Vol 1 Chapter 16 – Sound Waves

1. \( V_g = 230 \text{ m/s}, V_r = 6200 \text{ m/s}. \) Here \( S = 7 \text{ m}. \)
   \[ t = \frac{t_1 - t_2}{2} = \frac{1}{330} - \frac{1}{5200} = 2.75 \times 10^{-3} \text{ sec} = 2.75 \text{ ms}. \]

2. Here given \( S = 80 \text{ m} \times 2 = 160 \text{ m}. \)
   \( v = 320 \text{ m/s} \)
   So the maximum time interval will be
   \( t = \frac{S}{v} = 160/320 = 0.5 \text{ seconds}. \)

3. He has to clap 10 times in 3 seconds.
   So time interval between two clap = \( (3/10 \text{ second}) \)
   So the time taken go the wall = \( (3/2 \times 10) = 3/20 \text{ seconds}. \)
   = 333 m/s.

4. a) For maximum wavelength \( n = 20 \text{ Hz}. \)
   \[ \eta = \frac{1}{\lambda} \]
   b) For minimum wavelength, \( n = 20 \text{ kHz} \)
   \[ \lambda = \frac{360/(20 \times 10^3)}{18 \times 10^{-3}} \text{ m} = 18 \text{ mm} \]
   \[ x = (v/n) = \frac{360}{20} = 18 \text{ m}. \]

5. a) For minimum wavelength \( n = 20 \text{ KHz} \)
   \[ v = n\lambda \Rightarrow \lambda = \frac{1450}{20 \times 10^3} \text{ cm}. \]
   b) For maximum wavelength \( n \) should be minimum
   \[ v = n\lambda \Rightarrow \lambda = \frac{1450}{20} = 72.5 \text{ m}. \]

6. According to the question,
   a) \( \lambda = 20 \text{ cm} 	imes 10 - 200 \text{ cm} - 2 \text{ m} \)
   \( v = 340 \text{ m/s} \)
   so, \( n = v/\lambda = 340/2 = 170 \text{ Hz}. \)
   \[ N = v/\lambda \Rightarrow \frac{340}{2 \times 10^{-2}} = 17,000 \text{ Hz} = 17 \text{ KHz} \] (because \( \lambda = 2 \text{ cm} = 2 \times 10^{-2} \text{ m} \))

7. a) Given \( V_{rms} = 340 \text{ m/s}, n = 4.5 \times 10^4 \text{ Hz}. \)
   \[ \lambda_{rms} = \frac{(340 / 4.5) \times 10^{-3}}{7.36 \times 10^{-5} \text{ m}}. \]
   b) \( V_{rms} = 1500 \text{ m/s} \Rightarrow \lambda = \frac{(1500 / 4.5) \times 10^{-3} \text{ m}}{3.3 \times 10^{-5}}. \]

8. Here given \( f = 6.0 \times 10^{-2} \text{ m} \)
   a) Given \( 2\pi/\lambda = 1.8 \Rightarrow \lambda = (2\pi/1.8) \)
   \[ \frac{f \lambda}{2\pi} = \frac{6.0 \times 10^{-2} \text{ m/s}}{1.7 \times 10^{-4}} \text{ m}. \]
   b) Let, velocity amplitude = \( V_y \)
   \[ V = dy/dt = 3600 \cos (600 t - 1.8) \times 10^{-2} \text{ m/s} \]
   Here \( V_y = 3600 \times 10^{-5} \text{ m/s} \)
   Again, \( \lambda = 2\pi/1.8 \) and \( T = 2\pi/600 \Rightarrow \text{wave speed} - v = \lambda/T = 600/2.8 \times 1000 / 3 \text{ m/s}. \)
   So the ratio of \( (V_y/v) = \frac{3600 \times 3 \times 10^{-5}}{1000}. \)

9. a) Here given \( n = 100, v = 350 \text{ m/s}. \)
   \[ \lambda - \frac{350}{n} = 3.5 \text{ m}. \]
   In 2.5 ms, the distance travelled by the particle is given by
   \[ \Delta x = 350 \times 2.5 \times 10^{-3} \text{ m}. \]
So, phase difference \( \phi = \frac{2\pi}{\lambda} \times \Delta x \Rightarrow \frac{2\pi}{(350/100)} \times 350 \times 2.5 \times 10^{-3} = (\pi/2) \).

b) In the second case, Given \( \Delta \eta = 10 \text{ cm} = 10^{-1} \text{ m} \)

So, \( \phi = \frac{2\pi}{x} \Delta x = \frac{2\pi \times 10^{-1}}{(350/100)} = 2\pi/35 \).

