Sound Waves

Exercise Solutions

Solution 1:
Velocity of sound in air = v = 330 m/s
Velocity of sound through the steel tube = v_s = 5200 m/s
Length of the steel tube= S = 1 m

Required time gap = t = t_1 - t_2

Where t_1 = time taken by the sound in air = 1/330 and t_2 = time taken by the sound in steel tube = 1/5200

=> t = 1/330 - 1/5200 = 2.75 ms

Solution 2:
S = 80x2 = 160m

v= 320 m/s

So, maximum time interval is: t = S/v = 160/320 = 0.5 sec

Solution 3:
S = 50 m
Man has to clap 10 times in 3 sec
So, the time interval between two claps = 3/10
Time taken by the sound to reach the wall = t = 3/20 sec

Velocity = v = S/t

= 50/(3/20)

= 333 m/sec

Solution 4:
Speed of sound =v= 360 m/sec

Frequency for minimum wavelength, f = 20 kHz

We know, v = fλ

or λ = 18 x 10^{-3} mm

Again, Frequency for max. wavelength, f = 20 Hz

λ = 360/20 = 18 m

Solution 5:
Speed of sound =v= 1450 m/sec

For minimum wavelength, frequency should be max.

f = 20 kHz

We know, v = fλ

or λ = 1450/[20x10^3] = 7.25 cm

For minimum wavelength, frequency should be min.

λ = 20 Hz

v = fλ

λ = 1450/20 = 72.5 m

Solution 6:
Wavelength of the sound is 10 times the diameter of the loudspeaker.

λ = 20 x 10 = 200 cm or 2 m

(a) v = fλ

f = v/λ = 340/2 = 170 Hz

$\lambda = 2$ cm = 2×10^{-2} m

$f = v/\lambda = 340/(2 \times 10^{-2}) = 17000$ Hz = 17 k Hz

Solution 7: Frequency of ultrasonic wave = f= 4.5 MHz or 4.5×10^6 Hz
Speed of sound in tissue = 1.5 km/s
Velocity of air v = 340 m/sec

$v = f\lambda$

$\lambda = 340/[4.5 \times 10^6]$

$= 7.6 \times 10^{-5}$ m

(b) Velocity of sound in tissue:

$v_t = 1500$ m/s

$\lambda = v_t f$

$\lambda = 1500/[4.5 \times 10^6]$ m

$= 3.3 \times 10^{-4}$ m

Solution 8:
Given: $r_y = 6.0 \times 10^{-5}$ m

(a) $2\pi/\lambda = 1.8$

=> $\lambda = 2\pi/1.8$

So, $r_y/\lambda = [6.0 \times 10^{-5} \times 1.8]/2\pi$

$= 1.7 \times 10^{-5}$ m

(b) Let v_y be velocity amplitude.

$v = dy/dt = 3600 \cos(600t - 1.8) \times 10^{-5}$ m/s

Here $v_y = 3600 \times 10^{-5}$ m/s

and $\lambda = 2\pi/1.8$ and $T = 2\pi/600$

=> wave speed = $v = \lambda/T = 600/1.8 = 1000/3$ m/s

So, the ratio = $v_y/v = [3600 \text{x} 3 \text{x} 10^{-5}]/1000$

Solution 9:

(a) $v = f\lambda$

$\lambda = v/f = 350/100 = 3.5$ m

In 2.5 ms, the distance travelled by the particle,
$\Delta x = (350 \times 2.5 \times 10^{-3})$m

Now, phase difference = $\phi = (2\pi/\lambda)\ \Delta x$

$= [2\pi \text{x} 350 \text{x} 2.5 \text{x} 10^{-3}]/[3.5]$

=> $\phi = \pi/2$

(b) Distance between the two points:

$\Delta x = 10$ cm = 0.1 m

$\phi = (2\pi/\lambda)\ \Delta x$

On substituting the values,

$\phi = (2\pi(0.1)/3.5 = 2\pi/35$

Phase difference between the two points.

Solution 10:

(a) $\Delta x = 10$ cm and $\lambda = 5$ cm

=> $\phi = (2\pi/\lambda)\ \Delta x = (2\pi/5)10 = 4\pi$

Phase difference between the two waves is zero.

(b) Zero: the particles are in the same phase since they have the same path.

