विध्न विचारत भीरु जन, नहीं आरम्भे काम, विपति देख छोड़े तुरंत मध्यम मन कर श्याम।
पुरुष सिंह संकल्प कर, सहते विपति अनेक, 'बना' न छोड़े ध्येय को, रघुबर राखे टेक।।

रचितः मानव धर्म प्रणेता

सद्‌गुरु श्री रणछोड़दासजी महाराज

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KEY CONCEPTS

1. **Wave Equation :**

(i) The equation for a progressive wave travelling in the positive x-direction is

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

where y is the displacemnet at point x, at time t, A is the amplitude, T is the period and λ is the wavelength.

The frequency is $\frac{1}{T}$ and the velocity of the wave is $\frac{\lambda}{T}$.

(ii) The equation for a stationary wave is

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

(iii) Pitch, loudness and quality are the characteristics of a musical note. Pitch depends on the frequency. Loudness depends on intensity and quality depends on the waveform of the constituent overtones.

(iv) Resonance occurs when the forcing frequency is equal to the natural frequency of a vibrating body.

(v) Velocity of propagation of sound in a gas = $\sqrt{\frac{\gamma P}{D}}$, where D is the density of the gas and γ is the ratio of specific heats.

2. **Vibrating air columns :**

(i) In a pipe of length L closed at one end, the funamental note has a frequency $f_1 = \frac{v}{4L}$, where v is the velocity of sound in air.

(ii) The first overtone $f_2 = \frac{v}{L} = 2f_1$

3. **Propagation of sound in solids :**

(i) The velocity of propagation of a longitudinal wave in a rod of Young's modulus Y and density ρ is given by

$$v = \sqrt{\frac{Y}{\rho}}$$

(ii) The velocity of propagation of a transverse wave in a streched string

$$v = \sqrt{\frac{T}{m}}$$

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

(iii) In a sonometer wire of length L and mass per unit length m under tension T vibrating in n loops

$$f_n = \frac{n}{2L}\sqrt{\frac{T}{m}}$$

(iv) Propagation of sound in gases

Laplace formula $v = \sqrt{\dfrac{\gamma P}{\rho}}$

where γ is the ratio of specific heats, P is the pressure and ρ is the density.

$$\frac{v_t}{v_0} = \sqrt{\frac{T}{T_0}} = \sqrt{\frac{273 + t}{273}}$$

4. **Doppler Effects :**

(i) When a source of sound moves with a velocity v_s in a certain direction, the wavelength decreases in front of the source and increases behind the source.

$$\lambda' \text{ (in front)} = \frac{v - v_s}{f_s} \; ; \; f' = \frac{v}{\lambda'} = \frac{v}{v - v_s} f_s$$

$$\lambda'' \text{(behind)} = \frac{v + v_s}{f_s} \; ; \; f'' = \frac{v}{\lambda''} = \frac{v}{v + v_s} f_s$$

Here v is the velocity of sound in air.

(ii) The apparent frequency $= \dfrac{v - v_0}{v} f_s$

(a) When the source is moving towards the observer and the observer is moving away from the source, the apparent frequency

$$f_a = \frac{v - v_0}{v - v_s} f_s \qquad v_0 \longleftarrow o \qquad v_s \longleftarrow s$$

(b) When the source and the observer are moving towards each other.

$$f_a = \frac{v + v_0}{v - v_s} f_s \qquad o \longrightarrow v_0 \qquad v_s \longleftarrow s$$

(c) When the source and observer are moving away from each other,

$$f_a = \frac{v - v_0}{v + v_s} f_s \qquad v_0 \longleftarrow o \qquad s \longrightarrow v_s$$

(d) When the source is moving away from the observer and the observer is moving towards the source

$$f_a = \frac{v + v_0}{v + v_s} f_s \qquad o \longrightarrow v_0 \qquad s \longrightarrow v_s$$

Here all velocities are relation to the medium.

5. **Loudness of sound :**

The loudness level B of sound is expressed in decibels,

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

where I is the intensity, I_0 is a reference intensity.

6. **Beats :**

When two tuning forks of close but different frequencies f_1 and f_2 are vibrating simultaneously at nearby places, a listener observes a fluctuation in the intensity of sound, called beats. The number of beats heard per second is $f_1 - f_2$.

EXERCISE–I

Q.1 Two stationary sources A and B are sounding notes of frequency 680 Hz. An observer moves from A to B with a constant velocity u. If the speed of sound is 340 ms^{-1}, what must be the value of u so that he hears 10 beats per second?

