Waves

Question1

If the lengths of the open and closed pipes are in the ratio of 2 : 3, then the ratio of the frequencies of the third harmonic of the open pipe and the fifth harmonic of the closed pipe is

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Options:

A.

3 : 5

B.

9 : 5

C.

2 : 3

D.

4 : 9

Answer: B

Solution:

Step 1: Write the formula for frequency in an open pipe

The frequency of the nth harmonic in an open organ pipe is:

$f_0 = \frac{nv}{2l_0}$

Step 2: Find the frequency for the 3rd harmonic in the open pipe

For the third harmonic, $n = 3$:

$f_0' = \frac{3v}{2l_0}$

Step 3: Write the formula for frequency in a closed pipe

The frequency of the nth harmonic in a closed pipe is:

$f_c = \frac{nv}{4l_c}$

Step 4: Find the frequency for the 5th harmonic in the closed pipe

For the fifth harmonic, $n = 5$:

$f_c' = \frac{5v}{4l_c}$

Step 5: Write the ratio of the two frequencies

We want to find the ratio $\frac{f_0'}{f_c'}$.

$\frac{f_0'}{f_c'} = \frac{\frac{3v}{2l_0}}{\frac{5v}{4l_c}}$

Step 6: Simplify the ratio

First, simplify by dividing:

$\frac{3v}{2l_0} \times \frac{4l_c}{5v} = \frac{12l_c}{10l_0}$

Step 7: Use the ratio of lengths

It is given that the ratio of lengths of the open and closed pipes is $2:3$, so $\frac{l_0}{l_c} = \frac{2}{3}$.

Step 8: Substitute the value for $\frac{l_0}{l_c}$

$\frac{12}{10} \times \frac{1}{\frac{l_0}{l_c}} = \frac{12}{10} \times \frac{1}{\frac{2}{3}} = \frac{12}{10} \times \frac{3}{2} = \frac{36}{20} = \frac{9}{5}$

Step 9: State the final ratio

The ratio of the frequencies is $9:5$.

Question2

The equation of a transverse wave propagating on a stretched string is given by $y = 3\sin(4x + 200t)$, where x and y are in metre and the time ' t ' is in second. If the tension applied to the string is 500 N , the linear density of the string is

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Options:

A.

0.25 kg m^{-1}

B.

0.4 kg m^{-1}

C.

0.2 kg m^{-1}

D.

0.1 kg m^{-1}

Answer: C

Solution:

The standard form of a travelling wave is

$y = A \sin(kx \pm \omega t)$

Comparing

$y = 3 \sin(4x + 200t)$
$k = 4 \text{rad/m}$
$\omega = \text{rad/sec}$

wave speed is given by

$v = \frac{\omega}{k} = \frac{200}{4} = 50 \text{ m/s}$

Wave speed for string

$$v = \sqrt{\frac{T}{\mu}} \Rightarrow \mu = \frac{T}{v^2}$$
$$\mu = \frac{500}{(50)^2} = \frac{500}{2500} = 0.2 \text{ kg/m}$$

Question3

The fundamental frequency of transverse wave of a stretched string subjected to a tension T_1 is 300 Hz . If the length of the string is

doubled and subjected to a tension of T_2, the fundamental frequency of the transverse wave in the string becomes 100 Hz , then $T_2 : T_1 =$

(Linear density of the string is constant)

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Options:

A.

$1 : 2$

B.

$3 : 4$

C.

$2 : 3$

D.

$4 : 9$

Answer: D

Solution:

The initial fundamental frequency

$$f_1 = \frac{1}{2L_1}\sqrt{\frac{T_1}{\mu}}$$

$$300 = \frac{1}{2L_1}\sqrt{\frac{T_1}{\mu}} \qquad \ldots(i)$$

The new fundamental frequency

$$f_2 = \frac{1}{2L_2}\sqrt{\frac{T_2}{\mu}}$$

$$100 = \frac{1}{2\left(2L_1\right)}\sqrt{\frac{T_2}{\mu}}$$

$$100 = \frac{1}{4L_1}\sqrt{\frac{T_2}{\mu}} \qquad \ldots(ii)$$

Divide the Eq. (i) by the Eq. (ii)

$$\frac{300}{100}=\frac{\frac{1}{2L_1}\sqrt{\frac{T_1}{\mu}}}{\frac{1}{4L_1}\sqrt{\frac{T_2}{\mu}}}$$

$$3=\frac{\frac{1}{2}\sqrt{T_1}}{\frac{1}{4}\sqrt{T_2}} \Rightarrow 3=\frac{4}{2}\sqrt{\frac{T_1}{T_2}}$$

$$3=2\sqrt{\frac{T_1}{T_2}}=\frac{3}{2}=\sqrt{\frac{T_1}{T_2}}=\frac{9}{4}=\frac{T_1}{T_2}$$

$$\frac{T_2}{T_1}=\frac{4}{9}$$

The ratio of the new tension to the initial tension is $\frac{4}{9}$.

