SOLUTIONS TO CONCEPTS
CHAPTER – 16

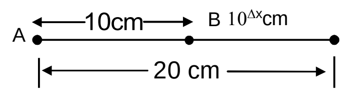
1. V_{air}= 230 m/s. V_s = 5200 m/s. Here S = 7 m
   So, $t = t_1 - t_2 = \left(\frac{1}{330} - \frac{1}{5200}\right) = 2.75 \times 10^{-3}$ sec = 2.75 ms.
2. Here given S = 80 m × 2 = 160 m.
   v = 320 m/s
   So the maximum time interval will be
   t = 5/v = 160/320 = 0.5 seconds.
3. He has to clap 10 times in 3 seconds.
   So time interval between two clap = (3/10 second).
   So the time taken go the wall = (3/2 × 10) = 3/20 seconds.
   = 333 m/s.
4. a) for maximum wavelength n = 20 Hz.
   as $\left(\eta \propto \frac{1}{\lambda}\right)$
   b) for minimum wavelength, n = 20 kHz
   $\therefore \lambda = 360/(20 \times 10^3) = 18 \times 10^{-3}$ m = 18 mm
   $\Rightarrow x = (v/n) = 360/20 = 18$ m.
5. a) for minimum wavelength n = 20 KHz
   $\Rightarrow v = n\lambda \Rightarrow \lambda = \left(\frac{1450}{20 \times 10^3}\right) = 7.25$ cm.
   b) for maximum wavelength n should be minium
   $\Rightarrow v = n\lambda \Rightarrow \lambda = v/n \Rightarrow 1450 / 20 = 72.5$ m.
6. According to the question,
   a) λ = 20 cm × 10 = 200 cm = 2 m
   v = 340 m/s
   so, $n = v/\lambda = 340/2 = 170$ Hz.
   $N = v/\lambda \Rightarrow \frac{340}{2 \times 10^{-2}}$ = 17.000 Hz = 17 KH_2 (because λ = 2 cm = 2×10^{-2} m)
7. a) Given V_{air} = 340 m/s , n = 4.5×10^6 Hz
   $\Rightarrow \lambda_{air} = (340 / 4.5) \times 10^{-6} = 7.36 \times 10^{-5}$ m.
   b) V_{tissue} = 1500 m/s $\Rightarrow \lambda_t = (1500 / 4.5) \times 10^{-6} = 3.3 \times 10^{-4}$ m.
8. Here given $r_y = 6.0 \times 10^{-5}$ m
   a) Given $2\pi/\lambda = 1.8 \Rightarrow \lambda = (2\pi/1.8)$
   So, $\frac{r_y}{\lambda} = \frac{6.0 \times (1.8) \times 10^{-5} m/s}{2\pi} = 1.7 \times 10^{-5}$ m
   b) Let, velocity amplitude = V_y
   V = dy/dt = 3600 cos (600 t – 1.8) × 10^{-5} m/s
   Here $V_y = 3600 \times 10^{-5}$ m/s
   Again, $\lambda = 2\pi/1.8$ and $T = 2\pi/600 \Rightarrow$ wave speed = $v = \lambda/T = 600/1.8 = 1000 / 3$ 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 m/s
   $\Rightarrow \lambda = \frac{v}{n} = \frac{350}{100} = 3.5$ m.
   In 2.5 ms, the distance travelled by the particle is given by
   $\Delta x = 350 \times 2.5 \times 10^{-3}$

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 $\Delta\eta = 10$ cm $= 10^{-1}$ m

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

10. a) Given $\Delta x = 10$ cm, $\lambda = 5.0$ cm



$\Rightarrow \phi = \frac{2\pi}{\lambda} \times \Delta\eta = \frac{2\pi}{5} \times 10 = 4\pi$.

So phase difference is zero.

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

11. Given that $p = 1.0 \times 10^5$ N/m^2, T = 273 K, M = 32 g = 32×10^{-3} kg

V = 22.4 litre = 22.4×10^{-3} m^3

$C/C_v = r = 3.5\ R / 2.5\ R = 1.4$

$\Rightarrow V = \frac{rp}{f} = \frac{1.4 \times 1.0 \times 10^{-5}}{32/22.4} = 310$ m/s (because $\rho = m/v$)

12. $V_1 = 330$ m/s, $V_2 = ?$

$T_1 = 273 + 17 = 290$ K, $T_2 = 272 + 32 = 305$ K

We know $v \propto \quad T$

$\frac{V_1}{V_2} = \frac{T_1}{T_2} \Rightarrow V_2 = \frac{V_1 \times T_2}{T_1}$

$= 340 \times \frac{305}{290} = 349$ m/s.

13. $T_1 = 273 \quad V_2 = 2V_1$

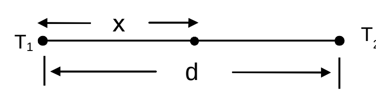
$V_1 = v \quad T_2 = ?$

We know that $V \propto \quad T \Rightarrow \frac{T_2}{T_1} = \frac{V_2^2}{V_1^2} \Rightarrow T_2 = 273 \times 2^2 = 4 \times 273$ K

So temperature will be $(4 \times 273) - 273 = 819$°c.

14. The variation of temperature is given by

$T = T_1 + \frac{(T_2 - T_2)}{d} x \qquad \ldots(1)$



We know that $V \propto \sqrt{T} \Rightarrow \frac{V_T}{V} = \sqrt{\frac{T}{273}} \Rightarrow VT = v\sqrt{\frac{T}{273}}$

$\Rightarrow dt = \frac{dx}{V_T} = \frac{du}{V} \times \sqrt{\frac{273}{T}}$

$\Rightarrow t = \frac{273}{V} \int_0^d \frac{dx}{[T_1 + (T_2 - T_1)/d)x]^{1/2}}$

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

$= T = \frac{2d}{V} \frac{\sqrt{273}}{\sqrt{T_2} + \sqrt{T_1}}$

Putting the given value we get

$= \frac{2 \times 33}{330} = \frac{\sqrt{273}}{\sqrt{280} + \sqrt{310}} = 96$ ms.

