CHAPTER = 12 ACOUSTICS
BOOK NUMERICAL

1 The equation of a wave is $\boldsymbol{y(x,t)} = \boldsymbol{3.5\sin\left\{\frac{\pi}{3.0}\,x - 66\,t\right\}}$ cm where t is in seconds and $\boldsymbol{x}$ and y both are in cm. Find (a) the amplitude and (b) the wavelength of this wave.

Wave equation is given by

$$\boldsymbol{y(x,t) = 3.5\sin\left\{\frac{\pi}{3.0}\,x - 66\,t\right\}}$$

$$\boldsymbol{y(x,t) = A\ \sin\{\,k\ x - \omega\ t\}}$$

Amplitude

A = 3.5 cm

Wavelength of wave

$$k = \frac{\pi}{3.0}$$

$$\frac{2\,\pi}{\lambda} = \frac{\pi}{3.0}$$

$$\frac{2}{\lambda} = \frac{1}{3.0}$$

$$\lambda = 6.0\ cm$$

2 Why is it that your own voice sounds strange to you when you hear it played back on a tape recorder, but your friends all agree that it is just what your voice sounds like?

Ans We normally here our own voice while talking we receive both sound transfer to our ears externally by air condition and sound transfer internally through our bones this bone conduction of sound delivers rich low frequency that are not included in air conducted vocal sound so that the voice you hear in your head when you speak is the result of both methods of transmission

When you hear your voice on a recording, you're only hearing sounds transmitted via air conduction. Since you're missing the part of the sound that comes from bone conduction within the head, your voice sounds different to you on a recording.

3 Why the speed of sound in solids is much faster than the speed of sound in air?

Ans In solid structure, as the particles are very closely placed to each other and there is less movement of the particles. This close proximity allows the energy of the sound wave to be transferred more quickly from particle to particle, resulting in a faster speed of sound. In contrast, the particles in air are much further apart. When a sound wave travels through air, it has to transfer its energy from one particle to the next over these greater distances. This takes more time, so the speed of sound is slower in air than in solids.

4 An increase in pressure of 100 k Pa causes a certain volume of water to decrease by $5x10^{-3}$percent of its original volume. Find (a) Bulk modulus of water. (b) What is the speed of sound in water?

DATA	SOLUTIONS
$\Delta P = 100\,kPa = 1 \times 10^5\ Pa$ $\frac{\Delta V}{V}\% = 5 \times 10^{-3}$ $\frac{\Delta V}{V} \times 100 = 5 \times 10^{-3}$ $\frac{\Delta V}{V} = \frac{5 \times 10^{-3}}{100}$ $\frac{\Delta V}{V} = 5 \times 10^{-5}$ $B = ?$ $v = ?$	$B = \frac{\Delta P}{\left(\frac{\Delta V}{V}\right)}$ $B = \frac{1 \times 10^5}{5 \times 10^{-5}}$ $B = 2 \times 10^9$ $v = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{2 \times 10^9}{1000}}$ $V = 1414.2\frac{m}{s}$

5 A uniform string of length 10.0 m and weight 0.25 N is attached to the ceiling. A weight of 1.00 kN hangs from its lower end. The lower end of the string is suddenly displaced horizontally. How long does it take the resulting wave pulse to travel to upper end? (Neglect the weight of string in comparison to hanging mass).

DATA	
$L = 10.0\ m$ $W_{string} = 0.25\ N$ $m_{string} = \frac{W}{g} = \frac{0.25}{9.8} = 0.0255\ kg$ $W_{hanging} = 1.00\ kN = 1.00 \times 10^3 N$ $v = ?$ $t = ?$ **SOLUTIONS** $v = \sqrt{\frac{T}{\mu}}$ $T = W_{hanging}$ $T = 1.00 \times 10^3 N$	$\mu = \frac{m_{string}}{L}$ $\mu = \frac{0.0255}{10.0}$ $\mu = 2.55 \times 10^{-3}$ $v = \sqrt{\frac{1.00 \times 10^3}{2.55 \times 10^{-3}}}$ $v = \sqrt{39215.86}$ $v = 626.2\frac{m}{s}$ Time taken $t = \frac{S}{v}$ $t = \frac{10.0}{626.2}$ $t = 0.0196\ s$

6 A traveling sine wave results from the superposition of two other sine waves with equal amplitudes, wavelengths, and frequencies. The two-component waves each have an amplitude of 5.00 cm. If the resultant wave has an amplitude of 6.69, what is the phase difference Φ between the component waves?

