PHYSICS

Crash Course for
JEE Main 2020

MECHANICAL WAVES

STRING WAVES

GENERAL EQUATION OF WAVE MOTION :

$$\frac{\partial^2 y}{\partial t^2} = v^2 \frac{\partial^2 y}{\partial x^2}$$

$y(x,t) = f\left(t \pm \frac{x}{v}\right)$

where, y (x, t) should be finite everywhere.

$\Rightarrow$ $f\left(t + \frac{x}{v}\right)$ represents wave travelling in – ve x-axis.

$\Rightarrow$ $f\left(t - \frac{x}{v}\right)$ represents wave travelling in + ve x-axis.

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

TERMS RELATED TO WAVE MOTION (FOR 1-D PROGRESSIVE SINE WAVE)

(e) Wave number (or propagation constant) (k) :

$k = 2\pi/\lambda = \frac{\omega}{v}$ (rad m^{-1})

(f) Phase of wave : The argument of harmonic function $(\omega t \pm kx + \phi)$ is called phase of the wave.

Phase difference $(\Delta\phi)$: difference in phases of two particles at any time t.

$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$ Also. $\Delta\phi = \frac{2\pi}{T}.\Delta t$

SPEED OF TRANSVERSE WAVE ALONG A STRING/WIRE.

$v = \sqrt{\frac{T}{\mu}}$ where T = Tension, μ = mass per unit length

POWER TRANSMITTED ALONG THE STRING BY A SINE WAVE

Average Power $\langle P \rangle = 2\pi^2 f^2 A^2 \mu v$

Intensity $I = \frac{\langle P \rangle}{s} = 2\pi^2 f^2 A^2 \rho v$

REFLECTION AND REFRACTION OF WAVES

$y_i = A_i \sin(\omega t - k_1 x)$

$$\left.\begin{aligned} y_t &= A_t \sin(\omega t - k_2 x) \\ y_r &= -A_r \sin(\omega t + k_1 x) \end{aligned}\right]$$ if incident from rarer to denser medium $(v_2 < v_1)$

$$\left.\begin{aligned} y_t &= A_t \sin(\omega t - k_2 x) \\ y_r &= A_r \sin(\omega t + k_1 x) \end{aligned}\right]$$ if incident from denser to rarer medium. $(v_2 > v_1)$

(d) Amplitude of reflected & transmitted waves.

$A_r = \frac{|k_1 - k_2|}{k_1 + k_2} A_i$ & $A_t = \frac{2k_1}{k_1 + k_2} A_i$

STANDING/STATIONARY WAVES :-

(b) $y_1 = A \sin(\omega t - kx + \theta_1)$

$y_2 = A \sin(\omega t + kx + \theta_2)$

$$y_1 + y_2 = \left[2\,A\cos\left(kx + \frac{\theta_2 - \theta_1}{2}\right)\right]\sin\left(\omega t + \frac{\theta_1 + \theta_2}{2}\right)$$

The quantity $2A\cos\left(kx + \frac{\theta_2 - \theta_1}{2}\right)$ represents resultant amplitude at x. At some position resultant amplitude is zero these are called **nodes**. At some positions resultant amplitude is 2A, these are called **antinodes.**

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

(d) Distance between successive nodes and antinodes = $\lambda/4$.

(e) All the particles in same segment (portion between two successive nodes) vibrate in same phase.

(f) The particles in two consecutive segments vibrate in opposite phase.

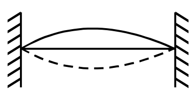
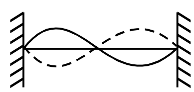
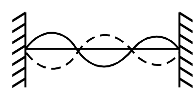
(g) Since nodes are permanently at rest so energy can not be transmitted across these.

VIBRATIONS OF STRINGS (STANDING WAVE)

(a) Fixed at both ends :

1. Fixed ends will be nodes. So waves for which

$L = \frac{\lambda}{2}$ $\quad$ $L = \frac{2\lambda}{2}$ $\quad$ $L = \frac{3\lambda}{2}$

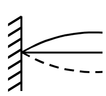
are possible giving

$L = \frac{n\lambda}{2}$ $\quad$ or $\lambda = \frac{2L}{n}$ where n = 1, 2, 3, ...

