
 cm





$$
= \sqrt{5A^2 + 2A^2} = A\sqrt{7} \qquad \therefore I = 7I_0
$$



The velocity of profile of each elementary section of the pulse is shown in figure 1 and figure 2.

When both the pulses completely overlaps, the velocity profiles of both the pulses in overlap region are identical. By superposition, velocity of each elementary section doubles. Therefore, KE of each section becomes four times. Hence the K.E. in the complete width of overlap becomes four times. velocity of profile of each elementary section of the<br>
is shown in figure 1 and figure 2.<br>
In both the pulses completely overlaps, the velocity<br>
les of both the pulses in overlap region are identical.<br>
uperposition, veloc welocity of profile of each elementary section of the<br>
2 is shown in figure 1 and figure 2.<br>
In both the pulses completely overlaps, the velocity<br>
les of both the pulses in overlap region are identical.<br>
uperposition, vel **1.**  $\int_{\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{e^{i\pi}}{i\pi^{4}t^{2}}$ <br>
Eigure 1 and figure 1 and figure 2<br>
Levelocity of profile of each elementary section of the<br>
se is shown in figure 1 and figure 2.<br>
Even both the pulses invertigation are ide city of profile<br>
Figure-1<br>
Figure-1<br>
Figure-1<br>
Figure-1<br>
Figure-1<br>
Figure-1<br>
Triggere-2<br>
City of profile of each elementary section of the<br>
the pulses inverting projection the pulses in the pulses of the distribution<br>
(pr **1.**  $\int_{0}^{\frac{\pi}{2}} \int_{0}^{\frac{\pi}{2}} \frac{\sec \theta}{1 + \sec \theta}$ <br>
Figure-1<br>
Figure-1<br>
Figure-1<br>
Service Figure-1<br>
Service of each elementary section of the<br>
shown in figure 1 and figure 2.<br>
Service of each elementary section of the<br>
shown Society of profile of each elementary section of the<br>
shown in figure 1 and figure 2. The and figure 2. The velocity overlaps, the velocity<br>
orth the pulses completely overlaps, the velocity<br>
erposition, velocity of each shown in figure 1 and figure 2.<br>
of both the pulses completely overlaps, the velocity<br>
or fboth the pulses in overlap region are identical.<br>
Example the direct of each elementary section<br>
Hence the K.E. in the complete wi ty of profile of each elementary section of the<br>
was in figure 1 and figure 2.<br>
the pulses completely overlaps, the velocity<br>
both the pulses in overlap region are identical.<br>
Sittion, velocity of each elementary section<br>

(7) **(D).** Fundamental frequency 
$$
f = \frac{1}{2\ell} \sqrt{\frac{T}{\mu}}
$$
  $t = \frac{400}{2}$ 

pronues of point the pulses in overlap region are identical.  
\nBy superposition, velocity of each elementary section  
\ndoubles. Therefore, KE of each elementary section  
\nbecomes four times.  
\n(b). Fundamental frequency 
$$
f = \frac{1}{2\ell} \sqrt{\frac{T}{\mu}}
$$
  
\n $\therefore \frac{f_1}{f_2} = \frac{\ell_1}{\ell_2} \sqrt{\frac{\mu_2}{\mu_1}}$  (since tension is same)  
\n $= \frac{2L}{L} \sqrt{\frac{\pi r^2 \rho}{\pi \cdot 4r^2 \rho}}$ , (since the wires are of same material) = 1  
\n(b).  $\frac{E_r}{E_i} = \left(\frac{A_r}{A_i}\right)^2 = \left(\frac{V_2 - V_1}{V_1 + V_2}\right)^2 = 1/9$ ;  $\frac{E_t}{E_i} = \frac{8}{9}$   
\n(c).  $v = \frac{n}{2\ell} \sqrt{\frac{T}{m}}$   $\Rightarrow n = 3$  initially.  
\nHence two more resonance will occur at 40cm. and 20cm.  
\n $1:(\sqrt{2}-1)$   
\n $\frac{1}{2} = \frac{V_1 - V_1}{V_2 + V_1} = \frac{V_1 - V_2}{V_1 + V_2} = \frac{V_1 - V_1}{V_1 + V_2}$   
\n $\Rightarrow \frac{V_1 - V_2}{V_1 + V_2} = \frac{V_1 - V_1}{V_1 + V_2}$   
\n $\Rightarrow \frac{V_1 - V_2}{V_1 + V_1} = \frac{V_1 - V_1}{V_1 + V_2} = \frac{V_1 - V_1}{V_1 + V_2}$   
\n $\Rightarrow \frac{V_1 - V_1}{V_1 + V_1} = \frac{V_1 - V_1}{V_1 + V_1} = \frac{V_1 - V_1}{V_1 + V_1}$   
\n $\Rightarrow \frac{V_1 - V_1}{V_1 + V_1} = \frac{V_1 - V_1}{V_1 + V_1} = \frac{V_1 - V_1}{V_1 + V_1} = \frac{V_1 - V_1}{V_1 + V_1}$   
\n $\Rightarrow \frac{V_1 - V_1}{V_1 + V_1} = \frac{V_1 - V_1}{V_1 + V_1} = \frac{V_1 - V_1}{V_1 + V_1}$ 

(8) **(D).** 
$$
\frac{E_r}{E_i} = \left(\frac{A_r}{A_i}\right)^2 = \left(\frac{V_2 - V_1}{V_1 + V_2}\right)^2 = 1/9; \frac{E_t}{E_i} = \frac{8}{9}
$$
 (13)

(9) (C). 
$$
v = {n \over 2\ell} \sqrt{1 \over m} \implies n = 3
$$
 initially.

Hence two more resonance will occur at 40cm. and 20cm. length of the horizontal part of wire. As acceleration of system is constant therefore ratio of time gap must be

- **(10) (B).** Given :
- $y = 4 \cos^2(t) \sin(1000t) = 2 [1 + \cos 2t] \sin(1000t)$ **STUDY MATERIAL: PHYSICS**<br>
ven:<br>
y = 4 cos<sup>2</sup> (t) sin (1000t) = 2 [1 + cos 2t] sin (1000t)<br>
2 sin 1000t + 2 sin 1000t · cos 2t<br>
= 2 sin 1000t + sin 1002t + sin 998t<br>
ne periodic motion consists of three components.<br>
y = A **STUDY MATERIAL: PHYSICS**<br>
ven :<br>
y = 4 cos<sup>2</sup> (t) sin (1000t) = 2 [1 + cos 2t] sin (1000t)<br>
2 sin 1000t + 2 sin 1000t · cos 2t<br>
= 2 sin 1000t + sin 1002t + sin 998t<br>
ne periodic motion consists of three components.<br>
y = **(10) (B).** Given:<br>  $y=4 \cos^2(t) \sin(1000t) = 2 [1 + \cos 2t] \sin(1000t)$ <br>  $2 \sin 1000t + 2 \sin 1000t \cdot \cos 2t$ <br>  $= 2 \sin 1000t + \sin 1002t + \sin 998t$ <br>
Thus the periodic motion consists of three components.<br> **(11) (B).** As  $y = A_b \sin(2\pi n_{av}t)$ ; **SDEAD: PHYSICS**<br> **B).** Given:<br>  $y = 4 \cos^2(t) \sin(1000t) = 2[1 + \cos 2t] \sin(1000t)$ <br>  $2 \sin 1000t + 2 \sin 1000t \cdot \cos 2t$ <br>  $= 2 \sin 1000t + \sin 1002t + \sin 998t$ <br>
Thus the periodic motion consists of three components.<br> **B).** As  $y = A_b \sin(2\pi n_{av}t)$ **ERIAL: PHYSICS**<br>  $-\cos 2t \sin (1000t)$ <br>
98t<br>
three components.<br>  $\frac{n_1 - n_2}{2}$ <br>
2<br>
ve in air is<br>
mference of the
	-

Thus the periodic motion consists of three components.

$$
A_b = 2A \cos (2\pi n_A t)
$$
, where  $n_A = \frac{n_1 - n_2}{2}$ 

**(12) (A).** The wavelength of the sound wave in air is

$$
\lambda = \frac{320}{16 \times 10^3} = 2 \times 10^{-2} \,\mathrm{m} \,.
$$

**SDEA**<br>
SUDY MATERIAL: PHYSICS<br>
B). Given:<br>  $y = 4 \cos^2(t) \sin(1000t) = 2 [1 + \cos 2t] \sin(1000t)$ <br>  $2 \sin 1000t + 2 \sin 1000t \cos 2t$ <br>  $= 2 \sin 1000t + \sin 1002t + \sin 998t$ <br>
Thus the periodic motion consists of three components.<br> **(B).** As  $y = A_b \$ The positions of maxima on the circumference of the circular track will be given by

 $d \sin \theta = n\lambda$ 

**STUDY MATERIAL: PHYSICS**<br>
iven :<br>
y = 4 cos<sup>2</sup> (t) sin (1000t) = 2 [1 + cos 2t] sin (1000t)<br>
2 sin 1000t + 2 sin 1000t · cos 2t<br>
= 2 sin 1000t + sin 1002t + sin 998t<br>
he periodic motion consists of three components.<br>
s y **STUDY MATERIAL: PHYSICS**<br>
Given:<br>  $y=4 \cos^2(t) \sin(1000t) = 2 [1 + \cos 2t] \sin(1000t)$ <br>  $2 \sin 1000t + 2 \sin 1000t \cdot \cos 2t$ <br>  $= 2 \sin 1000t + \sin 1002t + \sin 998t$ <br>
the periodic motion consists of three components.<br>
As  $y = A_b \sin(2\pi n_{av}t)$ ; where<br> When d is the separation between the sources and  $\theta$  is the angular position of  $n<sup>th</sup>$  maximum as shown in the figure



Since sin  $\theta$  lies between 0 and 1 there are 400 maxima on the entire circle.

