CHAPTER 15

Waves

15.2 Transverse and Longitudinal Waves

1. Which one of the following statements is true?
(a) Both light and sound waves can travel in vacuum.
(b) Both light and sound waves in air are transverse.
(c) The sound waves in air are longitudinal while the light waves are transverse.
(d) Both light and sound waves in air are longitudinal. *(2006)*

2. With the propagation of a longitudinal wave through a material medium, the quantities transmitted in the propagation direction are
(a) energy, momentum and mass
(b) energy
(c) energy and mass
(d) energy and linear momentum *(1992)*

15.3 Displacement Relation in a Progressive Wave

3. A wave travelling in the +ve x-direction having displacement along y-direction as 1 m, wavelength 2π m and frequency of $\frac{1}{\pi}$ Hz is represented by
(a) $y = \sin(10\pi x - 20\pi t)$
(b) $y = \sin(2\pi x + 2\pi t)$
(c) $y = \sin(x - 2t)$
(d) $y = \sin(2\pi x - 2\pi t)$ *(NEET 2013)*

4. Two waves are represented by the equations
$y_1 = a\sin(\omega t + kx + 0.57)$ m and
$y_2 = a\cos(\omega t + kx)$ m, where x is in meter and t in sec. The phase difference between them is
(a) 1.0 radian (b) 1.25 radian
(c) 1.57 radian (d) 0.57 radian *(2011)*

5. A wave in a string has an amplitude of 2 cm. The wave travels in the +ve direction of x axis with a speed of 128 m/s and it is noted that 5 complete waves fit in 4 m length of the string. The equation describing the wave is
(a) $y = (0.02)$ m $\sin(15.7x - 2010t)$
(b) $y = (0.02)$ m $\sin(15.7x + 2010t)$
(c) $y = (0.02)$ m $\sin(7.85x - 1005t)$
(d) $y = (0.02)$ m $\sin(7.85x + 1005t)$ *(2009)*

6. The wave described by $y = 0.25\sin(10\pi x - 2\pi t)$, where x and y are in meters and t in seconds, is a wave travelling along the
(a) +ve x direction with frequency 1 Hz and wavelength $\lambda = 0.2$ m.
(b) –ve x direction with amplitude 0.25 m and wavelength $\lambda = 0.2$ m.
(c) –ve x direction with frequency 1 Hz.
(d) +ve x direction with frequency π Hz and wavelength $\lambda = 0.2$ m *(2008)*

7. The phase difference between two waves, represented by
$y_1 = 10^{-6}\sin[100t + (x/50) + 0.5]$ m
$y_2 = 10^{-6}\cos[100t + (x/50)]$ m,
where x is expressed in metres and t is expressed in seconds, is approximately
(a) 1.07 radians (b) 2.07 radians
(c) 0.5 radians (d) 1.5 radians
(2004)

8. A wave travelling in positive X-direction with $a = 0.2$ m s^{-2}, velocity = 360 m s^{-1} and $\lambda = 60$ m, then correct expression for the wave is
(a) $y = 0.2\sin\left[2\pi\left(6t + \frac{x}{60}\right)\right]$
(b) $y = 0.2\sin\left[\pi\left(6t + \frac{x}{60}\right)\right]$
(c) $y = 0.2\sin\left[2\pi\left(6t - \frac{x}{60}\right)\right]$
(d) $y = 0.2\sin\left[\pi\left(6t - \frac{x}{60}\right)\right]$ *(2002)*

9. In a sinusoidal wave, the time required for a particular point to move from maximum displacement to zero displacement is 0.170 s. The frequency of wave is
(a) 0.73 Hz (b) 0.36 Hz
(c) 1.47 Hz (d) 2.94 Hz *(1998)*

10. The equation of a sound wave is
$y = 0.0015 \sin(62.4x + 316t)$.
The wavelength of this wave is
(a) 0.3 unit (b) 0.2 unit
(c) 0.1 unit
(d) cannot be calculated. *(1996)*

11. Two sound waves having a phase difference of 60° have path difference of (λ is wavelength of sound wave)
(a) $\frac{\lambda}{6}$ (b) $\frac{\lambda}{3}$ (c) 2λ (d) $\frac{\lambda}{2}$ *(1996)*

12. Which one of the following represents a wave?
(a) $y = A\sin(\omega t - kx)$
(b) $y = A\cos(at - bx + c)$
(c) $y = A\sin kx$
(d) $y = A\sin\omega t$. *(1994)*

13. The frequency of sinusodial wave
$y = 0.40\cos[2000\,t + 0.80]$ would be
(a) 1000π Hz (b) 2000 Hz
(c) 20 Hz (d) $\frac{1000}{\pi}$ Hz *(1992)*

14. Equation of progressive wave is given by $y = 4\sin\left[\pi\left(\frac{t}{5} - \frac{x}{9}\right) + \frac{\pi}{6}\right]$ where y, x are in cm and t is in seconds. Then which of the following is correct ?
(a) $v = 5$ cm (b) $\lambda = 18$ cm
(c) $a = 0.04$ cm (d) $f = 50$ Hz *(1988)*

15.4 The Speed of a Travelling Wave

15. A uniform rope of length L and mass m_1 hangs vertically from a rigid support. A block of mass m_2 is attached to the free end of the rope. A transverse pulse of wavelength λ_1 is produced at the lower end of the rope. The wavelength of the pulse when it reaches the top of the rope is λ_2. The ratio λ_2/λ_1 is
(a) $\sqrt{\frac{m_2}{m_1}}$ (b) $\sqrt{\frac{m_1 + m_2}{m_1}}$
(c) $\sqrt{\frac{m_1}{m_2}}$ (d) $\sqrt{\frac{m_1 + m_2}{m_2}}$
(NEET-I 2016)

16. 4.0 g of a gas occupies 22.4 litres at NTP. The specific heat capacity of the gas at constant volume is 5.0 J K^{-1} mol^{-1}. If the speed of sound in this gas at NTP is 952 m s^{-1}, then the heat capacity at constant pressure is (Take gas constant $R = 8.3$ J K^{-1} mol^{-1})
(a) 7.0 J K^{-1} mol^{-1} (b) 8.5 J K^{-1} mol^{-1}
(c) 8.0 J K^{-1} mol^{-1} (d) 7.5 J K^{-1} mol^{-1} *(2015)*

17. The equation of a simple harmonic wave is given by
$$y = 3\sin\frac{\pi}{2}(50t - x),$$
where x and y are in metres and t is in seconds. The ratio of maximum particle velocity to the wave velocity is
(a) 2π (b) $\frac{3}{2}\pi$ (c) 3π (d) $\frac{2}{3}\pi$
(Mains 2012)

18. Sound waves travel at 350 m/s through a warm air and at 3500 m/s through brass. The wavelength of a 700 Hz acoustic wave as it enters brass from warm air
(a) decrease by a factor 10
(b) increase by a factor 20
(c) increase by a factor 10
(d) decrease by a factor 20 *(2011)*

19. A transverse wave is represented by $y = A\sin(\omega t - kx)$. For what value of the wavelength is the wave velocity equal to the maximum particle velocity?
(a) $\pi A/2$ (b) πA
(c) $2\pi A$ (d) A *(2010)*

20. A transverse wave propagating along x-axis is represented by $y(x, t) = 8.0\sin(0.5\pi x - 4\pi t - \pi/4)$ where x is in metres and t is in seconds. The speed of the wave is
(a) 8 m/s (b) 4π m/s
(c) 0.5π m/s (d) $\pi/4$ m/s. *(2006)*

21. A point source emits sound equally in all directions in a non-absorbing medium. Two points P and Q are at distances of 2 m and 3 m respectively from the source. The ratio of the intensities of the waves at P and Q is
(a) 3 : 2 (b) 2 : 3
(c) 9 : 4 (d) 4 : 9. *(2005)*

22. The equation of a wave is represented by $y = 10^{-4}\sin\left(100t - \frac{x}{10}\right)$m, then the velocity of wave will be
(a) 100 m/s (b) 4 m/s
(c) 1000 m/s (d) 10 m/s *(2001)*

23. A transverse wave is represented by the equation
$$y = y_0\sin\frac{2\pi}{\lambda}(vt - x)$$
For what value of λ, is the maximum particle velocity equal to two times the wave velocity?
(a) $\lambda = \frac{\pi y_0}{2}$ (b) $\lambda = \frac{\pi y_0}{3}$
(c) $\lambda = 2\pi y_0$ (d) $\lambda = \pi y_0$ *(1998)*

