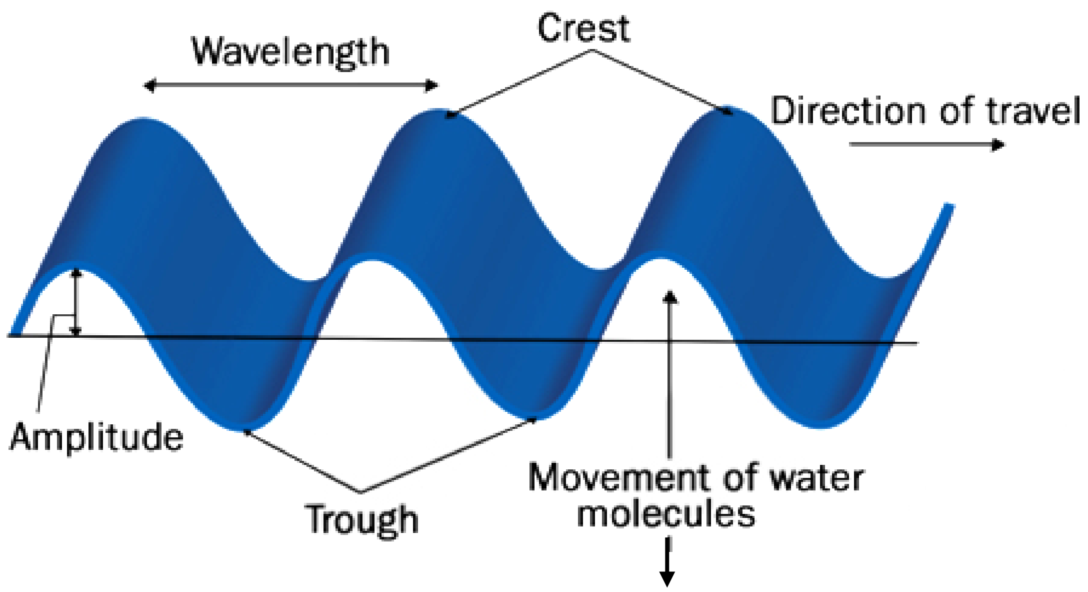
PHYSICS

for JEE, NEET & BOARD

11th

WAVE MOTION & SOUND WAVE



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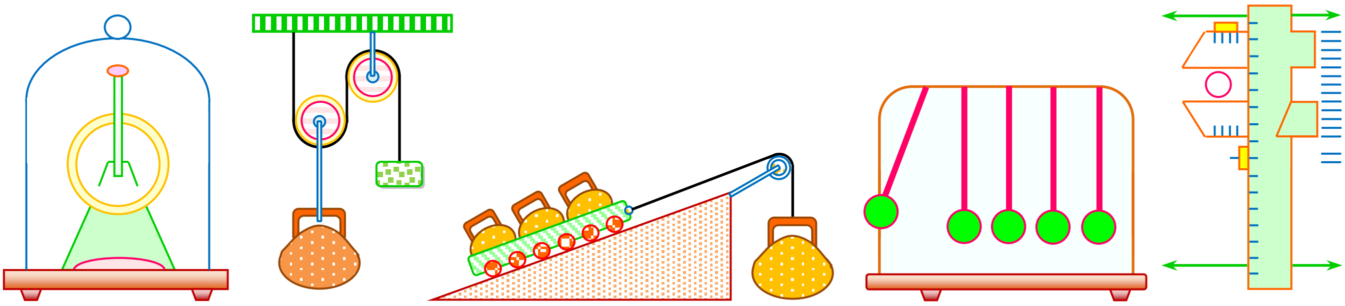

PHYSICS BOOKLET FOR JEE NEET & BOARDS

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WAVE MOTION AND SOUND WAVE

1 WAVE MOTION

1.1 WAVES

A wave may be defined as a periodic disturbance travelling with a finite velocity through a medium. Such a wave-motion remains unchanged in shape, as it progresses.

The important characteristics of a wave are:

(i) The particles of the medium traversed by a wave execute relatively small vibrations about their mean positions but the particles are not permanently displaced in the direction of propagation of the wave.

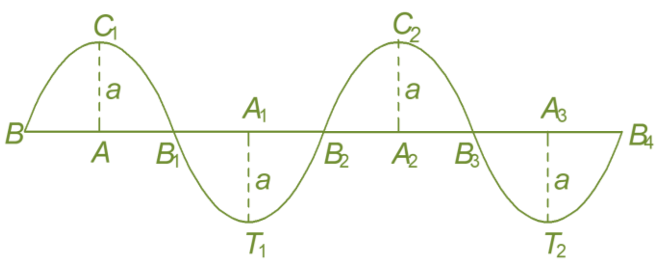
(ii) Each successive particle of the medium executes a motion quite similar to its predecessors along/ perpendicular to the line of travel of the wave.

(iii) During wave-motion only transfer of energy takes place but not a portion of the medium.

A vibration in its simplest form is called a simple harmonic motion and a particle executing such a motion may be considered as a source, which radiates waves in all directions. Usually the amplitude of vibration of the individual particles decreases as the distance of them from the source increases. But we will consider only the propagation of waves in which there is no change in amplitude as the wave progresses.

1.2 TRANSVERSE WAVES

A transverse wave is one in which particles of the medium vibrate in a direction at right angles to the line of propagation of the wave.



At any instant each particle of the medium is at its own displacement position in the process of executing a S.H.M. identical with others. The maximum displacement that every particle can have is called **the amplitude of the wave**.

The particles at A, A_1, A_2, ... are at their maximum displacement positions. The positions C_1, C_2 ... of the wave are called crests while the positions T_1, T_2, ... are called **troughs**.

Other particles of the medium are having their own individual displacements from the mean position which, sometime later would reach the maximum displacement position. Due to this it would appear as if crests and troughs travel forward in a wave-motion. As in S.H.M. the particle velocity is greatest where the displacement is least (zero) and the particles velocity is minimum where the displacement is maximum. Successive pairs of particles such as B and B_2, A and A_2, B_1 and B_3 are in the same phase and distance between such successive pairs in the same phase is called the wavelength of the wave (written as λ).

1.3 LONGITUDINAL WAVES

If the individual particles of the medium vibrate in the direction of propagation of the wave itself the wave is called a **longitudinal wave**.

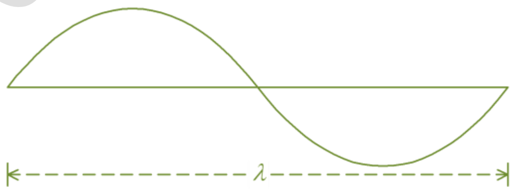
In the transverse wave-motion the displacement curve is a 'sine curve' of displacements with alternate crests and troughs. In the longitudinal wave the disturbance is passing along a succession of compressions and rarefactions. Compressions are points of maximum density and correspond to the crests of transverse wave while the rarefactions are points of minimum density corresponding to the troughs of a transverse wave. Yet the graphical representation of a longitudinal wave-motion will be quite identical with that of the transverse wave. As in the transverse wave the distance between successive pairs of particles in the same phase is called the wavelength (λ).

1.4 WAVE FREQUENCY

If the particles of the medium make n (also written as ν) vibrations per second, n is called the frequency of the wave. The time taken for one vibration is the wave period T and $T = \frac{1}{\nu}$ or $\nu = 1/T$; unit – hertz (Hz).

1.5 WAVELENGTH

We have already defined a wavelength λ is the distance travelled by the wave in one period T unit – metre.



1.6 WAVE VELOCITY

Wave velocity is the distance travelled by the wave in one second. Symbol v or c; unit – metre/second.

If the frequency of the wave is "f" hertz and wavelength is "λ" metres, then the wave velocity v is

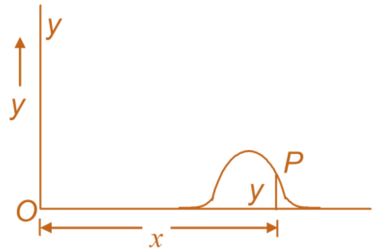
$$v = f\lambda \text{ m/s} \quad \dots (1)$$

Wave velocity = Frequency × Wavelength

2 GENERAL EQUATION OF PROGRESSIVE WAVES

Let us consider a series of particles forming a long string stretched along the x-axis as shown.

Suppose the particle at the origin O acts as the source of a disturbance, which travels as a transverse wave in the positive direction of the x-axis with a velocity v. As the wave proceeds, each successive particle is set in motion.



Let the time be measured from the instant when the particle at the origin O is passing through its equilibrium position. Then the displacement y of this particle at any instant t can be represented by

$$y = f(t)$$

where $f(t)$ is any function of time. The wave will reach a point P, distant x from O, in x/v second. Thus the particle at P will start moving x/v second later than the particle at O. Therefore, the displacement y of the particle at P at any instant t will be the same as the displacement of the particle at the origin x/v second earlier i.e., at $(t - x/v)$. Hence the displacement at P is given by

$y = f(t - x/v)$

Since v is a constant, we may write it as

$y = f\ (vt - x)$ … (i)

This is the equation of a wave of any shape travelling along the positive direction of x-axis with a constant velocity v. The function f determines the exact shape of the wave.

Similarly, the equation for a wave travelling along the negative direction of x-axis would be

$y = f(vt + x)$ … (ii)

Thus the functions $f(vt \pm x)$ represent travelling waves. We can also write these functions as $f(x \pm vt)$.

From equation (i) and (ii) the generation equation for the wave can be written as

$y = f_1(vt - x) + f_2(vt + x)$ … (iii)

To get the general differential equation, let us differentiate equation (iii) twice partially with respect to 't'. We get

$$\frac{\delta^2 y}{\delta t^2} = v^2 f_1''(vt - x) + v^2 f_2''(vt + x) \quad \text{… (a)}$$

where f_1'' and f_2'' are the second differentials of f_1 & f_2 respectively.

Again differentiating equation (iii) twice partially with respect to x, we get

$$\frac{\delta^2 y}{\delta x^2} = f_1''(vt - x) + f_2''(vt + x) \quad \text{… (b)}$$

Comparing (a) & (b)

$$\frac{\delta^2 y}{\delta t^2} = v^2 \frac{\delta^2 y}{\delta x^2} \quad \text{… (2)}$$

This is general differential equation for a one dimensional wave.

2.1 EQUATION OF A SINUSOIDAL PROGRESSIVE WAVE

Particle displacement (y)

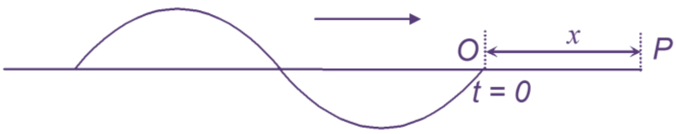
The displacement of a particle y from its mean position, taking $y = 0$ when $t = 0$ is given by the displacement-time equation for simple harmonic motion

$y = A \sin \omega t$ … (3)

where a is the amplitude of the oscillation and $\omega = 2\pi n$, where n is the wave frequency. Hence

$y = A \sin 2\pi nt$ … (4)

This equation is applicable to all individual particles affected by the wave. Suppose the wave is progressing forward with velocity v m/s. Suppose we start timing the operation when the wave reaches a certain particle O. Let us consider O as origin for the purpose of measuring distances. Then a particle P at a distance x from O will receive the wave $\frac{x}{v}$ s later than O did.



Hence its displacement will have to be considered according to

$$y = A \sin 2\pi f\left(t - \frac{x}{v}\right) \quad \text{… (5)}$$

Since $v = f\lambda, f = \frac{1}{T}$, the displacement equation can also take the form

$$y = A \sin \frac{2\pi}{\lambda}(vt - x) \quad \text{… (6)}$$

$$y = A \sin 2\pi \left(\frac{t}{T} - \frac{x}{\lambda}\right) \quad \text{... (7)}$$

Illustration 1

Question: **The equation of a progressive wave is represented as**

$$y = 8 \sin 2\pi (5t - 0.01x)$$

where x is in metres and t in seconds. Find (i) the frequency in Hz, (ii) the wavelength in metre and (iii) the velocity of the wave in m/s.

Solution: Comparing the given equation with the standard equation of progressive wave

$y = 8 \sin 2\pi (5t - 0.01\,x)$ – given equation

$y = A \sin 2\pi \left(\frac{t}{T} - \frac{x}{\lambda}\right)$ – standard equation

(i) $\frac{t}{T} = 5t$

(or) $\frac{1}{T} = 5$ hertz

∴ frequency of the wave = **5 Hz**

(ii) $-\frac{x}{\lambda} = -0.01\,x$

(or) $\frac{1}{\lambda} = 0.01$

∴ wavelength $\lambda = \frac{1}{0.01}$ = **100 m**

(iii) Wave velocity = $f\lambda$ = (5 Hz) (100 m) = **500 m/s**

Illustration 2

Question: **A wave travelling in the positive x-direction has an amplitude 0.01 m, frequency 125 Hz and velocity of propagation 375 m/s. Find the displacement and acceleration of a particle in the medium situated 1.5 m from the origin at t = 5 sec.**

Solution: Let the wave be represented as

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

Here amplitude A = 0.01 m
Velocity = 375 m/s

Frequency $\frac{1}{T} = f$ = 125 Hz

x = 1.5 m

Wavelength $\lambda = \frac{v}{f} = \frac{375}{125}$ = 3 m

t = 5 sec

Particle displacement is given by

$$y = 0.01 \sin 2\pi \left[125 \times 5 - \frac{1.5}{3}\right]$$

$$= 0.01 \sin 2\pi (625 - 0.5)$$
$$= 0.01 \sin 2\pi (624.5)$$
$$= 0.01 \sin (1249\pi)$$

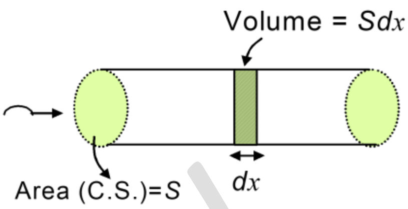
$= 0.01 \sin \pi = 0$

Particle acceleration

$$\frac{d^2y}{dt^2} = A \cdot \frac{4\pi^2}{T^2} \sin 2\pi \left(\frac{t}{T} - \frac{x}{\lambda}\right) = \mathbf{0}$$

3 ENERGY OF A PLANE PROGRESSIVE WAVE

Consider a plane wave propagating with a velocity v in x-direction across an area S. An element of material medium (density = ρ kg/m^3) will have a mass $\rho(Sdx)$.



The displacement of a particle from its equilibrium position is given by the wave equation.

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

Total **energy**, $dE = \frac{1}{2} dm\, V_{max}^2$

$$dE = \frac{1}{2}(\rho S dx)(A\omega)^2$$

$$= \rho S dx\,(2\pi^2 f^2 A^2)$$

$\Rightarrow$ energy density $= \frac{dE}{(Sdx)} = 2\pi^2 f^2 A^2 \rho$ (J/m^3)

energy per unit length = $\rho S (2\pi^2 f^2 A^2)$ ... (8)

$\therefore$ power transmitted = $2\pi^2 f^2 A^2 \rho S v$ (J/s) ... (9)

3.1 INTENSITY OF THE WAVE (I)

Intensity of the wave is defined as the power crossing per unit area

$\therefore$ **$I = 2\pi^2 f^2 A^2 \rho v$ (Watt/m^2)** ... (10)

for wave propagation through a taut string,

$\rho S = \mu$, the linear density in kg/m

$\therefore$ **Energy per unit length = $2\pi^2 f^2 A^2 \mu$** ... (11)

Illustration 3

Question: **The equation of a progressive wave is given as $y = 0.05 \sin 2\pi\left(\frac{64t - x}{3.2}\right)$ where the amplitude and wavelength are in metres. (i) Calculate the phase velocity of the wave, (ii) also calculate x, if the phase difference between two points at a distance 0.32 m apart, along the line of propagation is π/x (iii) if the wave propagates through air (density = 1.3 kg/m^3) find the intensity of wave. (Assuming $\pi^2 = 10$)**

Solution: **(i)** The progressive wave is represented by

$$y = 0.05 \sin \frac{2\pi}{3.2}(64t - x)$$

Comparing this with the standard equation

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

the phase velocity (wave velocity) = **64 m/s**

(ii) The phase difference of the particles separated by a distance of λ is equal to 2π.

$\therefore$ phase difference of particles separated by a distance 0.32 $m = \frac{2\pi}{3.2} \times 0.32$

$$= \frac{\pi}{5} \text{ radians}$$

$\therefore$ $x = \mathbf{5}$

(iii) The intensity of the sound wave is given by

$$I = \frac{1}{2}\rho v\omega^2 A^2 = \frac{1}{2}\left(1.3\frac{kg}{m^3}\right)\left(64\frac{m}{s}\right)\left(4\pi^2 n^2\right)(0.05m)^2$$

Here n is the frequency of the wave and is equal to $\frac{64}{3.2} = 20$ Hz

$\therefore \quad I = \frac{1}{2} \times 1.3 \times 64 \times 4\pi^2 \times 400 \times 0.0025$ W/m^2

$= \mathbf{1664\ W/m^2}$

4 WAVE SPEED

The speed of any mechanical wave, transverse or longitudinal, depends on both an inertial property of the medium and an elastic property of the medium.

4.1 TRANSVERSE WAVE IN A STRETCHED STRING

Consider a transverse pulse produced in a taut string of linear mass density μ. Consider a small segment of the pulse, of length Δl, forming an arc of a circle of radius R. A force equal in magnitude to the tension T pulls tangentially on this segment at each end.

Let us set an observer at the centre of the pulse, which moves along with the pulse towards right. For the observer any small length dl of the string as shown will appear to move backward with a velocity v.

Now the small mass of the string is in a circular path of radius R moving with speed v. Therefore the required centripetal force is provided by the only force acting (neglecting gravity) is the component of tension along the radius.

The net restoring force on the element is

$$F = 2T\sin(\Delta\theta) \approx 2T(\Delta\theta) = \frac{T\Delta l}{R}$$

The mass of the segment is $\Delta m = \mu\Delta l$

The acceleration of this element towards the centre of the circle is $a = \frac{v^2}{R}$, where v is the velocity of the pulse.

Using second law of motion

$$\frac{T\Delta l}{R} = (\mu\Delta l)\frac{v^2}{R}$$

or, $$v = \sqrt{\frac{T}{\mu}} \qquad \textbf{... (12)}$$

5 SUPERPOSITION OF WAVES

Two or more waves can traverse the same space independent of one another. The displacement of any particle in the medium at any given time is simply the sum of displacements that the individual waves would give it. This process of the vector addition of the displacement of the particle is called **superposition**.

5.1 INTERFERENCE

When two waves of the same frequency, superimpose each other, there occurs redistribution of energy in the medium, which causes the variation of intensity between the two limits a minimum intensity and maximum intensity. This phenomenon is called interference of waves.

Let the two of waves be

$y_1 = A_1\sin(\omega t - kx)$; $y_2 = A_2\sin(\omega t - kx + \delta)$

According to the principle of superposition

$y = y_1 + y_2$

$= A_1\sin(\omega t - kx) + A_2\sin(\omega t - kx + \delta)$

$= A_1\sin(\omega t - kx)(A_1 + A_2\cos\delta) + A_2\sin\delta\cos(\omega t - kx)$

$\mathbf{y = A\sin(\omega t - kx + \phi)}$ **... (13)**

where, $A_1 + A_2\cos\delta = A\cos\phi$

$A_2 \sin \delta = A \sin \phi$

and $A^2 = (A_1 + A_2 \cos\delta)^2 + (A_2 \sin \delta)^2$

$\therefore$ $A^2 = A_1^2 + A_2^2 + 2A_1A_2 \cos \delta$ … (14)

If I_1 & I_2 are intensities of the interfering waves and δ is the phase difference, then the resultant intensity is given by,

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\delta \quad \text{… (15)}$$

Now $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$ for $\delta = 2n\pi$

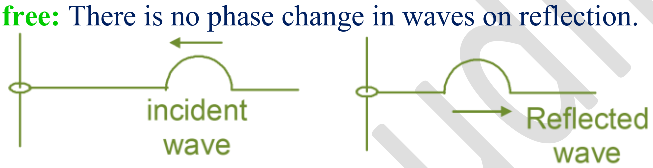
$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$ for $\delta = (2n + 1)\pi$ (where n = 0, 1, 2, 3, ……..)

5.2 REFLECTION AND TRANSMISSION OF WAVES

The nature of the reflected and transmitted wave depends on the nature of end point. There are three possibilities.

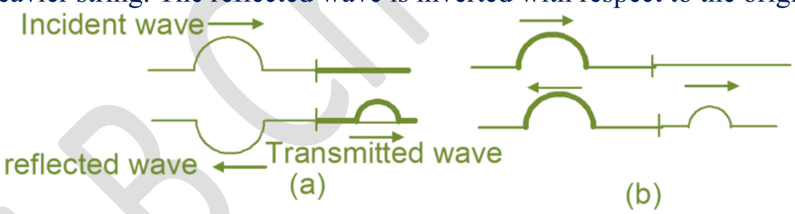
(a) **End point is fixed:** Waves on reflection from a fixed end undergoes a phase change of 180°.

(b) End point is free: There is no phase change in waves on reflection.



(c) End point is neither completely fixed nor completely free

For example, consider a light string attached to a heavier string as shown in figure. If a wave pulse is produced on the light string moving towards the junction, a part of the wave is reflected and a part is transmitted on the heavier string. The reflected wave is inverted with respect to the original one (figure (a).



On the other hand, if the wave is produced on the heavier string, which moves towards the junction, a part will be reflected and a part transmitted, no inversion of wave shape will take place (as shown in figure (b).

So the rule is: if a wave enters a region where the wave velocity is smaller, the reflected wave is inverted. If it enters a region where the wave velocity is larger, the reflected wave is not inverted. The transmitted wave is never inverted.

5.3 STANDING WAVES

A standing wave is formed when two identical waves travelling in the opposite directions along the same line interfere.

Consider two waves of the same frequency, speed and amplitude, which are travelling in opposite directions along a string. Two such waves may be represented by the equations.

$y_1 = A \sin (\omega t - kx)$

$y_2 = A \sin (kx + \omega t)$

Hence the resultant may be written as

$y = y_1 + y_2 = A \sin (\omega t - kx) + A \sin (\omega t + kx)$

$y = 2A \sin kx \cos \omega t$ … (16)

This is the equation of a standing wave.

Note:

(i) From the above equation it is seen that a particle at any particular point 'x' executes simple harmonic motion and all the particles vibrate with the same frequency.

(ii) The amplitude is not the same for different particle but varies with the location 'x' of the particle.

(iii) The points having maximum amplitudes are those for which $2A \sin kx$, has a maximum value of $2A$, these are at the positions.

$Kx = \pi/2, 3\pi/2, 5\pi/2, \ldots$

or $x = \lambda/4, 3\lambda/4, 5\lambda/4 \ldots.$

i.e., $x = (n + 1/2)\lambda/2 = (2n + 1)\lambda/2$; where $n = 0, 1, 2 \ldots$

There points are called **antinodes**.

(iv) The amplitude has minimum value of zero at positions

where $kx = \pi, 2\pi, 3\pi, \ldots.$

or $x = \frac{\lambda}{2}, \lambda, \frac{3\lambda}{2}, 2\lambda \ldots.$ i.e., $x = \frac{n\lambda}{2}$

These points are called **nodes**.

(v) It is clear that the separation between consecutive nodes or consecutive antinodes is $\lambda/2$.

(vi) As the particles at the nodes do not move at all, energy cannot be transmitted across them.

Illustration 4

Question: **A progressive and a stationary wave have same frequency 300 Hz and the same wave velocity 360 m/s.**

(i) the phase difference between two points on the progressive wave which are 0.4 m apart is $2\pi/x$, find x.

(ii) the distance between consecutive nodes (in cm) in the stationary wave.

Solution: Wave velocity $v = 360$ m/s

Frequency $n = 300$ Hz

$\therefore$ wavelength $\lambda = \frac{v}{f} = \frac{360}{300} = 1.2$ m

(i) The phase difference between two points at a distance one wavelength apart is 2π.

Phase difference between points 0.4 m apart is given by

$$\frac{2\pi}{\lambda} \times 0.4 = \frac{2\pi}{1.2} \times 0.4 = \frac{2\pi}{3} \text{ radians.}$$

$\therefore$ $x = \mathbf{3}$

(ii) The distance between the two consecutive nodes in the stationary wave is given by

$$\frac{\lambda}{2} = \frac{1.2}{2} = 0.6 \text{ m} = \mathbf{60\ cm}$$

5.4 DIFFERENCES BETWEEN A TRAVELLING WAVE AND A STANDING WAVE

(1) In a travelling wave, the disturbance produced in a region propagates with a definite velocity but in a standing wave, it is confined to the region where it is produced.

(2) In a travelling wave, the motion of all the particles is similar in nature. In a standing wave, different particles move with different amplitudes.

(3) In a standing wave, the particles at nodes always remain in rest. In travelling waves, there is no particle, which always remains in rest.

(4) In a standing wave, all the particles cross their mean positions together. In a travelling wave, there is no instant when all the particles are at the mean positions together.

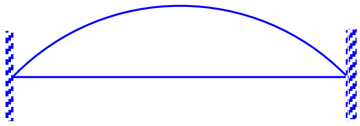
(5) In a standing wave, all the particles between two successive nodes reach their extreme positions together, thus moving in phase. In a travelling wave, the phases of nearby particles are always different.

(6) In a travelling wave, energy is transmitted from one region of space to other but in a standing wave, the energy of one region is always confined in that region.

5.5 STATIONARY WAVES IN STRINGS.

A string of length L is stretched between two points. When the string is set into vibrations, a transverse progressive wave begins to travel along the string. It is reflected at the other fixed end. The incident and the reflected waves interfere to produce a stationary transverse wave in which the ends are always nodes, if both ends of string are fixed.

Fundamental Mode



(a) In the simplest form, the string vibrates in one loop in which the ends are the nodes and the centre is the antinode. This mode of vibration is known as the fundamental mode and frequency of vibration is known as the fundamental frequency or first harmonic.

Since the distance between consecutive nodes is

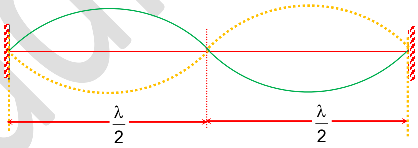
$$L = \frac{\lambda_1}{2} \quad \therefore \lambda_1 = 2L$$

If f_1 is the fundamental frequency of vibration, then the velocity of transverse waves is given as,

$$v = \lambda_1 f_1$$

or $$f_1 = \frac{v}{2L} \qquad \text{... (i)}$$

First Overtone



(b) The same string under the same conditions may also vibrate in two loops, such that the centre is also the node

$\therefore \quad L = 2\lambda_2/2 \quad \therefore \lambda_2 = L$

If f_2 is frequency of vibrations

$$\therefore \quad f_2 = \frac{v}{\lambda_2} = \frac{v}{L}$$

$$\therefore \quad f_2 = \frac{v}{L} \qquad \text{... (ii)}$$

The frequency f_2 is known as second harmonic or first overtone.

Second Overtone

(c) The same string under the same conditions may also vibrate in three segments.

$$\therefore \quad L = \frac{3\lambda_3}{2}$$

$$\therefore \quad \lambda_3 = \frac{2}{3}L$$

If f_3 is the frequency in this mode of vibration, then,

$$f_3 = \frac{3v}{2L} \qquad \text{... (iii)}$$

The frequency f_3 is known as third harmonic or second overtone.

Thus a stretched string vibrates with frequencies, which are integral multiples of the fundamental frequencies. These frequencies are known as harmonics.

The velocity of transverse wave in stretched string is given as $v = \sqrt{\frac{T}{\mu}}$. Where T = tension in the string.

μ = linear density or mass per unit length of string. If the string fixed at two ends, vibrates in its fundamental mode, then

$$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}} \qquad \text{... (17)}$$

5.6 FREQUENCY OF THE STRETCHED STRING

In general, if the string vibrates in p loops, the frequency of the string under that mode is given by

$$f = \frac{p}{2L}\sqrt{\frac{T}{\mu}} \qquad \dots (18)$$

Based on this relation three laws of transverse vibrations of stretched strings arise. They are law of length, law of tension and law of mass.

5.7 LAW OF LENGTH

The fundamental frequency f is inversely proportional to the length L of the stretched string.

$$f \propto \frac{1}{L} \qquad \dots (19)$$

(or) fL = a constant (T being constant)

5.8 LAW OF TENSION

The fundamental frequency is directly proportional to the square root of the tension in the string.

$$f \propto \sqrt{T}$$

(or) $\frac{f}{\sqrt{T}}$ **= a constant (L, m being constants)** **... (20)**

5.9 LAW OF MASS

The fundamental frequency is inversely proportional to the square root of mass per unit length of the given string when L and T are kept constants.

$$f \propto \frac{1}{\sqrt{\mu}}$$

(or) $f\sqrt{\mu}$ **= a constant (L, T being constants)** **... (21)**

5.10 FREQUENCY AND DENSITY OF WIRE

In the formula $f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$ for the fundamental frequency of a stretched string, if the tension T is due to a weight of M kg suspended from the free end of a wire as in a sonometer then $T = Mg$ newtons.

If the density of the material of the wire is ρ kg/m^3, and the radius of cross-section is r metre then the mass/unit length of the wire

m = volume × density = $(\pi r^2 \times 1)(\rho)$ kg

The fundamental frequency equation now becomes

$$f = \frac{1}{2L}\sqrt{\frac{Mg}{\pi r^2 \rho}} \qquad \dots (22)$$

Note that in this relation

M is in kg; r is in m; g is in m/s^2; ρ is in kg/m^3 L is in m

Illustration 5

Question: **A wire of length 1.5 m under tension emits a fundamental note of frequency 120 Hz.**

(a) What would be its fundamental frequency (in Hz) if the length is increased by half under the same tension?

(b) By how much the length (in metre) should be shortened so that it can increase its frequency three fold?

Solution: The variations in length take place under constant tension.