Solution 11:

$p = 1 \times 10^5\ N/m^2$, $T = 273$ K, $M = 32$ g and $g = 32\times10^{-3}$ kg

$v = 22.4\ l = 22.4 \times10^{-3}\ m^3$

Therefore, $C/C_v = r = 3.5R/2.5R = 1.4$

$V = \sqrt{}(rp/f) = [1.4\times1.0\times10^{-5}]/[32/22.4] = 310$ m/s

Solution 12:

velocity of sound = $v_1 = 340$ m/s

$T_1 = 17^o$ C = 17+273 = 290 K

Let v_2 velocity of sound at temp T_2

$T_2 = 32^o$ C = 32 + 273 = 305 K

Relation between velocity and temperature:

$v \propto \sqrt{T}$

Now, $v_1/v_2 = \sqrt{T_1}/\sqrt{T_2}$

=> $v_2 = 340 \times \sqrt{(305/290)} = 349$ m/s

The final velocity of sound is 349 m/s.

Solution 13:
$T_1 = 273$, $v_2 = 2v_1$, $v_1 = v$ and $T_2 = ?$

We know that, $v \propto \sqrt{T}$

=> $T_2/T_1 = v_2^2/v_1^2$

=> $T_2 = 273 \times 2^2 = 4 \times 273$ K

So, temp will be $(4 \times 273) - 273 = 819^o$ C

Solution 14:
Temperature variation:
$T = T_1 + [(T_2 - T_1)x]/d$

$v \propto \sqrt{T}$

$v_T/v = \sqrt{(T/273)}$

And, $dt = dx/v_T = du/v (\sqrt{(273/T)})$

$$t = \frac{\sqrt{273}}{v} \int_0^d \frac{dx}{\left[T_1 + \frac{(T_2 - T_1)}{d}x\right]^{\frac{1}{2}}}$$

$$t = \frac{\sqrt{273}}{v} \times \frac{2d}{T_2 - T_1}\left[T_1 + \frac{(T_2 - T_1)}{d}x\right]_0^d$$

$$t = \frac{\sqrt{273}}{v} \times \frac{2d}{T_2 - T_1}\left(\sqrt{T_2} - \sqrt{T_1}\right)$$

$$t = \left(\frac{2d}{v}\right)\left(\frac{\sqrt{273}}{\sqrt{T_2} + \sqrt{T_1}}\right)$$

We are given, initial temp = T_1 = 280k
Final temp = T_2 = 310 k

Space width = d = 33 m
and v = 330 m/s
=> $T = [2 \times 33 \times \sqrt{273}]/[330(\sqrt{280} + \sqrt{310})]$
= 96 m/s

Solution 15:
The velocity in terms of the bulk modulus and density :

$v = \surd(k/p)$

where, $k = v^2 \rho$

$\Rightarrow k = (1330)^2 \times 800\ N/m^2$

$K = (F/A)/(\Delta v/\Delta v)$

Therefore, $\Delta V = [\text{pressure} \times v]/k$

$\Delta v = [2\times10^5\times1\times10^{-3}]/[1330\times1330\times800]$

$= 0.14\ cm^3$

The change in the volume of kerosene $0.14\ cm^3$.

Solution 16:
Wavelength of sound wave = $\lambda = 35\ cm = 35 \times 10^{-2}\ m$
Pressure amplitude = $p_o = (1 \times 10^5 \pm 14)$ pa
Displacement amplitude of the air particles $= S_o = 5.5 \times 10^{-6}\ m$

Now,
Bulk modulus of air = $B = p_o\lambda/2\pi S_o = \Delta p/(\Delta v/v)$

$= [14\times35\times10^{-2}]/[2\pi(5.5 \times 10^{-6})]$

$= 1.4 \times 10^5\ N/m^2$

Solution 17:
(a) Distance of the source = r = 6.0 m

Intensity = I = P/A

here P = 20 W and A = area = $4\pi r^2$

=> $I = 20/[4\pi r^2]$
Given r = 6 m

=> I = 44 mw/m^2

(b) $I = p_o/2\rho v$

=> $p_o = \sqrt{(2I\rho v)}$

=> $p_o = \sqrt{(2x12x340x44x10^{-3})}$

=> p_o = 6 Pa

(c) As, $I = 2\pi^2 S_o^2\ v^2\ \rho v$

Where S_o is the displacement amplitude

s_o = $\sqrt{(I/2\pi^2 v^2\ \rho v)}$

on substituting the values, we get

$S_o = 1.2 \times 10^{-6}$ m

Solution 18:
Here $I_1 = 1 \times 10^{-8}$ W m^{-2}
r_1 = 5 m and r_2 = 25 m
I_2 =?