24. A hospital uses an ultrasonic scanner to locate tumours in a tissue. The operating frequency of the scanner is 4.2 MHz. The speed of sound in a tissue is 1.7 km/s. The wavelength of sound in the tissue is close to
(a) 4×10^{-3} m (b) 8×10^{-3} m
(c) 4×10^{-4} m (d) 8×10^{-4} m *(1995)*

25. The temperature at which the speed of sound becomes double as was at 27°C is
(a) 273°C (b) 0°C
(c) 927°C (d) 1027°C *(1993)*

26. Velocity of sound waves in air is 330 m/s. For a particular sound wave in air, a path difference of 40 cm is equivalent to phase difference of 1.6 π. The frequency of this wave is
(a) 165 Hz (b) 150 Hz
(c) 660 Hz (d) 330 Hz *(1990)*

27. A 5.5 metre length of string has a mass of 0.035 kg. If the tension in the string in 77 N, the speed of a wave on the string is
(a) 110 m s^{-1} (b) 165 m s^{-1}
(c) 77 m s^{-1} (d) 102 m s^{-1} *(1989)*

28. If the amplitude of sound is doubled and the frequency reduced to one fourth, the intensity of sound at the same point will be
(a) increasing by a factor of 2
(b) decreasing by a factor of 2
(c) decreasing by a factor of 4
(d) unchanged *(1989)*

29. The velocity of sound in any gas depends upon
(a) wavelength of sound only
(b) density and elasticity of gas
(c) intensity of sound waves only
(d) amplitude and frequency of sound *(1988)*

15.5 The Principle of Superposition of Waves

30. Two periodic waves of intensities I_1 and I_2 pass through a region at the same time in the same direction. The sum of the maximum and minimum intensities is
(a) $(\sqrt{I_1} - \sqrt{I_2})^2$ (b) $2(I_1 + I_2)$
(c) $I_1 + I_2$ (d) $(\sqrt{I_1} + \sqrt{I_2})^2$ *(2008)*

31. Two waves having equation
$x_1 = a\sin(\omega t - kx + \phi_1)$,
$x_2 = a\sin(\omega t - kx + \phi_2)$
If in the resultant wave the frequency and amplitude remain equal to amplitude of superimposing waves, the phase difference between them is
(a) $\frac{\pi}{6}$ (b) $\frac{2\pi}{3}$ (c) $\frac{\pi}{4}$ (d) $\frac{\pi}{3}$ *(2001)*

32. The equations of two waves acting in perpendicular directions are given as
$x = a\cos(\omega t + \delta)$ and $y = a\cos(\omega t + \alpha)$, where $\delta = \alpha + \frac{\pi}{2}$, the resultant wave represents
(a) a parabola (b) a circle
(c) an ellipse (d) a straight line *(2000)*

15.6 Reflection of Waves

33. A tuning fork with frequency 800 Hz produces resonance in a resonance column tube with upper end open and lower end closed by water surface. Successive resonance are observed at length 9.75 cm, 31.25 cm and 52.75 cm. The speed of sound in air is
(a) 500 m/s (b) 156 m/s
(c) 344 m/s (d) 172 m/s
(Odisha NEET 2019)

34. A tuning fork is used to produce resonance in a glass tube. The length of the air column in this tube can be adjusted by a variable piston. At room temperature of 27°C two successive resonances are produced at 20 cm and 73 cm of column length. If the frequency of the tuning fork is 320 Hz, the velocity of sound in air at 27°C is
(a) 330 m s^{-1} (b) 339 m s^{-1}
(c) 350 m s^{-1} (d) 300 m s^{-1} *(NEET 2018)*

35. The fundamental frequency in an open organ pipe is equal to the third harmonic of a closed organ pipe. If the length of the closed organ pipe is 20 cm, the length of the open organ pipe is
(a) 13.2 cm (b) 8 cm
(c) 12.5 cm (d) 16 cm *(NEET 2018)*

36. The two nearest harmonics of a tube closed at one end and open at other end are 220 Hz and 260 Hz. What is the fundamental frequency of the system?
(a) 20 Hz (b) 30 Hz
(c) 40 Hz (d) 10 Hz *(NEET 2017)*

37. The second overtone of an open organ pipe has the same frequency as the first overtone of a closed pipe L metre long. The length of the open pipe will be
(a) L (b) $2L$ (c) $\frac{L}{2}$ (d) $4L$
(NEET-II 2016)

38. An air column, closed at one end and open at the other, resonates with a tuning fork when the smallest length of the column is 50 cm. The next larger length of the column resonating with the same tuning fork is
(a) 150 cm (b) 200 cm
(c) 66.7 cm (d) 100 cm *(NEET-I 2016)*

39. A string is stretched between fixed points separated by 75.0 cm. It is observed to have resonant frequencies of 420 Hz and 315 Hz. There are no other resonant frequencies between these two. The lowest resonant frequency for this string is
(a) 10.5 Hz (b) 105 Hz
(c) 155 Hz (d) 205 Hz *(2015)*

40. The fundamental frequency of a closed organ pipe of length 20 cm is equal to the second overtone of an organ pipe open at both the ends. The length of organ pipe open at both the ends is
(a) 120 cm (b) 140 cm
(c) 80 cm (d) 100 cm *(2015)*

41. The number of possible natural oscillations of air column in a pipe closed at one end of length 85 cm whose frequencies lie below 1250 Hz are (Velocity of sound = 340 m s^{-1})
(a) 4 (b) 5
(c) 7 (d) 6 *(2014)*

42. If we study the vibration of a pipe open at both ends, then the following statement is not true.
(a) All harmonics of the fundamental frequency will be generated.
(b) Pressure change will be maximum at both ends.
(c) Open end will be antinode.
(d) Odd harmonics of the fundamental frequency will be generated. *(NEET 2013)*

43. The length of the wire between two ends of a sonometer is 100 cm. What should be the positions of two bridges below the wire so that the three segments of the wire have their fundamental frequencies in the ratio 1 : 3 : 5.
(a) $\frac{1500}{23}$ cm, $\frac{500}{23}$ cm
(b) $\frac{1500}{23}$ cm, $\frac{300}{23}$ cm
(c) $\frac{300}{23}$ cm, $\frac{1500}{23}$ cm
(d) $\frac{1500}{23}$ cm, $\frac{2000}{23}$ cm *(Karnataka NEET 2013)*

44. When a string is divided into three segments of length l_1, l_2 and l_3 the fundamental frequencies of these three segments are υ_1, υ_2 and υ_3 respectively. The original fundamental frequency (υ) of the string is
(a) $\sqrt{\upsilon}=\sqrt{\upsilon_1}+\sqrt{\upsilon_2}+\sqrt{\upsilon_3}$
(b) $\upsilon=\upsilon_1+\upsilon_2+\upsilon_3$
(c) $\frac{1}{\upsilon}=\frac{1}{\upsilon_1}+\frac{1}{\upsilon_2}+\frac{1}{\upsilon_3}$
(d) $\frac{1}{\sqrt{\upsilon}}=\frac{1}{\sqrt{\upsilon_1}}+\frac{1}{\sqrt{\upsilon_2}}+\frac{1}{\sqrt{\upsilon_3}}$ *(2012)*

45. The time of reverberation of a room *A* is one second. What will be the time (in seconds) of reverberation of a room, having all the dimensions double of those of room *A*?
(a) 1 (b) 2
(c) 4 (d) 1/2 *(2006)*

46. If the tension and diameter of a sonometer wire of fundamental frequency *n* is doubled and density is halved then its fundamental frequency will become
(a) $\frac{n}{4}$ (b) $\sqrt{2}n$
(c) n (d) $\frac{n}{\sqrt{2}}$ *(2001)*

47. A string is cut into three parts, having fundamental frequencies n_1, n_2, n_3 respectively. Then original fundamental frequency *n* related by the expression as
(a) $\frac{1}{n}=\frac{1}{n_1}+\frac{1}{n_2}+\frac{1}{n_3}$ (b) $n = n_1 \times n_2 \times n_3$
(c) $n = n_1 + n_2 + n_3$ (d) $n=\frac{n_1+n_2+n_3}{3}$ *(2000)*

48. A standing wave having 3 nodes and 2 antinodes is formed between two atoms having a distance 1.21 Å between them. The wavelength of the standing wave is
(a) 6.05 Å (b) 2.42 Å
(c) 1.21 Å (d) 3.63 Å *(1998)*

49. Standing waves are produced in 10 m long stretched string. If the string vibrates in 5 segments and wave velocity is 20 m/s, the frequency is
(a) 5 Hz (b) 10 Hz
(c) 2 Hz (d) 4 Hz *(1997)*