These 400 maxima will be heard by the person in the time

$$
t = \frac{400}{2} = 200s
$$

Speed of the train = 
$$
36 \text{ km/h} = 36 \times \frac{5}{18} = 10 \text{ m/s}
$$

From the obtained values so far we get length of the track  $\ell = (10 \text{ m/s}) (200 \text{s}) = 2000 \text{m}$ 

So radius of the track 
$$
=
$$
  $\frac{2000}{2\pi} = \frac{1000}{\pi}$  m

$$
\frac{E_t}{E_i} = \frac{8}{9}
$$
 (13) (C).  $V_1 = \sqrt{\frac{T}{\mu}}$ ;  $V_2 = \sqrt{\frac{T}{4\mu}}$   $\frac{4\mu}{\mu}$ 

 $V_2$  < V<sub>1</sub>  $\Rightarrow$  2nd is denser  $\Rightarrow$  phase change of  $\pi$ wave reflected from denser medium

Since sin 
$$
\theta
$$
 lies between 0 and 1 there are 400 maxima on  
the entire circle.  
These 400 maxima will be heard by the person in the time  
 $t = \frac{400}{2} = 200s$   
Speed of the train = 36 km/h = 36 ×  $\frac{5}{18}$  = 10 m/s  
From the obtained values so far we get length of the track  
 $\ell = (10 \text{ m/s})(200\text{s}) = 2000\text{m}$   
So radius of the track =  $\frac{2000}{2\pi} = \frac{1000}{\pi} \text{m}$   
(C).  $V_1 = \sqrt{\frac{T}{\mu}}$ ;  $V_2 = \sqrt{\frac{T}{4\mu}}$   
 $V_2 < V_1 \Rightarrow 2\text{nd is denser} \Rightarrow \text{phase change of } \pi$   
wave reflected from denser medium  
 $\Rightarrow A_r = \frac{V_2 - V_1}{V_2 + V_1} \times 6 = \frac{\frac{V_1}{2} - V_1}{\frac{V_2}{2} + V_1} \times 6 = -2\text{mm}$   
 $\Rightarrow$  eq<sup>n</sup>  $\Rightarrow$  -(2mm) sin (5t-40x)

$$
\Rightarrow eq^n \Rightarrow -(2mm)\sin(5t-40x)
$$

**254**



WAVES	Q.B. SOLUTIONS	EXERCISE-3		
(14) (D) $\frac{3}{8} = (2n+1)\frac{\lambda}{4}$ ;	$\lambda = \frac{340}{680} = \frac{1}{2}m \Rightarrow n = 1$	$3/8$	(1)	3. $\lambda = \frac{v}{f} = \frac{330}{500} = 0.66m = \frac{4\ell}{2n-1} \Rightarrow n = 3$
next overtone $\Rightarrow n = 2$	$x = \frac{\lambda}{2} = \frac{1}{4}m = 25$ cm	$x = \frac{\lambda}{2} = \frac{1}{4}m = 25$ cm	$t_0 = \frac{300 + 20}{330 + 20 - 10} = \frac{350}{340} \times 510 = 525$ Hz	
(15) (A). $\lambda_A = (10u - \frac{u}{2})\frac{1}{f} = \frac{9.5u}{f} \Rightarrow \frac{\lambda_A}{\lambda_B} = \frac{19}{21}$	(3)	12. Imagine a power Intensity of sound at the surface of cylinder is an everywhere. Therefore, $I = \frac{P}{2\pi rL}$		
(16) (A). The figure shows variation of displacement of particles in a closed organ pipe for 3 <sup>rd</sup> overtone.	(As sound is propagating radially out only, your ergy			
For third overtone	$\ell = \frac{7\lambda}{4}$ or $\lambda = \frac{4\ell}{7}$ or $\frac{\lambda}{4} = \frac{\ell}{7}$	Hence the amplitude at P at a distance $\ell/7$ from closed end is 'a' because there is an antinode at that point.	(4)	2. $f = \frac{1}{2\ell} \sqrt{\frac{T}{\mu}}$

(15) (A). 
$$
\lambda_A = \left(10u - \frac{u}{2}\right) \frac{1}{f} = \frac{9.5u}{f}
$$

$$
\Rightarrow \lambda_B = \left(10u + \frac{u}{2}\right) \frac{1}{f} = \frac{10.5u}{f} \Rightarrow \frac{\lambda_A}{\lambda_B} = \frac{19}{21}
$$

**(16) (A).** The figure shows variation of displacement of particles in a closed organ pipe for 3<sup>rd</sup> overtone.



For third overtone  $\ell = \frac{7\lambda}{4}$  or  $\lambda = \frac{4\ell}{7}$  or  $\frac{\lambda}{4} = \frac{\ell}{7}$ 4  $7$   $4$  7  $\ell = \frac{7\lambda}{4}$  or  $\lambda = \frac{4\ell}{7}$  or  $\frac{\lambda}{4} = \frac{\ell}{7}$  $7 \t 4 \t 7$ 

Hence the amplitude at P at a distance  $\ell/7$  from closed end is 'a' because there is an antinode at that point.

(17) (C). 
$$
A_t = \frac{2 \sqrt{\mu_\ell}}{\sqrt{\mu_\ell} + \sqrt{\mu_r}} A_i
$$
 (4)

 $\lambda_A = \left(10u - \frac{u}{2}\right) \frac{1}{f} = \frac{9.5u}{f}$ <br>  $\lambda_B = \left(10u + \frac{u}{2}\right) \frac{1}{f} = \frac{10.5u}{f}$ <br>  $\lambda_B = \frac{19}{21}$ <br>
The figure shows variation of displacement of<br>  $\lambda_E = \frac{P}{\sqrt{1.5}}$ <br>
The figure shows variation of displacement of<br>  $\ell = \$ **(18) (B).** Let the sound observed by the parachutist at  $t_0 = 12s$ be produced at  $t_1$ s. Velocity of source at the instant of sound  $=gt_1$  and velocity of observer at the instant of observing same sound =  $gt_0$ . Hence the relation between apparent frequency f ' and original frequency f will be (5) For third overtone  $\ell = \frac{7\lambda}{4}$  or  $\lambda = \frac{4\ell}{7}$  or  $\frac{\lambda}{4} = \frac{\ell}{7}$ <br>
For third overtone  $\ell = \frac{7\lambda}{4}$  or  $\lambda = \frac{4\ell}{7}$  or  $\frac{\lambda}{4} = \frac{\ell}{7}$ <br>
Hence the amplitude at IP at a distance  $\ell/7$  from closed<br>
and is 'a' be vertione  $\ell = \frac{7\lambda}{4}$  or  $\lambda = \frac{4\ell}{7}$  or  $\frac{\lambda}{4} = \frac{\ell}{7}$ <br>
e amplitude at P at a distance  $\ell/7$  from closed<br>  $\frac{2\sqrt{\mu_{\ell}}}{\sqrt{\mu_{\ell}} + \sqrt{\mu_{\tau}}}$  A<sub>i</sub><br>  $\frac{2}{\sqrt{\mu_{\ell}} + \sqrt{\mu_{\tau}}}$  A<sub>i</sub><br>  $\frac{2}{\sqrt{\mu_{\ell}} + \sqrt{\mu_{\tau}}}$  A<sub>i</sub><br>
(4) e figure shows variation of displacement of<br>  $\epsilon$  is in a closed organ pipe for 3<sup>rd</sup> overtone.<br>  $\epsilon$  is a closed organ pipe for 3<sup>rd</sup> overtone.<br>
The amplitude at P at a distance  $\ell$ ? from closed<br>  $\epsilon$  is the amplitude a articles in a closed organ pipe for 3<sup>rd</sup> overtone.<br>
Figure 1 and coverage the amplitude at P at a distance  $\ell/7$  from closed<br>
dis 'a' because there is an antimode at that point.<br>
Thence the amplitude at P at a distance

$$
f' = f\left(\frac{v + gt_0}{v - gt_1}\right).
$$



Here  $f = 800$  Hz,  $g = 10$  m/s<sup>2</sup>,  $v = 330$  m/s,  $t_0 = 12$ s and (7)  $f' = 800 + 700 = 1500$  Hz

Putting these, we get,  $t_1 = 9s$ 

Now the distance traveled by sound in  $(t_0 - t_1)$  sec is

$$
v(t_0 - t_1) = \left(h - \frac{1}{2}gt_0^2\right) + \left(h - \frac{1}{2}gt_1^2\right)
$$

Putting the values, we get,  $h = 1057.5m$ .

