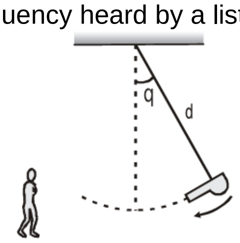
Self Practice Paper (SPP)

1. The displacement sound wave in a medium is given by the equation Y = A cos(ax + bt) where A, a and b are positive constants. The wave is reflected by an denser obstacle situated at x = 0. The intensity of the reflected wave is 0.64 times that of the incident wave. Tick the statement among the following that is incorrect.
(1) the wavelength and frequency of the wave are 2π/a and b/2π respectively
(2) the amplitude of the reflected wave is 0.8 A
(3) the resultant wave formed after reflection is y = A cos(ax + bt) + [– 0.8 A cos (ax – bt)] and V_{max} (maximum particle speed) is 1.8 bA
(4) the equation of the standing wave so formed is y = 1.8 A sin ax cos bt

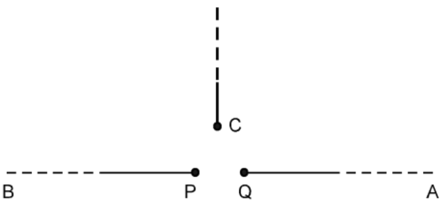
2. A source which is emitting sound of frequency f is initially at (– r, 0) and an observer is situated initially at (2r, 0). If observer and source both are moving with velocities $\vec{v}_{observer} = -\sqrt{2}V\hat{i} - \sqrt{2}V\hat{j}$ and $\vec{v}_{source} = \frac{V}{\sqrt{2}}\hat{i} + \frac{V}{\sqrt{2}}\hat{j}$, then which of the following is correct option ?
(1) Apparent frequency first increases, then decreases and observer observes the original frequency once during the motion.
(2) Apparent frequency first increases, then decreases and observer observes the original frequency twice during the motion.
(3) Apparent frequency first increases, then decreases during the motion and observer never observes the initial frequency.
(4) Apparent frequency continuously decreases and once during the motion, observer hears the original frequency.

3. A source on a swing which is covering an angle θ from the vertical is producing a frequency ν. The source is distant d from the place of support of swing. If velocity of sound is c, acceleration due to gravity is g, then the maximum and minimum frequency heard by a listener in front of swing is



(1) $\frac{c\nu}{\sqrt{2gd}-c}, \frac{c\nu}{\sqrt{2gd}+c}$ (2) $\frac{c\nu}{\sqrt{2gd(1-\cos\theta)}-c}, \frac{c\nu}{\sqrt{2gd(1-\cos\theta)}+c}$
(3) $\frac{c\nu}{c-\sqrt{2gd(1-\cos\theta)}}, \frac{c\nu}{c+\sqrt{2gd(1-\cos\theta)}}$ (4) $\frac{c\nu}{c-\sqrt{2gd(1-\sin\theta)}}, \frac{c\nu}{c+\sqrt{2gd(1-\sin\theta)}}$

4.* Two monochromatic sources of electromagentic wave, P and Q emit waves of wavelength λ = 20 m and separated by 5m as shown. A,B and C are three points where interference of these waves is observed. If phase of a wave generated by P is ahead of wave generated by Q by π/2 then (given intensity of both waves is I) :



(1) phase difference of these waves at B is 180^0
(2) intensities at A,B and C are in the ratio 2 : 0 : 1 respectively.
(3) intensities at A,B and C are in the ratio 1 : 2 : 0 respectively.
(4) phase difference at A is 0^0.

5*. A cylindrical tube, open at one end and closed at the other, is in acoustic unison (resonance) with an external source of sound of single frequency held at the open end of the tube, in its fundamental note. Then :
(1) the displacement wave from the source gets reflected with a phase change of π at the closed end
(2) the pressure wave from the source get reflected without a phase change at the closed end
(3) the wave reflected from the closed end again gets reflected at the open end
(4) the wave reflected from the closed end does not suffer reflection at the open end

