Waves

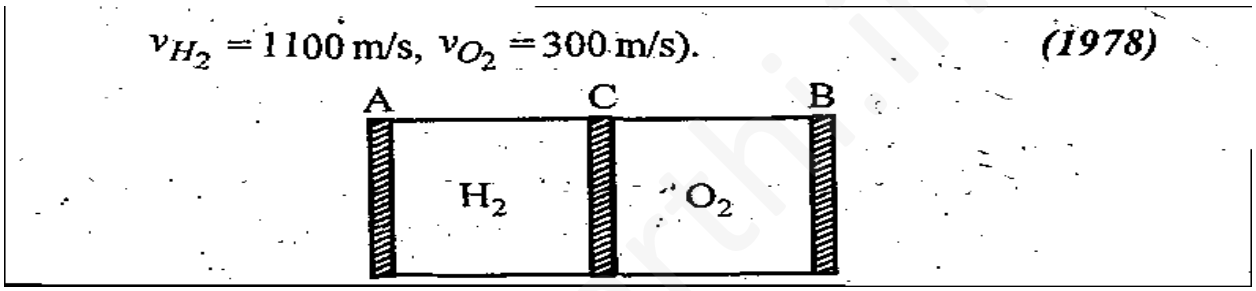
SUBJECTIVE PROBLEMS:

Q 1.

AB is a cylinder of length 1 m fitted with a thin flexible diaphragm C at the middle and other thin flexible diaphragms A and B at the ends. The portions AC and .BC contain hydrogen and oxygen gases respectively. The diaphragms' A and B are set into vibrations of same frequency. What is the minimum frequency of these vibrations for which diaphragm C is a node? (Under the conditions of experiment

(IIT JEE – 1978 – 4 Marks)

$v_{H_2} = 1100$ m/s, $v_{O_2} = 300$ m/s). *(1978)*



Q 2.

A copper wire is held at the two ends by rigid supports. At 30° C, the wire is just taut, with negligible tension. Find the speed of transverse waves in this wire at 10° C.

Given: Young modulus of copper = 1.3×10^{11} N/m^2. Coefficient of linear expansion of copper = 1.7×10^{-5} ° C^{-1}. Density of copper = 9×10^3 kg/m^3 **(IIT JEE – 1979 – 3 Marks)**

Q 3.

A tube of a certain diameter and of length 48 cm is open at both ends. Its fundamental frequency of resonance is found to be 320 Hz. The velocity of sound in air is 320 m/sec. Estimate the diameter of the tube. **(IIT JEE – 1980 – 4 Marks)**

One end of the tube is now closed. Calculate the lowest frequency of resonance for the tube.

Q 4.

A metal wire of diameter 1 mm is held on two knife edges separated by a distance of 50 cm. The tension in the wire is 100 N. The wires, vibrating with its fundamental frequency and a vibrating tuning fork

together produce 5 beats/ sec. The tension in the wire is [hen reduced to 81 N. When the two are excited, beats are created again at the same rate. Calculate.

(i) The frequency of the fork.

(ii) The density of the material of the wire. **(IIT JEE – 1980 – 4 Marks)**

Q 5.

A source of sound of frequency 256 Hz is moving rapidly towards wall with a velocity of 5m/sec. How many beats per second will be heard if sound travels at a speed of 330 m/sec?

(IIT – JEE 1981 – 4 MARKS)

Q 6.

A string 25 cm long and having a mass of 2.5 gm is under tension. A pipe closed at 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 beat frequency. If the speed of sound in air is 320 m/s, find the tension in the string.

(IIT JEE - 1982 - 7 Marks)

Q 7.

A Sonometer wire under tension of 64 Newtons vibrating in its fundamental mode is in resonance with a vibrating tuning fork. The vibrating portion of the sonometer wire has a length of 10 cm and a mass of 1 gm. The vibrating tuning fork is now moved away from the vibrating wire with a constant speed and an observer standing near the sonometer hears one beat per second. Calculate the speed with which the tuning fork is moved if the speed of sound in air is 300 m/ s. ***(IIT JEE - 1983 - 6 Marks)***

Q 8.