#### **EXERCISE-3**

LUTIONS  
\n**EXERCISE-3**  
\n(1) 
$$
3. \ \lambda = \frac{v}{f} = \frac{330}{500} = 0.66 \text{m} = \frac{4\ell}{2\text{n} - 1} \Rightarrow \text{n} = 3
$$
  
\n(2)  $525. \ \text{f} = \frac{c + v_w}{c + v_w - v_s \sin 30^\circ}$   
\n $f = \frac{300 + 20}{}$   $= \frac{350}{255} = 510 = 525 \text{ Hz}$ 

(2) 525. 
$$
f = \frac{c + v_w}{c + v_w - v_s \sin 30^\circ}
$$

$$
\text{NIS} \qquad \text{EXERCISE-3}
$$
\n
$$
3. \ \lambda = \frac{v}{f} = \frac{330}{500} = 0.66 \text{m} = \frac{4\ell}{2\text{n} - 1} \Rightarrow \text{n} = 3
$$
\n
$$
525. \ \text{f} = \frac{c + v_w}{c + v_w - v_s \sin 30^\circ}
$$
\n
$$
f_0 = \frac{300 + 20}{330 + 20 - 10} = \frac{350}{340} \times 510 = 525 \text{ Hz}
$$
\n
$$
12. \text{ Imagine a cyclinder of radius 7m and length 10m.}
$$

EXERCISE-3<br>  $=\frac{330}{500} = 0.66 \text{m} = \frac{4\ell}{2\text{n} - 1} \Rightarrow \text{n} = 3$ <br>  $=\frac{\text{c} + \text{v}_{\text{w}}}{\text{c} + \text{v}_{\text{w}} - \text{v}_{\text{s}} \sin 30^{\circ}}$ <br>  $=\frac{350}{340} \times 510 = 525 \text{ Hz}$ <br>
me a cyclinder of radius 7m and length 10m.<br>
of sound at the surface S<br>
S<br>
S<br>  $\lambda = \frac{v}{f} = \frac{330}{500} = 0.66m = \frac{4\ell}{2n-1} \Rightarrow n = 3$ <br>
25.  $f = \frac{c + v_w}{c + v_w - v_s \sin 30^\circ}$ <br>  $= \frac{300 + 20}{330 + 20 - 10} = \frac{350}{340} \times 510 = 525 \text{ Hz}$ <br>
2. Imagine a cyclinder of radius 7m and length 10m.<br>
tensity of sound a EXERCISE-3<br>
=  $\frac{v}{f} = \frac{330}{500} = 0.66m = \frac{4\ell}{2n-1} \Rightarrow n = 3$ <br>  $f = \frac{c + v_w}{c + v_w - v_s \sin 30^\circ}$ <br>  $\frac{300 + 20}{330 + 20 - 10} = \frac{350}{340} \times 510 = 525 \text{ Hz}$ <br>
magine a cyclinder of radius 7m and length 10m.<br>
sity of sound at the surf **EXERCISE-3**<br>  $=\frac{330}{500} = 0.66 \text{m} = \frac{4\ell}{2\text{n} - 1} \Rightarrow \text{n} = 3$ <br>  $\frac{\text{c} + \text{v}_{\text{w}}}{\text{c} + \text{v}_{\text{w}} - \text{v}_{\text{s}}} \sin 30^{\circ}$ <br>  $\frac{10 + 20}{\text{c} + 20 - 10} = \frac{350}{340} \times 510 = 525 \text{ Hz}$ <br>
ne a cyclinder of radius 7m and length 10 **(3) 12.** Imagine a cyclinder of radius 7m and length 10m. Intensity of sound at the surface of cylinder is same

$$
\frac{\lambda_{\rm A}}{\lambda_{\rm B}} = \frac{19}{21}
$$
 everywhere. Therefore,  $I = \frac{P}{2\pi rL}$ 

(As sound is propagating radially out only, sound energy

$$
\therefore I = 50 \text{ W/m}^2
$$



Energy intercepted by the detector =  $I \times A = 12$  mW

(4) 2. 
$$
f = \frac{1}{2\ell} \sqrt{\frac{T}{\mu}}
$$

If radius is doubled and length is doubled, mass per unit length will become four times.

Hence, 
$$
f' = \frac{1}{2 \times 2\ell} \sqrt{\frac{2T}{4\mu}} = \frac{f}{2\sqrt{2}}
$$

**(5) 2.** Velocity of sound is inversely proportional to the square root of density of the medium. e detector = I × A = 12 mW<br>
length is doubled, mass per unit<br>
length is doubled, mass per unit<br>
imes.<br>  $\frac{1}{2} = \frac{f}{2\sqrt{2}}$ <br>
versely proportional to the square<br>
dium.<br>  $\frac{f_1}{f_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{2\rho}{\rho}} = \sqrt{2}$ <br>
= 0 e detector = I × A = 12 mW<br>
length is doubled, mass per unit<br>
limes.<br>  $\frac{1}{2} = \frac{f}{2\sqrt{2}}$ <br>
versely proportional to the square<br>
dium.<br>  $\frac{f_1}{2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{2\rho}{\rho}} = \sqrt{2}$ <br>
= 0.33m<br>  $\times 10^9$ <br>
1.5  $\times 10^3$  1.50 .. I = 50 W/m<sup>2</sup><br>
P<br>
Retector = I × A = 12 mW<br>
ngth is doubled, mass per unit<br>
nes.<br>
=  $\frac{f}{2\sqrt{2}}$ <br>
rsely proportional to the square<br>
um.<br>
0.33m

Energy intercepted by the detector = I × A = 12 mW  
\n2. 
$$
f = \frac{1}{2\ell} \sqrt{\frac{T}{\mu}}
$$
  
\nIf radius is doubled and length is doubled, mass per unit  
\nlength will become four times.  
\nHence,  $f' = \frac{1}{2 \times 2\ell} \sqrt{\frac{2T}{4\mu}} = \frac{f}{2\sqrt{2}}$   
\n2. Velocity of sound is inversely proportional to the square  
\nroot of density of the medium.  
\ni.e.  $V.\rho = \text{constant} \Rightarrow \frac{V_1}{V_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{2\rho}{\rho}} = \sqrt{2}$   
\n100.  $\lambda_{\text{air}} = \frac{V_{\text{air}}}{f} = \frac{330}{1000} = 0.33 \text{m}$   
\n $\lambda_{\text{water}} = \sqrt{\frac{\beta}{\rho}} = \sqrt{\frac{2.25 \times 10^9}{1000}} = 1.5 \times 10^3 = 1500$   
\nwater =  $\frac{1500}{1000} = 1.5 \text{m}$ ;  $\lambda_{\text{water}} - \lambda_{\text{air}} = 1.5 - 0.33 = 1.17 \text{m}$ 

(6) **100.** 
$$
\lambda_{\text{air}} = \frac{V_{\text{air}}}{f} = \frac{330}{1000} = 0.33 \text{m}
$$

$$
\lambda_{\text{water}} = \sqrt{\frac{\beta}{\rho}} = \sqrt{\frac{2.25 \times 10^9}{1000}} = 1.5 \times 10^3 = 1500
$$

Energy intercepted by the detector = I × A = 12 mW  
\n2. 
$$
f = \frac{1}{2\ell} \sqrt{\frac{T}{\mu}}
$$
  
\nIf radius is doubled and length is doubled, mass per unit  
\nlength will become four times.  
\nHence,  $f' = \frac{1}{2 \times 2\ell} \sqrt{\frac{2T}{4\mu}} = \frac{f}{2\sqrt{2}}$   
\n2. Velocity of sound is inversely proportional to the square  
\nroot of density of the medium.  
\ni.e.  $V.\rho = \text{constant} \Rightarrow \frac{V_1}{V_2} = \sqrt{\frac{p_2}{\rho_1}} = \sqrt{\frac{2\rho}{\rho}} = \sqrt{2}$   
\n100.  $\lambda_{air} = \frac{V_{air}}{f} = \frac{330}{1000} = 0.33 \text{m}$   
\n $\lambda_{water} = \sqrt{\frac{\beta}{\rho}} = \sqrt{\frac{2.25 \times 10^9}{1000}} = 1.5 \times 10^3 = 1500$   
\n $\lambda_{water} = \frac{1500}{1000} = 1.5 \text{m}$ ;  $\lambda_{water} - \lambda_{air} = 1.5 - 0.33 = 1.17 \text{m}$   
\n9. For fundamental frequency,

**(7) 9.** For fundamental frequency,

0 1 1 1 h gt h gt 2 2 ; water air 1.5 0.33 1.17m 3 2 3.2gm 3.2 10 3.2 32 kg / m 40cm 40 4000 40 10 // /// /// /// // /// /// /// 

**255**



2 2 ........ (1) <sup>2</sup> 1000 1 T 64 32 / 4000 2 40 10 <sup>2</sup> 1000 32 <sup>2</sup> 2 40 10 T 64 4000 1000 32 10 T T N 64 4000 8 9 2 10 / 8 <sup>10</sup> Y 10 N / m 0.05 10 40 10 **(8) 9.** <sup>1</sup> <sup>r</sup>

Now, 
$$
Y = \frac{10^{-6}}{10^{-6}} = 10^{9} N/m^{2}
$$
  
\n $\frac{0.05 \times 10^{-2}}{40 \times 10^{-2}} = 10^{9} N/m^{2}$   
\n $\frac{1}{40 \times 10^{-2}} = 10^{9} N/m^{2}$   
\nSo answer is 256 – 5.  
\n(b) The  
\n60 **(C)**  $I_{1}^{-}I_{2}^{-} = 4$   
\n**(D)**  $I_{2}^{-} = \frac{V + V}{V} = \frac{6f}{V} = \frac{6f}{5}$ ; % increase in ft  
\n $V_{2}^{-} = \frac{6f}{300 - V} \Rightarrow V = 15 \text{ m/s}$   
\n $V_{1}^{-} = \frac{10u + u}{f_{1}} = \frac{11u}{18f} \times 19 = \frac{11 \times 19}{18} \cdot \frac{u}{f}$   
\n $V_{1}^{-} = \frac{19u}{2f} \times \frac{18f}{11 \times 19u} = \frac{9}{11}$ 