15. We know that v = $\sqrt{K/\rho}$

Where K = bulk modulus of elasticity

$\Rightarrow K = v^2 \rho = (1330)^2 \times 800\ N/m^2$

We know $K = \left(\frac{F/A}{\Delta V/V}\right)$

$\Rightarrow \Delta V = \frac{Pressures}{K} = \frac{2 \times 10^5}{1330 \times 1330 \times 800}$

So, $\Delta V = 0.15\ cm^3$

16. We know that,

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

Where P_0 = pressure amplitude $\Rightarrow P_0 = 1.0 \times 10^5$

S_0 = displacement amplitude $\Rightarrow S_0 = 5.5 \times 10^{-6}$ m

$\Rightarrow B = \frac{14 \times 35 \times 10^{-2} m}{2\pi(5.5) \times 10^{-6} m} = 1.4 \times 10^5\ N/m^2$.

17. a) Here given V_{air} = 340 m/s., Power = E/t = 20 W

f = 2,000 Hz, $\rho = 1.2\ kg/m^3$

So, intensity I = E/t.A

$= \frac{20}{4\pi r^2} = \frac{20}{4 \times \pi \times 6^2} = 44\ mw/m^2$ (because r = 6m)

b) We know that $I = \frac{P_0^2}{2\rho V_{air}} \Rightarrow P_0 = \sqrt{1 \times 2\rho V_{air}}$

$= \sqrt{2 \times 1.2 \times 340 \times 44 \times 10^{-3}} = 6.0\ N/m^2$.

c) We know that $I = 2\pi^2 S_0^2 v^2 \rho V$ where S_0 = displacement amplitude

$\Rightarrow S_0 = \sqrt{\frac{I}{\pi^2 \rho^2 \rho V_{air}}}$

Putting the value we get $S_g = 1.2 \times 10^{-6}$ m.

18. Here $I_1 = 1.0 \times 10^{-8}\ W_1/m^2$; I_2 = ?

r_1 = 5.0 m, r_2 = 25 m.

We know that $I \propto \frac{1}{r^2}$

$\Rightarrow I_1 r_1^2 = I_2 r_2^2 \Rightarrow I_2 = \frac{I_1 r_1^2}{r_2^2}$

$= \frac{1.0 \times 10^{-8} \times 25}{625} = 4.0 \times 10^{-10}\ W/m^2$.

19. We know that $\beta = 10 \log_{10}\left(\frac{I}{I_0}\right)$

$\beta_A = 10 \log \frac{I_A}{I_o}$, $\beta_B = 10 \log \frac{I_B}{I_o}$

$\Rightarrow I_A / I_0 = 10^{(\beta_A/10)} \Rightarrow I_B/I_o = 10^{(\beta_B/10)}$

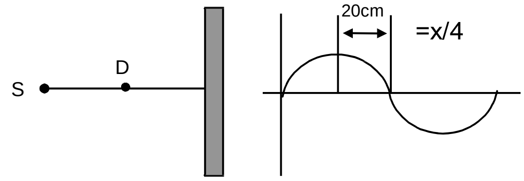
$\Rightarrow \frac{I_A}{I_B} = \frac{r_B^2}{r_A^2} = \left(\frac{50}{5}\right)^2 \Rightarrow 10^{(\beta_A - \beta_B)} = 10^2$

$\Rightarrow \frac{\beta_A - \beta_B}{10} = 2 \Rightarrow \beta_A - \beta_B = 20$

$\Rightarrow \beta_B = 40 - 20 = 20$ dβ.

20. We know that, $\beta = 10 \log_{10} J/I_0$
According to the questions
$\beta_A = 10 \log_{10} (2I/I_0)$
$\Rightarrow \beta_B - \beta_A = 10 \log (2I/I) = 10 \times 0.3010 = 3$ dB.
21. If sound level = 120 dB, then I = intensity = 1 W/m^2
Given that, audio output = 2W
Let the closest distance be x.
So, intensity = $(2 / 4\pi x^2) = 1 \Rightarrow x^2 = (2/2\pi) \Rightarrow x = 0.4$ m = 40 cm.
22. $\beta_1 = 50$ dB, $\beta_2 = 60$ dB
$\therefore I_1 = 10^{-7}$ W/m^2, $I_2 = 10^{-6}$ W/m^2
(because $\beta = 10 \log_{10} (I/I_0)$, where $I_0 = 10^{-12}$ W/m^2)
Again, $I_2/I_1 = (p_2/p_1)^2 = (10^{-6}/10^{-7}) = 10$ (where p = pressure amplitude).
$\therefore (p_2 / p_1) = \sqrt{10}$.
23. Let the intensity of each student be I.
According to the question
$$\beta_A = 10 \log_{10} \frac{50\,I}{I_0}\ ;\ \beta_B = 10 \log_{10}\left(\frac{100\,I}{I_0}\right)$$
$$\Rightarrow \beta_B - \beta_A = 10 \log_{10} \frac{50\,I}{I_0} - 10 \log_{10}\left(\frac{100\,I}{I_0}\right)$$
$$= 10 \log\left(\frac{100\,I}{50\,I}\right) = 10 \log_{10} 2 = 3$$
So, $\beta_A = 50 + 3 = 53$ dB.
24. Distance between tow maximum to a minimum is given by, $\lambda/4 = 2.50$ cm
$\Rightarrow \lambda = 10$ cm $= 10^{-1}$ m
We know, V = nx
$$\Rightarrow n = \frac{V}{\lambda} = \frac{340}{10^{-1}} = 3400 \text{ Hz} = 3.4 \text{ kHz}.$$
25. a) According to the data
$\lambda/4 = 16.5$ mm $\Rightarrow \lambda = 66$ mm $= 66 \times 10^{-6=3}$ m
$$\Rightarrow n = \frac{V}{\lambda} = \frac{330}{66 \times 10^{-3}} = 5 \text{ kHz}.$$
b) $I_{minimum} = K(A_1 - A_2)^2 = I \Rightarrow A_1 - A_2 = 11$
$I_{maximum} = K(A_1 + A_2)^2 = 9 \Rightarrow A_1 + A_2 = 31$
So, $\dfrac{A_1 + A_2}{A_1 + A_2} = \dfrac{3}{4} \Rightarrow A_1/A_2 = 2/1$
So, the ratio amplitudes is 2.
26. The path difference of the two sound waves is given by
$\Delta L = 6.4 - 6.0 = 0.4$ m
The wavelength of either wave = $\lambda = \dfrac{V}{\rho} = \dfrac{320}{\rho}$ (m/s)
For destructive interference $\Delta L = \dfrac{(2n+1)\lambda}{2}$ where n is an integers.
or 0.4 m = $\dfrac{2n+1}{2} \times \dfrac{320}{\rho}$
$$\Rightarrow \rho = n = \frac{320}{0.4} = 800\,\frac{2n+1}{2}\text{Hz} = (2n + 1)\ 400 \text{ Hz}$$
Thus the frequency within the specified range which cause destructive interference are 1200 Hz, 2000 Hz, 2800 Hz, 3600 Hz and 4400 Hz.