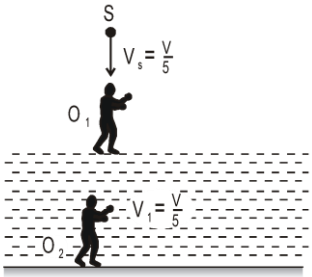
6*. Two narrow organ pipes, one open (length ℓ_1) and the other closed (length ℓ_2) are sounded in their respective fundamental modes. The beat frequency heard is 5 Hz. If now the pipes are sounded in their first overtones, then also the beat frequency heard is 5 Hz. Then:
(1) $\frac{\ell_1}{\ell_2} = \frac{1}{2}$ (2) $\frac{\ell_1}{\ell_2} = \frac{1}{1}$ (3) $\frac{\ell_1}{\ell_2} = \frac{3}{2}$ (4) $\frac{\ell_1}{\ell_2} = \frac{2}{3}$

7*. The effect of making a hole exactly at (1/3rd) of the length of the pipe from its closed end is such that :
(1) its fundamental frequency is an octave higher than the open pipe of same length
(2) its fundamental frequency is thrice of that before making a hole
(3) the fundamental friquency is 3/2 time of that before making a hole
(4) the fundamental alone is changed while the harmonics expressed as ratio of fundamentals remain the same

8*. In a resonance tube experiment, a closed organ pipe of length 120 cm is used. Initially it is completely filled with water. It is vibrated with tuning fork of frequency 340 Hz. To achieve resonance the water level is lowered then (given v_{air} = 340 m/sec., neglect end correction) :
(1) minimum length of water column to have the resonance is 45 cm.
(2) the distance between two succesive nodes is 50 cm.
(3) the maximum length of water column to create the resonance is 95 cm.
(4) the distance between two succesive nodes is 25 cm.

9.* A girl stops singing a pure note. She is surprised to hear an echo of higher frequency, i.e., a higher musical pitch. Then :
(1) there could be some warm air between the girl and the reflecting surface
(2) there could be two identical fixed reflecting surfaces, one half a wavelength of the sound wave away from the other
(3) the girl could be moving towards a fixed reflector
(4) the reflector could be moving towards the girl

10*. In the figure shown an observer O_1 floats (static) on water surface with ears in air while another observer O_2 is moving upwards with constant velocity $V_1 = V/5$ in water. The source moves down with constant velocity $V_s = V/5$ and emits sound of frequency 'f'. The velocity of sound in air is V and that in water is 4V. For the situation shown in figure :



(1) The wavelength of the sound received by O_1 is $\frac{4V}{5f}$
(2) The wavelength of the sound received by O_1 is V/f
(3) The frequency of the sound received by O_2 is $\frac{21f}{16}$
(4) The wavelength of the sound received by O_2 is $\frac{16V}{5f}$

11*. A sound wave of frequency ν travels horizontally to the right. It is reflected from a large vertical plane surface moving to left with a speed u. The speed of sound in medium is c.

(1) The number of waves striking the surface per second is $\frac{(c+u)}{c}\nu$ **[JEE - 95]**

(2) The wavelength of reflected wave is $\frac{c(c-u)}{\nu(c+u)}$

(3) The frequency of the reflected wave as observed by the stationary observor is $\nu\frac{(c+u)}{(c-u)}$

(4) The number of beats heard by a stationary listener to the left of the reflecting surface is $\frac{u\nu}{c-u}$

12. Two sound waves one in air and the other in fresh water are equal in intensity .
(a) Find the ratio of pressure amplitudes of the wave in water to that of the wave in air .
(b) If the pressure amplitudes of the waves are equal then what will be the ratio of the intensities of the waves .
[V_{sound} = 340 m/s in air & density of air = 1.22 kg/m^3, V_{sound} = 1488 m/s in water]

13. Find the number of possible natural oscillations of air column in a pipe whose frequencies lie below ν_0 = 1250 Hz. The length of the pipe is ℓ = 85 cm. The velocity of sound is v = 340 m/s.
Consider the two cases :
(a) the pipe is closed from one end
(b) the pipe is opened from both ends.
The open ends of the pipe are assumed to be the antinodes of displacement.