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DATA

$A_0 = 5.00$ cm

$A_0 = \frac{5.00}{100} = 0.05\ m$

$y = 6.69\ cm$

$y = \frac{6.69}{100} = 0.0669\ m$

$\Phi = ?$

SOLUTIONS

$y = 2\ A_0 \cos\left(\frac{\Phi}{2}\right)$

$0.0669 = 2\ (0.05) \cos\left(\frac{\Phi}{2}\right)$

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$0.0669 = 0.1 \cos\left(\frac{\Phi}{2}\right)$

$\cos\left(\frac{\Phi}{2}\right) = \frac{0.0669}{0.1}$

$\cos\left(\frac{\Phi}{2}\right) = 0.699$

$\left(\frac{\Phi}{2}\right) = \cos^{-1}(0.699)$

$\left(\frac{\Phi}{2}\right) = 48$

$\Phi = 2 \times 48 = 96^0$

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7 A string 2.0 m long is held fixed at both ends. If a sharp blow is applied to the string at its centre, it takes 0.050 s for the pulse to travel to both ends of the string and return to the middle. What is the fundamental frequency of oscillation for this string?

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DATA

L = 2.0 m

$t = 0.050\ s$

$f_0 = ?$

SOLUTIONS

$f_0 = \frac{v}{2L}$

$f_0 = \frac{1}{2L} \times v$

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$f_0 = \frac{1}{2L} \times \left(\frac{L}{t}\right) \quad \left\{v = \frac{S}{t} = \frac{L}{t}\right\}$

$f_0 = \frac{1}{2 \times 2.0} \times \left(\frac{2.0}{0.050}\right)$

$f_0 = \frac{1}{4} \times (40)$

$f_0 = 10\ HZ$

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8 In order to decrease the fundamental frequency of a guitar string by 4.0%, by what percentage should you reduce the tension?

DATA

$f_1 = $ 4% decrased by f_2

$f_1 = (100 - 4)\%\ \ f_2$

$f_1 = 96\ \%\ \ f_2$

$f_1 = 0.96\ \ f_2$

$\frac{\Delta T}{T} = ?$

SOLUTIONS

The fundamental frequency f_1 is given by

$$f_2 = \frac{1}{2L}\sqrt{\frac{T_2}{\mu}} \ \ldots\ldots\ldots (i)$$

Reducing frequency f_1 is given by

$$f_1 = \frac{1}{2L}\sqrt{\frac{T_1}{\mu}} \ \ldots\ldots\ldots (ii)$$

Dividing equation (ii) by (i)

$$\frac{f_1}{f_2} = \frac{\frac{1}{2L}\sqrt{\frac{T_1}{\mu}}}{\frac{1}{2L}\sqrt{\frac{T_2}{\mu}}}$$

$$\frac{f_1}{f_2} = \frac{\sqrt{\frac{T_1}{\mu}}}{\sqrt{\frac{T_2}{\mu}}}$$

$$\frac{f_1}{f_2} = \sqrt{\frac{T_1}{\mu}} \times \sqrt{\frac{\mu}{T_2}}$$

$$\frac{f_1}{f_2} = \sqrt{\frac{T_1}{\mu} \times \frac{\mu}{T_2}}$$

$$\frac{f_1}{f_2} = \sqrt{\frac{T_1}{T_2}}$$

$$\frac{0.96\ \ f_2}{f_2} = \sqrt{\frac{T_1}{T_2}}$$

$$0.96 = \sqrt{\frac{T_1}{T_2}}$$

Squaring both sides

$$(0.96\,)^2 = \left(\sqrt{\frac{T_1}{T_2}}\right)^2$$

$$0.9216 = \frac{T_1}{T_2}$$

$$T_1 = 0.9216\ T_2 \ \ldots\ldots\ldots\ldots (iii)$$

$$\Delta T = T_2 - 0.9216\ T_2$$

$$\Delta T = (1 - 0.9216)\ T_2$$

$$\Delta T = 0.0784\ T_2$$

$$\frac{\Delta T}{T_2} = 0.0784$$

$$\frac{\Delta T}{T_2}\% = 0.0784 \times 100$$

$$\frac{\Delta T}{T_2}\% = 7.84\ \%$$

9 A string 2.0 m long is held fixed at both ends. If a sharp blow is applied to the string at its centre, it takes 0.050 s for the pulse to travel to both ends of the string and return to the middle. What is the fundamental frequency of oscillation for this string?