50. A cylindrical tube, open at both ends has fundamental frequency *f* in air. The tube is dipped vertically in water, so that half of it is in water. The fundamental frequency of air column is now
(a) *f*/2 (b) 3*f*/4
(c) 2*f* (d) *f* *(1997)*

51. The length of a sonometer wire *AB* is 110 cm. Where should the two bridges be placed from *A* to divide the wire in 3 segments whose fundamental frequencies are in the ratio of 1 : 2 : 3 ?
(a) 60 cm and 90 cm (b) 30 cm and 60 cm
(c) 30 cm and 90 cm (d) 40 cm and 80 cm *(1995)*

52. A wave of frequency 100 Hz travels along a string towards its fixed end. When this wave travels back, after reflection, a node is formed at a distance of 10 cm from the fixed end. The speed of the wave (incident and reflected) is

(a) 20 m/s (b) 40 m/s
(c) 5 m/s (d) 10 m/s. *(1994)*

53. A stationary wave is represented by $y = A\sin(100t)\cos(0.01x)$, where y and A are in millimetres, t is in seconds and x is in metres. The velocity of the wave is
(a) 10^4 m/s (b) not derivable
(c) 1 m/s (d) 10^2 m/s *(1994)*

54. A stretched string resonates with tuning fork frequency 512 Hz when length of the string is 0.5 m. The length of the string required to vibrate resonantly with a tuning fork of frequency 256 Hz would be
(a) 0.25 m (b) 0.5 m
(c) 1 m (d) 2 m *(1993)*

55. A closed organ pipe (closed at one end) is excited to support the third overtone. It is found that air in the pipe has
(a) three nodes and three antinodes
(b) three nodes and four antinodes
(c) four nodes and three antinodes
(d) four nodes and four antinodes. *(1991)*

15.7 Beats

56. In a guitar, two strings A and B made of same material are slightly out of tune and produce beats of frequency 6 Hz. When tension in B is slightly decreased, the beat frequency increases to 7 Hz. If the frequency of A is 530 Hz, the original frequency of B will be
(a) 523 Hz (b) 524 Hz
(c) 536 Hz (d) 537 Hz *(NEET 2020)*

57. Three sound waves of equal amplitudes have frequencies $(n - 1)$, n, $(n + 1)$. They superimpose to give beats. The number of beats produced per second will be
(a) 1 (b) 4 (c) 3 (d) 2
(NEET-II 2016)

58. A source of unknown frequency gives 4 beats/s when sounded with a source of known frequency 250 Hz. The second harmonic of the source of unknown frequency gives five beats per second, when sounded with a source of frequency 513 Hz. The unknown frequency is
(a) 240 Hz (b) 260 Hz
(c) 254 Hz (d) 246 Hz *(NEET 2013)*

59. Two sources of sound placed close to each other, are emitting progressive waves given by

$$y_1 = 4\sin 600\pi t \text{ and } y_2 = 5\sin 608\pi t$$

An observer located near these two sources of sound will hear
(a) 4 beats per second with intensity ratio 25 : 16 between waxing and waning.
(b) 8 beats per second with intensity ratio 25 : 16 between waxing and waning.
(c) 8 beats per second with intensity ratio 81 : 1 between waxing and waning.
(d) 4 beats per second with intensity ratio 81 : 1 between waxing and waning. *(2012)*

60. Two identical piano wires, kept under the same tension T have a fundamental frequency of 600 Hz. The fractional increase in the tension of one of the wires which will lead to occurrence of 6 beats/s when both the wires oscillate together would be
(a) 0.01 (b) 0.02 (c) 0.03 (d) 0.04
(Mains 2011)

61. A tuning fork of frequency 512 Hz makes 4 beats per second with the vibrating string of a piano. The beat frequency decreases to 2 beats per second when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was
(a) 510 Hz (b) 514 Hz
(c) 516 Hz (d) 508 Hz *(2010)*

62. Each of the two strings of length 51.6 cm and 49.1 cm are tensioned separately by 20 N force. Mass per unit length of both the strings is same and equal to 1 g/m. When both the strings vibrate simultaneously the number of beats is
(a) 7 (b) 8
(c) 3 (d) 5 *(2009)*

63. Two vibrating tuning forks produce waves given by $y_1 = 4\sin 500\pi t$ and $y_2 = 2\sin 506\pi t$. Number of beats produced per minute is
(a) 360 (b) 180
(c) 60 (d) 3 *(2006)*

64. Two sound waves with wavelengths 5.0 m and 5.5 m respectively, each propagates in a gas with velocity 330 m/s. We expect the following number of beats per second.
(a) 6 (b) 12
(c) 0 (d) 1 *(2006)*

65. Two waves of wavelengths 50 cm and 51 cm produced 12 beats per second. The velocity of sound is
(a) 340 m/s (b) 331 m/s
(c) 306 m/s (d) 360 m/s *(1999)*

66. A source of sound gives 5 beats per second, when sounded with another source of frequency 100 second^{-1}. The second harmonic of the source, together with a source of frequency 205 second^{-1}

gives 5 beats per second. What is the frequency of the source?

(a) 105 second^{-1} (b) 205 second^{-1}
(c) 95 second^{-1} (d) 100 second^{-1} *(1995)*

67. A source of frequency υ gives 5 beats/second when sounded with a source of frequency 200 Hz. The second harmonic of frequency 2υ of source gives 10 beats/second when sounded with a source of frequency 420 Hz. The value of υ is

(a) 205 Hz (b) 195 Hz
(c) 200 Hz (d) 210 Hz. *(1994)*

68. Wave has simple harmonic motion whose period is 4 seconds while another wave which also possesses simple harmonic motion has its period 3 seconds. If both are combined, then the resultant wave will have the period equal to

(a) 4 s (b) 5 s
(c) 12 s (d) 3 s *(1993)*

69. For production of beats the two sources must have

(a) different frequencies and same amplitude
(b) different frequencies
(c) different frequencies, same amplitude and same phase
(d) different frequencies and same phase *(1992)*

15.8 Doppler Effect

70. Two cars moving in opposite directions approach each other with speed of 22 m s^{-1} and 16.5 m s^{-1} respectively. The driver of the first car blows a horn having a frequency 400 Hz. The frequency heard by the driver of the second car is (velocity of sound is 340 m s^{-1})

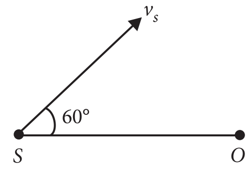
(a) 361 Hz (b) 411 Hz
(c) 448 Hz (d) 350 Hz *(NEET 2017)*

71. A siren emitting a sound of frequency 800 Hz moves away from an observer towards a cliff at a speed of 15 m s^{-1}. Then, the frequency of sound that the observer hears in the echo reflected from the cliff is (Take velocity of sound in air = 330 m s^{-1})

(a) 838 Hz (b) 885 Hz
(c) 765 Hz (d) 800 Hz *(NEET-I 2016)*

72. A source of sound S emitting waves of frequency 100 Hz and an observer O are located at some distance from each other. The source is moving with a speed of 19.4 m s^{-1} at an angle of 60° with the source observer line as shown in the figure. The observer is at rest. The apparent frequency observed by the observer (velocity of sound in air 330 m s^{-1}), is

(a) 106 Hz
(b) 97 Hz
(c) 100 Hz
(d) 103 Hz



(2015)

73. A speeding motorcyclist sees traffic jam ahead him. He slows down to 36 km hour^{-1}. He finds that traffic has eased and a car moving ahead of him at 18 km hour^{-1} is honking at a frequency of 1392 Hz. If the speed of sound is 343 m s^{-1}, the frequency of the honk as heard by him will be

(a) 1332 Hz (b) 1372 Hz
(c) 1412 Hz (d) 1454 Hz *(2014)*

74. Two sources P and Q produce notes of frequency 660 Hz each. A listener moves from P to Q with a speed of 1 m s^{-1}. If the speed of sound is 330 m/s, then the number of beats heard by the listener per second will be

(a) 4 (b) 8
(c) 2 (d) zero
(Karnataka NEET 2013)

75. A train moving at a speed of 220 m s^{-1} towards a stationary object, emits a sound of frequency 1000 Hz. Some of the sound reaching the object gets reflected back to the train as echo. The frequency of the echo as detected by the driver of the train is (Speed of sound in air is 330 m s^{-1})

(a) 3500 Hz (b) 4000 Hz
(c) 5000 Hz (d) 3000 Hz *(Mains 2012)*

76. The driver of a car travelling with speed 30 m/s towards a hill sounds a horn of frequency 600 Hz. If the velocity of sound in air is 330 m/s, the frequency of reflected sound as heard by driver is