(8) 9. 
$$
\lambda_1
$$
 = wavelength of the incident sound

$$
\frac{10u - (u/2)}{f} = \frac{19u}{2f}
$$

 $f_1$  = frequency of the incident sound

$$
= \frac{10u - u}{10u - (u/2)} f = \frac{18}{19} f = f_r
$$
 (6) (D).  $f = \frac{v + v}{v}$ 

= frequency of the reflected sound

 $\lambda_r$  = wavelength of the reflected sound

$$
\frac{0.05 \times 10^{-2}}{40 \times 10^{-2}}
$$
  
\n
$$
\frac{10u - (u/2)}{f} = \frac{19u}{2f}
$$
  
\n
$$
\frac{10u - (u/2)}{f} = \frac{19u}{2f}
$$
  
\n
$$
\frac{10u - (u/2)}{256 - 5} = \frac{19u}{2f}
$$
  
\n
$$
\frac{10u - u}{f} = \frac{19u}{2f}
$$
  
\n
$$
\frac{10u - u}{10u - (u/2)}f = \frac{18}{19}f = f_r
$$
  
\n
$$
\frac{10u - u}{10u - (u/2)}f = \frac{18}{19}f = f_r
$$
  
\n
$$
\frac{100}{19}f = \frac{18}{19}f = f_r
$$
  
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$$
\frac{100}{19}f = \frac{18}{19}f
$$
  
\n
$$
\frac{100}{19}f = \frac{18}{19}f
$$
  
\n
$$
\frac{120}{190 - v} \Rightarrow v = 15 \text{ m/s}
$$
  
\n
$$
\frac{120}{250 - v} \Rightarrow v = 15 \text{ m/s}
$$
  
\n
$$
\frac{120}{250 - v} \Rightarrow v = 15 \text{ m/s}
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\frac{120}{250 - v} \Rightarrow v = 15 \text{ m/s}
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\frac{120}{250 - v} \Rightarrow v = 15 \text{ m/s}
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\frac{120}{250 - v} \Rightarrow v = 15 \text{ m/s}
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\n
$$
\frac{120}{250 - v} \Rightarrow v = 15 \text{ m/s}
$$

$$
\frac{\lambda_i}{\lambda_r} = \frac{19u}{2f} \times \frac{18f}{11 \times 19u} = \frac{9}{11}
$$

## **EXERCISE-4**

$$
(1) \qquad (B). \qquad \qquad \overbrace{\qquad \qquad }
$$

Wire vibrate with minimum frequency or fundamental mode.  $\lambda_{\text{max}} = 2\ell = 2 \times 40 = 80 \text{cm}$ 

**(2) (B).** It is possible when wave reflected from rigid end. So phase difference found between incident and reflected wave is 180° and direction changed.

Incident wave equation  $\Rightarrow$  y = a sin ( $\omega$ t – kx)

Reflected wave equation  $\Rightarrow$  y = a sin ( $\omega$ t + kx + 180°)

$$
y = -a \sin(\omega t + kx)
$$

Q.B. SOLUTIONS  
\n
$$
f = \frac{v}{\lambda} = \frac{1}{2\ell} \sqrt{\frac{T}{\mu}}
$$
  
\n $f = \frac{v}{\lambda} = \frac{1}{2\ell} \sqrt{\frac{T}{\mu}}$   
\n $f = 10 \text{ kg-wt} = 10 \text{ gN}; \quad L = 1 \text{ m}$   
\n $n = \frac{1}{2L} \sqrt{\frac{T}{m}} = \frac{1}{2 \times 1} \sqrt{\frac{10 g}{9 \times 10^{-3}}} = 50 \text{ Hz}$   
\n $f = \frac{1}{2L} \sqrt{\frac{T}{m}} = \frac{1}{2 \times 1} \sqrt{\frac{10 g}{9 \times 10^{-3}}} = 50 \text{ Hz}$ 

$$
n = \frac{1}{2L} \sqrt{\frac{T}{m}} = \frac{1}{2 \times 1} \sqrt{\frac{10g}{9 \times 10^{-3}}} = 50 Hz
$$

 $(4)$  **(B).** n = 256Hz

STUDY MATERIAL: PHYSICS  
\n
$$
m=9.8 g/m=9\times 10^{-3} kg/m
$$
\n
$$
T=10 kg-wt=10 gN; \quad L=1m
$$
\n
$$
n=\frac{1}{2L}\sqrt{\frac{T}{m}}=\frac{1}{2\times 1}\sqrt{\frac{10g}{9\times 10^{-3}}}=50 Hz
$$
\n
$$
n=256 Hz
$$
\nPiano wire frequency may be  $\begin{cases} 256+5 \text{ or } 256-5 \text{ or } 256-5 \text{.} \end{cases}$ 

On increasing tension frequency decreases 2 beats per sec.

$$
\sqrt{2t \gamma \mu}
$$
  
\n
$$
1 + 10 \gamma_{\text{g}} \cdot \sqrt{2t \gamma_{\text{m}}}
$$
  
\n
$$
1 - 2 \gamma_{\text{g}} \cdot \sqrt{2t \gamma_{\text{m}}}
$$
  
\n
$$
1 - 2 \gamma_{\text{g}} \cdot \sqrt{2t \gamma_{\text{m}}}
$$
  
\n
$$
1 - 2 \gamma_{\text{g}} \cdot \sqrt{2t \gamma_{\text{m}}}
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1 - 2 \gamma_{\text{g}} \cdot \sqrt{2t \gamma_{\text{m}}}
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1 - 2 \gamma_{\text{g}} \cdot \sqrt{2t \gamma_{\text{m}}}
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1 - 2 \gamma_{\text{g}} \cdot \sqrt{2t \gamma_{\text{m}}}
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$$
  
\n
$$
1 - 2 \gamma_{\text{g}} \cdot \sqrt{2t \gamma_{\text{m}}}
$$
  
\n $$ 

So answer is  $256 - 5$ .

(5) (C). 
$$
|f_1 - f_2| = 4
$$

**(6) (D).**

 $=\frac{19u}{26}$  decrease and beats increase so  $f_1 > f_2$ . Since mass of second tuning fork increases so  $f<sub>2</sub>$ 

$$
\Rightarrow f_2 = f_1 - 4 = 196
$$

**(D).** 
$$
f = \frac{v + v/5}{v}f = \frac{6f}{5}
$$
; % increase in frequency = 20%

(7) **(D).** 
$$
f_{app} = \frac{f(300)}{300 - v} \Rightarrow v = 15 \text{ m/s}
$$

**(8) (C).** Ratio of vibrations frequency in stretched string

1 : 2 : 3 : 4 : ................

Even and odd both harmonics are present.

Given frequency ratio 315 : 420

 $3:4$ 

315 Hz is 3rd harmonic so fundamental frequency is one third of 3rd harmonic present.<br>
ental frequency is<br>  $\beta = \omega = \frac{2\pi}{T} = \pi$ 

$$
n_{\text{fundamental}} = \frac{315}{3} = 105 \text{Hz}
$$

6.33.24  
\n**1** 
$$
f_2 = f_1 - 4 = 196
$$
  
\n**1 1**

**(10) (D).**  $\lambda = 0.08$  m, T = 280

$$
\alpha=K=\frac{2\pi}{\lambda}=\frac{2\pi}{0.08}\times 100=25\pi\;;\;\beta=\omega=\frac{2\pi}{T}=\pi
$$



**(11) (C).** Variation of intensity due to superposition of waves having frequencies  $v -1$  & v and v &  $v + 1$  is as shown



Variation of intensity due to superposition of waves having frequencies  $v - 1$  and  $v + 1$  is as shown



Resultant of (a) and (b) be as shown



So number of beats/ $s = 2$ 

(12) **(B).** 
$$
\frac{94}{100}v = \frac{V - V_0}{V}v
$$
; 0.94V = V - V<sub>0</sub> (19) **(B)**  
\n $V_0 = 0.06V = 0.06 \times 330 = 19.8 \text{ m/s}$   
\n $V_0^2 = u^2 + 2as$ ; (19.8)<sup>2</sup> = 0<sup>2</sup> + (2) (2) s; s = 98m  
\n(13) **(D).** T =  $\mu v^2 = \mu \frac{\omega^2}{h^2} = 0.04 \frac{(2\pi/0.004)^2}{(2\pi/0.50)^2} = 6.25 \text{ N}$ 

(14) **(B).** 
$$
y(x, t) = e^{-[\sqrt{ax} + \sqrt{bt}]^2}
$$

It is transverse type y (x, t) =  $e^{-(ax+bt)^2}$ 

Speed 
$$
v = \frac{\sqrt{b}}{\sqrt{a}}
$$

and wave is moving along x direction.

**(15) (A).**  $f = v/2\ell$  Now, it will act like one end opened and other

closed. So, 
$$
f_0 = \frac{v}{4\ell} = \frac{v}{4(\ell/2)} = \frac{v}{2\ell} = f
$$

**(16) (B).** 
$$
f = \frac{v}{2\ell} = \frac{1}{2\ell} \sqrt{\frac{T}{\mu}} = \frac{1}{2\ell} \sqrt{\frac{T}{Ad}}
$$

Also, 
$$
Y = \frac{T\ell}{A\Delta\ell} \Rightarrow \frac{T}{A} = \frac{Y\Delta\ell}{\ell} \Rightarrow f = \frac{1}{2\ell} \sqrt{\frac{Y\Delta\ell}{\ell d}}
$$

$$
f = \sqrt{\frac{2}{7}} \times \frac{10^3}{3}
$$
 Hz ; f \approx 178.2 Hz

**LIITIONS**

\n
$$
f = \sqrt{\frac{2}{7}} \times \frac{10^{3}}{3} \text{ Hz}; f \approx 178.2 \text{ Hz}
$$
\n**(17)**

\n**(A).** In fundamental mode,  $\frac{\lambda}{4} = 0.85$ 

\n
$$
f = \frac{v}{\lambda} = \frac{340}{4 \times 0.85} = 100 \text{ Hz}
$$
\n
$$
\therefore \text{ Possible frequencies} = 100 \text{ Hz}, 300 \text{ Hz}, 500 \text{ Hz}, 700 \text{ Hz}, 900 \text{ Hz}, 1100 \text{ Hz} \text{ below } 1250 \text{ Hz}.
$$
\n**(18)**

\n**(A).**  $f_1 = f \left[ \frac{v}{v - v_s} \right] = f \left[ \frac{320}{320 - 20} \right] = f \times \frac{320}{300} \text{ Hz}$ 

 $\therefore$  Possible frequencies = 100 Hz, 300 Hz, 500 hz, 700Hz, 900 Hz 1100 Hz below 1250 Hz.