DATA L = 2.0 m $t = 0.050\ s$ $f_0 = ?$ **SOLUTIONS** $f_0 = \frac{v}{2L}$ $f_0 = \frac{1}{2L} \times v$	$f_0 = \frac{1}{2L} \times \left(\frac{L}{t}\right) \quad \left\{v = \frac{S}{t} = \frac{L}{t}\right\}$ $f_0 = \frac{1}{2 \times 2.0} \times \left(\frac{2.0}{0.050}\right)$ $f_0 = \frac{1}{4} \times (40)$ $f_0 = 10\ HZ$

10 A sound source of frequency f_o and an observer are located at a fixed distance apart. Both the source and observer are at rest. However, the propagation medium (through which the sound waves travel at speed v) is moving at a uniform velocity V_m in an arbitrary direction. Find the frequency detected by the observer giving a physical explanation.

The velocity of mechanical waves is affected by the motion of the medium. If the medium is moving with the velocity of $\boldsymbol{v_m}$ in the direction of propagation of sound waves, the affective velocity of sound is increased from $\boldsymbol{v\ to\ (v + v_m)}$ In this case, $\boldsymbol{v}$ is replaced by $(\boldsymbol{v + v_m})$ The frequency detected by observer is $\boldsymbol{f' = \frac{v}{\lambda}}$ $\boldsymbol{f' = \frac{v + v_m}{\frac{v}{f}}}$ $\boldsymbol{f' = \left(\frac{v + v_m}{v}\right) f}$	If the medium is moving with the velocity of $\boldsymbol{v_m}$ in the direction opposite to the direction of the wave propagation, the affective velocity of sound is decreased from $\boldsymbol{v\ to\ (v - v_m)}$ In this case, $\boldsymbol{v}$ is replaced by $(\boldsymbol{v - v_m})$ The frequency detected by observer is $\boldsymbol{f' = \frac{v}{\lambda}}$ $\boldsymbol{f' = \frac{v - v_m}{\frac{v}{f}}}$ $\boldsymbol{f' = \left(\frac{v - v_m}{v}\right) f}$

11 A train sounds its whistle while passing by a railroad crossing. An observer at the crossing measures a frequency of 219 Hz as the train approaches the crossing and a frequency of 184 Hz as the train leaves. The speed of the sound is 340 m/s. Find the speed of the train and the frequency of its whistle.

DATA

Observed frequency when the train approaches him , $f'_1 = 219\ Hz$

Observed frequency when the train moving away, $f'_2 = 184\ Hz$

$v = 340\ m/s$

SOLUTIONS

$$f'_1 = \left(\frac{v}{v - v_s}\right) f \ \ldots\ldots\ldots (i)$$

$$f'_2 = \left(\frac{v}{v + v_s}\right) f \ \ldots\ldots (ii)$$

Dividing equation (i) by (ii)

$$\frac{f'_1}{f'_2} = \frac{\left(\frac{v}{v - v_s}\right) f}{\left(\frac{v}{v + v_s}\right) f}$$

$$\frac{f'_1}{f'_2} = \frac{\left(\frac{v}{v - v_s}\right) \not{f}}{\left(\frac{v}{v + v_s}\right) \not{f}}$$

$$\frac{f'_1}{f'_2} = \left(\frac{\not{v}}{v - v_s}\right) \times \left(\frac{v + v_s}{\not{v}}\right)$$

$$\frac{219}{184} = \left(\frac{340 + v_s}{340 - v_s}\right)$$

$$1.19 = \left(\frac{340 + v_s}{340 - v_s}\right)$$

$$340 + v_s = 1.19(340 - v_s)$$

$$v_s + 1.19\, v_s = 404.6 - 340$$

$$2.19\, v_s = 64.6$$

$$v_s = \frac{64.6}{2.19}$$

$$v_s = 29.5\ m/s$$

Frequency emitted by sound

$$219 = \left(\frac{340}{340 - 29.5}\right) f$$

$$219 = \left(\frac{340}{310.5}\right) f$$

$$219 = 1.095\, f$$

$$\frac{219}{1.095} = f$$

$$200\ Hz = f$$

CHAPTER = 12 ACOUSTICS
WORKED EXAMPLES

1 If the velocity of sound in air at 27°C and at a pressure of 76 cm of mercury is 345 ms^{-1}. Find the velocity at 127°C and 75 cm of mercury.