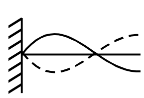
as $\quad v = \sqrt{\frac{T}{\mu}}$ $\quad$ $f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$, n = no. of loops

(b) String free at one end :

1. for fundamental mode $L = \frac{\lambda}{4}$ = or $\lambda = 4L$

 fundamental mode

First overtone $L = \frac{3\lambda}{4}$ Hence $\lambda = \frac{4L}{3}$

$\Rightarrow$  first overtone

so $f_1 = \frac{3}{4L}\sqrt{\frac{T}{\mu}}$ (First overtone)

Second overtone $f_2 = \frac{5}{4L}\sqrt{\frac{T}{\mu}}$

so $f_n = \frac{\left(n+\frac{1}{2}\right)}{2L}\sqrt{\frac{T}{\mu}} = \frac{(2n+1)}{4L}\sqrt{\frac{T}{\mu}}$

SOUND WAVES

(i) Longitudinal displacement of sound wave

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

(ii) Pressure excess during travelling sound wave

$P_{ex} = -B\frac{\partial \xi}{\partial x}$ (it is true for travelling

$= (BAk)\cos(\omega t - kx)$

wave as well as standing waves)

Amplitude of pressure excess = BAk

(iii) Speed of sound $C = \sqrt{\frac{E}{\rho}}$

Where E = Ellastic modulus for the medium

ρ = density of medium

– for solid $C = \sqrt{\frac{Y}{\rho}}$

where Y = young's modulus for the solid

– for liquid $C = \sqrt{\frac{B}{\rho}}$

where B = Bulk modulus for the liquid

– for gases $C = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M_0}}$

where M_0 is molecular wt. of the gas in (kg/mole)

Intensity of sound wave :

$< I > = 2\pi^2 f^2 A^2 \rho v = \frac{P_m^2}{2\rho v}$ $\quad < I > \propto P_m{}^2$

(iv) Loudness of sound : $L = 10\log_{10}\left(\frac{I}{I_0}\right)$ dB

where $I_0 = 10^{-12}$ W/m^2 (This the minimum intensity human ears can listen)

Intensity at a distance r from a point source = $I = \frac{P}{4\pi r^2}$

Interference of Sound Wave

if $P_1 = p_{m1}\sin(\omega t - kx_1 + \theta_1)$

$P_2 = p_{m2}\sin(\omega t - kx_2 + \theta_2)$

resultant excess pressure at point O is

$p = P_1 + P_2$

$p = p_0 \sin(\omega t - kx + \theta)$

$p_0 = \sqrt{p_{m_1}^2 + p_{m_2}^2 + 2p_{m_1}p_{m_2}\cos\phi}$

where $\phi = [k(x_2 - x_1) + (\theta_1 - \theta_2)]$

and $I = I_1 + I_2 + 2\sqrt{I_1 I_2}$

(i) For constructive interference

$\phi = 2n\pi$ and $\Rightarrow$ $p_0 = p_{m1} + p_{m2}$ (constructive interference)

(ii) For destructive interfrence

$\phi = (2n+1)\pi$ and $\Rightarrow$ $p_0 = |p_{m1} - p_{m2}|$ (destructive interference)

If ϕ is due to path difference only then $\phi = \frac{2\pi}{\lambda}\Delta x$.

Condition for constructive interference : $\Delta x = n\lambda$

Condition for destructive interference : $\Delta x = (2n+1)\frac{\lambda}{2}$.

(a) If $p_{m1} = p_{m2}$ and $\theta = \pi, 3\pi, \ldots$
resultant p = 0 i.e. no sound

(b) If $p_{m1} = p_{m2}$ and $\phi = 0, 2\pi, 4\pi, \ldots$
$p_0 = 2p_m$ & $I_0 = 4I_1$
$p_0 = 2p_{m1}$

Close organ pipe :

$f = \frac{v}{4\ell}, \frac{3v}{4\ell}, \frac{5v}{4\ell}, \ldots\ldots\ldots \frac{(2n+1)v}{4\ell}$ n = overtone

Open organ pipe :

$f = \frac{v}{2\ell}, \frac{2v}{2\ell}, \frac{3v}{2\ell}, \ldots\ldots\ldots \frac{nV}{2\ell}$

Beats : Beatsfrequency = $|f_1 - f_2|$.