<sup>94</sup> V V<sup>0</sup> v v 100 V 2 2 2 2 (2 / 0.004) T v 0.04 k (2 / 0.50) [ ax bt ] <sup>e</sup> 2 (ax bt) <sup>e</sup> v v v f f 4 4 ( / 2) 2 v 1 T 1 T <sup>f</sup> 2 2 2 Ad T T Y 1 Y Y f A A 2 d **(18) (A).** 1 <sup>s</sup> v 320 320 f f f f Hz v v 320 20 300 2 <sup>s</sup> v 320 f f f Hz v v 340 2 2 1 1 1 f f f 100 1 100 f f <sup>300</sup> 100 1 12% 340 **(19) (B).** Mgx <sup>T</sup> L ; Mgx <sup>T</sup> <sup>L</sup> V gx <sup>M</sup> L x T dx gx dt ; L 0 dx gt <sup>x</sup> 20 0 [2 x ] 10t ; 2 20 10t ; t 2 2s **(20) (C).** <sup>0</sup> = c/2L = c/4 (L/2) <sup>0</sup> L/2 L , where 

Fundamental frequency remains same.

**(21) (B).** This question involves the use of relativistic Doppler's effect. The usual non-relativistic Doppler formula will NOT applicable here as the velocity of observer is not small as compared to light.

The relativistic Doppler's formula is

v (observed) = v (actual) 
$$
\sqrt{\frac{1+\beta}{1-\beta}}
$$
, where  $\beta = \frac{V}{C}$ 

V is relative velocity of observer w.r.t. the source and is taken to be positive if observer and source are moving towards each other.



So, here v (observed)=(10 GHz) 
$$
\sqrt{\frac{1+1/2}{1-1/2}} = 17.3
$$
 GHz. So fundame

**Solution**  
\n**Q.B. SOLUTIONS**  
\n**STUDY MATERIAL: PHYSICS**  
\nSo, here v (observed) = (10 GHz) 
$$
\sqrt{\frac{1+1/2}{1-1/2}} = 17.3 \text{ GHz}
$$
  
\n**Q.D. IDENTIFY**  
\n

Using componendo & dividendo.

$$
\frac{A_1}{A_2} = \frac{5}{3} \Longrightarrow \frac{I_1}{I_2} = \left(\frac{5}{3}\right)^2 = \frac{25}{9}
$$

$$
\frac{1}{2 \times 0.6} \sqrt{\frac{9.27 \times 10^{10}}{2.7 \times 10^3}} = \frac{1}{1.2} \sqrt{\frac{9.27 \times 10^7}{2.7 \times 10^7}}
$$
  
\n
$$
= 4.88 \times 10^3 \text{ Hz} - 16 \Rightarrow \frac{\Lambda_{max}}{\Lambda_{min}} = 4 \Rightarrow \frac{\Lambda_1 + \Lambda_2}{\Lambda_1 - \Lambda_2 - 1}
$$
  
\n
$$
\frac{\Lambda_1}{\Lambda_2} = \frac{5}{3} \Rightarrow \frac{1}{1.2} = \left(\frac{5}{3}\right)^2 = \frac{25}{9}
$$
  
\n(24) (A), 60 =  $\sqrt{\frac{Mg}{\mu}}$ ; 60.5 =  $\sqrt{\frac{M(g^2 + a^2)^{1/2}}{\mu}}$   
\n
$$
= \frac{60.5}{60} = \sqrt{\frac{8}{\mu^2}} = \frac{4}{3}
$$
  
\n
$$
\frac{1}{\sqrt{16}} = \frac{6.3}{\sqrt{16}} = \frac{8^2 + a^2}{\sqrt{16}} = 1 + \frac{2}{60}
$$
  
\n
$$
= \frac{8}{\sqrt{60}} = \frac{8}{\sqrt{50}} = \frac{8}{5a\pi^2} = \frac{8}{5}
$$
  
\n(25) (A) Given  $\frac{a_1}{a_2} = \frac{1}{3}$ . It also of *in* (a) the *in* (b) the *in* (c) the *in* (d) the *in* (e) the *in* (f) the *in* (g) the *in* (h) the *i* (i) the *i* (j) the *i* (k) the *in* (l) the *i* (l) the *i*

Let mass per unit length of  $\bar{w}$  are  $\mu_1$  and  $\mu_2$  respectively. Materials are same, so density  $\rho$  is same.

$$
\therefore \quad \mu_1 = \frac{\rho \pi r^2 L}{L} = \mu \text{ and } \mu_2 = \frac{\rho 4 \pi r^2 L}{L} = 4\mu
$$
 (30) (A).

Tension in both are same = T.

Let speed of wave in wires are  $V_1$  and  $V_2$ 

$$
V_1 = \sqrt{\frac{T}{\mu}} = V \;\; ; \;\; V_2 = \sqrt{\frac{T}{4\mu}} = \frac{V}{2}
$$

 $\frac{1}{2}$  So fundamental frequencies in both wires are

$$
f_{01} = \frac{V_1}{2L} = \frac{V}{2L}
$$
 &  $f_{02} = \frac{V_2}{2L} = \frac{V}{4L}$ 

**O.B.- SOLUTIONS** STUDY MATERIAL: PHYSICS<br>
So fundamental frequencies in both wires are<br>  $f_{01} = \frac{V_1}{2L} = \frac{V}{2L} \& f_{02} = \frac{V_2}{2L} = \frac{V}{4L}$ <br>
Frequency at which both resonate is L.C.M of both<br>
frequencies i.e. V/2L. **Q.B.- SOLUTIONS** So fundamental frequencies in both wires are<br>  $\frac{1+1/2}{1-1/2} = 17.3 \text{ GHz.}$  So fundamental frequencies in both wires are<br>  $f_{01} = \frac{V_1}{2L} = \frac{V}{2L} \& f_{02} = \frac{V_2}{2L} = \frac{V}{4L}$ <br>
Frequency at which both r **STUDY MATERIAL: PHYSICS**<br>amental frequencies in both wires are<br> $\frac{V_1}{L} = \frac{V}{2L}$  &  $f_{02} = \frac{V_2}{2L} = \frac{V}{4L}$ <br>and thich both resonate is L.C.M of both<br>cies i.e. V/2L.<br>no. of loops in wires are 1 and 2 respectively. **STUDY MATERIAL: PHYSICS**<br>
o fundamental frequencies in both wires are<br>  $v_{01} = \frac{V_1}{2L} = \frac{V}{2L} \& f_{02} = \frac{V_2}{2L} = \frac{V}{4L}$ <br>
requency at which both resonate is L.C.M of both<br>
requencies i.e. V/2L.<br>
[ence no. of loops i **STUDY MATERIAL: PHYSICS**<br>
So fundamental frequencies in both wires are<br>  $f_{01} = \frac{V_1}{2L} = \frac{V}{2L}$  &  $f_{02} = \frac{V_2}{2L} = \frac{V}{4L}$ <br>
Frequency at which both resonate is L.C.M of both<br>
frequencies i.e. V/2L.<br>
Hence no. of l **STUDY MATERIAL: PHYSICS**<br>
Idamental frequencies in both wires are<br>  $\frac{V_1}{2L} = \frac{V}{2L} \& f_{02} = \frac{V_2}{2L} = \frac{V}{4L}$ <br>
ency at which both resonate is L.C.M of both<br>
meies i.e. V/2L.<br>
no. of loops in wires are 1 and 2 respe **STUDY MATERIAL: PHYSICS**<br>
undamental frequencies in both wires are<br>  $= \frac{V_1}{2L} = \frac{V}{2L}$  &  $f_{02} = \frac{V_2}{2L} = \frac{V}{4L}$ <br>
quency at which both resonate is L.C.M of both<br>
uencies i.e. V/2L.<br>
ce no. of loops in wires are 1 Frequency at which both resonate is L.C.M of both frequencies i.e. V / 2L. IAL: PHYSICS<br>wires are<br>L.C.M of both<br>2 respectively.<br> $\begin{bmatrix} 1 \\ N \end{bmatrix}$ <br> $\begin{bmatrix} 1 \\ \frac{1}{2} = \left(\frac{a_1}{a_2}\right)^2 = \frac{1}{9} \end{bmatrix}$ IAL: PHYSICS<br>wires are<br>L.C.M of both<br>2 respectively.<br> $\begin{bmatrix} N \\ N \end{bmatrix}$ <br> $N$ <br> $\frac{1}{2} = \left(\frac{a_1}{a_2}\right)^2 = \frac{1}{9}$ IAL: PHYSICS<br>wires are<br>L.C.M of both<br>12 respectively.<br> $\frac{1}{N}N$ <br> $\frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2 = \frac{1}{9}$ I a 9 L: PHYSICS<br>res are<br>C.M of both<br>respectively.<br>N<br> $=\left(\frac{a_1}{a_2}\right)^2 = \frac{1}{9}$ 

Hence no. of loops in wires are 1 and 2 respectively.



