SOUND WAVE

1. An ideal gas is in thermodynamic equilibrium. The number of degrees of freedom of a molecule of the gas in n. The internal energy of one mole of the gas is U_n and the speed of sound in the gas is v_n. At a fixed temperature and pressure, which of the following is the correct option ? **[JEE(Advanced) 2023]**

(A) $v_3 < v_6$ and $U_3 > U_6$

(B) $v_5 > v_3$ and $U_3 > U_5$

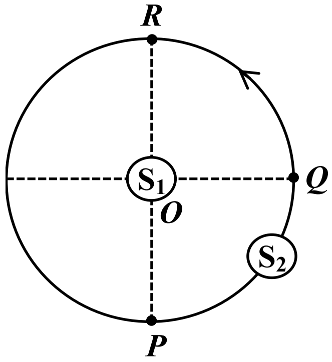
(C) $v_5 > v_7$ and $U_5 < U_7$

(D) $v_6 < v_7$ and $U_6 < U_7$

Paragraph For Question No. 2

S_1 and S_2 are two identical sound sources of frequency 656 Hz. The source S_1 is located at O and S_2 moves anti-clockwise with a uniform speed $4\sqrt{2}\ \text{ms}^{-1}$ on a circular path around O, as shown in the figure. There are three points P, Q and R on this path such that P and R are diametrically opposite while Q is equidistant from them. A sound detector is placed at point P. The source S_1 can move along direction OP.

[Given: The speed of sound in air is 324 ms^{-1}] **[JEE(Advanced) 2023]**



2. When only S_2 is emitting sound and it is Q, the frequency of sound measured by the detector in Hz is _____.

Paragraph For Question No. 3

S_1 and S_2 are two identical sound sources of frequency 656 Hz. The source S_1 is located at O and S_2 moves anti-clockwise with a uniform speed $4\sqrt{2}\ \text{ms}^{-1}$ on a circular path around O, as shown in the figure. There are three points P, Q and R on this path such that P and R are diametrically opposite while Q is equidistant from them. A sound detector is placed at point P. The source S_1 can move along direction OP.

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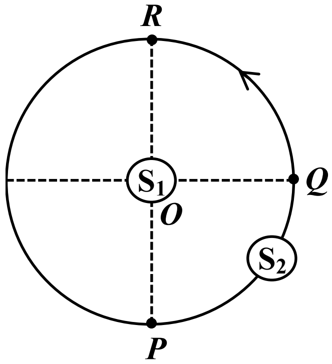


3. Consider both sources emitting sound. When S_2 is at R and S_1 approaches the detector with a speed 4 ms^{-1}, the beat frequency measured by the detector is _______Hz.

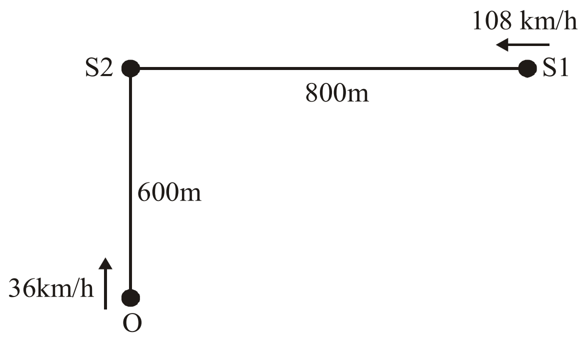
4. A source, approaching with speed u towards the open end of a stationary pipe of length L, is emitting a sound of frequency f_s. The farther end of the pipe is closed. The speed of sound in air is v and f_0 is the fundamental frequency of the pipe. For which of the following combination(s) of u and f_s, will the sound reaching the pipe lead to a resonance ? **[JEE(Advanced) 2021]**

(A) $u = 0.8\ v$ and $f_s = f_0$
(B) $u = 0.8\ v$ and $f_s = 2f_0$
(C) $u = 0.8\ v$ and $f_s = 0.5\ f_0$
(D) $u = 0.5\ v$ and $f_s = 1.5\ f_0$

5. A stationary tuning fork is in resonance with an air column in a pipe. If the tuning fork is moved with a speed of 2 ms^{-1} in front of the open end of the pipe and parallel to it, the length of the pipe should be changed for the resonance to occur with the moving tuning fork. If the speed of sound in air is 320 ms^{-1}, the smallest value of the percentage change required in the length of the pipe is ______.