27. According to the given data
V = 336 m/s,
$\lambda/4$ = distance between maximum and minimum intensity
= (20 cm) $\Rightarrow \lambda$ = 80 cm
$\Rightarrow$ n = frequency = $\frac{V}{\lambda} = \frac{336}{80 \times 10^{-2}}$ = 420 Hz.



28. Here given $\lambda = d/2$

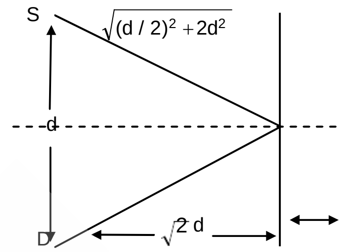
Initial path difference is given by = $2\sqrt{\left(\frac{d}{2}\right)^2 + 2d^2} - d$

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

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

$\Rightarrow \left(\frac{d}{2}\right)^2 + (\sqrt{2}d + x)^2 = \frac{169d^2}{64} \Rightarrow \frac{153}{64}d^2$

$\Rightarrow \quad \sqrt{2}d + x = 1.54\ d \Rightarrow x = 1.54\ d - 1.414\ d = 0.13\ d.$



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

Again, the wavelength of the either sound waves = $\frac{320}{\rho}$

We know, destructive interference will be occur

If $\Delta x = \frac{(2n+1)\lambda}{2}$

$\Rightarrow \sqrt{(3.2)^2 + (2.4)^2} - (3.2) = \frac{(2n+1)}{2}\frac{320}{\rho}$

Solving we get

$\Rightarrow V = \frac{(2n+1)400}{2} = 200(2n+1)$

where n = 1, 2, 3, …… 49. (audible region)

A A
$(3.2)^2 + (2.4)^2$
A

30. According to the data
λ = 20 cm, S_1S_2 = 20 cm, BD = 20 cm
Let the detector is shifted to left for a distance x for hearing the minimum sound.
So path difference AI = BC – AB

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

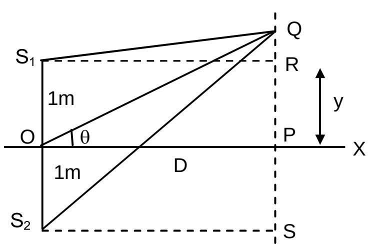
So the minimum distances hearing for minimum

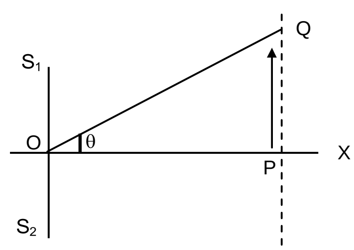
$= \frac{(2n+1)\lambda}{2} = \frac{\lambda}{2} = \frac{20}{2} = 10$ cm

$\Rightarrow \sqrt{(20)^2 + (10+x)^2} - \sqrt{(20)^2 + (10-x)^2}$ = 10 solving we get x = 12.0 cm.

A 20cm C
x 20cm
B

31.





Given, F = 600 Hz, and v = 330 m/s $\Rightarrow \lambda$ = v/f = 330/600 = 0.55 mm

Let OP = D, PQ = y $\Rightarrow \theta = y/R$ …(1)

Now path difference is given by, $x = S_2Q - S_1Q = yd/D$

Where d = 2m

[The proof of x = yd/D is discussed in interference of light waves]

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

$\therefore$ $yd/D = \lambda/2$ [for minimum y, $x = \lambda/2$]

$\therefore$ $y/D = \theta = \lambda/2 = 0.55 / 4 = 0.1375$ rad $= 0.1375 \times (57.1)° = 7.9°$

b) For minimum intensity, $x = 2n(\lambda/2)$

$yd/D = \lambda \Rightarrow y/D = \theta = \lambda/D = 0.55/2 = 0.275$ rad

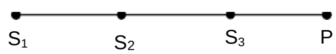
$\therefore$ $\theta = 16°$

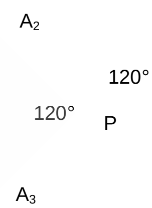
c) For more maxima,

$yd/D = 2\lambda, 3\lambda, 4\lambda, \ldots$

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

But since, the maximum value of θ can be 90°, he will hear two more maximum i.e. at 32° and 64°.

32. 



Because the 3 sources have equal intensity, amplitude are equal

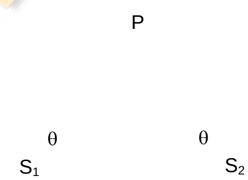
So, $A_1 = A_2 = A_3$

As shown in the figure, amplitude of the resultant = 0 (vector method)

So, the resultant, intensity at B is zero.

33. The two sources of sound S_1 and S_2 vibrate at same phase and frequency.

Resultant intensity at P = I_0



a) Let the amplitude of the waves at S_1 and S_2 be 'r'.

When $\theta = 45°$, path difference $= S_1P - S_2P = 0$ (because $S_1P = S_2P$)

So, when source is switched off, intensity of sound at P is $I_0/4$.

b) When $\theta = 60°$, path difference is also 0.

Similarly it can be proved that, the intensity at P is $I_0 / 4$ when one is switched off.

34. If V = 340 m/s, I = 20 cm $= 20 \times 10^{-2}$ m

Fundamental frequency $= \dfrac{V}{21} = \dfrac{340}{2 \times 20 \times 10^{-2}} = 850$ Hz

We know first over tone $= \dfrac{2V}{21} = \dfrac{2 \times 340}{2 \times 20 \times 10^{-2}}$ (for open pipe) = 1750 Hz

Second over tone = 3 (V/21) = 3 × 850 = 2500 Hz.

35. According to the questions V = 340 m/s, n = 500 Hz

We know that V/4l (for closed pipe)

$\Rightarrow l = \dfrac{340}{4 \times 500}$ m = 17 cm.