Doppler's Effect

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

and Apparent wavelength $\lambda' = \lambda\left(\frac{v - v_s}{v}\right)$

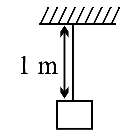
SECTION-1 SCQ

Q.1 A wave is propagating along x-axis. The displacement of particles of the medium in z-direction at t = 0 is given by: $z = \exp[-(x+2)^2]$, where 'x' is in meters. At t = 1s, the same wave disturbance is given by: $z = \exp[-(2-x)^2]$. Then, the wave propagation velocity is

(A) 4 m/s in + x direction (B) 4 m/s in –x direction

(C) 2 m/s in + x direction (D) 2 m/s in – x direction

Q.2 A block of mass 1 kg is hanging vertically from a string of length 1 m and mass/length = 0.001 Kg/m. A small pulse is generated at its lower end. The pulse reaches the top end in approximately



(A) 0.2 sec (B) 0.1 sec (C) 0.02 sec (D) 0.01 sec

Q.3 Consider a function $y = 10\sin^2(100\pi t + 5\pi z)$ where y, z are in cm and t is in second.

(A) the function represents a travelling, periodic wave propagating in (–z) direction with speed 20m/s.

(B) the function does not represent a travelling wave.

(C) the amplitude of the wave is 5 cm.

(D) the amplitude of the wave is 10 cm.

Q.4 A string 1m long is drawn by a 300Hz vibrator attached to its end. The string vibrates in 3 segments. The speed of transverse waves in the string is equal to

(A) 100 m/s (B) 200 m/s (C) 300 m/s (D) 400 m/s

Q.5 The resultant amplitude due to superposition of two waves $y_1 = 5\sin(wt - kx)$ and $y_2 = -5\cos(wt - kx - 150°)$

(A) 5 (B) $5\sqrt{3}$ (C) $5\sqrt{2-\sqrt{3}}$ (D) $5\sqrt{2+\sqrt{3}}$

Q.6 A taut string at both ends vibrates in its n^{th} overtone. The distance between adjacent Node and Antinode is found to be 'd'. If the length of the string is L, then

(A) L = 2d (n + 1) (B) L = d (n + 1) (C) L = 2dn (D) L = 2d (n – 1)

Q.7 A standing wave $y = A\sin\left(\frac{20}{3}\pi x\right)\cos(1000\pi t)$ is maintained in a taut string where y and x are expressed in meters. The distance between the successive points oscillating with the amplitude A/2 across a node is equal to

(A) 2.5cm (B) 25cm (C) 5cm (D) 10cm

Q.8 A string of length 1m and linear mass density 0.01kgm^{-1} is stretched to a tension of 100N. When both ends of the string are fixed, the three lowest frequencies for standing wave are f_1, f_2 and f_3. When only one end of the string is fixed, the three lowest frequencies for standing wave are n_1, n_2 and n3. Then

(A) $n_3 = 5n_1 = f_3 = 125$ Hz (B) $f_3 = 5f_1 = n_2 = 125$ Hz

(C) $f_3 = n_2 = 3f_1 = 150$ Hz (D) $n_2 = \frac{f_1 + f_2}{2} = 75$ Hz

Q.9 A person can hear frequencies only upto 10 kHz. A steel piano wire 50 cm long of mass 5 g is stretched with a tension of 400 N. The number of the highest overtone of the sound produced by this piano wire that the person can hear is

(A) 48 (B) 50 (C) 49 (D) 51

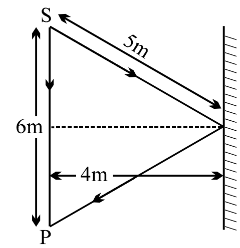
Q.10 A string of length 0.4 m & mass 10^{-2} kg is tightly clamped at its ends . The tension in the string is 1.6 N. Identical wave pulses are produced at one end at equal intervals of time, Δt . The minimum value of Δt which allows constructive interference between successive pulses is :

(A) 0.05 s (B) 0.10 s (C) 0.20 s (D) 0.40 s

Q.11 Three coherent waves of equal frequencies having amplitude 10 μm, 4μm and 7 μm respectively, arrive at a given point with successive phase difference of $\pi/2$. The amplitude of the resulting wave in μm is given by

(A) 5 (B) 6 (C) 3 (D) 4

Q.12 A person standing at a distance of 6 m from a source of sound receives sound wave in two ways, one directly from the source and other after reflection from a rigid boundary as shown in the figure. The maximum wavelength for which, the person will receive maximum sound intensity, is



(A) 4 m (B) $\frac{16}{3}$ m (C) 2 m (D) $\frac{8}{3}$ m

Q.13 In Quincke's tube a detector detects minimum intensity. Now one of the tube is displaced by 5 cm. During displacement detector detects maximum intensity 10 times, then finally a minimum intensity (when displacement is complete). The wavelength of sound is:

(A) 10/9 cm (B) 1 cm (C) 1/2 cm (D) 5/9 cm

Q.14 Two waves of sound having intensities I and 4I interfere to produce interference pattern. The phase difference between the waves is $\pi/2$ at point A and π at point B. Then the difference between the resultant intensities at A and B is

(A) 2I (B) 4I (C) 5I (D) 7I

Q.15 A tuning fork of frequency 340 Hz is vibrated just above a cylindrical tube of length 120 cm. Water is slowly poured in the tube. If the speed of sound is 340 ms^{-1} then the minimum height of water required for resonance is:

(A) 95 cm (B) 75 cm (C) 45 cm (D) 25 cm

Q.16 In a closed end pipe of length 105 cm, standing waves are set up corresponding to the third overtone. What distance from the closed end, amongst the following, is a pressure Node?

(A) 20 cm (B) 60 cm (C) 85 cm (D) 45 cm

Q.17 A pipe's lower end is immersed in water such that the length of air column from the top open end has a certain length 25 cm. The speed of sound in air is 350 m/s. The air column is found to resonate with a tuning fork of frequency 1750 Hz. By what minimum distance should the pipe be raised in order to make the air column resonate again with the same tuning fork?

(A) 7 cm (B) 5 cm (C) 35 cm (D) 10 cm

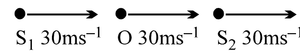
Q.18 Two tuning forks A & B produce notes of frequencies 256 Hz & 262 Hz respectively. An unknown note sounded at the same time as A produces beats . When the same note is sounded with B, beat frequency is twice as large . The unknown frequency could be :

(A) 268 Hz (B) 260 Hz (C) 250 Hz (D) 242 Hz

Q.19 A closed organ pipe and an open pipe of same length produce 4 beats when they are set into vibrations simultaneously. If the length of each of them were twice their initial lengths, the number of beats produced will be

(A) 2 (B) 4 (C) 1 (D) 8

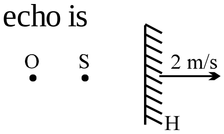
Q.20 Consider two sound sources S_1 and S_2 having same frequency 100Hz and the observer O located between them as shown in the fig. All the three are moving with same velocity in same direction. The beat frequency of the observer is



(A) 50Hz (B) 5 Hz (C) zero (D) 2.5 Hz

Q.21 A stationary sound source 's' of frequency 334 Hz and a stationary observer 'O' are placed near a reflecting surface moving away from the source with velocity 2 m/sec as shown in the figure. If the velocity of the sound waves in air is V = 330 m/sec, the apparent frequency of the echo is

(A) 332 Hz (B) 326 Hz
(C) 334 Hz (D) 330 Hz

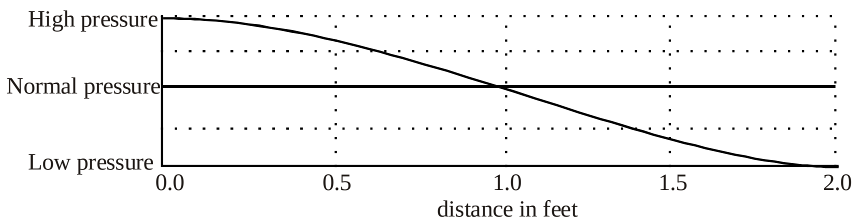


Q.22 A sounding body of negligible dimension emitting a frequency of 150 Hz is dropped from a height. During its fall under gravity it passes near a balloon moving up with a constant velocity of 2m/s one second after it started to fall.The difference in the frequency observed by the man in balloon just before and just after crossing the body will be : (Given that -velocity of sound = 300m/s; g = 10m/s^2)

(A) 12 (B) 6 (C) 8 (D) 4

Paragraph for Question Nos. 23 to 25

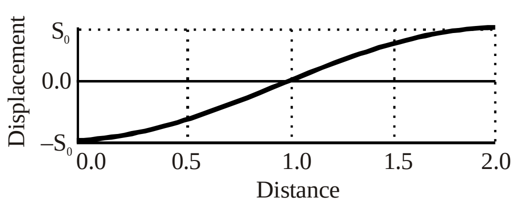
A tube of air 2 feet in length has a pressure versus distance graph as shown at t = 0. It is vibrating in one of its allowed standing wave modes.