[JEE(Advanced) 2020]

6. A train S1, moving with a uniform velocity of 108 km/h, approaches another train S2 standing on a platform. An observer O moves with a uniform velocity of 36 km/h towards S2, as shown in figure. Both the trains are blowing whistles of same frequency 120 Hz. When O is 600 m away from S2 and distance between S1 and S2 is 800 m, the number of beats heard by O is ______. **[JEE(Advanced) 2019]**
[Speed of the sound = 330 m/s]



7. Two men are walking along a horizontal straight line in the same direction. The man in front walks at a speed 1.0 ms^{-1} and the man behind walks at a speed 2.0 ms^{-1}. A third man is standing at a height 12 m above the same horizontal line such that all three men are in a vertical plane. The two walking men are blowing identical whistles which emit a sound of frequency 1430 Hz. The speed of sound in air is 330 ms^{-1}. At the instant, when the moving men are 10 m apart, the stationary man is equidistant from them. The frequency of beats in Hz, heard by the stationary man at this instant, is ________.

[JEE(Advanced) 2018]

8. In an experiment to measure the speed of sound by a resonating air column, a tuning fork of frequency 500 Hz is used. The length of the air column is varied by changing the level of water in the resonance tube. Two successive resonances are heard at air columns of length 50.7 cm and 83.9 cm. Which of the following statements is (are) true ? **[JEE(Advanced) 2018]**

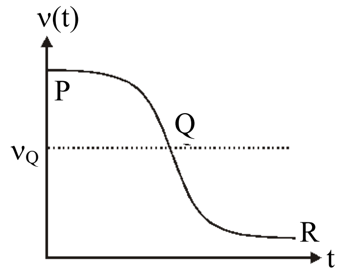
(A) The speed of sound determined from this experiment is 332 ms^{-1}
(B) The end correction in this experiment is 0.9 cm
(C) The wavelength of the sound wave is 66.4 cm
(D) The resonance at 50.7 cm corresponds to the fundamental harmonic

9. A stationary source emits sound of frequency f_0 = 492 Hz. The sound is reflected by a large car approaching the source with a speed of 2 ms^{-1}. The reflected signal is received by the source and superposed with the original. What will be the beat frequency of the resulting signal in Hz ?
(Given that the speed of sound in air is 330 ms^{-1} and the car reflects the sound at the frequency it has received).

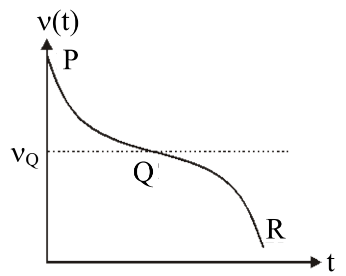
[JEE(Advanced) 2017]

10. Two loudspeakers M and N are located 20 m apart and emit sound at frequencies 118 Hz and 121 Hz, respectively. A car is initially at a point P, 1800 m away from the midpoint Q of the line MN and moves towards Q constantly at 60 km/hr along the perpendicular bisector of MN. It crosses Q and eventually reaches a point R, 1800 m away from Q. Let $\nu(t)$ represent the beat frequency measured by a person sitting in the car at time t. Let ν_P, ν_Q and ν_R be the beat frequencies measured at locations P, Q and R, respectively. The speed of sound in air is 330 ms^{-1}. Which of the following statement(s) is(are) true regarding the sound heard by the person ? **[JEE(Advanced) 2016]**

(A) The plot below represents schematically the variation of beat frequency with time



(B) The plot below represents schematically the variations of beat frequency with time



(C) The rate of change in beat frequency is maximum when the car passes through Q

(D) $\nu_P + \nu_R = 2\nu_Q$

11. Four harmonic waves of equal frequencies and equal intensities I_0 have phase angles 0, $\pi/3$, $2\pi/3$ and π. When they are superposed, the intensity of the resulting wave is nI_0. The value of n is.