(a) 555.5 Hz (b) 720 Hz
(c) 500 Hz (d) 550 Hz *(2009)*

77. A car is moving towards a high cliff. The driver sounds a horn of frequency f. The reflected sound heard by the driver has frequency $2f$. If v is the velocity of sound, then the velocity of the car, in the same velocity units, will be

(a) $v/\sqrt{2}$ (b) $v/3$
(c) $v/4$ (d) $v/2$ *(2004)*

78. An observer moves towards a stationary source of sound with a speed 1/5th of the speed of sound. The wavelength and frequency of the source emitted are λ and f respectively. The apparent frequency and wavelength recorded by the observer are respectively

(a) $1.2f$, 1.2λ (b) $1.2f$, λ
(c) f, 1.2λ (d) $0.8f$, 0.8λ *(2003)*

79. A whistle revolves in a circle with angular speed ω = 20 rad/s using a string of length 50 cm. If the frequency of sound from the whistle is 385 Hz, then what is the minimum frequency heard by an observer which is far away from the centre (velocity of sound = 340 m/s)
(a) 385 Hz (b) 374 Hz
(c) 394 Hz (d) 333 Hz *(2002)*

80. Two stationary sources each emitting waves of wavelength λ, an observer moves from one source to another with velocity u. Then number of beats heard by him
(a) $\frac{2u}{\lambda}$ (b) $\frac{u}{\lambda}$ (c) $\sqrt{u\lambda}$ (d) $\frac{u}{2\lambda}$ *(2000)*

81. A vehicle, with a horn of frequency n is moving with a velocity of 30 m/s in a direction perpendicular to the straight line joining the observer and the vehicle. The observer perceives the sound to have a frequency $n + n_1$. Then (if the sound velocity in air is 300 m/s)
(a) $n_1 = 0.1n$ (b) $n_1 = 0$
(c) $n_1 = 10n$ (d) $n_1 = -0.1n$ *(1998)*

82. Two trains move towards each other with the same speed. The speed of sound is 340 m/s. If the height of the tone of the whistle of one of them heard on the other changes to 9/8 times, then the speed of each train should be
(a) 20 m/s (b) 2 m/s
(c) 200 m/s (d) 2000 m/s *(1991)*

ANSWER KEY

1.	(c)	**2.**	(b)	**3.**	(c)	**4.**	(a)	**5.**	(c)	**6.**	(a)	**7.**	(a)	**8.**	(c)	**9.**	(c)	**10.**	(c)
11.	(a)	**12.**	(a, b)	**13.**	(d)	**14.**	(b)	**15.**	(d)	**16.**	(c)	**17.**	(b)	**18.**	(c)	**19.**	(c)	**20.**	(a)
21.	(c)	**22.**	(c)	**23.**	(d)	**24.**	(c)	**25.**	(c)	**26.**	(c)	**27.**	(a)	**28.**	(c)	**29.**	(b)	**30.**	(b)
31.	(b)	**32.**	(b)	**33.**	(c)	**34.**	(b)	**35.**	(a)	**36.**	(a)	**37.**	(b)	**38.**	(a)	**39.**	(b)	**40.**	(a)
41.	(d)	**42.**	(b)	**43.**	(d)	**44.**	(c)	**45.**	(b)	**46.**	(c)	**47.**	(a)	**48.**	(c)	**49.**	(a)	**50.**	(d)
51.	(a)	**52.**	(a)	**53.**	(a)	**54.**	(c)	**55.**	(d)	**56**	(b)	**57.**	(d)	**58.**	(c)	**59.**	(d)	**60.**	(b)
61.	(d)	**62.**	(a)	**63.**	(b)	**64.**	(a)	**65.**	(c)	**66.**	(a)	**67.**	(a)	**68.**	(c)	**69.**	(b)	**70.**	(c)
71.	(a)	**72.**	(d)	**73.**	(c)	**74.**	(a)	**75.**	(c)	**76.**	(b)	**77.**	(b)	**78.**	(b)	**79.**	(b)	**80.**	(a)
81.	(b)	**82.**	(a)																

Hints & Explanations

1. (c) : Light waves are electromagnetic waves. Light waves are transverse in nature and do not require a medium to travel, hence they can travel in vacuum. Sound waves are longitudinal waves and require a medium to travel. They do not travel in vacuum.

2. (b) : With the propagation of a longitudinal wave, energy alone is propagated.

3. (c) : The standard equation of a wave travelling along +ve x-direction is given by

$y = A\sin(kx - \omega t)$

where A = Amplitude of the wave
k = angular wave number
ω = angular frequency of the wave

Given: $A = 1\text{ m}, \lambda = 2\pi\text{ m}, \upsilon = \frac{1}{\pi}\text{ Hz}$

As $k = \frac{2\pi}{\lambda} = \frac{2\pi}{2\pi} = 1$; $\omega = 2\pi\upsilon = 2\pi \times \frac{1}{\pi} = 2$

$\therefore$ The equation of the given wave is
$y = 1\sin(1x - 2t) = \sin(x - 2t)$

4. (a) : $y_1 = a\sin(\omega t + kx + 0.57)$

$\therefore$ Phase, $\phi_1 = \omega t + kx + 0.57$

$$y_2 = a\cos(\omega t + kx) = a\sin\left(\omega t + kx + \frac{\pi}{2}\right)$$

$\therefore$ Phase, $\phi_2 = \omega t + kx + \frac{\pi}{2}$

Phase difference, $\Delta\phi = \phi_2 - \phi_1$

$$= \left(\omega t + kx + \frac{\pi}{2}\right) - (\omega t + kx + 0.57) = \frac{\pi}{2} - 0.57$$

= (1.57 – 0.57) radian = 1 radian

5. (c) : Amplitude = 2 cm = 0.02 m, v = 128 m/s

$$\lambda = \frac{4}{5} = 0.8\text{ m};\ \upsilon = \frac{128}{0.8} = 160\text{ Hz}$$

$$\omega = 2\pi\upsilon = 2\pi \times 160 = 1005;\quad k = \frac{2\pi}{\lambda} = \frac{2\pi}{0.8} = 7.85$$

$\therefore$ $y = (0.02)\text{m}\sin(7.85x - 1005t)$

6. (a) : $y = 0.25\sin(10\pi x - 2\pi t)$

$$y_{max} = 0.25,\ k = \frac{2\pi}{\lambda} = 10\pi \Rightarrow \lambda = 0.2\text{ m}$$

$\omega = 2\pi f = 2\pi \Rightarrow f = 1$ Hz

The sign is negative inside the bracket. Therefore this wave travels in the positive x-direction.

7. (a) : $y_1 = 10^{-6}\sin[100t + (x/50) + 0.5]$

$y_2 = 10^{-6}\cos[100t + (x/50)]$

$= 10^{-6}\sin[100t + (x/50) + \pi/2]$

$= 10^{-6}\sin[100t + (x/50) + 1.57]$

The phase difference = 1.57 – 0.5 = 1.07 radians

8. (c) : The equation of progressive wave travelling in positive x-direction is given by

$$y = a\sin\frac{2\pi}{\lambda}(vt - x)$$

Here $a = 0.2$ m, $v = 360$ m/s, $\lambda = 60$ m

$$\therefore \quad y = 0.2\sin\frac{2\pi}{60}(360t - x) = 0.2\sin\left[2\pi\left(6t - \frac{x}{60}\right)\right]$$

9. (c) : Displacement, $y_{max} = a$, $y_{min} = 0$

Time taken = $T/4$

$\therefore \quad T/4 = 0.170 \quad \therefore \; T = 0.68$

The frequency of wave = $1/T = 1.47$ Hz

10. (c) : Sound wave equation is

$y = 0.0015 \sin (62.4\, x + 316\, t)$

Comparing it with the general equation of motion

$$y = A\sin 2\pi\left[\frac{x}{\lambda} + \frac{t}{T}\right], \text{ we get } \frac{2\pi}{\lambda} = 62.4$$

$$\text{or} \quad \lambda = \frac{2\pi}{62.4} = 0.1 \text{ unit}$$

11. (a) : Phase difference $\theta = 60° = \frac{\pi}{3}$ rad

$$\text{Phase difference } (\theta) = \frac{2\pi}{\lambda} \times \text{Path difference}$$

$$\text{Therefore Path difference} = \frac{\pi}{3} \times \frac{\lambda}{2\pi} = \frac{\lambda}{6}$$

12. (a, b) : Option (a) represents a harmonic progressive wave in the standard form whereas (b) also represents a harmonic progressive wave, both travelling in the positive x- direction. In (b), a is the angular velocity, (ω) and b is k; c is the initial phase. (d) represents only S.H.M.

