25. b) Distance between a compression and the nearest rarefaction is $\frac{\lambda}{2} = 1m$. Hence $n = \frac{v}{\lambda} = \frac{360}{2} = 180\ Hz$.

26. (a) $v = \sqrt{\frac{\gamma P}{\rho}} \Rightarrow \frac{v_{O_2}}{v_{H_2}} = \sqrt{\frac{\rho_{H_2}}{\rho_{O_2}}} = \sqrt{\frac{1}{16}} = \frac{1}{4}$

27. (d) Speed of sound in gases is $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow$

$T \propto M$

(Because v, γ-constant). Hence $\frac{T_{H_2}}{T_{O_2}} = \frac{M_{H_2}}{M_{O_2}}$

$\Rightarrow \frac{T_{H_2}}{(273+100)} = \frac{2}{32} \Rightarrow T_{H_2} = 23.2K = -249.7°C$

28. (c) If the temperature changes then velocity of wave and its wavelength changes. Frequency amplitude and time period remains constant.

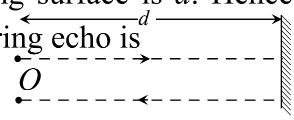
29. (b)

30. (d)

31. (c) Path difference $\Delta = \frac{\lambda}{2\pi} \times \phi \Rightarrow 1 = \frac{\lambda}{2\pi} \times \frac{\pi}{2} \Rightarrow \lambda$ $= 4m$

Hence $v = n\lambda = 120 \times 4 = 480\ m/s$

32. (a) Suppose the distance between shooter and reflecting surface is d. Hence time interval for hearing echo is



$t = \frac{2d}{v} \Rightarrow 8 = \frac{2d}{350} \Rightarrow d = 1400\ m$.

33. (b) $\text{Time} = \frac{\text{Distance}}{\text{Velocity}} = \frac{1000}{330} = 3.03\ \text{sec.}$

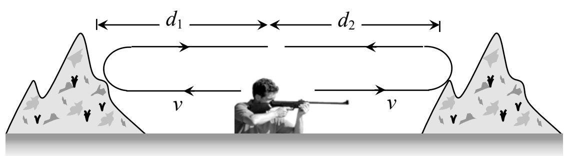
Sound will be heard after 3.03 sec. So his watch is set 3*sec*, slower.

34. (d) $v = \sqrt{\frac{\gamma P}{\rho}}$; as P changes, ρ also changes. Hence $\frac{P}{\rho}$ remains constant so speed remains constant.

35. (b) Speed of sound in gases is given by

$v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$

36. (b)



$2d_1 + 2d_2 = v \times t_1 + v \times t_2 \Rightarrow 2(d_1 + d_2) = v(t_1 + t_2)$

$d_1 + d_2 = \frac{v(t_1 + t_2)}{2} = \frac{340 \times (1.5 + 3.5)}{2} = 850\ m.$

37. (b) By using $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \sqrt{T}$

$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{T+600}{T}} = \sqrt{3} \Rightarrow T = 300\,K = 27^o C$

38. (a) Velocity of sound is independent of frequency. Therefore it is same (v) for frequency n and $4n$.

39. (c) $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \sqrt{T}$

i.e. if v is doubled then T becomes four times,

hence $T_2 = 4T_1 = 4(273+27) = 1200K = 927°C$

40. (d) $n = \frac{3600}{60} = 60\ Hz \Rightarrow \lambda = \frac{v}{n} = \frac{960}{60} = 16\ m$

41. (d) Speed do sound, doesn't depend up on pressure and density medium.

42. (d) If d is the distance between man and reflecting surface of sound then for hearing echo

$2d = v \times t \Rightarrow d = \frac{340 \times 1}{2} = 170\ m$

43. (c) $n = \frac{54}{60}\ Hz, \lambda = 10\ m \Rightarrow v = n\lambda = 9\ m/s.$

44. (a) $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \frac{1}{\sqrt{M}}$. Since M is minimum for H_2 so sound velocity is maximum in H_2.

45. (d) $2d = v \times t$, where v = velocity of sound = 332 m/s

t = Persistence of hearing = $\frac{1}{10}$ sec.

$\Rightarrow d = \frac{v \times t}{2} = \frac{332 \times \frac{1}{10}}{2} = 16.5\ m$

46. (c) Since solid has both the properties (rigidity and elasticity)

47. (b) If d is the distance between man and reflecting surface of sound then for hearing echo

$2d = v \times t \Rightarrow d = \frac{330 \times 1.5}{2} = 247.5\ m$

48. (d) Speed of sound $v \propto \sqrt{T}$ and it is independent of pressure.

49. (b) Frequency of wave is $n = \frac{3600}{2 \times 60} Hz \Rightarrow$

$\lambda = \frac{v}{n} = \frac{760}{30} = 25.3\, m.$

50. (a) Speed of sound $v = \sqrt{\frac{\gamma P}{d}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{d_2}{d_1}}$

($\because P$- constant)

51. (d) $\lambda = \frac{v}{n} = \frac{352}{384}$; during 1 vibration of fork sound will travel $\frac{352}{384} m$ during 36 vibration of fork sound will travel $\frac{352}{384} \times 36 = 33\ m$

52. (c) At given temperature and pressure

$v \propto \frac{1}{\sqrt{\rho}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{4}{1}} = 2:1$

53. (c) $v \propto \sqrt{T} \Rightarrow \sqrt{\frac{T_2}{T_1}} = \frac{v_2}{v_1} \Rightarrow T_2 = T_1 \left(\frac{v_2}{v_1}\right)^2$

$\Rightarrow T_2 = 273 \times 4 = 1092 K$

54. (c) $\bar{n} = \frac{1}{\lambda} = \frac{1}{6000 \times 10^{-10}} = 1.66 \times 10^6 m^{-1}$

55. (b) $v \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{v_{H_2}}{v_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{H_2}}} = \sqrt{\frac{32}{2}} \Rightarrow \frac{v_{H_2}}{v_{O_2}} = \frac{4}{1}$

56. (a) The minimum distance between compression and rarefaction of the wire $l = \frac{\lambda}{4}$ $\therefore$ Wave length $\lambda = 4l$

Now by $v = n\lambda \Rightarrow n = \frac{360}{4 \times 1} = 90\ \sec^{-1}$.

57. (a) $v_{sound} \propto \frac{1}{\sqrt{\rho}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{4}{1}} = 2 \Rightarrow v_2 = \frac{v_1}{2} = \frac{v_s}{2}$

58. (a) Suppose the distance between two fixed points is d then

$t = \frac{d}{v}$ also $v \propto \sqrt{T} \Rightarrow \frac{t_1}{t_2} = \frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}}$

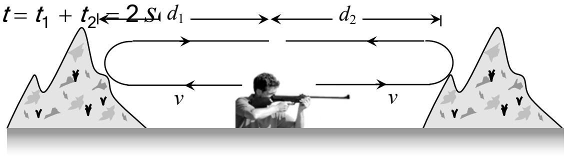
$\Rightarrow \frac{2}{t_2} = \sqrt{\frac{303}{283}} \Rightarrow t_2 = 1.9\ sec.$

59. (a) The density of moist air (*i.e.* air mixed with water vapours) is less than the density of dry air

Hence from $v = \sqrt{\frac{\gamma P}{\rho}} \Rightarrow v_{moist air} > v_{dry\ air}$

60. (a) Total time taken for both the echoes

$t = t_1 + t_2 = 2\ s$



but $t = \frac{2d_1}{v} + \frac{2d_2}{v} \Rightarrow t = \frac{2}{v}(d_1 + d_2)$

$\Rightarrow (d_1 + d_2) = \frac{v \times t}{2} = \frac{340 \times 2}{2} = 340 m.$

61. (d) Frequency of sound does not change with medium, because it is characteristics of source.

62. (c) Since $v = \sqrt{\frac{\gamma RT}{M}}$ *i.e.,* $v \propto \sqrt{T}$

63. (a) Frequency of waves remains same, *i.e.* 60 *Hz*

and wavelength $\lambda = \frac{v}{n} = \frac{330}{60 \times 10^3} = 5.5\ mm.$

64. (c) Path difference $\Delta = \frac{\lambda}{2\pi} \times \phi = \frac{\lambda}{2\pi} \times \frac{\pi}{3} = \frac{\lambda}{6}$

65. (d) Interference, diffraction and reflection occurs in both transverse and longitudinal waves. Polarisation occurs only in transverse waves.

66. (c) Water waves are transverse as well as longitudinal in nature.

67. (c)

68. (a) In transverse waves medium particles vibrate perpendicular to the direction of propagation of wave.

69. (d)

70. (a) Wave on a plucked string is stationary wave. Light waves are EM waves. Water waves are transverse as well as longitudinal.

71. (b)

72. (b) Transverse wave can propagate in solids but not in liquids and gases.

73. (b) Because sound waves in gases are longitudinal.

74. (d)

75. (c) Since distance between two consecutive crests is λ, so

$\phi = \frac{2\pi}{\lambda} \times \lambda = 2\pi.$

76. (b) The distance between two points *i.e.* path difference between them

$\Delta = \frac{\lambda}{2\pi} \times \phi = \frac{\lambda}{2\pi} \times \frac{\pi}{3} = \frac{\lambda}{6} = \frac{v}{6n}$ $(\because v = n\lambda) \Rightarrow$

$\Delta = \frac{360}{6 \times 500} = 0.12\, m = 12\, cm$

77. (d) Sound waves are longitudinal in nature so they can not be polarised

78. (b)

79. (b) Ultrasonic waves are those of higher frequencies than maximum audible range frequencies (audible range of frequencies is 20 *Hz* to 20000 *Hz*)

80. (b)

81. (d) Infrasonic waves have frequency less than (20 *Hz*) audible sound and wavelength more than audible sound.

82. (b) SONAR emits ultrasonic waves.

83. (b) EM waves do not requires medium for their propagation.

84. (b)

85. (d)

86. (d) $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow \frac{T_N}{T_0} = \frac{M_N}{M_0} \Rightarrow \frac{T_N}{273 + 55} = \frac{14}{16} = \frac{7}{8}$

$\Rightarrow T_N = 287 K = 14°C$

87. (a) We know that at night amount of carbon dioxide in atmosphere increases which raises the density of atmosphere. Since intensity is directly proportional to density, intensity of sound is more at night.

88. (c) $n = \frac{v}{\lambda} = \frac{300}{0.6 \times 10^{-2}} Hz = \frac{3}{6} \times 10^4\, Hz = 50{,}000\, Hz$

$\Rightarrow$ Wave is ultrasonic.

89. (a) $v = \sqrt{\frac{K}{\rho}}$ $\therefore$ $K = v^2 \rho = 2.86 \times 10^{10}\, N/m^3$

90. (a) $n = \frac{v}{\lambda} \propto v \Rightarrow \frac{n_{MW}}{n_{US}} \approx \frac{3 \times 10^8}{3 \times 10^2} \approx 10^6 : 1$

91. (a) Intensity $\propto \frac{1}{(\text{Distance})^2} \Rightarrow \frac{I_1}{I_2} = \left(\frac{d_2}{d_1}\right)^2 = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$

92. (d) $v = \frac{\sin i}{\sin r} = \frac{v_1}{v_2}$

$\Rightarrow \sin r = \sin 30° \times \frac{2u}{u} \Rightarrow \sin r = \frac{1}{2} \times 2 \times 1 \Rightarrow r = 90°$

93. (d) Number of waves per minute = 54

$\therefore$ Number of waves per second = 54/60

Now $v = n\lambda \Rightarrow n = \frac{54}{60} \times 10 = 9\, m/s$

94. (d) If d is the distance of rock from SONAR then

$2d = vt \Rightarrow d = \frac{v \times t}{2} = \frac{1600 \times 1}{2} = 800\, m$

Progressive Waves

1. (d) Comparing given equation with standard equation of progressive wave. The velocity of wave

$v = \frac{\omega(\text{Co-efficient of } t)}{k(\text{Co-efficient of } x)} = \frac{200\pi}{0.5\pi} = 400\, cm/s$

2. (c) Comparing with $y = a\cos(\omega t + kx - \phi)$,

We get $k = \frac{2\pi}{\lambda} = 0.02 \Rightarrow \lambda = 100\, cm$

Also, it is given that phase difference between particles $\Delta\phi = \frac{\pi}{2}$. Hence path difference between them $\Delta = \frac{\lambda}{2\pi} \times \Delta\phi = \frac{\lambda}{2\pi} \times \frac{\pi}{2} = \frac{\lambda}{4} = \frac{100}{4} = 25\, cm$

3. (b) Phase difference between two successive crest is 2π. Also, phase difference $(\Delta\phi) = \frac{2\pi}{T}$ time interval (Δt)

$\Rightarrow 2\pi = \frac{2\pi}{T} \times 0.2 \Rightarrow \frac{1}{T} = 5\, \sec^{-1} \Rightarrow n = 5\, Hz$

4. (c) Comparing with the standard equation,

$y = A \sin \frac{2\pi}{\lambda}(vt - x)$, we have

$v = 200\, cm/\sec$, $\lambda = 200\, cm$; $\therefore n = \frac{v}{\lambda} = 1\, \sec^{-1}$

5. (d) Let the phase of second particle be ϕ. Hence phase difference between two particles is $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$

$\Rightarrow \left(\phi - \frac{\pi}{3}\right) = \frac{2\pi}{60} \times 15 \Rightarrow \phi - \frac{\pi}{3} = \frac{\pi}{2} \Rightarrow \phi = \frac{5\pi}{6}$

6. (d) The given equation can be written as

$y = 4\sin\left(4\pi t - \frac{\pi x}{16}\right) \Rightarrow (v) = \frac{\text{Co-efficient of } t(\omega)}{\text{Co-efficient of } x(K)}$

$\Rightarrow v = \frac{4\pi}{\pi/16} = 64\, cm/sec$ along $+x$ direction.

7. (c) $v = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x} = \frac{628}{31.4} = 20\, cm/sec$

8. (d) $y_1 = a\sin(\omega t - kx)$

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

Hence phase difference between these two is $\frac{\pi}{2}$.

9. (c) $I \propto a^2 \propto \frac{1}{d^2} \Rightarrow a \propto \frac{1}{d}$

10. (c) $\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \left(\frac{0.06}{0.03}\right)^2 = \frac{4}{1}$

11. (c) After reflection from rigid support, a wave suffers a phase change of π.

12. (c) The given equation representing a wave travelling along $-y$ direction (because '+' sign is given between t term and x term).