Question4

Two sound waves each of intensity I are superimposed. If the phase difference between the waves is $\frac{\pi}{2}$, then the intensity of the resultant wave is

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Options:

A.

$2I$

B.

$3I$

C.

$4I$

D.

I

Answer: A

Solution:

$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$

Here, $\phi = \frac{\pi}{2}$ and $I_1 = I_2 = I$

$\therefore \quad I_R = I + I + 2\sqrt{I \cdot I} \cos \frac{\pi}{2} = 2I$

Question5

The tension applied to a metal wire of one metre length produces an elastic strain of 1%. The density of the metal is $8000 \mathrm{kgm}^{-3}$ and Young's modulus of the metal is $2 \times 10^{11} \mathrm{Nm}^{-2}$. The fundamental frequency of the transverse waves in the metal wire is

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Options:

A. 500 Hz

B. 375 Hz

C. 250 Hz

D. 125 Hz

Answer: C

Solution:

Given,

Length of the wire, $L = 1 \mathrm{~m}$

Elastic strain, $\varepsilon = 1\% = 0.01$

Density of metal, $\rho = 8000 \mathrm{~kg/m}^3$

Young's modulus, $Y = 2 \times 10^{11} \mathrm{~N/m}$

We know that, $Y = \frac{\sigma \text{ (stress)}}{\varepsilon \text{ (strain)}}$

$\sigma = Y \cdot \varepsilon = 2 \times 10^{11} \times 0.01$

$\sigma = 2 \times 10^9 \mathrm{~N/m}^2$

We also new that,

$\sigma = \frac{T}{A} \Rightarrow T = \sigma \times A$

Cross-sectional area is not given, so we consider mass per unit length μ of the wire,

$\mu = \rho \cdot A$

Putting in Eq. (i), we get

$T = \frac{\sigma \cdot \mu}{\rho}$

The fundamental frequency of the transvèrse waves in the metal wire is,

$f = \frac{1}{2L} \sqrt{\frac{T}{\mu}}$

$f = \frac{1}{2 \times 1} \sqrt{\frac{\sigma \cdot \mu}{\rho \cdot \mu}} = \frac{1}{2} \sqrt{\frac{\sigma}{\rho}}$

$f = \frac{1}{2} \sqrt{\frac{2 \times 10^9}{8000}} = \frac{1}{2} \times \sqrt{\frac{10^6}{4}}$

$f = \frac{1}{4} \times 10^3 = \frac{1000}{4}$

$f = 250 \text{ Hz}$

Question6

Two closed pipes when sounded simultaneously in their fundamental modes produce 6 beats per second. If the length of the shorter pipe is 150 cm , then the length of the longer pipe is

(Speed of sound in air $= 336 \text{ ms}^{-1}$)

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Options:

A. 168°cm

B. 184 cm

C. 176 cm

D. 192 cm

Answer: A

Solution:

Given,

Beat frequency, $f_{\text{beat}} = 6$ Hz

Length of the shorter pipe, $L_1 = 150$ cm

$= 1.5$ m

Speed of sound in air, $v = 336$ m/s

For a closed loop, fundamental frequency is given by,

$f = \frac{v}{4L}$

For the shorter pipe L_1,

$f_1 = \frac{336}{4 \times 1.5} = \frac{336}{6} = 56$ Hz

Let the length of longer pipe be L_2 and frequency be f_2.

Since the pipes produces 6 beats per second when sound together:

$|f_1 - f_2| = 6$

There are two possible cases for f_2,

Case (i) $f_2 = f_1 + 6 = 56 + 6 = 62$ Hz

Case (ii) $f_2 = f_1 - 6 = 56 - 6 = 50$ Hz

So, from Eq. (i),

Case (i) $f_2 = \frac{v}{4L_2} \Rightarrow 62 = \frac{336}{4L_2}$

$\Rightarrow \quad L_2 = \frac{336}{4 \times 62}$

$L_2 = 1.35$ m $= 135$ cm (Not used because it is less than 4)

Case (ii) $f_2 = \frac{v}{4L_2} \Rightarrow 50 = L_2 = \frac{336}{4L_2}$

$\Rightarrow \quad L_2 = \frac{336}{4 \times 50}$

$f_2 = 1.68$ m $= 168$ cm

So, the length of the longer pipe that results in the production of 6 beats per second when sounded with the shorter pipe is 168 cm .

Question7

The path difference between two particles of a sound wave is 50 cm and the phase difference between them is 1.8π. If the speed of sound in air is 340 ms^{-1}, the frequency of the sound wave is

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Options:

A. 672 Hz

B. 306 Hz

C. 612 Hz

D. 340 Hz

Answer: C

Solution:

Given:

Path difference (Δx): 50 cm = 0.5 m

Phase difference (ϕ): 1.8π

Velocity of sound (v): 340 m/s

We are to find the frequency of the sound wave.