DATA	SOLUTIONS
$T_1 = 27\ °C$ $T_1 = 27 + 273 = 300\ K$ $T_2 = 127\ °C$ $T_2 = 127 + 273 = 400\ K$ $v_1 = 345\ m/s$ $v_2 = ?$	$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$ $\frac{345}{v_2} = \sqrt{\frac{300}{400}}$ $\frac{345}{v_2} = 0.866$ $398.38\ m/s = v_2$

2 In a game of cricket match a spectator is sitting in the stand at a distance of 60.0 m away from the batsman. How long does it take the sound of the bat connecting with the ball hit for a six to travel to the spectator's ears? if the temperature of air is 27°C.

DATA	
$S = 60.0\ m$ $t = 27\ °C$ $v_0 = 332\ m/s$ $v_t = ?$ $time = ?$ **SOLUTIONS** Using equation $v_t = v_0 + 0.61\ t(°C)$ $v_t = 332 + 0.61\ (27)$	$v_t = 332 + 16.47$ $v_t = 348.47\ m/s$ Time taken to reach the sound to spectator's $time = \frac{S}{v}$ $time = \frac{60.0}{348.47}$ $time = 0.172\ seconds$

3 A 2 m long string with mass 0.004 kg is stretching horizontally one end over a pulley and attaching a 1.0 kg mass to it; find the speed of the transverse waves in the string and frequency of the fifth harmonic

DATA: **Length of the string L = 2 m** **Mass of the string m = 0.004 kg** **Mass suspended M = 1 kg** **Speed of the wave v = ?** **Frequency of the fifth harmonic v_5 = ?** **Solution:** **Speed of a transverse wave on a string is given by:** $V = \sqrt{\frac{T}{\mu}}$ $V = \sqrt{\frac{M g}{\mu}}$ $\mu = \frac{m}{L}$ $\mu = \frac{0.004}{2}$ $\mu = 0.002\ kg/m$	$V = \sqrt{\frac{1 \times 9.8}{0.002}}$ $V = \sqrt{\frac{9.8}{0.002}}$ $V = \sqrt{4900}$ ∴ **V= 70 m/s** Frequency for **n** harmonic is given by: $v_2 = n\left(\frac{V}{2L}\right)$ Frequency for fifth harmonic is given by: $v_5 = 5\left(\frac{V}{2L}\right)$ $v_5 = 5\left(\frac{70}{2x2}\right)$ $v_5 = 5(17.5)$ $v_5 = 87.5\ Hz$

4. Calculate the speed of sound in air at STP. What will be the speed of sound at 37 ^{0}C (given that P = 1.01 x 10^5 N/m^2, taking γ = 1.40 and ρ = 1.29 kg/m^3).

DATA: **Speed of sound at S.T.P , V = ?** **Speed of sound at 37° $V_{37\,C}$ = ?** **Temperature T = 37°+ 273 = 410 ^{0}C** **Density of air ρ = 1.29 Kg/m^2** **For air γ = 1.42** **1 atm. = 1.01 x 10^5 N/m^2** **SOLUTION:** $V = \sqrt{\frac{\gamma P}{\rho}}$ $V = \sqrt{\frac{1.42 \times 1.01 \times 10^5}{1.29}}$ $V = \sqrt{11117 8. 29}$	**V = 333.44 m/s** **Velocity at any temperature t is given by:** $V_t = V\sqrt{\frac{t + 273}{273}}$ $V_t = 333.44\sqrt{\frac{37+273}{273}}$ $V_t = 333.44 \times \sqrt{1.1355}$ $V_t = 333.44 \times 1.066$ **V_t = 355.31**

5. A string 2 m long and of mass 0.004 kg is stretched horizontally by passing one end over a pulley and at aching a 1 kg mass to it, find the speed of the transverse waves on the string and the frequency of the second harmonic.