10. a) Given \( \Delta x = 10 \text{ cm}, \lambda = 5.0 \text{ cm} \)

\( \Rightarrow \phi = \frac{2\pi}{\lambda} \Delta x = \frac{2\pi}{5} \times 10 = 4\pi \).

So phase difference is zero.

b) Zero, as the particle is in same phase because of having same path.

11. Given that \( p = 1.0 \times 10^4 \text{ Nm}^{-2}, T = 273 \text{ K}, M = 32 \times 10^{-3} \text{ kg} \)
\( V = 22.4 \text{ litre} = 22.4 \times 10^{-3} \text{ m}^3 \)
\( \text{C/}\text{C}_v = r = 3.5 \text{ R} / 2.5 \text{ R} = 1.4 \)

\( \Rightarrow \sqrt{\frac{p}{\text{C}} = \frac{1.4 \times 1.0 \times 10^{-5}}{32/22.4}} = 310 \text{ m/s} \) (because \( p = \text{m}/v \))

12. \( V_1 = 330 \text{ m/s}, V_2 = ? \)
\( T_1 = 273 + 17 = 290 \text{ K}, T_2 = 272 + 32 = 305 \text{ K} \)

We know \( v \propto \sqrt{T} \)

\( \frac{\sqrt{V_1}}{\sqrt{V_2}} = \frac{V_2}{V_1} = \frac{V_1 \times \sqrt{V_2}}{V_1} = 340 \times \frac{305}{290} = 349 \text{ m/s}. \)

13. \( T_s = 273 \text{ K}, V_2 = 2V_1 \)
\( V_1 = v \) \( T_s = ? \)

We know that \( V \propto \sqrt{T} \Rightarrow \frac{V_2}{T_2} = \frac{V_1}{T_1} \Rightarrow T_2 = 273 \times 2^2 - 4 \times 273 \text{ K} \)

So temperature will be \((4 \times 273) - 273 = 619^\circ\text{c}. \)

14. The variation of temperature is given by

\[ T = T_s + \left( \frac{T_2 - T_1}{d} \right) x \]  

...(1)

We know that \( V = \sqrt{T} \Rightarrow \frac{V}{\sqrt{T}} = \sqrt{\frac{T}{273}} \Rightarrow VT = v \sqrt{\frac{T}{273}}\)

\( \Rightarrow dx = VT \frac{V}{\sqrt{T}} \Rightarrow \frac{dx}{V} = \frac{273}{V} \left( \frac{V}{\sqrt{T}} + \frac{T}{d} \right) \frac{d}{dx} x^{1/2} \)

\( = \sqrt{\frac{273}{V}} \left[ \frac{2d}{V} - \frac{T}{d} \right] \frac{d}{dx} x^{1/2} \)

\( = \frac{2d}{\sqrt{V} \sqrt{T} + \sqrt{V} \sqrt{T}} \)

Putting the given value we get

\( = \frac{2 \times 33}{330} \sqrt{\frac{273}{320 + \sqrt{310}}} = 96 \text{ ms}. \)
15. We know that \( v = \sqrt{K/\rho} \)

Where \( K \) = bulk modulus of elasticity
\[ K = v^2 \rho = (1330)^2 \times 800 \text{ N/m}^2 \]

We know \( K = \frac{F/A}{\Delta V/V} \)
\[ \Rightarrow \Delta V = \frac{\text{Pressures}}{K} = \frac{2 \times 10^5}{1330 \times 1330 \times 800} \]
So, \( \Delta V = 0.15 \text{ cm}^3 \)

16. We know that,

Bulk modulus \( B = \frac{\Delta \rho}{\Delta V/V} = \frac{P_0 \lambda}{2\pi S_0} \)

Where \( P_0 \) = pressure amplitude \( \Rightarrow P_0 = 1.0 \times 10^5 \)
\( \lambda \) = displacement amplitude \( \Rightarrow \lambda = 5.5 \times 10^{-5} \text{ m} \)
\[ \Rightarrow B = \frac{14 \times 35 \times 10^{-3} \text{ m}}{2\pi (5.5) \times 10^{-5} \text{ m}} = 1.4 \times 10^5 \text{ N/m}^2. \]

17. a) Here given \( V_{aw} = 340 \text{ m/s} \), Power = \( E t = 20 \text{ W} \)
f = 2000 Hz, \( \rho = 1.2 \text{ kg/m}^3 \)