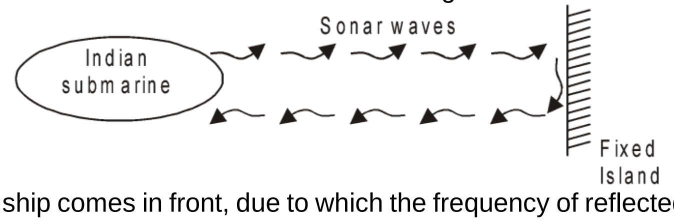
14. A metal wire of diameter 1 mm, is held on two knife edges separated by a distance of 50 cm. The tension in the wire is 100 N. The wire vibrating in its fundamental frequency and a vibrating tuning fork together produces 5 beats per sec. The tension in the wire is then reduced to 81 N. When the two are excited, beats are again at the same rate. Calculate
(a) the frequency of the fork
(b) the density of the material of the wire .

15. An observer rides with a sound source of frequency f and moving with velocity v towards a large vertical wall. Considering the velocity of sound waves as c, find :
(i) the number of waves striking the surface of wall per second
(ii) the wavelength of the reflected wave
(iii) the frequency of reflected wave as observed by observer.
(iv) beat frequency heard by the observer.

16. A source of sonic oscillations with frequency f_0 = 1000 Hz moves at right angles to the wall with a velocity u = 0.17 m/s. Two stationary receivers R_1 and R_2 are located on a straight line, coinciding with the trajectory of the source, in the following succession : R_1 – source – R_2 – wall. Which receiver registers the beatings and what is the beat frequency? The velocity of sound is equal to v = 340 m/s.

Comprehension – (17 to 19)

An Indian submarine is moving in "Arab Sagar" with a constant velocity. To detect enemy it sends out sonar waves which travel with velocity 1050 m/s in water. Initially the waves are getting reflected from a fixed island and the reflected waves are coming back to submarine. The frequency of reflected waves are detected by the submarine and found to be 10% greater than the sent waves.



Now an enemy ship comes in front, due to which the frequency of reflected waves detected by submarine becomes 21% greater than the sent waves.

17. The speed of Indian submarine is

(1) 10 m/sec (2) 50 m/sec (3) 100 m/sec (4) 20 m/sec.

18. The velocity of enemy ship should be :

(1) 50 m/sec. toward Indian submarine. (2) 50 m/sec. away from Indian submarine.

(3) 100 m/sec. toward Indian submarine. (4) 100 m/sec. away from Indian submarine.

19. If the wavelength received by enemy ship is λ´ and wavelength of reflected waves received by submarine is λ´´ then $\left(\frac{\lambda'}{\lambda''}\right)$ equals

(1) 1 (2) 1.1 (3) 1.2 (4) 2

20. A student is performing an experiment using a resonance column and a tuning fork of frequency 244s^{-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,P-1, 3/60]**

(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 value of $\sqrt{\frac{10}{M}}$ for each gas as given there.)

(1) Neon (M = 20, $\sqrt{\frac{10}{20}} = \frac{7}{10}$) (2) Nitrogen (M = 28, $\sqrt{\frac{10}{28}} = \frac{3}{5}$)

(3) Oxygen (M = 32, $\sqrt{\frac{10}{32}} = \frac{9}{16}$) (4) Argon (M = 36, $\sqrt{\frac{10}{36}} = \frac{17}{32}$)

SPP Answers

1. (4) **2.** (4) **3.** (3) **4.*** (1,2,4) **5*.** (1,2,3) **6*.** (2,3) **7*.** (2,4)

8*. (1,2,3) **9.*** (3,4) **10*.** (1,3,4) **11*.** (1,2,3) **12.** (a) $\frac{P_{0_w}}{P_{0_a}} = 60$ (b) $\frac{P_w}{P_a} = 2.8 \times 10^{-4}$

13. (a) $v_n = \frac{v}{4\ell}(2n+1)$; six oscillations; (b) $v_n = \frac{v}{2\ell}(n+1)$, also six oscillations.

Here n = 0, 1, 2, ...