We know, $I \propto 1/r^2$

=> $I_1 r_1^2 = I_2 r_2^2$

=> $I_2 = (I_1 r_1^2)/r_2^2$

$= [1\times10^{-8} \times 25]/[625]$

$= 4 \times 10^{-10}$ W m^{-2}

Solution 19:

Sound level $= \beta = 10 \log_{10} (I/I_o)$

As per given statement,

$\beta_A = 10 \log_{10} (I_A/I_o)$

=> $I_A/I_o = 10^{(\beta\_A/10)}$ ...(1)

Again,

$\beta_B = 10 \log_{10} (I_B/I_o)$

=> $I_B/I_o = 10^{(\beta\_B/10)}$ ...(2)

From (1) and (2)

$I_A/I_B = 10^{(\beta A - \beta B)}/10)$ ...(3)

Also,

$I_A/I_B = r_B^2/ r_A^2 = (50/5)^2 = 100$ ....(4)

From (3) and (4),

$10^2 = 10^{(\beta A - \beta B)}/10)$

=>2 = $(\beta_A - \beta_B)/10$

=> $\beta_A - \beta_B = 20$

=> $\beta_B = 40-20 = 20$ dB

Therefore, sound level of a point 50 m away from the point source is 20 dB.

Solution 20:
Sound level β_1:

$\beta_1 = 10 \log_{10} (I/I_o)$
Where, I_o is constant reference intensity

When the intensity doubles, the sound level:
$\beta_2 = 10 \log_{10} (2I/I_o)$

$\Rightarrow \beta_2 - \beta_1 = 10 \log(2I/I) = 10 \times 0.3010 = 3$ dB

Thus, sound level is increased by 3 dB.

Solution 21:
If sound level = 120 dB then I = intensity = 1 W/m^2
Audio output = 2W (given)

Let x be the closest distance.
So, intensity = $(2/4\pi x^2) = 1$

$\Rightarrow x^2 = 2/2\pi$

$\Rightarrow x = 0.4$ m or 40 cm

Solution 22:

Constant reference intensity = $I_o = 10^{-12}$ W/m^2

The initial intensity is:
$\beta_1 = 10 \log_{10} (I_1/I_o)$
Where, I_o is constant reference intensity

$50 = 10 \log_{10} (I_1/10^{-12})$

$\Rightarrow I_1 = 10^{-7}$ W/m^2

Similarly, $\beta_2 = 10 \log_{10} (I_2/I_o)$

$\Rightarrow I_2 = 10^{-6}$ W/m^2
Again,

$I_2/ I_1 = (p_2/p_1)^2 = 10^{-6}/10^{-7} = 10$

Therefore, $(p_2/p_1) = \sqrt{10}$.
The pressure amplitude is increased by factor $\sqrt{10}$.

Solution 23: Let I be the intensity of each student.

As per question,
$\beta_A = 10 \log_{10} (50I/I_o)$ and $\beta_B = 10 \log_{10} (100 I/I_o)$

Where, I_o is constant reference intensity
Now,
$\beta_B - \beta_A = 10 \log_{10} (100 I/50 I)$

$= 10 \log_{10}(2) = 3$

So, $\beta_A = 50 + 3 = 53$ dB

Solution 24:
Distance between maximum and minimum:

$\lambda/4 = 2.50$ cm

=> $\lambda = 2.50 \times 4 = 10$ cm $= 10^{-1}$ m

As we know, $v = f\lambda$

or $f = v/\lambda$

=> $f = 340/10^{-1} = 3400 = 3.4$ kHz

Therefore, the frequency of the sound is 3.4 kHz.

Solution 25:
(a) $\lambda/4 = 16.5$ mm

=> $\lambda = 16.5 \times 4 = 66$ mm $= 66 \times 10^{-3}$ m

We know, $v = f\lambda$

or $f = v/\lambda = 340/[66\times10^{-3}] = 5$ kHz

(b) Ratio of maximum intensity to minimum intensity:

$$\frac{I_{Max}}{I_{Min}} = \frac{K(A_1 - A_2)^2}{K(A_1 + A_2)^2} = \frac{I}{9I}$$

$$=> \frac{(A_1 - A_2)^2}{(A_1 + A_2)^2} = \frac{I}{9I}$$

$(A_1 + A_2)/(A_1 - A_2) = 1/9$

=> $A_1/A_2 = 2/1$

Ratio of the amplitudes is 2:1.