DATA:

Mass of the string m = 0.004 kg.
Length of the string L= 2 m
Mass suspended M = 1 kg
Speed of the wave v = ?
Frequency of second harmonic v_2 = ?

SOLUTION:

Speed of a transverse wave on a string is given by:

Speed of a transverse wave on a string is given by:

$$V = \sqrt{\frac{T}{\mu}}$$

$$V = \sqrt{\frac{M\,g}{\mu}}$$

$$\mu = \frac{m}{L}$$

$$\mu = \frac{0.004}{2}$$

$$\mu = 0.002\ \mathrm{kg/m}$$

$$V = \sqrt{\frac{1 \times 9.8}{0.002}}$$

$$V = \sqrt{\frac{9.8}{0.002}}$$

$$V = \sqrt{4900}$$

$\therefore$ **V= 70 m/s**

Fundamental frequency

$$v_0 = \frac{V}{2L}$$

$$v_0 = \frac{70}{2 \times 2}$$

$$v_0 = \frac{70}{4}$$

$$v_0 = 17.5\ Hz$$

Frequency for second harmonic is given by:

$$v_2 = 2\left(\frac{V}{2L}\right)$$

$$v_2 = 2(v_0)$$

$$v_2 = 2(17.5)$$

$$v_2 = 35\ Hz$$

6. A source of sound and a listener are moving towards each other with velocities, which are 0.5 time, and 0.2 time the speed of sound respectively. If the source is emitting 2KHz tone. Calculate the frequency heard by the listener.

DATA:

Vs = 0.5 V
V_0 = 0.2 V
v = 2 KHZ
v' = ?

SOLUTION:

When both the source and the listener moving towards each other the apparent frequency is:

$$v' = \left(\frac{V + V_0}{V - V_s}\right) v$$

$$v' = \left(\frac{V + 0.2\ V}{V - 0.5\ V}\right) 2000$$

$$v' = \frac{V}{V}\left(\frac{1 + 0.2}{1 - 0.5}\right) 2000$$

$$v' = \left(\frac{1.2}{0.5}\right) 2000$$

$$v' = \left(\frac{1200}{0.5}\right)$$

$$v' = 2400\ \mathrm{Hz}$$

$$v' = 2.4 \times 1000\ \mathrm{Hz}$$

$$v' = 2.4\ \mathrm{K\,Hz}$$

7. Two cars are moving straight to each other from opposite direction with same speed. The horn of one blowing with the frequency of 3000 Hz and is heard by the people in the other car with the frequency of 3000 Hz; find the speed of the cars if the speed of sound in air is 340 m/s

DATA:

Frequency produced $\upsilon = 3000$ Hz

Frequency heard $\upsilon' = 3400$ Hz

Speed of sound $v = 340$ m/s

Speed of each car $v_0 = ?$

SOLUTION:

Since both the cars, one producing sound (source) and in the other there is listener, are moving opposite to each other. Hence frequency heard in this case is given by:

$$\upsilon' = \left(\frac{V + V_0}{V - V_s}\right)\upsilon$$

$$3400 = \left(\frac{340 + V_0}{340 - V_s}\right)3000$$

$$3400(340 - V_0) = (340 + V_0)3000$$

$$3400x340 - 3400V_0 = 3000x340 + 3000V_0$$

$$3400x340 - 3000x340 = 3400xV_0 + 3000V_0$$

$$136000 = 6400V_0$$

$$V_0 = \frac{136000}{6400}$$

$$V_0 = 21.5 \text{ m/s}$$

Velocity of each car is 21.25 m/s.

9. A standing wave is establish in a 2.4 m long string fixed at both ends. The string vibrates in four segments when driven at 200 Hz. Determine (i) the wavelength (ii) the fundamental frequency.