Q.2 Find the intensity of sound wave whose frequency is 250 Hz. The displacement amplitude of particles of the medium at this position is 1×10^{-8} m. The density of the medium is 1 kg/m^3, bulk modulus of elasticity of the medium is 400 N/m^2.

Q.3 Two strings A and B with $\mu = 2$ kg/m and $\mu = 8$ kg/m respectively are joined in series and kept on a horizontal table with both the ends fixed. The tension in the string is 200 N. If a pulse of amplitude 1 cm travels in A towards the junction, then find the amplitude of reflected and transmitted pulse.

Q.4 A parabolic pulse given by equation y (in cm) = $0.3 - 0.1(x - 5t)^2$ ($y \geq 0$) x in meter and t in second travelling in a uniform string. The pulse passes through a boundary beyond which its velocity becomes 2.5 m/s. What will be the amplitude of pulse in this medium after transmission?

Q.5 A car moving towards a vertical wall sounds a horn. The driver hears that the sound of the horn reflected from the cliff has a pitch half-octave higher than the actual sound. Find the ratio of the velocity of the car and the velocity of sound.

Q.6 The first overtone of a pipe closed at one end resonates with the third harmonic of a string fixed at its ends. The ratio of the speed of sound to the speed of transverse wave travelling on the string is 2 :1. Find the ratio of the length of pipe to the length of string.

Q.7 A stretched uniform wire of a sonometer between two fixed knife edges, when vibrates in its second harmonic gives 1 beat per second with a vibrating tuning fork of frequency 200 Hz. Find the percentage change in the tension of the wire to be in unison with the tuning fork.

Q.8 Tuning fork A when sounded with a tuning fork B of frequency 480 Hz gives 5 beats per second. When the prongs of A are loaded with wax, it gives 3 beats per second. Find the original frequency of A.

Q.9 The loudness level at a distance R from a long linear source of sound is found to be 40dB. At this point, the amplitude of oscillations of air molecules is 0.01 cm. Then find the loudness level & amplitude at a point located at a distance '10R' from the source.

Q.10 A sonometer wires resonates with a given tuning fork forming standing waves with five antinodes between the two bridges when a mass of 9 kg is suspended from the wire. When this mass is replaced by M, the wire resonates with the same tuning fork forming three antinodes for the same position of bridges. Find the value of M.

Q.11 A car is moving towards a huge wall with a speed = c/10 , where c = speed of sound in still air. A wind is also blowing parallel to the velocity of the car in the same direction and with the same speed. If the car sounds a horn of frequency f, then what is the frequency of the reflected sound of the horn heared by driver of the car?

Q.12 A 40 cm long wire having a mass 3.2 gm and area of c.s. 1 mm^2 is stretched between the support 40.05 cm apart. In its fundamental mode. It vibrate with a frequency 1000/64 Hz. Find the young's modulus of the wire.

Q.13 A steel rod having a length of 1 m is fastened at its middle. Assuming young's modulus to be 2×10^{11} Pa, and density to be 8 gm/cm^3 find the fundamental frequency of the longitudinal vibration and frequency of first overtone.

Q.14 Two identical sounds A and B reach a point in the same phase. The resultant sound is C. The loudness of C is *n* dB higher than the loudness of A. Find the value of *n*.

Q.15 Sound of wavelength λ passes through a Quincke's tube, which is adjusted to give a maximum intensity I_0. Find the distance through the sliding tube should be moved to give an intensity $I_0/2$.

Q.16 In a resonance-column experiment, a long tube, open at the top, is clamped vertically. By a separate device, water level inside the tube can be moved up or down. The section of the tube from the open end to the water level act as a closed organ pipe. A vibrating tuning fork is held above the open end, first and the second resonances occur when the water level is 24.1 cm and 74.1 cm repsectively below the open end. Find the diameter of the tube.[Hint : end correction is 0.3 d]

Q.17 In a mixture of gases, the average number of degrees of freedom per molecule is 6. The rms speed of the molecules of the gas is *c*. Find the velocity of sound in the gas.

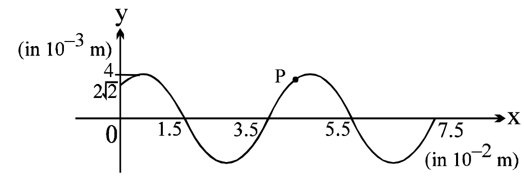
Q.18 A fixed source of sound emitting a certain frequency appears as f_a when the observer is approaching the source with speed v and frequency f_r when the observer recedes from the source with the same speed. Find the frequency of the source.

Q.19 A, B and C are three tuning forks. Frequency of A is 350Hz. Beats produced by A and B are 5 per second and by B and C are 4 per second. When a wax is put on A beat frequency between A and B is 2Hz and between A and C is 6Hz. Then, find the frequency of B and C respectively.