14. (a) 95 Hz (b) $\frac{40}{\pi}\times10^3$ kg/m3

15. (i) n = $\frac{fc}{c-v}$ (ii) λ′ = λ – $\left(\frac{v}{f}\right) = \left(\frac{c}{f}\right) - \left(\frac{v}{f}\right) = \left(\frac{c-v}{f}\right)$

(iii) n″ = n′ (iv) $f_{beat} = \left[\frac{(c+v)n'}{c}\right] - f$

16. v = 2 f_0 vu / (v^2 – u^2) ≈ $\frac{2f_0u}{v}$ = 1.0 Hz **17.** (2) **18.** (1) **19.** (2) **20.** (4)

SPP Solutions

1. y_1 = A cos (ax + bt)

so here k = a

$\frac{2\pi}{\lambda}$ = a ⇒ $\lambda = \frac{2\pi}{a}$

w = b ⇒ n = $\frac{b}{2\pi}$

$\frac{I_{incident}}{I_{reflected}} = \frac{I}{0.64I} = \left(\frac{a_{incident}}{a_{reflected}}\right)^2$ $a_{reflected}$ = 0.8 A

For reflected wave Displacement equation

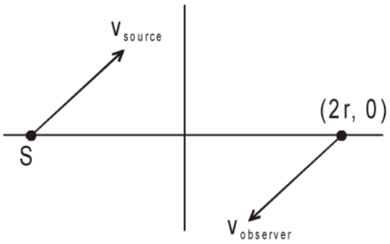
y_2 = 0.8 A cos (– ax + bt + π) = – 0.8 A cos (ax – bt)

by super position law resultant wave

y = y_1 + y_2

= A cos (ax + bt) + [– 0.8 A cos (ax – bt)] so incorrect option is D

2.



velocity of approach of observer & source decreases, becomes, zero and finally becomes velocity of seperation. Hence apparent freqeuncy continuously dereases. (f_{app} = f when v_{app} = 0)

3. Let the velocity of source at more position is u oberver hear maximum frequency when source approaching line from mean positions

$L_{max} = \frac{C}{C-u}$ z

and minimum frequency when source receacding from mean position $L_{max} = \frac{C}{C+u}$ z

velocity at mean position u = $\sqrt{2gd(1-\cos\theta)}$

put the value at c in heard frequency

4.* From progressive sound wave equation

y = A sin (wt – kx)

For extra path λ phase will decreases by 2π

so for extra ΔS path difference phase will decrease by

$\phi = \frac{2\pi}{\lambda}\Delta S$

so for wave for Q to B phase difference with respect to sound

$P = \frac{\frac{\pi}{2} + \frac{2\pi}{\lambda}}{} \times \Delta S$ $\quad = \frac{\frac{\pi}{2} + \frac{2\pi}{20}}{} \times 5 = \pi$

so A correct option

similarly phase difference at A = $\frac{\pi}{2} - \frac{2\pi}{\lambda}\Delta S = 0$

At B distructive interference so intensity = 0

At A Constrictive interfence so intensity = 4I

At C No tnterfurence so intensity = 2I

5*. When sound wave is reflected from rigid end displacement wave get extra phase at π and pressure wave get no extra phase So option A, B, C are correct .

6*. Fundamental frequency of

open pipe, $n_0 = \frac{V}{2\ell_1}$ closed pipe, $n_C = \frac{V}{4\ell_1}$

$\frac{V}{2\ell_1} - \frac{V}{4\ell_1} = 5$ ...(1)

For first overtone $n_0 = \frac{V}{\ell_1}$ $n_C = \frac{V}{2\ell_1}$

$\frac{V}{\ell_1} - \frac{V}{2\ell_2} = 5$ ...(2)

on solving (1) and (2) $\ell_1 = \ell_2 \Rightarrow \frac{\ell_1}{\ell_2} = \frac{1}{1}$

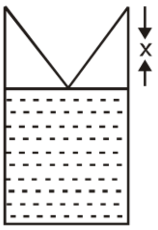
7*. Making hole at $\frac{\ell}{3}$ length from close end. Pipe start behaving as closed pipe of length $\frac{\ell}{3}$

