93 The wave produced on the surface of water are of two types; capillary waves and gravity waves. Which of the following statement is incorrect about them?
(a) Capillary waves are ripples of fairly short wavelength (few centimeter).
(b) Gravity waves have wavelength typically ranging from several meter to several hundered meters.
(c) The restoring force in gravity waves is surface tension while in capillary waves is the pull of gravity.
(d) The particle motion in water waves involves both motion up & down and back & forth.

94 If a propagating wave meets a boundary which is not completely rigid or is an interface between two different elastic media, then which of the statement(s) is/are correct?
(a) A part of the incident wave is reflected and a part is transmitted into the second medium.
(b) The incident wave is completely reflected from the boundary.
(c) Only a part of the wave is reflected and the remaining part disappears.
(d) None of the above

95 A standing wave is generated on a string. Which of the following statement(s) is/are correct for the stationary waves?
(a) The amplitude of stationary wave varies from point-to-point but each element of the string oscillates with the same angular frequency ω or time period.
(b) The string as a whole vibrates in phase with differing amplitudes at different points.
(c) The wave pattern in neither moving to the right nor to the left.
(d) All of the above

96 The air column in a pipe open at both ends is oscillating with certain frequency. Which of the given statement (s) is/are correct for the open air column at both ends?
(a) Each end of the pipe acts as an anti-node.
(b) An air column open at both ends generates all harmonics.
(c) Each end of the pipe is a node.
(d) Both (a) and (b)

III. Matching Type

97 A wave travelling along a string is described by

$$y(x, t) = 0.005 \sin(80x - 3t)$$

in which the numerical constants are in SI units. With reference to the above equation of wave motion, match the Column I (characteristics of wave) with Column II (respective value) and select the correct answer from the codes given below.

Column I		Column II	
A.	Wave number of the wave	1.	0.0785 SI units
B.	Wavelength of the wave	2.	0.48 SI units
C.	Frequency of the wave	3.	0.005 SI units
D.	Displacement y of the wave at a distance $x = 30$ cm and time $t = 20$ s	4.	80 SI units

	A	B	C	D
(a)	4	1	2	3
(b)	2	1	3	4
(c)	1	4	3	2
(d)	3	1	2	4

98 Match the Column I (condition) with Column II (name of process) and select the correct answer from the codes given below.

Column I		Column II	
A.	Constructive interference of two waves of same frequency and amplitude	1.	Beats
B.	Destructive interference of two waves of same frequency and amplitude	2.	Nodes
C.	Interference of two waves of nearly same frequency and equal amplitude.	3.	Anti-nodes

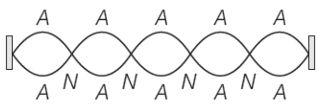
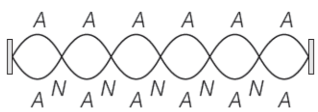
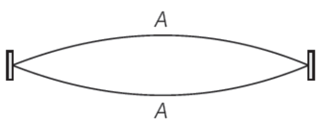
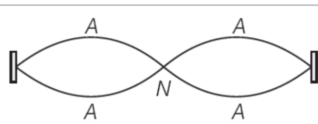
	A	B	C		A	B	C
(a)	1	2	3	(b)	2	3	1
(c)	3	2	1	(d)	2	1	3

99 If the incident travelling wave is given by $y(x, t) = a \sin(kx - \omega t)$, then match the Column I (condition) with Column II (equation of displacement) and select the correct answer from the codes given below.

Column I		Column II	
A.	Reflected wave from rigid boundary	1.	$a \sin(kx - \omega t)$
B.	Reflected wave from open boundary	2.	$-a \sin(kx - \omega t)$
C.	The resultant displacement at the rigid boundary	3.	$2a \sin(kx - \omega t)$
D.	The resultant displacement at the open boundary	4.	0

	A	B	C	D
(a)	2	1	4	3
(b)	1	2	3	4
(c)	2	1	3	4
(d)	1	2	4	3

100 Column I has figures showing different modes of oscillation of the system (a string tied at both the ends) and Column II has name of the corresponding modes. Match the Column I with Column II and select the correct answer from the codes given below.

	Column I		Column II
A.		1.	Fundamental mode
B.		2.	Second harmonic
C.		3.	Sixth harmonic
D.		4.	Fifth harmonic

	A	B	C	D		A	B	C	D
(a)	4	2	3	1	(b)	4	3	1	2
(c)	3	2	1	4	(d)	2	3	1	4

101 Considering the length of the vibrating air column (which is closed at one end) as L, the possible wavelengths of the standing waves as λ, wave velocity as v and the normal nodes or the natural frequencies of the system as ν. Match the Column I (characteristics) with Column II (respective value) and select the correct answer from the codes given below.

	Column I		Column II
A.	ν	1.	$\frac{2L}{(n+1/2)}$; $n = 0, 1, 2, 3, \cdots$
B.	λ	2.	$\left(n+\frac{1}{2}\right)\frac{v}{2L}$; $n = 0, 1, 2, 3, \cdots$
C.	ν_0 (fundamental mode)	3.	$\frac{v}{4L}$
D.	Longest wavelength	4.	$4L$

	A	B	C	D		A	B	C	D
(a)	2	1	3	4	(b)	4	2	3	1
(c)	3	4	2	1	(d)	2	3	1	4

102 Column I lists the figure for odd harmonic of air column and Column II names the corresponding harmonics. Match the Column I with Column II and select the correct answer from the codes given below.

	Column I		Column II
A.		1.	Third harmonic
B.		2.	Fifth harmonic
C.		3.	Ninth harmonic
D.		4.	Seventh harmonic

	A	B	C	D
(a)	1	2	3	4
(b)	4	3	2	1
(c)	2	3	4	1
(d)	3	2	1	4

103 Beats are produced by frequencies ν_1 and ν_2 (such that $\nu_1 > \nu_2$). Match the Column I (characteristic) with Column II (respective formula) and select the correct answer from the codes given below.

	Column I		Column II
A.	Beat frequency	1.	$\frac{1}{\nu_1 - \nu_2}$
B.	Duration of time between two successive maxima or minima	2.	$\nu_1 - \nu_2$
C.	$\omega_1 - \omega_2$	3.	$2\pi(\nu_1 - \nu_2)$

	A	B	C
(a)	1	2	3
(b)	2	1	3
(c)	3	2	1
(d)	3	1	2

NCERT & NCERT Exemplar

MULTIPLE CHOICE QUESTIONS

NCERT

104 A string of mass 2.5 kg is under tension of 200 N. The length of the stretched string is 20 m. If the transverse jerk is struck at one end of the string, the disturbance will reach the other end in
(a) 1s (b) 0.5s
(c) 2s (d) Data given is insufficient

105 A stone dropped from the top of a tower of height 300 m high splashes into the water of a pond near the base of the tower. When is the splash heard at the top given that the speed of sound in air is 340 ms^{-1}? (Take, $g = 9.8\ ms^{-2}$)
(a) 2.5 s (b) 4.3 s (c) 8.7 s (d) 15 s

106 A steel wire has a length of 12 m and a mass of 2.10 kg. What should be the tension in the wire so that speed of a transverse wave on the wire equals the speed of sound in dry air at 20°C $= 343\ ms^{-1}$?
(a) 2×10^4 N (b) 4×10^6 N (c) 6×10^8 N (d) 8×10^{10} N

107 A bat emits ultrasonic sound of frequency 100 kHz in air. If this sound meets a water surface, what is the wavelength of (i) the reflected sound, (ii) and the transmitted sound, respectively? Speed of sound in air $= 340\ ms^{-1}$ and in water $= 1486\ ms^{-1}$.
(a) 3.4×10^{-3} m, 1.49×10^{-2} m
(b) 1.4×10^{-3} m, 3.4×10^{-2} m
(c) 5×10^{-3} m, 15×10^{-2} m
(d) 34×10^{-3} m, 1.5×10^{-2} m

108 A hospital uses an ultrasonic scanner to locate tumours in a tissue. What is the wavelength of sound in the tissue in which the speed of sound is 1.7 kms^{-1}? The operating frequency of the scanner is 4.2 MHz.
(a) 2×10^{-2} m (b) 4×10^{-4} m
(c) 5×10^{-5} m (d) 6×10^{-6} m

109 A transverse harmonic wave on a string is described by

$$y(x,t) = 3\sin\left(36t + 0.018x + \frac{\pi}{4}\right)$$

where x and y are in cm and t is in second. The positive direction of x is from left to right. Then,
(a) angular frequency of the wave is 7.5 kHz
(b) the speed of the wave is 20 ms^{-1}
(c) frequency of the wave is 7.5 Hz
(d) the least distance between two successive crests in the wave is 2.5 cm

110 For the travelling harmonic wave

$$y(x,t) = 2\cos 2\pi(10t - 0.0080x + 0.35)$$

where, x and y are in cm and t in second. Calculate the phase difference between oscillatory motion of two points separated by a distance of 4 m.
(a) 1.4 π rad (b) 2.8 π rad (c) 4.5 π rad (d) 6.4 π rad

111 The displacement of a string is given by

$$y(x,t) = 0.06\sin\left(\frac{2\pi x}{3}\right)\cos(120\pi t)$$

where, x and y are in metre and t in second. The length of the string is 1.5 m and its mass is 3×10^{-2} kg, then
(a) it represents a progressive wave of frequency 60 Hz
(b) it represents a stationary wave of frequency 60 Hz
(c) amplitude of this wave is constant
(d) None of the above

112 The transverse displacement of a string (clamped at its both ends) is given by

$$y(x,t) = 0.06\sin\left(\frac{2\pi x}{3}\right)\cos(120\pi t).$$

For all the points on the string between two consecutive nodes vibration does not have
(a) same frequency (b) same phase
(c) same energy (d) different amplitude

113 A wire stretched between two rigid supports vibrates in its fundamental mode with a frequency of 45 Hz. The mass of the wire is 3.5×10^{-2} kg and its linear mass density is $4\times10^{-2}\ kgm^{-1}$. What is the speed of a transverse wave on the string (in ms^{-1})?
(a) 50.75 (b) 218
(c) 78.75 (d) 92.75

114 What is the tension in the string in the Q. 113?
(a) 124 N (b) 248 N
(c) 442 N (d) 628 N

115 A metre-long tube open at one end, with a movable piston at the other end, shows resonance with a fixed frequency source (a tuning fork of frequency 340 Hz), when the tube length is 25.5 cm or 79.3 cm. Estimate the speed of sound in air at the temperature of the experiment. Ignore edge effect.
(a) 366 ms^{-1} (b) 333 ms^{-1}
(c) 330 ms^{-1} (d) 370 ms^{-1}

116 Steel rod 100 cm long is clamped at its middle. The fundamental frequency of longitudinal vibrations of the rod is given to be 2.53 kHz. What is the speed of sound in steel? ***AIIMS 2018***

(a) 7.08 kms^{-1} (b) 25.3 kms^{-1}
(c) 5.06 kms^{-1} (d) 10.74 kms^{-1}

117 A pipe 20 cm long is closed at one end. Which harmonic mode of the pipe is resonantly excited by a 430 Hz source? Will this same source be in resonance with the pipe, if both ends are open? (Speed of sound $= 340 \text{ ms}^{-1}$)

(a) Fundamental mode, yes (b) Fundamental mode, no
(c) Second harmonic, yes (d) Second harmonic, no

118 Two sitar strings A and B playing the note 'Ga' are slightly out of tune and produce beats of frequency 6 Hz. The tension in the string A is slightly reduced and the beat frequency is found to reduce to 3 Hz. If the original frequency of A is 324 Hz, what is the frequency of B?

(a) 200 Hz (b) 318 Hz
(c) 300 Hz (d) 330 Hz

119 A train, standing at the outer signal of a railway station blows a whistle of frequency 400 Hz in still air. What is the frequency of the whistle for a platform observer when the train approaches the platform with a speed of 10 ms^{-1}? The speed of sound in still air can be taken as 340 ms^{-1}.

