High Level Problems (HLP)

SUBJECTIVE QUESTIONS

1. 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 in same horizontal plane. (v_{sound} = 330 m/s) **[JEE - 1996, 3]**

2. When 0.98 m long metallic wire is stretched, an extension of 0.02 m is produced. An organ pipe 0.5 m long & open at both ends, when sounded with this stressed metallic wire, produces 8 beats in its fundamental mode of both the instruments. By decreasing the strain in the wire, the number of beats are found to decrease. Find Young's modulus of the wire. The density of metallic wire is 10^4 kgm^{-3} & sound velocity in air is 292 ms^{-1}. **[REE – 1996, 5]**

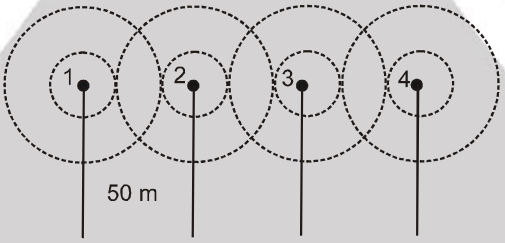
3. A point sound source is located on the perpendicular to the plane of a ring drawn through the centre O of the ring. The distance between the point O and the source is ℓ = 1.00 m, the radius of the ring is R = 0.50 m. If the mean energy flow rate across the area enclosed by the ring is x_0 (in μW). Find $\frac{x_0}{5}$.

Given, at the point O the intensity of sound is equal to I_0 = 30 $\mu W/m^2$ and assuming the damping of the waves is negligible.

4. Two observers A and B carry identical sound sources of frequency 256 Hz. If A is stationary while B moves away from A at a speed of 10 m/s, how many beats per second are heard by A and B ? (c = 343 m/s)

5. Two transverse sine waves, each of amplitude 4mm wavelength 2m and time period 1s and in phase at x = 0, t = 0 are travelling along the x-axis in opposite direction. Obtain the equation of the resultant wave and comment on its nature calculate the maximum displacement at x = 2.333 m. Also locate the antinodes and nodes.

6. A radio station broadcasting at a frequency of 1500 kHz generates a directional beam by using an array of 4 point source antennas driver in phase with each other by the same transmitter. The antennas are arranged along an east west line so that each antenna is 50 m from the next one.



(a) In what direction will be radiated signal be greatest ?
(b) How much signal radiates in east west direction.

7. Two organ pipes are identical except that one is filled with oxygen and other filled with a mixture of oxygen and nitrogen. The temperature and total pressure in each pipe are also the same. When the two are sounded together a note of 440 Hz is heard and beats once every second. What is the percentage partial pressure of the nitrogen in the mixture ? Assume that the molecular weight of oxygen is 32 and of nitrogen 28, and their principal specific heats are identical.

8. A tube 1.0 m long is closed at one end. A wire of length 0.3 m and mass 1×10^{-2} kg is stretched between two fixed ends and is placed near the open end. When the wire is plucked at its mid point the air column resonates in its 1st overtone. Find the tension in the wire if it vibrates in its fundamental mode. [V_{sound} = 330 m/s]

9. 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. (v_{sound} = 330 m/s) **[JEE - 1997, 5]**

10. 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 - 1997, 5]**

11. A 3 m long organ pipe open at both ends is driven to third harmonic standing wave. If the amplitude of pressure oscillation is 0.1 % of the mean atmospheric pressure ($P_0 = 10^5$ N/m^2). Find the amplitude of : (i) particle oscillation and (ii) density oscillation. Speed of sound v = 330 m/s, density of air ρ_0 = 1.0 kg/m^3.

12. 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 - 1998, 8/200]**
(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 ?