A uniform rope of length 12 m and mass 6 kg hangs vertically from a rigid support. A block of mass 2 kg is attached to the free end of the rope. A transverse pulse of wave length 0.06 m is produced at the lower end .of the rope. What is the wavelength of the pulse when it reaches the top of the rope?

(IIT JEE - 1984 – 6 Marks)

Q 9.

A steel of length 1m, 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 set up by plucking the string in the middle, calculate the frequency of the fundamental mode of vibration.

Given for steel Y = 2 x 10^{11} N/m^2

A = 1.21 x 10^{-5} per °C **(IIT JEE - 1984 – 6 Marks)**

Q 10.

The vibrations of a string length 60 cm fixed at both ends are represented by the equation –

$y = 4 \sin(\pi x/15) \cos(96 \pi t)$

Where x and y are in cm and t in seconds. **(IIT JEE - 1985 – 6 Marks)**

(i) What is the maximum displacement of a point at x = 5 cm?

(ii) Where are the nodes located along the string?

(iii) What is the velocity of the particle at x = 7.5 cm at t = 0.25 sec.?

(iv) Write down the equations of the component waves whose superposition gives the above wave.

Q 11.

Two tuning forks with natural frequencies of 340 Hz each move relative to a stationary observer. One fork moves away from the observer, while the other moves towards him at the same speed of the tuning fork. **(IIT JEE - 1986 – 8 Marks)**

Q 12.

The following equations represent transverse waves: **(IIT JEE - 1987 – 7 Marks)**

$z_1 = A \cos(kx - \omega t)$;

$z_2 = A \cos(kx + \omega t)$; $z_3 = A \cos(ky - \omega t)$

Identify the combination (s) of the waves which will produce (i) standing wave (s), (ii) a wave travelling in-the direction making an angle of 45° degrees with the positive x and positive y axes. In each case, find the positions at which the resultant intensity is always zero.

Q 13.

A train approaching a hill at a speed of 40 km/hr sounds a whistle of frequency 580 Hz when it is at a distance of 1 km from a hill. A wind with a speed of 40 km/hr is blowing in the direction of motion of the train Find **(IIT JEE - 1988 – 5 Marks)**

(i) The Frequency of the whistle as heard by an observer on the hill,

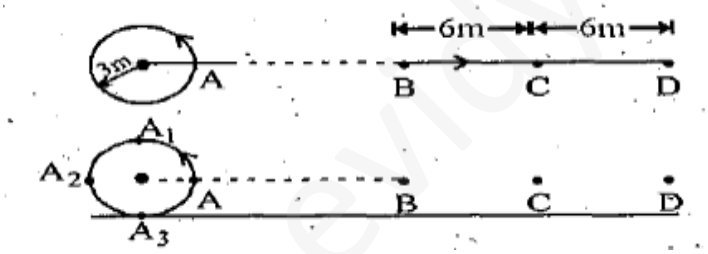
(ii) The distance from the hill at which the echo from the hill is heard by the driver and its frequency.

(Velocity of sound in air = 1,200 km /hr)

Q 14.

A source of sound is moving along a circular orbit of radius 3 meters with an angular velocity of 10 rad /s. A sound detector far away from the source is executing linear simple harmonic motion along the line BD with an amplitude BC = CD = 6 meters. The frequency of oscillation of the detector is $5/\pi$ per second. The source is at the point A when the detector is at the point B. If the source emits a continuous sound wave of frequency 340 Hz, find the maximum and the minimum frequencies recorded by the detector.

(IIT JEE - 1990 – 7 Marks)



Q 15.