(a) 312 Hz (b) 412 Hz
(b) 512 Hz (d) 670 Hz

120 A train, standing in a station yard, blows a whistle of frequency 400 Hz in still air. The wind starts blowing in the direction from the yard to the station with a speed of 10 ms^{-1}. Given that the speed of sound in still air is 340 ms^{-1}, then

(a) the frequency of sound as heard by an observer standing on the platform is 400 Hz
(b) the speed of sound for the observer standing on the platform is 340 ms^{-1}
(c) the frequency of sound as heard by the observer standing on the platform will increase
(d) the frequency of sound as heard by the observer standing on the platform will decrease

121 A travelling harmonic wave on a string is described by $y = 7.5 \sin\left(0.0050x + 12t + \frac{\pi}{4}\right)$. What are the displacement and velocity of oscillation of a point at $x = 1$ cm, and $t = 1$ s?

(a) 12 cm, 75 cms^{-1} (b) 10 cm, 50 cms^{-1}
(c) 5 cm, 90 cms^{-1} (d) 2 cm, 88 cms^{-1}

122 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 kmh^{-1}. What is the frequency of sound reflected by the submarine? Take, the speed of sound in water to be 1450 ms^{-1}.

(a) 20 kHz (b) 35 kHz
(c) 40 kHz (d) 46 kHz

123 Earthquakes generate sound waves inside the earth. Unlike a gas, the earth can experience both transverse S and longitudinal P sound waves. Typically, the speed of S wave is about 4 kms^{-1} and that of P wave is 8 kms^{-1}. A seismograph records P and S waves from an earthquake. The first P wave arrives 4 min before the first S wave. Assuming the waves travel in straight line, at what distance does the earthquake occur?

(a) 1620 km (b) 1720 km
(c) 1820 km (d) 1920 km

124 A bat is flitting about in a cave, navigating *via* ultrasonic beeps. Assume that the sound emission frequency of the bat is 40 kHz. During one fast swoop directly toward a flat wall surface, the bat is moving at 0.03 times the speed of sound in air. What frequency does the bat hear reflected off the wall?

(a) 24 kHz (b) 35 kHz
(c) 42 kHz (d) 50 kHz

NCERT Exemplar

125 Water waves produced by a motorboat sailing in water are

(a) neither longitudinal nor transverse
(b) both longitudinal and transverse
(c) only longitudinal
(d) only transverse

126 Sound waves of wavelength λ travelling in a medium with a speed of v ms^{-1} enter into another medium where its speed in $2v$ ms^{-1}. Wavelength of sound waves in the second medium is

(a) λ (b) $\frac{\lambda}{2}$ (c) 2λ (d) 4λ

127 Speed of sound wave in air

(a) is independent of temperature
(b) increases with pressure
(c) increases with increase in humidity
(d) decreases with increase in humidity

128 Change in temperature of the medium changes

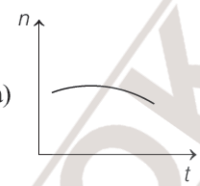
(a) frequency of sound waves
(b) amplitude of sound waves
(c) wavelength of sound waves
(d) loudness of sound waves

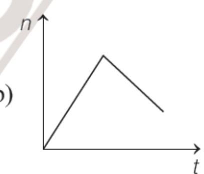
129 With propagation of longitudinal waves through a medium, the quantity transmitted is
(a) matter (b) energy
(c) energy and matter
(d) energy, matter and momentum

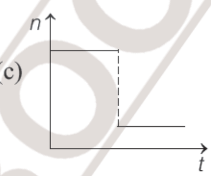
130 A sound wave is passing through air column in the form of compression and rarefaction. In consecutive compressions and rarefaction,
(a) density remains constant
(b) Boyle's law is obeyed
(c) bulk modulus of air oscillates
(d) there is no transfer of heat

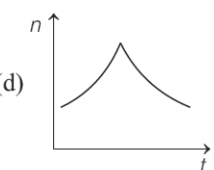
131 Equation of a plane progressive wave is given by $y_i = 0.6 \sin 2\pi \left(t - \frac{x}{2}\right)$. On reflection from a denser medium, its amplitude becomes (2/3) of the amplitude of the incident wave. The equation of the reflected wave is
(a) $y_r = 0.6 \sin 2\pi \left(t + \frac{x}{2}\right)$
(b) $y_r = -0.4 \sin 2\pi \left(t + \frac{x}{2}\right)$
(c) $y_r = 0.4 \sin 2\pi \left(t + \frac{x}{2}\right)$
(d) $y_r = -0.4 \sin 2\pi \left(t - \frac{x}{2}\right)$

132 A train whistling at constant frequency is moving towards a station at a constant speed v. The train goes past a stationary observer on the station. The frequency n of the sound as heard by the observer is plotted as a function of time t (figure). Identify the expected curve.

(a)


(b)


(c)


(d)


Answers

> Mastering NCERT with MCQs

1 (a)	2 (d)	3 (a)	4 (d)	5 (c)	6 (c)	7 (c)	8 (d)	9 (a)	10 (a)
11 (c)	12 (b)	13 (a)	14 (a)	15 (c)	16 (a)	17 (c)	18 (a)	19 (a)	20 (c)
21 (b)	22 (a)	23 (a)	24 (b)	25 (c)	26 (a)	27 (b)	28 (c)	29 (a)	30 (c)
31 (b)	32 (d)	33 (a)	34 (a)	35 (c)	36 (d)	37 (d)	38 (a)	39 (b)	40 (c)
41 (a)	42 (b)	43 (a)	44 (d)	45 (c)	46 (c)	47 (d)	48 (b)	49 (b)	50 (b)
51 (b)	52 (b)	53 (c)	54 (d)	55 (b)	56 (c)	57 (c)	58 (c)	59 (c)	60 (b)
61 (a)	62 (c)	63 (a)	64 (a)	65 (a)	66 (c)	67 (d)	68 (b)	69 (c)	70 (b)
71 (c)	72 (d)	73 (d)	74 (b)						

> Special Types Questions

75 (a)	76 (a)	77 (a)	78 (b)	79 (a)	80 (a)	81 (c)	82 (a)	83 (d)	84 (c)
85 (d)	86 (a)	87 (a)	88 (c)	89 (c)	90 (b)	91 (d)	92 (d)	93 (c)	94 (a)
95 (d)	96 (d)	97 (a)	98 (c)	99 (a)	100 (b)	101 (a)	102 (c)	103 (b)	

> NCERT & NCERT Exemplar MCQs

104 (b)	105 (c)	106 (a)	107 (a)	108 (b)	109 (b)	110 (d)	111 (b)	112 (c)	113 (c)
114 (b)	115 (a)	116 (c)	117 (b)	118 (b)	119 (b)	120 (a)	121 (d)	122 (d)	123 (d)
124 (c)	125 (b)	126 (c)	127 (c)	128 (c)	129 (b)	130 (d)	131 (b)	132 (d)	

Hints & Explanations

1 (*a*) In a mobile phone, initially sound waves are converted into an electric current signal which in turn generate electromagnetic waves (radio waves).

2 (*d*) Light waves, radiowaves, X-rays, are all electromagnetic waves which do not necessarily require a medium for their propagation.

While seismic waves are mechanical waves and hence require a material medium for their propagation.

4 (*d*) The wave generated from up and down jerk given to the string or by up and down motion of the piston at the end of the pipe will be transverse or longitudinal waves, respectively.

These transverse and longitudinal waves are also called progressive waves, as they travel from one part of the medium to another.

5 (*c*) In a water wave, it is the disturbance that moves, not water as a whole.

However, a stream constitutes motion of water as a whole.

Likewise a wind (motion of air as a whole) should not be confused with a sound wave which is a propagation of distrurbance (in pressure density) in air, without the motion of air medium as a whole.

6 (*c*) For mathematical description of a travelling wave, we need a function of both position x and time t.

Such a function at every instant should give the shape of the wave at that instant.

Also, at every given location, it should describe the motion of the constituent of the medium.

7 (*c*) Given, displacement of an elastic wave,

$$y = 3\sin\omega t + 4\cos\omega t$$

Assume, $3 = a\cos\phi$ ...(i)

$4 = a\sin\phi$ ...(ii)

Squaring and adding Eqs. (i) and (ii), we get

$$a^2\cos^2\phi + a^2\sin^2\phi = 3^2 + 4^2$$

$$\Rightarrow \quad a^2(\cos^2\phi + \sin^2\phi) = 25$$

$$a^2 \cdot 1 = 25 \Rightarrow a = 5$$

$[\because \sin^2 A + \cos^2 A = 1]$

Hence, $y = 5\cos\phi\sin\omega t + 5\sin\phi\cos\omega t$

$= 5(\cos\phi\sin\omega t + \sin\phi\cos\omega t) = 5\sin(\omega t + \phi)$

[using the trigonometric identity, $\sin(A+B) = \sin A\cos B + \cos A\sin B$]

Comparing the above equation with the general equation $y = A\sin(\omega t + \phi)$, we get resultant amplitude = 5 cm

8 (*d*) Given, equation for simple wave motion is

$$y = 5(\sin 4\pi t + \sqrt{3}\cos 4\pi t)$$

$$= [5\sin 4\pi t + 5\sqrt{3}\cos 4\pi t] \quad \text{...(i)}$$

For a left travelling wave, general equation for its motion is

$$y = A\sin(kx + \omega t) + B\cos(kx + \omega t) \quad \text{...(ii)}$$

$$= a\sin(kx + \omega t + \phi)$$

where, $a = \sqrt{A^2 + B^2}$ and $\phi = \tan^{-1}(B/A)$

From comparing both Eqs. (i) and (ii), we can say Eq. (i) represents Eq. (ii), where $x = 0$

Also, we get $A = 5$ and $B = 5\sqrt{3}$

$\therefore$ Amplitude, $a = \sqrt{5^2 + (5\sqrt{3})^2} = \sqrt{25 + 75} = \sqrt{100} = 10$

9 (*a*) A wave or oscillation is made up of a crest and a trough. The crest is the point of maximum positive displacement and the trough is the point of maximum negative displacement. So, in the given figure, notice the position of X w.r.t. time.

At $t = 0$, the crest X is at a displacement of one quarter of wave from origin. With time it progresses along $+X$-axis and at $t = 4$s, it is displaced by a full wave or oscillation i.e. one crest and one trough. Thus, only one wave crosses the origin in 4s.

10 (*a*) The wave equation is $y(x, t) = a\sin(kx - \omega t + \phi)$ is a sine function. Since, the sine function varies between -1 and $+1$, so the displacement $y(x, t)$ varies between a and $-a$.

The range of possible values of $y(x, t)$ is

$$-a \le y(x, t) \le a$$

11 (*c*) Given, wave equation, $y = 10\sin\left(\frac{2\pi}{45}t + \alpha\right)$

where, quantity $\left(\frac{2\pi}{45}t + \alpha\right)$ represents the total phase of the wave.

At $t = 0$, $y = 5$ cm, then from the above equation, we can write $5 = 10\sin\alpha$

$$\sin\alpha = \frac{1}{2} \Rightarrow \alpha = \frac{\pi}{6}$$

If $t = 7.5\text{ s} = (15/2)\text{ s}$, then

$$\text{total phase} = \frac{2\pi}{45} \times \frac{15}{2} + \frac{\pi}{6} = \frac{\pi}{3} + \frac{\pi}{6} = \frac{\pi}{2}$$

12 (*b*) Taking $\phi = 0$ in the given equation, the displacement at $t = 0$ becomes

$$y'(x, 0) = a\sin kx = a\sin(kx + 2n\pi)$$

($\because$ sine function repeats its value after every 2π change in angle)

$$= a\sin k\left(x + \frac{2n\pi}{k}\right)$$

$\Rightarrow$ The displacement at points x and $x + \frac{2n\pi}{k}$ are the same, where $n = 1, 2, 3, \ldots$.

