KING FHAD UNIVERSITY OF PETROLEUM & MINERALS
DEPARTMENT OF PHYSICS

PHYSICS 102 (992)
SOLUTION (CHAPTER 18)

Q.1 A string under tension τ_i oscillates in the third harmonic at frequency f_3, and the waves on the string have wavelength λ_3. If the tension is increased to $\tau_f = 4\tau_i$ and the string is again made to oscillate in the third harmonic, what then are (a) the frequency of oscillation in terms of f_3 and (b) the wavelength of the waves in terms of λ_3.

(a) The wave length must be the same.

$$f_i = \frac{v_i}{\lambda_3}, \quad f = \frac{2v_i}{\lambda_3} = 2f_3 \quad \left(\text{the speed doubles}\right)$$

(b) The same wave length λ_3

Q.2 In figure 18.2 two loudspeakers, separated by a distance of 2.00 m are in phase. Assume the amplitudes of the sound from the speakers are approximately the same at the position of a listener, who is 3.75 m directly in front of one of the speakers. (a) For what frequencies in the audible range (20-20,000 Hz) does the listener hear a minimum signal? (b) For frequencies is the signal maximum?

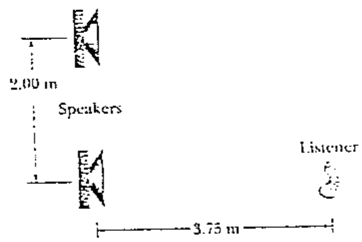
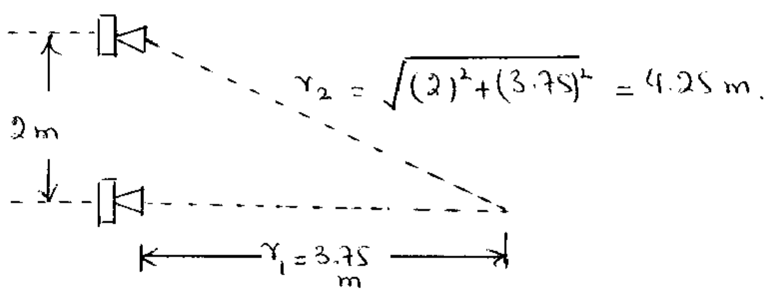


FIG 18.2



$$\Delta r = r_2 - r_1 = n\frac{\lambda}{2} \quad (n \text{ odd})$$

$$\Delta r = 4.25 - 3.75 = 0.50 = \frac{n}{2} \times \frac{343}{f} \Rightarrow f = 343\,n.$$

$n = 1$, $f = 343$ Hz is the lowest frequency that will give a minimum.

$n = \frac{20,000}{343} = 58.3$, therefore the largest odd number is 57. The frequencies that give a minimum.

$343, 3(343), 5(343), \ldots, (57)(343) = 19{,}551$ Hz.

(b) For maximum

$\Delta r = 0.5 = m\lambda, \quad m = 0, 1, 2, 3, \ldots$

$$0.5 = m\frac{v}{f} = m\frac{343}{f}$$

$$f = m(2)(343) = 686m$$

$(1)(686), 2(686), 3(868), \ldots, 29(686) = 19{,}894$ Hz.

Q.3 Two waves are propagating on the same very long string. A generator at one end of the string creates a wave given by

$$Y = (6.0 \text{ cm}) \cos(\pi/2)[(2.0 \text{ m}^{-1})x + (8.0 \text{ s}^{-1})t]$$

And one at the other end creates the wave

$$Y = (6.0 \text{ cm}) \cos(\pi/2)[(2.0 \text{ m}^{-1})x - (8.0 \text{ s}^{-1})t]$$

(a) Calculate the frequency, wavelength, and speed of each wave. (b) Find the points on the string at which there is no motion (the nodes). (c) At which points is the motion of the string a maximum (the antinodes)?

$$y_1 = 6 \cos \frac{\pi}{2} (2x + 8t)$$

$$y_2 = 6 \cos \frac{\pi}{2} (2x - 8t)$$

(a) $\omega = 2\pi f = \left(\frac{\pi}{2}\right)(8) = 4\pi \, s^{-1}, \quad f = 2 \text{ Hz}.$

$$\lambda = \frac{2\pi}{k} = \frac{2\pi}{\left(\frac{\pi}{2}\right)(2)} = 2 \, m, \quad v = \lambda f = 4 \, m/s$$

(b) $y = y_1 + y_2 = 6 \cos \frac{\pi}{2} (2x + 8t) + 6 \cos \frac{\pi}{2} (2x - 8t)$

derive the formula for $\cos x + \cos y = 2 \cos \frac{x+y}{2} \cos \frac{x-y}{2}$

$$\cos(\alpha + \beta) = \cos\alpha \cos\beta - \sin\alpha \sin\beta$$

$$\cos(\alpha - \beta) = \cos\alpha \cos\beta + \sin\alpha \sin\beta$$

add.

$$\cos(\alpha + \beta) + \cos(\alpha - \beta) = 2 \cos\alpha \cos\beta$$

Let $\alpha+\beta = x$, $\alpha = \dfrac{x+y}{2}$

$\alpha-\beta = y$, $\beta = \dfrac{x-y}{2}$

$$\cos x + \cos y = 2\cos\left(\frac{x+y}{2}\right)\cos\left(\frac{x-y}{2}\right)$$

Therefore

$$y = 2(6)\cos\frac{\pi}{2}(2x)\cos\frac{\pi}{2}(8t) = 12\cos\pi x\cos 4\pi t$$

Nodes:

$$\cos\frac{\pi}{2}(2x) = \cos\pi x = 0$$

$$\pi x = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, \ldots$$

$$x = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \ldots \quad (m)$$

Antinodes:

$$\cos\pi x = 1$$

$$\pi x = 0, \pi, 2\pi, 3\pi, \ldots$$

$$x = 0, 1, 2, 3, \ldots \quad (m)$$

Q.4 A sound wave of 40.0 cm wavelength enters the tube shown in figure 18.4 at the source end. What must be the smallest radius r such that a minimum will be heard at the detector end?

FIG. 18.4

Sound travels two different paths. The path difference is $\Delta r = \frac{1}{2}(2\pi r) - 2r = \pi r - 2r$

$$\Delta r = r(\pi - 2) = 1.14\, r \text{ m.}$$

$$\Delta r = 1.14 r = \frac{\lambda}{2}, \qquad \lambda = 40.0 \text{ cm} = 0.40 \text{ m.}$$

$$r = \frac{0.40}{2(1.14)} = 0.18 \text{ m or } 18 \text{ cm.}$$

Q.5 Two sound waves, from two different sources with the same frequency, 540 Hz, travel at a speed of 330 m/s. The sources are in phase. What is the phase difference of the waves at a point that is 4.40 m from one source and 4.00 m from the other? The waves are traveling in the same direction.

$f = 540\ Hz\ , \quad v = 330\ m/s$

$$\Delta\theta = \frac{\Delta r}{\lambda} 2\pi = \frac{4.40 - 4.00}{\frac{330}{540}} 2\pi$$

$\Delta\theta = 4.11$ radians