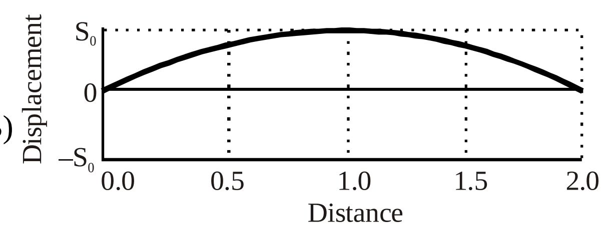


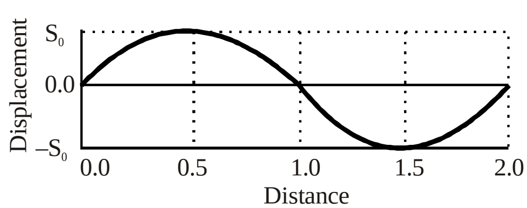
Q.23 The tube has
(A) both ends open (B) both ends closed
(C) left end open, right end closed (D) left end closed, right end open

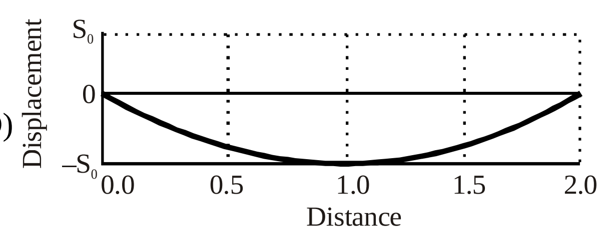
Q.24 Which standing wave is this?
(A) fundamental (B) second harmonic (C) second overtone (D) first overtone

Q.25 Which of the following graphs of molecular displacement vs. horizontal distance corresponds to the above pressure graph?

(A)


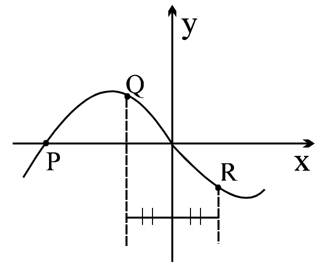
(B)


(C)


(D)


SECTION-2 MCQ

Q.1 At a certain moment, the photograph of a string on which a harmonic wave is travelling to the right is shown. Then, which of the following is true regarding the velocities of the points P, Q and R on the string.



(A) v_P is upwards (B) $v_Q = -v_R$

(C) $|v_P| > |v_Q| = |v_R|$ (D) $v_Q = v_R$

Q.2 A perfectly elastic uniform string is suspended vertically with its upper end fixed to the ceiling and the lower end loaded with the weight. If a transverse wave is imparted to the lower end of the string, the pulse will

(A) not travel along the length of the string (B) travel upwards with increasing speed

(C) travel upwards with decreasing speed (D) travelled upwards with constant acceleration

Q.3 One end of a string of length L is tied to the ceiling of a lift accelerating upwards with an acceleration 2g. The other end of the string is free. The linear mass density of the string varies linearly from 0 to λ from bottom to top.

(A) The velocity of the wave in the string will be 0.

(B) The acceleration of the wave on the string will be 3g/4 every where.

(C) The time taken by a pulse to reach from bottom to top will be $\sqrt{8L/3g}$.

(D) The time taken by a pulse to reach from bottom to top will be $\sqrt{4L/3g}$.

Q.4 The vibration of a string fixed at both ends are described by $Y = 2\sin(\pi x)\sin(100\pi t)$ where Y is in mm, x is in cm, t in sec then

(A) Maximum displacement of the particle at x = 1/6 cm would be 1 mm.

(B) velocity of the particle at x = 1/6 cm at time t = 1/600 sec will be $157\sqrt{3}$ mm/s

(C) If the length of the string be 10 cm, number of loop in it would be 5

(D) None of these

Q.5 The length, tension, diameter and density of a wire B are double than the corresponding quantities for another stretched wire A. Then.

(A) Fundamental frequency of B is $\frac{1}{2\sqrt{2}}$ times that of A.

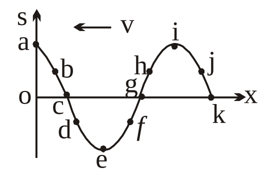
(B) The velocity of wave in B is $\frac{1}{\sqrt{2}}$ times that of velocity in A.

(C) The fundamental frequency of A is equal to the third overtone of B.

(D) The velocity of wave in B is half that of velocity in A.