13 (*a*) Given, wave equation

$$y(x,t)=4\sin\left[\pi\left(\frac{x}{9}-\frac{t}{5}+\frac{1}{6}\right)\right] \qquad \ldots(\text{i})$$

The general equation of a wave is

$$y(x,t)=a\sin(kx-\omega t+\phi)$$

Comparing Eq. (i) with general equation, we get

$$k=(\pi/9)\text{ rad cm}^{-1}$$

So, the angular wave number or propagation constant of the given wave is $\frac{\pi}{9}$ rad cm^{-1}.

14 (*a*) Given, wave equation

$$y(x,t)=a\sin(10\pi x+11\pi t+\pi/3) \qquad \ldots(\text{i})$$

Comparing Eq. (i) with the general equation of wave

$y=A\sin(kx+\omega t+\phi)$, we get

$k=10\pi$

We know that,

Wavelength of the wave, $\lambda=\frac{2\pi}{k}$

$$\Rightarrow \qquad \lambda=\frac{2\pi}{10\pi}=0.2\text{ unit}$$

15 (*c*) Given, wave equation

$$y(x,t)=0.07\sin(12\pi x-300\pi t)$$

Comparing the above equation with general equation

$y(x,t)=a\sin(kx-\omega t)$, we get

$a=0.07$ m, $k=12\pi$ m^{-1}

and $\qquad \omega=300\pi$ rads^{-1} $\Rightarrow \lambda=\frac{2\pi}{k}=\frac{2\pi}{12\pi}=\frac{1}{6}$ m

16 (*a*) Given, wave equation,

$$y=2\cos 2\pi(330t-x)$$

It can be expressed as

$$y=2\cos(2\pi\times 330t-2\pi x)$$

On comparing Eq. (i) with

$y=A\cos(\omega t-kx+\phi)$, we get

$\omega=2\pi\times 330$

$\Rightarrow$ Period, $T=2\pi/\omega=\frac{2\pi}{2\pi\times 330}=\left(\frac{1}{330}\right)$ s

17 (*c*) Let the time taken by a particle of the wave to complete one full oscillation is T.

$\Rightarrow T=4\times$(time to travel from maximum displacement to zero by a particle)

$\Rightarrow T=4\times 0.14\text{ s}=0.56$ s

Frequency, $\nu=\frac{1}{T}=\frac{1}{0.56}=\frac{100}{56}$

$=1.79$ Hz

18 (*a*) Given, wave equation $y=15\cos(660\pi t-0.02\pi x)$

On comparing with general equation of progressive wave,

$y(x,t)=a\cos(\omega t-kx)=a\cos\left(\frac{2\pi}{T}t-\frac{2\pi}{\lambda}x\right)$, we get

$$\frac{2\pi}{T}=660\pi \text{ or } \frac{1}{T}=330$$

or $\qquad \nu=\frac{1}{T}=330$ Hz

19 (*a*) Given, $a=1$ m, $\lambda=2\pi$ m and $\nu=\left(\frac{1}{\pi}\right)$ Hz

As, $y=a\sin(kx-\omega t)$

$=\sin\left(\frac{2\pi}{2\pi}\times x-2\pi\times\frac{1}{\pi}t\right)\left(\because k=\frac{2\pi}{\lambda}\text{ and }\omega=2\pi\nu\right)$

$=\sin(x-2t)$

21 (*b*) The given wave equation,

$$y=10^{-6}\sin(100t+20x+\pi/4) \qquad \ldots(\text{i})$$

On comparing Eq. (i) with standard wave equation

$y=a\sin(\omega t+kx+\phi)$, we get

$\omega=100$ rad s^{-1}, $k=20$ rad m^{-1}, $\phi=\pi/4$

$\Rightarrow$ Wave velocity, $v=\frac{\omega}{k}=\frac{100}{20}=5$ ms^{-1}

22 (*a*) The given wave equation is

$$y=0.2\sin 2\pi\left[\frac{t}{0.01}-\frac{x}{0.3}\right]$$

$$=0.2\sin\left[\frac{2\pi t}{0.01}-\frac{2\pi x}{0.3}\right]$$

$$=0.2\sin\left[\pi+\left(\frac{2\pi x}{0.3}-\frac{2\pi t}{0.01}\right)\right]$$

$$=0.2\sin\left(\frac{2\pi x}{0.3}-\frac{2\pi t}{0.01}+\pi\right) \qquad \ldots(\text{i})$$

Comparing Eq. (i) with standard wave equation

$y=a\sin(kx-\omega t+\phi)$, we get

$\omega=\frac{2\pi}{0.01}$ rad s^{-1}, $k=\frac{2\pi}{0.3}$ rad m^{-1} and $\phi=\pi$

$\Rightarrow$ Wave velocity, $v=\frac{\omega}{k}=\frac{2\pi/0.01}{2\pi/0.3}=\frac{0.3}{0.01}=30$ ms^{-1}

24 (*b*) Transverse wave speed over a string is given by

$$v=\sqrt{T/\mu} \qquad \ldots(\text{i})$$

where, T = tension in string

and $\quad \mu$ = mass per unit length of string.

Here, when velocity is v, then

tension, $T_1=2.06\times 10^4$ N

Let when velocity is $\frac{v}{2}$, then

tension is T, hence from Eq. (i), we get

$$\frac{v}{\frac{v}{2}}=\sqrt{\frac{T_1}{T}}$$

$$\Rightarrow \quad T=\frac{T_1}{4}=\frac{2.06\times 10^4}{4} \text{ or } T=5.15\times 10^3\text{ N}$$

25 (*c*) Given, wave equation, $y = 0.002\cos(300t - 15x)$

Mass density, $\mu = 0.1\,\text{kg/m}$

Comparing the given wave equation with $y = a\cos(\omega t - kx)$, we have

$\omega = 300\,\text{rad s}^{-1}$, $k = 15\,\text{rad m}^{-1}$

$\therefore$ Velocity of wave,

$$v = \frac{\omega}{k} = \frac{300}{15} = 20\,\text{m/s}$$

Wave speed in string is also given by

$$v = \sqrt{\frac{T}{\mu}} \qquad \ldots\text{(i)}$$

where, T = tension in the string

and μ = mass per unit length of string.

Substituting the values in Eq. (i), we get

$$20 = \sqrt{\frac{T}{0.1}} \Rightarrow 400 = \frac{T}{0.1}$$

$$\Rightarrow \qquad T = 40\,\text{N}$$

26 (*a*) Given, radius of wire A = 2 (radius of wire B)

i.e. $\qquad r_A = 2r_B$

Also, tension $T_B = T_A$

Mass of string A, m_A = volume × density

$$= (\pi r_A^2) \times l_A \times \rho_A \qquad \ldots\text{(i)}$$

and $\qquad m_B = (\pi r_B^2)\, l_B \times \rho_B \qquad \ldots\text{(ii)}$

Dividing Eq. (i) by Eq. (ii), we get

$$\therefore \qquad \frac{m_A}{m_B} = \frac{r_A^2\, l_A}{r_B^2\, l_B} \qquad (\because \rho_A = \rho_B)$$

$$\Rightarrow \qquad \frac{m_A / l_A}{m_B / l_B} = \frac{r_A^2}{r_B^2} \qquad \ldots\text{(iii)}$$

Since, linear mass density, $\mu = \dfrac{m}{l}$

$$\Rightarrow \qquad \frac{\mu_A}{\mu_B} = \frac{m_A / l_A}{m_B / l_B} = \left(\frac{r_A}{r_B}\right)^2$$

[using Eq. (iii)]

We know, speed of transverse wave, $v = \sqrt{\dfrac{T}{\mu}}$

$$\Rightarrow \qquad \frac{v_A}{v_B} = \sqrt{\frac{\mu_B}{\mu_A}} = \frac{r_B}{r_A} = \frac{1}{2} \qquad (\because r_A = 2r_B)$$

28 (*c*) Speed of sound waves in a fluid is given by

$v = \sqrt{\dfrac{B}{\rho}}$, where B is bulk modulus and ρ is density of the medium.

Clearly, $\qquad v \propto \dfrac{1}{\sqrt{\rho}} \qquad (\because$ for any fluid, B = constant)

and $\qquad v \propto \sqrt{B} \qquad (\because$ for medium, ρ = constant)

Hence, speed of sound wave depends on inversely square root of density and directly on square root of bulk modulus of the medium.

29 (*a*) The speed of wave in a bar, $v = \sqrt{\dfrac{Y}{\rho}}$

where, Y = Young's modulus of the material of the bar and ρ = mass density.

So, the ratio of the speed of longitudinal waves in the solid bars is

$$\frac{v_1}{v_2} = \sqrt{\frac{Y_1 \rho_2}{Y_2 \rho_1}}$$

Since, solid bars are made up of the materials with same density, i.e. $\rho_1 = \rho_2$

$$\Rightarrow \qquad \frac{v_1}{v_2} = \sqrt{\frac{Y_1}{Y_2}} = \sqrt{4} = 2 \qquad \left[\text{given}, \frac{Y_1}{Y_2} = 4\right]$$

30 (*c*) Speed of sound in different media as mentioned in the question at constant temperature is given as

$$v_{\underset{\text{(aluminium)}}{\text{solid}}} = 6420\,\text{ms}^{-1}$$

$$v_{\underset{\text{(water)}}{\text{liquid}}} = 1482\,\text{ms}^{-1}, \; v_{\text{air}} = 343\,\text{ms}^{-1}$$

$\therefore$ Correct order is $v_{\underset{\text{(aluminium)}}{\text{solid}}} > v_{\underset{\text{(water)}}{\text{liquid}}} > v_{\text{air}}$.

31 (*b*) We know that, 1 mol of any gas occupies 22.4 L at standard temperature and pressure (STP), therefore density of air at STP is

$$\rho_0 = \frac{\text{Mass of one mole of air}}{\text{Volume of one mole of air at STP}}$$

$$= \frac{29.0 \times 10^{-3}}{22.4 \times 10^{-3}} = 1.29\,\text{kg m}^{-3}$$

Also, at STP, pressure of air is $1.01 \times 10^5\,\text{Nm}^{-2}$.

So, according to Newton's formula for the speed of sound in medium, we get speed of sound in air at STP as

$$v = \sqrt{\frac{p}{\rho_0}} = \left[\frac{1.01 \times 10^5}{1.29}\right]^{1/2} = 279.81\,\text{ms}^{-1}$$

$$\cong 280\,\text{ms}^{-1}$$

32 (*d*) The speed of sound in a gas does not depend upon pressure of the gas, till temperature remains constant, i.e. speed remains the same whatever be the pressure.

Therefore, graph given in option (d) is correct.

33 (*a*) The Laplace correction shows that the pressure variations in the propagation of sound waves are so fast that there is a short time for the heat flow to maintain constant temperature.

So, these variations are adiabatic not isothermal in nature.

35 (*c*) Due to the principle of superposition, the displacement due to two pulses will exactly cancel out each other, i.e. at $t = 2\,\text{s}$, resultant displacement is zero.

37 (*d*) Consider the two waves of equal amplitude A and equal frequency travelling in the same direction as follows

$$y_1(x, t) = A\sin(kx - \omega t)$$
$$y_2(x, t) = A\sin(kx - \omega t + \phi)$$

So, by applying the principle of superposition of wave the resultant wave is given as

$$y(x,t) = A\sin(kx-\omega t) + A\sin(kx-\omega t+\phi)$$
$$= A\left[2\sin\left[\frac{(kx-\omega t)+(kx-\omega t+\phi)}{2}\right]\cos\frac{\phi}{2}\right]$$
$$= 2A\cos\frac{\phi}{2}\sin\left(kx-\omega t+\frac{\phi}{2}\right)$$

$\therefore$ The resultant amplitude $= 2A\cos\frac{\phi}{2}$

Since, the given cosine function will vary from 0 to π and hence, magnitude of wave varies between 0 to $2A$.