36. Here given distance between two nodes is = 4. 0 cm,

$\Rightarrow \lambda = 2 \times 4.0 = 8$ cm

We know that $v = n\lambda$

$\Rightarrow \eta = \dfrac{328}{8 \times 10^{-2}} = 4.1$ Hz.

37. V = 340 m/s

Distances between two nodes or antinodes

$\Rightarrow \lambda/4 = 25$ cm

$\Rightarrow \lambda = 100$ cm = 1 m

$\Rightarrow n = v/\lambda = 340$ Hz.

38. Here given that 1 = 50 cm, v = 340 m/s

As it is an open organ pipe, the fundamental frequency $f_1 = (v/21)$

$= \dfrac{340}{2 \times 50 \times 10^{-2}} = 340$ Hz.

So, the harmonies are
$f_3 = 3 \times 340 = 1020$ Hz
$f_5 = 5 \times 340 = 1700$, $f_6 = 6 \times 340 = 2040$ Hz
so, the possible frequencies are between 1000 Hz and 2000 Hz are 1020, 1360, 1700.

39. Here given $l_2 = 0.67$ m, $l_1 = 0.2$ m, f = 400 Hz
We know that
$\lambda = 2(l_2 - l_1) \Rightarrow \lambda = 2(62 - 20) = 84$ cm = 0.84 m.
So, $v = n\lambda = 0.84 \times 400 = 336$ m/s
We know from above that,
$l_1 + d = \lambda/4 \Rightarrow d = \lambda/4 - l_1 = 21 - 20 = 1$ cm.

40. According to the questions
f_1 first overtone of a closed organ pipe $P_1 = 3v/4l = \frac{3 \times V}{4 \times 30}$
f_2 fundamental frequency of a open organ pipe $P_2 = \frac{V}{2l_2}$
Here given $\frac{3V}{4 \times 30} = \frac{V}{2l_2} \Rightarrow l_2 = 20$ cm
$\therefore$ length of the pipe P_2 will be 20 cm.

41. Length of the wire = 1.0 m
For fundamental frequency $\lambda/2 = l$
$\Rightarrow \lambda = 2l = 2 \times 1 = 2$ m
Here given n = 3.8 km/s = 3800 m/s
We know $\Rightarrow v = n\lambda \Rightarrow n = 3800 / 2 = 1.9$ kH.
So standing frequency between 20 Hz and 20 kHz which will be heard are
$= n \times 1.9$ kHz where n = 0, 1, 2, 3, … 10.

42. Let the length will be l.
Here given that V = 340 m/s and n = 20 Hz
Here $\lambda/2 = l \Rightarrow \lambda = 2l$
We know $V = n\lambda \Rightarrow l = \frac{V}{n} = \frac{340}{2 \times 20} = \frac{34}{4} = 8.5$ cm (for maximum wavelength, the frequency is minimum).

43. a) Here given l = 5 cm = 5×10^{-2} m, v = 340 m/s
$\Rightarrow n = \frac{V}{2l} = \frac{340}{2 \times 5 \times 10^{-2}} = 3.4$ KHz
b) If the fundamental frequency = 3.4 KHz
$\Rightarrow$ then the highest harmonic in the audible range (20 Hz – 20 KHz)
$= \frac{20000}{3400} = 5.8 = 5$ (integral multiple of 3.4 KHz).

44. The resonance column apparatus is equivalent to a closed organ pipe.
Here l = 80 cm = 10×10^{-2} m ; v = 320 m/s
$\Rightarrow n_0 = v/4l = \frac{320}{4 \times 50 \times 10^{-2}} = 100$ Hz
So the frequency of the other harmonics are odd multiple of $n_0 = (2n + 1)$ 100 Hz
According to the question, the harmonic should be between 20 Hz and 2 KHz.

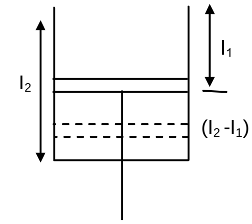
45. Let the length of the resonating column will be = 1
Here V = 320 m/s
Then the two successive resonance frequencies are $\frac{(n+1)v}{4l}$ and $\frac{nv}{4l}$
Here given $\frac{(n+1)v}{4l} = 2592$; $\lambda = \frac{nv}{4l} = 1944$
$\Rightarrow \frac{(n+1)v}{4l} - \frac{nv}{4l} = 2592 - 1944 = 548$ cm = 25 cm.

46. Let, the piston resonates at length l_1 andl_2

Here, l = 32 cm; v = ?, n = 512 Hz

Now $\Rightarrow 512 = v/\lambda$

$\Rightarrow v = 512 \times 0.64 = 328$ m/s.



47. Let the length of the longer tube be L_2 and smaller will be L_1.

According to the data $440 = \dfrac{3 \times 330}{4 \times L_2}$ …(1) (first over tone)

and $440 = \dfrac{330}{4 \times L_1}$ …(2) (fundamental)

solving equation we get $L_2 = 56.3$ cm and $L_1 = 18.8$ cm.

48. Let n_0 = frequency of the turning fork, T = tension of the string

L = 40 cm = 0.4 m, m = 4g = 4×10^{-3} kg

So, m = Mass/Unit length = 10^{-2} kg/m

$n_0 = \dfrac{1}{2l}\sqrt{\dfrac{T}{m}}$.

So, 2^{nd} harmonic $2n_0 = (2/2l) \quad T/m$

As it is unison with fundamental frequency of vibration in the air column

$\Rightarrow 2n_0 = \dfrac{340}{4 \times 1} = 85$ Hz

$\Rightarrow 85 = \dfrac{2}{2 \times 0.4} \quad \dfrac{T}{14} \Rightarrow T = 85^2 \times (0.4)^2 \times 10^{-2} = 11.6$ Newton.

49. Given, m = 10 g = 10×10^{-3} kg, l = 30 cm = 0.3 m

Let the tension in the string will be = T

μ = mass / unit length = 33×10^{-3} kg

The fundamental frequency $\Rightarrow n_0 = \dfrac{1}{2l} \quad \dfrac{T}{\mu}$ …(1)

The fundamental frequency of closed pipe

$\Rightarrow n_0 = (v/4l) \quad \dfrac{340}{4 \times 50 \times 10^2} = 170$ Hz …(2)

According equations (1) × (2) we get

$170 = \dfrac{1}{2 \times 30 \times 10^{-2}} \times \quad \dfrac{T}{33 \times 10^{-3}}$

$\Rightarrow T = 347$ Newton.

