14

Waves

TOPIC 1
Basics of Waves

01 A uniform rope of length L and mass m_1 hangs vertically from a rigid support. A block of mass m_2 is attached to the free end of the rope. A transverse pulse of wavelength λ_1 is produced at the lower end of the rope. The wavelength of the pulse when it reaches the top of the rope is λ_2. The ratio λ_2/λ_1 is **[NEET 2016]**

(a) $\sqrt{\frac{m_1+m_2}{m_2}}$ (b) $\sqrt{\frac{m_2}{m_1}}$

(c) $\sqrt{\frac{m_1+m_2}{m_1}}$ (d) $\sqrt{\frac{m_1}{m_2}}$

Ans. ***(a)***

According to question, we have

Wavelength of transphase pulse

$$\lambda = \frac{v}{f} \quad \text{...(i)}$$

(v = velocity of the wave; f = frequency of the wave)

As we know $v = \sqrt{\frac{T}{\mu}}$ ...(ii)

(T = tension in the spring; μ = mass per unit length of the rope)

From Eqs. (i) and (ii), we get

$$\lambda = \frac{1}{f}\sqrt{\frac{T}{\mu}}$$

$\Rightarrow \quad \lambda \propto \sqrt{T}$

So, for two different case, we get

$$\frac{\lambda_2}{\lambda_1} = \sqrt{\frac{T_2}{T_1}}$$

$$= \sqrt{\frac{m_1+m_2}{m_2}}$$

02 A wave travelling in the positive x-direction having displacement along y-direction as 1 m, wavelength 2π m and frequency of $\frac{1}{\pi}$ Hz is represented by **[NEET 2013]**

(a) $y = \sin(x - 2t)$
(b) $y = \sin(2\pi x - 2\pi t)$
(c) $y = \sin(10\pi x - 20\pi t)$
(d) $y = \sin(2\pi x + 2\pi t)$

Ans. ***(a)***

Given, $a = 1$ m

As $\quad y = a\sin(kx - \omega t)$

$$= \sin\left(\frac{2\pi}{2\pi} - 2\pi \times \frac{1}{\pi}t\right) = \sin(x - 2t)$$

03 Two waves are represented by the equations $y_1 = a\sin(\omega t + kx + \mathbf{0.57})$ m and $y_2 = a\cos(\omega t + kx)\,\mathbf{m}$, where x is in metre and t in second. The phase difference between them is **[CBSE AIPMT 2011]**

(a) 1.25 rad (b) 1.57 rad
(c) 0.57 rad (d) 1 rad

Ans. ***(d)***

According to question,

$y_1 = a\sin(\omega t + kx + 0.57)$

and $\quad y_2 = a\cos(\omega t + kx)$

or $\quad y_2 = a\sin\left(\frac{\pi}{2} + \omega t + kx\right)$

As phase difference,

$$\Delta\phi = \phi_2 - \phi_1 = \frac{\pi}{2} - 0.57$$

$$= 1.57 - 0.57 = 1\ \text{rad}$$

04 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 **[CBSE AIPMT 2011]**

(a) increases by a factor 20
(b) increases by a factor 10
(c) decreases by a factor 20
(d) decreases by a factor 10

Ans. ***(b)***

Velocity of a wave is given by

$$v = n\lambda$$

$\begin{bmatrix} n = \text{frequency of wave} \\ \lambda = \text{wavelength of wave} \end{bmatrix}$

So, for two different cases,

$v_1 = n_1\lambda_1$

$v_2 = n_2\lambda_2$

$\lambda_2 = \lambda_1 \frac{v_2}{v_1}$

$= \lambda_1 \times \frac{3500}{350} = \lambda_1 \times 10$

$[\because n_1 = n_2]$

$\lambda_2 = 10\,\lambda_1$

05 A transverse wave is represented by $y = A\sin(\omega t - kx)$. For what value of the wavelength is the wave velocity equal to the maximum particle velocity? **[CBSE AIPMT 2010]**

(a) $\pi A/2$ (b) πA
(c) $2\pi A$ (d) A

Ans. ***(c)***

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

As we know that wave velocity is given by

$$v_w = \frac{\lambda}{T} = \frac{\omega\lambda}{2\pi} \quad \text{...(i)}$$

$\left[T = \frac{2\pi}{\omega}\right]$

and maximum particle velocity is given by

$$v_p = A\omega \quad \text{...(ii)}$$

$\begin{bmatrix} A = \text{amplitude} \\ \omega = \text{angular frequency} \end{bmatrix}$

So, as Eq. (i) is equal to Eq. (ii),

$$A\omega = \frac{\omega\lambda}{2\pi}, \ \lambda = 2\pi A$$

06 A wave in a string has an amplitude of 2cm. The wave travels in the positive direction of x-axis with a speed of 128 ms^{-1} and it is noted that 5 complete waves fit in 4 m length of the string. The equation describing the wave is **[CBSE AIPMT 2009]**

(a) $y=(0.02)\text{m}\sin(7.85x+1005\ t)$
(b) $y=(0.02)\ \text{m}\ \sin(15.7x-2010\ t)$
(c) $y=(0.02)\text{m}\sin(15.7x+2010\ t)$
(d) $y=(0.02)\ \text{m}\sin(7.85x-1005\ t)$

Ans. ***(d)***

Given, amplitude of wave, $A=2$ cm
direction = +ve x direction
Velocity of wave
$$v=128\ \text{ms}^{-1}$$
and length of string, $5\lambda=4$
We know that,
$$k=\frac{2\pi}{\lambda}=\frac{2\pi\times5}{4}=7.85$$
and $v=\frac{\omega}{k}=128\ \text{ms}^{-1}$
[ω = Angular frequency]
$\Rightarrow\quad \omega=v\times k=128\times7.85=1005$
As, the wave travelling towards + x-axis is given by
$$y=A\sin(kx-\omega t)$$
So, $y=2\sin(7.85\,x-1005\,t)$
$$y=(0.02)\ \text{m}\ \sin(7.85\,x-1005\,t)$$

07 The wave described by
$$y=\mathbf{0.25}\sin(10\pi x-2\pi t),$$
where, x and y are in metre and t in second, is a wave travelling along the **[CBSE AIPMT 2008]**

(a) negative x-direction with frequency 1 Hz
(b) positive x-direction with frequency π Hz and wavelength $\lambda=0.2$ m
(c) positive x-direction with frequency 1 Hz and wavelength $\lambda=0.2$ m
(d) negative x-direction with amplitude 0.25 m and wavelength $\lambda=0.2$ m

Ans. ***(c)***

$y=0.25\sin(10\,\pi x-2\,\pi t)$
Compare the above equation with
$$y=A\sin(kx-\omega t)$$
As ωt and kx have opposite sign, wave travels along positive x.
As, $2\,\pi t=\omega t$
$\Rightarrow\quad \omega=2\pi=2\pi\nu$
$\Rightarrow\quad \nu=1\ \text{Hz}$
Also, $kx=10\,\pi\,x$
$$k=10\,\pi=\frac{2\pi}{\lambda}$$
$$\lambda=\frac{2\pi}{10\,\pi}=0.2$$
Hence, option (c) is correct.

08 Which one of the following statements is true ? **[CBSE AIPMT 2006]**

(a) Both light and sound waves in air are transverse
(b) he sound waves in air are longitudinal while the light waves are transverse
(c) Both light and sound waves in air are longitudinal
(d) Both light and sound waves can travel in vacuum

Ans. ***(b)***

In a longitudinal wave, the particles of the medium oscillate about their mean or equilibrium position along the direction of propagation of the wave itself. Sound waves are longitudinal in nature. In transverse wave, the particles of the medium oscillate about their mean or equilibrium position at right angles to the direction of propagation of wave itself. Light waves being electromagnetic are transverse waves.

09 The time of reverberation of a room A is 1s. What will be the time (in second) of reverberation of a room, having all the dimensions double of those of room A? **[CBSE AIPMT 2006]**

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

Ans. ***(a)***

Sabine's formula for reverberation time is
$$T=\frac{0.16\,V}{\Sigma as}$$
$$T\propto\frac{V}{s}$$
where, V is volume of hall in m^3.
$\Sigma as=a_1s_1+a_2s_2+\ldots$
= total absorption of the hall (room)
Here, $s_1, s_2, s_3\ldots$ are surface areas of the absorbers and $a_1, a_2, a_3\ldots$ are their respective absorption coefficients.
So, for two different cases of reverberation.
$$\therefore\quad \frac{T'}{T}=\frac{V'}{s'}\times\frac{s}{V}$$
$$=\frac{(2)^3}{(2)^2}=\frac{8}{4}=2$$
Hence, $T'=2T=2\times1=2\text{s}$

10 A transverse wave propagating along x-axis is represented by
$$y(x,t)=8\sin\left(0.5\,\pi x-4\pi t-\frac{\pi}{4}\right),$$
where, x is in metre and t is in second. The speed of the wave is **[CBSE AIPMT 2006]**

(a) 4π m/s (b) $0.5\,\pi$ m/s
(c) $\frac{\pi}{4}$ m/s (d) 8 m/s

Ans. ***(d)***

The given equation is
$$y(x,t)=8.0\sin\left(0.5\,\pi x-4\pi t-\frac{\pi}{4}\right)\quad\ldots(i)$$
Compare it with the standard wave equation
$$y=a\sin(kx-\omega t+\phi)\quad\ldots(ii)$$
where a is amplitude, k the propagation constant and ω the angular frequency, comparing the Eqs. (i) and (ii), we have
$$k=0.5\pi,\ \omega=4\pi$$
$\therefore$ Speed of transverse wave,
$$v=\frac{\omega}{k}=\frac{4\pi}{0.5\,\pi}=8\ \text{m}/\text{s}$$