The displacement of the medium in a sound wave is given by the equation $y_1 = A \cos (ax + bt)$ where A, a and b are positive constants. The intensity of the reflected wave is 0.64 times that of the incident wave.

(a) -What are the wave length and frequency of incident wave? **(IIT JEE - 1991 – 4 x 2 Marks)**

(b) Write the equation for the reflected wave.

(c) In the resultant wave formed after reflection, find the maximum and minimum values of the particle speeds in the medium.

(d) Express the resultant wave as a superposition of a standing wave and a travelling wave. What are the. Positions of the antinodes of the standing wave? What is the direction of propagation of travelling wave?

Q 16.

Two radio stations broadcast their program's at the same amplitude A and at slightly frequencies ω_1 and ω_2 respectively, where $\omega_1 - \omega_2 = 10^3$ Hz A detector receives the signals from the two stations simultaneously. It can only detect signals of intensity $\geq 2A^2$ **(IIT JEE- 1993 – 4 Marks)**

(i) Find the time interval between successive maxima of the intensity of the signal received by the detector.

(ii) Find the time for which the detector remains idle in each cycle of the intensity of the signal.

Q 17.

A metallic rod of length lm 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 at a point 2 cm from the mid – point and those of the constituent waves in the rod. **(IIT JEE - 1994 – 6 Marks)**

(Young's Modulus of the material of the rod = 2×10^{11} Nm $^{-2}$; density = 8000kgm^{-3}

Q 18.

A whistle emitting a sound of frequency 440 Hz is tied to a string of 1.5m 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 form the whistle. **(IIT JEE - 1996 – 3 Marks)**

Q 19.

The first overtone of an o0pen 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. **(IIT JEE - 1997 – 5 Marks)**

Q 20.

A band playing music it 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. **(IIT JEE - 1997 – 5 Marks)**

Q 21.

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 300 m s^{-1}. End corrections may be neglected. Let P_0 denote the mean pressure at any point in the pipe, and ΔP_0 the maximum amplitude of pressure variation.

(a) Find the length L of the air column. **(IIT JEE - 1998 – 8 Marks)**

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

(c) What are the maximum and minimum pressures at the open end of the pipe?

(d) What are the maximum and minimum pressures at the closed end of the pipe?

Q 22.

A long 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 0.2 Kg. The wire PQR is under a tension of 80 N. A sinusoidal wave – pulse of amplitude 3.5 cm is sent along the wire PQ from the end P. No power is dissipated during the propagation of the wave – pulse. **(IIT JEE - 1990 – 10 Marks)**

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.

Q 23.

A 3.6 m long vertical pipe resonates with a source of frequency 212.5 Hz when water level is at certain height in the pipe. Find the height of water level (from the bottom of the pipe) at which resonance

occurs. 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 occurrences of first two resonances. Speed of sound in air is 340 m/s and g = 10 m/s^2. **(IIT JEE - 2000 – 10 Marks)**

Q 24.

A boat is travelling in a river with a speed 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/s in the direction opposite the river stream. Determine the frequency of the sound detected by the air receiver.

(Temperature of the air and water = 20° C; Density of river water = 10^3 kg/m^3 ; Bulks 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) **(IIT JEE - 2001 – 10 Marks)**

Q 25.

Two narrow cylindrical pipes A and B have the same length. Pipe A is open at both ends and is filled with a monatomic gas of molar 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 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. **(IIT JEE - 2002 - 5 Marks)**

Q 26.

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. **(IIT JEE - 2003 – 2 Marks)**

Q 27.

A string tied 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. **(IIT JEE - 2003 – 4 Marks)**

Q 28.

A whistling train approaches a junction. An observer standing at junction observes the frequency to be 2.2 KHz and 1.8 KHz of the approaching and the receding train respectively. Find the speed of the train (speed of sound = 300 m/s) **(IIT JEE - 2005 – 2 Marks)**

Q 29.

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. **(IIT JEE - 2005 – 4 Marks)**