Solution 26:
The path difference of the two sound waves is:
$\Delta L = 6.4 - 6.0 = 0.4$ m

The wavelength of either wave = $\lambda = v/f = (320/f)$ m/s

For destructive interference,

$\Delta L = (2n+1)\lambda/2$; n = integer

or $0.4 = (2n+1)/2 \times (320/f)$
[using $f = 2\times0.4$]
=> $f = (2n+1)400$ Hz

On different values of n, the frequencies within the specified range that caused destructive interference are 1200 Hz, 2000 Hz, 2800 Hz, 3600 Hz and 4400 Hz.

Solution 27:

Distance between maximum and minimum intensity:

$\lambda/4 = 20$ cm

=> $\lambda = 80$ cm $= 80 \times 10^{-2}$ m

Let f Frequency of sound,
We know, $v = f\lambda$

Therefore, $f = v/\lambda$

$= 336/[80 \times 10^{-2}]$

= 420 Hz

Solution 28:

Wavelength of the source: $\lambda = d/2$

Initial path difference is $2\sqrt{[(d/2)^2 + 2d^2} - d]$

If it is shifted a distance x then path difference will be

$$2\left(\sqrt{\left(\frac{d}{2}\right)^2 + (\sqrt{2d} + x)^2}\right) - d = 2d + \frac{d}{4}$$

$$\left(\frac{d}{2}\right)^2 + (\sqrt{2d} + x)^2 = \frac{169}{64} d^2$$

$[\sqrt{(2d)} + x]^2 = [(169-16)/64]\, d^2 = (153/64)\, d^2$

=> $\sqrt{(2d)} + x = 1.54$ d

or $x = 1.54\text{ d} - 1.414\text{ d} = 0.13$ d

Solution 29:

Distance between the two speakers =d = 2.40 m
Speed of sound in air=v = 320 m/sec
Find Frequency of the two stereo speakers.

Path difference between the sound waves reaching the listener:

$\Delta x = \sqrt{[(3.2)^2 + (2.4)^2]} = 3.2$

Wavelength of either sound wave = 320/f

Now, destructive interference will occur.

$$\sqrt{(3.2)^2 + (2.4)^2} - 3.2 = \frac{(2n+1)}{2}\left(\frac{320}{f}\right)$$

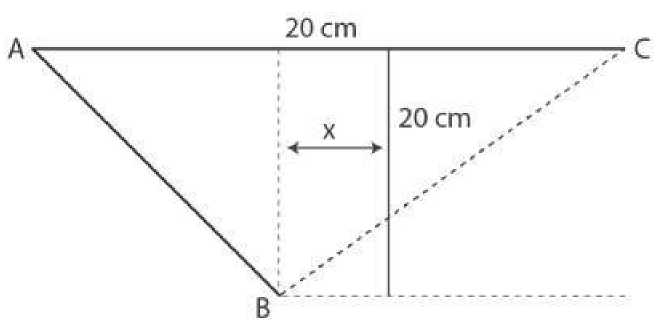
$$\sqrt{16} - 3.2 = \frac{(2n+1)}{2}\left(\frac{320}{f}\right)$$

1.6f = (2n + 1)320

=> f = 200(2n+1)

Where n = 1,2,3,...,49

Solution 30:



Wavelength of sound wave = λ = 20 cm
Distance of detector from source BD = 20 cm
Separation between the two sources AC = 20 cm

Now, Path difference = AB-BC

$= \sqrt{[(20^2+(10+x)^2]} - \sqrt{[(20^2+(10-x)^2]}$

To hear the minimum, this path difference:

$[(2n+1)\lambda]/2 = \lambda/2 = 10$ cm

$\Rightarrow \sqrt{[(20^2+(10+x)^2]} - \sqrt{[(20^2+(10-x)^2]} = 10$

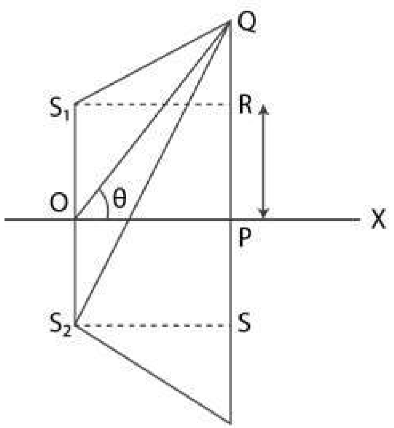
on solving above equation, we have

x = 12.6 cm

Solution 31:

f = 600 Hz and v = 330 m/s

We know, $v = f\lambda$
or $\lambda = v/f = 330/600 = 0.5$ mm



Let x be the path difference between the two sound waves reaching the man:

Form figure, $x = S_2Q - S_1 Q = yd/D$
Where y = distance travelled by man parallel to y-axis. and d = distance between the two speakers and D = Distance of man from origin.