Question No. 6 to 11 (6 questions)

The figure represents the instantaneous displacement-position graph of a longitudinal harmonic wave travelling along the negative x-axis. Identify the correct statement(s) related to the movement of the points shown in the figure.



Q.6 The points moving in the direction of wave are

(A) b (B) c (C) f (D) i

Q.7 The points moving opposite to the direction of propagation are

(A) a (B) d (C) f (D) j

Q.8 The stationary points are

(A) a (B) c (C) g (D) k

Q.9 The maximum displaced points are

(A) a (B) e (C) g (D) i

Q.10 The points of maximum compression are

(A) c (B) g (C) e (D) k

Q.11 The points of maximum rarefaction are

(A) a (B) e (C) g (D) i

Q.12 Two waves are propagating along a taut string that coincides with the x-axis. The first wave has the wave function $y_1 = A\cos[k(x - vt)]$ and the second has the wave function $y = A\cos[k(x + vt) + \phi]$.

(A) For constructive interference at $x = 0$, $\phi = \pi$. (B) For constructive interference at $x = 0$, $\phi = 3\pi$.

(C) For destructive interference at $x = 0$, $\phi = \pi$. (D) For destructive interference at $x = 0$, $\phi = 2\pi$.

Q.13 Two interfering waves have the same wavelength, frequency, and amplitude. They are traveling in the same direction but are 90° out of phase. Compared to the individual waves, the resultant wave will have the same.

(A) amplitude and velocity but different wavelength

(B) amplitude and wavelength but different velocity

(C) wavelength and velocity but different amplitude

(D) amplitude and frequency but different velocity

Q.14 A gas is filled in an organ pipe and it is sounded in fundamental mode. Choose the correct statement(s) : (T = constant)

(A) If gas is changed from H_2 to O_2, the resonant frequency will increase

(B) If gas is changed from O_2 to N_2, the resonant frequency will increase

(C) If gas is changed from N_2 to He, the resonant frequency will decrease

(D) If gas is changed from He to CH_4, the resonant frequency will decrease

Q.15 A closed organ pipe of length 1.2 m vibrates in its first overtone mode. The pressure variation is maximum at:

(A) 0.8 m from the open end (B) 0.4 m from the open end

(C) at the open end (D) 1.0 m from the open end

Q.16 For a certain organ pipe three successive resonance frequencies are observed at 425 Hz, 595 Hz and 765 Hz respectively. If the speed of sound in air is 340 m/s, then the length of the pipe is:

(A) 2.0 m (B) 0.4 m (C) 1.0 m (D) 0.2 m

Q.17 In an organ pipe whose one end is at x = 0, the pressure is expressed by

$$p = p_0 \cos\frac{3\pi x}{2}\sin 300\pi t$$ where x is in meter and t in sec. The organ pipe can be

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

(B) open at both ends, length = 1m

(C) closed at both ends, length = 2m

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

Q.18 Two whistles A and B each have a frequency of 500Hz. A is stationary and B is moving towards the right (away from A) at a speed of 50 m/s. An observer is between the two whistles moving towards the right with a speed of 25 m/s. The velocity of sound in air is 350 m/s. Assume there is no wind. Then which of the following statements are true:

(A) The apparent frequency of whistle B as heard by A is 444Hz approximately

(B) The apparent frequency of whistle B as heard by the observer is 469Hz approximately

(C) The difference in the apparent frequencies of A and B as heard by the observer is 4.5 Hz.

(D) The apparent frequencies of the whistles of each other as heard by A and Bare the same.

Q.19 A car moves towards a hill with speed v_c. It blows a horn of frequency f which is heared by an observer following the car with speed v_0. The speed of sound in air is v.

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

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

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

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

SECTION-3 INTEGER

Q.1 The wave function for a traveling wave on a taut string is (in SI units)

$$y(x, t) = (0.350 \text{ m}) \sin (10\pi t - 3\pi x + \pi/4)$$

(a) What are the speed and direction of travel of the wave ?

(b) What is the vertical displacement of the string at t = 0, x = 0.100 m ? ($\sin 9^\circ = 0.156$)

(c) What are wavelength and frequency of the wave ?

(d) What is the maximum magnitude of the transverse speed of a particle of the string ?