38 (*a*) Amplitude of the resultant of the two waves of same amplitude and equal frequency when they travel in the same direction in a medium having phase difference of ϕ is given as $A(\phi) = 2A\cos\left(\frac{\phi}{2}\right)$

Given, $\phi = 120°$

$\Rightarrow$ $A(\phi) = 2A\cos\left(\frac{120°}{2}\right) = 2A\cos 60°$

or $A(\phi) = 2A\times\frac{1}{2} = A$

40 (*c*) When a wave is incident normally on a rigid boundary, then assuming there is no absorption of energy by the boundary, the reflected wave has the same shape as the incident wave but it suffers a phase change of π or 180° on reflection.

This is because the boundary is rigid and the disturbance must have zero displacement at all times at the boundary.

41 (*a*) Since, there is a change in the medium at B such that the end point (boundary) at B is neither completely fixed nor completely free to move. So, when a wave pulse is generated at the end A and progresses towards junction B, a part of the wave is reflected with velocity v_r and a part of the wave is transmitted with velocity v_t.

Since, $(\mu_2 > \mu_1)$, i.e. wave is produced on the lighter string and moves towards the heavier string.

As, the velocity of the wave in a string is given as

$v = \sqrt{\frac{T}{\mu}}$ is smaller for heavier string (where it is transmitted) and larger for the lighter string (where it is reflected).

Hence, $v_r > v_t$.

42 (*b*) We have, incident wave, $y_1 = a\sin(kx-\omega t)$

So the reflected wave, $y_2 = a\sin(kx+\omega t)$

From principle of superposition,

The standing wave equation is obtained as

$$y(x,t) = y_1 + y_2 = a[\sin(kx-\omega t)+\sin(kx+\omega t)]$$
$$= 2a\sin kx\cos\omega t \quad \ldots(\text{i})$$

On comparing Eq. (i) with $y(x,t) = A(x)\cos\omega t$, we get

Amplitude, $A(x) = 2a\sin kx$

43 (*a*) In stationary waves, change in pressure and density are maximum at nodes while displacement is minimum (zero).

44 (*d*) In stationary waves, the positions of nodes and anti-nodes do not change with time. Hence, speed of stationary wave cannot be defined.

45 (*c*) Given equation of stationary wave is

$Y = 0.3\sin(0.157x)\cos(200\pi t)$

Comparing it with general equation of stationary wave, i.e. $Y = a\sin kx\cos\omega t$, we get

$$k = \left(\frac{2\pi}{\lambda}\right) = 0.157$$

$$\Rightarrow \lambda = \frac{2\pi}{0.157} = 4\pi^2 \quad \left(\because \frac{1}{2\pi}\approx 0.157\right) \ldots(\text{i})$$

and $\omega = 200\pi = \frac{2\pi}{T} \Rightarrow T = \frac{1}{20}$ s

As the possible wavelength associated with nth harmonic of a vibrating string, i.e. fixed at both ends is given as

$$\lambda = \frac{2l}{n} \text{ or } l = n\left(\frac{\lambda}{2}\right)$$

Now, according to question, string is fixed from both ends and oscillates in 4th harmonic, so

$$4\left(\frac{\lambda}{2}\right) = l \Rightarrow 2\lambda = l$$

or $l = 2\times 4\pi^2 = 8\pi^2$ [using Eq. (i)]

Now, $\pi^2 \approx 10 \Rightarrow l \approx 80$ m

46 (*d*) Possible frequencies of waves in a wire is given as

$$\nu_n = \frac{nv}{2l}$$

Fundamental frequency, $\nu_0 = \frac{v}{2L}$ ...(i) $(\because n = 1)$

Wave velocity, $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{T}{(m/L)}}$ ...(ii) $\left(\because \mu = \frac{m}{L}\right)$

$\because$ Mass of the string, m = Volume $\times$ Density

$$= (\pi r^2\times L)\times\rho \Rightarrow \mu = \frac{m}{L} = \pi r^2\rho$$

On substituting the value of μ in Eq. (ii), we get

$$\Rightarrow v = \sqrt{\frac{T}{\pi r^2\rho}} = \frac{1}{r}\sqrt{\frac{T}{\pi\rho}}$$

Substituting the value of v in Eq. (i), we get

$$\nu_0 = \frac{1}{2rL}\sqrt{\frac{T}{\pi\rho}} \Rightarrow \frac{\nu_{01}}{\nu_{02}} = \frac{L_2}{L_1}\times\frac{r_2}{r_1}\sqrt{\frac{T_1}{T_2}}$$

$$\Rightarrow \frac{600}{\nu_{02}} = \frac{2}{1}\times\frac{1}{2}\times\sqrt{\frac{T}{T/9}} = 3$$

$$\therefore \nu_{02} = \frac{600}{3} = 200\text{ Hz}$$

47 (*d*) Given $L = 75\,\text{cm}$, $\nu_1 = 420$ Hz and $\nu_2 = 315$ Hz

As, two consecutive resonant frequencies for a string fixed at both ends will be

$$\nu_1 = \frac{nv}{2L} \text{ and } \nu_2 = \frac{(n+1)v}{2L}$$

$$\Rightarrow \quad \nu_1 - \nu_2 = 420 - 315$$

$$\Rightarrow \quad \frac{(n+1)\,v}{2L} - \frac{nv}{2L} = 105 \text{ Hz} \Rightarrow \frac{v}{2L} = 105 \text{ Hz}$$

Thus, lowest resonant frequency of a string is 105 Hz.

48 (*b*) Frequency of vibration of a string in *n*th harmonic is given by

$$f_n = n \cdot \frac{v}{2l} \qquad \text{... (i)}$$

where, v = speed of sound and l = length of string.

Here, $f_3 = 240$ Hz, $l = 2$ m and $n = 3$

Substituting these values in Eq. (i), we get

$$\therefore \quad 240 = 3 \times \frac{v}{2 \times 2} \Rightarrow v = \frac{4 \times 240}{3} = 320 \text{ ms}^{-1}$$

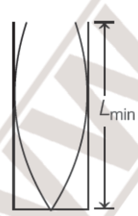
Also, fundamental frequency is

$$f = \frac{f_n}{n} = \frac{f_3}{3} = \frac{240}{3} = 80 \text{ Hz}$$

50 (*b*) At open end, phase of pressure wave changes by 180°, so compression returns as rarefaction. At closed end, there is no phase change. So, compression returns as compression and rarefaction as rarefaction.

Hence, for an open pipe blown with high pressure pulse, low pressure pulse starts travelling up. Similarly, for closed pipe, high pressure pulse starts travelling up and down the pipe.

51 (*b*) The smallest length of the air column is associated with fundamental mode of vibration of the air column closed at one end and open at the other as shown in the diagram below.



$\because$ For such an air column, $L = \left(n + \frac{1}{2}\right)\frac{\lambda}{2}$

$\Rightarrow$ For fundamental mode $n = 0$, $\quad L_{min} = \frac{\lambda}{4}$

$$50 \text{ cm} = \frac{\lambda}{4} \qquad [\text{given, } L_{min} = 50 \text{ cm}]$$

$$\Rightarrow \quad \lambda = 200 \text{ cm} \qquad \text{...(i)}$$

The next larger length of the air column is

$$L = \frac{\lambda}{4} + \frac{\lambda}{2} = \frac{\lambda + 2\lambda}{4} = \frac{3\lambda}{4}$$

$$= \frac{3}{4} \times 200 = 150 \text{ cm} \qquad [\text{from Eq. (i)}]$$

52 (*b*) Frequency of *n*th harmonic in a tube closed at one end tube and open at other end is

$$\Rightarrow \quad \nu = \frac{(2n+1)\,v}{4L},$$

where $n = 0, 1, 2, 3, \ldots$.

Now, given two nearest harmonics that exists in this tube are of frequency 220 Hz and 260 Hz.

$$\therefore \quad \frac{(2n+1)\,v}{4L} = 220 \text{ Hz} \qquad \text{...(i)}$$

Next harmonic occurs at

$$\frac{(2n+3)\,v}{4L} = 260 \text{ Hz} \qquad \text{...(ii)}$$

On subtracting Eq. (i) from Eq. (ii), we get

$$\frac{\{(2n+3)-(2n+1)\}\,v}{4L} = 260 - 220$$

$$2\left(\frac{v}{4L}\right) = 40 \Rightarrow \frac{v}{4L} = 20 \text{ Hz}$$

$\therefore$ Fundamental frequency of the system $= \frac{v}{4L} = 20$ Hz

53 (*c*) For an organ pipe, closed from one end frequency of *n*th harmonic/oscillation is given as

$$\nu = \frac{(2n+1)\,v}{4L}$$

where, $n = 0, 1, 2, \ldots$

Given, $v = 340 \text{ ms}^{-1}$, $L = 85 \text{ cm} = 0.85$ m

and $\nu = 1250$ Hz

According to question,

$$\frac{(2n+1)v}{4L} < 1250$$

Substituting the given values in the above relation, we get

$$\Rightarrow \quad (2n+1) < 1250 \times \frac{4 \times 0.85}{340}$$

$$(2n+1) < 12.5$$

$$\Rightarrow \quad 2n < 11.50$$

$$n < 5.75$$

So, n can be 0, 1, 2, 3, 4, 5.

Therefore, we have 6 possible number of natural oscillations whose frequencies lie below 1250 Hz.

54 (*d*) Given, speed of sound in air, $v = 330$ m/s

Length of organ pipe, $L = 1$ m and frequency,

$$\nu = 1000 \text{ Hz}$$

For an open organ pipe,

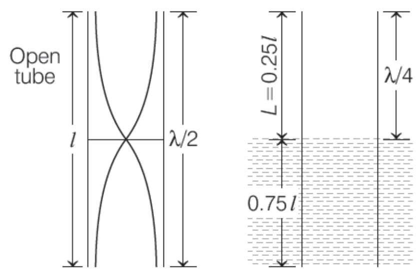
Fundamental frequency, $\nu_1 = \frac{v}{2L}$

$$= \frac{330}{2 \times 1} = 165 \text{ Hz}$$

$\therefore$ Number of tones present in the open organ pipe

$$= \frac{\nu}{\nu_1} = \frac{1000}{165} = 6.06 \simeq 6$$

55 (*b*) When open tube is dipped in water, it becomes a tube closed at one end as shown below,



Fundamental frequency for open tube is $v/2l$.

Fundamental frequency of string $(\nu_0) = \dfrac{v}{2l}$

Fundamental frequency for closed tube,

$$\nu_{0(\text{closed tube})} = \frac{v}{4L}$$

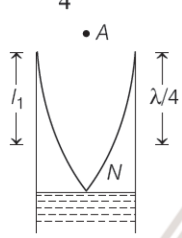
Length available for resonance for closed tube is 0.25 l.

$\Rightarrow \quad L = 0.25\, l$

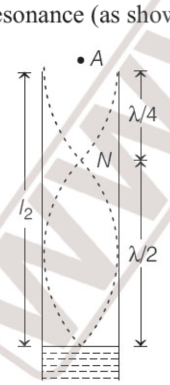
$$\therefore \nu_{0\,(\text{closed tube})} = \frac{v}{4(0.25l)} = \frac{v}{2l} \times 2$$

$$= 2\times \text{ frequency of string} \Rightarrow \frac{\nu_{0(\text{closed tube})}}{\nu_{0(\text{string})}} = 2$$

56 (*c*) For vibrating tuning fork over a resonance column tube with upper end open and lower end closed by water surface, the first resonance (as shown below) is obtained at the length, $L_1 = \dfrac{\lambda}{4}$ ...(i)



and for second resonance (as shown below)



$$L_2 = \frac{\lambda}{4} + \frac{\lambda}{2} = \frac{3\lambda}{4} \qquad \text{...(ii)}$$

From Eqs. (i) and (ii), we get

$$L_2 - L_1 = \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2}$$

$\Rightarrow \qquad \lambda = 2(L_2 - L_1)$

$\Rightarrow \qquad v = 2\nu(L_2 - L_1) \qquad \text{...(iii)} \left(\because \lambda = \dfrac{v}{\nu}\right)$

Given, $\nu = 800$ Hz, $L_1 = 9.75$ cm and $L_2 = 31.25$ cm

Substituting the given values in Eq. (iii), we get

$\Rightarrow \qquad v = 2 \times 800(31.25 - 9.75)$

$= 34400$ cm/s $= 344$ m/s

$\therefore$ Speed of sound in air is 344 m/s.