11 A point source emits sound equally in all directions in a non-absorbing medium. Two points P and Q are at distance of 2m and 3m respectively from the source. The ratio of the intensities of the waves at P and Q is **[CBSE AIPMT 2005]**

(a) 9 : 4 (b) 2 : 3 (c) 3 : 2 (d) 4 : 9

Ans. ***(a)***

Intensity of sound, $I=\frac{p}{4\pi r^2}$
$$\left[\begin{array}{l}p=\text{pressure of sound waves}\\ r=\text{distance between source}\\ \qquad\text{and the point}\end{array}\right]$$
or $I\propto\frac{1}{r^2}$
or $\frac{I_1}{I_2}=\left(\frac{r_2}{r_1}\right)^2$
Here, $r_1=2\,\text{m}, r_2=3\,\text{m}$
Substituting the values, we have
$$\frac{I_1}{I_2}=\left(\frac{3}{2}\right)^2=\frac{9}{4}$$

12 The phase difference between two waves, represented by
$$y_1=10^{-6}\sin\left\{100t+\left(\frac{x}{50}\right)+0.5\right\}\text{m}$$
$$y_2=10^{-6}\cos\left\{100t+\left(\frac{x}{50}\right)\right\}\text{m},$$

where, x is expressed in metre and t is expressed in second, is approximately **[CBSE AIPMT 2004]**

(a) 1.07 rad (b) 2.07 rad
(c) 0.5 rad (d) 1.5 rad

Ans. *(a)*

The given waves are

$$y_1 = 10^{-6} \sin\left[100\,t + \left(\frac{x}{50}\right) + 0.5\right] \text{m} \quad \ldots\text{(i)}$$

and $y_2 = 10^{-6} \cos\left[100\,t + \left(\frac{x}{50}\right)\right] \text{m} \quad \ldots\text{(ii)}$

Eq. (ii) can be written as

$$\Rightarrow \quad y_2 = 10^{-6} \sin\left[100\,t + \left(\frac{x}{50}\right) + \frac{\pi}{2}\right] \text{m}$$

$$\left[\because \sin\left(\frac{\pi}{2} + \theta\right) = \cos\theta\right]$$

Hence, the phase difference between the waves is

$$\Delta\phi = \left(\frac{\pi}{2} - 0.5\right) \text{rad}$$

$$= \left(\frac{3.14}{2} - 0.5\right) \text{rad}$$

$$= (1.57 - 0.5) \text{ rad}$$

$$= (1.07) \text{ rad}$$

NOTE

The given waves are sine and cosine functions, so they are plane progressive harmonic waves.

13 A wave of amplitude $a = 0.2\,\mathbf{m}$, velocity $v = 360\,\mathbf{m/s}$ and wavelength 60 m is travelling along positive x-axis, then the correct expression for the wave is **[CBSE AIPMT 2002]**

(a) $y = 0.2 \sin 2\pi\left(6\,t + \frac{x}{60}\right)$

(b) $y = 0.2 \sin \pi\left(6\,t + \frac{x}{60}\right)$

(c) $y = 0.2 \sin 2\pi\left(6\,t - \frac{x}{60}\right)$

(d) $y = 0.2 \sin \pi\left(6\,t - \frac{x}{60}\right)$

Ans. *(c)*

The general expression of travelling wave can be written as

$$y = a \sin(\omega t \pm kx) \quad \ldots\text{(i)}$$

For travelling wave along positive x-axis we should use minus (–) sign only.

$$\therefore \quad y = a \sin(\omega t - kx)$$

but $\omega = \frac{2\pi v}{\lambda}$ and $k = \frac{2\pi}{\lambda}$

So, $$y = a \sin\frac{2\pi}{\lambda}(vt - x) \quad \ldots\text{(ii)}$$

Given, $a = 0.2$ m, $v = 360$ m/s, $\lambda = 60$ m,
Substituting in Eq. (ii), we have

$$y = 0.2 \sin\frac{2\pi}{60}(360\,t - x)$$

or $$y = 0.2 \sin 2\pi\left(6\,t - \frac{x}{60}\right)$$

14 The equation of a wave is given by $y = a \sin\left(100t - \frac{x}{10}\right)$, where x and y are in metre and t in second, then velocity of wave is **[CBSE AIPMT 2001]**

(a) 0.1 m/s (b) 10 m/s
(c) 100 m/s (d) 1000 m/s

Ans. *(d)*

The given wave equation is

$$y = a \sin\left(100\,t - \frac{x}{10}\right)$$

Compare it with the standard wave equation, we obtain

$$\omega = 100,\ k = \frac{1}{10}$$

Velocity of the wave,

$$v = \frac{\omega}{k} = \frac{100}{1/10}$$

$$= 100 \times 10 = 1000 \text{ m/s}$$

15 A wave enters to water from air. In air frequency, wavelength, intensity and velocity are n_1, λ_1, I_1 and v_1 respectively. In water the corresponding quantities are n_2, λ_2, I_2 and v_2 respectively, then **[CBSE AIPMT 2001]**

(a) $I_1 = I_2$ (b) $n_1 = n_2$
(c) $v_1 = v_2$ (d) $\lambda_1 = \lambda_2$

Ans. *(b)*

When a wave enters from one medium to another, its frequency remains unchanged, i.e.

$n_1 = n_2$ but wavelength, intensity and velocity get changed.

16 Two strings A and B have lengths l_A and l_B and carry masses M_A and M_B at their lower ends, the upper ends being supported by rigid supports. If n_A and n_B are the frequencies of their vibrations and $n_A = 2\,n_B$, then **[CBSE AIPMT 2000]**

(a) $l_A = 4l_B$, regardless of masses
(b) $l_B = 4l_A$, regardless of masses
(c) $M_A = 2M_B, l_A = 2l_B$
(d) $M_B = 2M_A, l_B = 2l_A$

Ans. *(b)*

The frequency of vibrations of string is

$$n = \frac{1}{2}\sqrt{\frac{g}{l}} \quad \ldots\text{(i)}$$

Given, $n_A = 2\,n_B$

$$\therefore \quad \frac{1}{2}\sqrt{\frac{g}{l_A}} = 2 \cdot \frac{1}{2}\sqrt{\frac{g}{l_B}}$$

or $$\frac{1}{l_A} = \frac{4}{l_B} \text{ or } l_B = 4l_A$$

It is obvious from Eq. (i), the frequency of vibrations of strings does not depend on their masses.

17 In a sinusoidal wave, the time required for a particular point, to move from maximum displacement to zero displacement is 0.170 s. The frequency of the wave is **[CBSE AIPMT 1998]**

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

Ans. *(a)*

If T is the time period, then time required for a point to move from maximum displacement to zero displacement is $\frac{T}{4}$.

So, $\frac{T}{4} = 0.170$ or $T = 0.170 \times 4 = 0.680$ s

Therefore, the frequency of wave is

$$n = \frac{1}{T} = \frac{1}{0.680} = 1.47 \text{ Hz}$$

18 A transverse wave is represented by the equation

$$y = y_0 \sin\frac{2\pi}{\lambda}(vt - x)$$

For what value of λ is the maximum particle velocity equal to two times the wave velocity? **[CBSE AIPMT 1998]**

(a) $\lambda = 2\pi y_0$ (b) $\lambda = \frac{\pi y_0}{3}$

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

Ans. *(d)*

The given wave equation is

$$y = y_0 \sin\frac{2\pi}{\lambda}(vt - x) \quad \ldots\text{(i)}$$

In the wave equation, v is the particle velocity.

Differentiating Eq. (i) with respect to time,

$$u = \frac{dy}{dt} = y_0 \frac{2\pi v}{\lambda} \cos\frac{2\pi vt}{\lambda}$$

Maximum particle velocity,

$$u_{\max} = y_0 \frac{2\pi v}{\lambda}$$

Now, it is given that,

Maximum particle velocity = 2 × wave velocity

or $\quad y_0 \frac{2\pi v}{\lambda} = 2v \quad$ or $\quad \lambda = \pi y_0$

19 The equation of a sound wave is given as $y = \mathbf{0.005} \sin(\mathbf{62.4}x + 316t)$. The wavelength of this wave is **[CBSE AIPMT 1996]**

(a) 0.4 unit (b) 0.3 unit
(c) 0.2 unit (d) 0.1 unit

Ans. *(d)*

Equation of plane progressive harmonic wave is

$$y = a\sin(\omega t + kx) \qquad \text{...(i)}$$

Given equation is

$$y = 0.005\sin(62.4x + 316t) \qquad \text{...(ii)}$$

Comparing Eq. (ii) with Eq. (i),

$$\omega = 316,\ k = 62.4$$

$$\Rightarrow \quad k = \frac{2\pi}{\lambda} = 62.4$$

$$\therefore \quad \lambda = \frac{2\pi}{62.4} = \frac{2 \times 3.14}{62.4} = 0.1 \text{ unit}$$

20 What is the effect of humidity on sound waves when humidity increases? **[CBSE AIPMT 1996]**

(a) Speed of sound waves increases
(b) Speed of sound waves decreases
(c) Speed of sound waves remains same
(d) Speed of sound waves becomes zero

Ans. *(a)*

The presence of water vapours in air changes its density. That is why the velocity of sound changes with humidity of air.

Suppose, ρ_m = density of moist air
ρ_d = density of dry air
v_m = velocity of sound in moist air
v_d = velocity of sound in dry air

Assuming that effect of humidity on γ is negligible.

As velocity of wave in a medium is given by

$$\therefore \quad v_m = \sqrt{\frac{\gamma p}{\rho_m}}$$

$$\begin{bmatrix} \gamma = \text{elasticity of medium} \\ \rho_m = \text{density of medium} \\ p = \text{pressure of sound waves} \end{bmatrix}$$

and $\quad v_d = \sqrt{\frac{\gamma p}{\rho_d}}$

Dividing, we get $\frac{v_m}{v_d} = \sqrt{\frac{\rho_d}{\rho_m}}$

The presence of water vapours reduces the density of air.

i.e. $\quad \rho_m < \rho_d$

Hence, velocity of sound in moist air is greater, then the velocity of sound in dry air.