[JEE(Advanced) 2015]

12. A student is performing an experiment using a resonance column and a tuning fork of frequency 244 s^{-1}. He is told that the air in the tube has been replaced by another gas (assume that the column remains filled with the gas). If the minimum height at which resonance occurs is (0.350 ± 0.005) m, the gas in the tube is **[JEE(Advanced) 2014]**

(Useful information : $\sqrt{167RT} = 640\ J^{1/2}\ mole^{-1/2}$; $\sqrt{140RT} = 590\ J^{1/2}\ mole^{-1/2}$. The molar masses M in grams are given in the options. Take the values of $\sqrt{\frac{10}{M}}$ for each gas as given there.)

(A) Neon $\left(M = 20, \sqrt{\frac{10}{20}} = \frac{7}{10}\right)$

(B) Nitrogen $\left(M = 28, \sqrt{\frac{10}{28}} = \frac{3}{5}\right)$

(C) Oxygen $\left(M = 32, \sqrt{\frac{10}{32}} = \frac{9}{16}\right)$

(D) Argon $\left(M = 36, \sqrt{\frac{10}{36}} = \frac{17}{32}\right)$

SOLUTIONS

1. Ans. (C)

Sol. $U = \frac{1}{2} fnrT = \frac{frT}{2}$

$\therefore$ A and B are wrong.

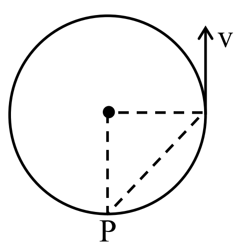
$v_{sound} = \sqrt{\frac{\gamma RT}{M}} = \sqrt{\left(\frac{2}{f}+1\right)\frac{RT}{M}}$

$\Rightarrow$ more 'f', less 'v'

$\therefore v_5 > v_7$

2. Ans. (648.00)

Sol.



$f' = \frac{C}{C + v\cos 45°} f$

$= \frac{324}{324 + 4\sqrt{2} \times \frac{1}{\sqrt{2}}} \times 656 = 648$ Hz

3. Ans. (8.00 to 8.40)

Sol. $f_{P \text{ from } S_2} = 656\text{Hz}$

$f_{P \text{ from } S_1} = \frac{C}{C - V} f = \frac{656 \times 324}{324 - 4} = 664.2$

$\Delta f = 664.2 - 656 = 8.2\text{Hz}$

4. Ans. (A, D)

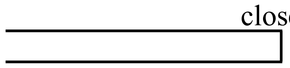
Sol. $f = f_s\left(\frac{v}{v-u}\right)$

(A) $f = f_0\left(\frac{v}{v-0.8v}\right) = 5f_0$

(B) $f = 2f_0\left(\frac{v}{v-0.8v}\right) = 10f_0$

(C) $f = 0.5f_0\left(\frac{v}{v-0.8v}\right) = 2.5f_0$

(D) $f = 1.5f_0\left(\frac{v}{v-0.5v}\right) = 3f_0$



All odd harmonics are available in closed pipe therefore correct Answer (A, D).

5. Ans. (0.62 to 0.64)

Sol. $f \propto \frac{1}{\ell_1} \Rightarrow f = \frac{k}{\ell_1}$ ....(1)

($\ell_1 \Rightarrow$ initial length of pipe)

$\left(\frac{V}{V - V_T}\right) f = \frac{k}{\ell_2}$

$\{V_T$ Speed of tuning fork, $\ell_2 \rightarrow$ new length of pipe$\}$

....(2)

(1) $\div$ (2)

$\frac{V - V_T}{V} = \frac{\ell_2}{\ell_1}$

$\frac{\ell_2}{\ell_1} - 1 = \frac{V - V_T}{V} - 1$

$\frac{\ell_2 - \ell_1}{\ell_1} = \frac{-V_T}{V}$

$\frac{\ell_2 - \ell_1}{\ell_1} \times 100 = \frac{-2}{320} \times 100 = -0.625$

Therefore smallest value of percentage change required in the length of pipe is 0.625.

