Exercise Solutions

Question 1:

Solution:

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

Question 2:

Solution:

S = 80x2 = 160m

v= 320 m/s

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

Question 3:

Solution:
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

Question 4:

Solution:
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

Question 5:

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

For minimum wavelength, frequency should be max.

f = 20 kHz

We know, v = fλ

or $\lambda = 1450/[20\times10^3] = 7.25$ cm

For minimum wavelength, frequency should be min.

λ = 20 Hz

v = fλ

λ = 1450/20 = 72.5 m

Question 6:

Solution:
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 $= 2 \times 10^{-2}$ m

$f = v/\lambda = 340/(2\times10^{-2}) = 17000$ Hz = 17 k Hz

Question 7:

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

v= fλ

λ = 340/[4.5x10^6]

= 7.6 x 10^{-5} m

(b) Velocity of sound in tissue:

v_t = 1500 m/s

λ = v_t f

λ = 1500/[4.5x10^6] m

= 3.3 x 10^{-4} m

Question 8:

Solution:
Given: r_y = 6.0 x 10^{-5} m

(a) 2π/λ = 1.8

=> λ = 2π/1.8

So, r_y/λ = [6.0 x 10^{-5} x 1.8]/2π

$= 1.7 \times 10^{-5}$ 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 = $v_y/v = [3600 \times 3 \times 10^{-5}]/1000$

Question 9:

Solution:

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

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

=> $\phi = \pi/2$

(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.

Question 10:

Solution:

(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.

Question 11:

Solution:
$p = 1 \times 10^5$ N/m^2, T = 273 K, M = 32 g and g = 32×10^{-3} kg
v = 22.4 l = 22.4×10^{-3} m^3

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

$V = \sqrt{(rp/f)} = [1.4 \times 1.0 \times 10^{-5}]/[32/22.4] = 310$ m/s

Question 12:

Solution:
velocity of sound = v_1 = 340 m/s

T_1 = 17° C = 17+273 = 290 K

Let v_2 velocity of sound at temp T_2

T_2 = 32° 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.

Question 13:

Solution:
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 x 273) - 273 = 819° C

Question 14:

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

v a √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

Question 15:

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

$v = \sqrt{(k/p)}$

where, $k = v^2 \rho$

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

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

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

$\Delta v = [2x10^5x1x10^{-3}]/[1330x1330x800]$

$= 0.14\ cm^3$

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

Question 16:

Solution:
Wavelength of sound wave = λ = 35 cm = 35×10^{-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 = $B = p_o\lambda/2\pi S_o = \Delta p/(\Delta v/v)$

$= [14 \times 35 \times 10^{-2}]/[2\pi(5.5 \times 10^{-6})]$

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

Question 17:

Solution:
(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) $I = p_o/2\rho v$

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

=> $p_o = \sqrt{(2 \times 12 \times 340 \times 44 \times 10^{-3})}$

=> $p_o = 6$ 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

Question 18:

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

We know, I a $1/r^2$

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

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

= $[1 \times 10^{-8} \times 25]/[625]$

= 4×10^{-10} W m^{-2}

Question 19:

Solution:
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)

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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),

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

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

$=> \beta_A - \beta_B = 20$

$=> \beta_B = 40\text{-}20 = 20$ dB

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

Question 20:

Solution:

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:

$\beta_2 = 10 \log_{10} (2I/I_o)$

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

Thus, sound level is increased by 3 dB.

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Question 21:

Solution:

If sound level = 120 dB then I = intensity = 1 W/m^2

Audio output = 2W (given)

Let x be the closest distance.

So, intensity = $(2/4\pi x^2) = 1$

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

=> x = 0.4 m or 40 cm

Question 22:

Solution:

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

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

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

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

$=> I_2 = 10^{-6}$ 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 $\sqrt{10}$.

Question 23:

Solution: 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

Question 24: In Quincke's experiment the sound detected is changed from a maximum to a minimum when the sliding tube is moved through a distance of 2.50 cm. Find the frequency of sound if the speed of sound in air is 340 m s^{-1}.

Solution:
Distance between maximum and minimum:

$\lambda/4 = 2.50$ cm

$\Rightarrow \lambda = 2.50 \times 4 = 10$ 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.

Question 25:

Solution:
(a) λ/4 = 16.5 mm

=> λ = 16.5 x 4 = 66 mm = 66 x 10^{-3} m

We know, v = fλ

or f = v/λ = 340/[66x10^{-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.

Question 26:

Solution:
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 = 2x0.4]
=> $f = (2n+1)400$ 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.

Question 27:

Solution:

Distance between maximum and minimum intensity:

$\lambda/4 = 20$ cm

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=> λ = 80 cm = 80 x 10^{-2} m

Let f Frequency of sound,
We know, v = fλ

Therefore, f = v/λ

= 336/[80x10^{-2}]

= 420 Hz

Question 28:

Solution:

Wavelength of the source: λ = 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

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

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

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

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

or $x = 1.54\ d - 1.414\ d = 0.13\ d$

Question 29:
Solution:

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.

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

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

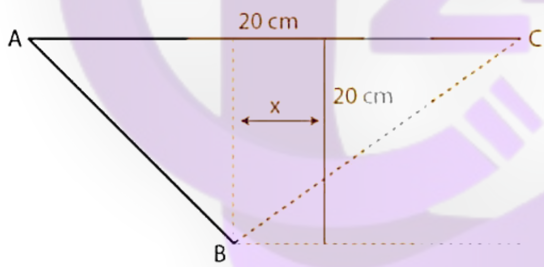
1.6f = (2n + 1)320

=> f = 200(2n+1)

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

Question 30:

Solution:



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

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

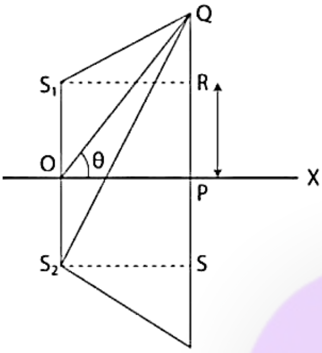
on solving above equation, we have

x = 12.6 cm

Question 31:
Solution:

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, $x = S_2Q - S_1Q = yd/D$
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

=> $yd/D = \lambda$
or $\theta = \lambda/d = 0.55/2 = 0.275$ rad = 16^o

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

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

=> $y/D = \theta = 32^o, 64^o, 128^o$

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

Question 32:

Solution:
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.

Question 33:

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Solution:

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

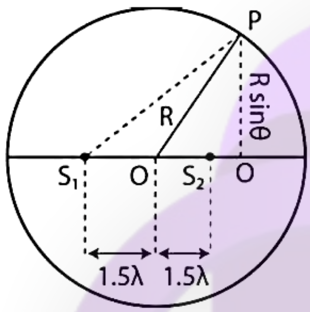
When $n = 2$, $x = 0$

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

Question 34:

Solution:

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, ….

$\theta = 0°, 48.2°, 70.5°$ and $90°$ are similar points in other quadrants.

Question 35:

Solution:

(a) When $\theta = 45°$:
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 $\theta = 60°$, 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.