21 The speed of a wave in a medium is 760 m/s. If 3600 waves are passing through a point in the medium in 2 min, then their wavelength is **[CBSE AIPMT 1995]**

(a) 13.8 m (b) 25.3 m
(c) 41.5 m (d) 57.2 m

Ans. *(b)*

Given, speed of wave (v) = 760 m/s

Number of waves = 3600

Time, t = 2 min = 2 × 60 = 120 s

$\therefore$ Frequency of waves,

$$\nu = \frac{\text{Total no. of waves}}{\text{time taken}} = \frac{3600}{120} = 30 \text{ Hz}$$

$\therefore$ Wavelength of waves

$$\lambda = \frac{v}{\nu} = \frac{760}{30} = 25.3 \text{ m}$$

22 A hospital uses an ultrasonic scanner to locate tumours in a tissue. The operating frequency of the scanner is 4.2 MHz. The speed of sound in a tissue is 1.7 km/s. The wavelength of sound in tissue is close to **[CBSE AIPMT 1995]**

(a) 4×10^{-4} m
(b) 8×10^{-4} m
(c) 4×10^{-3} m
(d) 8×10^{-3} m

Ans. *(a)*

Wavelength of a wave is the length of one wave. It is equal to the distance travelled by the wave during one complete cycle, wavelength of a wave is given by

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

where v = velocity of wave (sound)
ν = frequency of wave (sound)

Given, $\quad v = 1.7 \times 10^3$ m / s
$\nu = 4.2 \times 10^6$ Hz

$$\therefore \quad \lambda = \frac{1.7 \times 10^3}{4.2 \times 10^6} = 4 \times 10^{-4} \text{ m}$$

23 Two waves are said to be coherent, if they have **[CBSE AIPMT 1995]**

(a) same phase but different amplitude
(b) same frequency but different amplitude
(c) same frequency, phase and amplitude
(d) different frequency, phase and amplitude

Ans. *(c)*

Two wave are said to be coherent, when they have same frequency, amplitude and constant phase difference.

24 From a wave equation

$$y = \mathbf{0.5}\sin\frac{2\pi}{3.2}(64t - x),$$

the frequency of the wave is **[CBSE AIPMT 1995]**

(a) 5 Hz (b) 15 Hz
(c) 20 Hz (d) 25 Hz

Ans. *(c)*

Standard equation of plane progressive harmonic wave is

$$y = a\sin\frac{2\pi}{\lambda}(vt - x) \qquad \text{...(i)}$$

Given equation is

$$y = 0.5\sin\frac{2\pi}{3.2}(64t - x) \qquad \text{...(ii)}$$

Comparing Eq. (ii) with Eq. (i)

$$v = 64 \quad \text{and} \quad \lambda = 3.2$$

$$\therefore \text{Frequency } \nu = \frac{v}{\lambda} = \frac{64}{3.2} = 20 \text{ Hz}$$

25 If c_s be the velocity of sound in air and c be the rms velocity, then **[CBSE AIPMT 1994]**

(a) $c_s < c$ (b) $c_s = c$
(c) $c_s = c\left(\frac{\gamma}{3}\right)^{1/2}$ (d) None of these

Ans. *(c)*

Velocity of sound (c_s) is given by

$$c_s = \sqrt{\frac{\gamma p}{\rho}} \qquad \text{...(i)}$$

where, p is pressure, s is density and γ is atomicity of gas or ratio of C_p and C_V.

RMS velocity of gas molecules is given by

$$c = \sqrt{\left(\frac{3p}{\rho}\right)} \qquad \text{...(ii)}$$

From Eqs. (i) and (ii)

$$\frac{c_s}{c} = \sqrt{\frac{\gamma p}{\rho} \times \frac{\rho}{3p}} = \sqrt{\frac{\gamma}{3}}$$

$$\Rightarrow \quad c_s = c \times \sqrt{\left(\frac{\gamma}{3}\right)}$$

26 Which of the following equation represents a wave ? **[CBSE AIPMT 1994]**

(a) $y = a\sin\omega t$
(b) $y = a\cos kx$
(c) $y = a\sin(\omega t - bx + c)$
(d) $y = a\sin(\omega t - kx)$

Ans. *(d)*

A wave equation travelling in +ve x direction is represented as

$$y = A\sin\omega\left(t - \frac{x}{v}\right)$$

$$\begin{bmatrix} y = \text{displacement of wave at any time t} \\ A = \text{amplitude of wave} \\ \frac{x}{v} = \text{time delay of motion of each particle} \end{bmatrix}$$

Other forms of wave equations are

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

27 The frequency of sinusoidal wave, $0.40\cos(2000t + 0.80)$ would be **[CBSE AIPMT 1992]**

(a) 1000π Hz (b) 2000 Hz
(c) 20 Hz (d) $\frac{1000}{\pi}$ Hz

Ans. *(d)*

Equation of harmonic wave in cosine function is

$$y = a\cos(2\pi\nu t + \phi) \quad \text{...(i)}$$

$$\begin{bmatrix} \text{where, } a = \text{amplitude} \\ \nu = \text{frequency} \\ \text{and } \phi = \text{phase} \end{bmatrix}$$

Given equation is

$$= 0.40\cos(2000t + 0.80) \quad \text{...(ii)}$$

Comparing this equation with Eq. (i)

$$2\pi\nu = 2000$$

$$\therefore \quad \nu = \frac{2000}{2\pi} = \frac{1000}{\pi}\text{ Hz}$$

28 With the propagation of a longitudinal wave through a material medium, the quantities transmitted in the propagation direction are **[CBSE AIPMT 1992]**

(a) energy, momentum and mass
(b) energy
(c) energy and mass
(d) energy and linear momentum

Ans. *(b)*

In longitudinal waves, energy is propagated along with the wave motion without any net transport of the mass of the medium.

29 The transverse wave represented by the equation $y = 4\sin\frac{\pi}{6}\sin(3x - 15t)$ has **[CBSE AIPMT 1990]**

(a) amplitude $= 4\pi$
(b) wavelength $= \frac{4\pi}{3}$
(c) speed of propagation $= 5$
(d) period $= \frac{\pi}{15}$

Ans. *(c)*

The standard equation of transverse wave is

$$y = a\sin\left[\frac{2\pi t}{T} - \frac{2\pi x}{\lambda}\right] \quad \text{...(i)}$$

Given equation is

$$y = 4\sin\frac{\pi}{6}\sin(15t - 3x) \quad \text{...(ii)}$$

Comparing Eq. (ii) with Eq. (i)

$$\frac{2\pi}{\lambda} = 3,$$

$$\therefore \quad \lambda = \frac{2\pi}{3} \text{ and } \frac{2\pi}{T} = 15$$

$$\therefore \quad T = \frac{2\pi}{15}$$

$\therefore$ Speed of propagation wave,

$$v = \frac{\lambda}{T} = \frac{2\pi/3}{2\pi/15} = 5$$

30 Velocity of sound waves in air is 330 m/s. For a particular sound wave in air, path difference of 40 cm is equivalent to phase difference of 1.6π. The frequency of this wave is **[CBSE AIPMT 1990]**

(a) 165 Hz (b) 150 Hz
(c) 660 Hz (d) 330 Hz

Ans. *(c)*

At a given time (t = constant), the phase changes with position x. The phase change $(\Delta\phi)$ at a given time for a wavelength (λ) for a distance Δx is given by

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x \quad \text{...(i)}$$

From Eq. (i), $\Delta x = \frac{\lambda}{2\pi}\cdot\Delta\phi$ or $\lambda = 2\pi\cdot\frac{\Delta x}{\Delta\phi}$

Here, $\Delta x = 0.4$ m

$\Delta\phi = 1.6\pi$

$$\therefore \quad \lambda = 2\pi\cdot\frac{0.4}{1.6\pi} = 0.5$$

$\therefore$ Frequency of wave is

$$\nu = \frac{v}{\lambda} = \frac{330}{0.5} = 660\text{ Hz}$$

where, v = 330 m/s = velocity of sound

31 A 5.5 m length of string has a mass of 0.035 kg. If the tension in the string is 77 N, the speed of a wave on the string is **[CBSE AIPMT 1989]**

(a) 110 ms^{-1} (b) 165 ms^{-1}
(c) 77 ms^{-1} (d) 102 ms^{-1}

Ans. *(a)*

The velocity of propagation of a transverse wave on a stretched string is given by

$$v = \sqrt{\left(\frac{T}{\mu}\right)}$$

where T is tension in the string and μ is linear density of the string i.e. mass per unit length of the string.

Here, $\mu = \frac{0.035}{5.5}$ kg/m

$T = 77$ N

$$\therefore \quad v = \sqrt{\frac{77 \times 5.5}{0.035}} = 110\text{ m/s}$$

32 If the amplitude of sound is doubled and the frequency reduced to one-fourth, the intensity of sound at the same point will **[CBSE AIPMT 1989]**

(a) increase by a factor of 2
(b) decrease by a factor of 2
(c) decrease by a factor of 4
(d) remains unchanged

Ans. *(c)*

Factors on which intensity depends are

(i) Amplitude (a) of vibration of the source, $I \propto a^2$
(ii) Surface area (A) of the vibrating body, $I \propto A$
(iii) Density (ρ) of the medium, $I \propto \rho$
(iv) Frequency (ν) of the source, $I \propto \nu^2$
(v) Motion of the medium which changes effective velocity v of sound, $I \propto v$

As $I \propto a^2$ and $I \propto \nu^2$

Therefore, intensity becomes $\frac{2^2}{4^2} = \frac{1}{4}$th.