50. We know that $f \propto \sqrt{T}$

According to the question $f + \Delta f \propto \sqrt{\Delta T} + T$

$\Rightarrow \dfrac{f + \Delta f}{f} = \sqrt{\dfrac{\Delta t + T}{T}} \Rightarrow 1 + \dfrac{\Delta f}{f} = \left(1 + \dfrac{\Delta T}{T}\right)^{1/2} = 1 + \dfrac{1}{2}\dfrac{\Delta T}{T} + \ldots$ (neglecting other terms)

$\Rightarrow \dfrac{\Delta f}{f} = (1/2)\dfrac{\Delta T}{T}$.

51. We know that the frequency = f, T = temperatures

$f \propto \sqrt{T}$

So $\dfrac{f_1}{f_2} = \dfrac{\sqrt{T_1}}{\sqrt{T_2}} \Rightarrow \dfrac{293}{f_2} = \dfrac{\sqrt{293}}{\sqrt{295}}$

$\Rightarrow f_2 = \dfrac{293 \times \sqrt{295}}{\sqrt{293}} = 294$

52. V_{rod} = ?, V_{air} = 340 m/s, $L_r = 25 \times 10^{-2}$, $d_2 = 5 \times 10^{-2}$ metres

$$\frac{V_r}{V_a} = \frac{2L_r}{D_a} \Rightarrow V_r = \frac{340 \times 25 \times 10^{-2} \times 2}{5 \times 10^{-2}} = 3400 \text{ m/s.}$$

53. a) Here given, $L_r = 1.0/2 = 0.5$ m, $d_a = 6.5$ cm $= 6.5 \times 10^{-2}$ m

As Kundt's tube apparatus is a closed organ pipe, its fundamental frequency

$$\Rightarrow n = \frac{V_r}{4L_r} \Rightarrow V_r = 2600 \times 4 \times 0.5 = 5200 \text{ m/s.}$$

b) $$\frac{V_r}{V_a} = \frac{2L_r}{d_a} \Rightarrow v_a = \frac{5200 \times 6.5 \times 10^{-2}}{2 \times 0.5} = 338 \text{ m/s.}$$

54. As the tunning fork produces 2 beats with the adjustable frequency the frequency of the tunning fork will be $\Rightarrow$ n = (476 + 480) / 2 = 478.

55. A tuning fork produces 4 beats with a known tuning fork whose frequency = 256 Hz
So the frequency of unknown tuning fork = either 256 – 4 = 252 or 256 + 4 = 260 Hz
Now as the first one is load its mass/unit length increases. So, its frequency decreases.
As it produces 6 beats now original frequency must be 252 Hz.
260 Hz is not possible as on decreasing the frequency the beats decrease which is not allowed here.

56. Group – I
Given V = 350
$\lambda_1 = 32$ cm
$= 32 \times 10^{-2}$ m
So η_1 = frequency = 1093 Hz

Group – II
v = 350
$\lambda_2 = 32.2$ cm
$= 32.2 \times 10^{-2}$ m
$\eta_2 = 350 / 32.2 \times 10^{-2} = 1086$ Hz

So beat frequency = 1093 – 1086 = 7 Hz.

57. Given length of the closed organ pipe, $l = 40$ cm $= 40 \times 10^{-2}$ m
$V_{air} = 320$

So, its frequency $\rho = \dfrac{V}{4l} = \dfrac{320}{4 \times 40 \times 10^{-2}} = 200$ Hertz.

As the tuning fork produces 5 beats with the closed pipe, its frequency must be 195 Hz or 205 Hz.
Given that, as it is loaded its frequency decreases.
So, the frequency of tuning fork = 205 Hz.

58. Here given $n_B = 600 = \dfrac{1}{2l}\dfrac{TB}{14}$

As the tension increases frequency increases
It is given that 6 beats are produces when tension in A is increases.

So, $n_A \Rightarrow 606 = \dfrac{1}{2l}\sqrt{\dfrac{TA}{M}}$

$$\Rightarrow \frac{n_A}{n_B} = \frac{600}{606} = \frac{(1/2l)\sqrt{(TB/M)}}{(1/2l)\sqrt{(TA/M)}} = \frac{\sqrt{TB}}{\sqrt{TA}}$$

$$\Rightarrow \frac{\sqrt{T_A}}{\sqrt{T_B}} = \frac{606}{600} = 1.01 \qquad \Rightarrow \frac{T_A}{T_B} = 1.02.$$

59. Given that, $l = 25$ cm $= 25 \times 10^{-2}$ m

By shortening the wire the frequency increases, [$f = (1/2l)\sqrt{(TB/M)}$]

As the vibrating wire produces 4 beats with 256 Hz, its frequency must be 252 Hz or 260 Hz.
Its frequency must be 252 Hz, because beat frequency decreases by shortening the wire.

$$\text{So, } 252 = \frac{1}{2 \times 25 \times 10^{-2}}\sqrt{\frac{T}{M}} \qquad \ldots(1)$$

Let length of the wire will be l, after it is slightly shortened,

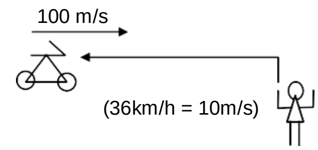
$\Rightarrow 256 = \dfrac{1}{2 \times l_1}\sqrt{\dfrac{T}{M}}$ …(2)

Dividing (1) by (2) we get

$\dfrac{252}{256} = \dfrac{l_1}{2 \times 25 \times 10^{-2}} \Rightarrow l_1 = \dfrac{252 \times 2 \times 25 \times 10^{-2}}{260} = 0.2431$ m

So, it should be shorten by (25 – 24.61) = 0.39 cm.

60. Let u = velocity of sound; V_m = velocity of the medium;
v_o = velocity of the observer; v_a = velocity of the sources.



$f = \left(\dfrac{\vec{u} + \vec{v}_m - \vec{v}_o}{\vec{v} + \vec{v}_m - \vec{v}_s}\right)F$

using sign conventions in Doppler's effect,

$V_m = 0$, u = 340 m/s, $v_s = 0$ and v_o = –10 m (36 km/h = 10 m/s)

$= \left(\dfrac{340 + 0 - (-10)}{340 + 0 - 0}\right) \times$ 2KHz = 350/340 × 2 KHz = 2.06 KHz.