So, ratio of no. of antinodes is 1 : 2.

(26) (A). Given 
$$
\frac{a_1}{a_2} = \frac{1}{3}
$$
; Ratio of intensities,  $\frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2 = \frac{1}{9}$ 

$$
\frac{I_{\text{max}}}{I_{\text{min}}} = \left(\frac{\sqrt{I_1} + \sqrt{I_2}}{\sqrt{I_1} - \sqrt{I_2}}\right)^2 = \left(\frac{1+3}{1-3}\right)^2 = 4
$$

(27) (A). 
$$
V = \sqrt{\frac{T}{\mu}}
$$
;  $T = \mu v^2$ ;  $\frac{\mu v^2}{A} = Y \frac{\Delta \ell}{\ell}$ ;  $\Delta \ell = \frac{\mu v^2 \ell}{AY}$ 

After substituting value of  $\mu$ , v,  $\ell$ , A and Y we get,  $\Delta \ell$  = 0.03 mm

Hence no. of loops in wires are 1 and 2 respectively.  
\n
$$
\frac{A_1 + A_2}{A_1 - A_2} = \frac{4}{1}
$$
\nSo, ratio of no. of antimodes is 1 : 2.  
\n
$$
\frac{A_1 + A_2}{A_1 - A_2} = \frac{4}{1}
$$
\nSo, ratio of no. of antimodes is 1 : 2.  
\n
$$
\frac{1}{1000}
$$
\n
$$
\frac{V}{2}
$$
\n $$ 

**(29) 106.00**

$$
v_s = \sqrt{\frac{\gamma P}{\rho}}
$$
,  $\frac{v_{gas}}{v_{air}} = \sqrt{\frac{\rho_{air}}{\rho_{gas}}}$   $\Rightarrow \frac{v_{gas}}{300} = \frac{1}{\sqrt{2}}$   
 $\Rightarrow v_{gas} = \frac{300}{\sqrt{2}}$   $\therefore v_{gas} = 150\sqrt{2}$ 

$$
n_2 - n_1 = \frac{v_{\text{gas}}}{2\ell} = \frac{150\sqrt{2}}{2(1)} = 75\sqrt{2} \implies \Delta n = 106.06 \text{ Hz}
$$

 $2_{\text{I}}$  **(30) (A).** Let amplitude of each wave is A.

 $\overline{L}$  = 4 $\mu$  Resultant wave equation

$$
\mu, \quad \frac{\pi}{4} = 1 \frac{\pi}{\ell}; \quad \Delta t = \frac{\pi}{4Y}
$$
\nsubstituting value of  $\mu$ ,  $\nu$ ,  $\ell$ ,  $A$  and  $Y$  we get,\n
$$
0.03 \text{ mm}
$$
\n
$$
\downarrow \quad \frac{\sigma}{2}
$$
\n
$$
\frac{\sigma}{\omega} - \frac{\sigma}{\sqrt{2}} - \frac{\sigma}{\sqrt{2}} = 2 \quad \frac{\sigma}{2}
$$
\n
$$
\frac{\sigma}{\sqrt{2}} - \frac{\sigma}{\sqrt{2}} = \frac{\sqrt{2}a\sin \theta}{\sqrt{2}} = \frac{a\sin \theta}{\sqrt{2}} = \frac{1}{\sqrt{2}}
$$
\n
$$
\frac{300}{\sqrt{2}} \therefore v_{\text{gas}} = 150\sqrt{2}
$$
\n
$$
\frac{300}{2\ell} \therefore v_{\text{gas}} = 150\sqrt{2}
$$
\n
$$
\frac{v_{\text{gas}}}{2\ell} = \frac{150\sqrt{2}}{2(1)} = 75\sqrt{2} \implies \Delta n = 106.06 \text{ Hz}
$$
\n
$$
\text{mplitude of each wave is A.}
$$
\n
$$
\tan t \text{ wave equation}
$$
\n
$$
= A \sin \omega t + A \sin \left(\omega t - \frac{\pi}{4}\right) + A \sin \left(\omega t + \frac{\pi}{4}\right)
$$
\n
$$
\omega t + \sqrt{2} \text{ A} \sin \omega t = (\sqrt{2} + 1) \text{ A} \sin \omega t
$$
\n
$$
\tan t \text{ wave amplitude} = (\sqrt{2} + 1) \text{ A}
$$

$$
= A \sin \omega t + \sqrt{2} A \sin \omega t = (\sqrt{2} + 1) A \sin \omega t
$$



as I 
$$
\propto A^2
$$
 so  $\frac{I}{I_0} = (\sqrt{2} + 1)^2$ ; I = 5.8 I<sub>0</sub>

#### **EXERCISE-5**

**(1) (C).** Maximum particle velocity,  $(v_p)_{max} = A\omega$ 

**1 EXERCISE-5**  
\nas I 
$$
\propto A^2
$$
 so  $\frac{I}{I_0} = (\sqrt{2} + 1)^2$ ; I = 5.8 I<sub>0</sub>  
\n**EXERCISE-5**  
\n
$$
V = (v_p)_{max}
$$
;  $\frac{\omega}{k} = A_0$   
\n
$$
\frac{1}{k} = A_0 \text{ or } \frac{\lambda}{2\pi} = A_0
$$
\n
$$
\frac{1}{k} = A_0 \text{ or } \frac{\lambda}{2\pi} = A_0
$$
\n**2 2 3 4 4 5 5 6**  
\n
$$
V = (v_p)_{max}
$$
;  $\frac{\omega}{k} = A_0$   
\n
$$
V = (v_p)_{max}
$$
;  $\frac{\omega}{k} = A_0$   
\n**6 6** 

- **(2) (D).** Let the frequencies of tuning fork and piano string be  $v_1$  and  $v_2$  respectively.
	- $\therefore$   $v_2 = v_1 \pm 4 = 512 \pm 4 = 516$  Hz or 508Hz

Increase in the tension of a piano string increases its frequecy.

If  $v_2 = 516$  Hz, further increase in  $v_2$ , resulted in an (11) increase in the beat frequency. But this is not given  $(12)$ in the question.

If  $v_2$  = 508 Hz, further increase in  $v_2$  resulted in decrease in the beat frequency. This is given in the question. When the beat frequency decreases to 2 beats per second. Fv<sub>2</sub> = 516 Hz, further increase in v<sub>2</sub>, resulted in an (11) (A). Pressure change will<br>crease in the beat frequency. But this is not given (12) (D). In fundamental mod<br>the question.<br>the pressure change will the question.

Therefore, the frequency of the piano string before increasing the tension was 508 Hz.

(3) **(B).** 
$$
y_2 = a \sin(\omega t + kx + \pi/2)
$$

 $y_1 = a \sin(\omega t + kx + 0.57)$ 

Phase difference =  $\frac{\pi}{2}$  – 0.57 = 1 radian.

**(4) (D).**  $\therefore$  Frequency is same in both the medium  $\therefore \lambda \propto$  speed

(5) (A). 
$$
\frac{1}{2\ell} \sqrt{\frac{T}{\mu}} = f
$$
 (for fundamental mode)

Taking ln on both side & differentiating

$$
\frac{dT}{2T} = \frac{df}{f} \Rightarrow \frac{dT}{T} = \frac{2 \times df}{f} = 2 \times \frac{6}{600} = 0.02
$$

**(6) (C).** Fundamental frequency is given by

If v<sub>2</sub> = 508 Hz, further increase in v<sub>2</sub> resulted in  
decrease in the beat frequency. This is given in the  
question. When the beat frequency decreases to 2  
beats per second.  
Therefore, the frequency of the piano string before  
increasing the tension was 508 Hz.  
(3) (B) 
$$
v_2 = a \sin(\omega t + kx + \pi/2)
$$
  
 $y_1 = a \sin(\omega t + kx + \pi/2)$   
 $y_1 = a \sin(\omega t + kx + \pi/2)$   
Phase difference =  $\frac{\pi}{2} - 0.57 = 1$  radian.  
(4) (D).  $\therefore$  Frequency is same in both the medium  
 $\therefore \lambda \propto$  speed  
 $\therefore \lambda \propto$  speed  
 $\therefore \lambda \propto$   $\frac{1}{2\ell} \sqrt{\frac{\Gamma}{\mu}} = f$  (for fundamental mode)  
 $\frac{d\Gamma}{2T} = \frac{df}{f} \Rightarrow \frac{dT}{T} = \frac{2 \times df}{f} = 2 \times \frac{6}{600} = 0.02$   
(6) (C). Fundamental frequency is given by  
 $v_2 = \frac{1}{2\ell} \sqrt{\frac{\Gamma}{\mu}} \Rightarrow v \propto \frac{1}{\ell}, \ell = \ell_1 + \ell_2 + \ell_3$ ;  $\frac{1}{v} = \frac{1}{v_1} + \frac{1}{v_2} + \frac{1}{v_3}$   
 $v_2 = \frac{1}{2\ell} \sqrt{\frac{\Gamma}{\mu}} \Rightarrow v \propto \frac{1}{\ell}, \ell = \ell_1 + \ell_2 + \ell_3$ ;  $\frac{1}{v} = \frac{1}{v_1} + \frac{1}{v_2} + \frac{1}{v_3}$   
(15) (B).  $\frac{V}{4(20cm)} = \frac{3V}{2(\epsilon_{\text{open}})} = \frac{3V}{2(\epsilon_{\text{open}})} = 120cm$ .  
(7) (D)  $2\pi f_1 = 600\pi$ ;  $f_1 = 300$  .......(1)  
 $2\pi f_2 = 608\pi$ ;  $f_2 = 304$  .......(2)  
 $|f_1 - f_2| = 4$  beats

$$
\frac{I_{\text{max}}}{I_{\text{min}}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5 + 4)^2}{(5 - 4)^2} = \frac{81}{1}
$$