33 The velocity of sound in any gas depends upon **[CBSE AIPMT 1988]**

(a) wavelength of sound
(b) density and elasticity of gas
(c) intensity of sound waves
(d) amplitude and frequency of sound

Ans. *(b)*

From purely theoretical considerations, Newton came to the conclusion that velocity of longitudinal waves through any medium; solid, liquid or gas depends upon the elasticity and density of the medium. Newton gave the formula

$$v = \sqrt{\left(\frac{E}{\rho}\right)}$$

where v = velocity of sound in the medium

E = coefficient of elasticity in the medium

ρ = density of the (undisturbed) medium

34 Equation of progressive wave is given by

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

Then, which of the following is correct ? **[CBSE AIPMT 1988]**

(a) $v = 5$ cm (b) $\lambda = 18$ cm

(c) $a = 0.04$ cm (d) $f = 50$ Hz

Ans. *(b)*

Equation of plane progressive simple harmonic wave is

$$y = a\sin\left[2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) + \phi\right] \quad \text{...(i)}$$

The given equation is

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

Multiplying and dividing $\left(\frac{t}{T} - \frac{x}{\lambda}\right)$ by 2.

It is written as,

$$y = 4\sin\left[2\pi\left(\frac{t}{10} - \frac{x}{18}\right) + \frac{\pi}{6}\right] \quad \text{...(ii)}$$

Comparing Eqs. (i) and (ii), we find

$a = 4$ cm, $T = 10$ s, $\lambda = 18$ cm

and $\phi = \frac{\pi}{6}$

Hence option (b) is correct.

TOPIC 2
Superposition and Reflection of Waves

35 The length of the string of a musical instrument is 90 cm and has a fundamental frequency of 120 Hz. Where should it be pressed to produce fundamental frequency of 180 Hz? **[NEET (Oct.) 2020]**

(a) 75 cm (b) 60 cm

(c) 45 cm (d) 80 cm

Ans. *(b)*

Length of string of musical instrument,

$l = 90 \text{ cm} = 0.9 \text{ m}$

Fundamental frequency, $f_1 = 120$ Hz

$f_2 = 180$ Hz

$\therefore$ We know that $f \propto \frac{1}{l}$

$$\Rightarrow \frac{f_1}{f_2} = \frac{l_2}{l_1} \Rightarrow l_2 = \frac{f_1 l_1}{f_2} = \frac{120 \times 0.9}{180}$$

$$= \frac{2}{3} \times 0.9 = 0.6 \text{ m} = 60 \text{ cm}$$

36 In a guitar, two strings *A* and *B* made of same material are slightly out of tune and produce beats of frequency 6 Hz. When tension in *B* is slightly decreased, the beat frequency increases to 7 Hz. If the frequency of *A* is 530 Hz, the original frequency of *B* will be **[NEET (Sep.) 2020]**

(a) 524 Hz (b) 536 Hz

(c) 537 Hz (d) 523 Hz

Ans. *(a)*

In case of beats formation unknown frequency $(\nu_B) = \nu_A \pm \text{beats}$

where, $\nu_A = 530$ Hz and beats $= 6$ Hz.

$\Rightarrow \nu_B = 530 \pm 6 = 536$ or 524 Hz

When tension in *B* is slightly decreased, then beats frequency increases to 7 Hz. This is possible if we take original frequency of *B* as 524 Hz.

Hence, correct option is (a).

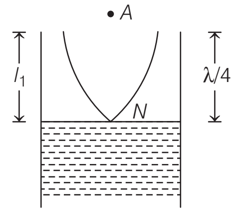
37 A tuning fork with frequency 800 Hz produces resonance in a resonance column tube with upper end open and lower end closed by water surface. Successive resonance are observed at length 9.75 cm, 31.25 cm and 52.75 cm. The speed of sound in air is **[NEET (Odisha) 2019]**

(a) 500 m/s (b) 156 m/s

(c) 344 m/s (d) 172 m/s

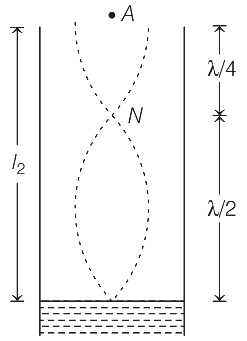
Ans. *(c)*

For vibrating tunning fork over a resonance tube, the first resonance is obtained at the length



$$l_1 = \frac{\lambda}{4} \quad \text{...(i)}$$

and for second resonance,



$$l_2 = \frac{\lambda}{4} + \frac{\lambda}{2} = \frac{3\lambda}{4} \quad \text{...(ii)}$$

From Eq. (i) and (ii), we get

$$l_2 - l_1 = \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2}$$

$\Rightarrow \lambda = 2(l_2 - l_1)$

$\Rightarrow v = 2f(l_2 - l_1)$ ...(iii) $\left(\because \lambda = \frac{v}{f}\right)$

Here, $f = 800$ Hz, $l_1 = 9.75$ cm, $l_2 = 31.25$ cm

Substituting the given values in Eq. (iii), we get

$\Rightarrow v = 2 \times 800(31.25 - 9.75)$

$= 34400$ cm/s $= 344$ m/s

38 The fundamental frequency in an open organ pipe is equal to the third harmonic of a closed organ pipe. If the length of the closed organ pipe is 20 cm, the length of the open organ pipe is **[NEET 2018]**

(a) 12.5 cm (b) 8 cm

(c) 13.3 cm (d) 16 cm

Ans. *(c)*

Fundamental frequency for an open organ pipe is given as

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

where, L is the length of the open organ pipe. Third harmonic for a closed organ pipe is given as

$$f' = \frac{3v}{4L'}$$

where, L' is the length of closed organ pipe. According to the question,

$$f = f'$$

$$\frac{v}{2L} = \frac{3v}{4L'}$$

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

Given, $L' = 20$ cm

$\Rightarrow L = \frac{2}{3} \times 20 \text{ cm} = \frac{40}{3} \text{ cm} = 13.3 \text{ cm}$

39 A tuning fork is used to produce resonance in a glass tube. The length of the air column in this tube can be adjusted by a variable piston. At room temperature of 27°C, two successive resonances are produced at 20 cm and 73 cm of column length. If the frequency of the tuning fork is 320 Hz, the velocity of sound in air at 27°C is **[NEET 2018]**

(a) 350 m/s (b) 339 m/s
(c) 330 m/s (d) 300 m/s

Ans. *(b)*

For first resonance, $l_1 = \frac{\lambda}{4}$

For second resonance, $l_2 = \frac{3\lambda}{4}$

$\therefore \quad (l_2 - l_1) = \frac{3\lambda}{4} - \frac{\lambda}{4}$

or $\quad \lambda = 2(l_2 - l_1) \quad$ ...(i)

As, velocity of sound wave is given as,

$$v = \nu\lambda$$

where, ν is the frequency.

$\Rightarrow \quad v = \nu[2(l_2 - l_1)]$[from Eq. (i)]

Here, $\nu = 320$ Hz, $l_2 = 0.73$ m, $l_1 = 0.20$ m

$\Rightarrow \quad v = 2[320(0.73 - 0.20)]$

$= 2 \times 320 \times 0.53$

$= 339.2 \text{ ms}^{-1} \simeq 339 \text{ ms}^{-1}$

40 The two nearest harmonics of a tube closed at one end and open at other end are 220 Hz and 260 Hz. What is the fundamental frequency of the system? **[NEET 2017]**

(a) 10 Hz (b) 20 Hz
(c) 30 Hz (d) 40 Hz

Ans. *(b)*

Thinking Process Frequency of nth harmonic in a closed end tube

$\Rightarrow \quad f = \frac{(2n-1)v}{4l} \quad n = 1, 2, 3, \ldots$

Also, only odd harmonics exists in a closed end tube.

Now, given two nearest harmonics are of frequency 220 Hz and 260 Hz.

$\therefore \quad \frac{(2n-1)v}{4l} = 220 \text{ Hz} \quad$ ...(i)

Next harmonic occurs at

$\frac{(2n+1)v}{4l} = 260 \text{ Hz} \quad$ ...(ii)

On subtracting Eq. (i) from Eq. (ii), we get

$$\frac{\{(2n+1)-(2n-1)\}v}{4l} = 260 - 220$$

$$2\left(\frac{v}{4l}\right) = 40 \Rightarrow \frac{v}{4l} = 20 \text{ Hz}$$

$\therefore$ Fundamental frequency of the system

$$= \frac{v}{4l} = 20 \text{ Hz}$$

41 The second overtone of an open organ pipe has the same frequency as the first overtone of a closed pipe L metre long. The length of the open pipe will be **[NEET 2016]**

(a) L (b) $2L$
(c) $L/2$ (d) $4L$

Ans. *(b)*

For an open organ pipe,

$\nu_n = \frac{n}{2L}v$, where $n = 1, 2, 3, \ldots$

For second overtons $n = 3$, $v_{2O} = \frac{3}{2L_1}v$

L_1 = length of open organ pipe ...(i)

For closed organ pipe $\nu_n = \left(\frac{2n+1}{4L}\right)v$

where, $n = 0, 1, 2, 3, \ldots$

Ist overtone for closed organ pipe, $n = 1$

$\nu_{1_c} = \frac{3}{4L}v \quad$ ...(ii)

$\because \quad \nu_{2_o} = \nu_{1_c} \Rightarrow \frac{3v}{2L_1} = \frac{3}{4L}v$

$\Rightarrow \quad L_1 = 2L$

42 Three sound waves of equal amplitudes have frequencies $(n-1)$, n, $(n+1)$. They superimpose to give beats. The number of beats produced per second will be **[NEET 2016]**