(a) Applying the relation for the stretched string

$f_1L_1 = f_2L_2$ (T being constant)

$120 \times L = f_2 \times \frac{3L}{2}$ (or) $f_1 = \frac{2 \times 120}{3}$ = **80 Hz**

(b) Again applying the relation

$f_1L_1 = f_2L_2$

$f_1 \times L_1 = (3f_1)L_2$

$L_2 = \frac{L_1}{3} = \frac{1.5}{3} = 0.5$ m

∴ the length of the wire should be shortened by (1.5 – 0.5) m = **1 m**

Illustration 6

Question: **Two strings *A* (length L_1) and *B* (length L_2) are made of steel and are kept under the same tension. If *A* has a radius twice that of *B*, what should be value of L_2/L_1 for them to have the same fundamental frequencies? What should be the value of L_2/L_1 if the first overtone of the former should equal the third harmonic of the latter?**

Solution:

	String A	**String B**	
Tension	T	T	(same tension)
Linear mass density	$\pi r^2\rho$	$\pi\left(\frac{r}{2}\right)^2\rho$	ρ = density of steel
Fundamental frequency	f	f	(same)
Lengths	L_1	L_2	

For the string *A*, $f = \frac{1}{2L_1}\sqrt{\frac{T}{\pi r^2\rho}}$

For the string *B*, $f = \frac{1}{2L_2}\sqrt{\frac{T}{\pi\left(\frac{r}{2}\right)^2\rho}} = \frac{1}{2L_2}\sqrt{\frac{4T}{\pi r^2\rho}}$

Since both have the same fundamental frequency $\frac{1}{2L_1}\sqrt{\frac{T}{\pi r^2\rho}} = \frac{1}{2L_2}\sqrt{\frac{4T}{\pi r^2\rho}}$

$\frac{L_2}{L_1} = \mathbf{2}$

If f be the fundamental frequency of string *A* with length L_1

$f = \frac{1}{2L_1}\sqrt{\frac{T}{\pi r^2\rho}}$

The first overtone of *A* = second harmonic = $2n$

∴ $2f = \frac{1}{L_1}\sqrt{\frac{T}{\pi r^2\rho}}$

Let n' be the fundamental frequency of the string *B* with vibrating length L_2

$f' = \frac{1}{2L_2}\sqrt{\frac{4T}{\pi r^2\rho}}$

The third harmonic of this is $3n'$

$3f' = \frac{3}{2L_2}\sqrt{\frac{4T}{\pi r^2\rho}}$

Since $2f = 3f'$

$\frac{1}{L_1}\sqrt{\frac{T}{\pi r^2\rho}} = \frac{3}{2L_2}\sqrt{\frac{4T}{\pi r^2\rho}} = \frac{3}{L_2}\sqrt{\frac{T}{\pi r^2\rho}}$; $\frac{L_2}{L_1} = \mathbf{3}$

Illustration 7

Question: **A thin steel wire has been stretched so that its length increases by 1%. The fundamental frequency of one metre length of the wire is *x*. Find [*x*], where [ ] denotes greatest integer. Young's modulus for steel = 20 x 10^{10} N/m^2 and density of steel = 7800 kg/m^3.**

Solution: Let the original length of the wire be L and ΔL be the increase in length under the stretching force T. T is the tension in the wire. Let A be the area of cross-section of the wire. Then

$$T = \frac{YA\Delta L}{L} = 20 \times 10^{10} A\left(\frac{\Delta L}{L}\right)$$

$$= 20 \times 10^{10} \times \frac{1}{100} \times A = 2 \times 10^{9} A \text{ newton}$$

The frequency of vibration of 1 m length of the wire is given by

$$f = \frac{1}{2L}\sqrt{\frac{T}{m}} \qquad = \frac{1}{2(1)}\sqrt{\frac{2\times10^9\times A}{(\pi r^2)\rho}}$$

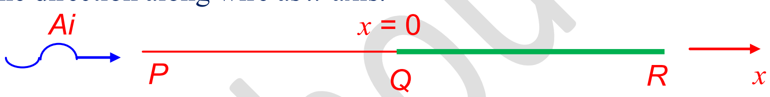
$$= \frac{1}{2}\sqrt{\frac{2\times10^9\times A}{A\cdot\rho}} \qquad = \frac{1}{2}\sqrt{\frac{2\times10^9}{7800}} = 253.2 \text{ Hz.}$$

$\therefore \qquad [x] = \mathbf{253}$

5.11 AMPLITUDE OF REFLECTED & TRANSMITTED WAVES

A long wire PQR is made by joining two wires PQ and QR of equal radii. PQ has a length l_1 and mass m_1, QR has length l_2 and mass m_2. The wire PQR is under a tension T. A sinusoidal wave pulse of amplitude A_i is sent along the wire PQ from the end P. No power is dissipated during the propagation of the wave pulse.

Let us take the direction along wire as x-axis.



Let us take the direction along wire as x-axis

Velocity of wave in wire PQ = $\sqrt{\frac{T}{m_1/l_1}} = \sqrt{\frac{T\,l_1}{m_1}} = v_1$ and velocity of wave in wire

$QR = v_2 = \sqrt{\frac{Tl_2}{m_2}}$

Then for incident wave we can write

$y_i = A_i \sin\omega\,[\,t - x/v_1]$ … (i)

In reflected and transmitted wave, 'ω' will not change, therefore we can write

$y_r = A_r \sin\omega\,[t + x/v_1]$ … (ii)

$y_t = A_t \sin\omega\,[\,t - x/v_2]$ … (iii)

Now as wave is continuous, so at the boundary ($x = 0$)

Continuity of displacement requires

$y_i + y_r = y_t$ for $x = 0$

Substituting from (i), (ii) and (iii) in the above,

$A_i + A_r = A_t$ … (iv)

Also, at the boundary, slope of wave will be continuous, i.e., $\frac{\delta y_i}{\delta x} + \frac{\delta y_r}{\delta x} = \frac{\delta y_t}{\delta x}$ for $x = 0$

Which gives, $A_i - A_r = \left(\frac{v_1}{v_2}\right)A_t$ … (v)

Solving (iv) and (v) for A_r and A_t we get the required equations, i.e.,

$$A_r = \frac{v_2 - v_1}{v_2 + v_1}A_i \qquad \textbf{… (23)}$$

and $$A_t = \frac{2v_2}{v_2 + v_1}A_i \qquad \textbf{… (24)}$$

PROFICIENCY TEST– I

The following questions deal with the basic concepts of this section. Answer the following briefly. Go to the next section only if your score is at least 80%. Do not consult the Study Material while attempting these questions.

1. Find the amplitude (in cm), frequency (in Hz) and wavelength (in cm) of the wave represented by equation

$$y = 2\cos^2\left(100\pi t - \frac{2\pi x}{4}\right)$$, where x and y are in cm and t is in second.

2. Two identical strings are stretched at tensions T_A and T_B. A tuning fork is used to set them in vibration. A vibrates in its fundamental mode and B in its second harmonic mode. Find the ratio $\frac{T_A}{T_B}$.

3. A uniform rope of mass 1 kg hangs vertically from the ceiling, with its lower end free. A disturbance on the rope travels upward from the lower end. Find the time taken in second by the disturbance to reach the top of the rope if the length of the rope is L = 10 m. (g = 10m/s^2).

4. A string A has double the length, double the tension, double the diameter and double the density as another string B. If their fundamental frequencies of vibration are n_A & n_B respectively then find n_B/n_A.

5. $y(x, t) = \frac{0.8}{[4(x+5t)^2+5]}$ represents a moving pulse, where x, y are in metre and t in seconds. Then find the distance moved by it in 2 seconds.

ANSWERS TO PROFICIENCY TEST– I

1. Amplitude = 1 cm, frequency =100 Hz, wavelength = 2 cm

2. 4

3. $t = 2$ s

4. 4

5. 10 m

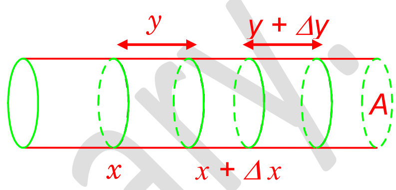
6 SOUND

Sound is produced in a material medium by a vibrating source. Sound waves constitute alternate compression and rarefaction pulses travelling in the medium. The compression travels in the medium at a speed, which depends on the elastic and inertial properties of the medium.

The description in terms of pressure wave is more appropriate than the description in terms of the displacement wave as far as sound properties are concerned.

6.1 SOUND AS PRESSURE WAVE

A longitudinal wave in a fluid is described either in terms of the longitudinal displacements suffered by the particles of the medium or in terms of the excess pressure generated due to the compression or rarefaction.



Consider a wave going in the *x*-direction in a fluid. Suppose that at a time *t*, the particle at the undisturbed position *x* suffers a displacement *y* in the *x*-direction.

$$y = y_o \sin\omega\left(t - \frac{x}{v}\right) \quad \ldots \text{(i)}$$

A is cross-sectional area.

Increase in volume of this element at time t is

$$\Delta V = A\,dy$$

$$= Ay_o\left(\frac{-\omega}{v}\right)\cos\omega\left(t - \frac{x}{v}\right)\Delta x$$

where Δy has been obtained by differentiating equation (i) with respect to *t*.

$$\Rightarrow \quad \text{volume strain is } \frac{\Delta V}{V} = -\frac{Ay_o\omega\cos\omega\left(t - \frac{x}{v}\right)\Delta x}{vA\Delta x} = -\frac{y_o\omega}{v}\cos\omega\left(t - \frac{x}{v}\right) = \frac{\delta y}{\delta x}$$

$$\therefore \quad \textbf{volume strain} = \frac{\delta y}{\delta x} \quad \ldots \textbf{(25)}$$

The corresponding stress i.e., the excess pressure developed in the element at *x*, at time *t* is

$$p = B\left(\frac{-\Delta V}{V}\right)$$ where *B* is the bulk modulus of the material.

$$\Rightarrow \quad p = \frac{By_o\omega}{v}\cos\omega\left(t - \frac{x}{v}\right) \quad \ldots \text{(ii)}$$

$$\therefore \quad P = -\frac{B\delta y}{\delta x} \quad \ldots \textbf{(26)}$$

Comparing equations (i) and (ii), the relation between the pressure amplitude p_0 and the displacement amplitude s_0 is

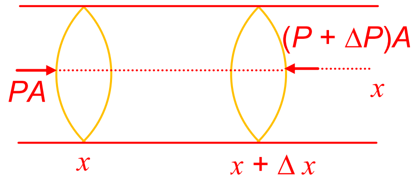
$$p_o = \frac{B\omega}{v}y_o = Bky_o \Rightarrow y_o = \frac{p_o\lambda}{2\pi B}$$ **where *k* is a wave number.** **… (27)**

As observed from equations (i) and (ii), pressure wave is ‘cos θ’ type, if displacement is described as ‘sin θ’ type.

Thus, the pressure-maxima occur where the displacement is zero and displacement-maxima occur where the pressure is at its normal level.

6.2 SPEED OF SOUND WAVE IN A MATERIAL MEDIUM

The resultant force on element of fluid (which is contained between the positions x and $x + \Delta x$ where A is the area of cross section) is



$$\Delta F = Ap - A(p + \Delta p) = -A\Delta p$$

Acceleration, $a = \dfrac{\Delta F}{\rho A \Delta x}$ (using Newton's law)

Also, $a = \dfrac{\partial^2 y}{\partial t^2}$

$$\therefore \quad \frac{B y_o \omega^2}{\rho v^2} = \omega^2 y_o$$

$$\Rightarrow \quad v = \sqrt{\frac{B}{\rho}} \qquad \dots (28)$$

6.3 POWER (*W*) TRANSMITTED BY WAVE:

$W = pA\dfrac{\partial y}{\partial t}$ (Since power $= \dfrac{FS}{t}$ and pressure $= \dfrac{F}{A}$) $= \dfrac{A\omega^2 y_o^2 B}{v}\cos^2\omega\left(t - \dfrac{x}{v}\right)$

The average of $\cos^2\theta$ over a complete cycle or over a long time is $\dfrac{1}{2}$.

Intensity I is the average power transmitted across unit cross-sectional area.

$$I = \frac{1}{2}\frac{\omega^2 y_o^2 B}{v}$$

$$\Rightarrow \quad I = \frac{p_o^2 v}{2B} \qquad \dots (29)$$

(Since $\omega = 2\pi f$ and $p_0 = \dfrac{B\omega y_o}{v}$)

$$\Rightarrow \quad I \propto p_o^2$$

This is similar or analogous to

$$I \propto y_o^2$$

In other words, intensity is proportional to the square of the amplitude (whether displacement or pressure).

Loudness is measured in terms of sound level (in decibels i.e., dB) denoted by β.

$\beta = 10\log_{10}\left(\dfrac{I}{I_o}\right)$ **where I_0 is the reference intensity equal to 10^{-12} W/m².** ... (30)

6.4 AUDIBLE RANGE AND ULTRASONICS

The audible range of sound waves in air in terms of frequency f is "20 Hz to 20 kHz".

Since velocity of sound in air at STP (Standard Temperature and Pressure) is v = 332 m/s, the wavelengths (λ) for audibility lie in the range 1.66 cm to 16.6 m (using $v = n\lambda$).

Longitudinal mechanical waves having frequency greater than 20 kHz are called **ultrasonic waves**. Ultrasonic sound waves also travel with same velocity 332 m/s at S.T.P.

Hence, the wavelength of ultrasonics λ < 1.66 cm. Though human ear cannot detect these ultrasonic waves, certain creatures such as mosquito and bat show response to these. These waves can be produced by the frequency of a quartz crystal under an alternating electric field (piezo-electric effect) or by the vibrations of a ferromagnetic rod under an alternating magnetic field (magnetostriction effect). For infrasonic waves λ > 16.6 m.

6.5 LONGITUDINAL VIBRATIONS IN SOLIDS AND FLUIDS

The velocity of longitudinal waves in a solid or fluid is given by

$$v = \sqrt{\frac{E}{\rho}} \qquad \ldots (31)$$

where E is the elasticity of the medium.

Solids: In the case of solids the stress is tensile or unidirectional. The strain is linear and the modulus of elasticity involved is Young's modulus.

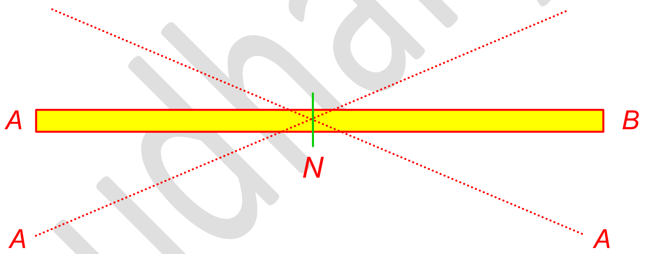
Hence $E = Y$ (Young's modulus)

$$\therefore \quad v = \sqrt{\frac{Y}{\rho}} \qquad \ldots (32)$$

The velocity of longitudinal wave in a solid is given by

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

It is possible to establish a stationary wave in a rod like AB, which is clamped in the middle and striked at one of its ends. Stationary waves are set up with the clamped point remaining as a node and the free ends as antinodes. If L is the length of the rod, λ the wavelength of the wave then



we have

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

The fundamental frequency, $f = \frac{v}{\lambda} = \frac{v}{2L} = \frac{1}{2L}\sqrt{\frac{Y}{\rho}}$

Gases: In the case of gases the elasticity is bulk modulus as it brings about volume strain. Newton first assumed that the changes in gases are isothermal and the isothermal bulk modulus was taken by him as p. But later Laplace modified the formula and got the adiabatic bulk modulus which is γp, where γ is the ratio of specific heats of the gas. The velocity of sound in a gas is therefore

$$v = \sqrt{\frac{\gamma p}{\rho}}. \qquad \ldots (33)$$

6.6 VELOCITY OF SOUND IN AN IDEAL GAS

The motion of sound wave in air is adiabatic. In the case of an ideal gas, the relation between pressure P and volume V during an adiabatic process is given by

PV^{γ} **= constant**

Where γ is the ratio of the heat capacity at constant pressure to that at constant volume.

After differentiating, we get

$$V^{\gamma}\frac{dP}{dV} + \gamma PV^{\gamma-1} = 0$$

Since $B = -\frac{vdP}{dV} = \gamma P$

(Laplace correction is constant to newtons' formula $v = \sqrt{\frac{P}{\rho}}$) using the gas equation

$\frac{P}{\rho} = \frac{RT}{M}$ where M is the molar mass.

Thus $v = \sqrt{\dfrac{\gamma RT}{M}}$ **(T = temperature is Kelvin)** **… (34)**

6.7 EFFECT OF TEMPERATURE, PRESSURE AND HUMIDITY ON VELOCITY OF SOUND IN GASES

(i) Effect of temperature: If the specific volume of gas is v. The velocity of sound

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

If c_1 and c_2 be the velocities of sound in a gas at temperatures $t_1^\circ C$ and $t_2^\circ C$ and P_1 and P_2 the respective pressures and V_1 and V_2 the specific volumes at these temperatures, ratio of the two velocities of sound is

$$\frac{v_1}{v_2} = \sqrt{\frac{P_1V_1}{P_2V_2}} = \sqrt{\frac{RT_1}{RT_2}}$$ where T and T_2 are the absolute temperatures.

$$\therefore \quad \frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{273+t_1}{273+t_2}} \quad \text{… (35)}$$

If c and c_0 are the velocities at t°C and 0°C, then

$$\frac{v}{v_0} = \sqrt{\frac{273+t}{273}}$$

$$v = v_0\left(1+\frac{t}{273}\right)^{\frac{1}{2}} = v_0\left(1+\frac{t}{546}\right)$$

Calculations would show that the velocity of sound in air increases approximately at the rate of 0.6 metre/sec per degree rise of temperature.

(i) **Effect of pressure:** At constant temperature the ratio $\dfrac{P}{\rho}\left(=\dfrac{RT}{M}\right)$ is constant (Boyle's law). Hence the velocity of sound in gases at constant temperature is independent of pressure.

(ii) **Effect of humidity:** The presence of moisture in air decrease the density of air. Hence if the humidity is high the density decreases and the velocity of sound increases. Thus the velocity of sound in moist air is greater than the velocity of sound in dry air.

6.8 WAVE VELOCITY AND MOLECULAR VELOCITY IN A GAS

The velocity of propagation of sound waves through a gas is

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

According to this relation the velocity of sound will depend on the pressure of the gas. Also according to the kinetic theory of gases the pressure of gas is

$$P = \frac{1}{3}\rho v_{rms}^{\ 2}$$

where ρ is the density of gas and v_{rms} is the root mean square velocity of the molecules at a particular temperature.

$$\frac{P}{\rho} = \frac{v_{rms}^{\ 2}}{3}$$

Substituting this value of $\dfrac{P}{\rho}$ in the above equation for velocity of sound in a gas

$$v = \sqrt{\frac{\gamma v_{rms}^2}{3}} = v_{rms}\sqrt{\frac{\gamma}{3}}$$

$$v_{rms} = v\sqrt{\frac{3}{\gamma}} \quad \text{... (36)}$$

From the above equation if velocity of sound and γ of gas are known the r.m.s velocity can be calculated.

Illustration 8

Question: **(a) What is the ratio of velocities of sound in hydrogen and oxygen at the same temperature? (b) Find the temperature at which the speed of sound in oxygen is the same as that in hydrogen at 27°C.**

Solution: **(a)** The temperature of the two gases H_2 and O_2 are given to be the same. Now

$$v = \sqrt{\frac{\gamma RT}{M}}$$

$$v_0 = \sqrt{\frac{\gamma RT}{M_O}} \text{ and } v_H = \sqrt{\frac{\gamma RT}{M_H}}$$

γ is same for both the gases.

$$\therefore \quad \frac{v_H}{v_O} = \sqrt{\frac{M_O}{M_H}} = \sqrt{\frac{32}{2}} = \sqrt{16} = 4$$

$\therefore$ $\mathbf{v_H : v_0 = 4 : 1}$

(b) Velocity of sound in hydrogen at 27°C is given by

$$v_H = \sqrt{\frac{\gamma . R . 300}{M_H}}$$

The velocity of sound in oxygen at a temperature t°C is

$$V_0 = \sqrt{\frac{\gamma . R(273+t)}{M_O}}$$

If $v_H = v_0$,

$$\sqrt{\frac{\gamma R(300)}{M_H}} = \sqrt{\frac{\gamma R(273+t)}{M_O}} \quad \text{or,} \quad \frac{300}{M_H} = \frac{273+t}{M_O}$$

or $273 + t = \frac{300}{2} \times 32 = 16 \times 300$

$t = 4800 - 273 = \mathbf{4527°C}$

Illustration 9

Question: **A gas is a mixture of two parts by volume of hydrogen and one part by volume of nitrogen. If the velocity of sound in hydrogen at 0°C is 1300 m/s find the velocity of sound in the gaseous mixture at 27°C.**

Solution: Hydrogen and nitrogen are both diatomic and hence their ratio of specific heats γ is the same. Hence we can take the γ of the mixture also to be that of diatomic gas.

Velocity of sound in hydrogen gas at 0°C

$$v_H = \sqrt{\frac{\gamma P}{\rho_H}} \qquad \rho_H = \text{Density of hydrogen.}$$

Since molecular weights of hydrogen and nitrogen are 2 and 28 respectively, nitrogen is 14 times heavier than hydrogen at the same pressure and temperature.

Considering the gaseous mixture, the density of mixture

$$\rho_m = \frac{2V\rho_H + V(14\rho_H)}{3V} \quad \rho_{\text{nitrogen}} = 14\rho_H$$

$$\rho_m = \frac{16\rho_H}{3}$$

Velocity of sound in the mixture at 0°C

$$v_0 = \sqrt{\frac{\gamma P}{\rho_m}} \qquad \rho_m = \text{Density of mixture} = \sqrt{\frac{\gamma P.3}{16\rho_H}}$$

Now $\frac{v_0}{v_H} = \sqrt{\frac{\gamma P}{\rho_H}.\frac{3}{16}} \Big/ \sqrt{\frac{\gamma P}{\rho_H}} = \sqrt{\frac{3}{16}}$

$$v_0 = \frac{1300 \times \sqrt{3}}{4} = 325\sqrt{3} \text{ m/s}$$

Velocity of sound in the mixture at a temperature 27°C is given by

$$v_t = v_0\left(1 + \frac{t}{546}\right) \text{ (approx)} = 325\sqrt{3}\left(1 + \frac{27}{546}\right) = \mathbf{591\ m/s}$$

Illustration 10

Question: **Calculate the R.M.S. velocity in m/s of gas molecules at NTP if the velocity of sound in that gas is 300 m/s. Ratio of the specific heats of the gas is 1.5. (given √2 = 1.4)**

Solution: R.M.S. velocity of gas molecules $v_{rms} = \sqrt{\frac{3RT}{M}}$

Velocity of sound in the gas $v = \sqrt{\frac{\gamma RT}{M}}$; $\therefore \frac{v}{v_{rms}} = \sqrt{\frac{\gamma RT}{M} \times \frac{M}{3RT}} = \sqrt{\frac{\gamma}{3}}$

$$v_{rms} = v\sqrt{\frac{3}{\gamma}} = 300\sqrt{\frac{3}{1.5}} = 300\sqrt{2} = \mathbf{420\ m/s}$$

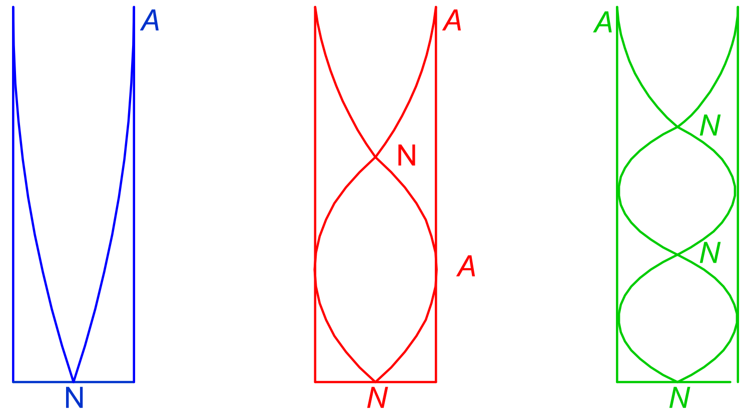
7 VIBRATIONS OF AIR COLUMNS

An air column is one, which is enclosed in a pipe. When an air column is excited the column is set into vibration and longitudinal waves are set up. The waves are reflected back at the boundaries of air columns. The incident and reflected waves produce longitudinal stationary waves.

Suppose we consider a closed tube, which is closed at one end and open at the other. At the closed end a compression is reflected as compression and a rarefaction as a rarefaction. At the open end a compression is reflected as a rarefaction while a rarefaction is reflected as a compression. Hence the closed end must be a displacement node while the open end must be a displacement antinode.

7.1 VIBRATION IN CLOSED PIPES – OVERTONES AND HARMONICS

A stationary wave pattern can be maintained in a closed tube containing a gas only for a frequency, which has one of the values making the length of the column a whole number of quarter wavelengths. It should be noted that the open end is always an antinode and the closed end a node. According to this condition there arises a number of standing waves as shown in Figure. The wave pattern, which has the lowest frequency, is called fundamental and the others are called overtones.



First Mode of vibration (Fundamental mode)

The length of air column L is equal to $\frac{\lambda}{4}$.

$\therefore \quad \lambda = 4L$

$v = f\lambda$

$$f = \frac{v}{\lambda} = \frac{v}{4L} \qquad \dots (37)$$

where f is the frequency of fundamental mode.

Second Mode of Vibration (First overtone)

$$L = \frac{3\lambda_1}{4}$$

$$\lambda_1 = \frac{4L}{3}$$

$$\therefore \quad \textbf{frequency } f_1 = \frac{v}{\lambda_1} = \frac{3v}{4L} = 3f. \qquad \dots \text{(i)}$$

The frequency of first overtone is 3 times the value of fundamental.

Third Mode of Vibration (Second overtone)

Here $L = \frac{5\lambda_2}{4}$

$$\lambda = \frac{4L}{5}$$

$$\therefore \quad \text{frequency } f_2 = \frac{v}{\lambda_2} = \frac{5v}{4L} = 5f. \qquad \dots \text{(ii)}$$

When an air column is excited the fundamental and a number of possible overtones are present in the vibration. Of these the loudest is the fundamental and overtones progressively become weaker in intensity. The overtones whose frequencies are integral multiples of fundamental are called harmonics. The fundamental with frequency f itself is taken as first harmonic. The overtone with frequency $2f$ is called second harmonic and the overtone with frequency $3f$ is called third harmonic and so on.

In the case of closed type indicated above all odd harmonics are present and even harmonics are absent.

End correction: In the above discussion it is assumed that the position of antinode coincides with the open end of pipe exactly. This is not however true and it is found that antinode is a little bit displaced above the open end. If e is the end correction, then for fundamental mode.

$$\frac{\lambda_1}{4} = (L + e)$$

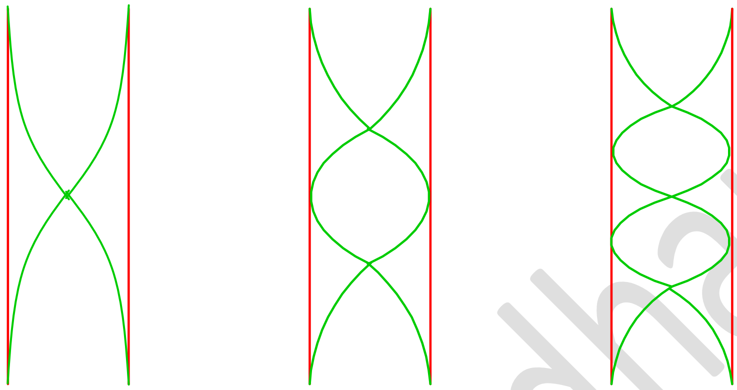
For the first overtone,

$$\frac{3\lambda_2}{4} = (L + e) \text{ and so on.}$$

The end correction depends upon the diameter of the pipe. If d is the diameter, the end correction $e = 0.3\ d$.

7.2 VIBRATION IN OPEN PIPES

A pipe with both ends open is called open pipe. The first three modes of vibrations, starting from fundamental in open pipes are shown in figures below.



First mode of vibration (Fundamental mode): In the fundamental mode there is a node between antinodes at each end.

$$\therefore \quad L = \frac{\lambda}{2} \quad \text{or} \quad \lambda = 2L$$

$$f = \frac{v}{\lambda} = \frac{v}{2L} \qquad \textbf{(38)}$$

Second mode of vibration (First overtone): If λ_1 and f_1 are the wavelength and frequency of the first overtone in open pipe.

$$\lambda_1 = L$$

$$f_1 = \frac{v}{\lambda_1} = \frac{v}{L} = \frac{2v}{2L} = 2f \qquad \ldots \text{(i)}$$

The frequency of first overtone is twice that of fundamental. It corresponds to second harmonic.

Second overtone: If λ_2 and f_2 be the wavelength and frequency of second overtone in the open pipe,

$$L = \frac{3\lambda_2}{2}$$

$$\lambda_2 = \frac{2L}{3}$$

$$f_2 = \frac{v}{\lambda_2} = \frac{3v}{2L} = 3f \qquad \ldots \text{(ii)}$$

This corresponds to third harmonic of the vibrating system.

In an open pipe all the harmonics, both odd and even are present.

7.3 FREE, DAMPED AND FORCED VIBRATIONS

A body capable of vibration, if excited, and set free, vibrates freely in its own natural way. The frequency of such free vibration depends on the mass, elastic property and dimensions of the body. The frequency is called free frequency or natural frequency of the body.

7.4 DAMPED VIBRATIONS

The amplitude of free vibrations of a body gradually diminishes and finally the vibrations die away after sometime. This is due to the vibratory motion being damped by forces internal and external to the body.

7.5 FORCED VIBRATIONS

If an external periodic force is applied to a body which is capable of vibration and if the frequency of the applied periodic force is not the same as the free frequency of the body, the body begins to vibrate initially with its own natural frequency but these vibrations die down quickly and the body ultimately vibrates with the frequency of the external periodic force. Such vibrations are called forced vibrations

8 RESONANCE

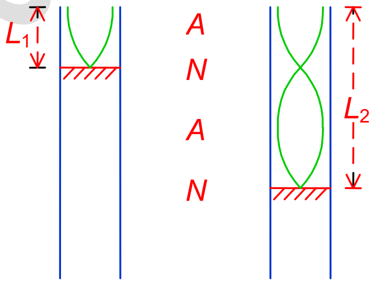
Resonance is a special case of forced vibration. If the frequency of the external periodic force is the same as the natural frequency of the body, the body responds to the forced vibrations more willingly and there is a gain in the amplitude of its vibrations. This is called resonance.

Resonance has vast applications in acoustics, electrical circuits and electronics.

8.1 RESONANCE IN AIR COLUMNS-RESONANCE TUBES

Suppose the length of air column in a long tube can be adjusted either by dipping the tube in a reservoir of water or by allowing the water level to occupy a desired position in the tube by pressure flow, the column can be made to vibrate in resonance with an excited tuning fork kept over the mouth of the tube.

For two lengths of air column L_1 and L_2, $3L_1$, the resonance would occur and the positions correspond to the fundamental mode and the first overtone respectively.



If λ be the wavelength of sound in air and v the velocity of sound in air, then

$$L_1 + e = \frac{\lambda}{4}$$

$$L_2 + e = \frac{3\lambda}{4}$$

where e is the end correction.

From the above equations we get

$$\frac{\lambda}{2} = L_2 - L_1 \quad \text{or,} \quad \lambda = 2(L_2 - L_1)$$

$$v = f\lambda = 2f(L_2 - L_1) \qquad \dots (39)$$

where f is the frequency of vibration of the air column which is in resonance with the tuning fork of same frequency.

Illustration 11

Question: **A rod of length 1 m clamped at its midpoint is set up with a Kundt's tube containing air. When the rod is set vibrating in its longitudinal mode of vibrations it is found that the internodal distance in the tube is 0.063 m. The temperature of air inside the tube is 10°C and the velocity of sound in air at 0°C is 330.95 m/s. Calculate the frequency of the note emitted by the rod and the value of x if Young's modulus of the rod is $x \times 10^8$ N/m². Given the density of the rod = 7600 kg/m³.**

Solution: Velocity of sound at 0°C = 330.95 m/s

Velocity of sound at 10°C = 330.95 + (10 × 0.61) = 337.05 m/s

(Velocity of sound increases at the rate of 0.61 m/s per °C rise in temperature approximately).

Internodal distance = $\frac{\lambda_{air}}{2}$ = 0.063 m or λ_{air} = 0.126 m

Frequency of vibrations in air = $\frac{337.05}{0.126}$ = 2675 Hz

This is equal to the frequency of vibrations of the rod.

∴ frequency of the note emitted by the rod = **2675 Hz**

$$f = \frac{1}{2l}\sqrt{\frac{y}{p}}$$

$$y = 4l^2f^2\rho = 4 \times 1^2 \times 2675^2 \times 7600 = 2.175 \times 10^{11} \text{ N/m}^2.$$

∴ x = **2175**

Illustration 12

Question: **A tube of a certain diameter and length 48 cm is open at both ends. Its fundamental frequency is found to be 320 Hz. The velocity of sound in air is 320 m/s. Estimate the value of end correction in cm.**

Solution: Let the length of the open tube be L. The end correction on both sides is e. The tube vibrates in its fundamental. Then

$$\frac{\lambda}{2} = L + 2e \text{ or } \lambda = 2(L + 2e)$$

If v be the velocity of sound in air the fundamental frequency is given by

$$f = \frac{v}{\lambda} = \frac{v}{2(L+2e)}$$

f = 320 Hz; v = 320 m/s or, $320 = \frac{320}{2(L+2e)}$

or $L + 2e = 0.5$ m

$2e = 0.5 \text{ m} - 0.48 \text{ m} = 0.02$ m

$e = 0.01$ m = **1 cm**

Illustration 13

Question: **The length of an organ pipe is 33 cm. What is the change in its length required to maintain its frequency unchanged if the temperature falls from 90°C to 27°C?**

Solution: Let L_1 and L_2 be the lengths of the pipe at t_1 = 27°C and t_2 = 7°C respectively.