On comparing it with $x = A\sin(\omega t + ky)$

We get $k = \frac{2\pi}{\lambda} = 12.56 \Rightarrow \lambda = \frac{2\times 3.14}{12.56} = 0.5\,m$

13. (c) Comparing with $y = a\sin(\omega t - kx) \Rightarrow$ $a = \frac{10}{\pi}, \omega = 200\pi$

$\therefore v_{max} = a\omega = \frac{10}{\pi}\times 2000\pi = 200 m/sec$

and $\omega = \frac{2\pi}{T} \Rightarrow 200\pi = \frac{2\pi}{T} \Rightarrow T = 10^{-3} sec$

14. (b) Comparing the given equation with $y = a\cos(\omega t - kx)$

We get $k = \frac{2\pi}{\lambda} = \pi \Rightarrow \lambda = 2cm$

15. (b) Comparing the given equation with $y = a\sin(\omega t - kx)$, We get $a = Y_0$, $\omega = 2\pi f$, $k = \frac{2\pi}{\lambda}$. Hence maximum particle velocity $(v_{max})_{particle} = a\omega = Y_0 \times 2\pi f$ and wave velocity $(v)_{wave} = \frac{\omega}{k} = \frac{2\pi f}{2\pi/\lambda} = f\lambda$

$\because (v_{max})_{Particle} = 4v_{Wave} \Rightarrow Y_0 \times 2\pi f = 4f\lambda \Rightarrow \lambda = \frac{\pi Y_0}{2}$.

16. (a,b,c,d) On comparing the given equation with $y = a\sin(\omega t + kx)$, it is clear that wave is travelling in negative x-direction.

It's amplitude $a = 10^4\,m$ and $\omega = 60$, $k = 2$.

Hence frequency $n = \frac{\omega}{2\pi} = \frac{60}{2\pi} = \frac{30}{\pi} Hz$

$k = \frac{2\pi}{\lambda} = 2 \Rightarrow \lambda = \pi\,m$ and $v = \frac{\omega}{k} = \frac{60}{2} = 30\,m/s$

17. (b) $\because y = a\cos\left(\frac{2\pi}{\lambda}vt + \frac{2\pi x}{\lambda}\right) = 0.5\cos(4\pi t + 2\pi x)$

18. (b) $v = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x} = \frac{100}{50} = 2\,m/\sec$.

19. (d) $y = f(x^2 - vt^2)$ doesn't follows the standard wave equation.

20. (b,c) Standard wave equation which travel in negative x-direction is $y = A\sin(\omega t + kx + \phi_0)$

For the given wave $\omega = 2\pi n = 15\pi$, $k = \frac{2\pi}{\lambda} = 10\pi$

Now $v = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x} = \frac{\omega}{k} = \frac{15\pi}{10\pi} = 1.5\,m/sec$

and $\lambda = \frac{2\pi}{k} = \frac{2\pi}{10\pi} = 0.2\,m$.

21. (a) $v_{max} = a\omega = 3\times 10 = 30$

22. (b) $y_1 = a_1\sin\left(\omega t - \frac{2\pi x}{\lambda}\right)$ and

$y_2 = a_2\cos\left(\omega t - \frac{2\pi x}{\lambda} + \phi\right) = a_2\sin\left(\omega t - \frac{2\pi x}{\lambda} + \phi + \frac{\pi}{2}\right)$

So phase difference $= \phi + \frac{\pi}{2}$ and $\Delta = \frac{\lambda}{2\pi}\left(\phi + \frac{\pi}{2}\right)$

23. (a) Both waves are moving opposite to each other .

24. (a) The velocity of wave

$v = \frac{\omega\,(\text{Co-efficient of } t)}{k\,(\text{Co-efficient of } x)} = \frac{10}{1} = 10\,m/s$

25. (a) $v = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x} = \frac{7\pi}{0.04} = 175\,m/s$.

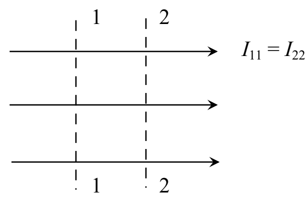
26. (a) The given equation is $y = 10\sin(0.01\pi x - 2\pi t)$

Hence $\omega =$ coefficient of $t = 2\pi$

$\Rightarrow$ Maximum speed of the particle $v_{max} = a\omega = 10\times 2\pi$

$= 10 \times 2 \times 3.14 = 62.8 \approx 63\ cm/s$

27. (a,c,d) For a travelling wave, the intensity of wave remains constant if it is a plane wave.



Intensity of wave is inversely proportional to the square of the distance from the source if the wave is spherical

$\left(I = \frac{P}{4\pi r^2}\right)$

Intensity of spherical wave on the spherical surface centred at source always remains same. Here total intensity means power P.

28. (d) On comparing the given equation with standard equation $y = a\sin\frac{2\pi}{\lambda}(vt - x)$. It is clear that wave speed $(v)_{wave} = v$ and maximum particle velocity $(v_{max})_{particle} = a\omega$ $= y_0 \times$ co-efficient of t $= y_0 \times \frac{2\pi v}{\lambda}$

$\because (v_{max})_{particle} = 2(\omega)_{wave} \Rightarrow \frac{a \times 2\pi v}{\lambda} = 2v \Rightarrow \lambda = \pi y_0$

29. (a) Given $y = A\sin(kx - \omega t)$

$\Rightarrow v = \frac{dy}{dt} = -A\omega\cos(kx - \omega t)$: $\Rightarrow v_{max} = A\omega$

30. (a) Comparing with $y = (x, t) = a\sin(\omega t - kx)$

$k = \frac{2\pi}{\lambda} = 0.01\pi \Rightarrow \lambda = 200\ m.$

31. (b)

32. (d) Comparing the given equation with standard equation $y = a\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) \Rightarrow T =$ 0.04 *sec* $\Rightarrow v = \frac{1}{T} = 25 Hz$

Also $(A)_{max} = \omega^2 a = \left(\frac{2\pi}{T}\right)^2 \times a = \left(\frac{2\pi}{0.04}\right)^2 \times 3$

$= 7.4 \times 10^4\ cm/sec^2$.

33. (b) From the given equation amplitude $a = 0.04 m$

Frequency $= \frac{\text{Co-efficient of t}}{2\pi} = \frac{\pi/5}{2\pi} = \frac{1}{10} Hz$

Wave length $\lambda = \frac{2\pi}{\text{Co-efficient of } x}$

$= \frac{2\pi}{\pi/9} = 18m.$

Wave speed $v = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x}$

$= \frac{\pi/5}{\pi/9} = 1.8 m/s.$

34. (d)

35. (d) Compare the given equation with $y = a\cos(\omega t + k\phi)$

$\Rightarrow \omega = 2\pi n = 2000 \Rightarrow n = \frac{1000}{\pi} Hz$

36. (d) $y = A\sin(at - bx + c)$ represents equation of simple harmonic progressive wave as it describes displacement of any particle (x) at any time (t). or It represents a wave because it satisfies wave equation $\frac{\partial^2 y}{\partial t^2} = v^2 \frac{\partial^2 y}{\partial x^2}$.

37. (a) Here $\omega = 2\pi n = 2\pi \Rightarrow n = 1$

38. (a) Compare the given equation with $y = a\sin(\omega t + kx)$. We get $\omega = 2\pi n = 100 \Rightarrow n = \frac{50}{\pi} Hz$

39. (b) Compare with $y = a\sin(\omega t - kx)$

We have $k = \frac{2\pi}{\lambda} = 62.4 \Rightarrow \lambda = \frac{2\pi}{62.4} = 0.1$

40. (b) Maximum velocity of the particle $v_{max} = a\omega = 0.5 \times 10\pi = 5\pi\ cm/sec$

41. (d) On reflection from fixed end (denser medium) a phase difference of π is introduced.

42. (c) Maximum particle velocity $v_{max} = \omega a$ and wave velocity $v = \frac{\omega}{k} \Rightarrow \frac{v_{max}}{v} = \frac{\omega a}{\omega / k} = ka$. From the given equation $k = \text{Co-efficient of } x = 6 micron$ $= 6 \times 10^{-6} m$

$\Rightarrow \frac{v_{max}}{v} = ka = 6 \times 10^{-6} \times 60 = 3.6 \times 10^{-4}$

43. (b) $\omega = 314$, $k = 1.57$ and $v = \frac{\omega}{k} = \frac{314}{1.57} = 200\ m/s.$

44. (c) $v = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x} = \frac{40}{1} = 40\ m/s$

45. (a) $n = \frac{\omega}{2\pi} = \frac{400\pi}{2\pi} = 200\ Hz$ (As $\omega = 400\pi$)

46. (a) Beats period $= \frac{1}{30 - 20} = 0.1$ *sec*

$\Delta\phi = \frac{2\pi}{T}\Delta.t = \frac{2\pi}{0.1} \times 0.6 = 2\pi \times 6 = 12\pi$ or Zero.

47. (d) Path difference $\Delta = \frac{\lambda}{2\pi} \times \phi = \frac{\lambda}{2\pi} \times \frac{\pi}{2} = \frac{\lambda}{4}$

$\because \Delta = 0.8\ m \Rightarrow \frac{\lambda}{4} = 0.8 \Rightarrow \lambda = 3.2\ m.$

$\therefore v = n\lambda = 120 \times 3.2 = 384\ m/s$

48. (a) $v = \frac{\text{co-efficient of } t}{\text{co-efficient of } x} = \frac{2\pi/0.01}{2\pi/0.3} = 30\ m/s$

49. (b) Comparing with $y = a\sin 2\pi\left[\frac{t}{T} - \frac{x}{\lambda}\right] \Rightarrow \lambda = 40$ *cm*

50. (d) $v = \frac{\omega}{k} = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x} = \frac{2}{0.01} = 200\ cm/\text{sec}.$

51. (d) From the given equation $k = 0.2\pi$

$\Rightarrow \frac{2\pi}{\lambda} = 0.2\pi \Rightarrow \lambda = 10\ cm$

$\Delta\phi = \frac{2\pi}{\lambda}\Delta x = \frac{2\pi}{10} \times 2 = \frac{2\pi}{5} = 72^o$

52. (a,b,c) $I = 2\pi n^2 a^2 \rho v \Rightarrow I \propto n^2 a^2 v$

53. (a) comparing the given equation with $y = a\sin(\omega t - kx)$

$\omega = 200,\ k = 1$ so $v = \frac{\omega}{k} = 200\ m/s$

54. (a) $v = \frac{\omega}{k} = \frac{2\pi}{2\pi} = 1\ m/s$

55. (b) By comparing it with standard equation

$y = a\cos(\omega t - kx) \Rightarrow k = \frac{2\pi}{\lambda} = \pi \Rightarrow \lambda = 2cm$

56. (d) Compare the given equation with

$y = a\sin(\omega t + kx) \Rightarrow \omega = 2\pi n = 100 \Rightarrow n = \frac{50}{\pi}\ Hz$

$k = \frac{2\pi}{\lambda} = 1 \Rightarrow \lambda = 2\pi$ and $v = \omega / k = 100\ m/s$

Since '+' is given between t terms and x term, so wave is travelling in negative x-direction.

57. (b) Given $A\omega = 4v \Rightarrow A2\pi n = 4n\lambda \Rightarrow \lambda = \frac{\pi A}{2}$

58. (d) $v = \frac{\omega}{k} = \frac{100}{1/10} = 1000\ m/s$

59. (c) A wave travelling in positive x-direction may be represented as $y = A\sin\frac{2\pi}{\lambda}(vt - x)$. On putting values $y = 0.2\sin\frac{2\pi}{60}(360\,t - x) \Rightarrow$

$y = 0.2\sin 2\pi\left(6\,t - \frac{x}{60}\right)$

60. (a) $v = \frac{\omega}{k} = \frac{7\pi}{0.4\pi} = 17.5\ m/s$

61. (b) $\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} \Rightarrow \frac{I_1}{I_2} = \frac{25}{100} = \frac{1}{4}$

62. (a) From the given equation $k = \frac{2\pi}{\lambda} =$ Co-efficient of x

$= \frac{\pi}{4} \Rightarrow \lambda = 8m$

63. (d) $y = 4\sin 2\pi\left(\frac{t}{0.02} - \frac{x}{100}\right)$.

Comparing this equation with $y = a\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$

$v = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x} = \frac{1/0.02}{1/100}$

64. (a) Comparing the given equation with $y = a\sin(\omega t - kx)$

We get $\omega = 3000\pi \Rightarrow n = \frac{\omega}{2\pi} = 1500\ Hz$

and $k = \frac{2\pi}{\lambda} = 12\pi \Rightarrow \lambda = \frac{1}{6}m$

So, $v = n\lambda \Rightarrow v = 1500 \times \frac{1}{6} = 250\ m/s$

65. (b) Positive sign in the argument of sin indicating that wave is travelling in negative x-direction.

66. (b) Comparing the given equation with $y = a\cos(\omega t - kx)$

$a = 25,\ \omega = 2\pi n = 2\pi \Rightarrow n = 1Hz$

67. (b) $v = \frac{\omega}{k} = \frac{600}{2} = 300 m/\sec.$

68. (b) $v = \frac{\text{Co-efficent of } t}{\text{Co-efficent of } x} = \frac{\omega}{k} = \frac{100}{20} = 5\ m/s.$

69. (d) Comparing with standard wave equation

$y = a\sin\frac{2\pi}{\lambda}(vt - x)$, we get, $v = 200\ m/s.$

70. (b) Phase difference $= \frac{2\pi}{\lambda} \times$ path difference

$\Rightarrow \frac{\pi}{2} = \frac{2\pi}{\lambda} \times 0.8 \Rightarrow \lambda = 4 \times 0.8 = 3.2m$

Velocity $v = n\lambda = 120 \times 3.2 = 384\ m/s.$

71. (a) Comparing the given equation with standard equation

We get $\omega = 2\pi n = 200\pi \Rightarrow n = 100\ Hz$

$k = \frac{20\pi}{17} \Rightarrow \lambda = \frac{2\pi}{k} = \frac{2\pi}{20\pi/17} = 1.7\,m$

and $v = \frac{\omega}{k} = \frac{200\pi}{20\pi/17} = 170\ m/s.$

72. (b) Given, $y = 0.5\sin(20x - 400t)$

Comparing with $y = a\sin(\omega t - kx)$

Gives velocity of wave $v = \frac{\omega}{k} = \frac{400}{20} = 20\ m/s.$

73. (d) $v = n\lambda \Rightarrow \lambda = 10\ cm$

Phase difference $\frac{2\pi}{\lambda} \times$ Path difference

$\frac{2\pi}{10} \times 2.5 = \frac{\pi}{2}$

74. (a, c) $v_{max} = a\omega = \frac{v}{10} = \frac{10}{10} = m/sec$

$\Rightarrow a\omega = a \times 2\pi n = 1 \Rightarrow n = \frac{10^3}{2\pi}$ $(\because a = 10^{-3}\ m)$

Since $v = n\lambda \Rightarrow \lambda = \frac{v}{n} = \frac{10}{10^3/2\pi} = 2\pi \times 10^{-2}\ m$

75. (c) Total energy is conserved.