(a) 1 (b) 4
(c) 3 (d) 2

Ans. *(a)*

As we know that

Beat frequency $= f_1 \sim f_2 = n - (n-1) = 1$

and similarly for n and $n + 1$

Beat frequency $= n + 1 - n = 1$

43 The fundamental frequency of a closed organ pipe of length 20 cm is equal to the second overtone of an organ pipe open at both the ends. The length of organ pipe open at both the ends is **[CBSE AIPMT 2015]**

(a) 80 cm (b) 100 cm
(c) 120 cm (d) 140 cm

Ans. *(c)*

The fundamental frequencies of closed and open organ pipe are givan as

$$\nu_c = \frac{v}{4l} \Rightarrow \nu_o = \frac{v}{2l'}$$

Given the second overtone (i.e. third harmonic) of open pipe is equal to the fundamental frequency of closed pipe

i.e. $\quad 3\nu_o = \nu_c$

$\Rightarrow \quad 3\frac{v}{2l'} = \frac{v}{4l}$

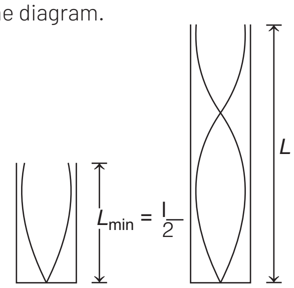
$\Rightarrow \quad l' = 6l = 6 \times 20 = 120$ cm

44 An air column, closed at one end and open at the other, resonates with a tunning fork when the smallest length of the column is 50 cm. The next larger length of the column resonating with the same tunning fork is **[CBSE AIPMT 2015]**

(a) 100 cm (b) 150 cm
(c) 200 cm (d) 66.7 cm

Ans. *(b)*

The smallest length of the air column is associated with fundamental mode of vibration of the air column as shown in the diagram.



$\because \quad L_{min} = \frac{\lambda}{4} \Rightarrow 50 \text{ cm} = \frac{\lambda}{4}$

$\Rightarrow \lambda = 200$ cm

The next higher length of the air column is

$$L = \frac{\lambda}{4} + \frac{\lambda}{2} = \frac{\lambda + 2\lambda}{4} = \frac{3\lambda}{4}$$

$$= \frac{3}{4} \times 200 = 150 \text{ cm}$$

45 A string is stretched between fixed points separated by 75.0 cm. It is observed to have resonant frequencies of 420 Hz and 315 Hz. There are no other resonant frequencies between these two. The lowest resonant frequency for this strings is **[CBSE AIPMT 2015]**

(a) 155 Hz (b) 205 Hz
(c) 10.5 Hz (d) 105 Hz

Ans. *(d)*

Given $l = 75$ cm, $f_1 = 420$ Hz and $f_2 = 315$ Hz.

As, two consecutive resonant frequencies for a string fixed at both ends will be

$f_1 = \frac{nv}{2l}$ and $f_2 = \frac{(n+1)v}{2l}$

$\Rightarrow \quad f_2 - f_1 = 420 - 315$

$\Rightarrow \frac{(n+1)v}{2l} - \frac{nv}{2l} = 105\text{ Hz}$

$\Rightarrow \quad \frac{v}{2l} = 105\text{ Hz}$

Thus, lowest resonant frequency of a string is 105 Hz.

46 If n_1, n_2 and n_3 are the fundamental frequencies of three segments into which a string is divided, then the original fundamental frequency n of the string is given by **[CBSE AIPMT 2014]**

(a) $\frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3}$

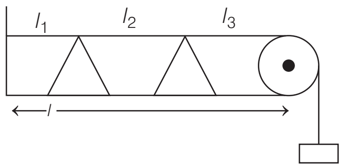
(b) $\frac{1}{\sqrt{n}} = \frac{1}{\sqrt{n_1}} + \frac{1}{\sqrt{n_2}} + \frac{1}{\sqrt{n_3}}$

(c) $\sqrt{n} = \sqrt{n_1} + \sqrt{n_2} + \sqrt{n_3}$

(d) $n = n_1 + n_2 + n_3$

Ans. *(a)*

Problem Solving Strategy In this problem, the fundamental frequencies of each part could be find. The fundamental frequency of the complete wire could be find. One should check each option for the given values.



For Ist part, $n_1 = \frac{v}{2l_1} \Rightarrow l_1 = \frac{v}{2n_1}$

For IInd part, $n_2 = \frac{v}{2l_2} \Rightarrow l_2 = \frac{v}{2n_2}$

For IIIrd part, $n_3 = \frac{v}{2l_3} \Rightarrow l_3 = \frac{v}{2n_3}$

For the complete wire, $n = \frac{v}{2l} \Rightarrow l = \frac{v}{2n}$

We have, $l = l_1 + l_2 + l_3$

$$\frac{v}{2n} = \frac{v}{2n_1} + \frac{v}{2n_2} + \frac{v}{2n_3}$$

$$\frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3}$$

47 The number of possible natural oscillations of air column in a pipe closed at one end of length 85 cm whose frequencies lie below 1250 Hz are (velocity of sound $= 340\text{ ms}^{-1}$) **[CBSE AIPMT 2014]**

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

Ans. *(d)*

For pipe closed at one end,

$f_n = n\left(\frac{v}{4l}\right)$, here n is an odd number.

$$= n\left[\frac{340}{4 \times 85 \times 10^{-2}}\right] = n[100]$$

Here, n is an odd number, so for the given condition, n can go upto $n = 11$

i.e. $n = 1, 3, 5, 7, 9, 11$

So, number of possible natural oscillations could be 6. Which are below 1250 Hz.

48 If we study the vibration of a pipe open at both ends, which of the following statements is not true? **[NEET 2013]**

(a) Open end will be antinode
(b) Odd harmonics of the fundamental frequency will be generated
(c) All harmonics of the fundamental frequency will be generated
(d) Pressure change will be maximum at both ends

Ans. *(d)*

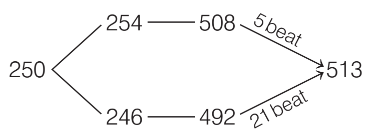
Statement (d) is not true, because at the open ends pressure change will be zero.

49 A source of unknown frequency gives 4 beat/s when sounded with a source of known frequency 250 Hz. The second harmonic of the source of unknown frequency gives 5 beat/s when sounded with a source of frequency 513 Hz. The unknown frequency is **[NEET 2013]**

(a) 254 Hz (b) 246 Hz
(c) 240 Hz (d) 260 Hz

Ans. *(a)*

Given,



Hence, unknown frequency is 254 Hz.

50 When a string is divided into three segments of lengths l_1, l_2 and l_3, the fundamental frequencies of these three segments are ν_1, ν_2 and ν_3 respectively. The original fundamental frequency (ν) of the string is **[CBSE AIPMT 2012]**

(a) $\sqrt{\nu} = \sqrt{\nu_1} + \sqrt{\nu_2} + \sqrt{\nu_3}$

(b) $\nu = \nu_1 + \nu_2 + \nu_3$

(c) $\frac{1}{\nu} = \frac{1}{\nu_1} + \frac{1}{\nu_2} + \frac{1}{\nu_3}$

(d) $\frac{1}{\sqrt{\nu}} = \frac{1}{\sqrt{\nu_1}} + \frac{1}{\sqrt{\nu_2}} + \frac{1}{\sqrt{\nu_3}}$

Ans. *(c)*

The fundamental frequency of string

$$\nu = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

$\therefore \quad \nu_1 l_1 = \nu_2 l_2 = \nu_2 l_3 = k \quad$ ...(i)

From Eq. (i),

$$l_1 = \frac{k}{\nu_1}, l_2 = \frac{k}{\nu_2}, l_3 = \frac{k}{\nu_3}$$

Original length,

$$l = \frac{k}{\nu}$$

Here, $\quad l = l_1 + l_2 + l_3$

$$\frac{k}{\nu} = \frac{k}{\nu_1} + \frac{k}{\nu_2} + \frac{k}{\nu_3}$$

$$\frac{1}{\nu} = \frac{1}{\nu_1} + \frac{1}{\nu_2} + \frac{1}{\nu_3}$$

51 Two sources of sound placed closed to each other, are emitting progressive waves given by $y_1 = 4\sin 600\pi t$ and $y_2 = 5\sin 608\pi t$ An observer located near these two sources of sound will hear **[CBSE AIPMT 2012]**

(a) 4 beat/s with intensity ratio 25 : 16 between waxing and waning
(b) 8 beat/s with intensity ratio 25 : 16 between waxing and waning
(c) 8 beat/s with intensity ratio 81 : 1 between waxing and waning
(d) 4 beat/s with intensity ratio 81 : 1 between waxing and waning

Ans. *(d)*

Given, $y_1 = 4\sin 600\pi t$

and $y_2 = 5\sin 608\pi t$

Comparing with general equation

$$y = a\sin 2\pi ft$$

We get, $\quad f_1 = 300\text{ Hz}$

and $\quad f_2 = 304\text{ Hz}$

So, number of beats $= f_2 - f_1 = 4\text{s}^{-1}$

We know that,

$$\frac{I_{\max}}{I_{\min}} = \left(\frac{a_1 + a_2}{a_1 - a_2}\right)^2 = \left(\frac{4+5}{4-5}\right)^2 = 81$$

52 A tuning fork of frequency 512 Hz makes 4 beat/s with the vibrating string of a piano. The beat frequency decreases to 2 beat/s when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was **[CBSE AIPMT 2010]**

(a) 510 Hz (b) 514 Hz
(c) 516 Hz (d) 508 Hz

Ans. *(d)*

Let n_p be the frequency of piano

As $(n_p \propto \sqrt{T})$

n_f = frequency of tuning fork = 512 Hz

x = Beat frequency = 4 beats/s, which is decreasing $(4 \to 2)$ after changing the tension of piano wire.