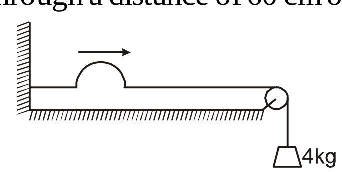
Q.2 A non–uniform rope of mass M and length L has a variable linear mass density given by $\mu = kx$, where x is the distance from one end of the wire and k is a constant .

(a) Show that $M = kL^2/2$.

(b) Show that the time required for a pulse generated at one end of the wire to travel to the other end is given by $t = \sqrt{(8ML / 9F)}$ where F (constant)is the tension in the wire.

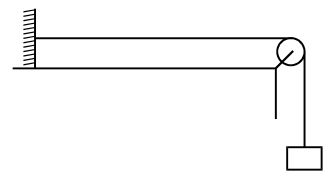
Q.3 A wire of 9.8×10^{-3} kg per meter mass passes over a frictionless pulley fixed on the top of an inclined frictionless plane which makes an angle of 30° with the horizontal. Masses M_1 & M_2 are tied at the two ends of the wire. The mass M_1 rests on the plane and the mass M_2 hangs freely vertically downwards. The whole system is in equilibrium. Now a transverse wave propagates along the wire with a velocity of 100 m/sec. Find the value of masses M_1 & M_2 .

Q.4 Figure shows a string of linear mass density 1.0 g/cm on which a wave pulse is travelling. Find the time taken by the pulse in travelling through a distance of 60 cm on the string. Take $g = 10 \text{ m/s}^2$.



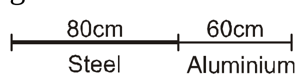
Q.5 A uniform horizontal rod of length 40 cm and mass 1.2 kg is supported by two identical wires as shown in figure. Where should a mass of 4.8 kg be placed on the rod so that the same tuning fork may excite the wire on left into its fundamental vibrations and that
on right into its first overtone? Take g = 10 m/s^2.

Q.6 Figure shows a string stretched by a block going over a pulley. The string vibrates in its tenth harmonic in resonance with a particular tuning fork. When a beaker containing water is brought under the block so that the block is completely dipped into the beaker, the string vibrates in its eleventh harmonic. Find the density of the material of the block. (node is formed at the pulley)



Q.7 A steel wire of length 1 meter, mass 0.1 kg and uniform cross sectional area 10^{-6} m^2 is rigidly fixed at both ends. The temperature of the wire is lowered by 20°C. If transverse waves are setup by plucking the string in the middle, calculate the frequency of the fundamental mode of vibration. Young's modulus of steel = 2×10^{11} N/m^2, coefficient of linear expansion of steel = 1.21×10^{-5}/ °C.

Q.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 40 N. The cross-sectional area of the steel wire is 1.0 mm^2 and that of the aluminium wire is 3.0 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.



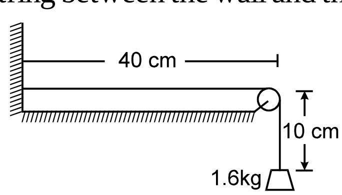
Q.9 A travelling wave of amplitude 5 A is partially reflected from a boundary with the amplitude 3 A.Due to superposition of two waves with different amplitudes in opposite directions a standing wave pattern is formed. Determine the amplitude at node and antinodes.

Q.10 Two waves are described by

$$y_1 = 0.30 \sin [\pi(5x - 200t)] \quad \text{and} \quad y_2 = 0.30 \sin [\pi(5x - 200t) + \pi/3]$$

where y_1, y_2 and x are in meters and t is in seconds. When these two waves are combined, a traveling wave is produced. What are the (a) amplitude, (b) wave speed, and (c) wave length of that traveling wave ?

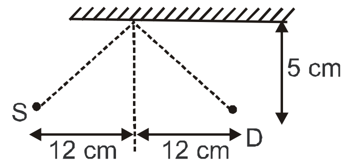
Q.11 A 50 cm long wire of mass 20 g supports a mass of 1.6 kg as shown in figure. Find the first overtone frequency of the portion of the string between the wall and the pulley. Take g = 10 m/s^2.



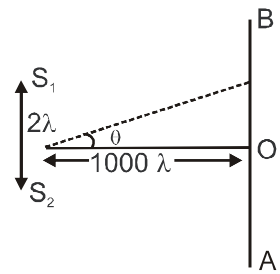
Q.12 (a) Find the speed of sound in a mixture of 1 mol of helium and 2 mol of oxygen at 27°C.
(b) If now temp. is raised by 1K from 300 K. Find the percentage change in the speed of sound in the gaseous mixture. [Note : This can be done after studying heat.]