Q.20 An open organ pipe filled with air has a fundamental frequency 500Hz. The first harmonic of another organ pipe closed at one end and filled with carbon dioxide has the same frequency as that of the first harmonic of the open organ pipe. Calculate the length of each pipe. Assume that the velocity of sound in air and in carbondioxide to be 330 and 264 m/s respectively.

EXERCISE–II

Q.1 The figure shows a snap photograph of a vibrating string at $t = 0$. The particle P is observed moving up with velocity 20π cm/s. The angle made by string with x-axis at P is 6°.



(a) Find the direction in which the wave is moving
(b) the equation of the wave
(c) the total energy carried by the wave per cycle of the string , assuming that μ, the mass per unit length of the string = 50 gm/m.

Q.2 A uniform rope of length L and mass m is held at one end and whirled in a horizontal circle with angular velocity ω. Ignore gravity. Find the time required for a transverse wave to travel from one end of the rope to the other.

Q.3 A symmetrical triangular pulse of maximum height 0.4 m and total length 1 m is moving in the positive x-direction on a string on which the wave speed is 24 m/s. At $t = 0$ the pulse is entirely located between $x = 0$ and $x = 1$ m. Draw a graph of the transverse velocity of particle of string versus time at $x = +1$m.

Q.4 A steel wire 8×10^{-4} m in diameter is fixed to a support at one end and is wrapped round a cylindrical tuning peg 5 mm in diameter at the other end. The length of the wire between the peg and the support is 0.06 m. The wire is initially kept taut but without any tension. What will be the fundamental frequency of vibration of the wire if it is tightened by giving the peg a quarter of a turn?
Density of steel = 7800 kg/m^3, Y of steel = 20×10^{10} N/m^2.

Q.5 The displacement of the medium in a sound wave is given by the equation ; $y_1 = A\cos(ax + bt)$ where A, a & b are positive constants. The wave is reflected by an obstacle situated at $x = 0$. The intensity of the reflected wave is 0.64 times that of the incident wave.
(a) what are the wavelength & frequency of the incident wave.
(b) write the equation for the reflected wave.
(c) in the resultant wave formed after reflection, find the maximum & minimum values of the particle speeds in the medium.

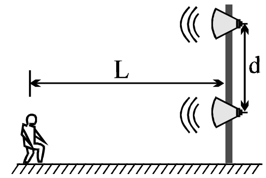
Q.6 In a stationary wave pattern that forms as a result of reflection of waves from an obstacle the ratio of the amplitude at an antinode and a node is $\beta = 1.5$. What percentage of the energy passes across the obstacle?

Q.7(a) A standing wave in second overtone is maintained in a open organ pipe of length l. The distance between consecutive displacement node and pressure node is ________ .
(b) Two consecutive overtones produced by a narrow air column closed at one end and open at the other are 750Hz and 1050Hz. Then the fundamental frequency from the column is _______.
(c) A standing wave of frequency 1100Hz in a column of methane at 20^0C produces nodes that are 20 cm apart. What is the ratio of the heat capacity at constant pressure to that at constant volume.

Q.8 A string, 25cm long, having a mass of 0.25 gm/cm, is under tension. A pipe closed at one end is 40cm long. When the string is set vibrating in its first overtone, and the air in the pipe in its fundamental frequency, 8 beats/sec 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 the tension in the string.

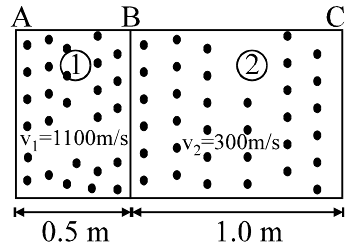
Q.9 A metal rod of length $l = 100$ cm is clamped at two points. Distance of each clamp from nearer end is a=30cm. If density and Young's modulus of elasticity of rod material are $\rho = 9000$ kg m^{-3} and Y = 144 GPa respectively, calculate minimum and next higher frequency of natural longitudinal oscillations of the rod.

Q.10 Two speakers are driven by the same oscillator with frequency of 200 Hz. They are located 4 m apart on a vertical pole. A man walks straight towards the lower speaker in a direction perpendicular to the pole, as shown in figure.



(a) How many times will he hear a minimum in sound intensity, and
(b) how far is he from the pole at these moments?
Take the speed of sound to be 330 m/s, and ignore any sound reflections coming off the ground.