Also, tension of piano wire is increasing so $n_p \uparrow$

Hence, $n_p \uparrow - n_f = x\downarrow \longrightarrow$ wrong

$n_f - n_p \uparrow = x\downarrow \longrightarrow$ correct

$n_p = n_f - x = 512 - 4 = 508$ Hz

53 Two periodic waves of intensities I_1 and I_2 pass through a region at the same time in the same direction. The sum of the maximum and minimum intensities is **[CBSE AIPMT 2008]**

(a) $I_1 + I_2$ (b) $(\sqrt{I_1} + \sqrt{I_2})^2$
(c) $(\sqrt{I_1} - \sqrt{I_2})^2$ (d) $2(I_1 + I_2)$

Ans. *(d)*

As intensity is directly proportional to the square of amplitude

i.e. $I \propto a^2$

So, maximum intensity is given by

$$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2 \quad \begin{bmatrix} I_1, I_2 \text{ are intensities} \\ \text{of two waves} \end{bmatrix}$$

and $I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$

$$\therefore I_{max} + I_{min} = (\sqrt{I_1} + \sqrt{I_2})^2 + (\sqrt{I_1} - \sqrt{I_2})^2 = 2(I_1 + I_2)$$

54 Two sound waves with wavelengths 5 m and 5.5 m respectively, each propagate in a gas with velocity 330 m/s. We expect the following number of beat per second **[CBSE AIPMT 2006]**

(a) 12 (b) zero (c) 1 (d) 6

Ans. *(d)*

Let $\lambda_1 = 5.0$ m, $v = 330$ m/s and $\lambda_2 = 5.5$ m

The relation between frequency (n), wavelength (λ) and velocity (v) is given by

$$v = n\lambda$$

$$\Rightarrow \quad n = \frac{v}{\lambda} \quad \text{....(i)}$$

The frequency corresponding to wavelength λ_1,

$$n_1 = \frac{v}{\lambda_1} = \frac{330}{5.0} = 66 \text{ Hz}$$

The frequency corresponding to wavelength λ_2,

$$n_2 = \frac{v}{\lambda_2} = \frac{330}{5.5} = 60 \text{ Hz}$$

Hence, number of beats per second

$$= n_1 - n_2 = 66 - 60 = 6$$

55 Two vibrating tuning forks produce progressive waves given by $y_1 = 4 \sin 500\pi t$ and $y_2 = 2\sin 506\pi t$. Number of beat produced per minute is **[CBSE AIPMT 2005]**

(a) 360 (b) 180 (c) 3 (d) 60

Ans. *(b)*

Given, $y_1 = 4 \sin 500\,\pi t$ ...(i)

$y_2 = 2 \sin 506\,\pi t$ ...(ii)

Comparing Eqs. (i) and (ii), we get

$y = a \sin \omega t$ ...(iii)

We have, $\omega_1 = 500\,\pi$

$$\Rightarrow \quad n_1 = \frac{500\pi}{2\pi} = 250 \text{ beats/s} \quad \left[\therefore n = \frac{\omega}{2\pi}\right]$$

and $\omega_2 = 506\,\pi$

$$\Rightarrow \quad n_2 = \frac{506\,\pi}{2\pi} = 253 \text{ beats/s}$$

Thus, number of beats produced

$$= n_2 - n_1 = 253 - 250 = 3 \text{ beats/s}$$
$$= 3 \times 60 \text{ beats/min} = 180 \text{ beats/min}$$

If equation of wave is given and to find physical quantities like amplitude, wavelength, time period, frequency, just compare the given equation with standard equation of wave.

56 Equations of two progressive waves are given by $y_1 = a \sin(\omega t + \phi_1)$ and $y_2 = a\sin(\omega t + \phi_2)$. If amplitude and time period of resultant wave are same as that of both the waves, then $(\phi_1 - \phi_2)$ is **[CBSE AIPMT 2001]**

(a) $\frac{\pi}{3}$ (b) $\frac{2\pi}{3}$ (c) $\frac{\pi}{6}$ (d) $\frac{\pi}{4}$

Ans. *(b)*

The given progressive waves are

$$y_1 = a \sin(\omega t + \phi_1)$$
$$y_2 = a \sin(\omega t + \phi_2)$$

The resultant of two waves is

$$y = y_1 + y_2$$
$$= a[\sin(\omega t + \phi_1) + \sin(\omega t + \phi_2)]$$

If A is the amplitude of resultant wave, then

$A = a$ (given)

$\therefore \quad A^2 = a^2 + a^2 + 2a^2 \cos\phi$

or $\quad a^2 = a^2 + a^2 + 2a^2 \cos\phi$

or $\quad \cos\phi = -\frac{1}{2} = \cos 120°$

$\therefore \quad \phi = 120° = \frac{2\pi}{3}$

Thus, $\quad \phi_1 - \phi_2 = \frac{2\pi}{3}$

57 A sonometer wire when vibrated in full length has frequency n. Now, it is divided by the help of bridges into a number of segments of lengths $l_1, l_2, l_3, \ldots$ When vibrated these segments have frequencies $n_1, n_2, n_3, \ldots$ Then, the correct relation is **[CBSE AIPMT 2000]**

(a) $n = n_1 + n_2 + n_3 + \ldots$
(b) $n^2 = n_1^2 + n_2^2 + n_3^2 + \ldots$
(c) $\frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3} + \ldots$
(d) $\frac{1}{\sqrt{n}} = \frac{1}{\sqrt{n_1}} + \frac{1}{\sqrt{n_2}} + \frac{1}{\sqrt{n_3}} + \ldots$

Ans. *(c)*

From law of length, the frequency of vibrating string is inversely proportional to its length,

i.e. $\quad n \propto \frac{1}{l}$

$$\begin{bmatrix} n = \text{frequency of string} \\ l = \text{length of string} \end{bmatrix}$$

or $\quad nl$ = constant (say k)

or $\quad l = \frac{k}{n}$

The segments of string of length $l_1, l_2, l_3 \ldots$ have frequencies $n_1, n_2, n_3, \ldots$

Total length of string is l.

So, $\quad l = l_1 + l_2 + l_3 + \ldots$

$\therefore \quad \frac{k}{n} = \frac{k}{n_1} + \frac{k}{n_2} + \frac{k}{n_3} + \ldots$

or $\quad \frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3} + \ldots$

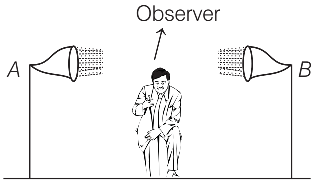
58 Two sources are at a finite distance apart. They emit sounds of wavelength λ. An observer situated between them on line joining approaches one source with speed u. Then, the number of beat heard/second by observer will be **[CBSE AIPMT 2000]**

(a) $\frac{2u}{\lambda}$ (b) $\frac{u}{\lambda}$ (c) $\frac{u}{2\lambda}$ (d) $\frac{\lambda}{u}$

Ans. *(a)*

Let v be the speed of sound and n the original frequency of each source.

They emit sounds of wavelength λ.



When observer moves towards one source (say A), the apparent frequency of A as observed by the observer will be

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

[u = speed of observer towards A]

The observer is now receding source B, so the apparent frequency of B observed will be

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

[u = speed of observer going away from B]

Thus, number of beats,

$$x = n' - n'' = n\left[\frac{v+u}{v} - \frac{v-u}{v}\right]$$

$$= \frac{n}{v}[v + u - v + u] = \frac{2nu}{v}$$

but $\quad v = n\lambda$

Thus, $\quad x = \frac{2nu}{n\lambda} = \frac{2u}{\lambda}$

59 Two waves of wavelength 50 cm and 51 cm produce 12 beat/s. The speed of sound is

[CBSE AIPMT 1999]

(a) 306 m/s (b) 331 m/s
(c) 340 m/s (d) 360 m/s

Ans. *(a)*

Beats produced due to the two frequencies is given by

$$n_1 - n_2$$

where, n_1 and n_2 are the frequencies of two waves.

Here, number of beats = 12/s

$$\lambda_1 = 50\text{ cm} = 0.50\text{ m}$$

$$\lambda_2 = 51\text{ cm} = 0.51\text{ m}$$

$$n_1 - n_2 = 12$$

or $\quad \frac{v}{\lambda_1} - \frac{v}{\lambda_2} = 12 \qquad \left[n = \frac{v}{\lambda}\right]$

or $\quad v\left(\frac{\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right) = 12$

or $\quad v = \frac{12\lambda_1\lambda_2}{\lambda_2 - \lambda_1}$

$\therefore \quad v$ = speed of sound

$$= \frac{12 \times 0.50 \times 0.51}{(0.51 - 0.50)} = \frac{12 \times 0.50 \times 0.51}{0.01}$$

$= 306$ m / s

Thus, speed of sound is 306 m/s.

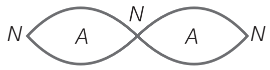
60 A standing wave having 3 node and 2 antinode is formed between two atoms having a distance 1.21 Å between them. The wavelength of the standing wave is

[CBSE AIPMT 1998]

(a) 1.21 Å (b) 1.42 Å
(c) 6.05 Å (d) 3.63 Å

Ans. *(a)*

The given standing wave is shown in the figure.



As length of one loop or segment is $\frac{\lambda}{2}$, so length of 2 segments is $2\left(\frac{\lambda}{2}\right)$.

So, according to question

$\therefore \quad 2\frac{\lambda}{2} = 1.21\text{ Å} \Rightarrow \lambda = 1.21\text{ Å}$

61 A cylindrical resonance tube open at both ends, has a fundamental frequency f, in air. If half of the length is dipped vertically in water, the fundamental frequency of the air column will be

[CBSE AIPMT 1997]

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

Ans. *(c)*

Fundamental frequency of open pipe,

$$f = \frac{v}{2l} \qquad \text{...(i)}$$

$\begin{bmatrix} v = \text{velocity of wave} \\ l = \text{length of open pipe} \end{bmatrix}$

When half length of tube is dipped vertically in water, then length of the air column becomes half $\left(l' = \frac{l}{2}\right)$ and the pipe becomes closed.