13. (d) : Compare with the equation,

$y = a\cos(2\pi\upsilon t + \phi)$

This give $2\pi\upsilon = 2000$; $\upsilon = \frac{1000}{\pi}$ Hz

14. (b) : The standard equation of a progressive wave is

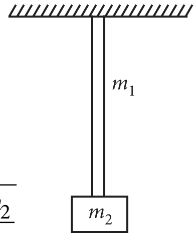
$$y = a\sin\left[2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) + \phi\right]$$

The given equation can be written as

$$y = 4\sin\left[2\pi\left(\frac{t}{10} - \frac{x}{18}\right) + \frac{\pi}{6}\right]$$

$\therefore \quad a = 4$ cm, $T = 10$ s, $\lambda = 18$ cm and $\phi = \pi/6$.

15. (d) : Wavelength of pulse at the lower end,



$$\lambda_1 \propto \text{velocity}(v_1) = \sqrt{\frac{T_1}{\mu}}$$

$$\text{Similarly, } \lambda_2 \propto v_2 = \sqrt{\frac{T_2}{\mu}}$$

$$\therefore \quad \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{(m_1 + m_2)g}{m_2 g}} = \sqrt{\frac{m_1 + m_2}{m_2}}$$

16. (c) : Since 4.0 g of a gas occupies 22.4 litres at NTP, so the molecular mass of the gas is $M = 4.0$ g mol^{-1}

As the speed of the sound in the gas is $v = \sqrt{\frac{\gamma RT}{M}}$

where γ is the ratio of two specific heats, R is the universal gas constant and T is the temperature of the gas.

$$\therefore \quad \gamma = \frac{Mv^2}{RT}$$

Here, $M = 4.0$ g mol^{-1} = 4.0×10^{-3} kg mol^{-1}, $v = 952$ m s^{-1}, $R = 8.3$ J K^{-1} mol^{-1} and

$T = 273$ K (at NTP)

$$\therefore \quad \gamma = \frac{(4.0 \times 10^{-3} \text{ kg mol}^{-1})(952 \text{ m s}^{-1})^2}{(8.3 \text{ J K}^{-1} \text{mol}^{-1})(273 \text{ K})} = 1.6$$

By definition, $\gamma = \frac{C_p}{C_v}$ or $C_p = \gamma C_v$

But $\gamma = 1.6$ and $C_v = 5.0$ J K^{-1} mol^{-1}

$\therefore \quad C_p = (1.6)(5.0$ J K^{-1} mol$^{-1}) = 8.0$ J K^{-1} mol^{-1}

17. (b) : The given wave equation is

$$y = 3\sin\frac{\pi}{2}(50t - x)$$

$$y = 3\sin\left(25\pi t - \frac{\pi}{2}x\right) \quad \text{...(i)}$$

The standard wave equation is

$y = A\sin(\omega t - kx)$ ...(ii)

Comparing (i) and (ii), we get

$$\omega = 25\pi, \; k = \frac{\pi}{2}$$

$$\text{Wave velocity, } v = \frac{\omega}{k} = \frac{25\pi}{(\pi/2)} = 50 \text{ m s}^{-1}$$

$$\text{Particle velocity, } v_p = \frac{dy}{dt} = \frac{d}{dt}\left(3\sin\left(25\pi t - \frac{\pi}{2}x\right)\right)$$

$$= 75\pi\cos\left(25\pi t - \frac{\pi}{2}x\right)$$

Maximum particle velocity, $(v_p)_{max} = 75\pi$ m s^{-1}

$$\therefore \quad \frac{(v_p)_{max}}{v} = \frac{75\pi}{50} = \frac{3}{2}\pi$$

18. (c) : Here, $v_{air} = 350$ m/s, $v_{brass} = 3500$ m/s

When a sound wave travels from one medium to another medium its frequency remains the same

$\because$ Frequency, $\upsilon = \frac{v}{\lambda}$

Since υ remains the same in both the medium

$$\Rightarrow \frac{v_{air}}{\lambda_{air}} = \frac{v_{brass}}{\lambda_{brass}}$$

$$\lambda_{brass} = \lambda_{air} \times \frac{v_{brass}}{v_{air}} = \lambda_{air} \times \frac{3500}{350} = 10\lambda_{air}$$

19. (c) : The given wave equation is

$$y = A\sin(\omega t - kx)$$

Wave velocity, $v = \frac{\omega}{k}$ ...(i)

Particle velocity, $v_p = \frac{dy}{dt} = A\omega\cos(\omega t - kx)$

Maximum particle velocity, $(v_p)_{max} = A\omega$ ...(ii)

According to the given question

$$v = (v_p)_{max};\ \frac{\omega}{k} = A\omega \quad \text{(Using (i) and (ii))}$$

$$\frac{1}{k} = A \text{ or } \frac{\lambda}{2\pi} = A \qquad \left(\because k = \frac{2\pi}{\lambda}\right)$$

$$\lambda = 2\pi A$$

20. (a) : $y(x,t) = 8.0\sin\left(0.5\pi x - 4\pi t - \frac{\pi}{4}\right)$

Compare with a standard wave equation,

$$y = a\sin\left(\frac{2\pi x}{\lambda} - \frac{2\pi t}{T} + \phi\right)$$

we get $\frac{2\pi}{\lambda} = 0.5\pi$ or, $\lambda = \frac{2\pi}{0.5\pi} = 4$ m

$$\frac{2\pi}{T} = 4\pi \text{ or, } T = \frac{2\pi}{4\pi} = \frac{1}{2}\text{ s}$$

$$\upsilon = 1/T = 2 \text{ Hz}$$

Wave velocity, $v = \lambda\upsilon = 4 \times 2 = 8$ m/s

21. (c) : $d_1 = 2$ m, $d_2 = 3$ m

Intensity $\propto \frac{1}{(\text{distance})^2}$

$$I_1 \propto \frac{1}{2^2} \text{ and } I_2 \propto \frac{1}{3^2} \qquad \therefore \frac{I_1}{I_2} = \frac{9}{4}$$

22. (c) : Comparing the given equation with general equation, $y = a\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$, we get

$$T = \frac{2\pi}{100} \text{ and } \lambda = 20\pi$$

$$\therefore \quad v = \upsilon\lambda = \frac{100}{2\pi} \times 20\pi = 1000 \text{ m/s}$$

23. (d) : The given equation of wave is

$$y = y_0 \sin\frac{2\pi}{\lambda}(vt - x)$$

Particle velocity $= \frac{dy}{dt} = y_0\frac{2\pi v}{\lambda}\cos\frac{2\pi}{\lambda}(vt - x)$

$$\left(\frac{dy}{dt}\right)_{max} = y_0\frac{2\pi}{\lambda}v$$

$$\therefore \quad y_0\frac{2\pi}{\lambda}v = 2v \text{ or } \lambda = \pi y_0$$

24. (c) : Frequency (υ) = 4.2 MHz = 4.2×10^6 Hz
speed of sound (v) = 1.7 km/s = 1.7×10^3 m/s

Wavelength of sound in tissue (λ) $= \frac{v}{\upsilon}$

$$= \frac{1.7\times10^3}{4.2\times10^6} = 4\times10^{-4} \text{ m}$$

25. (c) : Velocity of sound, $v \propto \sqrt{T}$

$$\therefore \quad \frac{v}{2v} = \frac{\sqrt{273+27}}{\sqrt{T}} \text{ or } T = 1200\text{ K} = 927°\text{C}$$

26. (c) : From $\Delta x = \frac{\lambda}{2\pi}\Delta\phi$

$$\lambda = 2\pi\frac{\Delta x}{\Delta\phi} = \frac{2\pi(0.4)}{1.6\pi} = 0.5 \text{ m}$$

$$\upsilon = \frac{v}{\lambda} = \frac{330}{0.5} = 660 \text{ Hz}$$

27. (a) : Mass per unit length $\mu = \frac{0.035}{5.5}$ kg / m, $T = 77$ N

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{77\times5.5}{0.035}} = 110 \text{ m/s}$$

28. (c) : Intensity $\propto$ (amplitude)^2 and also intensity $\propto$ (frequency)^2.
Therefore original $I \propto A^2\omega^2$

$$I' \propto 4A^2\frac{\omega^2}{16} \quad i.e., \ \frac{1}{4}I$$

29. (b) : Velocity of sound in any gas depends upon density and elasticity of gas.

$$v = \sqrt{\frac{\gamma P}{\rho}} \text{ or } \sqrt{\frac{B}{\rho}}$$

30. (b) : Other factors such as ω and v remaining the same, $I = A^2 \times$ constant (K) or $A = \sqrt{\frac{I}{K}}$