Q.11 A cylinder ABC consists of two chambers 1 and 2 which contains two different gases. The wall C is rigid but the walls A and B are thin diaphragms. A vibrating tuning fork approaches the wall A with velocity u = 30 m/s and air columns in chamber 1 and 2 vibrates with minimum frequency such that there is node (displacement) at B and antinode (displacement) at A. Find



(i) the fundamental frequency of air column.
(ii) Find the frequency of tuning fork.
Assume velocity of sound in the first and second chamber be 1100 m/s and 300 m/s respectively. Velocity of sound in air 330 m/s.

Q.12 A source emits sound waves of frequency 1000 Hz. The source moves to the right with a speed of 32 m/s relative to ground. On the right a reflecting surface moves towards left with a speed of 64 m/s relative to the ground. The speed of sound in air is 332 m/s. Find
(a) the wavelength of sound in air by source
(b) the number of waves arriving per second which meet the reflecting surface.
(c) the speed of reflected waves.
(d) the wavelength of reflected waves.

Q.13 A supersonic jet plane moves parallel to the ground at speed v = 0.75 mach (1 mach = speed of sound). The frequency of its engine sound is $\nu_0 = 2$ kHz and the height of the jat plane is h = 1.5 km. At some instant an observer on the ground hears a sound of frequency $\nu = 2\,\nu_0$, Find the instant prior to the instant of hearing when the sound wave received by the observer was emitted by the jet plane. Velocity of sound wave in the condition of observer = 340 m/s.

Q.14 A train of length l is moving with a constant speed v along a circular track of radius R, The engine of the train emits a whistle of frequency f. Find the frequency heard by a guard at the rear end of the train.

Q.15 A bullet travels horizontally at 660 m/s at a height of 5 m from a man. How far is the bullet from the man when he hears its whistle? Velocity of sound in air = 340 m/s.

EXERCISE–III

Q.1 A metallic rod of length 1 m is rigidly clamped at its mid–point . Longitudinal stationary waves are set up in the rod in such a way that there are two nodes on either side of the mid–point . The amplitude of an antinode is 2×10^{-6}m . Write the equation of motion at a point 2 cm from the mid-point and those of the constituent waves in the rod. [Young's modulus = 2×10^{11} Nm^{-2}, density = 8000 Kg m^{-3}]. [JEE '94, 6]

Q.2 A whistle emitting a sound of frequency 440 Hz is tied to a string of 1.5 m length and rotated with an angular velocity of 20 rad s^{-1} in the horizontal plane . Calculate the range of frequencies heard by an observer stationed at a large distance from the whistle . [JEE '96, 3]

Q.3 Select the correct alternative : [JEE '96, $2\times2=4$]

(i) The extension in a string, obeying Hooke's law is x . The speed of wave in the stretched string is v. If the extension in the string is increased to 1.5 x , the speed of wave will be

(A) 1.22 v (B) 0.61 v (C) 1.50 v (D) 0.75 v

(ii) An open pipe is suddenly closed at one end with the result that the frequency of third harmonic of the closed pipe is found to be higher by 100 Hz than the fundamental frequency of the open pipe . The fundamental frequency of the open pipe is :

(A) 200 Hz (B) 300 Hz (C) 240 Hz (D) 480 Hz

Q.4 A whistle giving out 450 Hz approaches a stationary observer at a speed of 33 m/s. The frequency heard by the observer in Hz is : [JEE '97, 1]

(A) 409 (B) 429 (C) 517 (D) 500

Q.5 The first overtone of an open organ pipe beats with the first overtone of a closed organ pipe with a beat frequency of 2.2 Hz. The fundamental frequency of the closed organ pipe is 110 Hz . Find the lengths of the pipes. [JEE '97, 5]

Q.6 A place progressive wave of frequency 25 Hz, amplitude 2.5×10^{-5} m & initial phase zero propagates along the (–ve) x–direction with a velocity of 300 m/s . At any instant, the phase difference between the oscillations at two points 6 m apart along the line of propagation is ____ & the corresponding amplitude difference is ____ m. [JEE '97, 2]

Q.7 A band playing music at a frequency f is moving towards a wall at a speed v_b . A motorist is following the band with a speed v_m . If v is the speed of sound, obtain an expression for the beat frequency heard by the motorist . [JEE '97, 5]

Q.8 A travelling in a stretched string is described by the equation $y = A\sin(kx - \omega t)$. The maximum particle velocity is : [JEE '97, 1]

(A) $A\omega$ (B) ω/k (C) $d\omega/dk$ (D) x/t

Q.9 Select the correct alternative(s). [JEE '98, 2 + 2 + 2]

(i) The (x , y) co–ordinates of the corners of a square plate are (0, 0) (L, 0) (L, L) & (0, L). The edges of the plate are clamped & transverse standing waves are set up in it . If u (x, y) denotes t he displacement of the plate at the point (x, y) at some instant of time, the possible expression(s) for u is/are : (a = positive constant)