76. (b) $v = \frac{\text{Co-efficent of } t}{\text{Co-efficent of } x} = \frac{1/2}{1/4} = 2\ m/s$

Hence $d = vt = 2\times 8 = 16m$

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

$y_2 = 10^{-6}\sin\left[100t + \left(\frac{x}{50}\right) + \left(\frac{\pi}{2}\right)\right]$

Phase difference ϕ

$= [100t + (x/50) + 1.57] - [100t + (x/50) + 0.5]$

$= 1.07$ *radians*.

78. (c) Resultant amplitude

$A_R = 2A\cos\left(\frac{\theta}{2}\right) = 2\times(2a)\cos\left(\frac{\theta}{2}\right) = 4a\cos\left(\frac{\theta}{2}\right)$

79. (b) The particle will come after a time $\frac{T}{4}$ to its mean position.

80. (a) Maximum particle velocity $= a\omega = 2\times 2 = 4$ units.

Interference and Superposition of Waves

1. (b) With path difference $\frac{\lambda}{2}$, waves are out of phase at the point of observation.

2. (d) $A_{max} = \sqrt{A^2 + A^2} = A\sqrt{2}$, frequency will remain same *i.e.* ω.

3. (a) Phase difference is 2π means constrictive interference so resultant amplitude will be maximum.

4. (d) Resultant amplitude

$A = \sqrt{a^2 + a^2 + 2aa\cos\phi} = \sqrt{4a^2\cos^2\left(\frac{\phi}{2}\right)}$

$\because\ I \propto A^2 \Rightarrow I \propto 4a^2$

5. (b) $A^2 = a^2 = a^2 + a^2 + 2a^2\cos\theta \Rightarrow \cos\theta = -\frac{1}{2} \Rightarrow \theta = \frac{2\pi}{3}$

6. (d) $\lambda = \frac{v}{n} = \frac{350}{350} = 1\,m = 100\ cm$

Also path difference (Δx) between the waves at the point of observation is $AP - BP = 25cm$. Hence

$\Rightarrow \Delta\phi = \frac{2\pi}{\lambda}(\Delta x) = \frac{2\pi}{1}\times\left(\frac{25}{100}\right) = \frac{\pi}{2}$

$\Rightarrow A = \sqrt{(a_1)^2 + (a_2)^2} = \sqrt{(0.3)^2 + (0.4)^2} = 0.5\ mm$

7. (d) Path difference $(\Delta x) = 50\ cm = \frac{1}{2}m$

$\therefore$ Phase difference $\Delta\phi = \frac{2\pi}{\lambda}\times\Delta x \Rightarrow \phi = \frac{2\pi}{1}\times\frac{1}{2} = \pi$

Total phase difference $= \pi - \frac{\pi}{3} = \frac{2\pi}{3}$

$\Rightarrow A = \sqrt{a^2 + a^2 + 2a^2\cos(2\pi/3)} = a$

8. (b,c) Because in general phase velocity = wave velocity. But in case of complex waves (many waves together) phase velocity $\neq$ wave velocity.

$\therefore$ If two waves have same λ, v, then they have same frequency too

9. (c) If two waves of nearly equal frequency superpose, they

give beats if they both travel in straight line and $I_{min} = 0$ if they have equal amplitudes.

10. (c) Resultant amplitude $= \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}$

$= \sqrt{0.3^2 + 0.4^2 + 2\times 0.3\times 0.4\times\cos\frac{\pi}{2}} = 0.5\ cm$

11. (a) In the same phase $\phi = 0$ so resultant amplitude $= a_1 + a_2 = 2A + A = 3A$

12. (b) $\frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2 = \frac{1}{16} \Rightarrow \frac{a_1}{a_2} = \frac{1}{4}$

13. (c) For interference, two waves must have a constant phase relation ship. Equation '1' and '3' and '2' and '4' have a constant phase relationship of $\frac{\pi}{2}$ out of two choices.

Only one S_2 emitting '2' and S_4 emitting '4' is given so only (c) option is correct.

14. (d) This is a case of destructive interference.

15. (b) $a_1 = 5,\ a_2 = 10 \Rightarrow \frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \left(\frac{5+10}{5-10}\right)^2 = \frac{9}{1}$

16. (c) For the given super imposing waves

$a_1 = 3,\ a_2 = 4$ and phase difference $\phi = \frac{\pi}{2}$

$\Rightarrow A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\pi/2} = \sqrt{(3)^2 + (4)^2} = 5$

17. (a) Phase difference between the two waves is

$\phi = (\omega t - \beta_2) = (\omega t - \beta_1) = (\beta_1 - \beta_2)$

$\therefore$ Resultant amplitude

$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos(\beta_1 - \beta_2)}$

18. (a) $\frac{I_{max}}{I_{min}} = \left(\frac{\frac{a_1}{a_2} + 1}{\frac{a_1}{a_2} - 1}\right)^2 = \left(\frac{2+1}{2-1}\right)^2 = 9/1$

19. (b) $\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{\frac{I_1}{I_2}}+1}{\sqrt{\frac{I_1}{I_2}}-1}\right)^2 = \left(\frac{\sqrt{\frac{9}{4}}+1}{\sqrt{\frac{9}{4}}-2}\right)^2 = \frac{25}{1}$

20. (c) $\frac{I_{max}}{I_{min}} = \left(\frac{\frac{a_1}{a_2}+1}{\frac{a_1}{a_2}-1}\right)^2 = \left(\frac{\frac{4}{3}+1}{\frac{4}{3}-1}\right)^2 = \frac{49}{1}$

21. (a) The resultant amplitude is given by

$A_R = \sqrt{A^2 + A^2 + 2AA\cos\theta} = \sqrt{2A^2(1+\cos\theta)}$

$= 2A\cos\theta/2 \qquad (\because H\cos\theta = 2\cos^2\theta/2)$

22. (b) $\frac{I_{max}}{I_{min}} = \frac{\left(\frac{\sqrt{I_1}}{\sqrt{I_2}}+1\right)^2}{\left(\frac{\sqrt{I_1}}{\sqrt{I_2}}-1\right)^2} = \frac{\left(\sqrt{\frac{9}{1}}+1\right)^2}{\left(\sqrt{\frac{9}{1}}-1\right)^2} = \frac{4}{1}$

23. (a) Since $\phi = \frac{\pi}{2} \Rightarrow A = \sqrt{a_1^2 + a_2^2} = \sqrt{(4)^2 + (3)^2} = 5$

24. (c) $A = \sqrt{(a_1^2 + a_2^2 + 2a_1a_2\cos\phi)}$

Putting $a_1 = a_2 = a$ and $\phi = \frac{\pi}{3}$, we get $A = \sqrt{3}a$

25. (d) $y = \frac{1}{\sqrt{a}}\sin\omega t \pm \frac{1}{\sqrt{b}}\sin\left(\omega t + \frac{\pi}{2}\right)$

Here phase difference $= \frac{\pi}{2}$ $\therefore$ The resultant amplitude

$= \sqrt{\left(\frac{1}{\sqrt{a}}\right)^2 + \left(\frac{1}{\sqrt{b}}\right)^2} = \sqrt{\frac{1}{a}+\frac{1}{b}} = \sqrt{\frac{a+b}{ab}}$

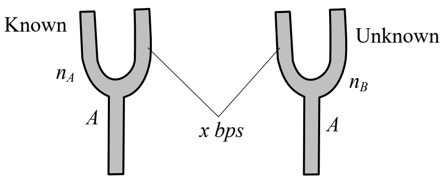
26. (b) Superposition of waves does not alter the frequency of resultant wave and resultant amplitude

$\Rightarrow a^2 = a^2 + a^2 + 2a^2\cos\phi = 2a^2(1+\cos\phi)$

$\Rightarrow \cos\phi = -1/2 = \cos 2\pi/3 \therefore \phi = 2\pi/3$

Beats

1. (c) Suppose two tuning forks are named *A* and *B* with frequencies $n_A = 256\ Hz$ (known), n_B = ? (unknown), and beat frequency *x* = 4 *bps*.



Frequency of unknown tuning fork may be

$n_B = 256 + 4 = 260\ Hz$

or $= 256 - 4 = 252\ Hz$

It is given that on sounding waxed fork *A* (fork of frequency 256 *Hz*) and fork *B*, number of beats (beat frequency) increases. It means that with decrease in frequency of *A*, the difference in new frequency of *A* and the frequency of *B* has increased. This is possible only when the frequency of *A* while decreasing is moving away from the frequency of *B*.

This is possible only if $n_B = 260\ Hz$.

Alternate method : It is given $n_A = 256\ Hz, n_B = ?$ and $x = 4\ bps$

Also after loading *A* (*i.e.* $n_A \downarrow$), beat frequency (*i.e.* *x*) increases ($\uparrow$).

Apply these informations in two possibilities to known the frequency of unknown tuning fork.

$n_A \downarrow - n_B = x\uparrow$ ... (i)

$n_B - n_A \downarrow = x\uparrow$ ... (ii)

It is obvious that equation (i) is wrong (ii) is correct so

$n_B = n_A + x = 256 + 4 = 260\ Hz.$

2. (d)

3. (c)

4. (a) Suppose n_A = known frequency = 100 *Hz*, n_B = ?

x = 2 = Beat frequency, which is decreasing after loading (*i.e.* $x\downarrow$)

Unknown tuning fork is loaded so $n_B\downarrow$

Hence $n_A - n_B \downarrow = x\downarrow \longrightarrow$ ... (i) Wrong

$n_B \downarrow - n_A = x\downarrow \longrightarrow$ ... (ii) Correct

$\Rightarrow n_B = n_A + x = 100 + 2 = 102\ Hz.$

5. (d) n_A = Known frequency = 256, n_B = ?

x = 2 *bps*, which is decreasing after loading (*i.e.* $x\downarrow$) known tuning fork is loaded so $n_A\downarrow$

Hence $n_A\downarrow - n_B = x\downarrow \longrightarrow$ ... (i) Correct

$n_B - n_A\downarrow = x\downarrow \longrightarrow$ ... (ii) Wrong

$\Rightarrow n_B = n_A - x = 256 - 2 = 254\ Hz.$

6. (b) n_A = Known frequency = 256 *Hz*, n_B = ?

x = 4 *bps*, which is decreasing after loading (*i.e.* $x\downarrow$) also known tuning fork is loaded so $n_A\downarrow$

Hence $n_A\downarrow - n_B = x\downarrow \longrightarrow$ ... (i)
Correct

$n_B - n_A\downarrow = x\downarrow \longrightarrow$ ... (ii)
Wrong

$\Rightarrow n_B = n_A - x = 256 - 4 = 252\ Hz.$

7. (c) Time interval between two consecutive beats

$$T = \frac{1}{n_1 - n_2} = \frac{1}{260-256} = \frac{1}{4}\text{ sec so, } t = \frac{1}{16} = \frac{T}{4}\text{ sec}$$

By using time difference $= \frac{T}{2\pi} \times$ Phase difference

$$\Rightarrow \frac{T}{4} = \frac{T}{2\pi}\times\phi \Rightarrow \phi = \frac{\pi}{2}$$

8. (a) The time interval between successive maximum intensities will be $\frac{1}{n_1 \sim n_2} = \frac{1}{454-450} = \frac{1}{4}$ sec.

9. (d) n_A = Known frequency = 341 *Hz*, n_B = ?

x = 6 *bps*, which is decreasing (*i.e.* $x\downarrow$) after loading (from 6 to 1 *bps*)

Unknown tuning fork is loaded so $n_B\downarrow$

Hence $n_A - n_B\downarrow = x\downarrow \longrightarrow$ ... (i)
Wrong

$n_B\downarrow - n_A = x\downarrow \longrightarrow$ ... (ii)
Correct

$\Rightarrow n_B = n_A + x = 341 + 6 = 347\ Hz.$

10. (b) $T = \frac{1}{258-256} = 0.5$ sec

11. (c) Suppose n_A = known frequency = 100 *Hz*, n_B = ?

x = 5 *bps*, which remains unchanged after loading

Unknown tuning fork is loaded so $n_B\downarrow$

Hence $n_A - n_B\downarrow = x$ ... (i)

$n_B\downarrow - n_A = x$ ... (ii)

From equation (i), it is clear that as n_B decreases, beat frequency. (*i.e.* $n_A - (n_B)_{new}$) can never be x again.

From equation (ii), as $n_B\downarrow$, beat frequency (*i.e.* $(n_B)_{new} - n_A$) decreases as long as $(n_B)_{new}$ remains greater than n_A, If $(n_B)_{new}$ become lesser than n_A the beat frequency will increase again and will be x. Hence this is correct.

So, $n_B = n_A + x = 100 + 5 = 105\ Hz.$

12. (b) n_A = Known frequency = 256 *Hz*, n_B = ?

x = 6 *bps*, which remains the same after loading.

Unknown tuning fork F_2 is loaded so $n_B\downarrow$

Hence $n_A - n_B\downarrow = x \longrightarrow$ ... (i)
Wrong

$n_B\downarrow - n_A = x \longrightarrow$ ... (ii)
Correct

$\Rightarrow n_B = n_A + x = 256 + 6 = 262\ Hz.$

13. (a) Probable frequencies of tuning fork be $n+4$ or $n-4$

Frequency of sonometer wire $n \propto \frac{1}{l}$

$\therefore \frac{n+4}{n-4} = \frac{100}{95}$ or $95(n+4) = 100(n-4)$

or $95n + 380 = 100n - 400$ or $5n = 780$ or $n = 156$

14. (c) After filling frequency increases, so n_A decreases ($\downarrow$). Also it is given that beat frequency increases (*i.e.*, $x\uparrow$)

Hence $n_A\downarrow - n_B = x\uparrow \longrightarrow$ ... (i)
Correct

$n_B - n_A\uparrow = x\uparrow \longrightarrow$ ... (ii)
Wrong

$\Rightarrow n_A = n_B + x = 512 + 5 = 517\ Hz.$

15. (c) Intensity $\propto$ (amplitude)^2

as $A_{max} = 2a_o$ (a_o= amplitude of one source)

so $I_{max} = 4I_o$.

16. (c) Number of beats per second = $n_1 \sim n_2$

$\omega_1 = 2000\pi = 2\pi n_1 \Rightarrow n_1 = 1000$

and $\omega_2 = 2008\pi = 2\pi n_2 \Rightarrow n_2 = 1004$

Number of beats heard per sec $= 1004 - 1000 = 4$

17. (c) The tuning fork whose frequency is being tested produces 2 beats with oscillator at 514 *Hz*, therefore, frequency of tuning fork may either be 512 or 516. With oscillator frequency 510 it gives 6 *beats/sec*, therefore frequency of tuning fork may be either 516 or 504.