57 (*c*) Given, $\nu = 1000$ Hz, $v = 332$ m/s and $L = 16.6$ cm $= 16.6 \times 10^{-2}$ m

Frequency of nth harmonic in an organ pipe open on both ends,

$$\nu = \frac{nv}{2L} \quad \text{or} \quad n = \frac{2\nu L}{v}$$

Substituting the given values in the above relation, we get

$$n = \frac{2 \times 1000 \times 16.6 \times 10^{-2}}{332} = 1$$

58 (*c*) In an open organ pipe, the frequency of its nth harmonic is

$$\nu_n = \frac{nv}{2L}, \text{ where } n = 1, 2, 3, \cdots \qquad \text{...(i)}$$

Given, $L = 30$ cm $= 0.3$ m and $v = 330$ ms^{-1}

Substituting the given values in Eq. (i), we get

$$\nu_n = \frac{n \times 330}{2 \times 0.3} = \left(\frac{n \times 330}{0.6}\right) = n550\,\text{s}^{-1}$$

Thus, few modes of an open pipe are

I. For $n = 1$, fundamental mode

$\nu_1 = 550 \times 1 = 550\,\text{s}^{-1}$

$\Rightarrow \quad \nu_1 = 550$ Hz

II. For $n = 2$, second harmonic

$\nu_2 = 2\,\nu_0 = 2 \times 550 = 1100$ Hz $= 1.1$ kHz

Thus, a source of frequency 1.1 kHz will resonate at second harmonic.

59 (*c*) Fundamental frequency for an open organ pipe is given as

$$\nu_1 = \frac{v}{2L}$$

where, L is the length of the open organ pipe.

Third harmonic for a closed organ pipe is given as

$$\nu' = \frac{3v}{4L'}$$

where, L' is the length of closed organ pipe.

According to the question,

$$\nu_1 = \nu'$$

$$\frac{v}{2L} = \frac{3v}{4L'} \Rightarrow L = \frac{2}{3}L'$$

Given, $L' = 20$ cm

$\Rightarrow \quad L = \dfrac{2}{3} \times 20 \text{ cm} = \dfrac{40}{3} \text{ cm} = 13.3 \text{ cm}$

$\therefore$ Length of the open organ pipe is 13.3 cm.

60 (*b*) For first resonance, $L_1 = \frac{\lambda}{4}$

For second resonance, $L_2 = \frac{3\lambda}{4}$

$\therefore \quad L_2 - L_1 = \frac{3\lambda}{4} - \frac{\lambda}{4}$ or $\lambda = 2(L_2 - L_1)$ ...(i)

As, velocity of sound wave is given as

$$v = \nu\lambda$$

where, ν is the frequency.

$\Rightarrow \quad v = \nu[2(L_2 - L_1)]$ ...(ii) [from Eq. (i)]

Given, $\nu = 320$ Hz, $L_2 = 73\,\text{cm} = 0.73\,\text{m}$
and $L_1 = 20\,\text{cm} = 0.20\,\text{m}$

Substituting the given values in Eq. (ii), we get

$\Rightarrow \quad v = 2[320(0.73 - 0.20)] = 2 \times 320 \times 0.53$
$= 339.2\,\text{ms}^{-1} \simeq 339\ \text{ms}^{-1}$

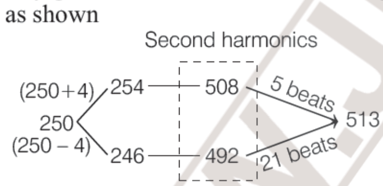
63 (*a*) For frequencies $\nu_1 = \nu - 1$ and $\nu_2 = \nu + 1$.

Beats = difference of frequencies
$= \nu_2 - \nu_1 = (\nu + 1) - (\nu - 1)$
$= \nu + 1 - \nu + 1 = 2$

64 (*a*) Increase in the tension of a string increases its frequency. If the original frequency of $B\,(\nu_B)$ were greater than that of $A\,(\nu_A)$, further increase in ν_B should have resulted in an increase in the beat frequency. But the beat frequency is found to decrease. This shows that $\nu_B < \nu_A$.

Since, $\quad \nu_A - \nu_B = 5$ Hz and $\nu_A = 427$ Hz,
we get $\quad \nu_B = 422$ Hz.

65 (*a*) Given, known frequency is 250 Hz and unknown frequency gives 4 beats/s, so there are two possible cases as shown



Hence, unknown frequency is 254 Hz.

66 (*c*) The frequency of fork 2 = frequency of fork 1 ± beat frequency
$= 200 \pm 4 = 196$ or 204 Hz.

Since, on attaching the tape on the prong of fork 2, its frequency decreases, but now the number of beats per second is 6, i.e. the frequency difference now increases. It is possible only when before attaching the tape, the frequency of fork 2 is less than the frequency of tuning fork 1. Hence, the original frequency of fork 2 was 196 Hz.

67 (*d*) Doppler effect is a wave phenomenon. It not only holds for sound waves but also for electromagnetic waves. As light wave is an electromagnetic wave, so this effect applies to it equally.

68 (*b*)Given, the speed of the car is

$$v_s = 36\ \text{km h}^{-1} = 36 \times \frac{5}{18} = 10\ \text{ms}^{-1}$$

Here, the observer, (i.e. the person) is at rest with respect to the car and the source (i.e., the car with the siren) is moving away from the observer.

$\therefore$ The apparent frequency heard by the person is

$$\nu' = \frac{v}{v + v_s}\nu$$

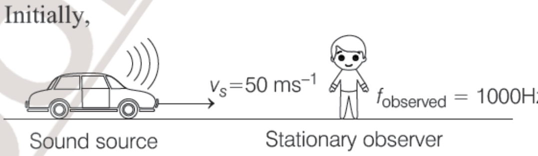
where, v is the speed of sound = 340 ms^{-1} and ν is the frequency of sound emitted by the siren, i.e. 500 Hz.

Substituting the given values in the above relation, we get

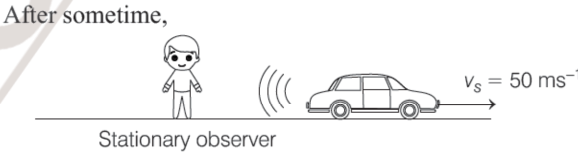
$$\nu' = \frac{340}{340 + 10} \times 500\,\text{Hz}$$
$$= 485.7 \cong 486\ \text{Hz}$$

$\therefore$ The apparent frequency of the wave coming directly from the siren to the person is 486 Hz.

69 (*c*) Initially,



After sometime,



When source is moving towards stationary observer, frequency observed is more than source frequency due to Doppler's effect, it is given by

$$f_{\text{observed}} = f\left(\frac{v}{v - v_s}\right)$$

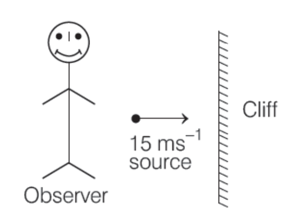
where, f = source frequency,
f_o = observed frequency = 1000 Hz,
v = speed of sound in air = 350 ms^{-1}
and $\quad v_s$ = speed of source = 50 ms^{-1}.

So, $\quad f = \frac{f_{\text{obs}}(v - v_s)}{v} = \frac{1000(350 - 50)}{350} = \frac{6000}{7}$ Hz

When source moves away from stationary observer, observed frequency will be lower due to Doppler's effect and it is given by

$$f_0 = f\left(\frac{v}{v + v_s}\right) = \frac{6000 \times 350}{7 \times (350 + 50)}$$
$$= \frac{6000 \times 350}{7 \times 400} = 750\,\text{Hz}$$

70 (*b*) According to question, situation can be drawn as follows



Frequency of sound that the observer hear in the echo reflected from the cliff is given by

$$\nu' = \left(\frac{v}{v - v_s}\right)\nu$$

where, ν = original frequency of source, v = velocity of sound and v_s = velocity of source.

Given, $\nu = 800$ Hz, $v_s = 15\ \text{ms}^{-1}$ and $v = 300\ \text{ms}^{-1}$.

So, $$\nu' = \left(\frac{330}{330 - 15}\right)800$$

$$= 838.09 \cong 838\ \text{Hz}$$

$\therefore$ The frequency of the sound that the observer heard in the echo reflected from the cliff is 838 Hz.

71 (c) Given, speed of the rocket, i.e. source $\nu_s = 220\ \text{ms}^{-1}$

Frequency emitted by the source, $\nu = 1000$ Hz

Speed of sound, $v = 330\ \text{ms}^{-1}$

As the source (i.e. rocket) is moving towards the stationary target, therefore the frequency of sound detected by the target is

$$\nu' = \frac{\nu_o v}{v - v_s}$$

$$= \frac{1000 \times 330}{330 - 220} = \frac{1000 \times 330}{110} = 3000\ \text{Hz}$$

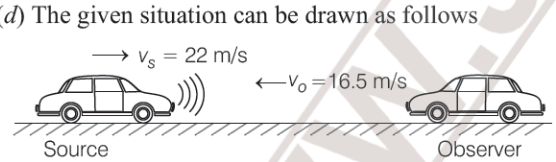
Now the target is the source (as it is the source of echo) and the rocket's is the observer who intercepts the echo of frequency ν'. Hence, the frequency of the echo detected by the rocket is

$$\nu'' = \frac{\nu'(v + v_0)}{v} = \frac{3000(330 + 220)}{330}$$

$$= 5000\ \text{Hz}$$

$\therefore$ The frequency of echo detected by the rocket is 5000 Hz.

73 (d) The given situation can be drawn as follows



where, frequency of the horn blown by the first car,

$$\nu_o = 400\ \text{Hz}$$

Speed of observer in the second car,

$$v_o = 16.5\ \text{m/s}$$

Speed of source,

$$v_s = \text{speed of first car} = 22\ \text{m/s}$$

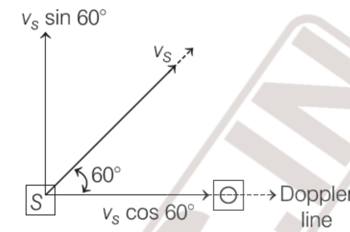
Frequency heard by the driver in the second car,

$$\nu_a = \nu_o\left(\frac{v + v_o}{v - v_s}\right)$$

Substituting the given values, we get

$$\nu_a = 400\left(\frac{340 + 16.5}{340 - 22}\right) = 448.42 \cong 448\ \text{Hz}$$

74 (b) Here, source is moving with a speed of $19.4\ \text{ms}^{-1}$ at an angle 60° with source-observer line as shown in figure.



The apparent frequency heard by observer

$$\nu_o = \nu_s\left[\frac{v}{v - v_s \cos 60°}\right]$$

$$= 100\left[\frac{330}{330 - 19.4 \times (1/2)}\right]$$

$$= 100\left[\frac{330}{330 - 9.7}\right] = 100\left[\frac{330}{320.3}\right]$$

$$= 103.03\ \text{Hz} \simeq 103\ \text{Hz}$$

75 (a) Light is an electromagnetic wave and can travel in vacuum as well, i.e. it does not necessarily require a medium to propagate.

So, the light emitted by star, which are hundreds of light years away reaches us through interstellar space even though the intersteller space is practically a vacuum.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

76 (a) In transverse waves, the particle motion is normal to the direction of propagation of the wave. Therefore, as the wave propagates each element of the medium undergoes a shearing strain. Transverse waves, can therefore, be propagated in those media, which can sustain shearing stress.