(A) $a\cos\left(\frac{\pi x}{2L}\right)\cos\left(\frac{\pi y}{2L}\right)$ (B) $a\sin\left(\frac{\pi x}{L}\right)\sin\left(\frac{\pi y}{L}\right)$

(C) $a\sin\left(\frac{\pi x}{L}\right)\sin\left(\frac{2\pi y}{L}\right)$ (D) $a\cos\left(\frac{2\pi x}{L}\right)\sin\left(\frac{\pi y}{L}\right)$

(ii) 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

(iii) A transverse sinusoidal wave of amplitude a, wavelength λ & frequency f is travelling on a stretched string . The maximum speed of any point on the string is $\frac{v}{10}$, where v is speed of propagation of the wave. If $a = 10^{-3}$ m and $v = 10$ ms^{-1}, then λ & f are given by :

(A) $\lambda = 2\pi \times 10^{-2}$ m (B) $\lambda = 10^{-2}$ m (C) $f = \frac{10^3}{2\pi}$ Hz (D) $f = 10^4$ Hz

Q.10 The air column in a pipe closed at one end is made to vibrate in its second overtone by a tuning fork of frequency 440 Hz . The speed of sound in air is 330 ms^{-1}. End corrections may be neglected. Let P_0 denote the mean pressure at any point in the pipe & ΔP_0 the maximum amplitude of pressure variation.

(i) Find the length L of the air column. [JEE '98, 2 + 2 + 2 + 2]

(ii) What is the amplitude of pressure variation at the middle of the column ?

(iii) What are the maximum & minimum pressures at the open end of the pipe .

(iv) What are the maximum & minimum pressures at the closed end of the pipe ?

Q.11 In hydrogen spectrum the wvaelength of H_α line is 656 nm, whereas in the spectrum of a distant galaxy, H_α line wavelength is 706 nm. Estimated speed of the galaxy with respect to earth is, [JEE '99, 2]

(A) 2×10^8 m/s (B) 2×10^7 m/s (C) 2×10^6 m/s (D) 2×10^5 m/s

Q.12 A long wire PQR is made by joining two wires PQ and QR of equal radii. PQ has length 4.8 m and mass 0.06 kg. QR has length 2.56 m and mass 0.2kg. The wire PQR is under a tension of 80N. A sinusoidal wave–pulse of amplitude 3.5cm is sent along the wire PQ from the end P. No power is dissipated during the propagation of the wave–pulse. Calculate

(a) the time taken by the wave–pulse to reach the other end R of the wire, and

(b) the amplitude of the reflected and transmitted wave–pulses after the incident wave–pulse crosses the joint Q. [JEE ''99, 4 + 6]

Q.13 As a wave progagates :

(A) the wave intensity remains constant for a plane wave

(B) the wave intensity decreases as the inverse of the distance from the sounce for a spherical wave

(C) the wave intensity decreases as the inverse square of the distance from the source for a spherical wave

(D) total power of the sherical wave over the spherical survace centered at the source remains constant at all times. [JEE '99, 3]

Q.14 $y(x, t) = 0.8/[(4x + 5t)^2 + 5]$ represents a moving pulse, where x & y are in meter and t in second . Then:
(A) pulse is moving in +x direction (B) in 2s it will travel a distance of 2.5 m
(C) its maximum displacement is 0.16 m (D) it is a symmetric pulse. [JEE '99, 3]

Q.15 In a wave motion $y = a \sin(kx - \omega t)$, y can represent :
(A) electric field (B) magnetic field (C) displacement (D) pressure [JEE '99, 3]

Q.16 Standing waves can be produced : [JEE '99, 3]
(A) on a string clamped at both the ends
(B) on a string clamped at one end and free at the other
(C) when incident wave gets reflected from a wall
(D) when two identical waves with a phase difference of p αre moving in same direction

Q.17 A train moves towards a stationary observer with speed 34m/s. The train sounds a whistle and its frequency registered by the observer is f_1. If the train's speed is reduced to 17m/s, the frequency registered is f_2. If the speed of sound is 340m/s then the ratio f_1/f_2 is [JEE 2000 (Scr), 1]
(A) 18/19 (B) 1/2 (C) 2 (D) 19/18