Now the frequency is maintained constant, irrespective of the organ pipe being a closed one or an open one, then,

$\frac{v}{L}$ = a constant v = velocity of sound in air

or $\frac{L_1}{L_2} = \frac{v_1}{v_2}$ v_1 = velocity at temperature $t_1^\circ C$

v_2 = velocity at temperature $t_2^\circ C$

But $\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$

∴ $\frac{L_1}{L_2} = \sqrt{\frac{273+90}{273+27}} = \;= 1.1$

Now $\frac{L_1 - L_2}{L_1} = \frac{1.1-1}{1.1} = \frac{1}{11}$

$L_1 - L_2 = 30 \times \frac{1}{1.1} = 3$ cm

The change in length is a decrease by 3 cm.

9 BEATS

When two interacting waves have slightly different frequencies the resultant disturbance at any point due to the superposition periodically fluctuates causing waxing and waning in the resultant intensity. The waxing and waving in the resultant intensity of two superposed waves of slightly different frequency are known as **beats**.

Let the displacement produced at a point by one wave be

$y_1 = A \sin(2\pi f_1 t - \phi_1)$

and the displacement produced at the point produced by the other wave of equal amplitude as

$y_2 = A \sin(2\pi f_2 t - \phi_2)$

By the principle of superposition, the resultant displacement is

$$y = y_1 + y_2 = A \sin(2\pi f_1 t - \phi_1) + A \sin(2\pi f_2 t - \phi_2)$$

$$y = 2A \sin\left\{2\pi\left(\frac{f_1+f_2}{2}\right)t - \left(\frac{\phi_1+\phi_2}{2}\right)\right\}\cos 2\pi\left(\frac{f_1-f_2}{2}t + \frac{\phi_2-\phi_1}{2}\right)$$

$$y = R \sin\left\{2\pi\left(\frac{f_1+f_2}{2}\right)t - \left(\frac{\phi_1+\phi_2}{2}\right)\right\} \qquad \ldots (40)$$

where $R = 2A \cos 2\pi\left(\frac{f_1-f_2}{2}t + \frac{\phi_2-\phi_1}{2}\right)$

for $\phi_1 = \phi_2$, $R = 2A \cos 2\pi\left(\frac{f_1-f_2}{2}t\right)$

The time for one beat is the time between consecutive maxima or minima.

First maxima would occur when

$$\cos 2\pi\left(\frac{f_1-f_2}{2}\right)t = +1$$

Then $2\pi\left(\frac{f_1-f_2}{2}\right)t = 0$

$\therefore$ $t = 0$

Second maxima would occur when $\cos 2\pi\left(\frac{f_1-f_2}{2}\right)t = -1$

Then $2\pi\left(\frac{f_1-f_2}{2}\right)t = \pi$

or $t = \frac{1}{(f_1-f_2)}$

The time for one beat $= \left\{\frac{1}{(f_1-f_2)} - 0\right\} = \frac{1}{f_1-f_2}$

Similarly it can also be shown time between two consecutive minima is $\frac{1}{(f_1-f_2)}$

Hence frequency of beat i.e., number of beats in one second $= f_1 \sim f_2$ ... (41)

Illustration 14

Question: **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 15°C. When the temperature falls to 10°C the two produce 3 beats per second. The frequency of fork is *f*, then find the value of 5*f*.**

Solution: Let λ be the wavelength and n be the frequency of fork.

At 15°C, $\frac{v_{15}}{\lambda} - f = 4$ or $\frac{v_{15}}{\lambda} = f + 4$

At 10°C, $\frac{v_{10}}{\lambda} - f = 3$ or $\frac{v_{10}}{\lambda} = f + 3$

$\therefore \quad \dfrac{v_{15}}{v_{10}} = \dfrac{f+4}{f+3}$

But $\quad \dfrac{v_{15}}{v_{10}} = \sqrt{\dfrac{273+15}{273+10}} = \sqrt{\dfrac{288}{283}}$

$\therefore \quad \sqrt{\dfrac{288}{283}} = \dfrac{f+4}{f+3}$

$$\left(1+\frac{5}{283}\right)^{1/2} = \frac{f+4}{f+3}$$

$$1+\frac{5}{566} = \frac{f+4}{f+3}$$

$$\frac{5}{566} = \frac{f+4-f-3}{f+3} = \frac{1}{f+3}$$

$5f + 15 = 566$

$5f =$ **551**

Illustration 15

Question: **Two tuning forks *A* and *B* when sounded together give 4 beats/sec. *A* is in unison with the note emitted by a length 0.96 m of a sonometer wire under a certain tension while *B* is in unison with 0.97 m of the same wire under the same tension. Find the frequencies of the forks.**

Solution: Let the frequency of the fork *A* be *f*. Since *A* is in unison with a smaller length of the sonometer wire than *B* which is in unison with a larger length of the wire, the frequency of fork *A* should be larger than that of *B*.

$\therefore$ frequency of fork $B = (f - 4)$ Hz

Now $f \times 0.96 = (f - 4)(0.97)$

$$\frac{f-4}{f} = \frac{96}{97}$$

$$1-\frac{4}{f} = 1-\frac{1}{97}$$

$$\frac{4}{f} = \frac{1}{97}$$

or, $f = 4 \times 97 = 388$ Hz

$\therefore$ the frequency of fork A = **388 Hz**

and that of B = **384 Hz.**

10 DOPPLER EFFECT

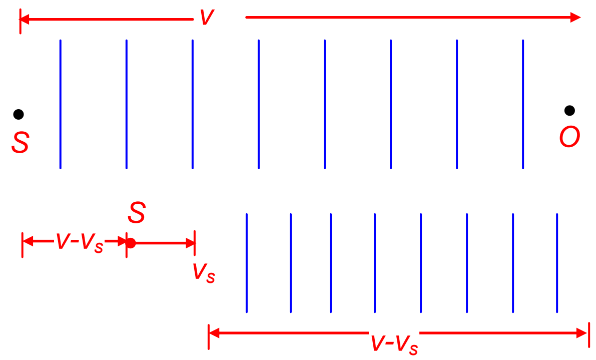
When a sound source and an observer are in relative motion with respect to the medium in which the waves propagate, the frequency of waves observed is different from the frequency of sound emitted by the source. This phenomenon is called Doppler effect. This is due to the wave-nature of sound propagation and is therefore applicable to light waves also. The apparent change of colour of a star can be explained by this principle.

10.1 CALCULATION OF APPARENT FREQUENCY

Suppose v is the velocity of sound in air, v_0 is the velocity of the observer (O) and f is the frequency of the source.

(i) **Source moves towards stationary observer:** If the source S were stationary the f waves sent out in one second towards the observer O would occupy a distance v, and the wavelength would be v/f.

If S moves with a velocity v_s towards O, the f waves sent out occupy a distance $(v - v_s)$ because S has moved a distance v_s towards O in 1 s. So the apparent wavelength would be:



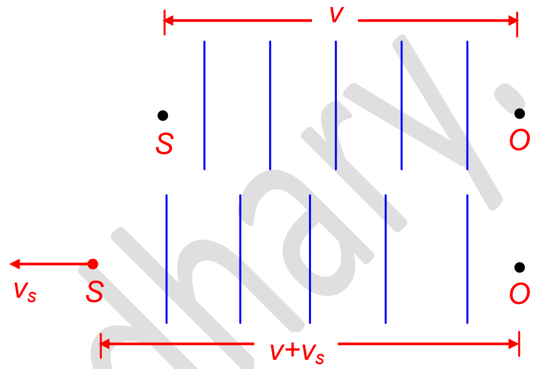
$$\lambda' = \left(\frac{v - v_s}{f}\right)$$

Thus, apparent frequency

$$f' = \frac{\text{velocity of sound relative to } O}{\text{wavelength of wave reaching } O}$$

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

(ii) **Source moves away from stationary observer:** Now, apparent wavelength



$$\lambda' = \frac{v + v_s}{f}$$

$\therefore$ Apparent frequency

$f' = v/\lambda'$

or $$f' = f\left(\frac{v}{v + v_s}\right)$$

(iii) **Observer, moves towards stationary source**

$$f' = \frac{\text{velocity of sound relative to } O}{\text{wavelength of wave reaching } O}$$

Here, velocity of sound relative to $O = v + v_0$

and wavelength of waves reaching $O = v/f$

$$\therefore f' = \frac{v + v_0}{v/f} = f\left(\frac{v + v_0}{v}\right)$$

(iv) **Observer moves away from the stationary source**

$$f' = \frac{v - v_0}{v/f} = f\left(\frac{v - v_0}{v}\right)$$

(v) **Source and observer both moves towards each other**

$$f' = \frac{(v + v_0)}{\left(\frac{v - v_s}{f}\right)} = f\left(\frac{v + v_0}{v - v_s}\right)$$

(vi) **Both moves away from each other**

$$f' = f\left[\frac{v - v_0}{v + v_s}\right]$$

(vii) **Source moves towards observer but observer moves away from source**

$$f' = f\left(\frac{v - v_0}{v - v_s}\right)$$

(viii) **Source moves away from observer but observer moves towards source**

$$f' = f\left[\frac{v + v_0}{v + v_s}\right]$$

Effect of wind on Doppler Effect in sound: The formulae derived in the previous sections are valid only where there is no wind. If there is a wind velocity v_w, the effective velocity of sound would become $(v + v_w)$ or $(v - v_w)$ according as v_w is in the direction of v or opposite to it.

Observed frequency using Doppler's effect is given by

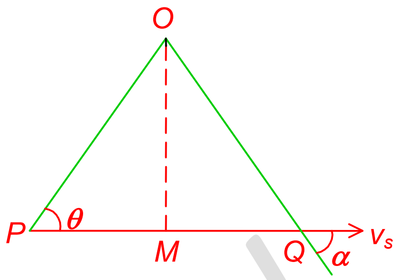
$$f' = \frac{[(v \pm v_W) \pm v_0)]}{[(v \pm v_W) \pm v_s]} f \qquad \ldots (42)$$

10.2 DOPPLER EFFECT WHEN THE SOURCE IS MOVING AT AN ANGLE TO THE OBSERVER

Let O be a stationary observer and let a source of sound of frequency f be moving along the line PQ with constant speed v_s.

When the source is at P, the line PO makes angle θ with PQ, which is the direction of v_s.

The component of velocity v_s along PO is $v_s \cos\theta$ and it is towards the observer.



The apparent frequency in this case

$$f_a = \frac{v}{v - v_s\cos\theta} \cdot f \quad \text{... (43)}$$

As the source moves along PQ, θ increases cos θ decreases and the apparent frequency continuously diminishes. At M, $\theta = 90°$ and hence

$f_a = f$

When the source is at Q, the component of velocity v_s is $v_s \cos\alpha$ which is directed away from the observer. Hence the apparent frequency

$$f_a = \frac{v}{v + v_s\cos\alpha} \cdot f \quad \text{... (44)}$$

10.3 REFLECTION OF SOUND AND ECHO

Like light, sound waves can also be reflected and refracted. But the sound requires an extended reflector like a wall as its wavelength is very large compared to that of light.

The phenomenon of echo is due to reflection of sound. When a sound wave is reflected by a distant reflector like a wall or mountain cliff an observer hears two sounds, one from the source directly and the other as reflected from the reflector which is the echo.

In order to hear a clear and distinct echo a minimum distance must be maintained between the reflector and the observer. This is necessary because when a sound is heard the impression persists for a fraction of a second in the ear due to the persistence of hearing. Until this impression is removed the echo cannot be heard as a distinct sound. The persistence of hearing usually lasts for $\frac{1}{10}$ th of a second. If the time interval between the emission of the sound and the return of the reflected wave is more than $\frac{1}{10}$ th of a second the reflected sound is heard after a silent 'interval' and is called an echo.

11 LOUDNESS, PITCH AND QUALITY OF SOUND

GENERALLY

Loudness of a sound depends on its intensity

Pitch on the frequency and

Quality of sound depends on the combination of frequencies, overtones and their relative intensities. Together these three quantities determine the characteristics of sound - musical or otherwise.

LOUDNESS

Loudness is a physiological sensation in the human ear, which is intimately connected with the intensity of the wave incident.

The ear is sensitive to sound of frequencies anywhere from 20 Hz to 20000 Hz and is most sensitive to frequencies between 2000 and 3000 Hz.

The ear can detect sounds varying from the hardly audible low intensity of 10^{-12} (W/m^2) to very high intensities of 1 W/m^2.

Because of this enormous range of intensity to which the ear responds, a logarithmic scale is used to measure loudness levels instead of a linear scale.

If we take I_0 as the standard intensity level we can define another intensity level I as a ratio $\frac{I}{I_o}$, which is dimensionless. The difference L in intensity levels of two sound waves of intensity I and I_0 is defined in units of bel as

$$L = \log\left(\frac{I}{I_o}\right) \text{ bel} = 10\log\left(\frac{I}{I_o}\right) \text{ decibels } (dB) \quad \ldots (45)$$

The standard threshold of audibility I_0 is taken to be intensity of 10^{-12} W/m^2.

According to this the intensity level of an average sound which may have a loudness of 10^{-6} W/m^2 will be

$$I = 10\log\frac{10^{-6}}{10^{-12}}\ dB = 10\log 10^6 = 60\ dB$$

It is found that the intensity of the sound level must be doubled before an observer can respond to the change in intensity and say that the sound is definitely louder.

PITCH

The pitch refers to that characteristic of sound sensation that enables one to classify a note as a high note or a low note.

Pitch depends on the frequency. The higher the frequency the higher the pitch.

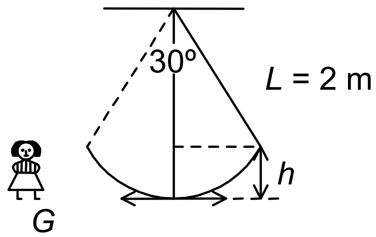
If we go up the scale by one octave we double the frequency.

QUALITY OR TIMBRE

The tone quality of any musical sound is determined by the presence of the number of overtones and their relative intensities

Illustration 16

Question: **A boy sitting on a swing which is moving to an angle of 30° from the vertical is blowing a whistle which has a frequency of 1000 Hz. The whistle is 2.0 m from the point of support of the swing. A girl stands infront of the swing. Calculate the maximum and minimum frequencies, she will hear (Velocity of sound = 330 m/s; g = 9.8 m/s^2).**



Solution: The maximum speed of the swing is when it crosses the lowest point. If h is the height of the swing above the lowest point at its maximum displacement position, then

the potential energy = mgh

$= mgL(1 - \cos\theta) = 2mg(1 - \cos 30°)$

This is equal to the K.E. at the lowest position of the swing, where v is the maximum

$$\text{K.E.} = \frac{1}{2}mv^2 = mgh = 2mg(1 - \cos 30°)$$

$$v^2 = 4 \times 9.8(1 - 0.866) = 5.25$$

$$\Rightarrow \quad v = 2.3 \text{ m/s}$$

The maximum frequency is heard when the swing comes towards the girl.

$$f_{max} = \frac{v - v_o}{v - v_s} \times f = \frac{330 - 0}{330 - 2.3} \times 1000 = \mathbf{1007\ Hz}$$

The minimum frequency is heard when the swing goes away from the observer.

$$f_{min} = \frac{330}{330 + 2.3} \times 1000 = \mathbf{993\ Hz}$$

PROFICIENCY TEST– II

The following questions deal with the basic concepts of this section. Answer the following briefly. Go to the next section only if your score is at least 80%. Do not consult the Study Material while attempting these questions.

1. A tuning fork of frequency 500 Hz is sounded on a resonance tube; the first and second resonance is obtained at 17 cm and 52 cm. Find the velocity of the sound in m/s.

2. Two vibrating turning forks producing progressive waves given by $y_1 = 4\sin(500\pi t)$, $y_2 = 2\sin(506\pi t)$ are held near the ear of a person. Find how many beats the person will hear and also the intensity ratio between maxima and minima.

3. A train moves towards a stationary observer with speed 34 m/s. The train sounds a whistle and its frequency registered by the observer is 95 Hz. If the train's speed is reduced to 17m/s, the frequency registered is f_2. Find the value of f_2 in Hz if the speed of sound is 340m/s.

4. If the velocity of sound in air is 320 m/s then find the frequency of the fundamental note emitted by a tube of length 1 m. closed at one end.

5. A stationary sound wave $y = 2\sin 3t \sin 4x$ is produced in a medium (where x and y are in cm) of bulk modulus $B = 5\text{N/m}^2$. Find the pressure amplitude in that medium (in SI unit).

ANSWERS TO PROFICIENCY TEST– II

1. 350 m/s

2. 3 beats/s, $\frac{I_{max}}{I_{min}} = 9$

3. 90 Hz

4. 80 Hz

5. 40

SOLVED OBJECTIVE EXAMPLES

***Example* 1:**

A wave equation which gives the displacement along the *y*-direction is given by

$y = 10^{-4}\sin(60t + 2x)$

where x and *y* are in metres and *t* is time in seconds. This represents a wave

(a) travelling with a velocity of 30 m/s in the negative *x*-direction

(b) of wavelength π m

(c) of frequency $\frac{30}{\pi}$ Hz

(d) of amplitude 10^{-4} m travelling along the negative *x*-direction

Solution:

The wave equation is given by $y = 10^{-4}\sin(60t + 2x)$

Comparing this with the standard equation $y = A\sin 2\pi\left(ft - \frac{x}{\lambda}\right)$

Here amplitude $A = 10^{-4}$

$2\pi f = 60$

Frequency $f = \frac{60}{2\pi} = \frac{30}{\pi}$ Hz $\qquad -\frac{2\pi x}{\lambda} = 2x$

$\therefore$ wavelength $\lambda = \frac{2\pi}{2} = -\pi$ (in magnitude)

Velocity $v = f\lambda = \frac{60}{2\pi}\times\pi = $ **30 m/s**

Hence (a), (b), (c) and (d) are correct.

$\therefore$ **(a), (b), (c) and (d)**

***Example* 2:**

A wave is represented by the equation

$y = A\sin\left(10\pi x + 15\pi t + \frac{\pi}{3}\right)$

where *x* is in metres and t in seconds. The expression represents,

(a) a wave travelling in the positive *x*-direction with a velocity 1.5 m/s

(b) a wave travelling in the negative *x*-direction with a velocity 1.5 m/s

(c) a wave travelling in the negative *x*-direction having a wavelength 0.2 m

(d) a wave travelling in the positive *x*-direction having a wavelength 0.2 m

Solution:

Comparing the given equation with $y = A\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$

we have

$\frac{2\pi}{\lambda} = 10\pi$ giving $\lambda = \frac{1}{5} = 0.2$ m

and $v = \frac{\lambda}{T} = 0.2\times\frac{15\pi}{2\pi} = $ **1.5 m/s**

Also the positive term in x indicates wave that travels in the negative direction.

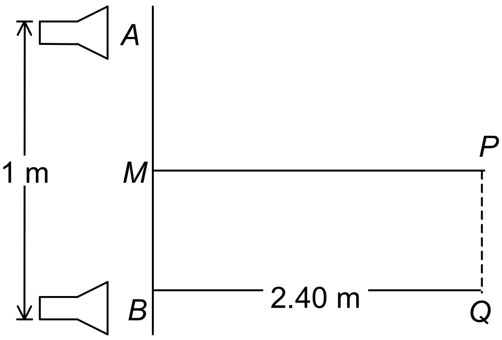
$\therefore$ **(b) and (c)**

***Example* 3:**

Two small loud speakers *A*, *B*, 1.00 m apart are connected to the same oscillator so that both emit sound waves of a definite frequency in phase. A sensitive detector, moving parallel to *AB* along *PQ*, 2.40 m away (see Figure) detects a maximum wave at *P* on the perpendicular bisector *MP* of *AB* and another maximum wave when it first reaches a point *Q* directly opposite to *B*. The velocity of the sound waves is 340 ms^{-1}. The frequency of the oscillator is

(a) 1500 Hz (b) 1700 Hz

(c) 3400 Hz (d) 800 Hz



Solution:

Since Q is the first maximum after P, $AQ - BQ = \lambda$

$BQ = 2.4$ m, $AB = 1.0$ m, $ABQ = 90°$

Hence $AQ = \sqrt{BQ^2 + AB^2} = \sqrt{(2.4)^2 + (1.0)^2} = 2.6 m$

Also $\lambda = 2.60 - 2.40 = 0.20$ m

Hence wave speed, $C = 340 = f \cdot \lambda = f \cdot (0.20)$

Hence frequency, $f = \dfrac{340}{0.20}$

$= \mathbf{1{,}700\ Hz}$

$\therefore$ **(b)**

***Example* 4:**

The engine of a train has just completed a long *U*-bend of a track. The guard-van is just entering the bend, which is an exact semi-circle (see figure). The driver blows the whistle of the train located in front of the engine to warn a workman on the track ahead. The whistle has a frequency of 400 Hz and the speed of the train is 17 m/s with velocity of sound being 340 m/s. The apparent frequency of the sound as heard by the workman *A* on the track ahead, the driver *B* on the engine, the guard *G* in the guard-van and a passenger *P* in the centre of the train are respectively ν_A, ν_B, ν_C and ν_D. The values of these apparent frequencies a respectively (in Hz)

(a) $\nu_A = 421$, $\nu_B = 400$, $\nu_C = 381$, $\nu_D = 362$ (b) $\nu_A = 421$, $\nu_B = 400$, $\nu_C = 400$, $\nu_D = 400$

(c) $\nu_A = 421$, $\nu_B = 381$, $\nu_C = 400$, $\nu_D = 442$ (d) $\nu_A = 421$, $\nu_B = 362$, $\nu_C = 442$, $\nu_D = 400$

Solution:

(1) Frequency heard by the worker (A) on the track $= \nu_A = \dfrac{v}{(v - v_s)} \nu_0 = \dfrac{400}{(1 - 17/340)}$ = **421 Hz**

(2) Frequency heard by the driver (B) on the train: (The driver travels towards the source with the same speed as the source recedes from him.)

$$\nu_B = \left(\frac{v + v_0}{v - v_s}\right)\nu_0 = \textbf{400 Hz}$$

(3) Frequency heard by the guard on the train. The motion of both the source and the observer and perpendicular to the direction in which sound propagates. Thus the motions have no effect. Hence frequency heard by the guard = **400 Hz**

(4) Frequency heard by the passenger (P) on the train: Here the source recedes at an angle $\theta' = 45°$ and the observer approaches the source at an angle $\phi = 45°$. Hence $\nu_P = \dfrac{(v\cos\phi + v_0)}{(v\cos\phi' + v_s)} = \nu_0$, ($v_0 = v_s = 17 m/s$, since $\phi = 45°$ being the angles of tangents and a chord of a semi-circle. Hence observed frequency = **400 Hz**

$\therefore$ **(b)**

***Example* 5:**

A longitudinal wave sent by a ship to the bottom of the sea returns after a lapse of 2.64 s. Elasticity of water is 220 kg/mm^2 and density of sea water is 1.1 gm/cc. The depth of the sea is (in metres)

(a) 1400 (b) 1848 (c) 924 (d) 700

Solution:

The velocity of sound in seawater is $v = \sqrt{\frac{E}{\rho}}$

$$v = \sqrt{\frac{E}{\rho}} = \sqrt{\frac{220\times10^6\times9.8}{1.1\times10^3}} = \sqrt{196\times10^4}\ \text{m/s} = 14\times10^2\ \text{m/s.}$$

The depth of the well is therefore $= \left(\frac{2.64}{2}\right)\times 14\times10^2$ m = **1848 m**

∴ **(b)**

***Example* 6:**

The difference between the apparent frequency of a source of sound as perceived by an observer during its approach and its recession is 2% of the natural frequency of the source. If the velocity of sound in air is 300 m/s the velocity of the source is

(a) 6 m/s (b) 3 m/s (c) 1.5 m/s (d) 12 m/s

Solution:

The apparent frequency during approach is

$$f_a = f_0\left(\frac{v}{v-v_s}\right) = f_0\left(\frac{300}{300-v_a}\right)$$

The apparent frequency during recession is

$$f_r = f_0\left(\frac{v}{v+v_s}\right) = f_0\left(\frac{300}{300+v_r}\right)$$

Hence $(f_a - f_r)\left(\frac{2}{100}\right)f_0 = f_0\left[\frac{300}{300-v} - \frac{300}{300+v}\right]$,

∵ $v_a = v_r = v$ = velocity of source

or $2[(300)^2 - v^2] = 3[2v]\times10^4$

or $v^2 + 3\times10^4\, v - (300)^2 = 0$

Omitting v^2, as small quantity,

$$v = \frac{(300)^2}{3\times10^4} = \mathbf{3\ m/s}$$

∴ **(b)**

***Example* 7:**

A man on the platform is watching two trains, one leaving and the other entering the station with equal speed of 4 m/s. If they sound their whistles each of natural frequency 240 Hz, the number of beats heard by the man (velocity of sound in air = 320 m/s) will be

(a) 6 (b) 3 (c) 0 (d) 12

Solution:

Apparent frequency of the approaching train is

$$f_a = (240)\left(\frac{320}{320+4}\right) = \left(\frac{240\times320}{316}\right)$$

Apparent frequency of the leaving train is, $f_l = (240)\left(\frac{320}{320+4}\right) = \left(\frac{240\times320}{324}\right)$

Hence the number of beats heard by the man per second

$$= (f_a - f_l) = 240\times320\left[\frac{1}{316} - \frac{1}{324}\right] = \frac{\mathbf{240\times320\times8}}{\mathbf{316\times324}} - \mathbf{6}$$

∴ **(a)**

***Example* 8:**

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 than the fundamental frequency of the open pipe. The fundamental frequency of the open pipe is

(a) 200 Hz **(b) 300 Hz** **(c) 240 Hz** **(d) 480 Hz**

Solution:

Fundamental frequency of open pipe $f_0 = \frac{v}{2l}$

Fundamental frequency of closed pipe $f_0' = \frac{v}{4l}$

where v = velocity of sound in air,
l = length of pipe.

$\therefore \quad \frac{f_0}{f_0'} = 2 \Rightarrow f_0 = 2f_0'$

By data, $3f_0' = f_0 + 100 \quad \Rightarrow 3 \times \frac{f_0}{2} = f_0 + 100$

$\Rightarrow \quad 3f_0 = 2f_0 + 200 \Rightarrow f_0 = \mathbf{200\ Hz}$

$\therefore$ **(a)**

***Example* 9:**

When the speed of sound in air is 330 m/s, the shortest air column, closed at one end that will respond to a tuning fork with a frequency of 440 vibs/sec has a length of (approximately).

(a) 19 cm **(b) 33 cm** **(c) 38 cm** **(d) 67 cm**

Solution:

Frequency $f = \frac{v}{4l}$

$\Rightarrow \quad 440 = \frac{330}{4l}$, where l is in metres

$\Rightarrow \quad l = \frac{3}{16} m$

$\Rightarrow \quad l = \frac{3}{16} \times 100 \approx \mathbf{19 cm.}$

$\therefore$ **(a)**

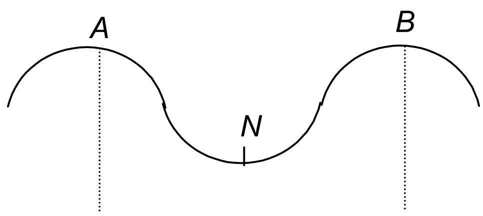
***Example* 10:**

A vibrating diaphragm sets up strong vibrations at the mouth of a horizontal tube containing air and a small amount of fine powder. If the powder becomes arranged in piles 1 cm apart, the wavelength of this sound in air is

(a) $\frac{1}{4}$ cm **(b) $\frac{1}{2}$ cm** **(c) 1 cm** **(d) 2 cm**

Solution:

In figure, A, B are antinodes and N is node.
Distance between piles A and B is



$\frac{\lambda}{2} = 1\,\text{cm}$

$\Rightarrow \quad \lambda = \mathbf{2\ cm}$

$\therefore$ **(d)**

SOLVED SUBJECTIVE EXAMPLES

***Example* 1:**

A metallic rod of length 1 m is rigidly clamped at its midpoint. Longitudinal stationary waves are set up in the rod in such a way that there are two nodes on either side of the midpoint. The amplitude of an antinode is 2×10^{-6} m. (Young's modulus = 2×10^{11} Nm^{-2} and density = 8000 kg m^{-3})

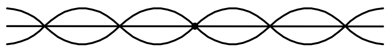
(a) Find the value of wavelength in cm.

(b) Velocity of wave in 10^3 m/s.

(c) Amplitude in cm of particle at a distance 30 cm formed.

***Solution*:**

(a) In the present problem the length L of the rod = 1 metre.



i.e., $L = \frac{5\lambda}{2}$ or $\lambda = \frac{2}{5}$ metre = 40 cm

(b) $v = \sqrt{\frac{Y}{\rho}} = 5 \times 10^3$ m/s

$\therefore$ **5**

(c) At a distance 30 cm node is formed so amplitude is **zero**.

***Example* 2:**

The length of a sonometer wire between its fixed ends is 110 cm. Where should two bridges be placed in between the ends so as to divide the wire into 3 segments whose fundamental frequencies are in the ratio 1 : 2 : 3?

***Solution*:**

If L_1, L_2, L_3 be the lengths of the three segments then

$L_1 + L_2 + L_3 = 100$

If n_1, n_2 and n_3 be the fundamental frequencies of the three segments then

$f_1 = f$

$f_2 = 2f$

$f_3 = 3f$,

since $f_1 : f_2 : f_3 = 1 : 2 : 3$

The tension remains the same throughout the wire. Hence

$f_1L_1 = f_1L_2 = f_3L_3$

or, $fL_1 = 2fL_2 = 3fL_3$

or, $L_1 = 2L_2 = 3L_3$

If $L_3 = x$, $L_2 = \frac{3}{2}x$, $L_1 = 3x$

$\therefore$ $L_1 + L_2 + L_3 = 3x + \frac{3}{2}x + x = 110$ cm

or, $11x = 220$ cm

$L_3 = x =$ 20 cm

$L_2 = \frac{3}{2}x = 30$ cm

$L_1 = 3x =$ **60 cm**

The bridges should be placed in the positions of 54.54 cm from the zero end and 18.18 cm from the other end.

***Example* 3:**

Calculate the velocity of sound in a mixture of oxygen, nitrogen and argon at 0°C. The mixture consists of the gases oxygen, nitrogen and argon in the mass ratio 2 : 7 : 1. (Given

R = 8.323 J mol^{-1} K^{-1}. Ratio of specific heats of the gases are argon 1.67, oxygen 1.4, nitrogen 1.4. The molecular weights of the respective gases are 40, 32 and 28.

Solution:

The relation for the velocity of sound in a gas $v = \sqrt{\frac{\gamma RT}{M}}$

Considering the mixture of gas while all the constituents of the mixture occupy the same volume their masses vary. Let m_0, m_N, m_A be the fractions of masses of the respective gases and M_0, M_N, M_A be their respective molecular weights. Now the velocity of sound in the mixture can be given by the relation,

$$v = \sqrt{RT}\left[\frac{\gamma_O m_O}{M_O} + \frac{\gamma_N m_N}{M_N} + \frac{\gamma_A m_A}{M_A}\right]^{1/2}$$

$$= \left[8.323 \times 273\left(\frac{1.4\times\frac{2}{10}}{32\times 10^{-3}} + \frac{1.4\times\frac{7}{10}}{28\times 10^{-3}} + \frac{1.67\times\frac{1}{10}}{40\times 10^{-3}}\right)\right]^{1/2}$$

$= [8.323 \times 273 \times 1000(8.75 \times 10^{-3} + 35 \times 10^{-3} + 4.175 \times 10^{-3})]^{1/2}$

$= [8.323 \times 273 \times 47.925]^{1/2}$

= 330 m/s

***Example* 4:**

The second overtone of an open pipe has the same frequency as the first overtone of a closed pipe 2 m long. What is the length of the open pipe in metre?