On superposition

$$A_{max} = A_1 + A_2 \text{ and } A_{min} = A_1 - A_2$$

$$\therefore \quad A^2_{max} = A_1^2 + A_2^2 + 2A_1A_2$$

$$\Rightarrow \frac{I_{max}}{K} = \frac{I_1}{K} + \frac{I_2}{K} + \frac{2\sqrt{I_1I_2}}{K}$$

$$A^2_{min} = A_1^2 + A_2^2 - 2A_1A_2$$

$$\Rightarrow \frac{I_{min}}{K} = \frac{I_1}{K} + \frac{I_2}{K} - \frac{2\sqrt{I_1I_2}}{K}$$

$$\therefore \quad I_{max} + I_{min} = 2I_1 + 2I_2 = 2(I_1 + I_2)$$

31. (b) : Resultant amplitude = $2a$ (1 + cosϕ) = a

$\therefore \quad (1+\cos\phi)=1/2;\ \cos\phi=-\frac{1}{2};\quad \phi=\frac{2\pi}{3}$

32. (b) : Given : $x = a\cos(\omega t + \delta)$
and $y = a\cos(\omega t + \alpha)$ ...(i)
where, $\delta = \alpha + \pi/2$
$\therefore \quad x = a\cos(\omega t + \alpha + \pi/2) = -a\sin(\omega t + \alpha)$ ...(ii)
Given the two waves are acting in perpendicular direction with the same frequency and phase difference $\pi/2$.
From equations (i) and (ii),

$x^2 + y^2 = a^2$

which represents the equation of a circle.

33. (c) : Frequency (υ) = 800 Hz
As the pipe is closed at one end, so

$l_3 - l_2 = l_2 - l_1 = \frac{\lambda}{2} = 21.5 \text{ cm}$

$\therefore \quad \lambda = 43.0$ cm

As $\upsilon = \frac{v}{\lambda} \Rightarrow v = \upsilon\lambda$

$\therefore \quad v = \frac{800\times 43}{100} = 344 \text{ m s}^{-1}$

34. (b) : The velocity of sound in air at 27°C is $v = 2(\upsilon)\ [L_2 - L_1]$; where υ = frequency of tuning fork and L_1, L_2 are the successive column length.

$\therefore \quad v = 2 \times 320[73 - 20] \times 10^{-2}$
$= 339.2 \text{ m s}^{-1} \approx 339 \text{ m s}^{-1}$

35. (a) : For closed organ pipe, third harmonic is $\frac{3v}{4l}$.

For open organ pipe, fundamental frequency is $\frac{v}{2l'}$

Given, third harmonic for closed organ pipe
= fundamental frequency for open organ pipe.

$\therefore \quad \frac{3v}{4l} = \frac{v}{2l'} \quad \Rightarrow \quad l' = \frac{4l}{3\times 2} = \frac{2l}{3}$

where l and l' are the lengths of closed and open organ pipes respectively.

$\therefore \quad l' = \frac{2\times 20}{3} = 13.33 \text{ cm}$

36. (a) : Nearest harmonics of an organ pipe closed at one end is differ by twice of its fundamental frequency.

$\therefore \quad 260 - 220 = 2\upsilon,\ \upsilon = 20$ Hz

37. (b) : Second overtone of an open organ pipe

$\text{(Third harmonic)} = 3\times\upsilon_0' = 3\times\frac{v}{2L'}$

First overtone of a closed organ pipe

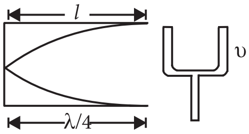
$\text{(Third harmonic)} = 3\times\upsilon_0 = 3\times\frac{v}{4L}$

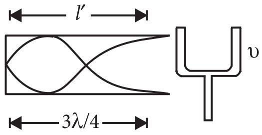
According to question,

$3\upsilon_0' = 3\upsilon_0 \Rightarrow 3\times\frac{v}{2L'} = 3\times\frac{v}{4L}$

$\therefore \quad L' = 2L$

38. (a) : From figure,





First harmonic is obtained at

$l = \frac{\lambda}{4} = 50 \text{ cm}$

Third harmonic is obtained for resonance,

$l' = \frac{3\lambda}{4} = 3\times 50 = 150 \text{ cm}$

39. (b) : For a string fixed at both ends, the resonant frequencies are

$\upsilon_n = \frac{nv}{2L}$ where $n = 1, 2, 3, ...$

The difference between two consecutive resonant frequencies is

$\Delta\upsilon_n = \upsilon_{n+1} - \upsilon_n = \frac{(n+1)v}{2L} - \frac{nv}{2L} = \frac{v}{2L}$

which is also the lowest resonant frequency (n = 1).
Thus the lowest resonant frequency for the given string = 420 Hz –315 Hz = 105 Hz

40. (a) : For closed organ pipe, fundamental frequency is given by $\upsilon_c = \frac{v}{4l}$

For open organ pipe, fundamental frequency is given by

$\upsilon_o = \frac{v}{2l'}$

2nd overtone of open organ pipe

$\upsilon' = 3\upsilon_0;\ \upsilon' = \frac{3v}{2l'}$

According to question, $\upsilon_c = \upsilon'$

$\frac{v}{4l} = \frac{3v}{2l'};\ l' = 6l$

Here, l = 20 cm, l' = ?
$\therefore \quad l' = 6 \times 20 = 120$ cm

41. (d) : Fundamental frequency of the closed organ pipe is

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

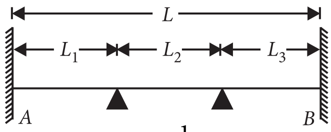
Here, $v = 340 \text{ m s}^{-1}$, L = 85 cm = 0.85 m

$\therefore \quad \upsilon = \frac{340 \text{ m s}^{-1}}{4\times 0.85 \text{ m}} = 100 \text{ Hz}$

The natural frequencies of the closed organ pipe will be
$\upsilon_n = (2n - 1)\upsilon = \upsilon, 3\upsilon, 5\upsilon, 7\upsilon, 9\upsilon, 11\upsilon, 13\upsilon,...$
= 100 Hz, 300 Hz, 500 Hz, 700 Hz, 900 Hz, 1100 Hz, 1300 Hz,... and so on
Thus, the number of natural frequencies lies below 1250 Hz is 6.

42. (b) : Pressure change will be minimum at both ends.

43. (d) : Let $L(= 100 \text{ cm})$ be the length of the wire and L_1, L_2 and L_3 are the lengths of the segments as shown in the figure.



Fundamental frequency, $\upsilon \propto \frac{1}{L}$

As the fundamental frequencies are in the ratio of 1 : 3 : 5,

$$\therefore \quad L_1 : L_2 : L_3 = \frac{1}{1} : \frac{1}{3} : \frac{1}{5} = 15 : 5 : 3$$

Let x be the common factor. Then

$$15x + 5x + 3x = 100$$

$$23x = 100 \text{ or } x = \frac{100}{23}$$

$$\therefore \quad L_1 = 15 \times \frac{100}{23} = \frac{1500}{23} \text{ cm}$$

$$L_2 = 5 \times \frac{100}{23} = \frac{500}{23} \text{ cm} ; L_3 = 3 \times \frac{100}{23} = \frac{300}{23} \text{ cm}$$

$\therefore$ The bridges should be placed from A at $\frac{1500}{23}$ cm and $\frac{2000}{23}$ cm respectively.

44. (c) : Let l be the length of the string.