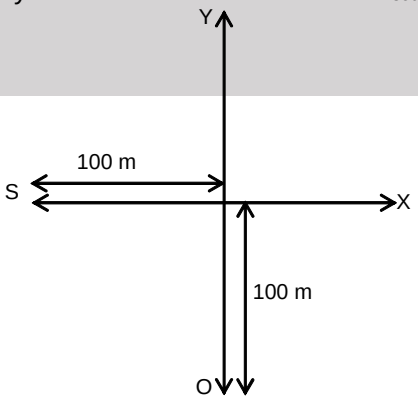
13. A source of sonic oscillations with frequency f = 1700 Hz and a receiver are located at the same point. At the moment t = 0 the source starts receding from the receiver with constant acceleration a = 10.0 m/s^2. Find the oscillation frequency registered by the stationary receiver at t = 10.0 second after the start of the motion, assuming the velocity of the sound to be equal to v = 340m/s. [You can find the answer in variables]

14. A source is moving across a circle given by the equation $x^2 + y^2 = R^2$ with constant speed $v_S = \frac{330\pi}{6\sqrt{3}}$ m/s. in clockwise sense. A detector is stationary at the point (2R, 0) w.r.t. the centre of the circle. The frequency emitted by the source is f_S
(a) What are the co-ordinates of the source when the detector records the maximum and minimum frequencies.
(b) Find these frequencies. Take speed of sound v = 330 m/s.

15. A sonar system fixed in a submarine operates at a frequency 40 KHz. An enemy submarine moves towards the sonar with a speed of 360 Km/h. What is frequency (approximate) of sound received to sonar system, reflected by the submarine? Given : V_{sound} = 1450 m/s in water.

16. A road passes at some distance from a standing man. A truck is coming on the road with some acceleration. The truck driver blows a whistle of frequency 500 Hz when the line joining the truck and the man makes an angle θ with the road. The man hears a note having a frequency of 600 Hz when the truck is closest to him. Also the speed of truck has got doubled during this time. Find the value of 'θ'.

17. At t = 0, a source of sonic oscillations S and on observer O start moving along x and y axes with 5 m/s and 10 m/s. The figure shows their positions at t = 0. If frequency of source is 1000 Hz. Find the frequency of signals received by the observer after 5 second. V_{sound} = 330 m/sec.



18. A point sound source is located on the perpendicular to the plane of a ring drawn through the centre O of the ring. The distance between the point O and the source is ℓ = 1.00 m, the radius of the ring is R = 0.50 m. Find the mean energy flow rate across the area enclosed by the ring if at the point O the intensity of sound is equal to I_0 = 30 μW/m^2. The damping of the waves is negligible.

HLP Answers

1. f_{max} = 484 Hz, f_{min} = 403.3 Hz **2.** Y = 1.76 × 10^{11} N/m^2 **3.** 4

4. Number of beats = 7.5 s^{-1} and 0.725 s^{-1}

5. $y_1 + y_2 = 4 \times 10^{-3}\left[\sin 2\pi\left(t-\frac{x}{2}\right)+\sin 2\pi\left(t+\frac{x}{2}\right)\right]$

At t = 0 and x = 0, $y_1 + y_2 = 0$
At x = 2.333, $y_1 + y_2 = 4 \times 10^{-3}$ m
Autinodes at x = 1, 2
Nodes at $x = \frac{1}{2}, \frac{3}{2}$

6. (a) maximum in a direction perpendicular to the array (b) net signal in EW direction is zero.

7. 3.6% **8.** 735 N **9.** L_c = 0.75 m ; L_o = 0.99 m or 1.006 m

10. $\frac{2v_b(v+v_m)f}{v^2-v_b^2}$ **11.** (i) $\frac{1}{1089\,\pi}$ m (ii) $\frac{1}{1089}$ kg/m^3

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

13. $f = \frac{2\,V\,v_0^2}{2v_0\sqrt{V^2+2aVt}+a} \cong \frac{V\,v_0}{\sqrt{V^2+2aVt}} \cong 1.35$ khz

14. $\left(\frac{\sqrt{3}R}{2}, \frac{R}{2}\right)$, (0, – R) $f'_{min} = \frac{6\sqrt{3}}{6\sqrt{3}+\pi} f_S$; $f'_{max} = \frac{6\sqrt{3}}{6\sqrt{3}-\pi} f_S$

15. 46 KHz **16.** $\theta = 60^o$ **17.** $\frac{33\sqrt{13}+2}{33\sqrt{13}-1.5} \equiv 1030$ Hz

18. $\langle \phi \rangle = 2\pi\ell^2 I_0\left(1-\frac{1}{\sqrt{1+(R/\ell)^2}}\right)$ = 20 μW.