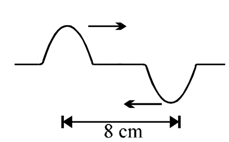
Q.18 Two monatomic ideal gases 1 and 2 of molecular masses m_1 and m_2 respectively are enclosed in separate container kept at the same temperature. The ratio of the speed of sound in gas 1 to that in gas 2 is given by
(A) $\sqrt{\frac{m_1}{m_2}}$ (B) $\sqrt{\frac{m_2}{m_1}}$ (C) $\frac{m_1}{m_2}$ (D) $\frac{m_2}{m_1}$ [JEE 2000 (Scr)]

Q.19 Two vibrating strings of the same material but lengths L and 2L have radii 2r and r respectively. They are stretched under the same tension . Both the strings vibrate in their fundamental modes, the one of length L with frequency f_1 and the other with frequency f_2. The ratio f_1/f_2 is given by
(A) 2 (B) 4 (C) 8 (D) 1 [JEE 2000 (Scr), 1]

Q.20 A 3.6 m long vertical pipe resonates with a source of frequency 212.5 Hz when water level is at certain heights in the pipe . Find the heights of water level (from the bottom of the pipe) at which resonances occur . Neglect end correction . Now, the pipe is filled to a height H (~ 3.6 m). A small hole is drilled very close to its bottom and water is allowed to leak. Obtain an expression for the rate of fall of water level in the pipe as a function of H. If the radii of the pipe and the hole are 2×10^{-2} m and 1×10^{-3} m respectively, calculate the time interval between the occurence of first two resonances . Speed of sound in air is 340 m/s and $g = 10\ m/s^2$. [JEE 2000, 10]

Q.21 The ends of a stretched wire of length L are fixed at x = 0 and x = L. In one experiment, the displacement of the wire is $y_1 = A \sin(\pi x/L) \sin \omega t$ and energy is E_1 and in another experiment its displacement is $y_2 = A\sin(2\pi x/L) \sin 2\omega t$ and energy is E_2. Then [JEE 2001 (Scr)]
(A) $E_2 = E_1$ (B) $E_2 = 2E_1$ (C) $E_2 = 4E_1$ (D) $E_2 = 16E_1$

Q.22 Two pulses in a stretched string whose centres are initially 8 cm apart are moving towards each other as shown in figure. The speed of each pulse is 2 cm/s. After 2 seconds, the total energy of the pulses will be



(A) zero (B) purely kinetic
(C) purely potential (D) partly kinetic and partly potential
[JEE 2001 (Scr)]

Q.23 A boat is travelling in a river with a speed of 10 m/s along the stream flowing with a speed 2 m/s. From this boat, a sound transmitter is lowered into the river through a rigid support. The wavelength of the sound emitted from the transmitter inside the water is 14.45 mm. Assume that attenuation of sound in water and air is negligible.

(a) What will be the frequency detected by a receiver kept inside the river downstream ?

(b) The transmitter and the receiver are now pulled up into air. The air is blowing with a speed 5 m/sec in the direction opposite the river stream. Determine the frequency of the sound detected by the receiver. (Temperature of the air and water = 20°C ; Density of river water = 10^3 Kg/m^3; Bulk modulus of the water = 2.088×10^9 Pa; Gas constant R = 8.31 J/mol-K; Mean molecular mass of air = 28.8×10^{-3} kg/mol; C_P/C_V for air = 1.4) [JEE 2001, 5 + 5]

Q.24 A siren placed at a railway platform is emitting sound of frequency 5 kHz. A passenger sitting in a moving train A records a frequency of 5.5 kHz while the train approaches the siren. During his return journey in a different train B he records a frequency of 6.0 kHz while approaching the same siren. The ratio of the velocity of train B to that of train A is [JEE 2002 (Scr), 3]

(A) 242/252 (B) 2 (C) 5/6 (D) 11/6

Q.25 A sonometer wire resonates with a given tuning fork forming standing waves with five antinodes between the two bridges when a mass of 9 kg is suspended from the wire. When this mass is replaced by a mass M, the wire resonates with the same tuning fork forming three antinodes for the same positions of the bridges. The value of M is [JEE 2002 (Scr), 3]

(A) 25 kg (B) 5 kg (C) 12.5 kg (D) 1/25 kg

Q.26 Two narrow cylindrical pipes A and B have the same length. Pipe A is open at both ends and is filled with a monoatomic gas of malar mass M_A. Pipe B is open at one end and closed at the other end, and is filled with a diatomic gas of molar mass M_B. Both gases are at the same temperature.

(a) If the frequency of the second harmonic of the fundamental mode in pipe A is equal to the frequency of the third harmonic of the fundamental mode in pipe B, determine the value of M_A/M_B.