61. $f^1 = \left(\dfrac{\vec{u} + \vec{v}_m - \vec{v}_o}{\vec{u} + \vec{v}_m - \vec{v}_s}\right)f$ [18 km/h = 5 m/s]

18km/h = 5m/s

using sign conventions,

app. Frequency = $\left(\dfrac{340 + 0 - 0}{340 + 0 - 5}\right) \times 2400 = 2436$ Hz.

62.

I II

a) Given v_s = 72 km/hour = 20 m/s, ρ = 1250

apparent frequency = $\dfrac{340 + 0 + 0}{340 + 0 - 20} \times 1250 = 1328\ H_2$

b) For second case apparent frequency will be = $\dfrac{340 + 0 + 0}{340 + 0 - (-20)} \times 1250 = 1181$ Hz.

63. Here given, apparent frequency = 1620 Hz

So original frequency of the train is given by

$1620 = \left(\dfrac{332 + 0 + 0}{332 - 15}\right) f \Rightarrow f = \left(\dfrac{1620 \times 317}{332}\right)$ Hz

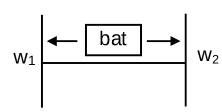
So, apparent frequency of the train observed by the observer in

$f^1 = \left(\dfrac{332 + 0 + 0}{332 + 15}\right) f \times \left(\dfrac{1620 \times 317}{332}\right) = \dfrac{317}{347} \times 1620 = 1480$ Hz.

64. Let, the bat be flying between the walls W_1 and W_2.

So it will listen two frequency reflecting from walls W_2 and W_1.

So, apparent frequency, as received by wall W = $fw_2 = \dfrac{330 + 0 + 0}{330 - 6} \times f = 330/324$



Therefore, apparent frequency received by the bat from wall W_2 is given by

F of wall $W_{B_2 1} = \left(\dfrac{330 + 0 - (-6)}{330 + 0 + 0}\right) f_{w_2} = \left(\dfrac{336}{330}\right) \times \left(\dfrac{330}{324}\right) f$

Similarly the apparent frequency received by the bat from wall W_1 is

$f_{B_1} = (324/336)f$

So the beat frequency heard by the bat will be = 4.47 × 10^4 = 4.3430 × 10^4 = 3270 Hz.

65. Let the frequency of the bullet will be f

Given, u = 330 m/s, v_s = 220 m/s

a) Apparent frequency before crossing = $f' = \left(\frac{330}{330 - 220}\right) f = 3f$

b) Apparent frequency after crossing = $f'' = \left(\frac{330}{530 + 220}\right) f = 0.6\ f$

So, $\left(\frac{f'}{f'}\right) = \frac{0.6f}{3f} = 0.2$

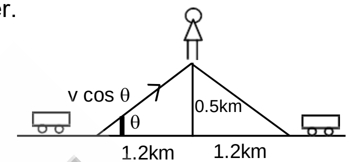
Therefore, fractional change = 1 – 0.2 = 0.8.

66. The person will receive, the sound in the directions BA and CA making an angle θ with the track.

Here, $\theta = \tan^{-1}(0.5/2.4) = 22°$

So the velocity of the sources will be ‘v cos θ’ when heard by the observer.

So the apparent frequency received by the man from train B.



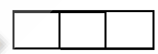
$f' = \left(\frac{340 + 0 + 0}{340 - v\cos 22°}\right) 500 = 529$ Hz

And the apparent frequency heard but the man from train C,

$f'' = \left(\frac{340 + 0 + 0}{340 - v\cos 22°}\right) \times 500 = 476$ Hz.

67. Let the velocity of the sources is = v_s

a) The beat heard by the standing man = 4



So, frequency = 440 + 4 = 444 Hz or 436 Hz

$\Rightarrow 440 = \left(\frac{340 + 0 + 0}{340 - v_s}\right) \times 400$

On solving we get V_s = 3.06 m/s = 11 km/hour.

b) The sitting man will listen less no.of beats than 4.

68. Here given velocity of the sources $v_s = 0$

Velocity of the observer v_0 = 3 m/s

So, the apparent frequency heard by the man = $\left(\frac{332 + 3}{332}\right) \times 256 = 258.3$ Hz.

from the approaching tuning form = f′

f'' = [(332–3)/332] × 256 = 253.7 Hz.

So, beat produced by them = 258.3 – 253.7 = 4.6 Hz.

69. According to the data, V_s = 5.5 m/s for each turning fork.

So, the apparent frequency heard from the tuning fork on the left,

$f' = \left(\frac{330}{330 - 5.5}\right) \times 512 = 527.36$ Hz = 527.5 Hz

similarly, apparent frequency from the tunning fork on the right,

$f'' = \left(\frac{330}{330 + 5.5}\right) \times 512 = 510$ Hz

So, beats produced 527.5 – 510 = 17.5 Hz.

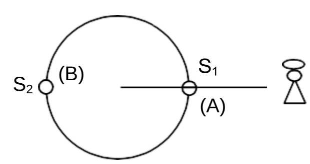
70. According to the given data

Radius of the circle = $100/\pi \times 10^{-2}$ m = $(1/\pi)$ metres; ω = 5 rev/sec.

So the linear speed v = $\omega r = 5/\pi = 1.59$

So, velocity of the source V_s = 1.59 m/s

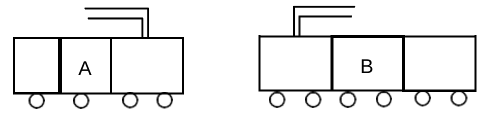
As shown in the figure at the position A the observer will listen maximum and at the position B it will listen minimum frequency.



So, apparent frequency at A = $\frac{332}{332 - 1.59} \times 500 = 515$ Hz

Apparent frequency at B = $\frac{332}{332 + 1.59} \times 500 = 485$ Hz.

71. According to the given data V_s = 90 km/hour = 25 m/sec.
v_0 = 25 m/sec
So, apparent frequency heard by the observer in train B or observer in = $\left(\frac{350+25}{350-25}\right)$ × 500 = 577 Hz.