Therefore, the actual frequency is 516 *Hz* which gives 2 *beats/sec* with 514 *Hz* and 6 *beats/sec* with 510 *Hz*.

18. (b) If suppose n_S = frequency of string $= \frac{1}{2l}\sqrt{\frac{T}{m}}$

n_f = Frequency of tuning fork = 480 *Hz*

x = Beats heard per second = 10

as tension T increases, so n_S increases (↑)

Also it is given that number of beats per sec decreases (*i.e.* $x\downarrow$)

Hence $n_S\uparrow - n_f = x\downarrow \longrightarrow$ ... (i) Wrong

$n_f - n_S\uparrow = x\downarrow \longrightarrow$ ... (ii) Correct

$\Rightarrow n_S = n_f - x = 480 - 10 = 470$ *Hz*.

19. (c) It is given that

n_A = Unknown frequency = ?

n_B = Known frequency = 256 *Hz*

x = 3 *bps*, which remains same after loading

Unknown tuning fork A is loaded so $n_A\downarrow$

Hence $n_A\downarrow - n_B = x \longrightarrow$ ... (i) Correct

$n_B - n_A\downarrow = x \longrightarrow$ ... (ii) Wrong

$\Rightarrow n_A = n_B + x = 256 + 3 = 259$ *Hz*.

20. (a) Frequency of the source = 100 ± 5 = 105 *Hz* or 95 *Hz*.

Second harmonic of the source = 210 *Hz* or 190 *Hz*.

As the second harmonic gives 5 *beats/sec* with sound of frequency 205 *Hz*, the second harmonic should be 210 *Hz*.

$\Rightarrow$ Frequency of the source = 105 *Hz*.

21. (d) For producing beats, their must be small difference in frequency.

22. (c) n_A = Known frequency = 256 *Hz*, n_B = ?

x = 4 *beats per sec* which is decreasing (4 *bps* to $\frac{5}{2}$ *bps*) after loading (*i.e.* $x\downarrow$)

Unknown tuning fork B, is loaded so $n_B\downarrow$

Hence $n_A - n_B\downarrow = x\downarrow \longrightarrow$ ... (i) Wrong

$n_B\downarrow - n_A = x\downarrow \longrightarrow$ ... (ii) Correct

$\Rightarrow n_B = n_A + x = 256 + 4 = 260$ *Hz*.

23. (d) $n_A\downarrow - n_B = x\uparrow$ ... (i) Wrong

$n_B - n_A\downarrow = x\uparrow$ ... (ii) Correct

$\Rightarrow n_B = n_A + x = 200 + 5 = 205$ *Hz*.

24. (c) $n_A - n_B\downarrow = x$ (same) $\longrightarrow$ ... (i) Wrong

$n_B\downarrow - n_A = x$ (same) $\longrightarrow$ ... (ii) Correct

$\Rightarrow n_B = n_A + x = 320 + 4 = 324$ *Hz*.

25. (c) Beat period $T = \frac{1}{n_1 \sim n_2} = \frac{1}{384 - 380} = \frac{1}{4}$ sec.

Hence minimum time interval between maxima and minima $t = \frac{T}{2} = \frac{1}{8}$ sec.

26. (d) $\frac{I_{max}}{I_{min}} = \left(\frac{a_1 + a_2}{a_1 - a_2}\right)^2 = \frac{(5+3)^2}{(5-3)^2} = \frac{16}{1}$

27. (a) $n_1 = \frac{v}{\lambda_1} = \frac{v}{0.50}$ and $n_2 = \frac{v}{\lambda_2} = \frac{v}{0.51}$

$\Delta n = n_1 - n_2 = v\left[\frac{1}{0.05} - \frac{1}{0.51}\right] = 12$

$\Rightarrow v = \frac{12 \times 0.51 \times 0.50}{0.01} = 306\ m/s$

28. (c) $n_1 = \frac{316}{2\pi}$ and $n_2 = \frac{310}{2\pi}$ Number of beats heard per second = $n_1 - n_2 = \frac{316}{2\pi} - \frac{310}{2\pi} = \frac{3}{\pi}$

29. (b) Beat frequency = $\frac{2}{0.4} = 5\,Hz$

30. (a) Since source of frequency x gives 8 beats per second with frequency 250 *Hz*, it's possible frequency are 258 or 242. As source of frequency x gives 12 beats per second with a frequency 270 *Hz*, it's possible frequencies 282 or 258 *Hz*. The only possible frequency of x which gives 8 beats with frequency 250 *Hz* also 12 beats per second with 258 *Hz*.

31. (c) $n_1 = \frac{1000\pi}{2\pi} = 500\,Hz$ and $n_2 = \frac{998\pi}{2\pi} = 499\ Hz$

Hence beat frequency = $n_1 - n_2 = 1$

32. (a) $v_0 = 332$ *m/s*. Velocity sound at $t°C$ is $v_t = (v_0 + 0.61\,t)$

$\Rightarrow v_{20} = v_0 + 0.61 \times 20 = 344.2\ m/s$

$\Rightarrow \Delta n = v_{20}\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = 344.2\left(\frac{100}{50} - \frac{100}{51}\right) = 14$

33. (a) Persistence of hearing is 10 sec^{-1}.

34. (a)

35. (d) $n_A = ?$, $n_B = 384\ Hz$

$x = 6\ bps$, which is decreasing (from 6 to 4) *i.e.* $x\downarrow$

Tuning fork A is loaded so $n_A\downarrow$

Hence $n_A\downarrow - n_B = x\downarrow \longrightarrow$ Correct

$n_B - n_A\downarrow = x\downarrow \longrightarrow$ Wrong

$\Rightarrow n_A = n_B + x = 384 + 6 = 390\ Hz$.

36. (b) For hearing beats, difference of frequencies should be approximately 10 Hz.

37. (a) $n \propto \frac{1}{l} \Rightarrow n_1 l_1 = n_2 l_2 \Rightarrow$

$(n+4)49 = (n-4)50 \Rightarrow n = 396$

38. (a) No of beats, $x = \Delta n = \frac{30}{3} = 10\ Hz$

$\Rightarrow$

Also $\Delta n = v\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right] = v\left[\frac{1}{5} - \frac{1}{6}\right] = 10 \Rightarrow v = 300\ m/s$

39. (a) $\Delta n = v\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right] = 396\left[\frac{1}{0.99} - \frac{1}{1}\right] = 3.96 \approx 4.$

40. (b) n_A = Known frequency = 288 cps, $n_B = ?$

$x = 4\ bps$, which is decreasing (from 4 to 2) after loading *i.e.* $x\downarrow$

Unknown fork is loaded so $n_B\downarrow$

Hence $n_A - n_B\downarrow = x\downarrow \longrightarrow$ Wrong

$n_B\downarrow - n_A\downarrow = x\downarrow \longrightarrow$ Correct

$\Rightarrow n_B = n_A + x = 288 + 4 = 292\ Hz$.

41. (a) Frequency = $\frac{\text{Number of beats}}{\text{Time}} = \frac{2}{0.04} = 50\ Hz$

42. (c) No. of beats = frequency difference = $\frac{4}{0.25} = 16$

43. (d) Suppose n_P = frequency of piano = ? $(n_P \propto \sqrt{T})$

n_f = Frequency of tuning fork $= 256 Hz$

x = Beat frequency = 5 bps, which is decreasing (5→2) after clanging the tension of piano wire

Also, tension of piano wire is increasing so $n_P\downarrow$

Hence $n_P\uparrow - n_f = x\downarrow \longrightarrow$ Wrong

$n_f - n_P\uparrow = x\downarrow \longrightarrow$ Correct

$\Rightarrow n_P = n_f - x = 256 - 5\ Hz$.

44. (b) With temperature rise frequency of tuning fork decreases. Because, the elastic properties are modified when temperature is changed

also, $n_t = n_0(1 - 0.00011t)$

where n_t = frequency at $t°C$, n_0 = frequency at $0°C$

45. (a) $n_x = 300 Hz$, $n_y = ?$

x = beat frequency = 4 Hz, which is decreasing (4→2)

after increasing the tension of the string y.

Also tension of wire y increasing so $n_y\uparrow$ $(\because n \propto \sqrt{T})$

Hence $n_x - n_y\uparrow = x\downarrow \longrightarrow$ Correct

$n_y\uparrow - n_x = x\downarrow \longrightarrow$ Wrong

$\Rightarrow n_y = n_x - x = 300 - 4 = 296 Hz$

46. (c) Let n be the frequency of fork C then

$n_A = n + \frac{3n}{100} = \frac{103n}{100}$ and $n_B = n - \frac{2n}{100} = \frac{98}{100}$

but $n_A - n_B = 5 \Rightarrow \frac{5n}{100} = 5 \Rightarrow n = 100\ Hz$

$\therefore n_A = \frac{(103)(100)}{100} = 103\ Hz$

47. (a)

48. (b) From the given equations of progressive waves $\omega_1 = 500\pi$ and $\omega_2 = 506\pi$ $\therefore$ $n_1 = 250$ and $n_2 = 253$

So beat frequency $= n_2 - n_1 = 253 - 250 = 3$ *beats per sec* $\therefore$ Number of beats per min = 180.

49. (b)

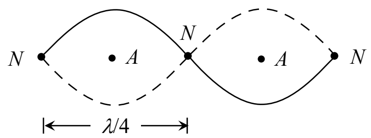
50. (b) Frequency $= \frac{360}{60} \times 60 = 360 Hz.$

51. (b) $v = n\lambda \Rightarrow \lambda = \frac{v}{n} = \frac{340}{170} \Rightarrow \lambda = 2$

Distance separating the position of minimum intensity $= \frac{\lambda}{2} = \frac{2}{2} = 1\ m$

Stationary Waves

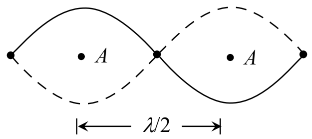
1. (c) The distance between the nearest node and antinode in a stationary wave is $\frac{\lambda}{4}$



2. (c) At nodes pressure change (strain) is maximum

3. (c) Both the sides of a node, two antinodes are present with separation $\frac{\lambda}{2}$

So phase difference between then $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$



4. (c) Progressive wave propagate energy while no propagation of energy takes place in stationary waves.

5. (b)

6. (a) Comparing given equation with standard equation

$y = 2a\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi vt}{\lambda}$ gives us $\frac{2\pi}{\lambda} = \frac{\pi}{15} \Rightarrow \lambda = 30$

Distance between nearest node and antinodes = $\frac{\lambda}{4} = \frac{30}{4} = 7.5$

7. (b) On comparing the given equation with standard equation $y = 2a\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi vt}{\lambda} \Rightarrow$

$\frac{2\pi x}{\lambda} = \frac{\pi x}{3} \Rightarrow \lambda = 6$

Separation between two adjacent nodes = $\frac{\lambda}{2} = 3\,cm$

8. (d)

9. (a) On comparing the given equation with standard equation $y = 2a\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi vt}{\lambda}$]

We get $\frac{2\pi}{\lambda} = \frac{\pi}{20} \Rightarrow \lambda = 40$

Separation between two consecutive nodes = $\frac{\lambda}{2} = \frac{40}{2} = 20\ cm$

10. (a)

11. (b) Since the point $x = 0$ is a node and reflection is taking place from point $x = 0$. This means that reflection must be taking place from the fixed end and hence the reflected ray must suffer an additional phase change of π or a path change of $\frac{\lambda}{2}$.

So, if $y_{incident} = a\cos(kx - \omega t)$

$\Rightarrow y_{reflected} = a\cos(-kx - \omega t + \pi) = -a\cos(\omega t + kx)$

12. (d) Particles have kinetic energy maximum at mean position.

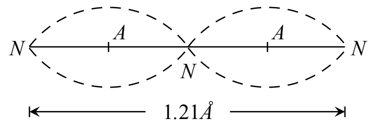
13. (b) On comparing the given equation with standard equation $\frac{2\pi}{\lambda} = 5 \Rightarrow \lambda = \frac{6.28}{5} = 1.256m$

14. (d)

15. (d)

16. (a,b,c) Standing waves can be produced only when two similar type of waves (same frequency and speed, but amplitude may be different) travel in opposite directions.

17. (a) $\lambda = 1.21\mathring{A}$



18. (d) $\frac{\lambda}{4} = 20 \Rightarrow \lambda = 80\,cm$, also $\Delta\phi = \frac{\lambda}{2\pi}.\Delta x$

$\Rightarrow \Delta\phi = \frac{60}{80} \times 2\pi = \frac{3\pi}{2}$

19. (a) Required distance $= \frac{\lambda}{4} = \frac{v/n}{4} = \frac{1200}{4 \times 300} = 1\ m$

20. (a) Waves *A* and *B* satisfied the conditions required for a standing wave.

21. (a) By comparing given equation with $y = a\sin(\omega t)\cos kx$

$\Rightarrow v = \frac{\omega}{k} = \frac{100}{0.01} = 10^4\ m/s$

22. (b) At fixed end node is formed and distance between two consecutive nodes $\frac{\lambda}{2} = 10\ cm \Rightarrow$

$\lambda = 20\ cm$

$\Rightarrow\ v = n\lambda = 20\ m/sec$

23. (c) $a\cos(kx + \omega t)$

hence $y_{reflected} = a\cos(-kx + \omega t + \pi) = -a\cos(kx - \omega t)$

24. (b) Distance between the consecutive node $= \frac{\lambda}{2}$,

but $\lambda = \frac{v}{n} = \frac{20}{n}$ so $\frac{\lambda}{2} = \frac{10}{n}$

25. (a) Energy is not carried by stationary waves

26. (c) On comparing the given equation with standard equation $\Rightarrow \frac{2\pi}{\lambda} = \frac{\pi}{3} \Rightarrow \lambda = 6\,cm$.

Hence, distance between two consecutive nodes $\Rightarrow \lambda = 3\,cm$

27. (d) Minimum time interval between two instants when the string is flat $= \frac{T}{2} = 0.5\,\text{sec} \Rightarrow T = 1\,\text{sec}$

Hence $\lambda = v \times T = 10 \times 1 = 10\,m$.

28. (c)

29. (b) Distance between two nodes $= \frac{\lambda}{2}$

$= \frac{v}{2n} = \frac{16}{2n} = \frac{8}{n}$

30. (d)

31. (b) In stationary wave all the particles in one particular segment (*i.e.,* between two nodes) vibrates in the same phase.