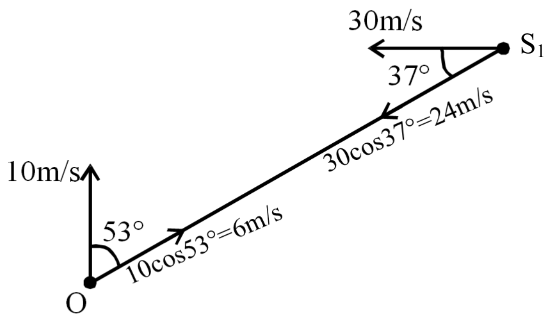
6. Ans. (7.00 to 10.00)

Sol. Frequency observed by O from S_2

$f_2 = \frac{330+10}{330} \times 120 = \frac{340}{330} \times 120 = 123.63\,\text{Hz}$

frequency observed by O from S_1

$f_1 = \frac{330+6}{330-24} \times 120 = \frac{336}{306} \times 120 \approx 131.76\text{Hz}$

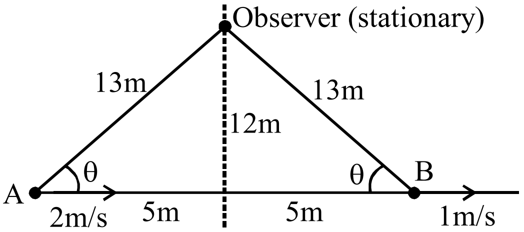


beat frequency = 131.76 – 123.63

= 8.128 ≈ 8.12 to 8.13 Hz

7. Ans. (5.00)

Sol.



$$\cos\theta = \frac{5}{13}$$

$$f_A = 1430\left[\frac{330}{330-2\cos\theta}\right] = 1430\left[\frac{1}{1-\frac{2\cos\theta}{330}}\right]$$

$$= 1430\left[1+\frac{2\cos\theta}{330}\right]$$

(By bionomial expansion)

$$f_B = 1430\left[\frac{330}{330+1\cos\theta}\right] = 1430\left[1-\frac{\cos\theta}{330}\right]$$

$$\Delta f = f_A - f_B = 1430\left[\frac{3\cos\theta}{330}\right] = 13\cos\theta$$

$$= 13\left(\frac{5}{13}\right) = 5.00\text{Hz}$$

8. Ans. (A, C or A, B, C)

Sol. Let n_1 harmonic is corresponding to 50.7 cm & n_2 harmonic is corresponding 83.9 cm.
since both one consecutive harmonics.

$\therefore$ their difference $= \frac{\lambda}{2}$

$\therefore \frac{\lambda}{2} = (83.9 - 50.7)$ cm

$\frac{\lambda}{2} = 33.2$ cm $= 66.4$ cm

$\therefore \frac{\lambda}{4} = 16.6$ cm

length corresponding to fundamental mode must be close to $\frac{\lambda}{4}$ & 50.7 cm must be closed to an odd multiple of this length as 16.6 × 3 = 49.8 cm. therefore 50.7 is 3rd harmonic

If end correction is e, then

$e + 50.7 = \frac{3\lambda}{4}$

$e = 49.8 - 50.7 = -0.9$ cm

speed of sound, $v = f\lambda$

$\therefore v = 500 \times 66.4$ cm/sec $= 332.000$ m/s

9. Ans. (6)

Sol. Frequency of sound as received by large car approaching the source.