So new fundamental frequency $n_1 = \frac{V}{4\ell/3}$

original fundamental frequency $n = \frac{V}{4\ell/3}$ $n_1 = 3n$

8*. $x = \frac{\lambda}{4}$

$\lambda = \frac{V}{n} = \frac{340}{340} = 1$ m



fundamental tone

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$x = \frac{1}{4}$ m = 25 cm

For other resonance position

$x = (2n - 1)\frac{\lambda}{4}$

so x = 25, 75, 125 cm.....................
Tube length is only 120 cm so get resonance minimum length of water = 120 – 75 = 45
maximum length = 120 – 29 = 95

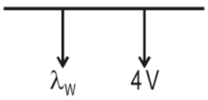
Distance between two successes nodes = $\frac{\lambda}{2} = \frac{100}{2}$ = 50

9.* High pitch means apparent frequency is increased in reflected wave so there is relative motion between girl and reflection and it approaching nature so C and D is correct.

10*. For observer O_1 , $\lambda_1 = \frac{V - V_s}{f} = \frac{V - V/5}{f} = \frac{4V}{5f}$

For O_2, there is change of medium hence at the surface of water, keeping frequency unchanged

$\frac{V}{\lambda_a} = \frac{4V}{\lambda_w}$ $\Rightarrow \lambda_w = 4\lambda_a = \frac{16V}{5f}$



$$f'' = \frac{\text{velo. of wave relative to observer}}{\lambda_w} = \frac{4V + \frac{V}{5}}{\lambda_w} = \frac{21V}{5} \cdot \frac{5f}{16V} = \frac{21f}{16}$$

11*. By the concept of doppler effect

Apparent frequency (no. of waves) striking the wall = $\upsilon = \frac{C + u}{C}\upsilon$

frequency of reflected wave (wall become source) $\upsilon'' = \frac{C + u}{C - u}\upsilon$

Apparent wavelength = $\frac{C}{\upsilon''} = \frac{C(C - u)}{\upsilon(C + u)}$

12. (a) $\frac{P_0^2}{2\rho V} = I$ Given $I_w = I_{air}$

$$\left(\frac{P_0^2}{2\rho V}\right)_{Water} = \left(\frac{P_0}{2\rho V}\right)^2_{air}$$

$$\left(\frac{P_{0\,water}}{P_{air}}\right)^2 = \frac{\rho_W V_W}{\rho_{air} V_{air}}$$

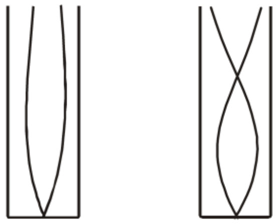
$$\frac{P_{0\,water}}{P_{0\,air}} = \sqrt{\frac{\rho_w V_w}{\rho_{air} V_{air}}} = \sqrt{\frac{1000}{1.22} \times \frac{1488}{340}} = 59.89 \cong 60$$

(b) $P_0 = \sqrt{2I\rho V}$

$$\left(\sqrt{2I\rho V}\right)_{water} = \left(\sqrt{2I\rho V}\right)_{air}$$

$$\frac{I_w}{I_{air}} = \frac{\rho_{air} V_{air}}{\rho_{water} V_{water}} = 2.78 \times 10^{-4}$$

13. $\frac{\lambda}{4} = \ell$



$\frac{3\lambda}{4} = \ell$ and for n_{th} overtone $(2n+1)\frac{\lambda}{4} = \ell$

$(2n + 1)\frac{\lambda}{4} = \ell$, $\lambda = \frac{4\ell}{(2n+1)}$

$f = \frac{V(2n+1)}{4\ell} < 1250$ Hg $= \frac{340(2n+1)\times 100}{4\times 85} < 1250$

$= (2n + 1) < 12.5$ n – overtone number

$2n < 11.5$

$n < \frac{11.5}{2}$ $n = 0, 1, 2, 3, 4, 5$

$n < 5.75$ number of n oscillations = 6

simillarly for open organ pipe

$f = \frac{V}{2\ell}(n + 1) < 1250$ $\Rightarrow \frac{340\times 100}{2\times 85}(n + 1) < 1250$

$n + 1 < \frac{12.5}{2}$

$n + 1 < 6.25$

$n < 5.25$

n = number of overtone

$n = 0, 1, 2, 3, 4, 5$

number of oscillations (6)

14. $\frac{1}{2\ell}\sqrt{\frac{100}{\mu}} - n = 5$ ....(1)