(b) Now the open end of pipe B is also closed (so that the pipe is closed at both ends). Find the ratio of the fundamental frequency in pipe A to that in pipe B. [JEE 2002, 3 + 2]

Q.27 A police van moving with velocity 22 m/s and emitting sound of frequency 176 Hz, follows a motor cycle in turn is moving towards a stationary car and away from the police van. The stationary car is emitting frequency 165 Hz. If motorcyclist does not hear any beats then his velocity is [JEE 2003 (Scr)]

(A) 22 m/s (B) 24 m/s (C) 20 m/s (D) 18 m/s

Q.28 A cylindrical tube when sounded with a tuning fork gives, first resonance when length of air column is 0.1 and gives second resonance when the length of air column is 0.35 m. Then end correction is

(A) 0.025 m (B) 0.020 m (C) 0.018 m (D) 0.012 m

[JEE 2003 (Scr)]

Q.29 A stringe between x = 0 and x = l vibrates in fundamental mode. The amplitude A, tension T and mass per unit length μ is given. Find the total energy of the string. [JEE 2003]

Q.30 A tuning fork of frequency 480 Hz resonates with a tube closed at one end of length, 16 cm and diameter 5 cm in fundamental mode. Calculate velocity of sound in air. [JEE 2003]

Q.31 A closed organ pipe of length L and an open organ pipe contain gases of densities ρ_1 and ρ_2 respectively. The compressibility of gases are equal in both the pipes. Both the pipes are vibrating in their first overtone with same frequency. The length of the open organ pipe is [JEE' 2004 (Scr)]

(A) $\frac{L}{3}$ (B) $\frac{4L}{3}$ (C) $\frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$ (D) $\frac{4L}{3}\sqrt{\frac{\rho_2}{\rho_1}}$

Q.32 A source of sound of frequency 600 Hz is placed inside water. The speed of sound in water is 1500m/s and in air it is 300m/s. The frequency of sound recorded by an observer who is standing in air is

(A) 200 Hz (B) 3000 Hz (C) 120 Hz (D) 600 Hz [JEE' 2004 (Scr)]

Q.33 A string fixed at both ends is in resonance in its 2nd harmonic with a tuning fork of frequency f_1. Now its one end becomes free. If the frequency of the tuning fork is increased slowly from f_1 then again a resonance is obtained when the frequency is f_2. If in this case the string vibrates in nth harmonic then

(A) $n = 3, f_2 = \frac{3}{4}f_1$ (B) $n = 3, f_2 = \frac{5}{4}f_1$ (C) $n = 5, f_2 = \frac{5}{4}f_1$ (D) $n = 5, f_2 = \frac{3}{4}f_1$

[JEE' 2005 (Scr)]

Q.34 In a resonance column method, resonance occurs at two successive level of $l_1 = 30.7$ cm and $l_2 = 63.2$ cm using a tuning fork of $f = 512$ Hz. What is the maximum error in measuring speed of sound using relations $v = f\lambda$ & $\lambda = 2(l_2 - l_1)$

(A) 256 cm/sec (B) 92 cm/sec (C) 128 cm/sec (D) 102.4 cm/sec

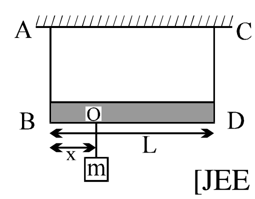
[JEE' 2005 (Scr)]

Q.35 A whistling train approaches a junction. An observer standing at junction observers the frequency to be 2.2 KHz and 1.8 KHz of the approaching and the receding train. Find the speed of the train (speed sound = 300 m/s). [JEE 2005]

Q.36 A transverse harmonic disturbance is produced in a string. The maximum transverse velocity is 3 m/s and maximum transverse acceleration is 90 m/s^2. If the wave velocity is 20 m/s then find the waveform.

[JEE 2005]

Q.37 A massless rod is suspended by two identical strings AB and CD of equal length. A block of mass m is suspended from point O such that BO is equal to 'x'. Further, it is observed that the frequency of 1st harmonic (fundamental frequency) in AB is equal to 2nd harmonic frequency in CD. Then, length of BO is



(A) $\frac{L}{5}$ (B) $\frac{L}{4}$

(C) $\frac{4L}{5}$ (D) $\frac{3L}{4}$

[JEE 2006]

Comprehension –I

Q.38 Two waves $y_1 = A\cos(0.5\,\pi x - 100\,\pi t)$
and $y_2 = A\cos(0.46\,\pi x - 92\,\pi t)$ are travelling in a pipe placed along x-axis. Find the number of times intensity is maximum in time interval of 1 sec.
(A) 4 (B) 6 (C) 8 (D) 10 [JEE 2006]

Q.39 Find wave velocity of louder sound
(A) 100 m/s (B) 192 m/s (C) 200 m/s (D) 96 m/s [JEE 2006]