DATA:

Length of the string	$L = 2.4$ m
Number of segments	$n = 4$
Frequency	$f_4 = 200$ Hz
Wave length	$\lambda_4 = ?$
Fundamental Frequency	$f_4 = ?$

SOLUTION:

Wave length of a wave is given by:

$$\lambda_n = \frac{2L}{n}$$

$$\therefore \lambda_4 = \frac{2 \times 2.4}{4}$$

$$\lambda_4 = 1.2\text{m}$$

Wave length of standing waves when the string vibrates in four segments is 1.2m. Similarly:

$$f_1 = \frac{f_4}{4} \qquad \left\{ f_1 = \frac{f_n}{n} \right\}$$

$$\therefore f_1 = \frac{200}{4} = 50\text{Hz.}$$

10. Find the speed of sound in air at the temperature of 27 ^{0}C .
[Given γ =1.42, R = 8.313 j/mol-K, molecular mass of air 28.8 x 10^{-3} Kg/ mol]

DATA:

Temperature at air T = 27°C= 27 + 273 = 300K

Molecular mass M = 28.8 x 10^{-3} kg/mole

For air $\gamma = 1.42$

Speed of sound V = ?

Solution:

$$V = \sqrt{\frac{\gamma RT}{M}}$$

$$V = \sqrt{\frac{1.42 \text{ x } 8.313 \text{ x } 300}{0.0288}}$$

$$V = \sqrt{\frac{3541.338}{28.8x10^{-3}}}$$

$$V = \sqrt{122963.125}$$

$$V = 350.66 \text{ m/s}$$

11. A note of frequency 650 Hz is emitted from an ambulance. What frequency will detected by listener if the ambulance moves (i) at the speed of 18 m/s towards the listener, (ii) at the speed of 15 m/s away from the listener[speed of sound = 340

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DATA

v = 650 Hz

v' = ?

(i) V_s = 18 m/s towards the listner

(ii) V_s = 15 m/s away form the listner

V = 340 m/s

SOLUTION:

For the apparent frequency heard by the stationary listner when ambulance is moved towards him

$$v' = \left(\frac{V}{V - V_s}\right) v$$

$$v' = \left(\frac{340}{340 - 18}\right) 650$$

$$v' = \left(\frac{340}{332}\right) 650$$

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$$v' = \left(\frac{340 \times 650}{332}\right)$$

$$v' = 665.66\ Hz$$

For the apparent frequency heard by the stationary listner when ambulance is moved taway from him

$$v' = \left(\frac{V}{V + V_s}\right) v$$

$$v' = \left(\frac{340}{340 + 15}\right) 650$$

$$v' = \left(\frac{340}{358}\right) 650$$

$$v' = \left(\frac{340 \times 650}{355}\right)$$

$$v' = 622.5\ Hz$$

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12. A note of frequency 500 Hz is being emitted by an ambulance moving towards a listener standing on the bus stop. If the frequency heard by the listener is 526 Hz ; find the speed of the ambulance (speed of sound in air 340 m/s

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DATA

v = 500 Hz

v' = 526 Hz

V_s = ?

V = 340 m/s

SOLUTION:

$$v' = \left(\frac{V}{V - V_s}\right) v$$

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$$526(= \left(\frac{340}{340 - V_s}\right) 500$$

$$526(340 - V_s) = 340 \text{ x } 500$$

$$178840 - 526 \times V_s = 170000$$

$$178840 = 170000 + 526 \times V_s$$

$$178840 - 170000 = 526 \times V_s$$

$$8840 = 526 \times V_s$$

$$16.8\ m/s = V_s$$

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13. A sonometer wire of length 1 m, when plucked at the centre, vibrates with frequency of 250 Hz. Calculate the wavelength and the speed of the wave in the string?

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DATA:

L = 1.0 m

n = 1

v_0 = 120 Hz

(i) λ = ?

(ii) V = ?

SOLUTION:

We know that,

$$L = \frac{\lambda}{2}$$

$$\lambda = 2L$$

$$\lambda = 2 \times 1.0$$

$$\lambda = 2.0 \text{ m}$$

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We have

$$V = v_0 \lambda$$

$$V = 250 \times 2.0$$

$$V = 500 \text{ m/s}$$

(Your turn)

Q Standing wave is established in a 120 cm long string fixed at both ends. The string vibrates in four segments when driven at 120 Hz (a) Determine the wavelength (b) What is the fundamental frequency?

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14. A string 2 meter long and mass 0.004 Kg is stretched horizontally by passing one of its ends over a pulley and the string is attached with one Kilogram mass to it vertically find the speed of the transverse wave on the string and the frequency of the fundamental and fifth harmonic at which the string vibrates.

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DATA:

Mass of the string m = 0.004 kg.