Also, we are given d = 2m

Now, $\theta = y/D$

(a) For minimum intensity:
$x = (2n + 1)(\lambda/2)$

For n = 0

$yd/D = \lambda/2$

We know, $\theta = y/D$

$\Rightarrow \theta d = \lambda/2$

$\Rightarrow \theta = \lambda/2d = 0.55/4 = 0.1375 \text{ rad} = 7.9^\circ$

(b) For maximum intensity:

$x = n\lambda$

For n =1

$\Rightarrow yd/D = \lambda$
or $\theta = \lambda/d = 0.55/2 = 0.275 \text{ rad} = 16^\circ$

(c) The more number of maxima is given by the path difference:

$yd/D = 2\lambda, 3\lambda, ...$

$\Rightarrow y/D = \theta = 32^\circ, 64^\circ, 128^\circ$

Therefore, man can hear two more maxima at 32° and 64° because the maximum value of may be at 90°.

Solution 32:
Since the 3 sources are of the same size, the amplitude is equal to So, $A_1 = A_2 = A_3$
The resulting amplitude = 0 (By vector method)
So, the resulting intensity at B is zero.

Solution 33:
S_1 and S_2 are in the same phase. At O, there will be maximum intensity.
There will be maximum intensity at P.

From right angled triangles, ΔS_1PO and ΔS_2PO

$(S_1P)^2 - (S_2P)^2$

$= (D^2 + x^2) - ((D-2\lambda)^2 + x^2)^2$

$= 4\lambda D + 4\lambda^2$

$= 4\lambda D$

If λ is small, then λ^2 is neglisible.

$(S_1P + S_2P)(S_1P - S_2P) = 4\lambda D$

$\Rightarrow (S_1P - S_2P) = 4\lambda D/[2\sqrt{(x^2+D^2)}] = n\lambda$

$\Rightarrow 2D/\sqrt{(x^2+D^2)} = n$

or $x = (D/n)\sqrt{(4-n^2)}$

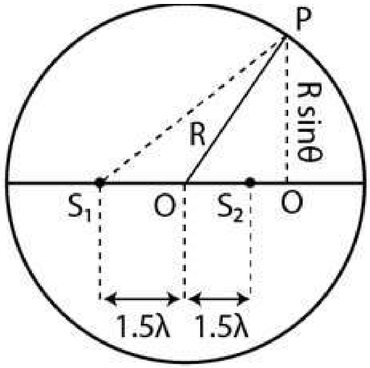
When $n = 1$, $x = \sqrt{3}D$

When $n = 2$, $x = 0$

When $x = \sqrt{3}D$, the intensity at P is equal to the intensity at O.

Solution 34:

Let S_1 and S_2 sound waves from the two coherent sources reach the point P.



From the figure,

$PS_1^2 = PQ^2 + QS^2 = (R \sin\theta)^2 + (R\cos\theta - 1.5\lambda)^2$

$PS_1^2 = PQ^2 + QS_1^2 = (R \sin\theta)^2 + (R\cos\theta - 1.5\lambda)^2$

Path difference between the sound waves reaching point P:

$(S_1P)^2 - (S_2P)^2 = [(R \sin\theta)^2 + (R\cos\theta + 1.5\lambda)^2] - [(R \sin\theta)^2 + (R\cos\theta - 1.5\lambda)^2]$

$= 6\lambda \cos\theta$

$\Rightarrow (S_1P - S_2P) = 3\lambda \cos\theta = n\lambda$

$\Rightarrow \cos\theta = n/3$

$\Rightarrow \theta = \cos^{-1}(n/3)$

Where n = 0, 1, 2, ….

θ = 0°, 48.2°, 70.5°and 90° are similar points in other quadrants.

Solution 35:

(a) When θ = 45°:
Path difference = $S_1P - S_2P = 0$
So, when the source is switched off, the intensity of sound at P is $I_o/4$.

(b) When θ = 60°, the path difference is also zero. Similarly, it can be proved that the intensity at P is $I_o/4$ When the source is switched off.