So, new fundamental frequency of closed pipe

$$f' = \frac{v}{4l'} = \frac{v}{4\left(\frac{l}{2}\right)} = \frac{v}{2l} \qquad \text{...(ii)}$$

From Eqs. (i) and (ii), we get,

$$f' = f$$

Hence, there will be no change in fundamental frequency.

62 A pulse of a wave train travels along a stretched string and reaches the fixed end of the string. It will be reflected back with

[CBSE AIPMT 1997]

(a) a phase change of 180° with velocity reversed
(b) the same phase as the incident pulse with no reversal of velocity
(c) a phase change of 180° with no reversal of velocity
(d) the same phase as the incident pulse but with velocity reversed

Ans. *(a)*

A pulse of a wave train when travels along a stretched string and reaches the fixed end of the string, then it will be reflected back to the same medium and the reflected ray suffers a phase change of π with the incident wave and wave velocity after reflection will reverse.

63 Standing waves are produced in a 10 m long stretched string. If the string vibrates in 5 segments and the wave velocity is 20 m/s, the frequency is **[CBSE AIPMT 1997]**

(a) 10 Hz (b) 5 Hz (c) 4 Hz (d) 2 Hz

Ans. *(b)*

In the case of standing wave, the length of one segment is $\frac{\lambda}{2}$. There are 5 segments and total length of string is 10 m.

$\therefore \quad 5\frac{\lambda}{2} = 10 \Rightarrow \lambda = 4\text{ m}$

Frequency, $\quad n = \frac{v}{\lambda} = \frac{20}{4} = 5\text{ Hz}$

$(\because v = 20\text{ m / s})$

Standing wave is an example of interference. Destructive interference means node and constructive interference means antinode.

64 Two waves of same frequency and intensity superimpose on each other in opposite phases. After the super-position, the intensity and frequency of waves will **[CBSE AIPMT 1996]**

(a) increase (b) decrease
(c) remain constant (d) become zero

Ans. *(d)*

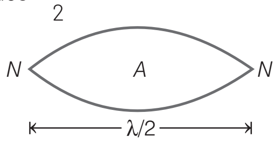
Interference phenomenon is common to sound and light. In sound, the interference is said to be constructive at points where resultant intensity is maximum (are in phase) and destructive at points where resultant intensity is minimum or zero (are in opposite phase).

65 Two waves are approaching each other with a velocity of 20 m/s and frequency n. The dist nodes is **[CBSE AIPMT 1995]**

(a) $\frac{20}{n}$ (b) $\frac{10}{n}$ (c) $\frac{5}{n}$ (d) $\frac{n}{10}$

Ans. *(b)*

Distance between two successive nodes $= \frac{\lambda}{2}$



but we know that, $v = \nu\lambda$

$\therefore \quad \frac{\lambda}{2} = \frac{v}{2\nu}$

Given, $v = 20$ m/s

frequency, $\nu = n$

So, $\frac{\lambda}{2} = \frac{20}{2n} = \frac{10}{n}$

66 A wave of frequency 100 Hz is sent along a string towards a fixed end. When this wave travels back after reflection, a node is formed at a distance of 10 cm from the fixed end of the string. The speed of incident (and reflected) wave are **[CBSE AIPMT 1994]**

(a) 5 m/s (b) 10 m/s
(c) 20 m/s (d) 40 m/s

Ans. *(c)*

As fixed end is a node, therefore distance between two consecutive nodes

$$= \frac{\lambda}{2} = 10 \text{ cm}$$

[λ = wavelength of wave sent]

$\Rightarrow \quad \lambda = 20\text{ cm} = 0.2\text{ m}$

As we know, $v = \nu\lambda$

$\left[\begin{array}{l} v = \text{velocity of wave} \\ \nu = \text{frequency of wave} \end{array}\right]$

$\therefore \quad v = 100 \times 0.2 = 20$ m/s

67 A standing wave is represented by $y = a\sin(100t)\cos(\mathbf{0.01})x$, where y and a are in millimetre, t in second and x is in metre. Velocity of wave is **[CBSE AIPMT 1994]**

(a) 10^4 m/s (b) 1 m/s
(c) 10^{-4} m/s (d) None of these

Ans. *(a)*

The standard equation of standing wave is

$$y = a\sin(\omega t)\cos(kx) \quad \text{...(i)}$$

Given equation is

$$y = a\sin(100t)\cos(0.01x) \quad \text{...(ii)}$$

Comparing Eqs. (i) and (ii)

$\omega = 100$ and $k = 0.01$

$\therefore$ Velocity of wave is

$$v = \frac{\lambda}{T} = \frac{\omega}{k} = \frac{100}{0.01} \quad \left[\begin{array}{l}\text{As, } \omega = \frac{2\pi}{T} \\ \text{and } k = \frac{2\pi}{\lambda}\end{array}\right]$$

$$= 10^4 \text{ m/s}$$

68 A stretched string resonates with tuning fork of frequency 512 Hz when length of the string is 0.5 m. The length of the string required to vibrate resonantly with a tuning fork of frequency 256 Hz would be **[CBSE AIPMT 1993]**

(a) 0.25 m (b) 0.5 m (c) 1 m (d) 2 m

Ans. *(c)*

The frequency of fundamental note of the stretched string is given by

$$\nu = \frac{1}{2L}\sqrt{\left(\frac{T}{\mu}\right)} \quad \text{...(i)}$$

where, T is tension in string and μ is mass per unit length of the string.

From Eq. (i) $\nu \propto \frac{1}{L}$

[As string is same so μ will be same]

For two different case

$\therefore \quad \frac{\nu_1}{\nu_2} = \frac{L_2}{L_1}$

Here, $\nu_1 = 512$ Hz, $L_1 = 0.5$ m

$\nu_2 = 256$ Hz, $L_2 = ?$

$\therefore \quad \frac{512}{256} = \frac{L_2}{0.5}$

$\Rightarrow \quad L_2 = 0.5 \times 2 = 1$ m

69 For production of beats the two sources must have **[CBSE AIPMT 1992]**

(a) different frequencies and same amplitude
(b) different frequencies
(c) ifferent frequencies, same amplitude and same phase
(d) different frequencies and same phase

Ans. *(b)*

When two sound waves of slightly different frequencies travel in a medium along the same direction and superimpose on each other, intensity of the resultant sound at a particular position rises and falls alternately with time. This phenomenon of alternate variation in the intensity of sound with time at a particular position, when two sound waves of nearly equal frequencies (but not equal) superimpose on each other is called beats.

70 A closed organ pipe (closed at one end) is excited to support the third overtone. It is found that air in the pipe has **[CBSE AIPMT 1991]**

(a) three nodes and three antinodes
(b) three nodes and four antinodes
(c) four nodes and three antinodes
(d) four nodes and four antinodes

Ans. *(d)*

In a closed organ pipe, only alternate harmonics of frequencies $\nu_1, 3\nu_1, 5\nu_1, ...$ etc are present. The harmonics of frequencies $2\nu_1, 4\nu_1, 6\nu_1, ...$ are missing. In general, the frequency of note produced in nth normal mode of vibration of closed organ pipe would be

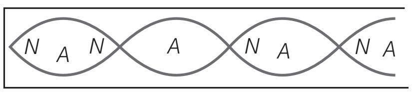
$$\nu_n = \frac{(2n-1)v}{4L} = (2n-1)\nu_1$$

This is $(2n-1)$ th harmonic or $(n-1)$ th overtone.

Third overtone has a frequency $7\nu_1$, which means

$$L = \frac{7\lambda}{4} = \frac{\lambda}{2} + \frac{\lambda}{2} + \frac{\lambda}{2} + \frac{\lambda}{4}$$

hich is three full loops and a half loop, which is equal to four nodes and four antinodes.



TOPIC 3
Doppler Effect

71 Two cars moving in opposite directions approach each other with speed of 22 m/s and 16.5 m/s respectively. The driver of the first car blows a horn having a frequency 400 Hz. The frequency heard by the driver of the second car is [velocity of sound 340 m/s] **[NEET 2017]**

(a) 350 Hz (b) 361 Hz
(c) 411 Hz (d) 448 Hz

Ans. *(d)*

Thinking Process When both source and observer are moving towards each other, apparent frequency is given by

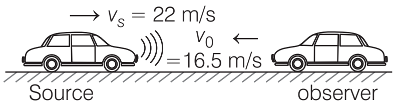
$$f_a = f_0\left(\frac{v + v_0}{v - v_s}\right)$$

where, f_0 = original frequency of source

v_s = speed of source
v_0 = speed of observer
v = speed of sound

Frequency of the horn,
$f_0 = 400$ Hz

Speed of observer in the second car,
$v_0 = 16.5$ m/s



Speed of source,
v_s = speed of first car
$= 22$ m/s

Frequency heard by the driver in the second car

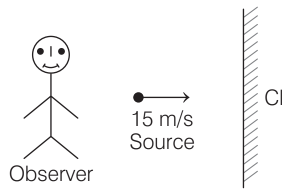
$$f_a = f_0\left(\frac{v+v_0}{v-v_s}\right) = 400\left(\frac{340+16.5}{340-22}\right)$$
$$= 448 \text{ Hz}$$

72 A siren emitting a sound of frequency 800 Hz moves away from an observer towards a cliff at a speed of 15ms^{-1}. Then, the frequency of sound that the observer hears in the echo reflected from the cliff is (Take, velocity of sound in air $= 330 \text{ ms}^{-1}$) **[NEET 2016]**