So, intensity \( I = \frac{E}{t A} \)
\[ \Rightarrow I = \frac{20}{4 \pi r^2} = \frac{20}{4 \pi \times 6^2} = 44 \text{ mW/m}^2 \text{ (because } r = 6\text{m)} \]

b) We know that \( I = \frac{P_0^2}{2\rho V_{ar}} \)
\[ \Rightarrow P_0 = \sqrt{2 \times 1.2 \times 340 \times 44 \times 10^{-3}} = 6.0 \text{ N/m}^2. \]

c) We know that \( I = 2\pi S_0^2 \rho^2 V \) where \( S_0 \) = displacement amplitude
\[ \Rightarrow S_0 = \sqrt{\frac{I}{2\pi \rho^2 V}} \]
Putting the value we get \( S_0 = 1.2 \times 10^{-6} \text{ m}. \)

18. Here \( I_1 = 1.0 \times 10^{-3} \text{ W/m}^2 \); \( I_2 = ? \)
\( r_1 = 5.0 \text{ m}, r_2 = 25 \text{ m} \)

We know that \( I = \frac{1}{r^2} \)
\[ \Rightarrow I_1 r_1^2 = I_2 r_2^2 \Rightarrow I_2 = \left( \frac{r_1}{r_2} \right)^2 I_1 \]
\[ = \frac{1.0 \times 10^{-6} \times 25}{625} = 4.0 \times 10^{-10} \text{ W/m}^2. \]

19. We know that \( \beta = 10 \log_{10} \left( \frac{l_1}{l_2} \right) \)

\[ \beta_A = 10 \log_{10} \left( \frac{l_A}{l_b} \right), \beta_B = 10 \log_{10} \left( \frac{l_B}{l_b} \right) \]
\[ \Rightarrow \frac{l_A}{l_B} - 10^{\beta_A/10} \Rightarrow I_1/l_2 - 10^{\beta_A/10} \]
\[ \Rightarrow \frac{l_A}{l_b} = \frac{r_A^2}{r_b^2} = \left( \frac{50}{5} \right)^2 = 100^{\beta_A/10} = 10^2 \]
\[ \Rightarrow \frac{\beta_A - \beta_B}{40} = 2 \Rightarrow \beta_B = 20 \]
\[ \Rightarrow 8_B = 40 - 20 = 20 \text{ dB}. \]
20. We know that, \( \beta = 10 \log_{10} \dfrac{I}{I_0} \)

According to the question
\[
\beta_x = 10 \log_{10} \left( \dfrac{2I}{I_0} \right)
\]

\( \Rightarrow \beta_x - \beta_a = 10 \log \left( \dfrac{2I}{I} \right) = 10 \times 0.3010 = 3 \text{ dB} \)

21. If sound level = 120 dB, then \( I = \text{intensity} = 1 \text{ W/m}^2 \)

Given that, audio output = 2W

Let the closest distance be \( x \).

So, \( \text{intensity} = \dfrac{2}{(2 \pi x)^2} = 1 \Rightarrow x^2 = \dfrac{(2/2\pi)}{x} \Rightarrow x = 0.4 \text{ m} = 40 \text{ cm} \).

22. \( I_1 = 50 \text{ dB}, I_2 = 60 \text{ dB} \)

\[
I_1 = 10^{-7} \text{ W/m}^2, I_2 = 10^{-4} \text{ W/m}^2
\]

(because \( \beta = 10 \log_{10} \left( \dfrac{I}{I_0} \right) \), where \( I_0 = 10^{-12} \text{ W/m}^2 \))

Again, \( I/I_0 = (p/p_0)^2 = (10^{-7}/10^{-8}) = 10 \) (where \( p \) = pressure amplitude).

\( (p_2/p_1) = \sqrt{10} \).

23. Let the intensity of each student be \( I \).

According to the question
\[
\beta_a = 10 \log_{10} \left( \dfrac{50I}{I_0} \right), \beta_b = 10 \log_{10} \left( \dfrac{100I}{I_0} \right)
\]

\( \Rightarrow \beta_a - \beta_b = 10 \log_{10} \left( \dfrac{50I}{I_0} \right) - 10 \log_{10} \left( \dfrac{100I}{I_0} \right) \)

\( = 10 \log \left( \dfrac{50I}{100I} \right) - 10 \log_{10} 2 = 3 \)

So, \( \beta_a = 50 + 3 = 53 \text{ dB} \).

24. Distance between two maximum to a minimum is given by, \( \lambda/4 = 2.50 \text{ cm} \)

\( \Rightarrow \lambda = 10 \text{ cm} = 10^{-1} \text{ m} \)

We know, \( V = nx \)

\( \Rightarrow n = \dfrac{V}{\lambda} = \dfrac{340}{10^{-1}} = 3400 \text{ Hz} = 3.4 \text{ kHz} \).