Since, solids and strings have shear modulus and hence they can sustain shearing stress. So, transverse waves can be generated in them.

However, fluids have approximately zero shear modulus. Thus, they cannot sustain shearing stress and get deformed, i.e. they do not have shape of their own and hence no transverse wave is possible in fluids.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

77 (a) In longitudinal waves, the constituents of the medium oscillate about their mean position along the direction of wave propagation. This means, it involve compressive stress (pressure).

Since, solids as well as fluids have bulk modulus, i.e. they can sustain compressive stress. So, longitudinal waves can be propagated through solids and fluids both.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

78 (*b*) Speed of sound in a medium is given as $v = \sqrt{\frac{B}{\rho}}$ ...(i)

where, B is the bulk modulus and ρ is the density of the medium.

Since, solids and liquids are much more difficult to compress than gases, so they have much higher values of bulk modulus.

Also, generally solids and liquids have higher mass densities (ρ) than gases.

But corresponding increase in both the modulus B of solids and liquids is much higher. So, in accordance to Eq. (i), we can say that sound waves travel faster in solids and liquids.

Therefore, Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

79 (*a*) From the principle of superposition of waves, the net displacement of two light travelling waves

$$y_1(x, t) = A \sin(kx - \omega t)$$

and $y_2(x, t) = A \sin(kx - \omega t + \phi)$ is

$$y(x, t) = 2A \cos\frac{\phi}{2} \sin\left(kx - \omega t + \frac{\phi}{2}\right)$$

The initial phase angle $= \frac{\phi}{2}$

The resultant amplitude of the given wave is

$$A(\phi) = 2A \cos\frac{\phi}{2}$$

As, from $0 \le \phi \le \pi$, cosine function is decreases.

Thus, resultant amplitude also decreases for $0 \le \phi \le \pi$.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

80 (*a*) The beat frequency due to the interference of two harmonic waves of nearly equal frequencies is given as

$$\nu_{\text{beat}} = |\nu_1 - \nu_2|$$

Given, $\nu_1 = 11\text{ Hz}$ and $\nu_2 = 9\text{ Hz}$

$\Rightarrow$ $\nu_{\text{beat}} = |11 - 9| = 2\text{ Hz}$.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

81 (*c*) According to the property of persistence of hearing, the impression of a sound heard persists on our mind for $\left(\frac{1}{10}\right)$ s. So, in order to hear distinct beats the time interval between the two successive beats should be greater than $\left(\frac{1}{10}\right)$ s. Thus, the difference between two frequencies must be less than 10.

Also, the number of beats per second gives the difference of frequencies. So, more the number of beats, lesser would be the confusion.

Therefore, Assertion is correct but Reason is incorrect.

82 (*a*) Statements I and III are correct but II is incorrect and it can be corrected as,

If a cork piece is put on it, it moves up and down but do not move along with the disturbances in the same direction.

83 (*d*) Statements I, III and IV are correct but II is incorrect and it can be corrected as,

Waves can transport energy from one point to another.

84 (*c*) A steel bar possesses both bulk and shear elastic moduli, thus can propagate longitudinal as well as transverse waves.

Since, these waves propagating in the bar are due to the different moduli of elasticily. Thus, the speed of longitudinal and transverse waves in the bar would be different.

Morever, air can propagate only longitudinal waves, e.g. sound waves.

So, statements I and II are correct but III is incorrect.

85 (*d*) Statements I and II are correct but III is incorrect and it can be corrected as,

When a wave is incident obliquely on the boundary between two different media, a part of incident wave is reflected and a part is transmitted into the second medium which is known as refracted wave.

86 (*a*) Statements I and II are correct but III and IV are incorrect and these can be corrected as,

In a standing wave, the disturbance produced and the energy of one region remains confined to that region only.

Amplitude of all particles is different at different position. It means, it varies from point-to-point.

87 (*a*)

I. For the given waves, the standing wave is represented by the equation

$$y(x, t) = 2a \sin kx \cos \omega t = A(x) \cos \omega t$$

For nodes,

$$A(x) = 0$$

$\therefore$ $2a \sin kx = 0$

$\Rightarrow$ $kx = n\pi$

where, $n = 0, 1, 2, 3, \ldots$.

Since, $k = \frac{2\pi}{\lambda}$

$\therefore$ $x = \frac{n\pi}{k} \Rightarrow x = \frac{n\pi}{(2\pi/\lambda)} = \frac{n\lambda}{2}$

where $n = 0, 1, 2, 3, \ldots$.

Thus, the position of nodes is given as $x = \frac{n\lambda}{2}$.

II. For anti-nodes,

$$A(x) = \text{maximum}$$

$$|\sin kx| = 1$$

$\Rightarrow$ $kx = \left(n + \frac{1}{2}\right)\pi$, where $n = 0, 1, 2, 3, \ldots$.

Using $k = \frac{2\pi}{\lambda}$, we get $x = \left(n + \frac{1}{2}\right)\frac{\pi}{k}$

$x = \left(n + \frac{1}{2}\right)\frac{\lambda}{2}$, where $n = 0, 1, 2, 3, \ldots$.

III. In case of anti-nodes,

For $n = 0$, $x_1 = \frac{\lambda}{4}$

For $n = 1$, $x_2 = \frac{3\lambda}{4}$

$\therefore$ Distance between any two successive antinodes

$$= x_2 - x_1 = \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{2\lambda}{4} = \frac{\lambda}{2}$$

So, statement I is incorrect but II and III are correct.

88 (*c*) Statements I, II and III are correct but IV is incorrect and it can be corrected as

For fundamental mode, $n = 1$

$$\therefore \quad \nu_0 = \frac{nv}{2L} = \frac{v}{2L}$$

89 (*c*) In a closed organ pipe, two waves travelling in opposite direction superimpose with each other to develop a wave pattern which is standing or stationary.

Possible wavelengths of stationary waves in this type of organ pipe is given as

$$\lambda_n = \frac{4L}{(2n+1)}$$

or
$$\lambda_n = 4L, \frac{4L}{3}, \frac{4L}{5}, \ldots$$

(On putting, $n = 0, 1, 2, 3\ldots$)

As frequency, $\nu = \frac{v}{\lambda}$

So, frequencies of nth harmonics can be given as,

$$\nu_n = \frac{v}{4L}, \frac{3v}{4L}, \frac{5v}{4L}, \ldots$$

$\therefore \quad \nu_1 : \nu_2 : \nu_3 \ldots = 1 : 3 : 5 \ldots$

So, only odd harmonics are present in case of closed organ pipe.

However, in case of open organ pipe,

frequencies of nth harmonics, $\nu_n = \frac{nv}{2L}$

Thus, even and odd or all the harmonics are present.

So, statements I and II are correct but III is incorrect.

90 (*b*) Given resultant wave equation,

$$S = [2a\cos \omega_b t]\cos \omega_a t = A(t)\cos \omega_a t$$

So, the resultant wave is oscillating with the average angular velocity ω_a.

Here, resulting amplitude, $A(t) = 2a \cos \omega_b t$

Thus, amplitude is largest when $A(t)$ is maximum.

i.e. $|\cos \omega_b t| = 1$ or $\cos \omega_b t = \pm 1$

So, all statements are correct.

91 (*d*) Statement given in option (d) is incorrect and it can be corrected as,

Mechanical waves have different speeds in different medium.

Rest statements are correct.

92 (*d*) When end A is pulled suddenly and released spring I gets disturbed from its equilibrium length.

Since, the spring II is connected to the I, it will also be stretched or compressed and so on.

The disturbance generated at end A will propagate to the other end but each spring will only executes small oscillations about its equilibrium position.

Thus, the statements given in options (a) and (b) are correct and statement given in option (c) is incorrect.

93 (*c*) Statement given in option (c) is incorrect and it can be corrected as,

The restoring force that produces gravity waves is the pull of gravity, which tends to keep the water surface at its lowest level. These waves extends to the very bottom with diminishing amplitude.

Rest statements are correct.

94 (*a*) If a boundary is an interface between two different elastic media which means that the boundary is not completely rigid, then a part of the incident wave is reflected and a part is transmitted into the second medium.

Thus, the statement given in option (a) is correct but rest are incorrect.

96 (*d*) In case of air column in a pipe open at both ends, each end acts an as anti-node.

The frequency of the possible nth harmonics in this pipe is given as $\nu_n = \frac{nv}{2L}$, where $n = 0, 1, 2, \ldots$. Thus, an air column open at both ends generates all harmonics.

Thus, statements given in options (a) and (b) are correct but option (c) is incorrect.

97 (*a*) Given,wave equation is

$$y(x, t) = 0.005\sin(80x - 3t) \quad \ldots\text{(i)}$$

A. The standard wave equation for a right travelling wave is given by

$$y(x, t) = a\sin(kx - \omega t) \quad \ldots\text{(ii)}$$

On comparing Eq. (ii) with Eq. (i), we get

Amplitude, $a = 0.005$ SI units

Wave number, $k = 80$ SI units,

Angular frequency, $\omega = 3$ SI units

B. Wavelength, $\lambda = \frac{2\pi}{k} = \frac{2\pi}{80} = 0.0785$ SI units

C. Frequency, $\nu = \frac{1}{T}$

As, $T = \frac{2\pi}{\omega} = \frac{2\pi}{3} = 2.09$ s

$\Rightarrow \quad \nu = \frac{1}{2.09\text{ s}} = 0.48$ SI units

D. The displacement y at $x = 30$ cm and time $t = 20$ s is given by

$$y = (0.005)\sin(80.0 \times 0.3 - 3 \times 20)$$
$$= 0.005\sin(-36) = 0.005\sin(-36 + 12\pi)$$

$(\because 12\pi = 2n\pi$, where $n = 6)$

$= 0.005 \sin(1.699) = 0.005 \sin(97°)$
≈ 0.005 or SI unit

Hence, A $\to$ 4, B $\to$ 1, C $\to$ 2 and D $\to$ 3.

99 (*a*) Given, incident wave equation,

$$y(x,t) = a\sin(kx - \omega t)$$

A. Reflected wave from a rigid boundary suffers a phase change of π radians.

$$\Rightarrow \quad y_{r_1}(x,t) = a\sin(kx - \omega t + \pi) = -a\sin(kx - \omega t)$$

B. Reflected wave from an open boundary (non-rigid) will be in same phase with the incident wave.

$$y_{r_2}(x,t) = a\sin(kx - \omega t)$$

C. At the rigid boundary,

The resultant displacement $= y(x,t) + y_{r_1}(x,t)$
$= [a\sin(kx - \omega t)] + [-a\sin(kx - \omega t)] = 0$

D. At the open boundary,

The resultant displacement $= y(x,t) + y_{r_2}(x,t)$
$= a\sin(kx - \omega t) + a\sin(kx - \omega t)$
$= 2a\sin(kx - \omega t)$

Hence, A $\to$ 2, B $\to$ 1, C $\to$ 4 and D $\to$ 3.

100 (*b*) For a string tied at both the ends, the fixed end points behave as nodes.

A. From figure, number of nodes = 6

Distance between consecutive nodes $= \dfrac{\lambda}{2}$

Length of the string, $L = 5\left(\dfrac{\lambda}{2}\right) = \dfrac{5\lambda}{2}$ ...(i)

Also, we know, $L = \dfrac{n\lambda}{2}$; $n = 1, 2, 3, \cdots$ ...(ii)

On comparing Eqs. (i) and (ii), we get

$$n = 5$$

Thus, the figure represents fifth harmonic.

B. Number of nodes = 7

$\Rightarrow \; L = 6\left(\dfrac{\lambda}{2}\right)$ ...(i)

Again, comparing with $L = n\lambda/2$, we get $n = 6$

Thus, the figure represents sixth harmonic.