32. (a) If $y_{incident} = a\sin(\omega t - kx)$ and $y_{stationary} = a\sin(\omega t)\cos kx$

then it is clear that frequency of both is same (ω)

33. (b)

34. (a) On comparing the given equation with standard equation $\frac{2\pi}{\lambda} = \frac{\pi}{4} \Rightarrow \lambda = 8$

Hence distance between two consecutive nodes $\frac{\lambda}{2} = 4$

35. (a)

36. (a) Waves $Z_1 = A\sin(kx - \omega t)$ is travelling towards positive x-direction.

Wave $Z_2 = A\sin(kx + \omega t)$, is travelling towards negative x-direction.

Wave $Z_3 = A\sin(ky - \omega t)$ is travelling towards positive y direction.

Since waves Z_1 and Z_2 are travelling along the same line so they will produce stationary wave.

37. (a) When two waves of equal frequency and travelling in opposite direction superimpose, then the stationary wave is produced. Hence Z_1 and Z_2 produces stationary wave.

38. (d) The distance between adjacent nodes $x = \frac{\lambda}{2}$

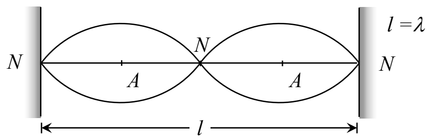
Also $k = \frac{2\pi}{\lambda}$. Hence $x = \frac{\pi}{k}$.

39. (d) $y = 5\sin\left(\frac{2\pi x}{3}\right)\cos 20\pi t$, comparing with equation

$y = 2a\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi vt}{\lambda} \Rightarrow \lambda = 3$, distance between two adjacent nodes $= \lambda/2 = 1.5\,cm$.

Vibration of String

1. (c)



2. (d) $n \propto \frac{1}{l} \Rightarrow \frac{n_2}{n_1} = \frac{l_1}{l_2} \Rightarrow n_2 = \frac{l_1}{l_2} n_1 = \frac{1 \times 256}{1/4} = 1024\,Hz$

3. (c) String vibrates in five segment so $\frac{5}{2}\lambda = l \Rightarrow \lambda = \frac{2l}{5}$

Hence $n = \frac{v}{\lambda} = 5 \times \frac{v}{2l} = 5 \times \frac{20}{2 \times 10} = 5\,Hz$

4. (c) Here $\frac{\lambda}{2} = 5.0\,cm \Rightarrow \lambda = 10\,cm$

Hence $n = \frac{v}{\lambda} = \frac{200}{10} = 20\,Hz$.

5. (c)

6. (b) As we know plucking distance from one end $= \frac{l}{2p}$

$\Rightarrow 25 = \frac{100}{2p} \Rightarrow p = 2$. Hence frequency of vibration

$n = \frac{p}{2l}\sqrt{\frac{T}{m}} = \frac{2}{2 \times 1}\sqrt{\frac{20}{5 \times 10^{-4}}} = 200\,Hz.$

7. (b) To produce 5 *beats/sec.* Frequency of one wire should be increase up to 505 Hz. *i.e.* increment of 1% in basic frequency.

$n \propto \sqrt{T}$ or $T \propto n^2 \Rightarrow \frac{\Delta T}{T} = 2\frac{\Delta n}{n}$

$\Rightarrow$ percentage change in Tension $= 2(1\%) = 2\%$

8. (d) $y = 0.021\sin(x + 30t) \Rightarrow v = \frac{\omega}{k} = \frac{30}{1} = 30\ m/s.$

Using, $v = \sqrt{\frac{T}{m}} \Rightarrow 30 = \sqrt{\frac{T}{1.3\times 10^{-4}}} \Rightarrow T = 0.117\,N$

9. (a) $n \propto \sqrt{T}$

10. (c) $n \propto \sqrt{T}$

11. (d) $n \propto \sqrt{T}$

$\Rightarrow n_1 : n_2 : n_3 : n_4 = \sqrt{1} : \sqrt{4} : \sqrt{9} : \sqrt{16} = 1 : 2 : 3 : 4$

12. (c) Let the frequency of tunning fork be N

As the frequency of vibration string $\propto \frac{1}{\text{length of string}}$

For sonometer wire of length 20 *cm*, frequency must be (N + 5) and that for the sonometer wire of length 21*cm*, the frequency must be (N – 5) as in each case the tunning fork produces 5 beats/sec with sonometer wire

Hence $n_1 l_1 = n_2 l_2 \Rightarrow (N+5)\times 20 = (N-5)\times 21$

$\Rightarrow N = 205\,Hz.$

13. (c) $\lambda = \frac{2l}{p}$ (p = Number of loops)

14. (a) String will vibrate in 7 loops so it will have 8 nodes 7 antinodes.

Number of harmonics = Number of loops = Number of antinodes $\Rightarrow$ Number of antinodes = 7

Hence number of nodes = Number of antinodes + 1

$= 7 + 1 = 8$

15. (a)

16. (d) $n \propto \frac{1}{l}\sqrt{T} \Rightarrow \frac{n'}{n} = \sqrt{\frac{T'}{T}} \times \frac{l}{l'} = \sqrt{4}\times\frac{1}{2} = 1 \Rightarrow n' = n$

17. (a) Sonometer is used to produce resonance of sound source with stretched vibrating string.

18. (a) $n \propto \frac{1}{l} \Rightarrow \frac{l_2}{l_1} = \frac{n_1}{n_2} \Rightarrow l_2 = l_1\left(\frac{n_1}{n_2}\right) = 50\times\frac{270}{1000} = 13.5\,cm$

19. (c) $n \propto \sqrt{T} \Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{T_1}{T_2}} \Rightarrow \frac{n}{2n} = \sqrt{\frac{10}{T_2}} \Rightarrow T_2 = 40\,N$

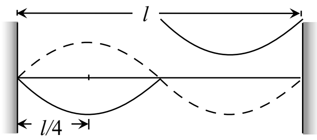
20. (b) $n \propto \sqrt{T}$

21. (d) $n = \frac{1}{2l}\sqrt{\frac{T}{m}} \Rightarrow n \propto \frac{\sqrt{T}}{l}$

$\Rightarrow \frac{T_2}{T_1} = \left(\frac{n_2}{n_1}\right)^2\left(\frac{l_2}{l_1}\right)^2 = (2)^2\left(\frac{3}{4}\right)^2 = \frac{9}{4}$

22. (c) $v = \sqrt{\frac{T}{m}} \Rightarrow v = \sqrt{\frac{60.5}{(0.035/7)}} = 110\ m/s$

23. (a) Second harmonic means 2 loops in a total length



Hence plucking distance from one end $= \frac{l}{2p} = \frac{l}{2\times 2} = \frac{l}{4}.$

24. (b) $v = \sqrt{\frac{T}{m}} = \sqrt{\frac{T}{\pi r^2 \rho}}$

$v \propto \frac{\sqrt{T}}{r} \Rightarrow \frac{v_A}{v_B} = \sqrt{\frac{T_A}{T_B}}.\frac{r_B}{r_A} = \sqrt{\frac{1}{2}}.\frac{1}{2} = \frac{1}{2\sqrt{2}}$

25. (a) The frequency of vibration of a string $n = \frac{p}{2l}\sqrt{\frac{T}{m}}$

Also number of loops = Number of antinodes.

Hence, with 5 antinodes and hanging mass of 9 *kg*.

We have p = 5 and T = 9g $\Rightarrow n_1 = \frac{5}{2l}\sqrt{\frac{9g}{m}}$

With 3 antinodes and hanging mass M

We have p = 3 and T = Mg $\Rightarrow n_2 = \frac{3}{2l}\sqrt{\frac{Mg}{m}}$

$\because\ n_1 = n_2 \Rightarrow \frac{5}{2l}\sqrt{\frac{9g}{m}} = \frac{3}{2l}\sqrt{\frac{Mg}{m}} \Rightarrow M = 25\ kg.$

26. (b) $n \propto \frac{\sqrt{T}}{l} \Rightarrow l \propto \sqrt{T}$ (As n= constant)

$\Rightarrow \frac{l_2}{l_1} = \sqrt{\frac{T_2}{T_1}} = l_1\sqrt{\frac{169}{100}} \Rightarrow l_2 = 1.3 l_1 = l_1 + 30\%$ of l_1

27. (b) $n_1 l_1 = n_2 l_2 \Rightarrow 250\times 0.6 = n_2\times 0.4 \Rightarrow n_2 = 375\,Hz$

28. (b) In fundamental mode of vibration wavelength is maximum $\Rightarrow$ $l = \frac{\lambda}{2} = 40\,cm \Rightarrow \lambda = 80\,cm$

29. (c) $n_1 l_1 = n_2 l_2 \Rightarrow 800\times 50 = 1000\times l_2 \Rightarrow l_2 = 40\ cm$

30. (c) $n \propto \sqrt{T} \Rightarrow \frac{\Delta n}{n} = \frac{\Delta T}{2T}$

If tension increases by 2%, then frequency must increases by 1%.

If initial frequency $n_1 = n$ then final frequency $n_2 - n_1 = 5$

$\Rightarrow \frac{101}{100}n - n = 5 \Rightarrow n = 500\,Hz.$

Short trick : If you can remember then apply following formula to solve such type of problems.

Initial frequency of each wire (n)

$= \frac{\text{(Number of beats heard per sec)} \times 200}{\text{(per centage change in tension of the wire)}}$

Here $n = \frac{5 \times 200}{2} = 500\,Hz$

31. (b) First overtone of string A = Second overtone of string B.

$\Rightarrow$ Second harmonic of A = Third harmonic of B

$\Rightarrow n_2 = n_3 \Rightarrow [2(n_1)]_A = [3(n_1)]_B$ ($\because n_1 = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}}$)

$\Rightarrow 2\left[\frac{1}{2l_A r_A}\sqrt{\frac{T}{\pi\rho}}\right] = 3\left[\frac{1}{2l_B r_B}\sqrt{\frac{T}{\pi\rho}}\right]$

$\frac{l_A}{l_B} = \frac{2}{3}\frac{r_B}{r_A} \Rightarrow \frac{l_A}{l_B} = \frac{2}{3} \times \frac{r_B}{(2r_B)} = \frac{1}{3}$

32. (a) Fundamental frequency in case of string is

$n = \frac{1}{2l}\sqrt{\frac{T}{m}} \Rightarrow n \propto \frac{\sqrt{T}}{l} \Rightarrow \frac{n'}{n} = \sqrt{\frac{T'}{T}} \times \frac{l}{l'}$

putting $T' = T + 0.44T = \frac{144}{100}T$ and $l' = l - 0.4l = \frac{3}{5}l$

We get $\frac{n'}{n} = \frac{2}{1}$.

33. (d) Frequency in a stretched string is given by

$n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}} = \frac{1}{l}\sqrt{\frac{T}{\pi d^2 \rho}}$ (d = Diameter of string)

$\Rightarrow \frac{n_1}{n_2} = \frac{l_2}{l_1}\sqrt{\frac{T_1}{T_2} \times \left(\frac{d_2}{d_1}\right)^2 \times \left(\frac{\rho_2}{\rho_1}\right)}$

$= \frac{35}{36}\sqrt{\frac{8}{1} \times \left(\frac{1}{4}\right)^2 \times \frac{2}{1}} = \frac{35}{36} \Rightarrow n_2 = \frac{36}{35} \times 360 = 370$

Hence beat frequency = $n_2 - n_1 = 10$

34. (b) Frequency of first overtone or second harmonic (n_2) $= 320\,Hz$. So, frequency of first harmonic $n_1 = \frac{n_2}{2} = \frac{320}{2} = 160\,Hz$

35. (d) Similar to Q. 30

Initial frequency of each wire (n)

$= \frac{\text{(Number of beats heared per sec)} \times 200}{\text{(per centage change in tension of the wire)}}$

$= \frac{(3/2) \times 200}{1} = 300\,\sec^{-1}$

36. (c) $n \propto \frac{1}{l} \Rightarrow \frac{\Delta n}{n} = -\frac{\Delta l}{l}$

If length is decreased by 2% then frequency increases by 2% *i.e.*, $\frac{n_2 - n_1}{n_1} = \frac{2}{100}$

$\Rightarrow n_2 - n_1 = \frac{2}{100} \times n_1 = \frac{2}{100} \times 392 = 7.8 \approx 8.$

37. (d) Observer receives sound waves (music) which are longitudinal progressive waves.

38. (a) Because both tuning fork and string are in resonance condition.

39. (d) $n = \frac{1}{2l}\sqrt{\frac{T}{m}} \Rightarrow \frac{n_1}{n_2} = \frac{l_2}{l_1}\sqrt{\frac{T_1}{T_2}} = \frac{1}{4}\sqrt{\frac{1}{4}} = \frac{1}{8}$

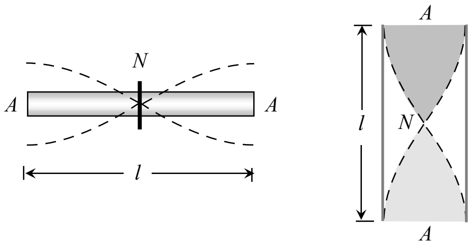
$\Rightarrow n_2 = 8n_1 = 8 \times 200 = 1600\,Hz$

40. (b) $n = \frac{1}{2l}\sqrt{\frac{T}{m}} \Rightarrow n_1 l_1 = n_2 l_2 = n_3 l_3 = k$

$l_1 + l_2 + l_3 = l \Rightarrow \frac{k}{n_1} + \frac{k}{n_2} + \frac{k}{n_3} = \frac{k}{n}$

$\Rightarrow \frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3} + ...$

41. (a) If a rod clamped at middle, then it vibrates with similar fashion as open organ pipe vibrates as shown.



Hence, fundamental frequency of vibrating rod is given by $n_1 = \frac{v}{2l} \Rightarrow 2.53 = \frac{v}{4 \times 1} \Rightarrow v$ = 5.06 *km/sec.*

42. (a) Change in amplitude does not produce change in frequency, $\left(n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}}\right)$.