72. Here given $f_s = 16 \times 10^3$ Hz
Apparent frequency $f' = 20 \times 10^3$ Hz (greater than that value)
Let the velocity of the observer = v_o
Given $v_s = 0$
So $20 \times 10^3 = \left(\frac{330+v_o}{330+0}\right) \times 16 \times 10^3$

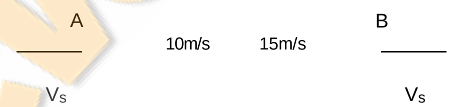
$\Rightarrow (330 + v_o) = \frac{20 \times 330}{16}$

$\Rightarrow v_o = \frac{20 \times 330 - 16 \times 330}{4} = \frac{330}{4}$ m/ s = 297 km/h

b) This speed is not practically attainable ordinary cars.

73. According to the questions velocity of car A = V_A = 108 km/h = 30 m/s
V_B = 72 km/h = 20 m/s, f = 800 Hz
So, the apparent frequency heard by the car B is given by,
$f' = \left(\frac{330-20}{330-30}\right) \times 800 \Rightarrow 826.9 = 827$ Hz.

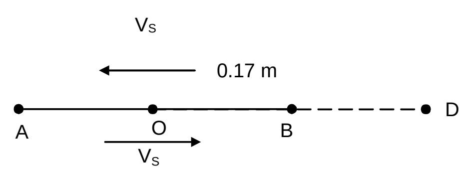
74. a) According to the questions, v = 1500 m/s, f = 2000 Hz, v_s = 10 m/s, v_o = 15 m/s
So, the apparent frequency heard by the submarine B,
$= \left(\frac{1500+15}{1500-10}\right) \times 2000 = 2034$ Hz



b) Apparent frequency received by submarine A,
$= \left(\frac{1500+10}{1500-15}\right) \times 2034 = 2068$ Hz.

75. Given that, r = 0.17 m, F = 800 Hz, u = 340 m/s
Frequency band = $f_1 - f_2$ = 6 Hz
Where f_1 and f_2 correspond to the maximum and minimum apparent frequencies (both will occur at the mean position because the velocity is maximum).

Now, $f_1 = \left(\frac{340}{340-v_s}\right) f$ and $f_2 = \left(\frac{340}{340+v_s}\right) f$



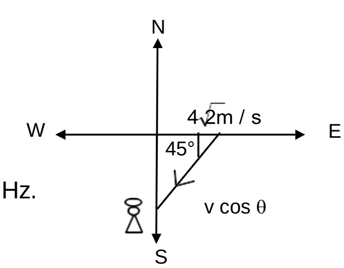
$\therefore f_1 - f_2 = 8$

$\Rightarrow 340 f \left(\frac{1}{340-v_s} - \frac{1}{340+v_s}\right) = 8$

$\Rightarrow \frac{2v_s}{340^2 - v_s^2} = \frac{8}{340 \times 800}$

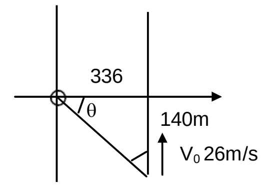
$\Rightarrow 340^2 - v_s^2 = 68000\ v_s$
Solving for v_s we get, v_s = 1.695 m/s
For SHM, $v_s = r\omega \Rightarrow \omega = (1.695/0.17) = 10$
So, $T = 2\pi / \omega = \pi/5 = 0.63$ sec.

76. u = 334 m/s, $v_b = 4\sqrt{2}$ m/s, $v_o = 0$
so, $v_s = V_b \cos\theta = 4\sqrt{2} \times (1/\sqrt{2}) = 4$ m/s.
so, the apparent frequency $f' = \left(\frac{u+0}{u - v_b \cos\theta}\right) f = \left(\frac{334}{334-4}\right) \times 1650 = 1670$ Hz.



77. $u = 330$ m/s, $v_0 = 26$ m/s

a) Apparent frequency at, $y = -336$

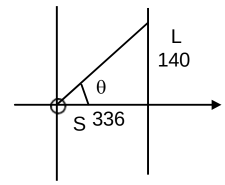


$$m = \left(\frac{v}{v - u\sin\theta}\right) \times f$$

$$= \left(\frac{330}{330 - 26\sin 23°}\right) \times 660$$

[because, $\theta = \tan^{-1}(140/336) = 23°$] = 680 Hz.

b) At the point $y = 0$ the source and listener are on a x-axis so no apparent change in frequency is seen. So, $f = 660$ Hz.



c) As shown in the figure $\theta = \tan^{-1}(140/336) = 23°$

Here given, = 330 m/s ; $v = V\sin 23° = 10.6$ m/s

So, $F'' = \dfrac{u}{u + v\sin 23°} \times 660 = 640$ Hz.

78. V_{train} or $V_s = 108$ km/h = 30 m/s; $u = 340$ m/s

a) The frequency by the passenger sitting near the open window is 500 Hz, he is inside the train and does not hair any relative motion.

b) After the train has passed the apparent frequency heard by a person standing near the track will be, so $f'' = \left(\dfrac{340 + 0}{340 + 30}\right) \times 500 = 459$ Hz

c) The person inside the source will listen the original frequency of the train.

Here, given $V_m = 10$ m/s

For the person standing near the track

Apparent frequency = $\dfrac{u + V_m + 0}{u + V_m - (-V_s)} \times 500 = 458$ Hz.

79. To find out the apparent frequency received by the wall,

a) $V_s = 12$ km/h = 10/3 = m/s

$V_o = 0$, $u = 330$ m/s

So, the apparent frequency is given by = $f' = \left(\dfrac{330}{330 - 10/3}\right) \times 1600 = 1616$ Hz

b) The reflected sound from the wall whistles now act as a sources whose frequency is 1616 Hz.

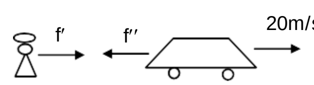
So, $u = 330$ m/s, $V_s = 0$, $V_o = 10/3$ m/s

So, the frequency by the man from the wall,

$\Rightarrow f'' = \left(\dfrac{330 + 10/3}{330}\right) \times 1616 = 1632$ m/s.

80. Here given, $u = 330$ m/s, $f = 1600$ Hz

So, apparent frequency received by the car



$f' = \left(\dfrac{u - V_o}{u - V_s}\right) f = \left(\dfrac{330 - 20}{330}\right) \times 1600$ Hz … [$V_o = 20$ m/s, $V_s = 0$]

The reflected sound from the car acts as the source for the person.