(a) 800 Hz (b) 838 Hz
(c) 885 Hz (d) 765 Hz

Ans. ***(b)***

According to question, situation can be drawn as follows



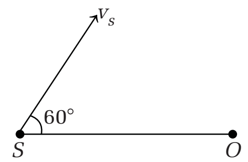
Frequency of sound that the observer hear in the echo reflected from the cliff is given by

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

where f = original frequency of source;
v = velocity of sound
v_s = velocity of source

So, $f' = \left(\frac{330}{330-15}\right)800 = 838$ Hz

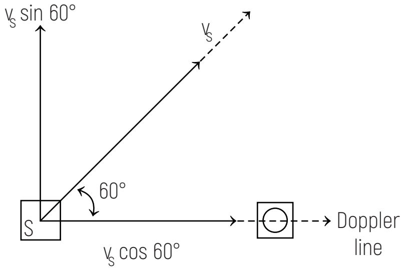
73 A source of sound S emitting waves of frequency 100 Hz and an observer O are located at some distance from each other. The source is moving with a speed of 19.4 ms^{-1} at an angle of $60°$ with the source observer line as shown in the figure. The observer is at rest. The apparent frequency observed by the observer (velocity of sound in air is 330 ms^{-1}), is **[CBSE AIPMT 2015]**



(a) 100 Hz (b) 103 Hz
(c) 106 Hz (d) 97 Hz

Ans. ***(b)***

Given, as a source of sound S emitting waves of frequency 100 Hz and an observer O are located at some distance. Such that, source is moving with a speed of 19.4 m/s at angle $60°$ with source-observer line as shown in figure.



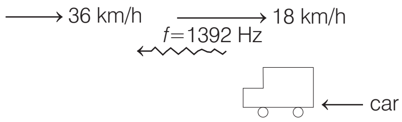
The apparent frequency heared by observer

$$f_0 = f_s\left[\frac{v}{v-v_s \cos 60°}\right]$$
$$= 100\left[\frac{330}{330-19.4\times\frac{1}{2}}\right]$$
$$= 100\left[\frac{330}{300-9.7}\right] = 100\left[\frac{330}{320.3}\right]$$
$$= 103.02 \text{ Hz}$$

74 A speeding motorcyclist sees traffic jam ahead of him. He slows down to 36 km/h. He finds that traffic has eased and a car moving ahead of him at 18 km/h is honking at a frequency of 1392 Hz. If the speed of sound is 343 m/s, the frequency of the honk as heard by him will be **[CBSE AIPMT 2014]**

(a) 1332 Hz (b) 1372 Hz
(c) 1412 Hz (d) 1454 Hz

Ans. ***(c)***



$\Rightarrow$ As both observer and source are moving, we can use the formula of apparent frequency as

$$f = f_0\left(\frac{v+v_0}{v+v_s}\right)$$
$$= 1392\left[\frac{343+10}{343+5}\right]$$

[$\because v_0 = 36$ km / h $= 10$ m / s and
$v_s = 18$ km / h $= 5$ m / s]

$$= 1392\left[\frac{353}{348}\right] = 1412 \text{ Hz}$$

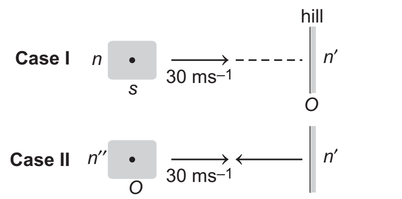
75 The driver of a car travelling with speed 30 ms^{-1} towards a hill sounds a horn of frequency 600 Hz. If the velocity of sound in air is 330 ms^{-1}, the frequency of reflected sound as heard by driver is **[CBSE AIPMT 2009]**

(a) 550 Hz
(b) 555.5 Hz
(c) 720 Hz
(d) 500 Hz

Ans. ***(c)***

Concept Use Doppler's effect.

According to Doppler's effect, whenever there is a relative motion between a source of sound and the observer (listener), the frequency of sound heard by the observer is different from the actual frequency of sound emitted by source.



[for case **I**] $n' = \frac{v}{v-30}n$ ...(i)

[n = frequency emitted by car
v = velocity of sound]

[for case **II**] $n'' = \frac{v+30}{v}n'$ ...(ii)

[n'' = frequency heard by the driver after reflection]

From Eqs. (i) and (ii), we get

$$n'' = \frac{v+30}{v-30}n = \frac{360}{300}\times 600 = 720 \text{ Hz}$$

76 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 **[CBSE AIPMT 2004]**

(a) $\frac{v}{\sqrt{2}}$ (b) $\frac{v}{3}$ (c) $\frac{v}{4}$ (d) $\frac{v}{2}$

Ans. *(b)*

When the sound is reflected from the cliff, it approaches the driver of the car. Therefore, the driver acts as an observer and both the source (car) and observer are moving.

Hence, apparent frequency heard by the observer (driver) is given by

$$f' = f\left(\frac{v+v_o}{v-v_s}\right) \quad \text{...(i)}$$

where, v = velocity of sound,

v_o = velocity of car = v_s

Thus, Eq. (i) becomes

$$\therefore \quad 2f = f\left(\frac{v+v_o}{v-v_o}\right)$$

or $2v - 2v_o = v + v_o$

or $3v_o = v$ or $v_o = \frac{v}{3}$

77 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 **[CBSE AIPMT 2003]**

(a) $f, 1.2\lambda$ (b) $0.8f, 0.8\lambda$
(c) $1.2f, 1.2\lambda$ (d) $1.2f, \lambda$

Ans. *(d)*

When an observer moves towards a stationary source of sound, then apparent frequency heard by the observer increases. The apparent frequency heard in this situation

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

As source is stationary hence, $v_s = 0$

$$\therefore \quad f' = \left(\frac{v+v_o}{v}\right)f$$

Given, $v_o = \frac{v}{5}$

Substituting in the relation for f', we have

$$f' = \left(\frac{v+v/5}{v}\right)f = \frac{6}{5}f = 1.2f$$

Motion of observer does not affect the wavelength reaching the observer, hence, wavelength remains λ.

78 A whistle revolves in a circle with angular velocity $\omega = 20$ rad/s using a string of length 50 cm. If the actual frequency of sound from the whistle is 385 Hz, then the minimum frequency heard by the observer far away from the centre is (velocity of sound $v = 340$ m/s) **[CBSE AIPMT 2002]**

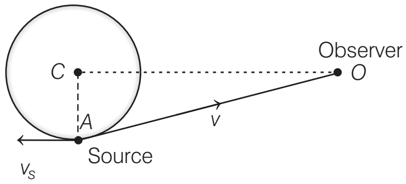
(a) 385 Hz (b) 374 Hz
(c) 394 Hz (d) 333 Hz

Ans. *(b)*

Velocity of source (whistle) is given by

$$v_s = r\omega = (0.5 \text{ m})(20 \text{ rad/s}) = 10 \text{ m/s}$$

The frequency of sound observed by the observer will be minimum when he is at point A. Thus, at this point minimum frequency of source as observed by observer is



$$f_{min} = \left(\frac{v}{v+v_s}\right)n$$

$$f_{min} = \frac{340}{340+10} \times 385$$

$$= \frac{34}{35} \times 385 = 34 \times 11 = 374 \text{ Hz}$$

79 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 (If the sound velocity in air is 300 m/s) **[CBSE AIPMT 1998]**

(a) $n_1 = 10n$ (b) $n_1 = 0$
(c) $n_1 = 0.1n$ (d) $n_1 = -0.1n$

Ans. *(b)*

When velocity of source (vehicle) is perpendicular to the line joining the observer and source, then there is no Doppler effect of sound as the component of velocity either towards or away from the observer is zero. So, there is no change in apparent frequency. Therefore, $n_1 = 0$.

80 A star which is emitting radiation at a wavelength of 5000 Å is approaching the earth with a velocity of 1.50×10^6 m/s. The change in wavelength of the radiation as received on the earth is **[CBSE AIPMT 1996]**

(a) 0.25 Å (b) 2.5 Å (c) 25 Å (d) 250 Å

Ans. *(c)*

The phenomenon of apparent change in frequency (or wavelength) of the light due to the relative motion between the source of light and the observer is called Doppler effect in light.

So, $$\Delta\lambda = \lambda \times \frac{v}{c} \quad \text{...(i)}$$

Given, wavelength $\lambda = 5000$ Å

Velocity of source $= 1.5 \times 10^6$ m/s

$c = 3 \times 10^8$ m/s

$$\therefore \quad \Delta\lambda = 5000 \times \frac{1.5 \times 10^6}{3 \times 10^8} = 25 \text{Å}$$

81 Two trains move towards each other with the same speed. The speed of sound is 340 m/s. If the height of the tone of the whistle of one of them heard on the other changes 9/8 times, then the speed of each train should be **[CBSE AIPMT 1991]**

(a) 20 m/s (b) 2 m/s
(c) 200 m/s (d) 2000 m/s

Ans. *(a)*

According to Doppler's effect, whenever there is a relative motion between a source of sound and listener, the apparent frequency of sound heard by the listener is different from the actual frequency of sound emitted by the source.

Apparent frequency of sound wave heard by the listener is

$$\nu' = \frac{v - v_l}{v - v_s} \times \nu$$

where, ν is actual frequency of sound emitted by the source, v_s is velocity of source and v_l is velocity of listener.

According to problem, $\nu' = (9/8)\nu$ and source and observer are moving in opposite directions with same speed (say v), then apparent frequency

$$\nu' = \nu \times \left(\frac{v + v_l}{v - v_s}\right)$$

$$\therefore \quad \frac{9}{8}\nu = \nu \times \frac{340 + v}{340 - v}$$

$$\therefore \quad 17v = 340$$

or $$v = \frac{340}{17} = 20 \text{ m/s}$$