C. Number of nodes = 2,

$\Rightarrow \; L = \dfrac{\lambda}{2} \Rightarrow n = 1$

Thus, the figure represents first harmonic or fundamental mode.

D. Number of nodes = 3 or $L = 2\left(\dfrac{\lambda}{2}\right) = \lambda$

So, $\quad n = 2$

Thus, the figure represents second harmonic.

Hence, A $\to$ 4, B $\to$ 3, C $\to$ 1 and D $\to$ 2.

101 (*a*) **For closed organ pipe** (one end closed)

B. Taking the end of the pipe to be at $x = 0$, which is the node condition. Then, the other end $x = L$ is an anti-node.

where, $L = \left(n + \dfrac{1}{2}\right)\dfrac{\lambda}{2}$; where, $n = 0, 1, 2, \cdots$.

So, the possible wavelengths of the waves in this pipe is given as

$\Rightarrow \quad \lambda = \dfrac{2L}{\left(n + \dfrac{1}{2}\right)}$; where $n = 0, 1, 2, 3, \cdots$ ...(i)

A. The normal modes or natural frequencies of the system are

$\nu = \dfrac{v}{\lambda} = \left(n + \dfrac{1}{2}\right)\dfrac{v}{2L}$; where $n = 0, 1, 2, 3, \cdots$ ...(ii)

C. For fundamental mode, put $n = 0$ in Eq. (ii), we get

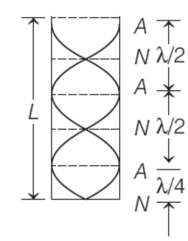
$$\nu_0 = \frac{v}{4L}$$

D. For longest wavelength, $(n = 0)$, $\lambda = \dfrac{2L}{0 + \dfrac{1}{2}} = 4L$

Hence, A $\to$ 2, B $\to$ 1, C $\to$ 3 and D $\to$ 4.

102 (*c*) Distance between consecutive anti-nodes $= \dfrac{\lambda}{2}$

Distance between node and anti-node $= \dfrac{\lambda}{4}$



A. From figure,

$\Rightarrow \quad L = \lambda + \dfrac{\lambda}{4} = \dfrac{5\lambda}{4}$ ...(i)

Since, for an air column closed at one end,

$L = \left(n + \dfrac{1}{2}\right)\dfrac{\lambda}{2} = (2n + 1)\dfrac{\lambda}{4}$ ...(ii)

On comparing Eqs. (i) and (ii), we get

$$(2n + 1) = 5 \text{ or } n = 2$$

So, 5th harmonic occurs.

B. Similarly, $L = 2\lambda + \dfrac{\lambda}{4} = \dfrac{9\lambda}{4}$

$\Rightarrow \dfrac{(2n+1)\lambda}{4} = \dfrac{9\lambda}{4} \Rightarrow n = 4$

Hence, it represents 9th harmonic.

C. $L = \dfrac{3\lambda}{2} + \dfrac{\lambda}{4} = \dfrac{7\lambda}{4} \Rightarrow \dfrac{(2n+1)\lambda}{4} = \dfrac{7\lambda}{4} \Rightarrow n = 3$

Hence, it represents 7th harmonic.

D. $L = \dfrac{\lambda}{2} + \dfrac{\lambda}{4} = \dfrac{3\lambda}{4} \Rightarrow \dfrac{(2n+1)\lambda}{4} = \dfrac{3\lambda}{4} \Rightarrow n = 2$

Hence, it represents 3rd harmonic.

Hence, A $\to$ 2, B $\to$ 3, C $\to$ 4 and D $\to$ 1.

104 (*b*) Given, mass, $m = 2.5$ kg, length of string, $l = 20$ m

As, μ = mass per unit length

$$= \frac{m}{l} = \frac{2.5}{20} = \frac{1.25}{10} = 0.125\ \text{kgm}^{-1}$$

Speed of transverse waves in any string,

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{200}{0.125}}$$

As, length of the stretched string,

$$l = v \times t \Rightarrow 20 = \sqrt{\frac{200}{0.125}} \times t$$

$$\Rightarrow \quad t = 20 \times \sqrt{\frac{125}{2 \times 10^5}} = 20 \times \sqrt{\frac{25 \times 5}{2 \times 10^5}} = 0.5\ \text{s}$$

105 (*c*) Height of the tower, $h = 300$ m

Initial velocity, $u = 0$

Acceleration due to gravity, $g = 9.8\ \text{ms}^{-2}$

Speed of sound in air, $v = 340\ \text{ms}^{-1}$

Time taken by stone to reach the pond $= t_1$

Using equation of motion, $h = ut + \frac{1}{2}gt_1^2$

$$\Rightarrow \quad 300 = 0 + \frac{1}{2} \times 9.8 t_1^2 \Rightarrow t_1 = \sqrt{\frac{300 \times 2}{9.8}} = 7.82\ \text{s}$$

Time taken by the sound to reach the top of the tower,

$$t_2 = \frac{h}{v} = \frac{300}{340} = 0.88\ \text{s}$$

$\therefore$ Total time, $t = t_1 + t_2 = 7.82 + 0.88 = 8.7$ s

So, the splash is heard at the top after 8.7 s.

106 (*a*) Given, speed of the transverse wave in wire,

v = speed of sound in dry air at 20°C = 343 ms^{-1}

Mass of steel wire, $m = 2.10$ kg, length, $l = 12$ m

Tension required, $T = ?$

Mass density, $\mu = \frac{m}{l} = \frac{2.10}{12} = 0.175\ \text{kgm}^{-1}$

Speed of transverse wave in wire, $v = \sqrt{\frac{T}{\mu}}$

$$\Rightarrow \quad T = v^2\mu = (343)^2 \times 0.175 = 20588.575\text{N}$$

or $\quad T \approx 2.06 \times 10^4\ \text{N} \simeq 2 \times 10^4$ N

107 (*a*) Given, $\nu = 100$ kHz $= 10^5$ Hz,

$v_a = 340\ \text{ms}^{-1}$, $v_w = 1486\ \text{ms}^{-1}$

Frequency of both, the reflected and transmitted sound remains unchanged.

(i) Wavelength of reflected sound,

$$\lambda_a = \frac{v_a}{\nu} = \frac{340}{10^5} = 3.4 \times 10^{-3}\ \text{m}$$

(ii) Wavelength of transmitted sound,

$$\lambda_w = \frac{v_w}{\nu} = \frac{1486}{10^5} = 1.49 \times 10^{-2}\ \text{m}$$

108 (*b*) Given, speed of the sound wave, $v = 1.7\ \text{kms}^{-1}$

$$= 1.7 \times 10^3\ \text{ms}^{-1}$$

Operating frequency of the scanner, $\nu = 4.2$ MHz

$$= 4.2 \times 10^6\ \text{Hz}$$

$\therefore$ Wavelength of sound in the tissue,

$$\lambda = \frac{v}{\nu} = \frac{1.7 \times 10^3}{4.2 \times 10^6} \approx 4 \times 10^{-4}\ \text{m}$$

109 (*b*) Given equation is

$$y(x, t) = 3\sin\left(36t + 0.018x + \frac{\pi}{4}\right)$$

Comparing the above equation with the standard equation

$$y = a\sin(\omega t + kx + \phi), \text{ we get}$$

$$\omega = 36\ \text{rad}^{-1} \Rightarrow 2\pi\nu = 36$$

$$\Rightarrow \quad \text{Frequency, } \nu = \frac{36}{2\pi} = \frac{18}{\pi} = 5.7\ \text{Hz}$$

$$k = 0.018 \Rightarrow \frac{2\pi}{\lambda} = 0.018$$

$$\Rightarrow \frac{2\pi\nu}{\nu\lambda} = 0.018 \Rightarrow \frac{\omega}{v} = 0.018 \qquad (\because \nu\lambda = v)$$

$$\Rightarrow \frac{36}{v} = 0.018 = \frac{18}{1000}$$

$$\Rightarrow \quad v = 2000\ \text{cms}^{-1} = 20\ \text{ms}^{-1}$$

So, speed of the wave is 20 ms^{-1}.

As, $\quad \frac{2\pi}{\lambda} = 0.018$

$$\Rightarrow \quad \lambda = \frac{2\pi}{0.018}\text{cm} = \frac{2000\pi}{18}\ \text{cm}$$

$$= \frac{20\pi}{18}\text{m} = 3.48\ \text{m}$$

Hence, least distance between two successive crests is $\lambda = 3.48$ m.

110 (*d*) Given wave equation,

$$y(x, t) = 2\cos 2\pi(10t - 0.0080x + 0.35)$$
$$= 2\cos(20\pi t - 0.016\pi x + 0.70\pi)$$

On comparing with standard equation

$$y(x, t) = a\cos(\omega t - kx + \phi)$$

We get, $k = 0.016\pi$ rad cm^{-1}, $a = 2$ cm, $\omega = 20\pi$ rad s^{-1}

Phase difference, $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$ (where, Δx = path difference)

Now, $\Delta x = 4$ m $= 400$ cm

Phase difference, $\Delta\phi = \frac{2\pi}{\lambda}\Delta x = k\Delta x$

$$= 0.016\pi \times 400 = 6.4\pi\ \text{rad}$$

111 (*b*) Given equation is

$$y(x, t) = 0.06\sin\left(\frac{2\pi x}{3}\right)\cos(120\pi t)$$

Comparing with a standard equation of stationary wave

$$y(x, t) = a\sin(kx)\cos(\omega t)$$

Clearly, we can conclude that the given equation belongs to stationary wave.

Also, we get $\omega = 120\pi$

$\Rightarrow$ $2\pi\nu = 120\pi$

Frequency, $\nu = 60$ Hz

$$k = \frac{2\pi}{3} = \frac{2\pi}{\lambda}$$

$\Rightarrow$ $\lambda = \text{Wavelength} = 3\text{m}$

Speed, $v = \nu\lambda$

$= 60 \times 3 = 180\ \text{ms}^{-1}$

Since in stationary wave, all particles of the medium execute SHM with varying amplitude. So, amplitude of this wave is not a constant.

112 (*c*) Given equation is

$$y(x,t) = 0.06\sin\left(\frac{2\pi}{3}x\right)\cos(120\pi t)$$

Comparing with standard equation of stationary wave

$$y(x, t) = a\sin(kx)\cos(\omega t)$$

We can conclude that, it represents a stationary wave.

In this wave,

The amplitude is $0.06\sin\left(\frac{2\pi}{3}x\right)$. Thus, in this wave pattern the amplitude varies from point-to-point, but each element of the string oscillates with the same frequency ω or time period.

There is no phase difference between oscillations of different elements of wave.

Since the amplitude is different at different points. Thus, the energy of the elements of the string oscillate with varying energy.