Q.13 Two sources of sound, S_1 and S_2, emitting waves of equal wavelength 2 cm, are placed with a separation of 3 cm between them. A detector can be moved on a line parallel to S_1S_2 and at a distance of 24 cm from it. Initially, the detector is equidistant from the two sources. Assuming that the waves emitted by the sources are in phase, find the minimum distance through which the detector should be shifted to detect a minimum of sound.

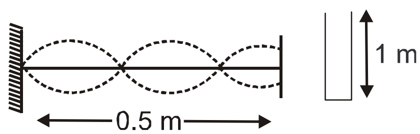
Q.14 A sound source, detector and a cardboard are arranged as shown in figure. The wave is reflected from the cardboard at the line of symmetry of source and detector. Initially the path difference between the reflected wave and the direct wave is one third of the wavelength of sound. Find the minimum distance by which the cardboard should be moved upwards so that both waves are in phase.



Q.15 Two coherent sources S_1 and S_2 (in phase with each other) are placed at a distance of 2λ as shown where λ is wavelength of sound. A detector moves on line A B parallel to S_1 S_2. Find the θ where detector detects maximum intensity at finite distance from O.



Q.16 A 0.5 m wire of mass 5g in its second overtone is in resonance with organ pipe of 1m in its fundamental mode. Find the tension in wire if speed of sound in air is 320 m/s.



Q.17 A string 25 cm long fixed at both ends and having a mass of 2.5 g is under tension . A pipe closed from one end is 40 cm long. When the string is set vibrating in its first overtone and the air in the pipe in its fundamental frequency, 8 beats per second are heard. It is observed that decreasing the tension in the string decreases the beat frequency. If the speed of sound in air is 320 m/s. Find tension in the string.

Q.18 A source of sound of frequency f is dropped from rest from a height h above the ground. An observer O_1 stands on the ground and another observer O_2 stands inside water at a depth d from the ground. Both O_1 and O_2 are vertically below the source. The velocity of sound in water is $4V$ and that in air is V . Find :

(a) The frequency of the sound detected by O_1 and O_2 corresponding to the sound emitted by the source initially.

(b) The frequency detected by both O_1 and O_2 corresponding to the sound emitted by the source at height $\frac{h}{2}$ from the ground .

ANSWER KEY

SECTION-1
SCQ

Q.1	A	Q.2	D	Q.3	C	Q.4	B	Q.5	A	Q.6	A	Q.7	C
Q.8	D	Q.9	C	Q.10	B	Q.11	A	Q.12	A	Q.13	B	Q.14	B
Q.15	C	Q.16	D	Q.17	D	Q.18	C	Q.19	A	Q.20	C	Q.21	D
Q.22	A	Q.23	B	Q.24	A	Q.25	D						

SECTION-2
MCQ

Q.1	C, D	Q.2	B, D	Q.3	B, C	Q.4	A, B	Q.5	C, D	Q.6	A, B	Q.7	C
Q.8	A	Q.9	A, B, D			Q.10	A, D	Q.11	C	Q.12	C	Q.13	C
Q.14	B, D	Q.15	B	Q.16	C	Q.17	C	Q.18	B, C	Q.19	B, D		

SECTION-3
INTEGER

Q.1 (a) $\frac{10}{3}\hat{i}$ m/s (b) –5.48 cm (c) 0.667 m, 5.00 Hz (d) 11.0 m/s

Q.2 (a) $K = \frac{2M}{L^2}$ (b) $\sqrt{\frac{8ML}{9F}}$

Q.3 $M_2 = 10$ kg , $M_1 = 20$ kg

Q.4 0.03 sec.

Q.5 5 cm from the left end

Q.6 $\frac{121}{21} \times 10^3$ kg/m^3

Q.7 11 vibrations/sec.

Q.8 180 Hz

Q.9 2 A, 8 A

Q.10 (a) 0.52 m; (b) 40 m/s ; (c) 0.40 m

Q.11 50 Hz.

Q.12 (a) ≈ 400.9 m/s (b) $\frac{1}{6}$ %

Q.13 8.5 cm

Q.14 4 cm

Q.15 ± 30º

Q.16 10.25

Q.17 27.0400 N

Q.18 (a) $f_2 = f_1 = \frac{2vf^2}{2vf - g}$ (b) $f_1 = f_2 = \frac{2vf^2}{2(v - \sqrt{gh})f - g}$