$n - \frac{1}{2\ell}\sqrt{\frac{81}{\mu}} = 5$ ....(2)

add equ (1) and (2)

$\frac{1}{2\ell}\left[\frac{1}{\sqrt{\mu}}\right] = 10$ $\sqrt{\mu} = \frac{1}{20\ell} = \frac{1}{20\times .5} = \frac{1}{10}$ $\mu = 0.01$

$\rho\,\pi r^2 = 0.01$

$\rho = \frac{.01}{(0.5\times 10^{-3})^2\pi} = \frac{10^4}{0.5\times 0.5\pi} = \frac{40}{\pi}\times 10^3$ kg/m^3

put $\mu = 0.01$ in eq. (1)

$\frac{1}{2\times 0.5}\sqrt{\frac{100}{0.01}} - n = 5$

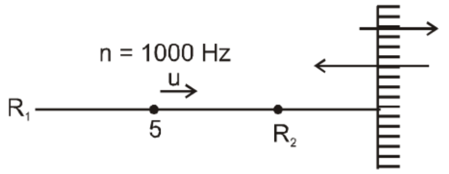
$n = 100 - 5 = 95$ Hz

15. (i) $n_1 = \frac{Cf}{C-V}$ (ii) $\lambda_1 = \frac{C-V}{f}$

(iii) $n_{11} = n_1$

(iv) $n_{beat} = \left(\frac{C+V}{C}\right) n' - f$

16.



for R_1

$n_{Direct} = \frac{V}{V+u}n$

for R_1

$n_{reflected} = \frac{V}{V-u}n$

for R_2

$n_{Direct} = \frac{V}{V-u}n$

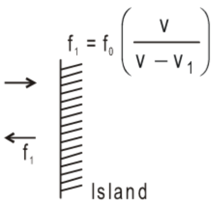
for R_2

$n_{reflected} = \frac{V}{V-u}n$

So R_1 will observe be along

$\Delta n = \frac{V}{V-u}n - \frac{V}{V+u}n = \frac{Vn\,2u}{V^2-u^2} = \frac{1u\ n}{V} = 1$ Hz.

17.



$f'' = f_0\left(\frac{v+v_1}{v-v_1}\right)$, v = 1050 $\left[\frac{f''-f_o}{f_o} = 0.1\right]$

$\frac{f''-f_o}{f_o} = \frac{2V_1}{V-V_1}$ $v_1 = 50$ m/sec.

18.

$f'' = f'\left(\frac{v+50}{v-v_2}\right)$ $f_1 = f_0\left(\frac{v+v_2}{v-50}\right)$

$f'' = f_0\left(\frac{(v+v_2)(v+50)}{(v-v_2)(v-50)}\right) = 1.21f_0$ [21% greater then sent waves]

get v_2 = 50 m/sec toward Indian submarine

19. $\lambda' = \frac{\text{v wrt to observer}}{f'} = \frac{v+v_2}{f_0\frac{(v+v_2)}{(v-50)}} = \frac{v-50}{f_0}$

$\lambda'' = \frac{v+50}{f_0\frac{(v+v_2)(v+50)}{(v-v_2)(v-50)}} = \frac{(v-v_2)(v-50)}{f_0(v+v_2)}$ $\Rightarrow$ $\frac{\lambda'}{\lambda''} = \frac{v+v_2}{v-v_2} = \frac{1050+50}{1050-50} = 1.1$

20. $f = \frac{1}{4\ell}\sqrt{\frac{\gamma RT}{M}}$ & $\frac{\Delta f}{f} = \frac{\Delta \ell}{\ell}$

(1) $M = 20 \times 10^{-3}$	f = 320 Hz	$\Delta f = \pm 4.5$ Hz	Not possible
(2) $M = 20 \times 10^{-3}$	f = 253 Hz	$\Delta f = \pm 3.6$ Hz	Not possible
(3) $M = 32 \times 10^{-3}$	f = 237 Hz	$\Delta f = \pm 3.4$ Hz	Not possible
(4) $M = 36 \times 10^{-3}$	f = 242.8 Hz	$\Delta f = \pm 3.5$ Hz	possible