Solution:

Let L_0 be the length of the open pipe. The fundamental frequency of the pipe is given by

$f_o = \frac{v}{\lambda_f} = \frac{v}{2L_o}$, v = velocity of sound in air

The second overtone of the open pipe has a frequency $3f_o = \frac{3v}{2L_o}$ Hz

The length of the closed pipe $L_C = 2\ m$

The frequency of the fundamental emitted by the closed pipe

$f_c = \frac{v}{\lambda} = \frac{v}{4L_c}$

The first overtone of the closed pipe has a frequency

$3f_c = \frac{3v}{4L_c} = \frac{3v}{4\times 2} = \frac{3v}{8}$ Hz

Now $3f_0 = 3f_c$ or, $\frac{3v}{4L_o} = \frac{3v}{8}$

or $2L_0 = 8$ or L_0 = **4m**

***Example* 5:**

Two identical steel wires are under tension and are in unison. When the tension in one of the wires is increased by 1 percent 4 beats per second is heard. Find the original frequency in Hz of the wires.

Solution:

By unison of the wires, we mean that they have the same frequency of vibration. Since they are identical in linear density and length they must be under the same tension to be in unison.

Let the tension in one wire be increased to $T_1 = \frac{101T}{100}$

where T is the original tension. Let f_1 be the new fundamental frequency in H2.

Now $\frac{f_1}{f} = \sqrt{\frac{T_1}{T}} = \sqrt{\frac{101}{100}}$

But $f_1 > f$ and $f_1 - f = 4$

$\therefore \quad \frac{f+4}{f} = \sqrt{\frac{101}{100}} \quad 1 + \frac{4}{n} = \left(1 + \frac{1}{100}\right)^{1/2} \approx 1 + \frac{1}{200}$

$\therefore \quad \frac{4}{f} = \frac{1}{200}$; f = **800 Hz.**

***Example* 6:**

A column of air at 51°C and a tuning fork produce 4 beats per second when sounded together. As the temperature of the air column is decreased the number of beats per second tends to decrease and when the temperature is 16°C, the two produce one beat per second. Find the possible frequency (in Hz) of the tuning fork.

***Solution*:**

Let the velocity of sound in air at 51°C be v_1.
Let the corresponding wavelength and frequency be λ_1 and f_1 in the air column.
When the temperature decreases to 16°C, the corresponding quantities be v_2, λ_2 and f_2 respectively.
But the length of the tube remains the same and hence λ of stationary waves in both the cases will be the same. Hence

$v_1 = f_1\lambda$ and $v_2 = f_2\lambda$

or $\quad \frac{v_1}{v_2} = \frac{f_1}{f_2}$

Since $\quad v_t = v_0\sqrt{1 + \frac{t_1}{273}}$

$$v_1 = v_0\sqrt{\frac{273 + t_1}{273}} = v_0\sqrt{\frac{273 + 51}{273}} = v_0\sqrt{\frac{324}{273}}$$

$$v_2 = v_0\sqrt{\frac{273 + 16}{273}} = v_0\sqrt{\frac{289}{273}} \quad \text{or,} \quad \frac{v_1}{v_2} = \sqrt{\frac{324}{289}} = \frac{18}{17}$$

or $\quad \frac{f_1}{f_2} = \frac{18}{17}$

If n be the frequency of the tuning fork $\quad n_1 = n \pm 4$

$f_2 = f \pm 1$

Since $\quad f_1 > f_2, f_1 = f + 4$

$f_2 = f + 1$

$18(f + 1) = 17(f + 4)$

$18f + 18 = 17f + 68$

$f = 68 - 18 =$ **50 Hz**

It is also possible $f_2 = f - 1$

$\therefore \quad 18(f - 1) = 17(f + 4)$

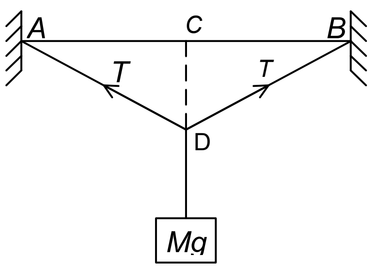
$18f - 18 = 17f + 68$

$f = 68 + 18 =$ **86 Hz**

$\therefore \quad$ frequency of the fork = 50 Hz or 86 Hz

***Example* 7:**

A wire of length 2 m is kept just taut horizontally between two walls. A mass hanging from its midpoint depresses it by 10 mm. The frequency of transverse vibrations of each segment of the wire is found to be the same as the fundamental frequency of air column in a closed tube of length 5 m. (Velocity of sound in air = 360 m/s). If Young's modulus of the material of the wire is $x \times 10^8$ N/m², find the value of x. (density of the material of the wire is 10000 kg/m³).



***Solution*:**

$AB = 2$ m; $AC = CB = 1$ m = 100 cm; $CD = 10$ mm = 1 cm

The extension produced in the segment AC of the wire due to the load Mg is given by

$$\Delta L = AD - AC = \sqrt{100^2 + 1^2} - 100$$

$$= 100\left(1 + \frac{1}{100^2}\right)^{1/2} - 100 = 100\left(1 + \frac{1}{2 \times 10^4}\right) - 100 = 0.005 \text{ cm.}$$

The tension T in the wire is therefore given by $T = \frac{Ya\Delta L}{L}$.

Frequency of the fundamental, $f = \frac{1}{2L}\sqrt{\frac{T}{m}}$

$$f^2 = \frac{1}{4L^2}\cdot\frac{T}{m} = \frac{1}{4L^2}\cdot\frac{Ya\Delta L}{L}\cdot\frac{1}{a\cdot\rho} \quad (\rho = \text{density})$$

or, $$Y = \frac{4L^3 f^2 \rho}{\Delta L} = \frac{4(1)^3 (f^2)\ (10000)}{5\times 10^{-5}}$$

The frequency of the wire is the same as the fundamental of a closed tube of 5 m length.

$$f = \frac{v}{4L} = \frac{360}{4\times 5} = 18 \text{ Hz}$$

∴ the Young's modulus of the material of the wire

$$Y = \frac{4\times (1)^3 \times (18)^2 \times (10000)}{5\times 10^{-5}} = \mathbf{2592 \times 10^8\ N/m^2}$$

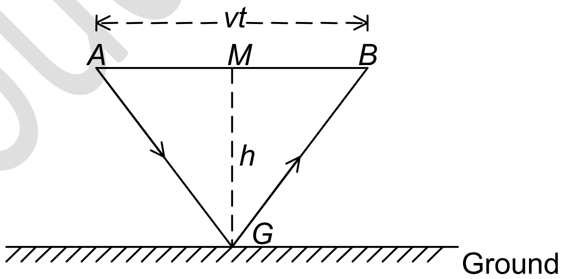
∴ **X = 2592**

***Example* 8:**

A pilot of an aeroplane travelling horizontally at 198 km/hr fires a gun and hears the echo from the ground after an interval of 3 seconds. If the velocity of sound is 330 m/s, find the height of the aeroplane from the ground.

***Solution*:**

When the plane is in position A, the gun is fired. When it reaches position B, it hears the echo. This echo is due to sound travelling along the path AGB. GM gives the altitude of the plane.



Let $GM = h$; $AG = GB = x$

The total distance travelled by the sound = $2x$

Now, $\frac{2x}{v} = t \qquad \frac{2x}{330} = 3$

∴ $x = \frac{3\times 330}{2} = 495$ m

Now, AB = velocity of plane × time of travel

$= 198 \times \frac{5}{18}$ m/s × 3s = 55 × 3 = 165 m

∴ $AM = \frac{165}{2} = 82.5$ m

Now $h = \sqrt{495^2 - 82.5^2} = \mathbf{488\ m}$

MIND MAP

1. Wave function:

$$\frac{d^2y}{dt^2} = v^2 \frac{d^2y}{dx^2}$$

Sinusoidal wave:

2. Energy of a plane progressive wave:

$P = 2\pi^2 f^2 A^2 \rho S v$ (J/s)

Intensity of the wave

3. Stationary waves in strings:

(1) String fixed at both the ends

$y = -2a\sin kx \cos\omega t$

WAVE MOTION & SOUND

4. Amplitude of reflected & transmitted wave:

$A_r = \frac{v_2 - v_1}{(v_2 + v_1)} A_i$

$A_t = \frac{2v_2}{v_2 + v_1} A_i$

Phase change on reflection from:

5. Sound Wave:

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

$P = P_0 \cos(\omega t - kx)$

Volume strain: $= \frac{\delta y}{\delta x}$

Pressure: $-\frac{P\delta y}{\delta x}$

Velocity of longitudinal wave:

(i) **Solid:** $v = \sqrt{\frac{Y}{\rho}}$

(ii) **Liquid:** $v = \sqrt{\frac{B}{\rho}}$

6. Organ Pipe:

(1) **Closed pipe:**

$f = \frac{(2n-1)}{4l} v$

(2) **Open pipe:**

$f = \frac{nv}{2l}$

7. Beat frequency

$f = f_1 - f_2$

8. Doppler Effect:

EXERCISE – I

IIT JEE & NEET-SINGLE CHOICE CORRECT

1. 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 air-column is now.
(a) $f/2$ (b) $3f/4$ (c) f (d) $2f$

2. If the speed of sound is 336 m/s in air, the shortest closed tube that will resonate with a fork of frequency 210 Hz is
(a) 4 m (b) 0.2 m (c) 1 m (d) 0.4 m

3. A travelling wave in a stretched string is described by the equation, $y = A \sin(kx - \omega t)$. The maximum particle velocity is
(a) $A\omega$ (b) ω/k (c) $\frac{d\omega}{dk}$ (d) $\frac{x}{t}$

4. The displacement of a particle executing periodic motion is given by $y = 4\cos^2(t/2)\sin(1000t)$. This expression may be considered to be a result of supper position of
(a) two waves (b) three waves (c) four waves (d) five waves

5. With what velocity should be an observer approach stationary sound source so that the apparent frequency of sound appear to be double of the initial frequency? (Given velocity sound = v)
(a) $v/2$ (b) $3v$ (c) $2v$ (d) v

6. A tuning fork produces waves in a medium. If the temperature of the medium changes, then which of the following will change
(a) amplitude (b) frequency (c) wavelength (d) time-period

7. A wave is reflected from a rigid support. The change in phase on reflection will be
(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{2}$ (c) π (d) 2π

8. Beats are produced by two waves $y_1 = a\sin 1000\pi t$, $y_2 = a\sin 998\pi t$. The number of beats heard/sec is
(a) 0 (b) 2 (c) 1 (d) 4

9. An air column in a pipe which is closed at one end will be in resonance with a vibrating tuning fork of frequency 264 Hz if the length of the column in cm is (velocity of sound in air = 330 m/s).
(a) 31.25 (b) 72 (c) 90.75 (d) 125

10. Two wires of same material and same radius have the same fundamental frequency. If the ratio of their lengths is 1: 2 the ratio of tension in the two wires is
(a) 1 : 2 (b) 2 : 1 (c) 1 : 4 (d) 4 : 1

11. An organ pipe P_1 closed at one end vibrating in its first overtone and another pipe P_2 open at both ends vibrating in its third overtone are in resonance with a given tuning fork. The ratio of the length of P_1 to that of P_2 is
(a) $\frac{8}{3}$ (b) $\frac{3}{8}$ (c) $\frac{1}{2}$ (d) $\frac{1}{3}$

12. Two harmonic waves are described by $y_1 = 3\sin\pi(x + 0.6t)$ cm, $Y_2 = 3\sin\pi(x - 0.6t)$ cm
The three smallest values of x corresponding to antinodes are

(a) $\frac{1}{4},\frac{1}{3},\frac{1}{2}$ (b) $\frac{1}{2},\frac{3}{2},\frac{5}{2}$ (c) $\frac{1}{3},\frac{1}{6},\frac{1}{9}$ (d) 0, $\frac{1}{2}$, 1

13. A standard tuning fork of frequency n is used to find velocity of sound in air by resonance air column apparatus. The difference between two resonating lengths is 0.5 m. Then the velocity of sound in air is (in m/s)

(a) n (b) 2 n (c) $\frac{n}{2}$ (d) 3 n

14. A light pointer fixed to one prong of a tuning fork touches a vertical plate. The fork is set vibrating and the plate is allowed to fall freely. Eight complete oscillations are counted when the plate falls through 10 cm. What is the frequency of the tuning fork?

(a) 112 Hz (b) 56 Hz (c) $\frac{8}{7}$ Hz (d) $\frac{7}{8}$ Hz

15. Three waves of equal frequency having amplitudes 10 mm, 4 mm and 7 mm arrive at a given point with successive phase difference of $\pi/2$; the amplitude of the resulting wave in mm is given by

(a) 7 (b) 6 (c) 5 (d) 4

16. An open pipe of length L vibrates in fundamental made. The pressure variation is maximum at

(a) $L/4$ from ends (b) the middle of pipe
(c) the ends of pipe (d) $L/8$ from ends

17. The ratio of the speed of sound in nitrogen gas to that in helium gas, at 300 K is

(a) $\sqrt{2/7}$ (b) $\sqrt{1/7}$ (c) $\sqrt{3}/5$ (d) $\sqrt{6}/5$

18. In a sinusoidal wave, the time required for a particular point to move from maximum displacement to zero displacement is 0.170 second. The frequency of the wave is

(a) 1.47 Hz (b) 0.36 Hz (c) 0.73 Hz (d) 2.94 Hz

19. A stone is dropped in a well which is 19.6 m deep. Echo sound is heard after 2.06 sec (after dropping) then the velocity of sound is

(a) 332.6 m/sec (b) 326.7 m/sec (c) 300.4 m/sec (d) 290.5 m/sec

20. The fundamental frequency of a string stretched with a mass of 4 kg is 256 Hz. The mass required to produce its octave is

(a) 4 kg (b) 8 kg (c) 12 kg (d) 16 kg

21. When stationary waves are set up, pick out the correct statement from the following

(a) all the particles in the medium are in the same phase of vibration at all times and distance
(b) the particles with an interval between two consecutive nodes are in phase, but the particles in two such consecutive intervals are of opposite phase
(c) the phase lag along the path of the wave increases as the distance from the source increases
(d) only antinodes are in same phase

22. The fundamental frequency of a sonometer wire carrying a block of mass 1 kg and density 1.8 is 260 Hz. When the block is completely immersed in a liquid of density 1.2 then what will be its new frequency?

(a) 300 Hz (b) 150 Hz (c) 450 Hz (d) none of these

23. In a resonance column experiment, the first resonance is obtained when the level of the water in the tube is at 20 cm from the open end. Resonance will also be obtained when the water level is at a distance of

(a) 40 cm from the open end
(b) 60 cm from the open end
(c) 80 cm from the open end
(d) 90 cm from the open end

24. In the experiment for the determination of the speed of 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 0.1m. When this length is changed to 0.35 m, the same tuning fork resonates with the first overtone. Calculate the end correction.
(a) 0.012 m
(b) 0.025 m
(c) 0.05 m
(d) 0.024 m

25. Two sinusoidal waves with same wavelengths and amplitudes travel in opposite directions along a string with a speed 10 ms^{-1}. If the minimum time interval between two instants when the string is flat is 0.5s, the wavelength of the waves is
(a) 25 m
(b) 20 m
(c) 15 m
(d) 10 m

EXERCISE – II

IIT-JEE- SINGLE CHOICE CORRECT

1. A transverse wave is described by the equation $y = y_0 \sin 2\pi\left(ft - \frac{x}{\lambda}\right)$. The maximum particle velocity is equal to four times the wave velocity if

(a) $\lambda = \frac{\pi y_0}{4}$ (b) $\lambda = \frac{\pi y_0}{2}$ (c) $\lambda = \pi y_0$ (d) $\lambda = 2\pi y_0$

2. For which one of the following examples will the observed frequency of sound be greater than the true frequency?
(a) When the source of sound moves away from a stationary observer.
(b) When the source of sound moves in a circle with the observer at the centre.
(c) When the source of sound and the observer both move with the same speed in the same direction.
(d) When the observer moves towards a stationary source of sound.

3. The first overtone of an open pipe has the same frequency as the first overtone of a closed pipe of 30 cm long. The length of the open pipe is
(a) 0.3 m (b) 0.4 m (c) 0.5 m (d) 0.6 m

4. A wave equation which gives the displacement along y-direction is given: $y = 10^4 \sin(60t + 2x)$ where x and y are in metre and t in sec. Among the following choose the correct statement
(a) It represents a wave propagating along positive x-axis with a velocity of 30 m/s.
(b) It represents a wave propagating along negative x-axis with a velocity of 120 m/s.
(c) It represents a wave propagating along negative x-axis with a velocity of 30 m/s.
(d) It represents a wave propagating along negative x-axis with a velocity of 10^4 m/s.

5. The distance between two consecutive crests in a wave train produced in a string is 5 cm. If two complete waves pass through a point per sec, the velocity of the wave is
(a) 10 cm per sec (b) 2.5 cm per sec (c) 5 cm per sec (d) 15 cm per sec

6. 56 tuning forks are so arranged in series that each fork given 4 beats per sec with the previous one. The frequency of the last fork is 3 times that of the first. The frequency of the first fork is
(a) 110 (b) 56 (c) 60 (d) 52

7. 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 $\frac{A}{3}$ (b) sinusoidal shape with amplitude $\frac{A}{2}$
(c) sinusoidal shape with amplitude A (d) straight line

8. A string in musical instrument is 50 cm long and its fundamental frequency is 800 Hz. If a fundamental frequency of 1000 Hz is to be produced under same tension, then required length of string is
(a) 62.5 cm (b) 50 cm (c) 40 cm (d) 37.5 cm

9. A tube closed at one end and containing air produces, when excited, the fundamental note of frequency 512 Hz. If the tube is open at both ends, the fundamental frequency that can be excited is (in Hz)
(a) 1024 (b) 512 (c) 256 (d) 128

10. Two vibrating tuning forks producing progressive waves given by $y_1 = 4\sin(500\pi t)$, $y_2 = 2\sin(506\pi t)$ are held near the ear of a person. If the number of beats heard per second be *B* and the ratio of maximum to minimum intensity be *A*, then
(a) $B = 3$ and $A = 2$ (b) $B = 3$ and $A = 9$ (c) $B = 6$ and $A = 2$ (d) $B = 6$ and $A = 9$

11. The frequency of tuning fork *A* is 2% more than the frequency of a standard tuning fork. The frequency of a tuning fork *B* is 3% less than the frequency of same standard tuning fork. If 6 beats per second are heard when the two tuning forks *A* and *B* are excited, the frequency of *A* is
(a) 120 Hz (b) 122.4 Hz (c) 116.4 Hz (d) 130 Hz

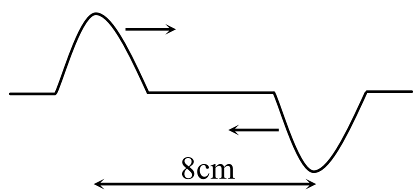
12. A plane sound wave is travelling in a medium. With reference to a frame *A*, its equation is $y = a\cos(\omega t - kx)$. With reference to a frame *B*, moving with a constant velocity *v* in the direction of propagation of the wave, equation of the wave will be
(a) $y = a\cos[(\omega + kv)t - kx]$ (b) $y = -a\cos[(\omega - kv)t - kx]$
(c) $y = a\cos[(\omega - kv)t - kx]$ (d) $y = a\cos[(\omega + kv)t + kx]$

13. Four simple harmonic vibrations, $y_1 = 8\cos\omega t$, $y_2 = 4\cos\left(\omega t + \frac{\pi}{2}\right)$, $y_3 = 2\cos(\omega t + \pi)$, $y_4 = \cos\left(\omega t + \frac{3\pi}{2}\right)$ are superposed on each other. The resulting amplitude and phase are respectively
(a) $\sqrt{45}$ and $\tan^{-1}(1/2)$ (b) $\sqrt{45}$ and $\tan^{-1}(1/3)$
(c) $\sqrt{75}$ and $\tan^{-1}(1/2)$ (d) $\sqrt{75}$ and $\tan^{-1}(1/3)$

14. A string of length 0.4 m and mass 10^{-2} kg is tightly clamped at the ends. The tension in the string is 1.6 newton. Identical wave pulses are produced at one end at equal intervals of time Δt. The minimum value of Δt which allows constructive interference between successive pulses, is
(a) 0.05 sec (b) 0.10 sec (c) 0.20 sec (d) 0.40 sec

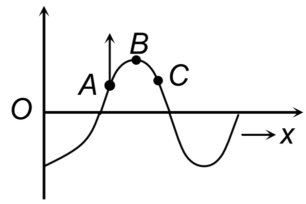
15. A closed organ pipe of length *L* and an open organ pipe contain gases of densities ρ_1 and ρ_2 respectively. The compressibility of gasses are equal in both the pipes. Both the pipes are vibrating in their first overtone with same frequency. The length of the open organ pipe is
(a) $\frac{L}{3}$ (b) $\frac{4L}{3}$ (c) $\frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$ (d) $\frac{4L}{3}\sqrt{\frac{\rho_2}{\rho_1}}$

16. Two pulse in a stretched string whose centers are initially 8 cm apart are moving towards each other as shown in the figure. The speed of each pulse is 2 cm/s. After 2 seconds, the total energy of the pulses will be



(a) zero (b) purely kinetic
(c) purely potential (d) partly kinetic and partly potential

17. A wave is travelling along a string. At an instant, shape of the string is as shown in figure. At this instant, point A is moving upwards. Which of the following statements is incorrect.



(a) The wave is travelling to the left
(b) Displacement amplitude of the wave is equal to displacement of *B* at this instant
(c) At this instant velocity of *C* is also directed upwards
(d) Phase difference between *A* and *C* may be equal to $\frac{\pi}{2}$

18. Two speakers connected to the same source of fixed frequency are placed 2.0 m apart in box. A sensitive microphone placed at a distance of 4.0 m from their midpoint along the perpendicular bisector shows maximum response. The box is slowly rotated until the speakers are in line with the microphone. The distance between the midpoint of the speakers and the microphone remains unchanged. Exactly five maximum responses are observed in the microphone in doing this. The wavelength of the sound wave is
(a) 0.2 m (b) 0.4 m (c) 0.6 m (d) 0.8 m

19. An observer moves towards a stationary source of sound with a speed (1/5)th of the speed of sound. The wavelength and frequency of the source emitted are λ and f respectively. The apparent frequency and wavelength recorded by the observer are respectively.
(a) $1.2 f$ and λ (b) f and 1.2λ (c) $0.8 f$ and 0.8λ (d) $1.2 f$ and 1.2λ

20. A string of length *L* and mass *M* hangs freely from a fixed point. Then the velocity of transverse waves along the string at a distance *x* from the free end is
(a) $\sqrt{gL}$ (b) $\sqrt{gx}$ (c) gL (d) gx

ONE OR MORE THAN ONE CHOICE CORRECT

1. A wave disturbance in a medium is described by $y(x,t) = 0.02\cos\left(50\pi t + \frac{\pi}{2}\right)\cos(10\pi x)$
where x and y are in meter and t is in second. Then
(a) First node occurs at $x = 0.15$m
(b) First antinode occurs at $x = 0.3$ m
(c) The speed of interfering waves is 5.0 m/s
(d) The wavelength is 0.2 m

2. A plane wave $y = a\sin(bx + ct)$ is incident on a surface. Equation of the reflected wave is $y' = a'\sin(ct - bx)$. Which of the following statements is/are correct?
(a) The wave is incident normally on the surface
(b) Reflecting surface is y-z plane
(c) Medium, in which incident wave is travelling, is denser than the other medium
(d) a' cannot be greater than a

3. Mark the correct statement(s)

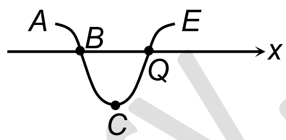
(a) If all the particles of a string are oscillating in same phase, the string is resonating in its fundamental tone

(b) If particles of a string, near its ends, are oscillating in opposite phase then the string is resonating in an even harmonic

(c) If a string is resonating in its fundamental tone then all the particles of the string cannot oscillate in same phase

(d) none of these

4. The figure represents a longitudinal wave travelling in positive x-direction. Then



(a) part *ABC* represents compression

(b) part *ABC* represents rarefaction

(c) part *CDE* represents compression

(d) part *CDE* represents rarefaction

5. Two identical straight wires are stretched so as to produce 6 beats per second when vibrating simultaneously. On changing the tension slightly in one of them, the beat frequency remains unchanged. Denoting by T_1 and T_2 the higher and the lower initial tension in the strings, then it could be said that while making the above changes in tension

(a) T_2 was decreases (b) T_2 was increased

(c) T_1 was decreased (d) T_1 was increased

6. A transverse sinusoidal wave of amplitude *a*, wavelength λ and frequency *f* is travelling on a stretched string. The maximum speed of any point on the string is *v*/10, where *v* is the speed of propagation of the wave. If $a = 10^{-3}$ m and v = 10 m/s, then λ and *f* are given by

(a) $\lambda = 2\pi \times 10^{-2}$ m (b) $\lambda = 10^{-3}$ m (c) $f = \frac{10^3}{2\pi}$ Hz (d) $f = 10^4$ Ha

7. A sound wave of frequency *f* travels horizontally to the right. It is reflected from a large vertical plane surface moving to the left with a speed *v*. The speed of sound in the medium is *c*. Then

(a) the number of waves striking the surface per second is $\frac{f(c+v)}{c}$

(b) the wavelength of the reflected wave is $\frac{c(c-v)}{f(c+v)}$

(c) the wavelength of the reflected wave is $\frac{c(c+v)}{f(c-v)}$

(d) the number of beats heard by the stationary observer to the left of the reflecting surface is $\frac{2vf}{c-v}$.

8. For a certain stretched string, three consecutive resonance frequencies are observed as 105, 175, 245 Hz respectively. Then select the correct alternative (s)

(a) the string is fixed at both ends (b) the string is fixed at one end only

(c) the fundamental frequency is 35 Hz (d) the fundamental frequency is 52.5 Hz

9. Two waves of equal frequency f and velocity v travel in opposite directions along the same path. The waves have amplitudes A and $3A$. Then:

(a) the amplitude of the resulting wave varies with position between maxima of amplitude $4A$ and minima of zero amplitude

(b) the distance between a maxima and adjacent minima is $v/2f$

(c) at point on the path the average displacement is zero

(d) the position of a maxima or minima of amplitude does not change with time.

10. S_1 and S_2 are two sources of sound emitting sine waves. The two sources are in phase, at point F.

The waves of wavelength:

(a) 1 m will result in constructive interference.

(b) 0.67 m will result in constructive interference.

(c) 2 m will result in destructive interference.

(d) 4 m will result in constructive interference.

EXERCISE – III

MATCH THE FOLLOWING

Note: Each statement in column – I has one or more than one match in column –II.

1. Consider a situation (i) that two sound waves, $y_1 = (0.2m)\sin 504\pi(t - x/300)$ and $y_2 = (0.6m)\sin 490\pi(t - x/300)$ are superimposed. Consider another situation (ii) that two sound waves, $y_1 = (0.2m)\sin 504\pi(t - x/300)$ and $y_2 = (0.4m)\sin 504\pi(t + x/300)$, are superimposed.
Match the column I with column II.

Column I		Column II	
I.	In situation (i)	**A.**	Stationary waves are formed.
II.	In situation (ii)	**B.**	There will be the phenomenon of Beats.
III.	When two waves of same frequency and amplitude and travelling in opposite directions superimpose.	**C.**	Amplitude of the resultant wave will vary periodically with position.
IV.	If the intensity of sound alternately increases and decreases periodically as a result of superposition of waves of slightly different frequencies.	**D.**	Amplitude of the resultant wave will vary periodically with time.
		E.	Energy of the wave remains constant

REASONING TYPE

Directions: Read the following questions and choose

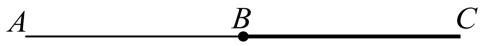
(A) If both the statements are true and statement-2 is the correct explanation of **statement-1**.

(B) If both the statements are true but statement-2 is not the correct explanation of **statement-1**.

(C) If statement-1 is True and **statement-2** is False.

(D) If statement-1 is False **and statement-2** is True.

1. **Statement-1**: A long wire *ABC* is made by joining two wires *AB* and *BC* of equal cross section area. *AB* has length 4.80 *m* and mass 0.12 *kg*. *BC* has length 2.56 *m* and mass 0.4 *kg*. When a sinusoidal mechanical wave is sent along the wire *ABC* from end *A*, it is found that reflected wave from junction *B* suffers a phase change of π.



Statement-2: Wire *BC* is a denser medium for the mechanical wave as compared to the wire *AB*.

(a) (A) (b) (B) (c) (C) (d) (D)

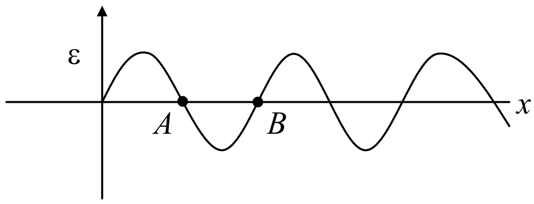
2. **Statement-1:** A mechanical wave can not travel through a mass less and inextensible string.
Statement-2: A mechanical wave can pass through only those media which have inertia and elasticity.

(a) (A) (b) (B) (c) (C) (d) (D)

3. **Statement-1:** A transverse mechanical wave is traveling on a string. An element of the string has potential energy minimum at the mean position.
Statement-2: An element of a vibrating string has maximum kinetic energy in the mean position.

(a) (A) (b) (B) (c) (C) (d) (D)

4. **Statement-1:** A longitudinal mechanical wave $\varepsilon = a\sin(kx - \omega t)$ is travelling through a medium as shown in figure, where ε is displacement of the particle from the mean position. At points *A* and *B* change in pressure is found to be maximum.



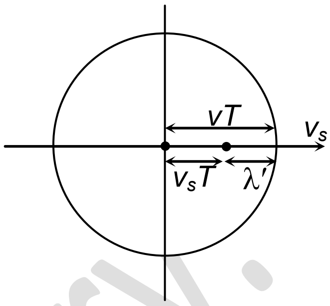
Statement-2: At point *A* and *B* compressions are formed**.**

(a) (A) (b) (B) (c) (C) (d) (D)

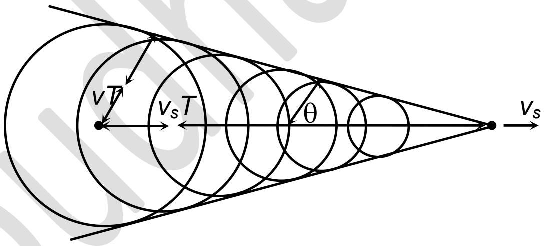
5. **Statement-1:** A function $\varepsilon = a\,e^{-\alpha x}\cos(\omega t - kx)$, where a, α, ω and k are constants, represents a plane wave.
Statement-2: Any differentiable function $f(t + \alpha x)$ provides a solution of wave equation.

(a) (A) (b) (B) (c) (C) (d) (D)

LINKED COMPREHENSION TYPE



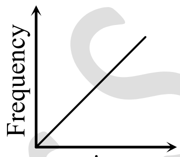
When a source of sound is moving toward a stationary detector, the frequency of sound perceived by the detector is not the same as that emitted by the source. In order to see this quantitatively, consider the time T elapsed between the emissions of a successive pair of spherical wave fronts as shown in the figure. A source moving with speed v_s emits the first wave front. At this point, the first wave front has already traveled a distance vT, where v = 340 m/s is the speed of sound. Therefore, the wavelength detected along the direction of motion is given by the difference $\lambda' = vT - v_sT$. Using the fact that $\lambda' f' = \lambda f = v$ and $T = 1/f$, we find that the shifted frequency f' perceived by the detector is $f' = fv/(v - v_s)$.