43. (d) Mass per unit length $m = \frac{2 \times 10^{-4}}{0.5}\,kg/m$

$= 4 \times 10^{-4}\,kg/m$

Frequency of 2nd harmonic $n_2 = 2n_1$

$= 2\times\frac{1}{2l}\sqrt{\frac{T}{m}} = \frac{1}{0.5}\sqrt{\frac{20}{4\times10^{-4}}} = 447.2 Hz$

44. (d) $n = \frac{1}{2l}\sqrt{\frac{T}{m}} \Rightarrow n \propto \sqrt{T}$ For octave, $n' = 2n$

$\Rightarrow \frac{n'}{n} = \sqrt{\frac{T'}{T}} = 2 \Rightarrow T' = 4T = 16 kg\text{-}wt$

45. (d) Fundamental frequency $n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2\rho}}$

where m = Mass per unit length of wire

$\Rightarrow n \propto = \frac{1}{lr} \Rightarrow \frac{n_1}{n_2} = \frac{r_2}{r_1}\times\frac{l_2}{l_1} = \frac{r}{2r}\times\frac{2L}{L} = \frac{1}{1}$

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

$\Rightarrow \frac{n_1}{n_2} = \sqrt{\left(\frac{T_1}{T_2}\right)\left(\frac{r_2}{r_1}\right)^2\left(\frac{\rho_2}{\rho_1}\right)} = \sqrt{\left(\frac{1}{2}\right)\left(\frac{2}{1}\right)^2\left(\frac{1}{2}\right)} = 1$

$\therefore\ n_1 = n_2$

47. (a) $n = \frac{p}{2l}\sqrt{\frac{T}{m}} \propto \sqrt{T} \Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{T_1}{T_2}}$

$\Rightarrow \frac{260}{n_2} = \sqrt{\frac{50.7g}{(50.7 - 0.0075\times10^3)g}} \Rightarrow n_2 \approx 240$

48. (b) Given equation of stationary wave is $y = \sin 2\pi x \cos 2\pi t$, comparing it with standard equation $y = 2A\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi x}{\lambda}$

We have $\frac{2\pi x}{\lambda} = 2\pi x \Rightarrow \lambda = 1m$

Minimum distance of string (first mode) $L_{\min} = \frac{\lambda}{2} = \frac{1}{2}m$

49. (d) $n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2\rho}} \Rightarrow n \propto \frac{\sqrt{T}}{lr} \Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{T_1}{T_2}}\times\frac{l_2}{l_1}\times\frac{r_2}{r_1}$

$= \sqrt{\frac{T}{3T}}\times\frac{3l}{l}\times\frac{2r}{r} = 3\sqrt{3} \Rightarrow n_2 = \frac{n}{3\sqrt{3}}$

50. (c) For string $\lambda = \frac{2l}{p}$

where p = No. of loops = Order of vibration

Hence for forth mode $p = 4 \Rightarrow \lambda = \frac{l}{2}$

Hence $v = n\lambda = 500\times\frac{2}{2} = 500 Hz$

51. (d) $n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2\rho}} \Rightarrow n \propto \frac{\sqrt{T}}{r}$

$\Rightarrow \frac{n_2}{n_1} = \frac{r_1}{r_2}\sqrt{\frac{T_2}{T_1}} = \frac{1}{2}\times\sqrt{\frac{1}{2}} = \frac{1}{2\sqrt{2}}$

52. (b) In case of sonometer frequency is given by

$n = \frac{p}{2l}\sqrt{\frac{T}{m}} \Rightarrow \frac{n_2}{n_1} = \frac{l_1}{l_2} \Rightarrow n_2 = \frac{25}{16}\times256 = 400\ Hz$

Organ Pipe (Vibration of Air Column)

1. (c) $\lambda_1 = 2l, \lambda_2 = 2l + 2\Delta l \Rightarrow n_1 = \frac{v}{2l}$ and $n_2 = \frac{v}{2l+2\Delta l}$

$\Rightarrow$ No. of beats $= n_1 - n_2 = \frac{v}{2}\left(\frac{1}{l} - \frac{1}{l+\Delta l}\right) = \frac{v\Delta l}{2l^2}$

2. (a) Fundamental frequency of open pipe is double that of the closed pipe.

3. (c) If is given that First over tone of closed pipe = First over tone of open pipe $\Rightarrow 3\left(\frac{v}{4l_1}\right) = 2\left(\frac{v}{2l_2}\right)$; where l_1 and l_2 are the lengths of closed and open organ pipes hence $\frac{l_1}{l_2} = \frac{3}{4}$

4. (d) First overtone for closed pipe = $\frac{3v}{4l}$

Fundamental frequency for open pipe = $\frac{v}{2l}$

First overtone for open pipe = $\frac{2v}{2l}$.

5. (c) For closed pipe in general $n = \frac{v}{4l}(2N-1) \Rightarrow n \propto \frac{1}{l}$

i.e. if length of air column decreases frequency increases.

6. (a,c,d) Fundamental frequency of closed pipe $n = \frac{v}{4l}$

where $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \frac{1}{\sqrt{M}}$

$\because\ M_{H_2} < M_{air} \Rightarrow v_{H_2} > v_{air}$

Hence fundamental frequency with H_2 will be more as compared to air. So option (a) is correct.

Also $n \propto \frac{1}{l}$, hence if l decreases n increases so option (c) is correct.

It is well known that $(n)_{\text{Open}} = 2(n)_{\text{Closed}}$, hence option (d) is correct.

7. (d) For closed pipe $n_1 = \frac{v}{4l} \Rightarrow l = \frac{v}{4n} = \frac{332}{4\times166} = 0.5m$

8. (a) Fundamental frequency of open pipe

$n_1 = \frac{v}{2l} = \frac{350}{2\times 0.5} = 350\ Hz$.

9. (b) For closed pipe $n_1 = \frac{v}{4l} = \frac{330}{4}\ Hz$

Second note = $3n_1 = \frac{3\times 300}{4}\ Hz$.

10. (c) $n_{closed} = \frac{v}{4l}, n_{open} = \frac{v}{2l} \Rightarrow n_{open} = 2n_{closed} = 2f$

11. (b) Minimum audible frequency = 20 Hz.

$\Rightarrow \frac{v}{4l} = 20 \Rightarrow l = \frac{336}{4\times 20} = 4.2\ m$

12. (c) First overtone of closed organ pipe $n_1 = \frac{3v}{4l_1}$

Third overtone of open organ pipe $n_2 = \frac{4v}{2l_2}$

$n_1 = n_2$ (Given) $\Rightarrow \frac{3v}{4l_1} = \frac{4v}{2l_2} \Rightarrow \frac{l_1}{l_2} = \frac{3}{8}$

13. (b) For closed pipe $n_1 = \frac{v}{4l} \Rightarrow 250 = \frac{v}{4\times 0.2}$ $\Rightarrow v = 200\, m/s$

14. (b) $n_{open} = \frac{v}{2l_{open}}$

$n_{closed} = \frac{v}{4l_{closed}} = \frac{v}{4l_{open}/2} = \frac{v}{2l_{open}}$

$\left(As\ l_{closed} = \frac{l_{open}}{2}\right)$, *i.e.* frequency remains unchanged.

15. (b) For closed pipe second note = $\frac{3v}{4l} = \frac{3\times 330}{4\times 1.5} = 165\ Hz$.

16. (a) Fundamental frequency of open pipe

$n_1 = \frac{v}{2l} = \frac{330}{2\times 0.3} = 550\ Hz$

First harmonic = $2\times n_1 = 1100\ Hz$. = $1.1\ kHz$

17. (b) For first pipe $n_1 = \frac{v}{4l_1}$ and for second pipe $n_2 = \frac{v}{4l_2}$

So, number of beats = $n_2 - n_1 = 4$

$\Rightarrow 4 = \frac{v}{4}\left(\frac{1}{l_2} - \frac{1}{l_1}\right) \Rightarrow 16 = 300\left(\frac{1}{l_2} - \frac{1}{1}\right) \Rightarrow l_2 = 94.9\ cm$

18. (a) Maximum pressure at closed end will be atmospheric pressure adding with acoustic wave pressure

So $\rho_{max} = \rho_A + \rho_0$ and $\rho_{min} = \rho_A - \rho_0$

Thus $\frac{\rho_{max}}{\rho_{min}} = \frac{\rho_A + \rho_0}{\rho_A - \rho_0}$

19. (c) $n_1 - n_2 = 10$ .....(i)

Using $n_1 = \frac{v}{4l_1}$ and $n_2 = \frac{v}{4l_2}$

$\Rightarrow \frac{n_1}{n_2} = \frac{l_2}{l_1} = \frac{26}{25}$ .....(ii)

After solving these equation $n_1 = 260\,Hz$, $n_2 = 250\ Hz$

20. (a) Let l_1 and l_2 be the length's of closed and open pipes respectively. (Neglecting end correction)

$l_1 = \frac{\lambda_1}{4} \Rightarrow \lambda_1 = 4l_1$ and $l_2 = \frac{\lambda_2}{2} \Rightarrow \lambda_2 = 2l_2$

Given $n_1 = n_2$ so $\frac{v}{\lambda_1} = \frac{v}{\lambda_2} \Rightarrow \frac{v}{4l_1} = \frac{v}{2l_2} = \frac{l_1}{l_2} = \frac{1}{2}$

21. (b) Distance between two consecutive nodes

$= \frac{\lambda}{2} = 46 - 16 = 30 \Rightarrow \lambda = 60\,cm = 0.6m$

$\therefore\ v = n\lambda = 500\times 0.6 = 300\ m/s$.

22. (a) For closed pipe $n = \frac{v}{4l} \Rightarrow n = \frac{332}{4\times 42} = 2Hz$.

23. (a) For shortest length of pipe mode of vibration must be fundamental *i.e.,* $n = \frac{v}{4l} \Rightarrow l = \frac{v}{4n}$.

24. (b) $n_{Closed} = \frac{1}{2}(n_{Open}) = \frac{1}{2}\times 320 = 160\ Hz$

25. (c) Frequency of 2^{nd} overtone $n_3 = 5n_1 = 5\times 50 = 250\ Hz$.

26. (a) $\Delta n = n_1 - n_2 \Rightarrow 10 = \frac{v}{2l_1} - \frac{v}{2l_2} = \frac{v}{2}\left[\frac{1}{l_1} - \frac{1}{l_2}\right]$

$\Rightarrow 10 = \frac{v}{2}\left[\frac{1}{0.25} - \frac{1}{0.255}\right] \Rightarrow v = 255\, m/s$

27. (a) Fundamental frequency $n = \frac{v}{2l}$

$\Rightarrow 350 = \frac{350}{2l} \Rightarrow l = \frac{1}{2}m = 50\,cm$

28. (b) $\Delta n = n_1 - n_2 \Rightarrow 4 = \frac{v}{2l_1} - \frac{v}{2l_2} = \frac{v}{2}\left[\frac{1}{1.00} - \frac{1}{1.025}\right]$

$\Rightarrow 8 = [1 - 0.975] \Rightarrow v = \frac{8}{0.025} \approx 328\, m/s$

29. (a) In closed pipe only odd harmonics are present

30. (d) Fundamental frequency of open organ pipe $= \frac{v}{2l}$

Frequency of third harmonic of closed pipe $= \frac{3v}{4l}$

$\therefore \frac{3v}{4l} = 100 + \frac{v}{2l} \Rightarrow \frac{3v}{4l} - \frac{2v}{4l} = \frac{v}{4l} = 100 \Rightarrow \frac{v}{2l} = 200\,Hz$.

31. (c) $n_A = \frac{v}{2l}; n_B = \frac{v}{4l} \Rightarrow n_A / n_B = 2:1$

32. (a) Due to rise in temperature, the speed of sound increases. Since $n = \frac{v}{\lambda}$ and λ remains unchanged, hence n increases.

33. (b)

34. (b)

35. (b) In closed organ pipe. If $y_{incident} = a\sin(\omega t - kx)$ then $y_{reflected} = a\sin(\omega t + kx + \pi) = -a\sin(\omega t + kx)$

Superimposition of these two waves give the required stationary wave.

36. (b) $v = 330\ m/s$; $n = 165\ Hz$. Distance between two successive nodes $= \frac{\lambda}{2}$

$= \frac{v}{2n} = \frac{330}{2 \times 165} = 1m$

37. (b) At the middle of pipe, node is formed.

38. (c) For closed organ pipe $n_1 : n_2 : n_3 .... = 1:3:5:.....$

39. (b) First tone of open pipe = first overtone of closed pipe $\Rightarrow \frac{v}{2l_0} = \frac{3v}{4l_c} \Rightarrow$

$l_c = \frac{3 \times 2 \times 0.5}{4} = 0.75m$

40. (b) Only odd harmonics are present.

41. (b) Distance between six successive node

$= \frac{5\lambda}{2} = 85cm \Rightarrow \lambda = \frac{2 \times 85}{5} = 34\ cm = 0.34\ m$

Therefore speed of sound in gas

$= n\lambda = 1000 \times 0.34 = 340\ m/s$

42. (b) Let the base frequency be n for closed pipe then notes are $n, 3n, 5n.....$

$\therefore$ note $3n = 255 \Rightarrow n = 85$, note $5n = 85 \times 5 = 425$

note $7n = 7 \times 85 = 595$

43. (a) $l_2 = 3l_1 = 3 \times 24.7 = 74.1\ cm$

44. (c) Frequency of $p\ th$ harmonic

$n = \frac{pv}{2l} \Rightarrow p = \frac{2l/n}{v} = \frac{2 \times 0.33 \times 1000}{330} = 2$

45. (a) For closed pipe $l_1 = \frac{v}{4n}; l_2 = \frac{3v}{4n} \Rightarrow v = 2n(l_2 - l_1)$

$\Rightarrow n = \frac{v}{2(l_2 - l_1)} = \frac{330}{2 \times (0.49 - 0.16)} = 500\ Hz$

46. (c) Number of beats per second,

$n = \frac{16}{20} = \frac{4}{5} \Rightarrow n = n_1 - n_2 = \frac{v}{4}\left(\frac{1}{l_1} - \frac{1}{l_2}\right)$

$\Rightarrow \frac{4}{5} = \frac{v}{4}\left(\frac{1}{1} - \frac{1}{1.01}\right) = \frac{0.01v}{4 \times 1.01}$

$v = \frac{16 \times 101}{5} = 323.2\ ms^{-1}$

47. (a) In open organ pipe both even and odd harmonics are produced.

48. (d) Using $\lambda = 2(l_2 - l_1) \Rightarrow v = 2n(l_2 - l_1)$

$\Rightarrow 2 \times 512(63.2 - 30.7) = 33280\ cm/s$

Actual speed of sound $v_0 = 332\ m/s = 33200\ cm/s$

Hence error $= 33280 - 33200 = 80\ cm/s$

49. (b) Initially number of beats per second = 5

$\therefore$ Frequency of pipe = 200 ± 5 = 195 *Hz* or 205 *Hz* ...(i)

Frequency of second harmonics of the pipe = $2n$ and number of beats in this case = 10

$\therefore 2n = 420 \pm 10 \Rightarrow 410\ Hz$ or $430\ Hz$

$\Rightarrow n = 205\ Hz$ or $215\ Hz$
... (ii)

From equation (i) and (ii) it is clear that n = 205 *Hz*

50. (c) In case of open pipe, $n = \frac{N}{2l}$ where N = order of harmonics = order of mode of vibration $\Rightarrow N = \frac{n \times 2l}{v}$

$= \frac{480}{330} \times 2 \times 1 = 3$ (Here $v = 330\ m/s$)

51. (a) In first overtone of organ pipe open at one end,

end, $n_c = \frac{3v}{4l_c}$ .....(i)

Third harmonic or second overtone of organ pipe open at both end, $n_0 = \frac{3v}{2l_0}$

.....(ii)

given $n_c = n_o \Rightarrow \frac{3v}{4l_c} = \frac{3v_0}{2l_0} \Rightarrow \frac{l_c}{l_o} = \frac{1}{2}$.