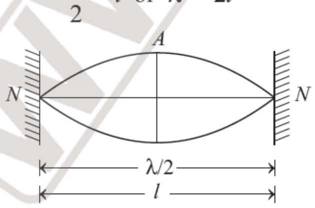
113 (*c*) Given, $\nu = 45$ Hz, $m = 3.5 \times 10^{-2}$ kg

Given, $\mu = \frac{m}{l} = 4 \times 10^{-2}\ \text{kg m}^{-1}$

$$\therefore \quad l = \frac{m}{\mu} = \frac{3.5 \times 10^{-2}}{4 \times 10^{-2}} = 0.875\ \text{m}$$

For a stretched string, in fundamental mode of vibration as shown below

$$\frac{\lambda}{2} = l \text{ or } \lambda = 2l$$



As, speed of transverse wave on the string ,

$$v = \nu\lambda = \nu(2l) \quad \ldots\text{(i)}$$

Substituting the given values in the above equation, we get

$$v = 45 \times 2 \times 0.875 = 78.75\ \text{ms}^{-1}$$

114 (*b*)As, $v = \sqrt{\frac{T}{\mu}} \Rightarrow T = v^2(\mu) = (78.75)^2 \times 4 \times 10^{-2}$

$= 248.06\ \text{N} \simeq 248\ \text{N}$

115 (*a*) For a tube open at one end, the possible wavelengths of the stationary waves are given as

$$\lambda = \frac{2L}{(n + 1/2)} \text{ or } L = \left(n + \frac{1}{2}\right)\frac{\lambda}{2}$$

So, for first resonance, $l_1 = \frac{\lambda}{4}$

For second resonance, $l_2 = \frac{3\lambda}{4}$

$$\Rightarrow \quad l_2 - l_1 = \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2} \text{ or } \lambda = 2(l_2 - l_1)$$

Given, length at which first resonance occurs, $l_1 = 25.5$ cm

Length at which second resonance occur, $l_2 = 79.3$ cm

Frequency, $\nu = 340$ Hz

$\therefore$ Wavelength, $\lambda = 2(l_2 - l_1)$

$= 2(79.3 - 25.5) = 2 \times 53.8$

$= 107.6\ \text{cm} = 107.6 \times 10^{-2}\ \text{m}$

Using, $v = \nu\lambda$

$\therefore$ Speed of sound in air, $v = 340 \times 107.6 \times 10^{-2}$

$= 365.84\ \text{ms}^{-1} \simeq 366\ \text{ms}^{-1}$

116 (*c*) As the rod is clamped at the middle, hence there will be node at the middle and anti-nodes at the two open ends.

So, for the fundamental mode of vibration

$$\lambda = 2L = 2 \times 100 = 200\ \text{cm} = 2\ \text{m}$$

Frequency, $\nu = 2.53\ \text{kHz} = 2530\ \text{Hz}$

$\therefore$ Speed of sound, $v = \nu\lambda = 2530 \times 2 = 5060\ \text{ms}^{-1}$

$= 5.06\ \text{km s}^{-1}$

117 (*b*) Given, length of the pipe, $L = 20\ \text{cm} = 0.20\ \text{m}$,

Speed of sound, $v = 340\ \text{ms}^{-1}$

Frequency of fundamental mode in the pipe closed at one end is

$$\nu = \frac{v}{4L} = \frac{340}{4 \times 0.20} = 425\ \text{Hz}$$

Hence, the fundamental mode of this pipe may be reasonably excited by a source of frequency 430 Hz.

Frequency of fundamental mode in pipe open at both ends is

$$\nu' = \frac{v}{2L} = \frac{340}{2 \times 0.20} = 850\ \text{Hz}$$

Hence, the same source of frequency 430 Hz will not be in resonance with pipe open at both ends.

118 (*b*) Given, frequency of A,

$$\nu_A = 324\ \text{Hz}$$

Now, frequency of B,

$$\nu_B = \nu_A \pm \text{beat frequency} = 324 \pm 6$$

or $\nu_B = 330$ or 318 Hz

Now, if tension in the string is slightly reduced, its frequency will also reduce from 324 Hz.

Now, if $\nu_B = 330$ Hz and ν_A reduces, then beat frequency should increase which is not the case but if $\nu_B = 318$ Hz and ν_A decreases the beat frequency should decrease, which is the case and hence, $\nu_B = 318$ Hz.

119 (*b*) Given, frequency of the whistle, $\nu = 400$ Hz

Speed of the train, $v_T = 10\,\text{ms}^{-1}$

Speed of sound, $v = 340\,\text{ms}^{-1}$

The apparent frequency ν' of the whistle when the train approaches the platform,

$$\nu' = \left(\frac{v}{v - v_T}\right)\nu = \left(\frac{340}{340-10}\right) \times 400$$

$$= 412.12\text{ Hz} \simeq 412\text{ Hz}$$

120 (*a*) Given, $\nu_0 = 400$ Hz, $v = 340\,\text{ms}^{-1}$

and speed of wind, $v_w = 10\,\text{ms}^{-1}$

As both source and observer are stationary, hence frequency observed will be same as natural frequency, $\nu_0 = 400$ Hz.

The speed of sound, $v = v + v_w$

$$= 340 + 10 = 350\,\text{ms}^{-1}$$

There will be no effect on frequency,because there is no relative motion between source and observer.

So, only option (a) is correct.

121 (*d*) Given $y = 7.5 \sin(0.0050x + 12t + \pi/4)$ ...(i)

$$= 7.5\sin\left[0.0050\left(\frac{12}{0.0050}t + x\right) + \pi/4\right]$$

At $x = 1$ cm and $t = 1$ s, displacement is

$$y = 7.5\sin(0.0050 \times 1 + 12 \times 1 + \pi/4)$$

$$= 7.5\sin(12.79)$$

$$= 7.5 \times 0.2222 = 1.67\text{ cm} \approx 2\text{ cm}$$

Velocity of oscillation of the particle is

$$u = \frac{dy}{dt} = \frac{d}{dt}[7.5\sin(0.0050x + 12t + \pi/4)]$$

$$= 7.5 \times 12\cos(0.0050x + 12t + \pi/4)$$

$$= 90\cos\left(0.0050x + 12t + \frac{\pi}{4}\right)$$

At $x = 1$ cm and $t = 1$ s,

$$u = 90\cos(0.0050 \times 1 + 12 \times 1 + \pi/4)$$

$$= 90\cos(12.79) = 90 \times 0.9751 = 87.76\text{ cm s}^{-1}.$$

$$\simeq 88\text{ cms}^{-1}$$

122 (*d*) Given, SONAR frequency,

$$\nu_s = 40\text{ kHz} = 40 \times 10^3\text{ Hz}$$

Speed of enemy submarine,

$$v_e = 360\text{ kmh}^{-1} = 360 \times \frac{5}{18}\text{ms}^{-1} = 100\text{ ms}^{-1}$$

$$\left(\because 1\text{ kmh}^{-1} = \frac{5}{18}\text{ms}^{-1}\right)$$

Speed of sound in water, $v = 1450\,\text{ms}^{-1}$

Apparent frequency received by the submarine,

$$\nu' = \left(\frac{v + v_e}{v}\right)\nu$$

$$= \left(\frac{1450 + 100}{1450}\right) \times 40 \times 10^3$$

$$= 42.76 \times 10^3\text{ Hz}$$

Now, the reflected waves from the submarines have a different frequency as

$$\nu'' = \left(\frac{v}{v - v_e}\right)\nu'$$

$$\Rightarrow \quad \nu'' = \left(\frac{1450}{1450 - 100}\right) \times 42.76 \times 10^3$$

$$= 45.93 \times 10^3\text{ Hz} = 45.93\text{ kHz} \simeq 46\text{ kHz}$$

123 (*d*) Given, speed of *P*-wave, $v_P = 8\text{ kms}^{-1}$,

Speed of *S*-wave, $v_S = 4\text{ kms}^{-1}$,

Time taken by *P*-wave to reach the recorder $= t_P$

and time taken by *S*-wave to reach the recorder $= t_S$.

Now, both waves travel same distance from centre to detector, therefore

$$\Rightarrow \quad v_P t_P = v_S t_S$$

$$\Rightarrow \quad 8 \times t_P = 4 \times t_S$$

or $\quad 2t_P = t_S$ ...(i)

Now, $\quad t_S - t_P = 4$ min (given)

or $\quad 2t_P - t_P = 4$ min [from Eq. (i)]

$$\Rightarrow \quad t_P = 4\text{ min} = 240\text{ s}$$

Hence, the distance between detector and centre of the earthquake, $\quad D = t_P v_P = t_S v_S$

$$= 240\text{ s} \times 8 \times 10^3\text{ ms}^{-1}$$

$$= 1920 \times 10^3\text{ m} = 1920\text{ km}$$

124 (*c*) Given, original frequency emitted by the bat, $\nu = 40$ kHz

Speed of the bat, $v_b = 0.03\,v$

where, v = speed of sound in air.

The apparent frequency received at the bat wall surface,

$$\nu' = \left(\frac{v}{v - v_b}\right)\nu = \left(\frac{v}{v - 0.03v}\right) \times 40 = \frac{40}{0.97}\text{ kHz}$$

This frequency will be reflected by the stationary flat wall surface towards the bat. Bat receives apparent frequency of the reflected frequency as ν'', where

$$\nu'' = \left(\frac{v + v_b}{v}\right)\nu' = \left(\frac{v + 0.03v}{v}\right) \times \frac{40}{0.97}$$

$$= \frac{1.03 \times 40}{0.97} = 42.47\text{ kHz} \simeq 42\text{ kHz}$$

126 (*c*) Given, $v' = 2v$

Let the frequency of the sound waves in the first medium is ν and in the second medium is ν'.

Since, frequency remains same in both the medium,

so $\nu = \nu'$

$\Rightarrow \quad \frac{v}{\lambda} = \frac{v'}{\lambda'} \quad (\because v = \nu\lambda)$

$\Rightarrow \quad \lambda' = \left(\frac{v'}{v}\right)\lambda$

where, λ & λ' are wavelengths and v & v' are the speeds of sound waves in first & second medium, respectively.

So, $\quad \lambda' = \left(\frac{2v}{v}\right)\lambda = 2\lambda$

$\therefore$ Wavelength of the sound waves in the second medium is 2λ.

127 (c) We know that, from Laplace correction formula, speed of sound in air is given by $v = \sqrt{\frac{\gamma p}{\rho}}$

For air, γ and p are constants.

$\therefore \quad v \propto \frac{1}{\sqrt{\rho}}$, where ρ is density of air.

$\Rightarrow \quad \frac{v_2}{v_1} = \sqrt{\frac{\rho_2}{\rho_1}}$

where, ρ_1 is density of dry air and ρ_2 is density of moist air.

As, $\quad \rho_2 < \rho_1 = \frac{v_2}{v_1} > 1 \Rightarrow v_2 > v_1$

Hence, speed of sound wave in air increases with increase in humidity.

However, speed of sound v in a medium (air) is directly proportional to square root of the temperature. Also, v does not depend upon the pressure of air, till temperature remains constant.

128 (c) Speed of sound wave in a medium,

$$v \propto \sqrt{T} \quad \ldots\text{(i)}$$

where, T is temperature of the medium.

Clearly, when temperature changes speed also changes.

As, $\quad v = \nu\lambda$

where, ν is frequency and λ is wavelength.

If frequency ν remains fixed, so

$\Rightarrow \quad v \propto \lambda$ or $\lambda \propto v$

$\Rightarrow \quad \lambda \propto \sqrt{T} \quad [\because$ from Eq. (i)]

130 (d) Due to compression and rarefaction, density of the medium (air) changes. At compressed regions, density is maximum and at rarefactions, density is minimum.

As density is changing, so Boyle's law is not obeyed.

Bulk modulus remains same.

The time of compression and rarefaction is too small, i.e., we can assume adiabatic process and hence no transfer of heat.

131 (b) Given, equation of incident wave,

$$y_i = 0.6 \sin 2\pi\left(t - \frac{x}{2}\right)$$

Equation of reflected wave, $y_r = A_r \sin 2\pi\left(t + \frac{x}{2} + \pi\right)$

[$\because$ at denser medium, phase changes by π]

The positive sign is due to reversal of direction of propagation,

Amplitude of reflected wave,

$$A_r = \frac{2}{3} \times A_i$$

$$= \frac{2}{3} \times 0.6 = 0.4 \text{ units}$$

$\therefore \quad y_r = -0.4 \sin 2\pi\left(t + \frac{x}{2}\right)$

[$\because \sin(\pi + \theta) = -\sin\theta$]

132 (d) Let the original frequency of the source is n_o.

and the speed of sound wave in the medium is v.

As observer is stationary,

apparent frequency, $n_a = \left(\frac{v}{v - v_s}\right) n_o$

[when train is approaching]

$\Rightarrow \quad n_a > n_o$

When the train is moving away from the observer, then

apparent frequency, $n_a = \left(\frac{v}{v + v_s}\right) n_o$

$\Rightarrow \quad n_a < n_o$

Hence, the expected curve is correctly depicted in option (d).