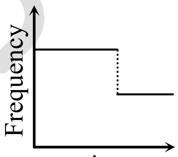


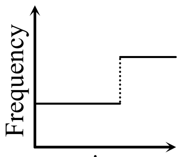
The previous equation does not describe situations where $v_s \geq v$. When the source travels faster than the speed of sound, a shock wave is produced by the spherical wave fronts. Figure 2 shows the spherical wave fronts produced by such a source at equally spaced positions over an arbitrary time t.

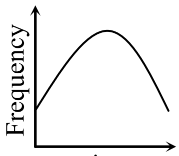
During this time, the source travels a distance v_st, and the first wave front travels a distance vt. However, in this case, the source emits each new wave after travelling beyond the front of the previously emitted wave. The wave fronts bunch along the surface of a cone called the match cone. The resulting rise and fall in air pressure as the surface of the cone passes through a point in space produces a shock wave.

1. A roller skater carrying a portable stereo skates at constant speed past an observer at rest. Which of the following accurately represents how frequency perceived by the observer changes with time?

(a) 

(b) 

(c) 

(d) 

2. A police car moving toward a stationary pedestrian at a speed of 10 m/s operates its siren. If the pedestrian perceives the frequency of the siren to be 1030 Hz, what is the frequency emitted by the siren? (Speed of sound = 340 m/s)

(a) 10 Hz (b) 100 Hz (c) 1000 Hz (d) 10, 000 Hz

3. A bat flies towards a stationary wall with speed v_b. If the bat emits a signal at frequency f, what is the correct expression for the frequency of the reflected signal that the bat hears?

(a) $f\dfrac{v}{v - v_b}$ (b) $f\dfrac{v - v_b}{v + v_b}$ (c) $f\dfrac{v + v_b}{v}$ (d) $f\dfrac{v + v_b}{v - v_b}$

EXERCISE – IV

SUBJECTIVE PROBLEMS

1. The vibration of a string of length 60 cm fixed at both ends are represented by the equation $y = 4\sin\frac{\pi x}{15}\cos(96\pi t)$, where x and y are in cm and t is in seconds.

(a) What is the maximum displacement in cm of a point at $x = 2.5$ cm?
(b) At what distance in cm from one end the nodes are located along the string?
(c) What is the velocity of the particle in cm/s at $x = 7.5$ cm and $t = 0.25$ s?

2. The amplitude of a wave disturbance propagating in the positive x-direction is given by $y=\frac{1}{1+x^2}$ at time $t = 0$ and by $y = \frac{1}{1+(x-1)^2}$ at $t = 2$ s, where x and y are in metres. The shape of the wave disturbance does not change during the propagation. What is the velocity in cm/s of the wave?

3. Two wires are fixed on a sonometer. Their tensions are in the ratio 8 : 1, the lengths in the ratio 36 : 35, the diameters in the ratio 4 : 1, the densities in the ratio 1 : 2. Find the frequency of beats if the note of higher pitch has a frequency of 360 Hz.

4. A source and a detector move away from each other each with a speed of 10 m/sec. If the detector detects a frequency of 1980 Hz coming from source, what is the original frequency in Hz of source? Speed of sound in air = 340 m/sec.

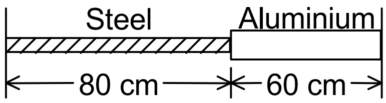
5. A progressive and a stationary simple harmonic wave each has the same frequency 250 Hz and the same velocity of 30 m/s. Calculate

(a) minimum path difference (in cm) between two vibrating points on the progressive wave if phase difference between them is $5\pi/3$.
(b) the distance between consecutive nodes (in cm) in the stationary wave.

6. Two wires 1 and 2, same length and same density, of radii r and $2r$ respectively are welded together end to end. The combination is used as a sonometer wire and is kept under tension T. The welded point is midway between the two bridges. What would be the ratio of number of loops $\frac{n_2}{n_1}$ formed in the wires such that the joint is a node, when stationary vibrations are set up in the wire?

7. A band playing music at a frequency 40 Hz is moving towards a wall at a speed $v/9$. A motorist is following the band with a speed $v/9$. If v is the speed of sound, obtain beat frequency heard by the motorist.

8. Figure shows an aluminium wire of length 60 cm joined to a steel wire of length 80 cm and stretched between two fixed supports. The tension produced is 312 N. The cross-sectional area of the steel wire is 1 mm^2 and that of the aluminium wire is 3 mm^2. What could be the minimum frequency of a tuning fork which can produce standing waves in the system with the joint as a node? The density of aluminium is 2.6 g/cm^3 and that of steel is 7.8 g/cm^3.



9. Two travelling waves of equal amplitudes and equal frequencies move in opposite directions along a string. They superimpose to produce a standing wave having the equation $y = A \cos kx \sin \omega t$ in which A = 1 mm, $k = 1.57$ cm^{-1} and $\omega = 78.5$ s^{-1}. ($\pi = 3.14$)

(a) Find the velocity in cm/s of the component travelling waves.

(b) Find the node closest to the origin in the region $x > 0$.

(c) Find the antinode closest to the origin in the region $x > 0$.

10. A metal wire of cross-sectional area 1 mm^2 is held on two knife-edges separated by a distance of 50 cm. The tension in the wire is 100 N. The wire vibrating with its fundamental frequency and a vibrating fork together produce 5 beats/sec. The tension in the wire is then reduced to 81 N. When the two are excited, beats are heard again at the same rate. Calculate (i) the frequency of the fork in Hz and (ii) the density of the material of the wire in 10^2 kg/m^3.

ANSWERS

EXERCISE – I

IIT JEE & NEET-SINGLE CHOICE CORRECT

1. (c)	2. (d)	3. (a)	4. (b)	5. (d)
6. (c)	7. (c)	8. (c)	9. (a)	10. (c)
11. (b)	12. (b)	13. (a)	14. (b)	15. (c)
16. (b)	17. (c)	18. (a)	19. (b)	20. (d)
21. (b)	22. (b)	23. (b)	24. (b)	25. (d)

EXERCISE – II

IIT-JEE-SINGLE CHOICE CORRECT

1. (b)	2. (d)	3. (b)	4. (c)	5. (a)
6. (a)	7. (d)	8. (c)	9. (a)	10. (b)
11. (b)	12. (c)	13. (a)	14. (b)	15. (c)
16. (b)	17. (c)	18. (b)	19. (a)	20. (b)

ONE OR MORE THAN ONE CHOICE CORRECT

1. (c,d)	2. (all)	3. (a,b)	4. (a,d)	5. (b,c)
6. (a,c)	7.(a,b,c)	8. (b,c)	9. (c,d)	10. (a,b)

EXERCISE – III

MATCH THE FOLLOWING

1. I – B, D, E; II – A, C, E; III – A, C, E; IV – B, D, E

REASONING TYPE

1. (a)	2. (a)	3. (d)	4. (c)	5. (d)

LINKED COMPREHENSION TYPE

1. (b)	2. (c)	3. (d)

EXERCISE – IV

SUBJECTIVE PROBLEMS

1. (a) y = 2 cm (b) $x = 0, 15, 30, 45, 60\ \text{cm}$ (c) 0

2. 50 m/s

3. 10

4. 2100 Hz

5. (a) 10 cm (b) 6 cm

6. 2

7. 10

8. 500 Hz.

9. (a) 50 cm/s (b) 1 cm (c) 2 cm

10. (i) 95 cycles/sec, (ii) 10

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 1

Q.1 The property of a medium necessary for wave propagation is -
(1) Its inertia (2) Its elasticity
(3) Its low resistance (4) All of above

Q.2 Water waves are -
(1) Transverse
(2) Longitudinal
(3) Sometimes longitudinal sometimes transverse
(4) Neither transverse nor longitudinal

Q.3 By which of the following waves, energy is not carried ?
(1) stationary waves
(2) longitudinal progressive waves
(3) transverse progressive waves
(4) electromagnetic waves

Q.4 Which of the following are longitudinal waves ?
(1) sound waves
(2) radio waves
(3) infrared waves
(4) electromagnetic waves.

Q.5 In stationary waves, energy is -
(1) transferred
(2) not transferred
(3) zero at every point
(4) transferred in the direction of propagation of waves.

Q.6 The wavelength of sound wave in a gas is -
(1) The distance between compression and rarefaction propagating in the medium.
(2) The distance travelled by the wave in one second.
(3) The distance between two consecutive particles of the medium oscillating in the same phase.
(4) None of these

Q.7 Sound waves in air do not show the phenomenon of polarisation because -
(1) Sound waves require a material medium for their propagation
(2) Sound waves in air are longitudinal
(3) Sound waves are transverse
(4) Sound waves have low velocity

Q.8 The propagation of sound waves is not possible through -
(1) Solids (2) Gases (3) Vacuum (4) Liquids

Q.9 The amplitude of a wave represented by displacement equation
$y = \frac{1}{\sqrt{a}} \sin \omega t \pm \frac{1}{\sqrt{b}} \cos \omega t$ will be -
(1) $\frac{a+b}{ab}$ (2) $\frac{\sqrt{a}+\sqrt{b}}{ab}$
(3) $\frac{\sqrt{a}\pm\sqrt{b}}{ab}$ (4) $\sqrt{\frac{a+b}{ab}}$

Q.10 The relation between the particles velocity and wave velocity is -

(1) $u = -v\dfrac{dy}{dx}$ (2) $u = \dfrac{v}{\left(\dfrac{dy}{dx}\right)}$

(3) $u = v$ (4) $u = v + \dfrac{dy}{dx}$

Q.11 Which of the following is not a formula of wave velocity ?

(1) $v = \dfrac{\omega}{K}$ (2) $v = n\lambda$

(3) $v = \dfrac{2\pi}{TK}$ (4) $v = \dfrac{K}{\omega}$

Q.12 The time taken by a particle in reaching from trough to crest in a transverse wave is -

(1) $\dfrac{T}{4}$ (2) $\dfrac{T}{2}$ (3) $\dfrac{3T}{4}$ (4) T

Q.13 A sine wave has amplitude A and wavelength λ. If V is the wave velocity and v be the maximum particle velocity, then -

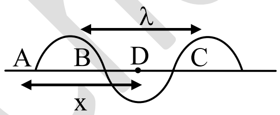
(1) V = v if $A = \dfrac{\lambda}{2\pi}$

(2) V = v if $A = 2\pi\lambda$

(3) V = v if $A = \pi\lambda$

(4) V can never be equal to v.

Q.14 In the diagram, the phase difference between points A and D is -



(1) $\dfrac{\pi}{\lambda}x$ (2) $\dfrac{2\pi}{\lambda}x$ (3) $\dfrac{\pi}{2\lambda}x$ (4) $\dfrac{\pi\lambda}{x}$

Q.15 If the energy density and velocity of a wave are u and c respectively then the energy propagating per second per unit area will be -

(1) uc (2) $\dfrac{c}{u}$ (3) $\dfrac{u}{c}$ (4) c^2u

Q.16 The velocity of a wave propagating along a stretched string is 10 m/s and its frequency is 100 Hz. The phase difference between the particles situated at a distance of 2.5 cm on the string will be -

(1) $\pi/8$ (2) $\pi/4$ (3) $3\pi/8$ (4) $\pi/2$

Q.17 Two points lie on a ray are emerging from a source of simple harmonic wave having period 0.040. The wave speed is 300 m/s and points are at 10 m and 16 m from the source. They differ in phase by -

(1) π (2) $\pi/2$

(3) 0 or 2π (4) none of these

Q.18 If the frequency of a wave is 100 Hz then the particles of the medium cross the mean position in one second -

(1) 100 times (2) 200 times

(3) 400 times (4) 50 times

Q.19 The velocity of sound in sea water is 1530 m/s. If a sound of frequency 1800 Hz is produced in sea water, then its wavelength will be -
(1) 0.18 m (2) 5.45 m
(3) 0.85 m (4) 1.18 m

Q.20 When a sound wave of frequency 300 Hz passes through a medium, the maximum displacement of a particle of the medium is 0.1 cm. The maximum velocity of the particle is equal to -
(1) 60 π cm/sec (2) 30 π cm/sec
(3) 30 cm/sec (4) 60 cm /sec

Q.21 The relation between frequency n, wavelength λ and velocity of propagation v of the wave is -
(1) $n = v\lambda$ (2) $n = \lambda/v$
(3) $n = 1/v$ (4) $n = v/\lambda$

Q.22 If the air pressure is doubled at constant temperature, then the speed of sound will become -
(1) Double
(2) Three times
(3) Four times
(4) Equal to its initial value

Q.23 If the frequency of a sound wave is doubled then the velocity of sound will become -
(1) Half (2) Double
(3) Remain unchanged (4) Zero

Q.24 If the frequency of a sound wave is increased by 25% then the change in its wavelength will be -
(1) 25% Decrease (2) 20% Decrease
(3) 20% Increase (4) 10% Increase

Q.25 Two sound waves are represented by the following equations :
$y_1 = 10 \sin (3\pi t - 0.03x)$ and
$y_2 = 5\{\sin(3\pi t - 0.03x) + \sqrt{3} \cos (3\pi t - 0.03x)\}$
Then the ratio of their amplitudes is given by -
(1) 1 : 1 (2) 1 : 2
(3) 2 : 1 (4) 2 : 5

Q.26 The displacement y of a particle executing periodic motion is given by $y = 4 \cos^2 (t) \sin (1000 t)$. This expression may be considered to be a result of the superposition of waves :
(1) Two (2) Three
(3) Four (4) Five

Q.27 The correct relation between phase difference (δ) and path difference (Δ) is -
(1) $\delta = \frac{2\pi}{\lambda} \Delta$ (2) $\delta = \frac{\lambda}{2\pi} \Delta$
(3) $\delta = \frac{\Delta}{\lambda}$ (4) $\delta = \Delta\lambda$

Q.28 The displacement of the medium in a sound wave is given by the equation $y_1 = A \cos (ax + bt)$ Where A, a and b are positive constants. Then the wavelength and frequency of the incident wave are -
(1) a, b (2) $2\pi a$, $2\pi b$

(3) $\frac{2\pi}{a}, \frac{2\pi}{b}$ (4) $\frac{2\pi}{a}, \frac{b}{2\pi}$

Q.29 The equation of a progressive wave moving in +ve X-direction is given by -

(1) $Y = A \sin 2\pi\left(\frac{vt}{\lambda} - x\right)$

(2) $Y = A \sin \frac{2\pi}{\lambda}\left(vt - \frac{x}{\lambda}\right)$

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

(4) $Y = A \sin \frac{2\pi}{\lambda}(x + vt)$

Q.30 Which of the following equation does not represent the progressive wave -

(1) $y = A \sin \omega\left(t - \frac{x}{v}\right)$

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

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

(4) $y = A \sin 2\pi\left(\frac{t}{T} - \frac{x}{v}\right)$

Q.31 Which of the following is not the equation of a plane progressive wave -

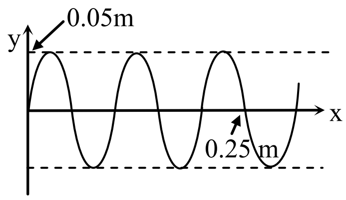
(1) $y = a \sin(\omega t \pm Kx)$

(2) $y = a \sin \frac{2\pi}{\lambda}[vt \pm x]$

(3) $y = a \sin 2\pi\left[\frac{t}{T} \pm \frac{x}{\lambda}\right]$

(4) $y = 2a \sin Kx \cos \omega t$

Q.32 If the speed of the wave shown in the figure is 330 m/s in the given medium, then the equation of the wave propagating in the positive x-direction will be –



(all quantities are in MKS units)

(1) $y = 0.05 \sin 2\pi(4000\,t - 12.5\,x)$

(2) $y = 0.05 \sin 2\pi(4000\,t - 122.5\,x)$

(3) $y = 0.05 \sin 2\pi(3300\,t - 10\,x)$

(4) $y = 0.05 \sin 2\pi(3300\,x - 10\,t)$

Q.33 The equation of the a progressive wave is $y = a \sin\left[\frac{\pi}{2}x - 200\pi t\right]$. The frequency of the wave will be -

(1) 0.1 Hz (2) 25 Hz

(3) 100 Hz (4) 200 Hz

Q.34 The equation of a transverse wave, out of the following is -
(1) $X = a \sin (Kx - \omega t)$
(2) $Y = a \sin (Ky - \omega t)$
(3) $Y = a \sin (Kx - \omega t)$
(4) $Z = a \cos (Kz - \omega t)$

Q.35 The equation of a transverse wave is given by $y = 10 \sin \pi (0.01x - 2.0t)$, where y and x are in cm and t is in second. The frequency of the wave will be -
(1) 1Hz (2) 2 Hz
(3) 3 Hz (4) 4 Hz

Q.36 In the equation of motion of a particle $y = 0.5 \sin (0.3t + 0.1)$, the initial phase of motion is -
(1) 0.1 (2) 0.3t
(3) 0.3 (4) (0.3t + 0.1)

Q.37 The equation for stationary wave is $y = 0.005 \cos \left(62.8t + 3.14x + \frac{\pi}{3}\right)$, its periodic time T and wavelength λ are -
(1) 3.14 sec, 1m
(2) 1 sec, 1 m
(3) 0.1 sec, 2m
(4) 0.1 sec, 1m

Q.38 The equation of a progressive wave is $y = 8 \sin \pi (.02x - 4t)$. If the x and y are expressed in cm and time in seconds, the value of wavelength and the periodic time will be -
(1) 50cm, 25 sec (2) 0.02 cm, 4 sec
(3) 100 cm, 0.5 sec (4) None of these

Q.39 The displacement produced by a simple harmonic wave is :
$y = \frac{10}{\pi} \sin \left[2000\pi t - \frac{\pi x}{17}\right]$ cm. The time period and maximum velocity of the particle will be respectively -
(1) 10^{-3} second and 200 m/s
(2) 10^{-2} second and 2000 m/s
(3) 10^{-3} second and 330 m/s
(4) 10^{-4} second and 20 m/s

Q.40 Equation of a progressive wave is given by $y = 0.2 \cos \pi \left(.04t + .02x - \frac{\pi}{6}\right)$. The distance is expressed in cm and time in second. What will be the minimum distance between two particles having the phase difference of
$\pi/2$?
(1) 4 cm (2) 8 cm
(3) 25 cm (4) 12.5 cm

Q.41 A progressive wave is represented by $y = 0.1 \sin \frac{8\pi}{7} \left(0.1t - \frac{x}{20}\right)$. Where all the observations are in MKS system. The wave velocity will be -
(1) 2m/sec
(2) 15 m/sec

(3) 20 m/sec
(4) 40 m/sec

Q.42 The equation of a transverse waves is given by y = 10 sinπ (0.01 x – 2.0t), where y and x are in cm and t is in second. The frequency of the wave will be -
(1) 1 Hz (2) 2Hz
(3) 3 Hz (4) 4 Hz

Q.43 The equation of a wave propagating in a string is y = 2cosπ (100t – x). Its wavelength will be -
(1) 5 cm (2) 2 m
(3) 20 m (4) 50 cm

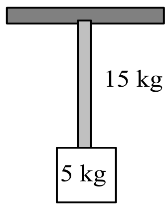
Q.44 A transverse wave, whose amplitude is 0.5 m wavelength is 1 m and frequency is 2Hz. is travelling along positive x direction. The equation of this wave will be-
(1) y = 0.5 cos (2πx – 4πt)
(2) y = 0.5 cos (2πx + 4πt)
(3) y = 0.5 sin (πx – 2πt)
(4) y = 0.5 cos (2πx + 2πt)

Q.45 The equation of plane progressive wave propagating in positive X-direction is $y = a \sin 2\pi \left[n - \frac{x}{\lambda}\right]$. If the maximum particle velocity is three time the wave velocity then the wavelength of wave is -
(1) $\frac{\pi a}{3}$ (2) πa
(3) $\frac{\pi a}{2}$ (4) $\frac{2\pi a}{3}$

Q.46 The equation of a progressive wave is Y = 10 sin 2π (60t + 2X), where X and Y are in metres and t is in seconds. It represents a wave whose velocity is -
(1) 60 metre/sec in +X direction
(2) 60 metre/sec in –X direction
(3) 30 metre/sec in +X direction
(4) 30 metre/sec in –X direction

Q.47 The correct equation of one dimensional wave is -
(1) $\frac{d^2y}{dx^2} = \frac{1}{V^2}\frac{d^2y}{dt^2}$
(2) $\frac{d^2y}{dx^2} = V^2 \frac{d^2y}{dt^2}$
(3) $\frac{d^2y}{dx^2} = \frac{1}{V}\frac{d^2y}{dt^2}$
(4) $\frac{d^2y}{dx^2} = V\frac{d^2y}{dt^2}$

Q.48 A uniform rope of length 10 m and mass 15 kg hangs vertically from a rigid support. A block of mass 5 kg is attached to the free end of the rope. A transverse pulse of wavelength 0.08 m is produced at the lower end of the rope. The wavelength of the pulse when it reaches the top of the rope will be-



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

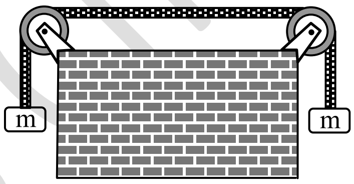
Q.49 The density of the material of a wire used in sonometer is 7.5×10^3 kg/m^3. If the stress on the wire is 3.0×10^8 N /m^2, the speed of transverse wave in the wire will be -
(1) 100 m/s (2) 200 m/s
(3) 300 m/s (4) 400 m/s

Q.50 The length of a copper wire is 5 m and its radius is 1 mm . A force of 31.4 N is applied at each end of the wire. The Young's modules of elasticity for copper is 11×10^{10} N/m^2. The density of copper is 8900 Kg/m^3 . The velocity of transverse waves in the wire is -
(1) 33.5 m/s (2) 82 m/s
(3) 123 m/s (4) 164 m/s

Q.51 When a body of mass 25Kg is suspended from a sonometer wire then it vibrates with frequency 200 Hz. If the volume of the body is 0.009 m^3 and it is immersed in water then the frequency of vibration of the wire will be -
(1) 220 Hz (2) 160 Hz
(3) 240 Hz (4) 180 Hz

Q.52 The length, mass and tension of a string are 1000 cm, 0.01 Kg and 10 N respectively. The speed of transverse waves in the string will be -
(1) 10^2 m/s (2) 10^4 m/s
(3) 10^6 m/s (4) None of these

Q.53 In the given arrangement, if hanging mass will be changed by 4%, then percentage change in the wave speed in string will be:



(1) 2% (2) 8% (3) 3% (4) 4%

Q.54 When waves are superposed. Which of the following properties of wave is not changed?
(1) Frequency (2) Energy density
(3) Velocity (4) Total energy

Q.55 If the amplitude of two sound waves is a_1 and a_2, then on superposition the resultant amplitude will be -
(1) $(a_1 + a_2)$ only
(2) $(a_1 - a_2)$ only
(3) $(a_1 + a_2)$ or $(a_1 - a_2)$
(4) $\sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\theta}$
(θ = phase difference between two waves)

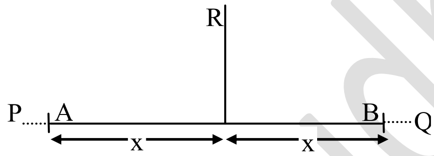
Q.56 Superposition is the main characteristic of -
(1) Wave motion
(2) Particle motion
(3) Wave and particle motion

(4) None of the two motions

Q.57 Two sound wave of equal intensity I superimpose at point P in the same phase. The resultant intensity at point P will be -
(1) I (2) 2I (3) $\sqrt{2}$ I (4) 4I

Q.58 The resultant amplitude, when two waves of same frequency but with amplitudes a_1 and a_2 superimpose at phase difference of $\frac{\pi}{2}$, will be -
(1) $a_1 + a_2$
(2) $a_1 - a_2$
(3) $\sqrt{a_1^2 + a_2^2}$
(4) $a_1^2 + a_2^2$

Q.59 The frequencies of sources A and B as shown in figure are same. The nature of interference at points P, Q and R will be if AB = $\frac{\lambda}{2}$ and the two sources are in same phase -



(1) constructive at P. destructive at Q and R.
(2) constructive at P and R. destructive at Q.
(3) constructive at P and Q. destructive at R.
(4) constructive at R. destructive at P and Q

Q.60 For superposition of two waves in interference -
(1) They must have equal frequency and wavelength
(2) They must have equal frequency but may have unequal wavelengths
(3) They must have the same wavelength but may have different frequencies
(4) They must have neither equal frequencies nor equal wavelengths

Q.61 Two waves of same frequency but of amplitudes a and 2a respectively superimpose over each other. The intensity at a point where the phase difference is $\frac{3\pi}{2}$, will be -
(1) $9a^2$ (2) $3a^2$ (3) a (4) $5a^2$

Q.62 Two waves of same frequency and of intensity I_0 and $9I_0$ produces interference. If at a certain point the resultant intensity is $7I_0$ then the minimum phase difference between the two sound waves will be -
(1) 90º (2) 100º
(3) 120º (4) 110º

Q.63 If the ratio of amplitudes of two waves at any point in the medium is 1:3, then the ratio of maximum and minimum intensities due to their superposition will be -
(1) 2 : 3 (2) 3 :1
(3) 2 : 1 (4) 4 : 1

Q.64 Two periodic waves of amplitudes A_1 and A_2 pass through a region, If $A_1 > A_2$, the difference in the maximum and minimum possible amplitudes will be -
(1) $A_1 - A_2$ (2) $A_1 + A_2$

(3) $2A_1$ (4) $2A_2$

Q.65 The ratio of sound intensities of two waves of the same frequency is 1 : 16. Then the ratio of the amplitudes will be -
(1) 1 : 2 (2) 1 : 4 (3) 1 : 8 (4) 1 : 16

Q.66 If two waves are represented by :
$y_1 = 2\sin(4x - 300t)$ & $y_2 = \sin(4x - 300t - 0.2)$
then their superposed wave will have angular frequency -
(1) $150/\pi$ (2) 150π
(3) 300 (4) 600π

Q.67 If two progressive waves of amplitude A_1 and A_2 superpose, while moving in the same direction, then the amplitude of the resultant wave will be -
(1) $A_1 + A_2$
(2) $\sqrt{A_1^2 + A_2^2}$
(3) Between $A_1 + A_2$ and $A_1 - A_2$
(4) $A_1 - A_2$

Q.68 Two waves of intensities I and 4I produce interference. Then the intensity at constructive and destructive interference respectively is -
(1) 3I, 5I (2) 5I, 3I
(3) I, 9I (4) 9I, I

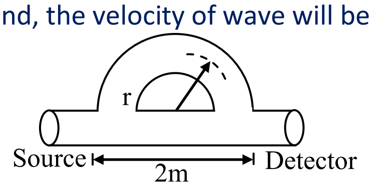
Q.69 When two trains of the same frequency and same amplitude 'a' are superposed in phase, the resulting intensity at the point of superposition is proportional to -
(1) $4a^2$ (2) $2a^2$ (3) 2a (4) 0

Q.70 Two sources of intensities I and 4I and waves, which interfere to produce a resultant intensity I_0 at a point of phase difference $\pi/2$. I_0 is equal-
(1) 5I (2) 4I (3) 3I (4) I

Q.71 Intensity at any point due to interference of two waves will be maximum, when path difference at that point is -
(1) $\frac{\lambda}{2}$ (2) λ
(3) $2n\lambda$ (4) $(2n + 1)\frac{\lambda}{2}$

Q.72 Two waves of same frequency and same amplitude reach a common point of the medium simultaneously. If the amplitude of resultant wave is zero then the path difference between the waves will be -
(1) λ (2) $\lambda/2$ (3) 2λ (4) $\frac{3\lambda}{4}$

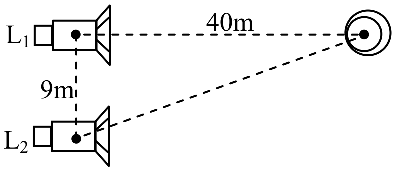
Q.73 A tuning fork of frequency 250 Hz is vibrating at one end of a tube as shown in figure. If maximum sound is heard at the other end, the velocity of wave will be -



(1) 285 m/s (2) 280 m/s

(3) 180 m/s (4) 320 m/s

Q.74 Two loudspeakers L_1 and L_2 driven by a common oscillator and amplifier are set up as shown in figure. As the frequency of the oscillator increases from zero, the detector at D recorded a series of maximum and minimum signals. What is the frequency at which the first maximum is observed. (Speed of sound = 330 m/s)



(1) 165Hz (2) 330Hz
(3) 495Hz (4) 660Hz

Q.75 Two waves travelling in mutually opposite direction in a medium superimpose over each other, then which event is observed -
(1) Beats (2) Resonance
(3) Stationary waves (4) Harmonic nodes

Q.76 If the displacement of the particles in a string stretched along X - direction is y, then the expression representing the stationary wave in it is -
(1) $K^2x^2 - \omega^2t^2$
(2) $\cos Kx \sin \omega t$
(3) $\cos(K^2x^2 - \omega^2t^2)$
(4) $\cos(K^2x^2 + \omega^2t^2)$

Q.77 Out of the following which equation represents a stationary wave ?
(1) $y = ae^{-bx}\sin(\omega t - Kx + x)$
(2) $y = (ax + b)\,x \sin(\omega t - Kx)$
(3) $y = a \sin Kx \sin(\omega t + x)$
(4) $y = a \sin(\omega t - Kx)$

Q.78 A stationary wave is represented by -
(1) $Y = 2A \cos Kx \sin \omega t$.
(2) $Y = 2A \sin K(x - vt) \sin \omega t$
(3) $Y = 2A \cos Kx \cos(\omega t - Kx)$
(4) $Y = 2A \cos K(X - vt) \cos \omega t$

Q.79 When a plane progressive wave superposes with another plane progressive wave reflected by a denser medium then the equation of resulting stationary wave will be -
(1) $y = 2a \sin Kx \cos \omega t$
(2) $y = 2a \cos Kx \cos \omega t$
(3) $y = 2a \sin Kx \sin \omega t$
(4) $y = 2a \cos Kx \sin \omega t$

Q.80 The following equations represent progressive waves - $z_1 = A\cos(kx - \omega t)$, $z_2 = A\cos(ky + \omega t)$ and $z_3 = A\cos(kz - \omega t)$. Which two waves can produce stationary waves ?
(1) 1 and 2
(2) 2 and 3
(3) 1 and 3
(4) none of the above

Q.81 The distance between two consecutive antinodes is -

(1) $\frac{\lambda}{4}$ (2) $\frac{\lambda}{2}$

(3) λ (4) 2λ

Q.82 The distance between consecutive node and antinode is -

(1) $\frac{\lambda}{4}$ (2) $\frac{\lambda}{2}$ (3) λ (4) 2λ

Q.83 The equation y = 0.15 sin 5x cos 300t represents a stationary wave. The wavelength of this stationary wave will be -

(1) zero (2)1.256 m

(3) 2.512 m (4) 0.628 m

Q.84 For stationary wave, which of the following statement is correct -

(1) All the particles vibrate in same phase

(2) All the particles between an antinode and node vibrate in phase

(3) Particles between any two consecutive nodes vibrate in phase

(4) All the particles vibrate in different phases.

Q.85 Which of the following statements is not true for stationary waves?

(1) All the particles of medium vibrate with same frequency

(2) All the particles are in the same phase between successive nodes

(3) All the particles are in the same phase between successive antinodes

(4) The distance between alternate nodes is equal to wavelength

Q.86 The equation of a stationary wave is Y = 10 sin $\frac{\pi x}{4}$ cos20 πt. The distance between two consecutive nodes in metres is -

(1) 4 (2) 2 (3) 5 (4) 8

Q.87 The phase difference between the two particles situated on both the sides of a node is -

(1) 0º (2) 90º (3) 180º (4) 360º

Q.88 In stationary wave in strings –

(1) Energy is uniformly distributed

(2) Energy is maximum at nodes and minimum at antinodes

(3) Energy is minimum at nodes and maximum at antinodes

(4) Alternating maxima and minima of energy are produced at nodes and antinodes

Q.89 The equation of stationary wave is given by -

(1) $y = 2y_0 \sin kx \cos\omega t$

(2) $y = y_0 \sin k(x - vt)$

(3) $y = y_0 \cos 2\pi \left(\frac{kx}{t} - \frac{t}{T}\right)$

(4) $y = y_0 \sin \frac{2vT}{\lambda}$

Q.90 Which of the following expression is that of a stationary wave -

(1) A sinωt (2) A sinωt coskx

(3) A sin (ωt – kx) (4) A coskx

Q.91 For the stationary wave, $y = 4 \sin(\pi x/15) \cos(96\pi t)$ the distance between a node and the next antinode is -
(1) 7.5 (2) 15 (3) 22.5 (4) 30

Q.92 For formation of standing wave, the medium -
(1) Should have infinite extension
(2) Should be bounded
(3) Should be a gas only
(4) Should be having zero inertia and zero elasticity.