Here, $V_s = -20$ m/s, $V_o = 0$

So $f'' = \left(\dfrac{330 - 0}{330 + 20}\right) \times f' = \dfrac{330}{350} \times \dfrac{310}{330} \times 160 = 1417$ Hz.

$\therefore$ This is the frequency heard by the person from the car.

81. a) $f = 400$ Hz,, $u = 335$ m/s

$\Rightarrow \lambda\ (v/f) = (335/400) = 0.8$ m = 80 cm

b) The frequency received and reflected by the wall,

$f' = \left(\dfrac{u - V_o}{u - V_s}\right) \times f = \dfrac{335}{320} \times 400$ …[$V_s = 54$ m/s and $V_o = 0$]

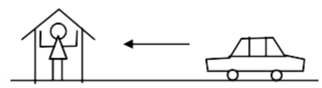
$\Rightarrow x' = (v/f) = \dfrac{320 \times 335}{335 \times 400} = 0.8 \text{ m} = 80 \text{ cm}$

c) The frequency received by the person sitting inside the car from reflected wave,
$f' = \left(\dfrac{335-0}{335-15}\right) f = \dfrac{335}{320} \times 400 = 467$ $[V_s = 0 \text{ and } V_o = -15 \text{ m/s}]$

d) Because, the difference between the original frequency and the apparent frequency from the wall is very high (437 – 440 = 37 Hz), he will not hear any beats.mm)

82. f = 400 Hz, u = 324 m/s, $f' = \dfrac{u-(-v)}{u-(0)} f = \dfrac{324+v}{324} \times 400$ …(1)

for the reflected wave,



$f'' = 410 = \dfrac{u-0}{u-v} f'$

$\Rightarrow 410 = \dfrac{324}{324-v} \times \dfrac{324+v}{324} \times 400$

$\Rightarrow 810\, v = 324 \times 10$

$\Rightarrow v = \dfrac{324 \times 10}{810} = 4$ m/s.

83. f = 2 kHz, v = 330 m/s, u = 22 m/s

At t = 0, the source crosses P

S P 330m Q

a) Time taken to reach at Q is

$t = \dfrac{S}{v} = \dfrac{330}{330} = 1$ sec

b) The frequency heard by the listner is

$f' = f\left(\dfrac{v}{v - u\cos\theta}\right)$

since, θ = 90°

f′ = 2 × (v/u) = 2 KHz.

c) After 1 sec, the source is at 22 m from P towards right.

84. t = 4000 Hz, u = 22 m/s

Let ‘t’ be the time taken by the source to reach at ‘O’. Since observer hears the sound at the instant it crosses the ‘O’, ‘t’ is also time taken to the sound to reach at P.

∴ OQ = ut and QP = vt

Cos θ = u/v

Velocity of the sound along QP is (u cos θ).

S u=22m/s θ P S′ O 660m/s

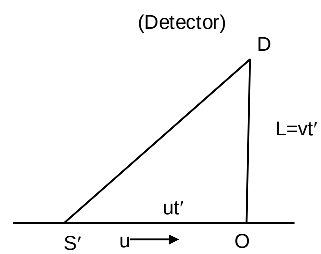
$f' = f\left(\dfrac{v-0}{v-u\cos\theta}\right) = f\left(\dfrac{v}{v - \dfrac{u^2}{v}}\right) = f\left(\dfrac{v^2}{v^2-u^2}\right)$

Putting the values in the above equation, $f' = 4000 \times \dfrac{330^2}{330^2 - 22^2} = 4017.8 = 4018$ Hz.

85. a) Given that, f = 1200 Hz, u = 170 m/s, L = 200 m, v = 340 m/s

From Doppler’s equation (as in problem no.84)

$f' = f\left(\dfrac{v^2}{v^2-u^2}\right) = 1200 \times \dfrac{340^2}{340^2-170^2} = 1600$ Hz.



b) v = velocity of sound, u = velocity of source

let, t be the time taken by the sound to reach at D

DO = vt′ = L, and S′O = ut′

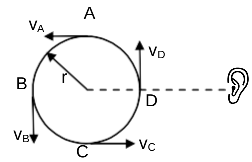
t′ = L/V

$S'D = \sqrt{S'O^2 + DO^2} = \sqrt{\frac{u^2L^2}{v^2} + L^2} = \frac{L}{v}\sqrt{u^2 + v^2}$

Putting the values in the above equation, we get

$S'D = \frac{220}{340}\sqrt{170^2 + 340^2} = 223.6$ m.

86. Given that, r = 1.6 m, f = 500 Hz, u = 330 m/s



a) At A, velocity of the particle is given by

$v_A = \sqrt{rg} = \sqrt{1.6 \times 10} = 4$ m/s

and at C, $v_c = \sqrt{5rg} = \sqrt{5 \times 1.6 \times 10} = 8.9$ m/s

So, maximum frequency at C,

$f'_c = \frac{u}{u - v_s} f = \frac{330}{330 - 8.9} \times 500 = 513.85$ Hz.

Similarly, maximum frequency at A is given by $f'_A = \frac{u}{u - (-v_s)} f = \frac{330}{330 + 4}(500) = 494$ Hz.

b) Velocity at B = $\sqrt{3rg} = \sqrt{3 \times 1.6 \times 10} = 6.92$ m/s

So, frequency at B is given by,

$f_B = \frac{u}{u + v_s} \times f = \frac{330}{330 + 6.92} \times 500 = 490$ Hz

and frequency at D is given by,

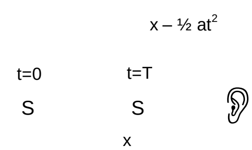
$f_D = \frac{u}{u - v_s} \times f = \frac{330}{330 - 6.92} \times 500$

87. Let the distance between the source and the observer is 'x' (initially)

So, time taken for the first pulse to reach the observer is $t_1 = x/v$

and the second pulse starts after T (where, T = 1/v)

and it should travel a distance $\left(x - \frac{1}{2}aT^2\right)$.



So, $t_2 = T + \frac{x - 1/2\, aT^2}{v}$

$t_2 - t_1 = T + \frac{x - 1/2\, aT^2}{v} - \frac{x}{v} = T - \frac{1}{2}\frac{aT^2}{v}$

Putting = T = 1/v, we get

$t_2 - t_1 = \frac{2uv - a}{2vv^2}$

so, frequency heard = $\frac{2vv^2}{2uv - a}$ (because, $f = \frac{1}{t_2 - t_1}$)

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