$$f_1 = \frac{C+V_0}{C}f_0 = \left(\frac{330+2}{330}\right)492\text{Hz.}$$

This car now acts as source for reflected sound wave

$\therefore f_{reflected} = f_1$

frequency of sound received by source,

$$f_2 = \left(\frac{C}{C-V_0}\right)f_{reflected}$$

$$= \left(\frac{330}{330-2}\right)\times f_1 = \frac{330}{328}\times\frac{332}{330}\times 492\text{Hz}$$

$\therefore$ Beat frequency $= |f_0 - f_2|$

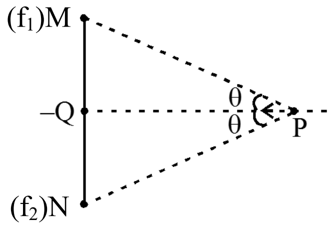
$$= \left(\frac{332}{328}-1\right)\times 492\text{ Hz}$$

$= 6$ Hz

10. Ans. (A, C, D)

Sol.

$$f_M = \frac{C+V\cos\theta}{C}f_1$$



$$f_N = \frac{C+V\cos\theta}{C}f_2$$

$\Delta f = f_N - f_M$

$$= \frac{C+V\cos\theta}{C}(f_2-f_1)$$

$$\frac{d(\Delta f)}{dt} = -\frac{V}{C}(f_2-f_1)\sin\theta\frac{d\theta}{dt}$$

$\therefore$ & $\frac{d(\Delta f)}{dt}$ is maximum when $\theta = 90°$

[$\therefore$ C is correct]

$$\nu_P = \left(1+\frac{V}{C}\cos\theta\right)\Delta f$$

$\nu_Q = \Delta f$

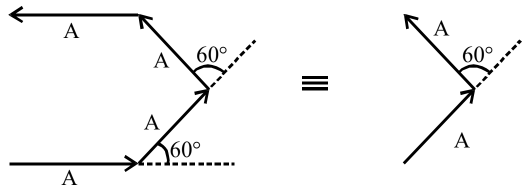
$$\nu_R = \left(1-\frac{V}{C}\cos\theta\right)\Delta f$$

$\therefore \nu_P + \nu_r = 2\nu_Q$

11. Ans. (3)

Sol. Let amplitude of individual wave is A.

then by using phasor method



So resultant amplitude $A_r^2 = A^2 + A^2 + 2a^2 \cos 60$

$\therefore\ A_r^2 = 3A^2$

$\therefore\ I_r = 3I_0$

12. Ans. (D)

Sol. $V = \sqrt{\frac{\gamma RT}{m}}$ [m should be taken in Kg]

Neon and argon are monoatomic gas $\Rightarrow \gamma = 1.67$

Nitrogn and oxygen are diatomic gas $\Rightarrow \gamma = 1.4$

$\therefore\quad V = \sqrt{\frac{1.67 \times RT \times 1000}{m}}$ (m is in grams)

$\therefore\quad$ For Neon, $V = \sqrt{167RT \times \frac{10}{20}} = 640 \times \frac{7}{10}$ m/s

$= 448$ m/s

For nitrogen, $V = \sqrt{140RT \times \frac{10}{28}} = 590 \times \frac{3}{5}$ m/s

$= 354$ m/s

For oxygen, $V = \sqrt{140RT \times \frac{10}{32}} = 590 \times \frac{9}{16}$ m/s

$= 331.875$ m/s

For argon, $V = \sqrt{167RT \times \frac{10}{36}} = 640 \times \frac{17}{32}$ m/s

$= 340$ m/s.

From the given information, f = 244 Hz

$\left.\frac{\lambda}{4}\right|_{max} = 0.350 + 0.005 = 0.355$ m $\qquad \left.\frac{\lambda}{4}\right|_{min}$

$= 0.350 - 0.005 = 0.345$ m

$\therefore\ \lambda_{max} = 1.420$ m $\ \lambda_{min} = 1.380$ m

$\therefore\ V_{max} = 244 \times \lambda_{max} = 346.48$ m/sec

$V_{min} = 244 \times \lambda_{min} = 336.72$ m/sec

Only Argon is between them