Q.93 In a stationary wave all particles are -
(1) At rest at the same time twice in every period of oscillation
(2) At rest at the same time once in every period of oscillation
(3) Never at rest at the same time
(4) At rest always

Q.94 In stationary waves, at the nodes -
(1) Energy is minimum
(2) Pressure and density variations are maximum
(3) Strain variation is maximum
(4) All of the above

Q.95 In the stationary waves in an open organ pipe -
(1) Both the ends are antinodes and in between them there is at least one node
(2) Both the ends are nodes and in between them there is at least one antinode
(3) Antinode at one end and node at the other
(4) Both the ends are antinodes and in between them there is no node.

Q.96 A stretched string of length L, fixed at both ends can sustain stationary waves of wavelength λ given by -
(1) $\lambda = n^2 / 2L$ (2) $\lambda = L^2 / 2n$
(3) $\lambda = 2L/n$ (4) $\lambda = 2Ln$

Q.97 In a stretched string -
(1) Only even harmonics are produced
(2) Only odd harmonics are produced
(3) Even as well as odd harmonics are produced
(4) Neither even nor odd harmonics are produced

Q.98 A wire of linear mass density 9×10^{-3} kg /m is stretched between two rigid supports under a tension of 360 N. The wire resonates at frequency 210 Hz. The next higher frequency at which the same wire resonates is 280 Hz. The number of loops produced in first case will be -
(1) 1 (2) 2
(3) 3 (4) 4

Q.99 In a stretched string under tension and fixed at both ends, the fundamental frequency is n. The ratio of harmonic frequencies produced is -
(1) n : 2n : 3n (2) n : 3n : 5n
(3) n : 2n : 5n (4) 3n : 7n : 11n

Q.100 The waves produced in the wire of a sonometer are -
(1) Transverse, progressive and polarized
(2) Longitudinal
(3) Transverse, stationary and polarized
(4) Transverse, stationary and unpolarised

Q.101 The length of the sonometer wire is fixed between two bridges. Its frequency can be increased -
(1) By increasing tension and decreasing mass per unit length of wire
(2) By decreasing tension and increasing mass per unit length of wire
(3) By increasing tension and mass per unit length of wire
(4) By decreasing tension and mass per unit length of the wire

Q.102 Four wires of same length and same material, whose diameters are in the ratio 4 : 3 : 2 :1, are clamped in such a way that each wire produces note of frequency double that of the preceding wire. If the tension in the first wire is 2 Kg-wt, then tension in the second wire will be -
(1) 4.5 (2) 8 (3) 9 (4) 16

Q.103 A 110 cm long wire is to be divided into three segments by two bridges. The ratio of frequencies of three segments is 1 : 2 : 3 . The positions of the bridges will be -
(1) 20 cm from one end 60 cm from another end
(2) 60 cm from one end and 20 cm from another end
(3) 30 cm from one end and 70 cm from another end
(4) 40 cm from one end and 50 cm from another end

Q.104 The relation between frequency 'n' of the string, if n_1, n_2, n_3,.... are the frequencies of segments of the stretched string, is -
(1) $n = n_1 + n_2 + n_3 + ...$
(2) $n = \sqrt{n_1 \times n_2 \times n_3 \times ....}$
(3) $\frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3} + ...$
(4) none of these

Q.105 Which of the following laws of strings is not correct -
(1) $n \propto \sqrt{T}$ (2) $n \propto \frac{1}{\ell}$
(3) $n \propto \frac{1}{\sqrt{m}}$ (4) $n \propto \ell$

Q.106 In a stretched string under tension and fixed at both ends, the tension is increased by four times, and the length is doubled, the frequency-
(1) Becomes half
(2) Remains the same
(3) Becomes twice
(4) Becomes four times

Q.107 The total mass of a sonometer wire remains constant. On increasing the distance between two bridges to four times, its frequency will become -
(1) 4 times (2) 1/2 times
(3) 8 times (4) $\sqrt{2}$ times

Q.108 The frequency of a note produced by vibrating stretched string increases if -
(1) Tension in it decreases
(2) Tension in it increases
(3) Its length increases
(4) Its mass per unit length increases

Q.109 The frequency of a sitar wire is 440 vibrations per second. If the sitar player reduces the length of the wire by 1/5 th, then the change in the frequency of sitar wire will be -
(1) 2200 vibrations /sec
(2) 1760 vibrations /sec
(3) 440 vibrations /sec
(4) 110 vibrations /sec

Q.110 The frequency ratio of two wires of copper is 2 : 3 if the diameter of the first wire is 0.6mm, the diameter of the other wire is -
(1) 0.9 mm (2) 0.4 mm
(3) 0.27 mm (4) 0.8 mm

Q.111 Two similar wires of length ℓ and 2 ℓ of same material produces vibrations of 100Hz and 150 Hz . The ratio of tensions in them is -
(1) 2 : 3 (2) 3 : 2 (3) 1 : 9 (4) 1 : 4

Q.112 If the density of materials of two strings of same length, tension and area of cross section are 2Kg/m^3 and 4Kg/m^3 respectively then the ratio of their frequencies will be -
(1) $\sqrt{2}$: 1 (2) 1 : $\sqrt{2}$
(3) 1 : 2 (4) 2 : 1

Q.113 In Melde's experiment, 8 loops are formed with a tension of a 0.75 N. If the tension is increased to four times then the number of loops produced will be -
(1) 4 (2) 8
(3) 2 (4) 12

Q.114 The ratio (V) of velocities of sound in dry air and humid air is -
(1) V < 1 (2) V > 1
(3) zero (4) V = 1

Q.115 The Laplace’s formula for sound waves is -
(1) V = $\sqrt{\frac{P}{\rho}}$ (2) V = $\sqrt{\frac{\gamma P}{\rho}}$
(3) V = $\sqrt{\frac{\rho}{\gamma P}}$ (4) V = $\sqrt{\frac{P}{\gamma \rho}}$

Q.116 Sound waves are propagating in a medium. The moduli of isothermal and adiabatic elasticity of the medium are E_r and E_s respectively. The velocity of sound waves is proportional to -
(1) $\frac{E_s}{E_r}$ (2) $\sqrt{E_r}$ (3) $\sqrt{E_s}$ (4) E_r

Q.117 If the air pressure is doubled at constant temperature, then the speed of sound will be become -
(1) Double
(2) Three times
(3) Four times
(4) Equal to its initial value

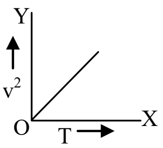
Q.118 At what temperature the speed of sound in air becomes double of its value of 0ºC -
(1) 273 K (2) 819 K
(3) 1092 K (4) 553 K

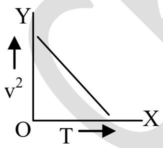
Q.119 At what temperature the speed of sound will be double of the speed at 27º C -
(1) 54º C (2) 108º C
(3) 927º C (4) 327º C

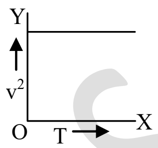
Q.120 The velocity of sound waves in an ideal gas at temperatures T_1K and T_2 K are respectively v_1 and v_2. The rms velocity of gas molecules at these two temperatures are ω_1 and ω_2, respectively then -
(1) $\frac{v_1}{v_2} = \frac{\omega_1}{\omega_2}$ (2) $\frac{v_1}{v_2} = \sqrt{\gamma}\frac{\omega_1}{\omega_2}$
(3) $\frac{v_1}{v_2} = \sqrt{\frac{\gamma}{3}}\frac{\omega_1}{\omega_2}$ (4) $\frac{v_1}{v_2} = \sqrt{\frac{\omega_1}{\omega_2}}$

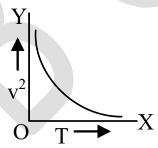
Q.121 The velocity of longitudinal waves in solid, is given by (where symbols have their usual meanings)-
(1) v = $\sqrt{\frac{T}{m}}$ (2) v = $\sqrt{\frac{Y}{\rho}}$
(3) v = $\sqrt{\frac{B}{\rho}}$ (4) v = $\sqrt{\frac{\gamma P}{\rho}}$

Q.122 The densities of two monoatomic gases are in the ratio of 16:9 . The velocities of sound in gases having the same pressure will be in the ratio of
(1) 4 : 3 (2) 3 : 4
(3) 16 : 9 (4) 9 : 16

Q.123 The correct graph between v^2 (square of the speed of sound) and absolute temperature T of the gas is –
(1) 

(2) 

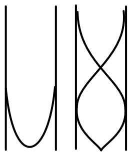
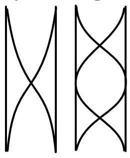
(3) 

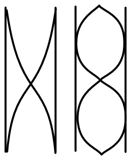
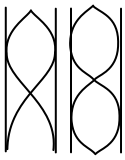
(4) 

Q.124 In the stationary waves in an open organ pipe -
(1) Both the ends are antinodes and in between them there is at least one node
(2) Both the ends are nodes and in between them there is at least one antinode
(3) Antinode at one end and node at the other
(4) Both the ends are antinodes and in between them there is no node.

Q.125 In open pipes, the positions of antinodes are obtained at –
(1) 0, $\frac{\lambda}{2}$, 2λ
(2) 0, $\frac{\lambda}{2}$, λ
(3) $\frac{\lambda}{4}$, $\frac{3\lambda}{4}$, λ
(4) $\frac{5\lambda}{4}$, $\frac{3\lambda}{4}$

Q.126 Modes of vibration in an open organ pipe are represented by –

(a) 
(b) 

(c) 
(d) 

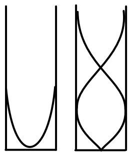
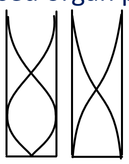
(1) a (2) b (3) c (4) d

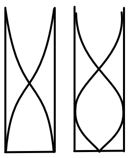
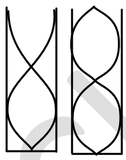
Q.127 In closed pipes, the positions of antinodes are obtained at –

(1) $\frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$ (2) $0, \frac{\lambda}{2}, \lambda$

(3) $\lambda, 2\lambda, 3\lambda$ (4) $2\lambda, 4\lambda, 6\lambda$

Q.128 Modes of vibration in a closed organ pipe are represented by –

(a) 
(b) 

(c) 
(d) 

(1) a (2) b (3) c (4) d

Q.129 The first overtone of a closed pipe is given by –

(1) $n_2 = \frac{V}{4\ell}$ (2) $n_2 = \frac{3V}{4\ell}$

(3) $n_2 = \frac{5V}{4\ell}$ (4) $n_2 = \frac{7V}{4\ell}$

Q.130 The frequency of an open organ pipe is n. If one of its ends is closed then its fundamental frequency will be –

(1) 2n (2) n (3) n/2 (4) 3n/4

Q.131 In an open organ pipe, if the fundamental frequency is n, the overtones produced in it are in the ratio of-

(1) 2n : 3n : 4n (2) 2n : 4n : 8n

(3) 3n : 5n : 7n (4) 3n : 7n : 11n

Q.132 An open pipe of length 33cm resonates with frequency of 1000Hz. If the speed of sound is 330m/s, then this frequency is -

(1) The fundamental frequency of the pipe

(2) The first overtone of the pipe

(3) The second overtone of the pipe

(4) The fourth overtone of the pipe

Q.133 The velocity of sound in air is 333 m/s. The length of an open pipe, in order to produce second overtone of frequency 999 Hz in it, will be -
(1) 1.5 m (2) 1.0 m (3) 0.5 m (4) 2 m

Q.134 The length of an open pipe is 48 cm and its fundamental frequency is 320 Hz. If one of the ends of the pipe is closed then its fundamental frequency will be- (V = 330m/s) -
(1) 160 Hz (2) 320 Hz
(3) 200 Hz (4) 240 Hz

Q.135 The ratio of the lengths of two closed pipes is 31/30. Their fundamental frequencies are in ratio of –
(1) $\frac{31}{30}$ (2) $\frac{30}{31}$ (3) $\frac{60}{31}$ (4) $\frac{31}{60}$

Q.136 The length of an open pipe is 0.5m and the velocity of sound in air is 332 m/sec. The fundamental frequency of the pipe is -
(1) 166 Hz (2) 332 Hz
(3) 664 Hz (4) 996 Hz

Q.137 Velocity of sound in air is 332 m/sec. The shortest length of an open pipe which will resonate with a tuning fork of frequency 166Hz is -
(1) 4.0 m (2) 2.0 m
(3) 1.0 m (4) 0.5 m

Q.138 With a closed end organ pipe of length ℓ, the fundamental tone has a frequency -
(1) ($v/2\ell$) and all harmonics are present
(2) ($v/4\ell$) and all harmonic are present
(3) ($v/4\ell$) and only odd harmonics are present
(4) ($v/4\ell$) and only even harmonics are present

Q.139 For an open organ pipe of length ℓ the wavelength of the fundamental note is equal to-
(1) ℓ (2) $\ell/2$ (3) $\ell/4$ (4) 2ℓ

Q.140 A cylindrical tube, open at the 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 -
(1) $f/2$ (2) $3f/4$ (3) f (4) $2f$

Q.141 An air column in a pipe, which is closed at one end. will be in resonance with a vibrating tuning fork of frequency 264 Hz if the length of the column in cm is-
(1) 31.25 (2) 62.50 (3) 93.75 (4) 125

Q. 142 If length of a closed organ pipe is 1 m and velocity of sound is 330 m/s, then the frequency is-
(1) $4\left(\frac{330}{4}\right)$ (2) $3\left(\frac{330}{4}\right)$
(3) $2\left(\frac{330}{4}\right)$ (4) None

Q. 143 In the open organ pipe, the fundamental frequency is 30 vibration /sec. If the organ pipe is closed, then the fundamental frequency will be-

(1) 10 vib/sec (2) 20 vib/sec
(3) 30 vib/sec (4) 15 vib/sec

Q. 144 An open organ pipe sounds a fundamental note of frequency of 230 Hz . It the speed of sound in air is 330 m/s., then the length of the pipe is nearly-
(1) 0.25 m (2) 0.50 m
(3) 0.75 m (4) 2.00 m

Q. 145 An open organ pipe has fundamental frequency of 300 Hz. The first overtone of this organ pipe is the same as the first overtone of a closed organ pipe. The length of the closed organ pipe is -
(1) 10 cm (2) 41 cm
(3) 82 cm (4) 164 cm

Q. 146 A tube closed at one end and containing air, produces, when excited , the fundamental note of frequency 512 Hz. If the tube is open at both ends, the fundamental frequency that can be excited is (in Hz) -
(1) 1024 (2) 512
(3) 256 (4) 128

Q. 147 An organ pipe P_1 closed at one end vibrating in its first harmonic and another pipe P_2 open at both ends vibrating in its third harmonic are in resonance with a given tuning fork. The ratio of the length of P_1 to that of P_2 is-
(1) 8/3 (2) 1/6
(3) 1/2 (4) 1/3

Q. 148 An organ pipe of effective length 0.6 m is closed at one end . Given that the speed of the sound in air is 300 m/sec, the two lowest frequencies for the pipe are-
(1) 250 Hz, 750 Hz (2) 250 Hz , 500 Hz
(3) 125 Hz, 375 Hz (4) 125 Hz , 250 Hz

Q. 149 The fundamental frequency of an open pipe is 30 Hz. If one end of this pipe is closed, then the fundamental frequency will be -
(1) 15 Hz (2) 30 Hz
(3) 45 Hz (4) 60 Hz

Q.150 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 100Hz than the fundamental frequency of the open pipe. The fundamental frequency of the open pipe is -
(1) 200 Hz (2) 300 Hz
(3) 240 Hz (4) 480 Hz

Q. 151 The velocity of sound in air is 330 m/s. Then the frequency that will resonate with an open pipe of length 1m is -
(1) 165 Hz (2) 330 Hz
(3) 495 Hz (4) All of the above

Q. 152 An open pipe of length L and another open pipe of length (L + x) are sounded together. If the velocity of sound is V and x << L, then the beat frequency produced will be -
(1) $Vx^2/2L$ (2) $VL/2x^2$
(3) $Vx/2L^2$ (4) $VL^2/ 2x$

Q. 153 The wave produced in a resonating air column is-
(1) Progressive longitudinal
(2) Stationary longitudinal

(3) Progressive transverse
(4) Stationary transverse

Q. 154 In a long cylindrical tube , the water level is adjusted and the air column above it is made to vibrate in unison with a vibrating tuning fork kept at the open end . Maximum sound is heard when the air column lengths are equal to-

(1) $\frac{\lambda}{4}, \frac{\lambda}{2}, \frac{3\lambda}{4}$ (2) $\frac{\lambda}{2}, \lambda, \frac{3\lambda}{2}$
(3) $\frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}$ (4) $\frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$

Q. 155 Standing stationary waves can be obtained in an air column even if interfering waves are-
(1) Of different pitches
(2) Of different amplitudes
(3) Of different qualities
(4) Moving with different velocities

Q. 156 The correct formula for determination of velocity of sound be resonance tube is -
(1) $V = n(\ell_2 - \ell_1)$ (2) $V = 2n(\ell_2 - \ell_1)$
(3) $V = \frac{2n}{(\ell_2 - \ell_1)}$ (4) $V = \frac{(\ell_2 - \ell_1)}{2n}$

Q. 157 The approximate relation between the first and second resonance lengths of a resonance tube is –
(1) $\ell_2 = \ell_1$ (2) $\ell_2 = 2\ell_1$
(3) $\ell_2 = 3\ell_1$ (4) $\ell_2 = \ell_1/2$

Q. 158 The first two resonance lengths in a resonance tube formed are 16.5 cm and 51cm. The end correction for the tube is –
(1) 0.25 cm (2) 0.50 cm
(3) 0.75 cm (4) 1.00 cm

Q. 159 A resonance tube is resonated with tuning fork of frequency 256 Hz, If the lengths of resonating air columns are 32cm and 100cm, then end correction will be -
(1) 2cm (2) 4cm
(3) 6 cm (4) 1 cm

Q.160 To reduce the frequency of a tuning fork –
(1) It should be scraped by a file
(2) It should be loaded with a little wax.
(3) Either of (1) and (2)
(4) Neither of (1) and (2)

Q. 161 The number of beats produced per second is equal to the -
(1) Sum of frequencies of two forks
(2) Difference of frequencies of two forks
(3) Ratio of frequencies of two forks
(4) Product of frequencies of two forks

Q. 162 Beats are the result of -
(1) Diffraction
(2) Destructive interference
(3) Constructive and destructive interference

(4) Superposition of two waves of nearly equal frequencies

Q. 163 Two adjacent piano keys are struck simultaneously. The notes emitted by them have frequencies n_1 and n_2 . The number of beats heard per sound is -
(1) $(n_1 - n_2)/2$ (2) $(n_1 + n_2)/2$
(3) $n_1 - n_2$ (4) $2(n_1 - n_2)$

Q. 164 The fork A of frequency 100 is sounded with another tuning fork B. The number of beats produced is 2. On putting some wax on the prong of B, the number of beats reduces to 1. The frequency of the fork B is -
(1) 101 (2) 99 (3) 102 (4) 98

Q. 165 If two tuning forks A and B are sounded together, they produce 4 beats per sound . A is then slightly loaded with wax, they produce two beats when sounded again. The frequency of A is 256. The frequency of B will be-
(1) 250 (2) 252 (3) 260 (4) 262

Q. 166 56 tuning forks are so arranged in series that each fork gives 4 beats per sec with the pervious one. The frequency of the last fork is 3 times that of the first. The frequency of the first fork is -
(1) 110 (2) 56 (3) 60 (4) 52

Q. 167 The frequency of a fork A is 3 % more than the frequency of a standard fork whereas the frequency of fork B is 3% less. The forks A and B produce 6 beats per second. The frequency of standard fork will be-
(1) 100 Hz (2) 106 Hz
(3) 103 Hz (4) 112 Hz

Q. 168 Beats are produced by two waves $y_1 = a \sin 2000 \pi t$ and $y_2 = a \sin 2008 \pi t$. The number of beats heard per second is-
(1) Zero (2) One
(3) Four (4) Eight

Q. 169 Two waves are $y = 0.25 \sin 316 t$ and $y = 0.25 \sin 310 t$ are travelling in same direction. The number of beats produced per second will be -
(1) 6 (2) 3 (3) $3/\pi$ (4) $\pi/3$

Q.170 A sources of sound gives 5 beats per second when sounded with another sources of frequency 100 $second^{-1}$. The second harmonic of the source, together with a source of frequency 205 $second^{-1}$ gives 5 beats per second. What is the frequency of the source ?
(1) 95 sec^{-1} (2) 100 sec^{-1}
(3) 105 sec^{-1} (4) 205 sec^{-1}

Q. 171 When tension in a string is 225N, then vibrating in fundamental mode it produces 6 beats per second with a tuning fork. The same string, when under tension of 256 N, again vibrating in fundamental mode produces with the same tuning fork 6 beats/sec. Then the frequency of the tuning fork is -
(1) 256Hz (2) 225Hz
(3) 240Hz (4) 186Hz

Q. 172 A sonometer wire is 31cm long is in resonance with a tuning fork of frequency n. If the length is increased by 1cm and it is vibrated with the same tuning fork, then 8 beats/sec are heard. The frequency of the tuning fork is -

(1) 248Hz (2) 256Hz
(3) 264Hz (4) None

Q. 173 A set of 24 tuning forks are so arranged that each gives 4 beats per second with the previous one and the last sounds the octave of the first. Then the frequency of the last fork is -

(1) 92 Hz (2) 184Hz
(3) 116Hz (4) 160Hz

Q. 174 Five beats per second are heard when a tuning fork is sounded together with a sonometer wire, when its length is either 95 cm or 100 cm. Then , the frequency of the tuning fork is -

(1) 190Hz (2) 195Hz
(3) 200Hz (4) 185 Hz

Q. 175 Voice of a child is more shrill than that of an elderly person because -

(1) The pitch of the child's voice is higher than that of the person
(2) The pitch is lower
(3) The child is more energetic
(4) None of the above

Q. 176 The terms pitch, quality and loudness of sound are associated with the following, respectively –

(1) Intensity, frequency and waveform
(2) Frequency, intensity and waveform
(3) Frequency, waveform and intensity
(4) Waveform, frequency and intensity

Q. 177 In an orchestra, the musical sounds of different instruments are distinguished from one another by which of the following characteristic –

(1) Pitch (2) Loudness
(3) Quality (4) Overtones

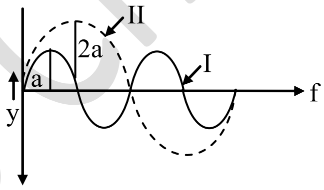
IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 2

Q.1 The wrong statement is -
(1) Superposition takes place between light waves
(2) Superposition takes place between sound wave
(3) Superposition takes place between light waves and sound waves both
(4) Superposition takes place between laser waves

Q.2 Which of the following properties is true for all types of waves ?
(1) All the waves of same frequency move with same velocity irrespective of the medium
(2) All the waves of same amplitude have same intensity
(3) All the waves transfer the energy of but not transfer of medium takes place
(4) All waves need medium

Q.3 When stationary waves are produced the energy is zero is nodes because -
(1) Energy is lost
(2) Energy in transferred to towards antinodes
(3) Some portion is transferred to antinodes and same is lost
(4) All of the above

Q.4 Disturbances of two waves are shown as a function of time in the following figure. The ratio of their intensities will be -



(1) 1 : 4 (2) 4 : 1
(3) 1 : 2 (4) 1 : 1

Q.5 The equation of a progressive wave is $y = a \sin\left(\frac{\pi}{2}x - 200\pi t\right)$. The frequency of the wave will be -
(1) 0.1 Hz (2) 25 Hz
(3) 100 Hz (4) 200 Hz

Q.6 Of the following properties of a wave, the one that is independent of the other is its -
(1) Amplitude (2) Velocity
(3) Wavelength (4) Frequency

Q.7 Two sound waves are respectively y = a sin ($\omega t - kx$) and y = b cos ($\omega t - kx$) the phase difference between the two waves is -
(1) $\pi / 2$ (2) $\pi / 4$ (3) π (3) $3\pi /4$

Q.8 At a moment in a progressive wave, the phase of a particle executing S.H.M. is $\frac{\pi}{3}$. Then the phase of the particle 15 cm ahead and at the time $\frac{T}{2}$ will be, if the wavelength is 60 cm -

(1) $\frac{\pi}{2}$ (2) $\frac{2\pi}{3}$ (3) zero (4) $\frac{5\pi}{6}$

Q.9 If the equation of progressive wave given by $y = 4 \sin \pi \left(\frac{t}{5} + \frac{x}{9} + \frac{\pi}{6}\right)$ then .Which of the following is correct-

(1) v = 5 cm/s (2) λ = 18 m
(3) A = 0.04 cm (4) f = 50 Hz

Q.10 The two waves having intensities in the ratio 1 : 9 produce interference. The ratio of the maximum to the minimum intensities is equal to -

(1) 10 : 8 (2) 9 :1 (3) 4 :1 (4) 2 :1

Q.11 If a wave is represented by the following equation $y = A \cos \frac{2\pi x}{\lambda} \sin \frac{2\pi vt}{\lambda}$ then it is a :

(1) Progressive wave
(2) Stationary wave
(3) Longitudinal progressive wave
(4) Transverse progressive wave

Q.12 A transverse wave is described by the equation $y = y_0 \sin 2\pi (f t - x/\lambda)$. The maximum particle velocity is equal to four times the wave velocity if -

(1) $\lambda = \pi y_0/4$ (2) $\lambda = \pi y_0/2$
(3) $\lambda = \pi y_0$ (4) $\lambda = 2\pi y_0$

Q.13 If the radius of a stretched string is reduced to one third, keeping its tension, density and force constant, then the speed of sound, as compared to its initial value will become -

(1) Double (2) Three times
(3) Four times (4) Zero

Q.14 In a stationary sound waves in air -

(1) At rest at the same time twice in every period of oscillation
(2) At rest at the same time once in every period of oscillation
(3) Never at rest at the same time
(4) Never at rest at all

Q.15 Stationary wave is represented by :
y = A sin (100t) cos (0.01x)
where y and A are in mm, t in sec, and x in m. The velocity of the wave -

(1) 1 m/s (2) 10^2 m/s
(3) 10^4 m/s (4) not derivable

Q.16 The time taken by a transverse wave to travel the full length of a uniform rope of mass 0.1 kg and length 2.45 m hanging from the ceiling, is-

(1) 1 s (2) 0.5 s (3) 2 s (4) 1.5 s

Q.17 A sonometer wire of density d and radius r is held between two bridges at a distance L apart. The wire has a tension T. The fundamental frequency of the wire will be -

(1) $f = \frac{1}{2Lr}\sqrt{\frac{T}{\pi d}}$ (2) $f = \frac{r}{2L}\sqrt{\frac{\pi d}{T}}$

(3) $f = \frac{1}{2Lr}\sqrt{\frac{d}{\pi T}}$ (4) $f = \frac{1}{2L}\sqrt{\frac{d}{T}}$

Q.18 The tension of a piano wire is 16 Kg weight. What must be the change in tension so as to produce a tone an octave lower -

(1) 8 kg weight (2) 32 kg weight

(3) 12 kg weight (4) 4 kg weight

Q.19 A stretched wire of length 114 cm is divided into three segments whose frequencies are in the ratio 1 : 3 : 4, the length of the segments must be in the ratio -

(1) 18 : 24 : 72 (2) 24 : 72 : 18

(3) 24 : 18 : 72 (4) 72 : 24 : 18

Q.20 A transverse wave along a string is given by

$y = 2 \sin\left(2\pi(3t - x) + \frac{\pi}{4}\right)$

where, x and y are in cm and t is second. The acceleration of a particle located at x = 4 cm at t = 1 s is -

(1) $36\sqrt{2}\pi^2$ cm/s^2 (2) $36\pi^2$ cm/s^2

(3) $-36\sqrt{2}\pi^2$ cm/s^2 (4) $-36\pi^2$ cm/s^2

Q.21 If the amplitudes of two sources, having equal frequency are not equal, then-

(1) There will be no interference

(2) The intensity of sound will be the same at all the points

(3) The intensity of sound at any point will decrease and increase

(4) The interference will be there, but the minimum intensity will not be zero.