Fundamental frequency is given by

$$\upsilon = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

or $\quad \upsilon \propto \frac{1}{l} \qquad (\because \ T \text{ and } \mu \text{ are constants})$

Here, $l_1 = \frac{k}{\upsilon_1}, l_2 = \frac{k}{\upsilon_2}, l_3 = \frac{k}{\upsilon_3}$ and $l = \frac{k}{\upsilon}$

But $l = l_1 + l_2 + l_3$

$$\therefore \quad \frac{1}{\upsilon} = \frac{1}{\upsilon_1} + \frac{1}{\upsilon_2} + \frac{1}{\upsilon_3}$$

45. (b) : Reverberation time, $T = \frac{0.61\,V}{aS}$

where V is the volume of room in cubic metres, a is the average absorption coefficient of the room, S is the total surface area of room in square metres.

$$\text{or, } T \propto \frac{V}{S} \text{ or, } \frac{T_1}{T_2} = \left(\frac{V_1}{V_2}\right)\left(\frac{S_2}{S_1}\right) = \left(\frac{V}{8V}\right)\left(\frac{4S}{S}\right) = \frac{1}{2}$$

or, $\quad T_2 = 2T_1 = 2 \times 1 = 2$ s $\qquad (\because \ T_1 = 1 \text{ s})$

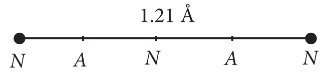
46. (c) : $n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}}$

$$\rho_1' = \frac{\rho}{2};\ T' = 2T \text{ and } D' = 2D \quad \text{or } r' = 2r$$

$$n' = \frac{1}{2l}\sqrt{\frac{2T}{\pi(2r)^2 \frac{\rho}{2}}} = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}} = n$$

47. (a)

48. (c) : Distance between a node and adjoining antinode = $\lambda/4$



From figure, distance between two atoms

$$= 4 \times \frac{\lambda}{4} = 1.21 \text{ Å} \text{ or, } \lambda = 1.21 \text{ Å}$$

49. (a) : The frequency of standing wave,

$$\upsilon = \frac{n}{2l}v = \frac{5 \times 20}{2 \times 10} = 5 \text{ Hz}$$

50. (d) : For the cylindrical tube open at both ends, $f = v/2l$

When half of the tube is in water, it behaves as a closed pipe of length $l/2$.

$$\therefore \quad f' = \frac{v}{4(l/2)} = \frac{v}{2l} \quad \Rightarrow \quad f' = f$$

51. (a) : Length of sonometer wire (l) = 110 cm and ratio of frequencies = 1 : 2 : 3.

$$\text{Frequency } (\upsilon) \propto \frac{1}{l} \text{ or } l \propto \frac{1}{\upsilon}$$

$$\text{Therefore } AC : CD : DB = \frac{1}{1} : \frac{1}{2} : \frac{1}{3} = 6 : 3 : 2$$

$$\text{Therefore } AC = 6 \times \frac{110}{11} = 60 \text{ cm and}$$

$$CD = 3 \times \frac{110}{11} = 30 \text{ cm}$$

Thus $AD = 60 + 30 = 90$ cm.

52. (a) : Frequency (υ) = 100 Hz and distance from fixed end = 10 cm = 0.1 m. When a stationary wave is produced, the fixed end behaves as a node.

Thus wavelength (λ) = 2 × 0.1 = 0.2 m.

Therefore velocity $v = \upsilon\lambda = 100 \times 0.2 = 20$ m/s.

53. (a) : $y = A\sin(100t)\cos(0.01x)$.

Comparing it with standard equation

$$y = A\sin\left(\frac{2\pi}{T}t\right)\cos\left(\frac{2\pi}{\lambda}x\right),$$

$$\text{we get } T = \frac{\pi}{50} \text{ and } \lambda = 200\,\pi$$

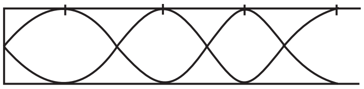
$$\text{Therefore velocity, } (v) = \frac{\lambda}{T} = \frac{200\pi}{\pi/50} = 200 \times 50$$

$$= 10000 = 10^4 \text{ m/s}$$

54. (c) : $f = \frac{1}{2l}\left[\frac{T}{\mu}\right]^{\frac{1}{2}}$ when f is halved, the length will be doubled.

Hence required length of string is 1 m.

55. (d) : Third overtone has a frequency $4n$, 4^{th} harmonic = three full loops + one half loop, which would make four nodes and four antinodes.



56. (b) : Frequency of string A, $\upsilon_A = 530$ Hz and beat frequency $\Delta\upsilon_1 = 6$ Hz.
Since, $\upsilon_B = \upsilon_A \pm \Delta\upsilon_1$, we have $\upsilon_B = 536$ Hz or 524 Hz.
Now, when tension on the string is reduced, its frequency reduces.
Now, the beat frequency, $\Delta\upsilon_2 = 7$ Hz.
∴ The original frequency of B, $\upsilon_B = 524$ Hz.

57. (d)

58. (c) : Let υ be frequency of the unknown source. As it gives 4 beats per second when sounded with a source of frequency 250 Hz,
∴ $\upsilon = 250 \pm 4 = 246$ Hz or 254 Hz
Second harmonic of this unknown source = 492 Hz or 508 Hz which gives 5 beats per second, when sounded with a source of frequency 513 Hz.
Therefore unknown frequency, $\upsilon = 254$ Hz

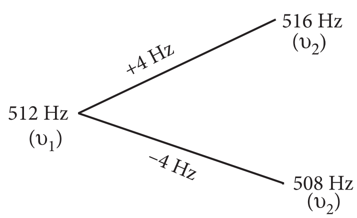
59. (d) : Given : $y_1 = 4\sin 600\pi t$, $y_2 = 5\sin 608\pi t$
∴ $\omega_1 = 600\pi$ or $2\pi\upsilon_1 = 600\pi$ or $\upsilon_1 = 300$ Hz
$A_1 = 4$
and $\omega_2 = 608\pi$ or $2\pi\upsilon_2 = 608\pi$ or $\upsilon_2 = 304$ Hz
$A_2 = 5$
Number of beats heard per second
$= \upsilon_2 - \upsilon_1 = 304 - 300 = 4$

$$\frac{I_{max}}{I_{min}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{(4+5)^2}{(4-5)^2} = \frac{81}{1}$$

60. (b) : As $\upsilon = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$ ∴ $\frac{\Delta\upsilon}{\upsilon} = \frac{1}{2}\frac{\Delta T}{T}$

$$\frac{\Delta T}{T} = 2\frac{\Delta\upsilon}{\upsilon} = 2\times\frac{6}{600} = 0.02$$

61. (d) : Let the frequencies of tuning fork and piano string be υ_1 and υ_2 respectively.
∴ $\upsilon_2 = \upsilon_1 \pm 4 = 512$ Hz $\pm 4 = 516$ Hz or 508 Hz



Increase in the tension of a piano string increases its frequency.
If $\upsilon_2 = 516$ Hz, further increase in υ_2, resulted in an increase in the beat frequency. But this is not given in the question.
If $\upsilon_2 = 508$ Hz, further increase in υ_2 resulted in decrease in the beat frequency. This is given in the question. When the beat frequency decreases to 2 beats per second. Therefore, the frequency of the piano string before increasing the tension was 508 Hz.

62. (a) : $l_1 = 0.516$ m, $l_2 = 0.491$ m, $T = 20$ N.
Mass per unit length, $\mu = 0.001$ kg/m.

$$\text{Frequency, } \upsilon = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

$$\upsilon_1 = \frac{1}{2\times 0.516}\sqrt{\frac{20}{0.001}}\text{ Hz} = 137\text{ Hz}$$

$$\upsilon_2 = \frac{1}{2\times 0.491}\sqrt{\frac{20}{0.001}}\text{ Hz} = 144\text{ Hz}$$

∴ Number of beats $= \upsilon_1 - \upsilon_2 = 7$ Hz

63. (b) : $y_1 = 4\sin 500\pi t$, $y_2 = 2\sin 506\pi t$
$\omega_1 = 500\,\pi = 2\pi\upsilon_1 \Rightarrow \upsilon_1 = 250$ Hz
$\omega_2 = 506\,\pi = 2\pi\upsilon_2 \Rightarrow \upsilon_2 = 253$ Hz
$\upsilon = \upsilon_2 - \upsilon_1 = 253 - 250 = 3$ beats/s
Number of beats per minute $= 3 \times 60 = 180$

64. (a) : $\text{Frequency} = \frac{\text{velocity}}{\text{wavelength}}$

$$\therefore \quad \upsilon_1 = \frac{v}{\lambda_1} = \frac{330}{5} = 66\text{ Hz}$$

$$\text{and} \quad \upsilon_2 = \frac{v}{\lambda_2} = \frac{330}{5.5} = 60\text{ Hz}$$

Number of beats per second $= \upsilon_1 - \upsilon_2 = 66 - 60 = 6$

65. (c) : Number of beats produced per second

$$= \upsilon_1 - \upsilon_2 = \frac{v}{\lambda_1} - \frac{v}{\lambda_2}$$

$$12 = v\left[\frac{1}{50} - \frac{1}{51}\right] \quad \text{or} \quad 12 = \frac{v\times 1}{50\times 51}$$

or, $v = 12 \times 50 \times 51$ cm/s $= 306$ m/s

66. (a) : Frequency of first source with 5 beats/sec = 100 Hz and frequency of second source with 5 beats/sec = 205. The possible frequency of unknown sources = 100 ± 5 = 105 or 95 Hz.
Therefore frequency of second harmonic of unknown source = 210 Hz or 190 Hz.
As the second harmonic gives 5 beats/second with the sound of frequency 205 Hz, therefore frequency of second harmonic of unknown source should be 210 Hz.
The frequency of unknown source = 105 Hz.