52. (a) For end correction x, $\frac{l_2 + x}{l_1 + x} = \frac{3\lambda/4}{\lambda/4} = 3$

$x = \frac{l_2 - 3l_1}{2} = \frac{70.2 - 3 \times 22.7}{2} = 1.05\ cm$

53. (b) For open tube, $n_0 = \frac{v}{2l}$

For closed tube length available for resonance is

$l' = l \times \frac{25}{100} = \frac{l}{4}$ $\therefore$ Fundamental frequency of water filled tube $n = \frac{v}{4l'} = \frac{v}{4 \times (l/4)} = \frac{v}{l} = 2n_0 \Rightarrow$

$\frac{n}{n_0} = 2$

Doppler's Effect

1. (d)

2. (b) $n' = n\left(\frac{v}{v - v_O}\right) = 450\left(\frac{340}{340 - 34}\right) = 500$ *cycles*/sec

3. (a) $n' = n\left(\frac{v}{v - v_s}\right) \Rightarrow \lambda' = \lambda\left(\frac{v - v_S}{v}\right)$

$\Rightarrow \lambda' = 120\left(\frac{330 - 60}{330}\right) = 98\ cm$

4. (b) $n' = n\left(\frac{v}{v - v_S}\right) = 600\left(\frac{330}{300}\right) = 660\ cps$

5. (c) Both listeners, hears the same frequencies.

6. (b)

7. (c) $n' = n\left(\frac{v + v_O}{v}\right) \Rightarrow 2n = n\left(\frac{v + v_0}{v}\right) \Rightarrow \frac{v + v_0}{v} = 2$

$\Rightarrow v_O = v = 332\ m/sec$

8. (b) Apparent frequency in this case $n' = \frac{n(v + v_O)}{v}$

$\because \frac{v + v_0}{v} > 1 \Rightarrow \frac{n'}{n} > 1$ *i.e.* $n' > n$.

9. (a) Wave number $= \frac{1}{\lambda}$ but $\frac{1}{\lambda'} = \frac{1}{\lambda}\left(\frac{v}{v - v_s}\right)$ and $v_S = \frac{v}{3}$

$\therefore$ (W.N.)' = (W.N.) $\left(\frac{v}{v - v/3}\right) = 256 \times \frac{v}{2v/3}$

$= \frac{3}{2} \times 256 = 384$

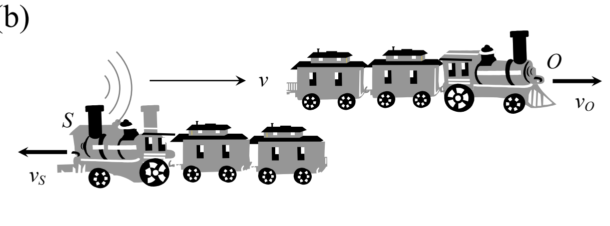
10. (a) By Doppler's formula $n' = \frac{nv}{(v - v_S)}$

Since, source is moving towards the listener so $n' > n$.

If n = 100 then n' = 102.5

$\Rightarrow 102.5 = \frac{100 \times 320}{(320 - v_S)} \Rightarrow v_s = 8\ m/\sec$

11. (b)

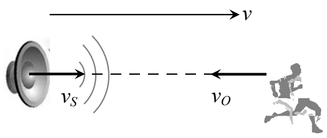


$n' = n\left(\frac{v - v_O}{v + v_S}\right) = 750\left(\frac{330 - 180 \times \frac{5}{18}}{330 + 108 \times \frac{5}{18}}\right) = 625\ Hz$

12. (a) By using $n' = n\left(\frac{v}{v - v_S}\right)$

$2n = n\left(\frac{v - v_O}{v - 0}\right) \Rightarrow v_O = -v = -$ (Speed of sound)

Negative sign indicates that observer is moving opposite to the direction of velocity of sound, as shown



13. (d) Since there is no relative motion between observer and source, therefore there is no apparent change in frequency.

14. (c)

15. (b)

16. (a) $n' = n\left(\frac{v}{v - v_S}\right) \Rightarrow \frac{n'}{n} = \frac{v}{v - v_S} \Rightarrow \frac{v}{v - v_S} = 3 \Rightarrow v_s = \frac{2v}{3}$

17. (a) $n' = n\left(\frac{v}{v - v_S}\right) = n\left(\frac{v}{v - v/10}\right) \Rightarrow \frac{n'}{n} = \frac{10}{9}$

18. (c) $n' = n\left(\frac{v}{v - v_S}\right) = 1200 \times \left(\frac{350}{350 - 50}\right) = 1400\ cps$

19. (d) $n' = n\left(\frac{v}{v - v_S}\right) = 1200\left(\frac{400}{400 - 100}\right) = 1600\ Hz$

20. (a) $n' = \frac{v}{v - v_S} \times n = \left(\frac{330}{330 - 110}\right) \times 150 = 225\ Hz$

21. (d) Doppler's effect is applicable for both light and sound waves.

22. (a) When source is approaching the observer, the frequency heard

$n_a = \left(\frac{v}{v - v_S}\right) \times n = \left(\frac{340}{340 - 20}\right) \times 1000 = 1063 Hz$

When source is receding, the frequency heard $n_r = \left(\frac{v}{v + v_S}\right) \times n = \frac{340}{340 + 20} \times 1000 = 944$

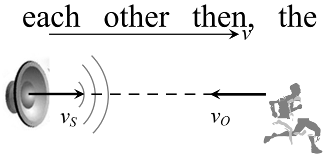
$\Rightarrow n_a : n_r = 9 : 8$

Short tricks : $\frac{n_a}{n_r} = \frac{v + v_S}{v - v_S} = \frac{340+20}{340-20} = \frac{9}{8}$.

23. (a) By using $\frac{n_{approaching}}{n_{receding}} = \frac{v + v_s}{v - v_s}$

$\Rightarrow \frac{1000}{n_r} = \frac{350+50}{350-50} \Rightarrow n_r = 750 Hz.$

24. (b) When source and listener both are moving towards each other then, the frequency heard



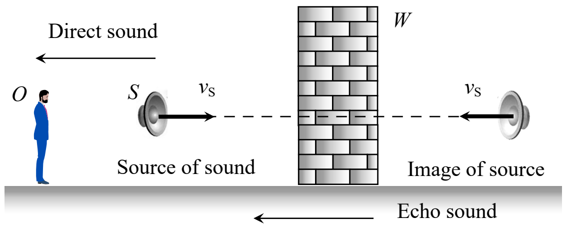
$n' = n\left(\frac{v+v_O}{v-v_S}\right) \Rightarrow n' = f\left(\frac{v+v/10}{v-v/10}\right) = 1.22\, f.$

25. (c) For source $v_S = r\omega = 0.70 \times 2\pi \times 5 = 22\, m/sec$

Minimum frequency is heard when the source is receding the man. It is given by $n_{min} = n\frac{v}{v+v_S}$

$= 1000 \times \frac{352}{352+22} = 941\ Hz$

26. (b) For direct sound source is moving away from the observes so frequency heard in this case



$n_1 = n\left(\frac{v}{v+v_s}\right) = 500\left(\frac{332}{332+2}\right) = 500\left(\frac{332}{334}\right) Hz$

The other sound is echo, reaching the observer from the wall and can be regarded as coming from the image of source formed by reflection at the wall. This image is approaching the observer in the direction of sound.

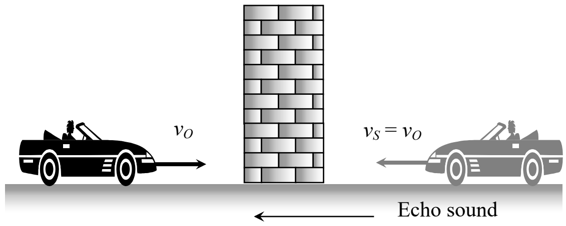
Hence for reflected sound, frequency heard by the observer is

$n_2 = n\left(\frac{v}{v-v_S}\right) = 500\left(\frac{332}{332-2}\right) = 500\left(\frac{332}{330}\right) Hz$

Beats frequency

$= n_2 - n_1 = 500 \times 332\left(\frac{1}{330} - \frac{1}{334}\right) = 6.$

27. (c) Similar to previous question



The frequency of reflected sound heard by the driver

$n' = n\left(\frac{v-(-v_O)}{v-v_S}\right) = n\left(\frac{v+v_O}{v-v_S}\right)$

$= 124\left[\frac{330+(72\times 5/18)}{330-(72\times 5/18)}\right] = 140$ *vibration/sec.*

28. (d) By using $n' = n\frac{v}{v-v_S} \Rightarrow \frac{n_1}{n} = \left(\frac{V}{V-S}\right)$

29. (b) In this case Doppler's effect is not applicable.

30. (d) The apparent frequency heard by the observer is given by

$n' = \frac{v}{v-v_S}n = \frac{330}{330-33} \times 450 = \frac{330}{297} \times 450 = 500\ Hz$

31. (a) $n' = n\left(\frac{v-v_O}{v}\right) = \left(\frac{330-33}{330}\right) \times 100 = 90\ Hz$

32. (c) When train is approaching frequency heard by the observer is

$n_a = n\left(\frac{v}{v-v_S}\right) \Rightarrow 219 = n\left(\frac{340}{340-v_S}\right)$ ...(i)

when train is receding (goes away), frequency heard by the observer is

$n_r = n\left(\frac{v}{v+v_S}\right) \Rightarrow 184 = n\left(\frac{340}{340+v_S}\right)$ ...(ii)

On solving equation (i) and (ii) we get $n = 200 Hz$

and $v_S = 29.5 m/s$

33. (d) Frequency is decreasing (becomes half), it means source is going away from the observes. In this case frequency observed by the observer is

$n' = n\left(\frac{v}{v+v_S}\right) \Rightarrow \frac{n}{2} = n\left(\frac{v}{v+v_S}\right) \Rightarrow v_S = v$

34. (d) Observer hears two frequencies

(i) n_1 which is coming from the source directly

(ii) n_2 which is coming from the reflection image of source

so, $n_1 = 680\left(\frac{340}{340-1}\right)$ and $n_2 = 680\left(\frac{340}{340+1}\right)$

$\Rightarrow \; n_1 - n_2 = 4 \; beats$

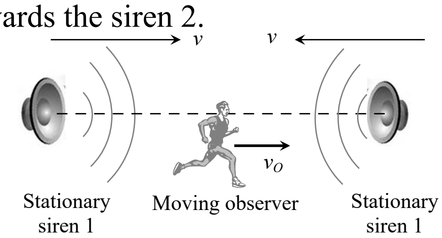
35. (a) From the figure, it is clear that

Frequency of reflected sound heard by the driver.

$n' = n\left[\frac{v-(-v_o)}{v-v_s}\right] = n\left[\frac{v+v_o}{v-v_s}\right] = n\left[\frac{v+v_{car}}{v-v_{car}}\right]$

$= 600\left[\frac{330+30}{330-30}\right] = 720 \; Hz.$

36. (b) Observer is moving away from siren 1 and towards the siren 2.



Hearing frequency of sound emitted by siren 1

$n_1 = n\left(\frac{v-v_0}{v}\right) = 330\left(\frac{330-2}{330}\right) = 328\,Hz$

Hearing frequency of sound emitted by siren 2

$n_2 = n\left(\frac{v+v_O}{v}\right) = 330\left(\frac{330+2}{330}\right) = 332\,Hz$

Hence, beat frequency $= n_2 - n_1 = 332 - 328 = 4.$

37. (c) $n' = n\left(\frac{v}{v-v_S}\right) = \frac{2000\times 1220}{(1220-40)} = 2068 \; Hz$

38. (d) $n' = n\left(\frac{v+v_O}{v-v_S}\right) n \Rightarrow 400 = n\left(\frac{360+40}{360-40}\right) \Rightarrow n = 320 \; cps$

39. (a) $n' = n\left(\frac{v}{v+v_S}\right) = 500\times\left(\frac{330}{300+50}\right) = 434.2\,Hz$

40. (c) Since there is no relative motion between the listener and source, hence actual frequency will be heard by listener.

41. (a) $n' = n\left(\frac{v}{v-v_S}\right) \Rightarrow n' = 500\left(\frac{330}{330-30}\right) = 550 \; Hz.$

42. (c) $n' = n\left(\frac{v}{v-v_S}\right) = 90\left(\frac{v}{v-\frac{v}{10}}\right) = 100\,\frac{Vibration}{sec}$

43. (a) The linear velocity of Whistle

$v_S = r\omega = 1.2\times 2\pi\frac{400}{60} = 50\,m/s$

When Whistle approaches the listener, heard frequency will be maximum and when listener recedes away, heard frequency will be minimum

So, $n_{\max} = n\left(\frac{v}{v-v_S}\right) = 500\left(\frac{340}{290}\right) = 586\,Hz$

$n_{\min} = n\left(\frac{v}{v+v_S}\right) = 500\left(\frac{340}{390}\right) = 436\,Hz$

44. (d) By using $n' = n\left(\frac{v}{v-v_S}\right)$

$\Rightarrow f_1 = n\left(\frac{v}{v-v_S}\right) = n\left(\frac{340}{340-34}\right) = \frac{340}{306}n$

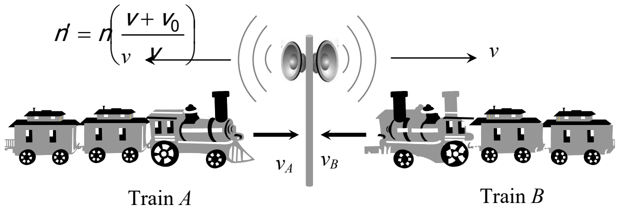
and $f_2 = n\left(\frac{340}{340-17}\right) = n\left(\frac{340}{323}\right) \Rightarrow \frac{f_1}{f_2} = \frac{323}{306} = \frac{19}{18}$

45. (d) No change in frequency.