Q.22 The beats are produced by two sound sources of same amplitude and of nearly equal frequencies. The maximum intensity of beats will be ..... that of one source -

(1) Same (2) Double

(3) Four times (4) Eight times

Q.23 Two vertical antennas situated at a distance $\frac{3\lambda}{2}$ emit radio signals of same wavelength. The intensity of each is I_0. The intensity at a point equidistant from two antennas will be -

(1) $4 I_0$ (2) $2 I_0$

(3) zero (4) I_0

Q.24 The keys of two pianos are simultaneously pressed. The frequencies of nodes produced by them are n_1 and n_2. The number of beats produced per second is -

(1) $(n_1 - n_2)$

(2) $\frac{(n_1 - n_2)}{2}$

(3) $\frac{(n_1 + n_2)}{2}$

(4) $2(n_1 - n_2)$

Q.25 On sounding two tuning forks A and B together 5 beats per second are produced. On filling A slightly, the number of beats per second becomes 2. If the frequency of the A is 384 Hz. Then the frequency of B will be -
(1) 319 Hz (2) 314 Hz
(3) 389 Hz (4) 334 Hz

Q.26 A tuning fork when sounded with tuning fork of frequency 256 produces 4 beats/sec and when sounded with another of frequency 250 produces 2 beats/sec. The frequency of the fork is -
(1) 260 (2) 252 (3) 248 (4) 250

Q.27 When a unknown fork is sounded with a known fork of frequency 288Hz then 5 beats per second are produced. The unknown fork is again sounded after loading it with wax and again 5 beats are produced. The frequency of unknown fork will be -
(1) 283 Hz (2) 293 Hz
(3) 288 Hz (4) 292 Hz

Q.28 If a vibrating tuning fork is put in contact with the sonometer box then the rider on the wire falls down. The frequency of tuning fork, as the compared to that of the sonometer wire will be -
(1) More
(2) Less
(3) Equal
(4) No relation between the two

Q.29 A metal wire of diameter 1 mm is stretched with a tension of 100N between two bridges 50cm apart. It vibrates with its fundamental frequency to produce 5 beats with a tuning fork. The same number of beats/s are heard when tension is reduced to 81 N. The frequency of the fork is -
(1) 75 Hz. (2) 85 Hz
(3) 95 Hz (4) 105 Hz

Q.30 If oil of density higher than that of water be used (in place of water) in a resonance tube, then its frequency will -
(1) Increase
(2) Decrease
(3) Remain the same
(4) Depend upon the density of the material of the tube

Q.31 The frequency of an open pipe is 300Hz. The first overtone of this pipe is the same as the first overtone of a closed pipe. The length of the closed organ pipe is -
(1) 21 cm (2) 42 cm (3) 11 cm (4) 84 cm

Q.32 The fundamental frequency of an open pipe is n. Keeping the pipe vertical it is submerged in water so that half of its length is filled with water. The fundamental frequency of the air column above water is -
(1) n/2 (2) 3n/4 (3) n (4) 2n

Q.33 A metallic rod of length 0.88 m is arranged in Kundt's tube by clamping at its midpoint. If the distance between two consecutive nodes in the tube is 8 cm then the velocity of sound in metal will be (V = 332 m/s) -
(1) 3652 m/s (2) 365 m/s
(3) 36.5 m/s (4) 3.65 m/s

Q.34 Two identical sonometer wires have a fundamental frequency of 500 Hz when kept under the same tension. What fractional increase in the tension of one wire would cause an occurence of 5 beats/sec when both wires vibrate together ?
(1) 1% (2) 2% (3) 3% (4) 4%

Q.35 Two sound waves, originating from the same sound source travel along different paths in air and than meet at a point . The speed of the sound is 330m/s. If the source vibrates at a frequency of 500 Hz and one path is 33 cm linger than the other, then the nature of interference is -
(1) Destructive
(2) Constructive
(3) Neither destructive nor constructive
(4) Nothing can be predicted

Q.36 Air is blown on the mouth of a tube of length 25 cm and diameter 2 cm. The tube is open at both the ends . The velocity of sound is 330 m/s. Then sound which is produced will correspond to frequencies -
(1) 660 Hz, 1320 Hz, 1980 Hz
(2) 330 Hz , 990 Hz, 1650 Hz
(3) 330 Hz, 660 Hz , 990 Hz
(4) All of the above

Q.37 A brass rod of length 3 meter is clamped at the centre. It emits a not of frequency 600 Hz when longitudinal vibrations are excited. If the density of the brass is 8.3×10^3 kg/m^3, then the Young's modulus of the brass is -
(1) 10.7×10^{10} N/m^2
(2) 3.8×10^{11} N/m^2
(3) 2.7×10^{10} N/m^2
(4) Can not be determined

Q.38 In a resonance tube, using a tuning fork of frequency 325 Hz, two successive resonance length are observed at 25.4 cm and 77.4 cm respectively . The velocity of sound in air is -
(1) 338 ms^{-1} (2) 328 ms^{-1}
(3) 330 ms^{-1} (4) 320 ms^{-1}

Q.39 An organ pipe P_1 closed at one end vibrating in its first harmonic and another pipe P_2 open at both ends vibrating in its third harmonic are in resonance with a given tuning fork. The ratio of the length of P_1 to that of P_2 is -
(1) 8/3 (2) 1/6
(3) 1/2 (4) 1/3

Q.40 A sonometer wire with a suspended mass of M =1 kg is in resonance with a given tuning fork. The apparatus is taken to the moon where the acceleration due to gravity is 1/6 that on the earth. To obtain resonance on the moon, the value of M should be -
(1) 1 kg (2) $\sqrt{6}$ kg
(3) 6 kg (4) 24 kg

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 3

Q.1 Which one of the following statements is true-
(1) Both light and sound waves in air are transverse
(2) The sound waves in air are longitudinal while the light waves are transverse
(3) Both light and sound waves in air are longitudinal
(4) Both light and sound waves can travel in vacuum

Q.2 The waves in which the particles of the medium vibrate in a direction perpendicular to the direction of wave motion is known as-
(1) transverse waves (2) propagated waves
(3) longitudinal waves (4) stationary waves

Q.3 The intensity of sound increases at night due to-
(1) increase in density of air
(2) decrease in density of air
(3) low temperature
(4) high temperature

Q.4 Newton's formula for the velocity of sound in gases-
(1) $v = \sqrt{\frac{2p}{\rho}}$ (2) $v = \sqrt{\frac{p}{\rho}}$ (3) $v = \sqrt{\frac{\rho}{p}}$ (4) $v = \frac{3}{2}\sqrt{\frac{p}{\rho}}$

Q.5 If vibrations of a string are to be increased to a factor of two, then tension in the string must be made-
(1) half (2) thrice
(3) four times (4) eight times

Q.6 A siren emitting sound of frequency 500 Hz is going away from a static listener with a speed of 50 m/sec. The frequency of sound to be heard directly from the siren is-
(1) 434.2 Hz (2) 589.3 Hz
(3) 484.2 Hz (4) 256.5 Hz

Q.7 'SONAR' emits which of the following waves ?
(1) radio waves (2) ultrasonic waves
(3) magnetic waves (4) light waves

Q.8 Energy is not carried by which of the following waves ?
(1) stationary (2) transverse
(3) progressive (4) electromagnetic

Q.9 The ratio of intensities of two waves is 9 : 1. When they superimpose, the ratio of maximum to minimum intensity will become-

(1) 4 : 1 (2) 3 : 1 (3) 2 : 1 (4) 1 : 1

Q.10 Two waves are said to be coherent, if they have-
(1) same frequency but different amplitude
(2) same phase and different amplitudes
(3) same frequency, phase and amplitudes
(4) different frequency, phase and amplitudes

Q.11 A wave is represented by the equation : $y = a \sin(0.01x - 2t)$ where a and x are in cm. Velocity of propagation of wave is-
(1) 20 cm/s (2) 50 cm/s
(3) 100 cm/s (4) 200 cm/s

Q.12 A vehicle, with a horn of frequency n is moving with a velocity of 30 m/s in a direction perpendicular to the straight line joining the observer and the vehicle. The observer perceives the sound to have a frequency $n + n_1$. Then – (Take velocity of sound in air 330 m/s)
(1) $n_1 = 10n$ (2) $n_1 = -n$
(3) $n_1 = 0$ (4) $n_1 = 2n$

Q.13 How does the red shift confirm that the universe is expanding ?
(1) wavelength of light emitted by galaxies appears to decrease
(2) wavelength of light emitted by galaxies appears to be the same
(3) wavelength of light emitted by galaxies appears to increase
(4) none of these

Q.14 A sings with a frequency (n) and B sings with a frequency 1/8 that of A. If the energy remains the same and the amplitude of A is a, then amplitude of B will be-
(1) 2a (2) 8a
(3) 4a (4) a

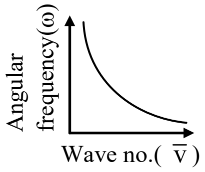
Q.15 The tension in a piano wire is 10N. What should be the tension in the wire to produce a note of double the frequency ?
(1) 10N (2) 20N
(3) 40N (4) 80N

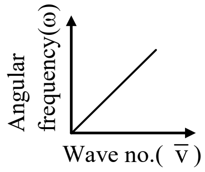
Q.16 If equation of a sound wave is $y = 0.0015 \sin(62.8x + 314t)$ then its wavelength will be-
(1) 2 unit (2) 0.3 unit
(3) 0.1 unit (4) 0.2 unit

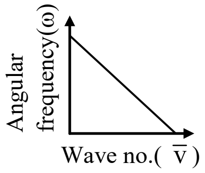
Q.17 A siren emitting sound of frequency 800 Hz is going away from a static listener with a speed of 30 m/s. Frequency of sound to be heared by the listener is-
(1) 286.5 Hz (2) 418.2 Hz
(3) 733.3 Hz (4) 644.8 Hz

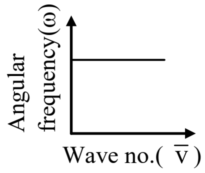
Q.18 The velocities of sound at the same pressure in two monatomic gases of densities ρ_1 and ρ_2 are v_1 and v_2 respectively. If $\frac{\rho_1}{\rho_2} = 4$, then the value of $\frac{v_1}{v_2}$ is-
(1) $\frac{1}{4}$ (2) $\frac{1}{2}$ (3) 2 (4) 4

Q.19 The graph between wave number ($\bar{v}$) and angular frequency (ω) is-

(1) 

(2) 

(3) 

(4) 

Q.20 A string in a musical instrument is 50 cm long and its fundamental frequency is 800 Hz. If a frequency of 1000 Hz is to be produced, then required length of string is-
(1) 62.5 cm (2) 50 cm
(3) 40 cm (4) 37.5 cm

Q.21 What is the path difference for destructive interference ?
(1) $n\lambda$ (2) $n(\lambda + 1)$
(3) $\frac{(n+1)\lambda}{2}$ (4) $\frac{(2n+1)\lambda}{2}$

Q.22 An earthquake generates both transverse (S) and longitudinal (P) sound waves in the earth. The speed of S waves is about 4.5 km/s and that of P waves is about 8.0 km/s. A seismograph records P and S waves from an earthquake. The first P wave arrives 4.0 min before the first S wave. The epicenter of the earthquake is located at a distance of about-
(1) 25 km (2) 250 km
(3) 2500 km (4) 5000 km

Q.23 The waves produced by a motorboat sailing in water are-
(1) Transverse
(2) Longitudinal
(3) Longitudinal and transverse
(4) Stationary

Q.24 An organ pipe closed at one end has fundamental frequency of 1500 Hz. The maximum number of overtones generated by this pipe which a normal person can hear is-
(1) 14 (2) 13 (3) 6 (4) 9

Q.25 A boat at anchor is rocked by waves whose crests are 100 m apart and velocity is 25 m/sec. The boat bounces up once in every-
(1) 2500 s (2) 75 s (3) 4 s (4) 0.25 s

Q.26 For a wave propagating in a medium, identify the property that is independent of the others-
(1) Velocity
(2) Wavelength
(3) Frequency
(4) All these depend on each other

Q.27 When a guitar string is sounded with a 440 Hz tuning fork a beat frequency of 5 Hz is heard if the experiment is repeated with a tuning fork of 437 Hz. The beat frequency is 8 Hz. The string frequency (in Hz) is-
(1) 445 (2) 435 (3) 429 (4) 448

Q.28 The driver of a car travelling with speed 30m/sec towards a hill sounds a horn of frequency 600 Hz. If the velocity of sound in air is 330 m/s, the frequency of reflected sound as heard by driver is-

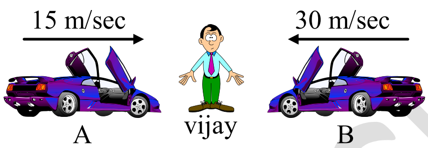
(1) 500 Hz (2) 550 Hz
(3) 555.5 Hz (4) 720 Hz

Q.29 A wave in a string has an amplitude of 2cm. The wave travels in the +ve direction of x-axis with a speed of 128 m/sec and it is noted that 5 complete waves fit in 4m length of the string. The equation describing the wave is-
(1) y = (0.02)m sin(7.85x – 1005t)
(2) y = (0.02)m sin(7.85x + 1005t)
(3) y = (0.02)m sin(15.7x – 2010t)
(4) y = (0.02)m sin(15.7x + 2010t)

Q.30 Each of the two strings of length 51.6 cm and 49.1 cm are tensioned separately by 20N force. Mass per unit length of both the strings is same and equal to 1 g/m. When both the strings vibrate simultaneously the number of beats is-
(1) 3 (2) 5 (3) 7 (4) 8

Q.31 A transverse wave passes through a string with the equation y = 10 sinπ(0.02 x – 2.00t), where x is in metre and t in second. The maximum velocity of the particle in wave motion is-
(1) 100 m/s (2) 63 m/s
(3) 120 m/s (4) 161 m/s

Q.32 Two cars A and B approach a stationary observer from opposite sides as shown in figure. Observer hears no beats. If the frequency of the horn of the car B is 504 Hz, the frequency of horn of car A will be-



(1) 529.2 Hz (2) 295.2 Hz
(3) 440.5 Hz (4) none of these

Q.33 Two sound waves have phase difference of 60º, then they will have the path difference of-
(1) 3λ (2) $\frac{\lambda}{3}$ (3) $\frac{\lambda}{6}$ (4) λ

Q.34 In a sinusoidal wave, the time required for a particular particle to move from mean position to maximum displacement is 0.17 sec then the frequency of wave is-
(1) 1.47 Hz (2) 0.36 Hz
(3) 2.94 Hz (4) 2.48 Hz

Q.35 At what temperature the speed of sound in air will become double of its value at 27ºC ?
(1) 54ºC (2) 627ºC
(3) 927ºC (4) 327ºC

Q.36 Two tuning forks P and Q when set vibrating, give 4 beats per second. If a prong of the fork P is filed, the beats are reduced to 2 per second. What is frequency of P, if that of Q is 250 Hz ?
(1) 246 Hz (2) 250 Hz
(3) 254 Hz (4) 252 Hz

Q.37 A person speaking normally produces a sound intensity of 40 dB at a distance of 1m. If the threshold intensity for reasonable audibility is 20 dB, the maximum distance at which he can be heard clearly is-
(1) 4 m (2) 5 m
(3) 10 m (4) 20 m

Q.38 A wave represented by the equation y = acos(kx – ωt) is superposed with another wave to form a stationary wave such that the point x = 0 is a node. The equation of the other wave is-
(1) a sin(kx + ωt) (2) –a cos(kx + ωt)
(3) –a cos(kx – ωt) (4) –a sin(kx – ωt)

Q.39 On producing the waves of frequency 1000 Hz in a Kundt's tube, the total distance between 6 successive nodes is 85 cm. Speed of sound in the gas filled in the tube is-
(1) 300 m/s (2) 350 m/s
(3) 340 m/s (4) 330 m/s

Q.40 Which of the following are not the transverse wave ?
(1) Sound waves in the gas
(2) Visible light waves
(3) X-rays
(4) γ-rays

Q.41 In a transverse progressive wave of amplitude A, the maximum particle velocity is four times its wave velocity, then the wavelength of the wave is-
(1) 2πA (2) πA (3) $\frac{\pi A}{2}$ (4) $\frac{\pi A}{4}$

Q.42 Masses of three wires of copper are in the ratio of 1 : 3 : 5 and their lengths are in the ratio of 5 : 3 : 1. The ratio of their electrical resistance is-
(1) 125 : 15 : 1 (2) 1 : 15 : 125
(3) 5 : 3 : 1 (4) 1 : 3 : 5

Q.43 The speed of a wave in a medium is 650 m/s. If 4000 waves are passing through a point in the medium in 1.67 minute, then its wavelength will be-
(1) 25.16 m (2) 16.25 m
(3) 32.50 m (4) 8.25 m

Q.44 A string is fixed at both ends and it oscillates in 5 segments each of length 8 m and velocity of wave is 32 m/s. What is the frequency of oscillation of the string ?
(1) 4 Hz (2) 2 Hz
(3) 3 Hz (4) 1 Hz

Q.45 Two sound sources emitting sound each of wavelength λ are fixed at a given distance apart. A listener standing between them moves with a velocity u along the line joining the two sources. The number of beats heard by him per second is-
(1) $\frac{u}{\lambda}$ (2) $\frac{2u}{\lambda}$ (3) $\frac{u}{2\lambda}$ (4) $\frac{3u}{\lambda}$

Q.46 Two waves, whose intensities are 9 : 16 are made to interfere the ratio of maximum and minimum intensities in the interference pattern is-
(1) 49 : 1 (2) 25 : 7
(3) 10 : 9 (4) 4 : 3

Q.47 Two organ pipes sounded together give 5 beats per second. If their length are in the ratio of 50 : 51, then the frequency of shorter and longer pipes are respectively-
(1) 250, 245 (2) 245, 250
(3) 250, 255 (4) 255, 250

Q.48 An organ pipe P_1 is closed at one end and vibrating in its first overtone and another pipe P_2 opened at both ends vibrating in its third overtone are in resonance with a given tuning fork. Then the ratio of length P_1 and P_2 is-
(1) $\frac{1}{3}$ (2) $\frac{2}{3}$ (3) $\frac{8}{3}$ (4) $\frac{3}{8}$

Q.49 A standing wave is represented by y =a sin(100t) cos(0.01x) where t is in second and x is in meter. Then the velocity of the wave is-
(1) 10^{-2} m/s (2) 10^{-4} m/s
(3) 1 m/s (4) 10^4 m/s

Q.50 The amplitude of the vibrating particle due to superposition of two simple harmonic motions of $y_1 = \sin\left(\omega t + \frac{\pi}{3}\right)$ and $y_2 = \sin(\omega t)$ will be-
(1) 2 (2) $\sqrt{3}$
(3) $\sqrt{2}$ (4) 1

Q.51 Two sine waves having unequal amplitudes and a phase difference of $\frac{\pi}{2}$, are travelling along x and y-axis respectively. When they superimpose, the resultant wave will be-
(1) elliptical (2) hyperbolic
(3) straight line (4) parabolic

Q.52 Two closed organ pipes of length 100 cm and 101 cm long gives 16 beats in 20 s. When each pipe is sounded in its fundamental mode, calculated the velocity of sound-
(1) 303 m/s (2) 332 m/s
(3) 323.2 m/s (4) 300 m/s

Q.53 If fundamental frequency of closed pipe is 50 Hz, then frequency of second overtone is-
(1) 100 Hz (2) 50 Hz
(3) 250 Hz (4) 150 Hz

Q.54 If C_S be the velocity of sound in air and C be the rms speed, then-
(1) $C_S > C$ (2) $C_S = C$
(3) $C_S = C.\sqrt{\frac{\gamma}{3}}$ (4) none of these

Q.55 The time of reverberation of a room A is one second. What will be the time (in second) of reverberation of a room, having all the dimensions double of those of room A ?
(1) 2 (2) 4 (3) $\frac{1}{2}$ (4) 1

Q56 A closed organ pipe of length 20 cm is sounded with tuning fork in resonance. What is the frequency of tuning fork ? (v = 332 m/s)
(1) 300 Hz (2) 350 Hz
(3) 375 Hz (4) 415 Hz

Q.57 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 ?
(1) 5 % (2) 20 % (3) Zero (4) 0.5 %

Q.58 The fundamental frequency of a closed pipe is 220 Hz. If $\frac{1}{4}$ of the pipe is filled with water, the frequency of the first overtone of the pipe now is-
(1) 220 Hz (2) 440 Hz
(3) 880 Hz (4) 1760 Hz

Q.59 A stationary wave is represented by y = Asin100t.cos(0.1πx), where y and A are in mm, t in second and x in cm. Then the positions of nodes are-
(1) 0, 10, 20, ... cm (2) 5, 15, 25, ... cm
(3) 4, 14, 24, ... cm (4) 0, 8, 18, ... cm

Q.60 A tuning fork A produces 4 beat/s with another tuning fork B of frequency 320 Hz. On filing one of the prongs of A, 4 beats/s are again heard when sounded with the same fork B. Then, the frequency of the fork A before filing is-
(1) 328 Hz (2) 316 Hz
(3) 324 Hz (4) 320 Hz

Q.61 The equation of a simple harmonic wave is given by y = $5\sin\frac{\pi}{2}(100t - x)$, where x and y are in metre and time t is in second. The period of the wave in second will be-
(1) 0.04 (2) 0.01
(3) 1 (4) 5

Q.62 The loudness and pitch of a sound note depends on-
(1) intensity and frequency
(2) frequency and number of harmonics
(3) intensity and velocity
(4) frequency and velocity

Q.63 The equation of a stationary wave along a stretched string is given by :
$$y = 4\sin\frac{2\pi x}{3}\cos 40\pi t$$
where x and y are in cm and t is in sec. The separation between two adjacent nodes is-
(1) 3 cm (2) 1.5 cm
(3) 6 cm (4) 4 cm

Q.64 A transverse wave is represented by y = A sin(ωt – kx). For what value of the wavelength is the wave velocity equal to the maximum particle velocity ?
(1) πA/2 (2) πA (3) 2πA (4) A

Q.65 A tuning fork of frequency 512 Hz makes 4 beats per second with the vibrating string of a piano. The beat 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-
(1) 510 Hz (2) 514 Hz(3) 516 Hz (4) 508 Hz

Q.66 Two waves are represented by the equations y_1 = a sin (ωt + kx + 0.57) m and y_2 = a cos (ωt + kx)m, where x is in meter and t in sec. The phase difference between them is :
(1) 0.57 radian (2) 10 radian
(3) 1.25 radian (4) 1.57 radian

Q.67 Out of the following functions representing motion of a particle which represents SHM :
(A) y = sin ωt – cos ωt (B) y = $\sin^3$ ωt

(C) $y = 5\cos\left(\frac{3\pi}{4} - 3\omega t\right)$

(D) $y = 1 + \omega t + \omega^2 t^2$

(1) Only (A) and (B)
(2) Only (A)
(3) Only (D) does not represent SHM
(4) Only (A) and (C)

Q.68 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 :
(1) decreases by a factor 20
(2) decreases by a factor 10
(3) increases by a factor 20
(4) increases by a factor 10

Q.69 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 :
(1) 0.01 (2) 0.02
(3) 0.03 (4) 0.04

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 4

Q.1 The intensity of the sound at 3m distance from a small loudspeaker of power 10 W is 2 W/m^2. If the power of loudspeaker is doubled then intensity at 6 m will be-
(1) 4 W/m^2 (2) 2 W/m^2
(3) 1 W/m^2 (4) 0.5 W/m^2

Q.2 Sound wave are not polarized because-
(1) Their speed is less
(2) The medium is needed for their propagation
(3) These are longitudinal
(4) Their speed depends on temperature

Q.3 The equation of wave is given as $Y = A\sin\omega(x/v - K)$ where ω is the angular velocity and v is the linear velocity. The dimension of K is-
(1) LT (2) T
(3) T^{-1} (4) T^2

Q.4 Ratio of amplitudes of two waves is 3 : 4. The ratio of maximum and minimum intensity obtained from then will be-
(1) 7 : 1 (2) 49 : 1
(3) 1 : 25 (4) 5 : 1

Q.5 In a string the speed of wave is 10 m/s and its frequency is 100 Hz. The value of the phase difference at a distance 2.5 cm will be-
(1) $\pi/2$ (2) $\pi/8$
(3) $3\pi/2$ (4) 2π

Q.6 Length of a sonometer wire is either 95 cm or 100 cm. In both the cases a tuning fork produces 4 beats then the frequency of tuning fork is-
(1) 152 (2) 156
(3) 160 (4) 164

Q.7 The displacement x (in metres) of a particle performing simple harmonic motion is related to time (t in seconds) as $x = 0.05\cos(4\pi t + \pi/4)$. The frequency of the motion will be-
(1) 0.5 Hz (2) 1.0 Hz
(3) 1.5 Hz (4) 2.0 Hz

Q.8 Four wires of identical lengths, diameters and of the same material are stretched on a sonometer wire. The ratio of their tension is 1 : 4 : 9 :16. The ratio of their fundamental frequencies is-
(1) 1 : 2 : 3 : 4 (2) 16 : 9 : 4 : 1

(3) 1 : 4 : 9 : 16 (4) 4 : 3 : 2 : 1

Q.9 A man standing on a cliff claps his hand and hears its echo after one second. If the sound is reflected from another mountain then the distance between the man & reflection points is V_{sound} = 340 m/sec.
(1) 680 m (2) 340 m
(3) 170 m (4) 85 m

Q.10 A string is rigided by two ends and its equation is given by $y = \cos 2\pi t \sin 2\pi x$. Then minimum length of string is -
(1) 1m (2) 1/2m
(3) 5m (4) 2πm

Q.11 If the velocity of wave is 360 m/sec and frequency 500 Hz then find the path difference corresponding to 60º phase difference-
(1) 10 cm (2) 12 cm
(3) 15 cm (4) 72 cm

Q.12 A tuning fork A produces 4 beats/sec with another tuning fork B of frequency 320 Hz. On filing the fork A, 4 beats/sec are again heard. The frequency of fork A, before filing is-
(1) 318 (2) 316 (3) 320 (4) 312

Q.13 A tuning fork produces 4 beats/sec with another tuning fork B of frequency 288 Hz. If fork is loaded with little wax, no. of beats per sec decreases. The frequency of the fork A, before loading is-
(1) 290 Hz (2) 288 Hz
(3) 292 Hz (4) 284 Hz

Q.14 The frequency of the first overtone of a closed pipe of length ℓ_c is equal to that of the third overtone of an open pipe of length ℓ_0. The ratio ℓ_0/ℓ_c will be -
(1) 7/6 (2) 4/5 (3) 8/3 (4) 3/8

Q.15 A source X of unknown frequency produces 8 beats per second with a source of 250 Hz and 12 beats per second with a source of 270 Hz. The frequency of the source X is (Hz) -
(1) 242 (2) 258
(3) 282 (4) 262

Q.16 An empty vessel is partially filled with water the frequency of vibration of air column in the vessel-
(1) decreases
(2) increases
(3) depends on the purity of water
(4) remains the same

Q.17 Two tuning forks having frequency 256 Hz (A) and 262 Hz(B) tuning fork. A produces some beats per second with unknown tuning fork, same unknown tuning fork produce double beats per second from B tuning fork then the frequency of unknown tuning fork is-
(1) 262 (2) 260 (3) 250 (4) 300

Q.18 Two waves are represented by equation
$y_1 = a \sin \omega t$, $y_2 = a \cos \omega t$ the first wave-
(1) leads the second by π
(2) lags the second by π
(3) leads the second by $\pi/2$

(4) lags the second by $\pi/2$

Q.19 Transverse wave of some frequency are generated in two steel wires A and B the diameter of A is twice of B and the tension in A is half that in B. The ratio of velocities of waves in A and B is-

(1) $1 : \sqrt{2}$ (2) 1 : 2
(3) $3 : 2\sqrt{2}$ (4) $1 : 2\sqrt{2}$

Q.20 Echo is due to-

(1) diffraction of sound
(2) interference of sound
(3) refraction of sound
(4) reflection of sound

Q.21 Two waves of intensities ratio are 9 : 1 then the ratio of their maximum and minimum intensities will be-

(1) 10 : 8 (2) 7 : 2 (3) 4 : 1 (4) 2 : 1

Q.22 A sound wave of frequency 50 Hz has velocity 360 m/s. If phase difference between two particles is 60º, then path difference will be-

(1) 1.2 m (2) 0.12 m
(3) 2.4 m (4) 12 m

Q.23 The phase difference between two particles separated by 1 m in a wave of frequency 120 Hz is 90º. The wave velocity will be-

(1) 720 m/sec (2) 480 m/sec
(3) 240 m/sec (4) 180 m/sec

Q.24 Wave of frequency 100 Hz travels along a string towards its fixed end. When this wave travels back, after reflection a node is formed at a distance of 10 cm from the fixed end. The speed of the wave (incident and reflected) is-

(1) 5 m/s (2) 10 m/s
(3) 20 m/s (4) 40 m/s

Q.25 Two wires are fixed in a sonometer. Their tensions are in the ratio 8 : 1. The lengths are in the ratio 36 : 35. The diameters are in the ratio 4 : 1, densities of the materials are in the ratio 1 : 2. If the higher frequency in the setting is 360 Hz, the beat frequency when the two wires sounded together is-

(1) 8 (2) 5 (3) 10 (4) 6

Q.26 What is the beat frequency produced when following two waves are sounded together ?

$x_1 = 10 \sin(404\pi t - 5\pi x)$
$x_2 = 10 \sin(400\pi t - 5\pi x)$

(1) 4 (2) 1 (3) 3 (4) 2

Q.27 In COP at temperature 10ºC the number of beats are 5. If temperature is made to 20ºC the number of beats will be-

(1) less than 5 (2) equal to 5
(3) more than 5 (4) nothing can be said

Q.28 The air column in a pipe with both ends open vibrates with a fundamental frequency f. If one of the ends of the pipe is closed, the fundamental frequency will be -

(1) f (2) 2f (3) $\frac{3}{2}f$ (4) $\frac{f}{2}$

Q.29 The displacement y of a particle varies with time t, in seconds, as $y = 2 \cos(\pi t + \pi/6)$. The time period of the oscillations is -
(1) 2 sec (2) 4 sec (3) 1 sec (4) 0.5 sec

Q.30 The number of beats per second resulting from the vibration $x_1 = a \cos 500\pi t$ and $x_2 = a \cos 508\pi t$ is
(1) zero (2) 2 (3) 4 (4) 8

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 5

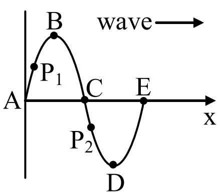
These questions of two statements each, printed as Assertion and Reason. While answering these Questions you are required to choose any one of the following four responses.
(A) If both Assertion & Reason are true & the Reason is a correct explanation of the Assertion.
(B) If both Assertion and Reason are true but Reason is not a correct explanation of the Assertion.
(C) If Assertion is true and Reason is false.
(D) If Assertion & Reason both are false.

Q.1 **Assertion :** In standing wave pattern particle of medium between two consecutive nodes vibrates in same phase but with different amplitude.
Reason : In stationary wave, the amplitude of vibration does not depends on the position of the particle.
(1) A (2) B (3) C (4) D

Q.2 **Assertion :** The velocity of sound in air decreases if the pressure of air decreases at constant temperature.
Reason : According to Laplace's formula as modified by Newton, velocity of sound in air is given by $v = \sqrt{\frac{\gamma P}{\rho}}$.
(1) A (2) B (3) C (4) D

Q.3 **Assertion :** A wave can represented by function $y = f(kx \pm \omega t)$.
Reason : Because it satisfy the differential equation $\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\left(\frac{\partial^2 y}{\partial t^2}\right)$ where $v = \frac{\omega}{k}$.
(1) A (2) B (3) C (4) D

Q.4 **Assertion :** The transverse wave is travelling along a string in the positive x-axis as shown



Points (A & P_1) moving ↓(downward) and points (C & P_2) moving ↑ (upward).
Reason : In a wave propagating in positive x direction, the points with +ve slope move downward and vice versa.