67. (a) : First case: Frequency = υ;
No. of beats/second = 5 and
frequency (sounded with) = 200 Hz
Second case: Frequency = $2\,\upsilon$;
No. of beats/sec and = 10 and frequency (sounded with) = 420 Hz
In the first case, frequency $(\upsilon) = 200 \pm 5 = 205$ or 195 Hz. And in the second case, frequency $(2\upsilon) = 420 \pm 10$

or υ = 210 ± 5 = 205 or 215. So common value of υ in both the cases is 205 Hz.

68. (c) : Beats are produced. Frequency of beats will be

$$\frac{1}{3}-\frac{1}{4}=\frac{1}{12} \text{ per second}$$

Hence time period = 12 s

69. (b) : For production of beats different frequencies are essential. The different amplitudes effect the minimum and maximum amplitude of the beats. If frequencies are different, phases will be different.

70. (c) : The required frequency of sound heard by the driver of second car is given as

$$\upsilon' = \upsilon\left(\frac{v+v_o}{v-v_s}\right),$$

where v = velocity of sound

v_o = velocity of observer, *i.e.*, second car

v_s = velocity of source *i.e.*, first car

$$\upsilon' = 400\left(\frac{340+16.5}{340-22}\right) = 400\left(\frac{356.5}{318}\right)$$

$\upsilon' \approx 448$ Hz

71. (a) : Here, frequency of sound emitted by siren,

υ_0 = 800 Hz

Speed of source, v_s = 15 m s^{-1}

Speed of sound in air, v = 330 m s^{-1}

Apparent frequency of sound at the cliff

= frequency heard by observer = υ

Using Doppler's effect of sound

$$\upsilon = \left(\frac{v}{v-v_s}\right)\upsilon_0 = \frac{330}{330-15}\times 800$$

$$= \frac{330}{315}\times 800 = 838.09 \text{ Hz} \approx 838 \text{ Hz}$$

72. (d) : Here, Frequency of source,

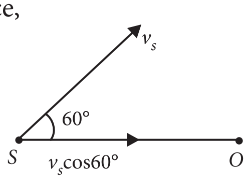
υ_0 = 100 Hz

Velocity of source,

v_s = 19.4 m s^{-1}

Velocity of sound in air,

v = 330 m s^{-1}



As the velocity of source along the source observer line is $v_s$cos60° and the observer is at rest, so the apparent frequency observed by the observer is

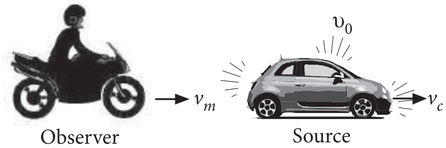
$$\upsilon = \upsilon_0\left(\frac{v}{v-v_s\cos 60^\circ}\right)$$

$$= (100 \text{ Hz})\left(\frac{330 \text{ m s}^{-1}}{330 \text{ m s}^{-1} - (19.4 \text{ m s}^{-1})\left(\frac{1}{2}\right)}\right)$$

$$= (100 \text{ Hz})\left(\frac{330 \text{ m s}^{-1}}{330 \text{ m s}^{-1} - 9.7 \text{ m s}^{-1}}\right)$$

$$= (100 \text{ Hz})\left(\frac{330 \text{ m s}^{-1}}{320.3 \text{ m s}^{-1}}\right) = 103 \text{ Hz}$$

73. (c) :



Here, speed of motorcyclist, v_m = 36 km hour^{-1}

$$= 36\times\frac{5}{18} = 10 \text{ m s}^{-1}$$

Speed of car, $v_c = 18 \text{ km hour}^{-1} = 18\times\frac{5}{18} \text{ m s}^{-1} = 5 \text{ m s}^{-1}$

Frequency of source, υ_0 = 1392 Hz,

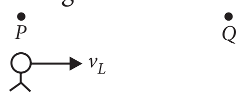
Speed of sound, v = 343 m s^{-1}

The frequency of the honk heard by the motorcyclist is

$$\upsilon' = \upsilon_0\left(\frac{v+v_m}{v+v_c}\right) = 1392\left(\frac{343+10}{343+5}\right)$$

$$= \frac{1392\times 353}{348} = 1412 \text{ Hz}$$

74. (a) : The situation as shown in the figure.



Here, speed of listener,

v_L = 1 m s^{-1}

Speed of sound, v = 330 m s^{-1}

Frequency of each source, υ = 660 Hz

Apparent frequency due to P, $\upsilon' = \dfrac{\upsilon(v-v_L)}{v}$

Apparent frequency due to Q, $\upsilon'' = \dfrac{\upsilon(v+v_L)}{v}$

Number of beats heard by the listener per second is

$$\upsilon'' - \upsilon' = \frac{\upsilon(v+v_L)}{v} - \upsilon\frac{(v-v_L)}{v}$$

$$= \frac{2\upsilon v_L}{v} = \frac{2\times 660\times 1}{330} = 4$$

75. (c) : Here, Speed of the train, v_T = 220 m s^{-1}

Speed of sound in air, v = 330 m s^{-1}

The frequency of the echo detected by the driver of the train is

$$\upsilon' = \upsilon\left(\frac{v+v_T}{v-v_T}\right) = 1000\left(\frac{330+220}{330-220}\right) = 1000\times\frac{550}{110} = 5000 \text{ Hz}$$

76. (b) : Car is the source and the hill is observer.

Frequency heard at the hill,

$$\upsilon_1 = \frac{\upsilon\times v}{(v-V)} = \frac{600\times 330}{330-30}$$

Now for reflection, the hill is the source and the driver is the observer.

$$\therefore\ \upsilon_2 = \upsilon_1\times\frac{(330+30)}{330}$$

$$\Rightarrow\ \upsilon_2 = \frac{600\times 330}{300}\times\frac{360}{330} \Rightarrow \upsilon_2 = 720 \text{ Hz}$$

77. (b) : 1st the car is the source and at the cliff, one observes f'.

$$\therefore \quad f' = \frac{v}{v - v_s} f$$

Now cliff is source. It emits frequency f' and the observer is now the driver who observes f''.

$$\therefore \quad f'' = \left[\frac{v + v_o}{v}\right] f' \quad \text{or} \quad 2f = \left[\frac{v + v_o}{v - v_s}\right] f$$

$\Rightarrow \quad 2v - 2v_o = v + v_o$ [as $v_s = v_o$]

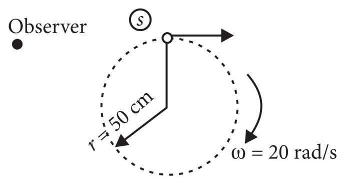
$$\Rightarrow \quad v_o = \frac{v}{3}$$

78. (b) : Apparent frequency,

$$f' = \frac{v + v_o}{v} f = \frac{v + (1/5)v}{v} f = 1.2f$$

Wavelength does not change by motion of observer.

79. (b) : The whistle is revolving in a circle of radius 50 cm. So the source (whistle) is moving and the observer is fixed.



The minimum frequency will be heard by the observer when the linear velocity of the whistle (source) will be in a direction as shown in the figure, *i.e.* when the source is receding.

The apparent frequency heard by the observer is then given by $\upsilon' = \upsilon\left(\frac{V}{V + v}\right)$

where V and v are the velocities of sound and source respectively and υ is the actual frequency.

Now, $v = r\,\omega = 0.5 \times 20 = 10$ m/s

$V = 340$ m/s, $\upsilon = 385$ Hz.

$$\therefore \quad \upsilon' = 385 \times \frac{340}{340 + 10} = 374 \text{ Hz.}$$

80. (a) : $f' = \frac{v - u}{v} f$; $f'' = \frac{v + u}{v} f$

Number of beats $= f'' - f' = \frac{2u}{\lambda}$

81. (b) : $n' = n + n_1 = \frac{nv}{v - v_s \cos\theta} = \frac{nv}{v} = n$

$[\because \cos 90° = 0]$

$\therefore \quad n_1 = 0$

82. (a) : Here $\upsilon' = \frac{9}{8}\upsilon$

Source and observer are moving in opposite direction, apparent frequency

$$\upsilon' = \upsilon \times \frac{(v + u)}{(v - u)} \quad \text{or,} \quad \frac{9}{8}\upsilon = \upsilon \times \frac{340 + u}{340 - u}$$

$\Rightarrow \quad 9 \times 340 - 9u = 8 \times 340 + 8u$

$$\Rightarrow \quad 17u = 340 \times 1 \Rightarrow u = \frac{340}{17} = 20 \text{ m/s}$$

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