Q.40 At x = 0 how many times the value of $y_1 + y_2$ is zero in one second?
(A) 100 (B) 46 (C) 192 (D) 96 [JEE 2006]

ANSWER KEY

EXERCISE–I

Q.1 2.5 ms^{-1} Q.2 $\frac{\pi^2 \times 10^{-9}}{4}$ W/m^2 Q.3 $A_r = -\frac{1}{3}$ cm, $A_t = \frac{2}{3}$ cm Q.4 0.2 cm

Q.5 1 : 5 Q.6 1 : 1 Q.7 1% Q.8 485 Hz

Q.9 30 dB, $10\sqrt{10}$ μm Q.10 25 kg Q.11 11f / 9

Q.12 1×10^9 Nm^2 Q.13 2.5 kHz, 7.5 kHz Q.14 6 Q.15 λ/8

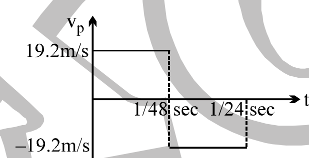
Q.16 3 cm Q.17 2c/3 Q.18 $\frac{f_r + f_a}{2}$ Q.19 345, 341 or 349 Hz

Q.20 33 cm and 13.2 cm

EXERCISE–II

Q.1 (a) negative x ; (b) $y = 4\times10^{-3} \sin 100\pi\left(3t + 0.5x + \frac{1}{400}\right)$ (x , y in meter) ; (c) $72\pi^2 \times 10^{-5}$ J

Q.2 $\frac{\pi}{\sqrt{2}\omega}$ Q.3



Q.4 10800 Hz

Q.5 (a) 2 π/a, b/2π, (b) $y_2 = \pm 0.8$ A cos (ax – bt), (c) max.=1.8 b A, min. = 0,

Q.6 96 % Q.7 (a) *l*/6; (b) 150 Hz; (c)1.28 Q.8 67.6 N

Q.9 10kHz, 30kHz Q.10 (a) 2 ; (b) 9.28 m and 1.99 m

Q.11 1650 Hz, 1500 Hz

Q.12 (a) 0.3 m, (b) 1320, (c) 332 m/s, (d) 0.2 m Q.13 5.9 sec Q.14 f Q.15 9.7 m

EXERCISE–III

Q.1 $y = 2\times10^{-6}\sin(0.1\pi)\cos(25000\,\pi t + \theta)$, for $\theta = 0 : y_1 = 10^{-6}\sin(5\pi x - 25000\pi t)$, $y_2 = 10^{-6}\sin(5\pi x + 25000\,\pi t)$

Q.2 $f_{max} = 484$ Hz , $f_{min} = 403.3$ Hz Q.3 (i) A, (ii) A

Q.4 D Q.5 $L_c = 0.75$ m ; $L_o = 0.99$ m or 1.006 m Q.6 π rad, 0 m

Q.7 $\frac{2v_b(v + v_m)f}{v^2 - v_b^{\,2}}$ Q.8 A Q.9 (i) B, C (ii) B, (iii) A,C

Q.10 (i) $L = \frac{15}{16}$ m, (ii) $\frac{\Delta P_0}{\sqrt{2}}$, (iii) $P_{max} = P_{min} = P_0$, (iv) $P_{max} = P_0 + \Delta P_0$, $P_{min} = P_0 - \Delta P_0$

Q.11 B

Q.12 (a) Time = 140 ms, (b) $A_r = \frac{V_2 - V_1}{V_2 + V_1} A_i = 1.5$ cm ; $A_t = \frac{2V_2}{V_1 + V_2} A_i = 2$ cm

Q.13 A,C,D Q.14 B, C,D Q.15 A, B, C Q.16 A, B, C Q.17 D

Q.18 B Q.19 D Q.20 h = 3.2, 2.4, 1.6, 0.8, 0; $v = 5 \times 10^{-3} \sqrt{5H}$; $\Delta t = 80\,(4 - 2\sqrt{3})$

Q.21 C Q.22 B Q.23 (a) 100696 Hz (b) 103038 Hz Q.24 B Q.25 A

Q.26 (a) 2.116, (b) $\frac{3}{4}$ Q.27 A Q.28 A Q.29 $E = \frac{A^2\pi^2 T}{4l}$ Q.30 336 m/s

Q.31 C Q.32 D Q.33 C Q.34 D Q.35 $V_s = 30$ m/s

Q.36 $y = (10\text{ cm}) \sin\left(30\,t \pm \frac{3}{2}x + \phi\right)$ Q.37 A Q.38 A

Q.39 C Q.40 A