**(**Q.B.- SOLUTIONS<br> **EXECUTIONS**<br>
( $\sqrt{2} + 1$ )<sup>2</sup>; I = 5.8 I<sub>0</sub><br> **EXECUTIONS**<br>  $\frac{I_{\text{max}}}{I_{\text{min}}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5 + 4)^2}{(5 - 4)^2} = \frac{81}{1}$ <br> **CISE-5**<br> **CISE-5**<br> **CISE-5**<br> **COLUTIONS**<br> **COLUTIONS**<br> **COLUTIONS Q.B.- SOLUTIONS**<br>  $=(\sqrt{2}+1)^2$ ; I = 5.8 I<sub>0</sub><br>  $\frac{I_{\text{max}}}{I_{\text{min}}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5+4)^2}{(5-4)^2} = \frac{81}{1}$ <br> **RCISE-5**<br> **(8) (C).** Fequency of the echo detected by the driver of the train is<br>  $f' = \left(\frac{v+u}{1}\right$  $\frac{\text{M}}{\text{DDM ADVANCED LEARNING}}$   $\frac{\text{max}}{\text{min}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5 + 4)^2}{(5 - 4)^2} = \frac{81}{1}$ <br>
equency of the echo detected by the driver of the<br>
ain is<br>  $\gamma = \left(\frac{v + u}{v}\right) f = \left(\frac{330 + 220}{1000 - 5000} + \frac{1}{2000}\right)$  $\frac{I_{\text{max}}}{I_{\text{min}}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5 + 4)^2}{(5 - 4)^2} = \frac{81}{1}$ <br>
Fequency of the echo detected by the driver of the rain is<br>  $f' = \left(\frac{v + u}{v - u}\right) f = \left(\frac{330 + 220}{330 - 220}\right) \times 1000 = 5000 \text{ Hz}$  $\frac{\text{I}_{\text{max}}}{\text{I}_{\text{min}}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5 + 4)^2}{(5 - 4)^2} = \frac{81}{1}$ <br>
Fequency of the echo detected by the driver of the<br>
rain is<br>  $f' = \left(\frac{v + u}{v - u}\right) f = \left(\frac{330 + 220}{330 - 220}\right) \times 1000 = 5000 \text{ Hz}$ <br>  $2\pi$   $2\pi$ **EDMADVANCED LEARNING**<br>  $= \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5+4)^2}{(5-4)^2} = \frac{81}{1}$ <br>
the echo detected by the driver of the s<br>
s **EXECUTE ARNING**<br>  $\frac{+A_2^2}{-A_2^2} = \frac{(5+4)^2}{(5-4)^2} = \frac{81}{1}$ <br>
F the echo detected by the driver of the<br>  $f = \left(\frac{330+220}{330-220}\right) \times 1000 = 5000 \text{ Hz}$ **(8) (C).** Fequency of the echo detected by the driver of the  $rac{\int_{\text{max}}^{\infty} \frac{1}{1_{\text{min}}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5 + 4)^2}{(5 - 4)^2} = \frac{81}{1}$ <br>
Fequency of the echo detected by the driver of the train is<br>  $f' = \left(\frac{v + u}{v - u}\right) f = \left(\frac{330 + 220}{330 - 220}\right) \times 1000 = 5000 \text{ Hz}$ <br>  $k = \frac{2\pi}{$  $rac{\text{SVD} \text{MMSUMGED IFARNING}}{2^2} = \frac{(5+4)^2}{(5-4)^2} = \frac{81}{1}$ <br>
echo detected by the driver of the<br>  $\frac{330+220}{330-220}$  × 1000 = 5000 Hz<br>
ad  $\omega = 2\pi f = (2\pi) (1/\pi) = 2$ <br>
ave<br>
sin (x - 2t) **SPON ADVANCED LEARNING**<br>  $\frac{2^2}{\sqrt{3^2}} = \frac{(5+4)^2}{(5-4)^2} = \frac{81}{1}$ <br>
echo detected by the driver of the<br>  $\frac{330+220}{330-220}$  × 1000 = 5000 Hz<br>
ad  $\omega = 2\pi f = (2\pi) (1/\pi) = 2$ <br>
ave<br>
sin (x-2t)<br>
nown source = 246 Hz or 254Hz **SOLUTARY ANGED LEARNING**<br>  $\frac{(2)^2}{(2)^2} = \frac{(5+4)^2}{(5-4)^2} = \frac{81}{1}$ <br>
echo detected by the driver of the<br>  $\left(\frac{330+220}{330-220}\right) \times 1000 = 5000 \text{ Hz}$ <br>
and  $\omega = 2\pi f = (2\pi) (1/\pi) = 2$ <br>
wave  $\frac{A_2^2}{(200\text{ N})(200\text{ N})(200\text{ N})(200\text{ N})(200\text{ N})(200\text{ N})}$ <br>  $\frac{A_2^2^2}{(200\text{ N})(200\text{ N})(200\text{ N})} = \frac{(330 + 220)}{(330 - 220)} \times 1000 = 5000 \text{ Hz}$ <br>  $A = \frac{330 + 220}{(330 - 220)} \times 1000 = 5000 \text{ Hz}$ <br>  $A = 2\pi f = (2\pi)(1/\pi) = 2$ <br>  $A = 2\$ **EXERUISE**<br> **EXERUITE AND SURVANCED LEARNING**<br>  $= \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5 + 4)^2}{(5 - 4)^2} = \frac{81}{1}$ <br>
ency of the echo detected by the driver of the<br>
is<br>  $\frac{v + u}{v - u}$   $f = \left(\frac{330 + 220}{330 - 220}\right) \times 1000 = 5000 \text{ Hz}$ <br>  $\$ 

$$
\frac{\text{max}}{\text{min}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5 + 4)^2}{(5 - 4)^2} = \frac{81}{1}
$$
\nequency of the echo detected by the driver of the  
\nain is\n
$$
r = \left(\frac{v + u}{v - u}\right) f = \left(\frac{330 + 220}{330 - 220}\right) \times 1000 = 5000 \text{ Hz}
$$
\n
$$
= \frac{2\pi}{\lambda} = \frac{2\pi}{2\pi} = 1 \text{ and } \omega = 2\pi f = (2\pi) (1/\pi) = 2
$$
\n
$$
a_1 = 0, \text{ equation of wave}
$$
\n
$$
= \sin (kx - \omega t) = \sin (x - 2t)
$$
\n
$$
a_2 = 246 \text{ Hz or } 254 \text{ Hz.}
$$
\n
$$
a_3 = 246 \text{ Hz or } 254 \text{ Hz.}
$$
\n
$$
a_4 = 246 \text{ Hz or } 254 \text{ Hz.}
$$
\n
$$
a_5 = 246 \text{ Hz or } 254 \text{ Hz.}
$$
\n
$$
a_6 = 246 \text{ Hz or } 254 \text{ Hz.}
$$
\n
$$
a_7 = 246 \text{ Hz or } 254 \text{ Hz.}
$$
\n
$$
a_8 = 246 \text{ Hz or } 254 \text{ Hz.}
$$
\n
$$
a_9 = 246 \text{ Hz or } 254 \text{ Hz.}
$$

(9) **(B).** 
$$
k = \frac{2\pi}{\lambda} = \frac{2\pi}{2\pi} = 1
$$
 and  $\omega = 2\pi f = (2\pi) (1/\pi) = 2$ 

So, equation of wave

 $y = \sin (kx - \omega t) = \sin (x - 2t)$ 

 $\frac{I_{\text{max}}}{I_{\text{min}}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5 + 4)^2}{(5 - 4)^2} = \frac{81}{1}$ <br>
Fequency of the echo detected by the driver of the<br>
rain is<br>  $f' = \left(\frac{v + u}{v - u}\right) f = \left(\frac{330 + 220}{330 - 220}\right) \times 1000 = 5000 \text{ Hz}$ <br>  $k = \frac{2\pi}{\lambda} = \frac{2$ **EXECUTE AREADLER AREADLER AREADLER AREADLER AREADLER AREADLER<br>
2 =**  $\frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(5 + 4)^2}{(5 - 4)^2} = \frac{81}{1}$ **<br>
energy of the echo detected by the driver of the<br>
is<br> \left(\frac{v + u}{v - u}\right) f = \left(\frac{330 + 220}{330 - 220}\right) (B).** Frequency of unknown source  $= 246$  Hz or 254Hz. Second harmonic of this source = 492Hz or 508 Hz, which gives 5 beats per second, when sounded with a source of frequency 513 Hz.