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

Q.5 **Assertion :** Longitudinal waves are called pressure waves.
Reason : Propagation of longitudinal waves through a medium involves changes in pressure (density of medium particles), when compressions and rarefactions are formed.
(1) A (2) B (3) C (4) D

Q.6 **Assertion :** Mechanical transverse waves cannot be generated in gaseous medium.
Reason : Mechanical transverse waves can be produced only in such medium which have shearing property.
(1) A (2) B (3) C (4) D

Q.7 **Assertion :** If three sources of sound of equal intensities with frequency n, n+1 and n+2 Hz are sounded simultaneously, the beat frequency heard is 2.
Reason : In beats at a given position, intensity varies periodically with time with periodicity $T = 1/(n_1 \sim n_2)$ while in interference at a given time, intensity varies periodically with position with periodicity λ.
(1) A (2) B (3) C (4) D

Q.8 **Assertion :** In transverse wave particle velocity is perpendicular to the direction of wave velocity.
Reason : In wave motion energy always transfered in the direction of wave propagation.
(1) A (2) B (3) C (4) D

Q.9 **Assertion :** In longitudinal wave propagation the distance between two consecutive compression is equal to wavelength of wave.
Reason : Standing wave does not transfered.
(1) A (2) B (3) C (4) D

Q.10 **Assertion :** Sound wave travels faster in moist air.
Reason : The density of moist air is less then density of dry air.
(1) A (2) B (3) C (4) D

Q.11 **Assertion :** Standing waves do not transferred energy in the medium.
Reason : Every particle vibrates with its own energy and it does not share its energy with any other particle.
(1) A (2) B (3) C (4) D

Q.12 **Assertion :** When two vibrating tuning forks having frequencies 240 Hz and 300 Hz are held near each other, beats cannot be heard by us.
Reason : This is because beats cannot be distinctly heard due to the property of persistence of hearing.
(1) A (2) B (3) C (4) D

Q.13 **Assertion :** Harmonics are the notes (a single sound of a certain pitch & wavelength) of frequencies which are integral multiple of the fundamental frequency.
Reason : Tones of frequencies higher than fundamental note are called overtones.
(1) A (2) B (3) C (4) D

Q.14 **Assertion :** Beats arise when two waves having slightly different frequencies are superposed.
Reason : Superposition of two identical waves moving in opposite directions produces standing waves.
(1) A (2) B (3) C (4) D

Q.15 **Assertion :** COP contain only odd harmonics.
Reason : OOP contain all odd and even harmonics.
(1) A (2) B (3) C (4) D

Q.16 **Assertion :** Due to end correction fundamental frequency of any pipe becomes less than frequency without end correction.
Reason : Due to end correction effective length of pipe increases.
(1) A (2) B (3) C (4) D

Q.17 **Assertion :** In Resonance tube $\ell_2 > 3\ \ell_1$, (ℓ_1, ℓ_2 first and second resonating length)
Reason : e = $\frac{\ell_2 - 3\ell_1}{2}$ (e = end correction) and 'e' remain always positive.
(1) A (2) B (3) C (4) D

Q.18 **Assertion :** Sonometer is used to determine frequency of unknown tuning fork.
Reason : In sonometer riders used as indicator.
(1) A (2) B (3) C (4) D

Q.19 **Assertion :** Frequency of COP is double of same length OOP.
Reason : For OOP frequency = $\frac{V}{4\ell}$ for COP frequency = $\frac{V}{2\ell}$.
(1) A (2) B (3) C (4) D

Q.20 **Assertion :** In stretched wire corresponding to P^{th} overtone, (P + 1) nodes are present.
Reason : In stretched wire corresponding to fundamental frequency n, P^{th} harmonic present.
(1) A (2) B (3) C (4) D

Q.21 **Assertion :** In COP corresponding to M^{th} overtone (2M + 1). Harmonic, (M + 1) node, (M + 1) antinode are present.
Reason : COP contain only even harmonics.
(1) A (2) B (3) C (4) D

Q.22 **Assertion :** For stationary wave general equation is 2Asin(Bt) sin(kx).
Reason : For progressive wave general equation is Asin(Bt ± Kx).
(1) A (2) B (3) C (4) D

Q.23 **Assertion :** For same length but different gas COP fundamental frequency are different.
Reason : Here frequency is proportional to velocity for same length given.
(1) A (2) B (3) C (4) D

Q.24 **Assertion :** Speed of wave = $\frac{\text{wavelength}}{\text{time period}}$.
Reason : Wavelength is the distance between two nearest particles in phase. **[AIIMS-2002]**
(1) A (2) B (3) C (4) D

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 6

Q.1 Doppler's effect will be more effectively observed when the observer -
(1) is moving along line joining be the source
(2) is in motion in a direction perpendicular to the source
(3) is moving in any direction relative to the source
(4) None of the above

Q.2 Doppler's effect is not applicable for -
(1) audio waves (2) ultrasonic waves (3) shock waves (4) infrasonic waves

Q.3 Doppler's effect can be observed for -
(1) Supersonic speeds (2) Sound waves
(3) both the above (4) neither of them

Q.4 Doppler's effect will not be observed, if velocity of sound is -
(1) Less than the velocity of source
(2) Less than the velocity of medium
(3) Less than the velocity of observer
(4) All of the above

Q.5 If the distance between the observer and source decreases with time then it shows that -
(1) apparent frequency will be less than actual frequency
(2) apparent frequency will be greater than actual frequency
(3) apparent frequency will be equal to the actual frequency
(4) nothing can be said about apparent frequency

Q.6 Doppler's displacement doesn't depend upon -
(1) velocity of source
(2) velocity of observer
(3) frequency of wave
(4) Separation between source & observer

Q.7 If the apparent frequency of sound heard by the observer is more than the actual frequency then-
(1) The listener will be moving away from source
(2) The source will be moving away from listener
(3) The separation between the source and listener will be increasing
(4) The separation between source and the listener is decreasing

Q.8 Apparent frequency of train A is heard by observer in train B as 3/4 of the true frequency. Find the value of velocity of train B in m/sec. taking train A to be stationary. If the sound velocity is 332 m/sec. -
(1) 110 (2) 108 (3) 75 (4) 83

Q.9 A source and a listener are in unidirection at motion with velocities 30 and 45 km/hour respectively. If both have started to move simultaneously from same place, then apparent frequency heard by the listener will be -
(1) always less than true frequency
(2) always more than true frequency
(3) more than actual frequency
(4) less than the actual frequency first and then more

Q.10 Which of the following property of waves is proved by Doppler's effect -
(1) Longitudinal nature
(2) Transverse nature
(3) both transverse and longitudinal nature
(4) neither longitudinal nor transverse nature

Q.11 A source of frequency n is moving with a uniform velocity v towards a stationary observer. If the velocity of sound is V, then the change in frequency would be -
(1) $\frac{vn}{V-v}$ (2) $\frac{vn}{V}$
(3) $\frac{Vn}{V-v}$ (4) $\frac{vn}{V+v}$

Q.12 If an observer is moving with uniform velocity v to wards a stationary source of frequency n, and if the velocity of sound in the medium is V, then the apparent change in the frequency of the sound, heard by the observer, is -
(1) $\frac{vn}{V-v}$ (2) $\frac{vn}{V}$
(3) $\frac{Vn}{V-v}$ (4) $\left(\frac{V+v}{v}\right)n$

Q.13 A source of sound crosses a stationary observer which is moving with uniform velocity v. If the velocity of sound in air is V, then the ratio of the apparent frequencies heard by the observer before and after the source crosses him would be -
(1) $\frac{V+v}{V-v}$ (2) $\frac{V-v}{V+v}$
(3) $\frac{V}{V-v}$ (4) $\frac{V+v}{V}$

Q.14 If a source of frequency n moving with velocity v crosses a stationary observer, then the change in the frequency of sound heard by the observer will be (velocity of sound = V)
(1) $\frac{2nVv}{V^2+v^2}$ (2) $\frac{2nVv}{(V^2-v^2)}$
(3) $\frac{2nVv}{(V+v)}$ (4) $\frac{2nVv}{(V-v)}$

Q.15 If a source of frequency n crosses a stationary observer with uniform velocity v and if the velocity of sound V >> v, then the change in the frequency due to Doppler effect would be -
(1) $\frac{2nv}{V}$ (2) $\frac{nv}{V}$

(3) $\frac{2nv}{V^2}$ (4) $\frac{2nV}{v^2}$

Q.16 If an observer moving with velocity v crosses a stationary source of frequency n, then the change in the frequency would be -

(1) $\frac{2n(V^2+v^2)}{Vv}$ (2) $\frac{2n(V^2-v^2)}{Vv}$

(3) $\frac{2nV}{v}$ (4) $\frac{2nv}{V}$

Q.17 A source of frequency n and an observer are moving on a straight line with velocities a and b respectively. If the source is ahead of the observer and if the medium is also moving in the direction of their motion with velocity c, (the velocity of sound being V), then the apparent frequency of the sound heard by the observer would be -

(1) $\left(\frac{V-c+b}{V-c+a}\right)n$ (2) $\left(\frac{V+c+b}{V+c+a}\right)n$

(3) $\left(\frac{V-c-b}{V-c-a}\right)n$ (4) $\left(\frac{V+c-b}{V+c-a}\right)n$

Q.18 Doppler effect does not depends on -
(1) The velocity of source and observer
(2) The distance between source and observer
(3) The frequency of the waves
(4) The rate of change of distance between source and observer

Q.19 Doppler effect in light differs with Doppler effect for sound, because -
(1) Shift in relative frequency for light is lesser then that for sound
(2) the velocity addition is valid for sound but same is not true for light
(3) velocity of light is greater whereas it is lesser for sound
(4) light can travel even in vacuum while sound cannot

Q.20 The velocity of light emitted by a source S and observed by an observer O who is at rest with respect to S is c. If the observer moves towards S with velocity v the velocity of light as observed will be -
(1) c – v (2) c + v
(3) c (4) $\sqrt{1-\frac{v^2}{c^2}}$

Q.21 The width of spectral lines (spreading of spectral line) can be explained by -
(1) Kirchoff's radiation law
(2) Doppler's effect
(3) Spin motion of electrons
(4) Stark's effect

Q.22 A star is receding from earth with a velocity 3×10^6 m/s. If the actual wavelength of the light emitted by the star is λ and $\Delta\lambda$ is the displacement in wavelength as observed on earth then $\Delta\lambda : \lambda$ is -
(1) $1 : 3 \times 10^6$ (2) $1 : 10^2$
(3) $10^3 : 1$ (4) $10^2 : 1$

Q.23 Due to the relative motion between a star and the earth, the following relation is obtained between the wavelength of light from star λ and Doppler displacement $\Delta\lambda$, (V_s = velocity of star)

(1) $\frac{\Delta\lambda}{\lambda} = V_sC$ (2) $\frac{\Delta\lambda}{\lambda} = \frac{C}{V_s}$

(3) $\frac{\Delta\lambda}{\lambda} = \frac{V_s}{C}$ (4) $\frac{\Delta\lambda}{\lambda} = \frac{1}{CV_s}$

Q.24 The apparent change in the frequency n of the electromagnetic signal, sent from a rocket approaching the moon with velocity v (v << c), when it is received back by the rocket driver being reflected by the moon, is -

(1) $\left(\frac{v}{c}\right)n$ (2) $\left(\frac{2v}{c}\right)n$

(3) $\left\{\left(\frac{c+v}{c}\right)\right\}n$ (4) $\left(\frac{v}{c}\right)^2 n$

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 7

Q.1 The frequency of the whistle of an engine is heard by a passenger on the platform first increases and then decreases. The motion of the engine and passenger is described by -
(1) The engine and the passenger are both approaching each other
(2) The engine is approaching the passenger and then receding away from him
(3) The engine and passenger are both moving away from each other
(4) The engine is approaching the passenger, while the passenger is receding from it

Q.2 The wavelength of a line of the spectrum of any star as seen by the observer stationed on the earth, shifts towards red end. From this observation he concludes that -
(1) star is moving away from the earth
(2) star is moving towards the earth
(3) star is fixed in space
(4) the shift has no relation with the motion of the star

Q.3 The Sun is rotating about its own axis. The spectrum lines obtained from its two ends are observed by an observer on the Earth -
(1) both lines shift towards red end
(2) both lines shift towards violet and
(3) one line shifts to red while the other shifts towards violet
(4) lines show no shift

Q.4 An observer moving towards a stationary source observes that the apparent frequency is three times the actual frequency of the source. If the velocity of sound is V, the velocity of the observer would be-
(1) 4V (2) V (3) 2V (4) V/2

Q.5 If the velocity of sound is V, velocity of the observer is V_o and the velocity of the source is V_s, then the necessary condition for the Doppler effect to hold good is -
(1) $V_s \geq V, V_o > V$ (2) $V_s \geq V, V_o < V$
(3) $V_s < V, V_o > V$ (4) $V_s < V, V_o < V$

Q.6 When a source of frequency n moves towards a stationary observer with velocity v, then the apparent change in the frequency of sound due to Doppler effect is Δn_1 and when an observer moves with velocity v towards a stationary source of frequency n, the apparent change in frequency is found to be Δn_2, then -
(1) $\Delta n_1 = \Delta n_2 \neq 0$ (2) $\Delta n_1 > \Delta n_2$
(3) $\Delta n_1 < \Delta n_2$ (4) $\Delta n_1 = \Delta n_2 = 0$

Q.7 When a source of frequency n is receding away from a stationary observer with velocity v, then the apparent change in frequency due to Doppler's effect is found to be Δn_1 and when the observer is reducing from a stationary source with the same velocity v, then the apparent change in frequency is Δn_2, then -

(1) $\Delta n_1 = \Delta n_2 = 0$ (2) $\Delta n_1 = \Delta n_2 \neq 0$

(3) $\Delta n_1 > \Delta n_2$ (4) $\Delta n_1 < \Delta n_2$

Q.8 When a source whistling with frequency n, is coming towards a stationary observer with velocity v, the observer finds the frequency to be increased by Δn_1, and when it is receding from the observer with equal velocity, the observer finds a decrease Δn_2 in the frequency, then -

(1) $\Delta n_1 = \Delta n_2 = 0$ (2) $\Delta n_1 = \Delta n_2 \neq 0$

(3) $\Delta n_1 > \Delta n_2$ (4) $\Delta n_1 < \Delta n_2$

Q.9 A source is approaching a stationary observer with uniform acceleration . The frequency of the sound heard by the observer appears to -

(1) Have increased, but does not vary as the source approaches

(2) Increases continuously

(3) Remains constant , equal to the actual frequency of the source

(4) Decreases continuously

Q.10 A star, emitting green light, is approaching the earth with uniform acceleration . The colour of the light received from this star, as observed by stationary observer on the earth, would be -

(1) to be green only

(2) to change slowly to red

(3) to change slowly to blue

(4) to changes slowly to yellow

Q.11 When a sound source moves towards a stationary observer, then the apparent change in frequency as observed by the observer takes place due to the -

(1) Change in wavelength in the medium

(2) Change in velocity of sound with respect to the observer

(3) Change in the rate of vibrations of the source due to its mobility

(4) None of the above

Q.12 A parachutist jumps from an aeroplane which is moving horizontal with constant speed. The relation between the apparent frequency n′ as observed by the parachutist and the frequency n of the sound of the aeroplane is -

(1) $n = n'$

(2) $n' > n$

(3) $n > n'$

(4) difficult to predict

Q.13 Which of the following statements is not true for Doppler effect -

(1) It is universal for all type of waves

(2) If the relative velocity is constant then, the acoustic Doppler displacement remains the same whether source or observer moves or not

(3) For same relative motion the acoustic Doppler displacement and optical Doppler displacement are not same

(4) Doppler effect supports the grand explosion in galaxy

Q.14 A man stands at rest in front of a large smooth wall. Directly in front of him, between him and the wall he holds a vibrating tuning fork of frequency 400Hz. He now moves the fork towards the wall

with a speed of 1m/s. How many beats/s will he hear between the sound waves reaching him directly from the fork, and those reaching him after being reflected from the wall?
(1) 1.15 beats/s (2) 2.30 beats/s
(3) 4.60 beats/s (4) 9.20 beats/s

Q.15 When a laser beam returns after reflection from an aeroplane observed change of frequency is 1% then the speed of the aeroplane is (c is the velocity of light)
(1) c/50 (2) c/100
(3) c/200 (4) c/2

Q.16 In a gas discharge tube spectrum line is obtained at 4800Å. The r.m.s. velocity of its atoms is 200km/s the width of the spectrum line due to Doppler effect will be -
(1) 3.2 A (2) 4.8 A
(3) 6.4 A (4) 12.8 A

Q.17 A whistle is rotated with 2 rotations/sec in a circle of radius 1 meter. A listener is setting in the plane of circle outside the centre, then ratio of maximum and minimum frequencies heard by him will be
(1) $\frac{(V+4\pi)}{(V-4\pi)}$ (2) $\frac{(V+4\pi)}{(V-2\pi)}$
(3) $\frac{(V+2)}{(V-2)}$ (4) $\frac{(V+4)}{(V-4)}$

Q.18 Two tuning forks with natural frequency of 340Hz move relative to a stationary observer. One fork moves away from the observer while the other moves towards him at the same speed. The observer hears beats of frequency 3Hz. The speed of tuning fork in m/s is (velocity of sound in air = 340m/s)
(1) 10 (2) 5
(3) 2.5 (4) 1.5

Q.19 

In the figure shown, S_1 and S_2 represents two stationary sources of sound having equal frequency, one observer is moving form A toward C with velocity V_o then -
(1) Beats for three position A, B and C will be heard
(2) Beats will be heard from A and C but not in case of B
(3) Beast will be not heard for A and C but will be heard for B
(4) Beats will be not heard for three position of A, B and C

Q.20 A person is standing at distance of r from a source of sound. The frequency and intensity of sound observed by him are f and I respectively. Now he moves with a uniform velocity away from sound source, then he will observers that -
(1) f and I remain unchanged
(2) f changes but I does not
(3) f does not change but I changes
(4) f and I both changes

Q.21 If the wavelength of light emitted by a star is shifted towards red end, then the star is -
(1) going away from earth
(2) approaching earth
(3) stationary
(4) none of the above

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 8

Q.1 A sound source is going away from an observer with the sound speed. The apparent frequency which the observer listen-
(1) will be half
(2) will remains same
(3) will be double
(4) will not be observed

Q.2 A person is seeing two trains one of these is coming with speed of 4m/sec and another is going with same speed. If two trains blowing a whistle with frequency 240 Hz, the beat frequency heard by stationary person will be (speed of sound in air = 320 m/sec)-
(1) zero (2) 3 (3) 6 (4) 12

Q.3 A whistle revolves in a circle with angular speed ω = 20 rad/sec using a string of length 50 cm. If the frequency of sound from the whistle is 385 Hz, then what is the minimum frequency heard by an observer which is far away from the centre- (V_{sound} = 340 m/s)
(1) 385 Hz (2) 374 Hz
(3) 394 Hz (4) 333 Hz

Q.4 An observer moves towards a stationary source of sound with a speed 1/5th of the speed of sound. The wavelength and frequency of the source emitted are λ and f respectively. The apparent frequency and wavelength recorded by the observer are respectively-
(1) 1.2 f, 1.2 λ (2) 1.2f, λ
(3) f, 1.2λ (4) 0.8f, 0.8λ

Q.5 A car is moving towards a high cliff. The car driver sounds a horn of frequency 'f'. The reflected sound heard by the driver has a frequency 2f. If 'v' be the velocity of sound then the velocity of the car, in the same velocity units, will be-
(1) $\frac{v}{3}$ (2) $\frac{v}{4}$ (3) $\frac{v}{2}$ (4) $\frac{v}{\sqrt{2}}$

Q.6 A siren emitting sound of frequency 500 Hz is going away from a static listener with a speed of 50 m/sec. The frequency of sound to be heard directly from the siren is-
(1) 434.2 Hz (2) 589.3 Hz
(3) 484.2 Hz (4) 256.5 Hz

Q.7 'SONAR' emits which of the following waves ?
(1) radio waves (2) ultrasonic waves

(3) magnetic waves (4) light waves

Q.8 A vehicle, with a horn of frequency n is moving with a velocity of 30 m/s in a direction perpendicular to the straight line joining the observer and the vehicle. The observer perceives the sound to have a frequency n + n_1. Then : (Take velocity of sound in air 330 m/s)-
(1) $n_1 = 10\,n$ (2) $n_1 = -n$
(3) $n_1 = 0$ (4) $n_1 = 2n$

Q.9 How does the red shift confirm that the universe is expanding ?
(1) wavelength of light emitted by galaxies appears to decrease
(2) wavelength of light emitted by galaxies appears to be the same
(3) wavelength of light emitted by galaxies appears to increase
(4) none of these

Q.10 A siren emitting sound of frequency 800 Hz is going away from a static listener with a speed of 30 m/s. Frequency of sound to be heard by the listener is : (Velocity of sound = 330 m/s)-
(1) 286.5 Hz (2) 481.2 Hz
(3) 733.3 Hz (4) 644.8 Hz

Q.11 The driver of a car travelling with speed 30m/sec towards a hill sounds a horn of frequency 600 Hz. If the velocity of sound in air is 330 m/s, the frequency of reflected sound as heard by driver is-
(1) 500 Hz (2) 550 Hz
(3) 555.5 Hz (4) 720 Hz

Q.12 Two sound sources emitting sound each of wavelength λ are fixed at a given distance apart. A listener standing between them moves with a velocity u along the line joining the two sources. The number of beats heard by him per second is-
(1) $\frac{u}{\lambda}$ (2) $\frac{2u}{\lambda}$ (3) $\frac{u}{2\lambda}$ (4) $\frac{3u}{\lambda}$

Q.13 Doppler's effect in sound is due to-
(1) motion of source
(2) motion of observer
(3) relative motion of source and observer
(4) none of the above

Q.14 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 ?
(1) 5 % (2) 20 % (3) Zero (4) 0.5 %

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 9

Q.1 The apparent change in the pitch of sound due to relative motion between observer and the source is called-
(1) Doppler's effect
(2) Resonance of waves
(3) Interference
(4) None of the above

Q.2 A siren blown in workshop emits waves of frequency 1000 Hz. A car driver approaches the workshop with velocity 90 km/hour then frequency of sound heard by driver will be in Hz -
(1) 926 (2) 1076
(3) 1176 (4) 1000

Q.3 A star is continuously moving away from us then wavelength coming from star on the earth-
(1) will shift towards voilet colour
(2) will shift towards red colour
(3) remain unchanged
(4) will shift sometimes towards voilet and while some other time it will shift towards red colour

Q.4 A sound is produced in water and moves towards surface of water and some sound moves in air. Velocity of sound in water is 1450 m/s and that in air is 330 m/s. When sound moves from water to air then the effect on frequency f and wavelength λ will be-
(1) f and λ will remain same
(2) f will remain same but λ will increase
(3) f will remain same but λ will decrease
(4) f will increase and λ will decrease

Q.5 An ambulance blowing siren of frequency 700 Hz is moving towards a vertical wall with velocity of 2 m/s. The velocity of sound is 352 m/sec. Then frequency of reflected sound heard by the driver will be-
(1) 692 Hz (2) 695 Hz
(3) 700 Hz (4) 708 Hz

Q.6 A source of frequency 200 Hz is moving towards an observer with a velocity equal to the sound velocity V. If observer also moves away from the source with same velocity then apparent frequency heard by observer will be-
(1) 50 Hz (2) 160 Hz
(3) 150 Hz (4) 200 Hz

Q.7 An observer moving towards a stationary source observer that the apparent frequency is three times the actual frequency then velocity of observer will be (sound velocity is V)
(1) 3V (2) 2V
(3) 4V (4) V/2

Q.8 Doppler's effect in the from of frequency doesn't depend upon-
(1) Frequency produced by waves
(2) Velocity of source
(3) Velocity of observer
(4) Separation between source & observer

Q.9 The wavelength of light received from a distant galaxy is 0.5 % greater than that received from an identical source on the earth. The galaxy-
(1) is stationary relative to the earth
(2) is moving towards the earth with velocity of light
(3) is moving away from the earth with light velocity
(4) is moving away from the earth with velocity 1.5×10^6 m/sec

Q.10 A source and a listener are moving towards each other with a speed (1/10)th that of sound. If frequency of sound emitted by the source is f then the frequency heard by listener will be-
(1) f (2) 1.11 f
(3) 1.22 f (4) 1.27 f

Q.11 The wavelength of a distant star is 5700 Å and the spectral light has a shift of 1.9 Å towards red end then the velocity of star relative to the earth will be-
(1) 5×10^5 m/sec (2) 2×10^5 m/sec
(3) 1.8×10^5 m/sec (4) 1.2×10^5 m/sec

Q.12 The wavelength of the light received from a galaxy is 0.4% greater than the wavelength on the earth then the velocity of galaxy relative to the earth will be-
(1) 1.2×10^7 m/sec (2) 1.2×10^6 m/sec
(3) 1.2×10^5 m/sec (4) 1.2×10^4 m/sec

Q.13 The term ''Red shift'' returning to Doppler's effect for light represent which of following property-
(1) decrease in frequency
(2) increase in frequency
(3) decrease in intensity
(4) increase in intensity

Q.14 Time period of rotational motion of the sun is 25 days and the radius of the sun is 7×10^8 meter. The Doppler displacement for the light of the wavelength of 6000 Å emitted from the surface of sun will be-
(1) 0.04 Å (2) 0.40 Å
(3) 4.00 Å (4) 40.0 Å

Q.15 Two trains A and B are moving in the same direction with velocities 30 m/s and 10 m/s respectively. B is behind from A blows a horn of frequency 450 Hz. Then the apparent frequency heard by the sound is 330 m/s-
(1) 425 Hz (2) 300 Hz
(3) 450 Hz (4) 350 Hz

Q.16 The frequency of a whistle is 256 Hz. It approaching towards in observer with a speed 1/3 the speed of sound. The frequency of sound as heard by the observer will be-
(1) 384 Hz (2) 300 Hz
(3) 200 Hz (4) 192 Hz

Q.17 A car moving at a speed of 28 m/s blows a horn of frequency 500 Hz and overtakes a car moving in the same direction with a speed of 13 m/s. The apparent frequency heard by the observer of another car will be (after overtaking) : (move speed = 342 m/sec) -
(1) 480 Hz (2) 500 Hz
(3) 520 Hz (4) 580 Hz

Q.18 An observer is standing between two trains one train approaching the observer and the other train reaches from the observer with a speed of 2 m/s. The emitted frequency of the two trains is 240 Hz each then, the beat frequency heard by the observer will be (Velocity of sound in 320 m/s)-
(1) 3 (2) 6
(3) 0 (4) 12

Q.19 Two source of sound S_1 and S_2 emitting sound of frequency 324 Hz and 320 Hz are situated at certain distance apart. An observer moves along the line joining the two sources. What should be the velocity of the observer if no beats are heard (Velocity of sound is 344 m/s)
(1) 20 m/s (2) 10 m/s
(3) 5 m/s (4) 2.1 m/s

Q.20 An astronaut approaches moon and sends a signal of frequency 5000 MHz. The frequency of the reflected signal increases by 86 KHz. The speed of the astronaut in km/s will be-
(1) 1.29 (2) 2.58
(3) 5.16 (4) 10.32

Q.21 Two sound source S_1 and S_2 have the frequencies 224 Hz and 220 Hz and are situated at some distance. An observer is moving on the line joining the sources. If the observer listen not beat, his speed will be-(given velocity of sound V = 344 m/s)
(1) 3.11 m/s (2) 6.2 m/s
(3) 9.3 m/s (4) 12.4 m/s

Q.22 Two sound source of frequency 340 Hz are moving relative to stationary observer one is going away while another is coming towards the observer. The observer listen 3 beats/sec. The speed of sound source is-
(1) 1.0 m/s (2) 1.2 m/s
(3) 1.46 m/s (4) 1.68 m/s

Q.23 A source and an observer moves away from each other, with a velocity of 15 m/sec with respect to ground. If observer finds the frequency of sound coming from source as 1950 Hz. Then actual frequency of source will be- (velocity of sound = 340 m/sec.
(1) 1785 Hz (2) 1968 Hz
(3) 1950 Hz (4) 2130 Hz

Q.24 A sound source is moving towards a stationary listener with $1/10^{th}$ of the speed of the sound. The ratio of apparent to real frequency will be-

(1) $\left(\frac{11}{10}\right)^2$ (2) $\left(\frac{9}{10}\right)^2$

(3) $\frac{10}{9}$ (4) $\frac{11}{10}$

Q.25 A sound wave of frequency 330 Hz is incident normally at reflected wall then minimum distance from wall at which particle vibrate very much- (V_{sound} = 330 m/s)-
(1) 0.25 m (2) 0.125 m
(3) 1 m (4) 0.5 m

Q.26 A person is observing of two trains each of velocity is 4 m/s. A train is coming towards an observer and another train is going away from an observer frequency of each whistle is 240 Hz then the beats heard by an observer will be-
(V = 320 m/s)
(1) zero (2) 3
(3) 6 (4) 5

Q.27 A bus is moving with a velocity of 5 m/s towards huge wall. The driver sounds a horn of frequency 165 Hz. If the speed of sound in air is 335 m/s, the number of beats heard per second by the passengers in the bus will be-
(1) 3 (2) 5 (3) 4 (4) 6

Q.28 A source of sound of frequency n and a listener approach each other with a velocity equal to $\frac{1}{20}$ of velocity of sound. The apparent frequency heard by the listener is-
(1) $\left(\frac{21}{19}\right)$n (2) $\left(\frac{20}{21}\right)$n
(3) $\left(\frac{21}{20}\right)$n (4) $\left(\frac{19}{20}\right)$n

Q.29 A train is moving with 30 m/s and speed of sound in air is 340 m/s. Another train is moving in opposite direction with speed 15 m/s, then apparent frequency (generated frequency by first train is 440 Hz and observer is in second train)-
(1) 458 Hz (2) 450 Hz
(3) 503 Hz (4) 490 Hz

Q.30 A man is sitting in fast moving train. Horn frequency of train is n and if frequency of horn heard by the man is n' then-
(1) n' = n (2) n' > n
(3) n' < n (4) n' ≥ n

Q.31 Velocity of star is 10^6 m/s and frequency of emitted light is 4.5 × 10^{14} Hz. If star is moving away, then apparent frequency will be-
(1) 4.5 Hz (2) 4.5 × 10^{16} Hz
(3) 4.485 × 10^{14} Hz (4) 4.5 × 10^8 Hz

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 10

These questions of two statements each, printed as Assertion and Reason. While answering these Questions you are required to choose any one of the following four responses.
(A) If both Assertion & Reason are true & the Reason is a correct explanation of the Assertion.
(B) If both Assertion and Reason are true but Reason is not a correct explanation of the Assertion.
(C) If Assertion is true and Reason is false.
(D) If Assertion & Reason both are false.

Q.1 **Assertion :** Intensity of sound wave changes when the listener moves towards or away from the stationary source.
Reason : The motion of listener causes the apparent change in wavelength.
(1) A (2) B (3) C (4) D

Q.2 **Assertion :** When source and observer both are moving in the same direction with same velocity, there occurs no change in the frequency of source.
Reason : There is no Doppler effect when relative velocity between source and observer becomes zero.
(1) A (2) B (3) C (4) D

Q.3 **Assertion :** Doppler effect in sound is not symmetrical.
Reason : Consider two cases, one in which the source is moving towards stationary observer and the other in which observer, is approaching towards stationary source. Although the relative velocity is same and the apparent frequency increases, but the changes in frequency are different in the two cases.
(1) A (2) B (3) C (4) D

Q.4 **Assertion :** Doppler effect for light is symmetrical.
Reason : Whether the source is moving towards a stationary observer of the observer is moving towards the stationary source, the Doppler shift for light is same for a given relative velocity.
(1) A (2) B (3) C (4) D

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 1 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	4	3	1	1	2	3	2	3	4	1	4	2	1	2	1	4	1	2	3	1
Q.No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	4	4	3	2	1	2	1	4	3	4	4	3	3	3	1	1	3	3	1	3
Q.No.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	1	1	2	1	4	4	1	3	2	1	2	1	1	4	4	1	4	3	4	1
Q.No.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Ans.	4	3	4	4	2	3	3	4	1	1	2	2	1	2	3	2	3	1	1,3	4
Q.No.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Ans.	2	1	2	3	3	1	3	3	1	2	1	2	1	4	1	3	3	3	1	3
Q.No.	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Ans.	1	1	2	3	4	2	2	2	4	2	3	1	1	1	2	3	4	3	3	1
Q.No.	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
Ans.	2	2	1	1	2	2	1	1	2	3	1	1	3	1	2	2	3	3	4	3
Q.No.	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
Ans.	1,3	2	4	3	2	1	2	3	4	1	4	3	2	4	2	2	3	1	1	2
Q.No.	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177			
Ans.	2	4	3	3	2	1	1	3	3	3	4	2	2	2	1	3	3			

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 2 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	4	3	2	4	3	1	1	4	2	3	2	2	2	1	4	1	1	3	2	3
Q.No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	4	3	1	1	3	2	2	3	3	3	2	3	1	2	1	1	1	1	2	3

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 3 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	2	1	3	2	3	1	2	1	1	3	4	3	3	2	3	3	3	2	2	3
Q.No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	4	3	3	3	3	1	1	4	1	3	2	1	3	1	3	1	3	2	3	1
Q.No.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	3	1	2	2	2	1	4	4	4	2	1	3	3	3	1	4	2	3	2	2
Q.No.	61	62	63	64	65	66	67	68	69											
Ans.	1	1	2	3	4	2	4	4	2											

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 4 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	3	3	2	2	1	2	4	1	3	2	2	2	3	3	2	2	3	4	4	4
Q.No.	21	22	23	24	25	26	27	28	29	30										
Ans.	3	1	2	3	3	4	3	4	1	3										

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 5 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	3	4	1	1	1	1	2	2	2	1	1	1	2	2	2	1	1	2	4	4
Q.No.	21	22	23	24																
Ans.	3	2	1	2																

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 6 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	1	3	2	4	2	4	4	4	1	4	1	2	1	2	1
Q.No.	16	17	18	19	20	21	22	23	24						
Ans.	4	1	2	2	3	2	2	3	2						

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 7 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	2	1	3	3	4	2	3	3	2	3	1	1	2	2	3
Q.No.	16	17	18	19	20	21									
Ans.	3	1	4	3	4	3									

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 8 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ans.	1	3	2	2	1	1	2	3	3	3	4	2	3	2

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 9 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Ans.	1	2	2	3	4	4	2	4	4	3	4	2	1	1	1	1
Q.No.	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Ans.	1	1	4	2	1	3	4	3	1	3	2	1	3	1	3	

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 10 (ANSWERS)

Q.No.	1	2	3	4
Ans.	3	1	1	1