25. a) According to the data
\( \lambda/4 = 16.5 \text{ mm} \Rightarrow \lambda = 66 \text{ mm} = 66 \times 10^{-3} \text{ m} \)

\( \Rightarrow n = \dfrac{V}{\lambda} = \dfrac{330}{66 \times 10^{-3}} = 5 \text{ kHz} \).

b) \( I_{\text{maximum}} = K(A_1 - A_2)^2 = I \Rightarrow A_1 - A_2 = 11 \)

\( I_{\text{maximum}} = K(A_1 + A_2)^2 = 9 \Rightarrow A_1 + A_2 = 31 \)

\( \Rightarrow A_1 + A_2 = 4 \Rightarrow A_1/A_2 = 2/1 \)

So, the ratio amplitudes is 2.

26. The path difference of the two sound waves is given by
\( \Delta \lambda = 0.4 - 0.0 = 0.4 \text{ m} \)

The wavelength of either wave = \( \lambda = \dfrac{V}{\rho} = \dfrac{320}{\rho} \text{ (m/s)} \)

For destructive interference \( \Delta \lambda = \dfrac{(2n + 1)\lambda}{2} \) where \( n \) is an integers.

\( \text{or } 0.4 = \dfrac{2n + 1}{2} \times \dfrac{320}{\rho} \)

\( \Rightarrow \rho = \dfrac{320}{0.4} = 800 \dfrac{2n + 1}{2} = (2n + 1) \times 400 \text{ Hz} \)

Thus the frequency within the specified range which cause destructive interference are 1200 Hz, 2000 Hz, 2600 Hz, 3600 Hz and 4400 Hz.
27. According to the given data
\[ v = 336 \text{ m/s}, \]
\[ \frac{\lambda}{4} = \text{distance between maximum and minimum intensity} \]
\[ = (20 \text{ cm}) \Rightarrow \lambda = 80 \text{ cm} \]
\[ \Rightarrow n = \text{frequency} = \frac{v}{\lambda} = \frac{336}{80 \times 10^{-2}} = 420 \text{ Hz} \]

28. Here given \( \lambda = \frac{d}{2} \)

Initial path difference is given by 
\[ 2\sqrt{\left( \frac{d}{2} \right)^2 + x^2} - d \]
If it is now shifted a distance \( x \) then path difference will be
\[ = 2\sqrt{\left( \frac{d}{2} \right)^2 + \left( \sqrt{2d} + x \right)^2} - d = \frac{d}{4} \left( \sqrt{2d} + \frac{d}{4} \right) \]
\[ \Rightarrow \left( \frac{d}{2} \right)^2 + \left( \sqrt{2d} + x \right)^2 = \frac{169d^2}{64} \Rightarrow \frac{153}{84} d^2 \]
\[ \Rightarrow \sqrt{2d} + x = 1.54 d \Rightarrow x = 1.54 d - 1.414 d = 0.13 d. \]

29. As shown in the figure the path differences \( 2A = \Delta x = \sqrt{(3.2)^2 + (2.4)^2} - 3.2 \)

Again, the wavelength of the ether sound waves is \( \frac{320}{\rho} \)

We know, destructive interference will be occur
If \( \Delta x = \frac{(2n + 1)\lambda}{2} \)
\[ \Rightarrow \sqrt{(3.2)^2 + (2.4)^2} - (3.2) = \frac{(2n + 1) \cdot 320}{2} \]
Solving we get
\[ \Rightarrow \lambda = \frac{(2n + 1) \cdot 400}{2} = 200(2n + 1) \]
where \( n = 1, 2, 3, \ldots \) 49. (audible region)

30. According to the data
\[ \lambda = 20 \text{ cm}, S_1S_2 = 20 \text{ cm}, BD = 20 \text{ cm} \]

Let the detector is shifted to left for a distance \( x \) for hearing the minimum sound.
So path difference \( AI = BC - AB = \sqrt{(20)^2 + (10 + x)^2} - \sqrt{(20)^2 + (10 - x)^2} \)
So the minimum distances hearing for minimum
\[ - \frac{(2n + 1)\lambda}{2} = \frac{20}{2} = 10 \text{ cm} \]
\[ \Rightarrow \sqrt{(20)^2 + (10 + x)^2} - \sqrt{(20)^2 + (10 - x)^2} = 10 \text{ solving we get } x = 12.0 \text{ cm}. \]