Therefore unknown frequency = 254 Hz

- **(11) (A).** Pressure change will be minimum at both open ends.
- **(12) (D).** In fundamental mode,

$$
\frac{\text{max}}{I_{\text{min}}} = \frac{(x_1 + x_2)}{(A_1 - A_2)^2} = \frac{(x_1 + x_2)}{(5 - 4)^2} = \frac{94}{1}
$$
\n(C). Frequency of the echo detected by the driver of the  
\ntrain is\n
$$
f' = \left(\frac{v + u}{v - u}\right) f = \left(\frac{330 + 220}{330 - 220}\right) \times 1000 = 5000 \text{ Hz}
$$
\n(B).  $k = \frac{2\pi}{\lambda} = \frac{2\pi}{2\pi} = 1$  and  $\omega = 2\pi f = (2\pi) (1/\pi) = 2$   
\nSo, equation of wave  
\n $y = \sin (kx - \omega t) = \sin (x - 2t)$   
\n(B). Frequency of unknown source = 246 Hz or 254 Hz.  
\nSecond harmonic of this source = 492 Hz or 508 Hz,  
\nwhich gives 5 beats per second, when sounded with  
\na source of frequency 513 Hz.  
\nTherefore unknown frequency = 254 Hz  
\n(A). Pressure change will be minimum at both open ends.  
\n(D). In fundamental mode,  
\n
$$
\frac{\lambda}{4} = 0.85; \lambda = 4 \times 0.85
$$
\n
$$
\frac{\lambda}{1/4} = 0.85 = \lambda/4
$$
\n
$$
f = \frac{v}{\lambda} = \frac{340}{4 \times 0.85} = 100 \text{ Hz}
$$
\n
$$
\therefore \text{ Possible frequencies} = 100 \text{ Hz}, 300 \text{ Hz}, 500 \text{ Hz}, 700 \text{ Hz}, 900 \text{ Hz} \& 1100 \text{ Hz} \& 111 \text{ Hz}
$$

 $\therefore$  Possible frequencies = 100 Hz, 300 Hz, 500 Hz, 700Hz, 900 Hz & 1100 Hz below 1250Hz.

$$
\frac{1}{k} = A
$$
 or  $\frac{\lambda}{2\pi} = A \left( \because k = \frac{2\pi}{\lambda} \right)$   
\n= 2 $\pi A$   
\n $k = 2\pi A$   
\nLet the frequencies of tuning fork and piano string  
\n $v_1 = v_1 + 4 = 515 \pm 4 = 5$  (6 Hz or 508 Hz).  
\n $v_2 = v_1 + 4 = 515 \pm 4 = 5$  (6 Hz or 254 Hz).  
\nTherefore,  
\n $v_1 = v_2 + 50$  HZs, further increase in  $v_2$ , resulted in  
\nintergence,  
\n $v_2 = 516$  Hz, further increase in  $v_2$ , resulted in  
\nthe question.  
\n $v_2 = 50$  Hz, further increase in  $v_2$  resulted in  
\nthe least frequency. This is given in the  
\n $v_2 = 508$  Hz, further increase in  $v_2$  resulted in  
\n $v_2 = 508$  Hz, further increase in  $v_2$  resulted in  
\n $v_2 = 508$  Hz.  
\nTherefore, the frequency of the piano string before  
\n $v_2 = \sin (\omega t + kx + \pi/2)$   
\n $v_1 = a \sin (\omega t + kx + \pi/2)$   
\n $v_1 = a \sin (\omega t + kx + \pi/2)$   
\n $v_1 = a \sin (\omega t + kx + 0.57)$   
\n $v_2 = a \sin (\omega t + kx + 0.57)$   
\n $v_1 = a \sin (\omega t + kx + 0.57)$   
\n $v_2 = a \sin (\omega t + kx + 0.57)$   
\n $v_1 = a \sin (\omega t + kx + 0.57)$   
\n $v_2 = a \sin (\omega t + kx + 0.57)$   
\n $v_1 = a \sin (\omega t + kx + 0.57)$ 

$$
n \propto \frac{1}{\ell}; \quad \ell = \ell_1 + \ell_2 + \ell_3 \Rightarrow \frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3}
$$
  
(14) (C).  $v_0 = 36 \text{ km/h} = 10 \text{ m/s}$   
 $v_s = 18 \text{ km/h} = 5 \text{ m/s}$   

$$
\underbrace{\bullet}_{0} \underbrace{\bullet}_{S} \underbrace{\bullet}_{f} = 1392 \text{ Hz}
$$
  

$$
f' = f \left[ \frac{v + v_0}{v + v_s} \right] = 1392 \times \left( \frac{343 + 10}{343 + 5} \right) \text{ Hz}
$$
  

$$
= 1392 \times \frac{353}{348} \text{ Hz} = 1412 \text{ Hz}
$$
  
(15) (B).  $\frac{V}{4 (20 \text{cm})} = \frac{3V}{2 \ell_{open}} \Rightarrow \ell_{open} = 120 \text{cm}.$   
(16) (C).  $f_0 = f_s \left( \frac{v}{v - v_s \cos 60^\circ} \right) = 100 \left( \frac{330}{330 - \frac{19.4}{2}} \right) \approx 103 \text{ Hz}$ 

$$
=1392 \times \frac{353}{348}
$$
 Hz = 1412 Hz

(15) **(B).** 
$$
\frac{V}{4 (20 \text{cm})} = \frac{3V}{2\ell_{\text{open}}} \Rightarrow \ell_{\text{open}} = 120 \text{cm}.
$$

**16)** (C). 
$$
f_0 = f_s \left( \frac{v}{v - v_s \cos 60^\circ} \right) = 100 \left( \frac{330}{330 - \frac{19.4}{2}} \right) \approx 103 \text{ Hz}
$$



 $\begin{bmatrix} I \\ L_{\text{min}} = 50 \end{bmatrix}$ 

**(17) (A).** The two consecutive resonant frequencies for a string

f i x e d a t b o t h e n d s w i l l b e nv (n 1) v and 

Which is the minimum resonant frequency.



**(20) (C).**  $L_{\text{min}} = 50 \text{ cm.}$ 

So other lengths for

resonance are

- $3L_{\text{min}}$ ,  $5L_{\text{min}}$ ,  $7L_{\text{min}}$ , etc.
- $\Rightarrow$  150 cm, 250 cm, 350 cm, etc.



**(22) (D).** Net beat frequency

 $\frac{V}{2\ell}$  = 105 Hz = LCM of individual beat frequencies

 $=$  LCM of  $[(n, n-1), (n, n+1), (n-1, n+1)]$ 

$$
=
$$
LCM of  $(1, 1, 2) = 2$  Hz

So, number of beats per second  $= 2$ 

**(23) (A).** Difference between any two consecutive frequencies

**STUDY MATERIAL: PHYSICS**  
\n
$$
\frac{3V}{2L_1} = \frac{3V}{4L} \Rightarrow L_1 = 2L
$$
\nNet beat frequency  
\n= LCM of individual beat frequencies  
\n= LCM of [(n, n-1), (n, n+1), (n-1, n+1)]  
\n= LCM of (1, 1, 2) = 2 Hz  
\nSo, number of beats per second = 2  
\nDifference between any two consecutive frequencies  
\nof COP =  $\frac{2v}{4\ell} = 260 - 220 = 40$  Hz  $\Rightarrow \frac{v}{4\ell} = 20$  Hz.  
\nSo fundamental frequency = 20 Hz.  
\n
$$
\frac{v_s = 22 \text{ m/s}}{f_0 = 400 \text{ Hz}} \xrightarrow{v_0} \frac{v_0 = 16.5 \text{ m/s}}{B}
$$

So fundamental frequency = 20 Hz.

(24) (C). 
$$
A_{f_0}^{v_s} = 22 \text{ m/s}
$$
  $v_0 = 16.5 \text{ m/s}$   
 $f_0 = 400 \text{ Hz}$ 

As we know for given condition

**STUDY MATERIAL: PHYSICS**  
\n
$$
\frac{3V}{2L_1} = \frac{3V}{4L} \Rightarrow L_1 = 2L
$$
\nNet beat frequency  
\n= LCM of [n, n-1), (n, n+1), (n-1, n+1)]  
\n= LCM of [1, 1, 2) = 2 Hz  
\nSo, number of beats per second = 2  
\nDifference between any two consecutive frequencies  
\nof COP =  $\frac{2v}{4\ell}$  = 260 – 220 = 40 Hz  $\Rightarrow \frac{v}{4\ell}$  = 20 Hz.  
\nSo fundamental frequency = 20 Hz.  
\n
$$
A \frac{v_s}{f_0} = 22 \text{ m/s} \qquad v_0 = 16.5 \text{ m/s}
$$
\nAs we know for given condition  
\n $f_{app} = f_0 \left( \frac{v + v_{observer}}{v - v_{source}} \right) = 400 \left( \frac{340 + 16.5}{340 - 22} \right)$   
\n $f_{app} = 448 \text{ Hz}$   
\nFor closed organ pipe, third harmonic = 3v / 4\ell  
\nFor open organ pipe, fundamental frequency = v / 2\ell'  
\n
$$
\frac{3v}{4\ell} = \frac{v}{2\ell'} \Rightarrow \ell' = \frac{4\ell}{3 \times 2} = \frac{2\ell}{3} = \frac{2 \times 20}{3} = 13.33 \text{ cm}.
$$
\n $v = 2$  (v)  $[L_2 - L_1] = 2 \times 320 [73 - 20] \times 10^{-2}$   
\n= 339.2 ms<sup>-1</sup> = 339 m/s

**(25) (C).** For closed organ pipe, third harmonic =  $3v/4\ell$ 

$$
\frac{3v}{4\ell} = \frac{v}{2\ell'} \Rightarrow \ell' = \frac{4\ell}{3 \times 2} = \frac{2\ell}{3} = \frac{2 \times 20}{3} = 13.33 \text{ cm}.
$$

**(26) (B).**  $v = 2 (v) [L_2 - L_1] = 2 \times 320 [73 - 20] \times 10^{-2}$  $= 339.2$  ms<sup>-1</sup> = 339 m/s