46. (b) $n' = n\left(\frac{v-v_O}{v+v_S}\right) = n\left(\frac{340-10}{340+10}\right) = 1950 \Rightarrow n = 2068 \; Hz$

47. (b) $n' = n\left(\frac{v+v_O}{v-v_S}\right) = 240\left(\frac{340+20}{340-20}\right) = 270 \; Hz.$

48. (b) In both the cases observer is moving towards, the source. Hence by using $n' = n\left(\frac{v+v_0}{v}\right)$



When passenger is sitting in train *A*, then

$5.5 = 5\left(\frac{v+v_A}{v}\right)$ …(i)

when passenger is sitting in train *B*, then

$6 = 5\left(\frac{v+v_B}{v}\right)$ …(ii)

On solving equation (i) and (ii) we get $\frac{v_B}{v_A} = 2$

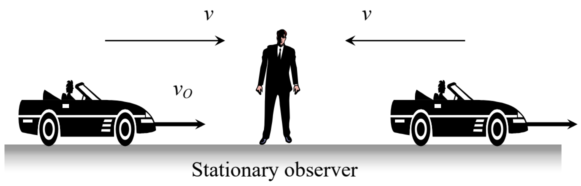
49. (b) Minimum frequency will be heard, when whistle moves away from the listener.

$n_{min} = n\left(\frac{v}{v+v_s}\right)$ where $v = r\omega = 0.5\times 10 = 1\, m/s$

$\Rightarrow n_{min} = 385\left(\frac{340}{340+10}\right) = 374\, Hz$

50. (a) $n' = n\left(\frac{v}{v+v_S}\right) = 800\left(\frac{330}{330+30}\right) = 733.33\, Hz$.

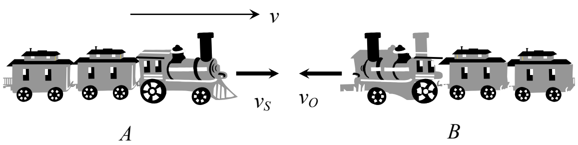
51. (a) $n_{Before} = \frac{v}{v-v_c}n$ and $n_{After} = \frac{v}{v+v_c}.n$



$\frac{n_{Before}}{n_{After}} = \frac{11}{9} = \left(\frac{v+v_c}{v-v_c}\right) \Rightarrow v_c \Rightarrow \frac{v}{10}$

52. (c) By using $n' = \left(\frac{v}{v-v_S}\right) \Rightarrow 2n = n\left(\frac{v}{v-v_S}\right) \Rightarrow v_S = \frac{v}{2}$

53. (d) The frequency of whistle heard by passenger in the train B, is



$n' = n\left(\frac{v+v_0}{v-v_s}\right) = 600\left(\frac{340+15}{340-20}\right) \approx 666\, Hz$

54. (b) At point A, source is moving away from observer so apparent frequency $n_1 < n$ (actual frequency) At point B source is coming towards observer so apparent frequency $n_2 > n$ and point C source is moving perpendicular to observer so $n_3 = n$

Hence $n_2 > n_3 > n_1$

55. (a) $n' = n\left[\frac{v+v_O}{v-v_S}\right]$; Here $v = 332\, m/s$ and $v_0 = v_s = 50\, m/s$

$\Rightarrow 435 = n\left[\frac{332+50}{332-50}\right] \Rightarrow n = 321.12\, sec^{-1} \approx 320\, sec^{-1}$

56. (c) Since apparent frequency is lesser than the actual frequency, hence the relative separation between source and listener should be increasing.

57. (c)

58. (d) $n' = n\left(\frac{v+v_0}{v-v_s}\right) = n\left(\frac{v+v/2}{v-v/2}\right) = 3n$

59. (c) When engine approaches towards observer

$n' = n\left(\frac{v}{v-v_S}\right)$

when engine going away from observer

$n'' = \left(\frac{v}{v+v_S}\right)n$

$\therefore \frac{n'}{n''} = \frac{v+v_S}{v-v_S} \Rightarrow \frac{5}{3} = \frac{340+v_S}{340-v_S} \Rightarrow v_S = 85\, m/s.$

60. (a) Frequency heard by the observer

$n' = n\left(\frac{v+v_0}{v}\right) = 240\left(\frac{330+11}{330}\right) = 248\, Hz$

61. (c) According the concept of sound image

$n' = \frac{v+v_{person}}{v-v_{person}}.272 = \frac{345+5}{345-5}\times 272 = 280\, Hz$

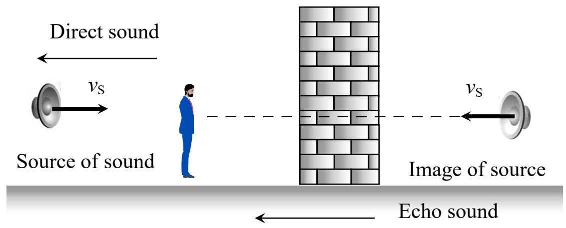
$\Delta n =$ Number of beats $= 280 - 272 = 8\, Hz$

62. (b) According the concept of sound image

$n' = \frac{v+v_B}{v-v_B}\times n = \frac{355+5}{355-5}\times 165 = 170\, Hz$

Number of beats $= n' - n = 170 - 165 = 5$

63. (a) The observer will hear two sound, one directly from source and other from reflected image of sound



Hence number of beats heard per second

$= \left(\frac{v}{v-v_S}\right)n - \left(\frac{v}{v+v_S}\right)n$

$= \frac{2nvv_S}{v^2 - v_S^2} = \frac{2\times 256\times 330\times 5}{335\times 325} = 7.8\, Hz$

64. (a) When a listener moves towards a stationary source apparent frequency

$n' = \left(\frac{v+v_O}{v}\right)n = 200$ .....(i)

When listener moves away from the same source

$n'' = \frac{(v-v_O)}{v}n = 160$ .....(ii)

From (i) and (ii)

$\frac{v+v_O}{v-v_O}=\frac{200}{160}\Rightarrow\frac{v+v_O}{v-v_O}=\frac{5}{4}\Rightarrow v=360 m/\sec$

65. (b) When observer moves towards stationary source then apparent frequency

$n'=\left[\frac{v+v_O}{v}\right]n=\left[\frac{v+v/5}{v}\right]n=\frac{6}{5}n=1.2n$

Increment in frequency = 0.2 n so percentage change in frequency = $\frac{0.2n}{n}\times 100=20\%$.

Musical Sound

1. (d)
2. (a) Intensity = $\frac{\text{Power}}{\text{Area}}=\frac{4}{4\pi\times(200)^2}=7.9\times10^{-6}$ W/m^2
3. (a) Intensity $\propto$ (Amplitude)^2
4. (c) $I=2\pi^2a^2n^2 v\rho\Rightarrow I\propto a^2n^2\Rightarrow\frac{I_1}{I_2}=\left(\frac{a_1}{a_2}\right)^2\times\left(\frac{n_1}{n_2}\right)^2$

$=\left(\frac{1}{2}\right)^2\times\left(\frac{1}{1/4}\right)^2\Rightarrow I_2=\frac{I_1}{4}$

5. (b) $L=10\log_{10}\left(\frac{I}{I_0}\right)=30\Rightarrow\frac{I}{I_0}=10^3$
6. (c)
7. (a) The quality of sound depends upon the number of harmonics present. Due to different number of harmonics present in two sounds, the shape of the resultant wave is also different.
8. (d) The sounds of different source are said to differ in quality. The number of overtones and their relative intensities determines the quality of any musical sound.
9. (d)
10. (d) Energy density $\propto$ (amplitude)^2
11. (d) Energy $\propto a^2n^2\Rightarrow\frac{a_B}{a_A}=\frac{n_A}{n_B}$ ($\because$ energy is same)

$\Rightarrow\frac{a_B}{a_A}=\frac{8}{1}$

12. (c) Loudness depends upon intensity while pitch depends upon frequency.
13. (d) Reverberation time $T=\frac{kV}{\alpha S}\Rightarrow T\propto V$.
14. (c) $I\propto\frac{1}{r^2}\Rightarrow\frac{I_2}{I_1}=\frac{r_1^2}{r_2^2}\Rightarrow\frac{I_2}{1\times10^{-2}}=\frac{2^2}{10^2}=\frac{4}{100}$

$\Rightarrow I_2=\frac{4\times10^{-2}}{100}=4\times10^{-4}\ \mu\ W/m^2$

15. (b) After passing the 3 meter intensity is given by

$I_3=\frac{90}{100}\times\frac{90}{100}\times\frac{90}{100}\times I=72.9\%$ of I

So, the intensity is 72.9 decibel.

16. (c)
17. (b)
18. (a) $P\propto I$

$L_1=10\log_{10}\left(\frac{I_1}{I_0}\right)$ and $L_2=10\log_{10}\left(\frac{I_2}{I_0}\right)$

So $L_2-L_1=10\log_{10}\left(\frac{I_2}{I_1}\right)$

$=10\log_{10}\left(\frac{P_2}{P_1}\right)=10\log_{10}\left(\frac{400}{20}\right)=10\log_{10}20$

$=10\log(2\times10)=10(0.301+1)=13dB$

19. (d) $I\propto\frac{1}{r^2}\Rightarrow\frac{\Delta I}{I}=-2\frac{\Delta r}{r}=-2\times2=-4\%$

Hence intensity is decreased by 4%.

20. (b) Musical interval is the ratio of frequencies = $\frac{320}{240}=\frac{4}{3}$
21. (c)
22. (d) By using $L=\log_{10}\frac{I}{I_0}$

$L_2-L_1=\log_{10}\frac{I_2}{I_0}-\log_{10}\frac{I_1}{I_0}$

$5-1=\log_{10}\frac{I_2}{I_1}\Rightarrow 4=\log_{10}\frac{I_2}{I_1}\Rightarrow\frac{I_2}{I_1}=10^4$

$\Rightarrow\frac{a_2^2}{a_1^2}=10^4\Rightarrow\frac{a_2}{a_1}=\frac{10^2}{1}\Rightarrow\frac{a_1}{a_2}=\frac{1}{10^2}$

23. (b)
24. (a) Pitch of mosquito is higher among all given options.
25. (b) The frequency of note 'Sa' is 256 *Hz* while that of note 'Re' and 'Ga' respectively are 288 *Hz* and 320 *Hz*.
26. (d)
27. (d) Indian classical vocalists don't like harmoniuim because it uses tempered scale.
28. (b)
29. (b) $I\propto\frac{1}{r^2}\Rightarrow\frac{I_2}{I_1}=\frac{r_1^2}{r_2^2}=\frac{2^2}{(40)^2}=\frac{1}{400}\Rightarrow I_1=400I_2$

Intensity level at point 1, $L_1=10\log_{10}\left(\frac{I_1}{I_0}\right)$

and intensity at point 2, $L_2 = 10\log_{10}\left(\frac{I_2}{I_0}\right)$

$\therefore\ L_1 - L_2 = 10\log\frac{I_1}{I_2} = 10\log_{10}(400)$

$\Rightarrow L_1 - L_2 = 10\times 2.602 = 26$

$L_2 = L_1 - 26 = 80 - 26 = 54\ dB$

30. (a) Intensity $\propto \frac{1}{(\text{Distance})^2} \Rightarrow$

$\frac{I_1}{I_2} = \left(\frac{d_2}{d_1}\right)^2 = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$.

31. (d)

32. (a) The pitch depends upon the frequency of the source. As the two waves have different amplitude therefore they having different intensity. While quality depends on number of harmonics/overtone produced and their relative intensity. Assuming that their frequencies are the same.

Critical Thinking Questions

1. (a,b,c,d) $y = 0.02\cos(10\pi x)\cos\left(50\pi t + \frac{\pi}{2}\right)$

At node, amplitude = 0

$\Rightarrow \cos(10\pi x) = 0 \Rightarrow 10\pi x = \frac{\pi}{2}, \frac{3\pi}{2}$

$\Rightarrow x = \frac{1}{20} = 0.05\ m,\ 0.15m$ …..

At antinode, amplitude is maximum

$\Rightarrow \cos(10\pi x) = \pm 1 \Rightarrow x = 0, \pi, 2\pi ...$

$\Rightarrow x = 0,\ 0.1m,\ 0.2m$ ...

Now $\lambda = 2\times$ Distance between two nodes or antinodes

$= 2\times 0.1 = 0.2\ m$ and $\frac{2\pi vt}{\lambda} = 50\pi t$

$v = 25\lambda = 25\times 0.2 = 5 m/\text{sec}$.

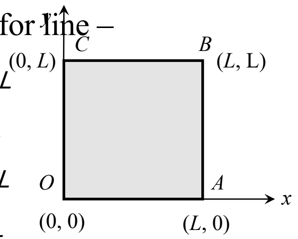
2. (b,c) Since the edges are clamped, displacement of the edges $u(x, y) = 0$ for line –

OA i.e. $y = 0$, $0 \le x \le L$

AB i.e. $x = L$, $0 \le y \le L$

BC i.e. $y = L$, $0 \le x \le L$

OC i.e. $x = 0$, $0 \le y \le L$



The above conditions are satisfied only in alternatives (b) and (c).

Note that $u(x, y) = 0$, for all four values e.g. in alternative (d), $u(x, y) = 0$ for $y = 0, y = L$ but it is not zero for $x = 0$ or $x = L$. Similarly in option (a). $u(x, y) = 0$ at $x = L, y = L$ but it is not zero for $x = 0$ or $y = 0$, while in options (b) and (c), $u(x, y) = 0$ for $x = 0, y = 0, x = L$ and $y = L$

3. (c) Energy (E) $\propto$ (Amplitude)^2 (Frequency)^2

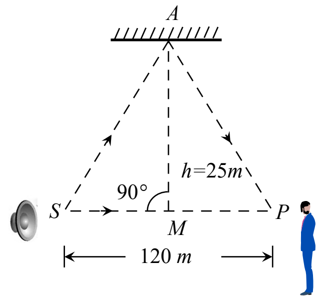
Amplitude is same in both the cases, but frequency 2ω in the second case is two times the frequency (ω) in the first case. Hence $E_2 = 4E_1$.

4. (a) Let S be source of sound and P the person or listner.

The waves from S reach point P directly following the path SMP and being reflected from the ceiling at point A following the path SAP. M is mid-point of SP (*i.e.* $SM = MP$) and $\angle SMA = 90^o$

Path difference between waves $\Delta x = SAP - SMP$

We have $SAP = SA + AP = 2(SA)$



$= 2\sqrt{[(SM)^2 + (MA)^2]} = 2\sqrt{(60^2 + 25^2)} = 130\ m$

$\therefore$ Path difference = SAP – SMP $= 130 - 120 = 10\,m$

Path difference due to reflection from ceiling = $\frac{\lambda}{2}$

$\therefore$ Effective path difference $\Delta x = 10 + \frac{\lambda}{2}$