Length of the string L = 2 m

Mass suspended M = 1 kg

Speed of the wave V = ?

Frequency of second harmonic v_2 = ?

SOLUTION:

Speed of a transverse wave on a string is given by:

$$V = \sqrt{\frac{T}{\mu}}$$

$$V = \sqrt{\frac{Mg}{\mu}}$$

$$\mu = \frac{m}{L}$$

$$\mu = \frac{0.004}{2}$$

$$\mu = 0.002 \text{ kg/m}$$

$$V = \sqrt{\frac{1 \times 9.8}{0.002}}$$

$$V = \sqrt{\frac{9.8}{0.002}}$$

$$V = \sqrt{4900}$$

∴ **V= 70 m/s**

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Fundamental frequency

$$v_0 = \frac{V}{2L}$$

$$v_0 = \frac{70}{2 \times 2}$$

$$v_0 = \frac{70}{4}$$

$$v_0 = 17.5\ Hz$$

Frequency for second harmonic is given by:

$$v_2 = 2\left(\frac{V}{2L}\right)$$

$$v_2 = 2(v_0)$$

$$v_2 = 2(17.5)$$

$$v_2 = 35\ Hz$$

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15. A car has its siren sounding 2KHz tone if the frequency heard by stationary listener is 2143 Hz. Find the speed with which the car approaches the stationary listener. Speed of sound in air 340 m/s. (K. Board 2011,2005)

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DATA:

Frequency of sound produced

v = 2kHz. = 2000 Hz.

Frequency heard v′ = 2153 Hz.

Speed V_8 = ?

speed of sound V = 332 m/s

SOLUTION:

$$v' = \left(\frac{V}{V - V_s}\right) v$$

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$$2143 = \left(\frac{340}{340 - V_s}\right) \times 2000$$

$$340 - V_s = \left(\frac{340}{2143}\right) \times 2000$$

$340 - V_s = 317.3$

$340 = 317.3 + V_s$

$340 - 317.3 = V_s$

$22.68 \text{ m/s} = V_s$

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16 Find the velocity of sound in a gas when two waves of wavelength 0.8 m and 0.81 m respectively, produces 4 beats per second.

[259.02m/s]

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Data:

λ_1 = 0.8m;

λ_2 = 0.81m

f_b = 4 beats / s

V = ?

Solution:

$f_b = f_1 - f_2$

$$f_b = \frac{V}{\lambda_1} - \frac{V}{\lambda_2}$$

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$$4 = \left(\frac{V}{0.80} - \frac{V}{0.81}\right)$$

$$4 = V\left(\frac{1}{0.80} - \frac{1}{0.81}\right)$$

4 = V (1.25 – 1.23456)

$$V = \frac{4}{0.01544}$$

$$V = 259.02 \text{ m/s}$$

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17 A sound wave of frequency 500Hz in air enters from a region of temperature 25 ℃ to a region of temperature 5 ℃. Calculate the percent fractional change in wavelength.

[3.414 %]

Data: V = 4000 Hz $\frac{\Delta\lambda}{\lambda_1}\% = ?$ T_1 = 25°C + 273 = 298 K T_2 = 5°C + 273 = 278 K **SOLUTION:** The speed of sound follows mathematical relation with the temperature $\frac{V_1}{V_2} = \sqrt{\frac{T_1}{T_2}}$ $\frac{v\,\lambda_1}{v\,\lambda_2} = \sqrt{\frac{298}{278}}$ $\frac{\lambda_1}{\lambda_2} = \sqrt{1.07194}$	$\lambda_1 = 1.03534\,\lambda_2$ $\lambda_2 = \frac{1}{1.03534}\,\lambda_1$ $\lambda_2 = 0.9658\,\lambda_1$ then change in wave length $\Delta\lambda = \lambda_1 - \lambda_2$ $\Delta\lambda = \lambda_1 - 0.9658\,\lambda_1$ $\Delta\lambda = \lambda_1\,(1 - 0.9658)$ $\frac{\Delta\lambda}{\lambda_1} = (1 - 0.9658)$ $\frac{\Delta\lambda}{\lambda_1} = 0.0342$ $\frac{\Delta\lambda}{\lambda_1}\% = 0.0342 \times 100$ $\frac{\Delta\lambda}{\lambda_1}\% = 3.42\%$