First, use the relationship between phase difference, path difference, and wavelength:

$\phi = \frac{2\pi}{\lambda} \times \Delta x$

Substitute the given values:

$1.8\pi = \frac{2\pi}{\lambda} \times 0.5$

Solve for λ (wavelength):

$1.8\pi = \frac{\pi}{\lambda}$

$\lambda = \frac{1}{1.8} \text{ m}$

Next, use the equation relating velocity, frequency, and wavelength:

$v = f \times \lambda$

Substitute the known values:

$340 = f \times \frac{1}{1.8}$

Solve for f (frequency):

$f = 340 \times 1.8$

$f = 612\,\text{Hz}$

Thus, the frequency of the sound wave is 612 Hz.

Question8

A source at rest emits sound waves of frequency 102 Hz . Two observers are moving away from the source of sound in opposite directions each with a speed of 10% of the speed of sound. The ratio of the frequencies of sound heard by the observes is

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Options:

A. 9 : 11

B. 1 : 1

C. 7 : 9

D. 2 : 3

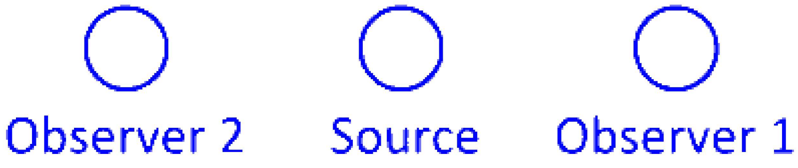
Answer: B

Solution:

Given:

Frequency of source, $f_0 = 102\,\text{Hz}$

Source velocity, $v_S = 0\,\text{m/s}$



Observers' Motion:

Each observer is moving with a velocity that is 10% of the speed of sound, i.e., $v_0 = 0.1v$.

Doppler Effect Calculation:

For each observer moving away from the source, the frequency heard is given by:

$f_{\text{observer}} = f_0 \left(\frac{v - v_0}{v}\right)$

where v is the speed of sound in the medium.

Frequency Calculation for Both Observers:

Since both observers are moving away from the source at the same speed and in opposite directions, the formula for frequency remains consistent for both:

$$f_{\text{observer 1}} = f_0\left(\frac{v-0.1v}{v}\right) = f_0\left(\frac{0.9v}{v}\right) = 0.9f_0$$

$$f_{\text{observer 2}} = f_0\left(\frac{v-0.1v}{v}\right) = f_0\left(\frac{0.9v}{v}\right) = 0.9f_0$$

Ratio of Frequencies:

The ratio of the frequencies heard by the two observers is:

$$\frac{f_{\text{observer 1}}}{f_{\text{observer 2}}} = \frac{0.9f_0}{0.9f_0} = 1:1$$

Thus, both observers hear the same frequency, resulting in a ratio of 1:1.

Question9

The difference between the fundamental frequencies of an open pipe and a closed pipe of same length is 100 Hz . The difference between the frequencies of the second harmonic of the open pipe and the third harmonic of the closed pipe is

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Options:

A. 100 Hz

B. 150 Hz

C. 200 Hz

D. 250 Hz

Answer: A

Solution:

Fundamental frequency of open pipe

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

Fundamental frequency of closed pipe

$$f_C = \frac{v}{4L}$$

$$\frac{v}{2L} - \frac{v}{4L} = 100 \text{ Hz}$$

$$\frac{v}{4L} = 100 \text{ Hz}$$

(given)

Now, 2nd harmonic of open pipe

$f = \frac{2v}{2L} \left(f_n = \frac{nv}{2L}\right)$

3rd harmonic of closed pipe

$(2n-1)\frac{v}{4L} = \frac{5v}{4L}$

Difference, $\frac{5v}{4L} - \frac{v}{L} = \frac{v}{4L}$

$\frac{v}{4L} = 100 \text{ Hz}$

Question10

The displacement equations of sound waves produced by two sources are given by $y_1 = 5\sin 400\pi t$ and $y_2 = 8\sin 408\pi t$, where t is time in seconds. If the waves are produced simultaneously, the number of beats produced per minute is

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Options:

A. 4

B. 8

C. 120

D. 240

Answer: D

Solution:

$y_1 = 5\sin 400\pi t, y_2 = 8\sin 408\pi t$

Compare with standard wave equation

$y = A \sin \omega t$

$\omega_1 = 400\pi, \omega_2 = 408\pi$

We know that, $\omega = 2\pi f$

$\omega_1 = 2\pi f_1 = 400\pi$

$f_1 = 200 \text{ Hz}$

$\omega_2 = 2\pi f_2 = 408\pi$

$f_2 = 204 \text{ Hz}$

Number of beats/second

$f_2 - f_1 = 204 - 200 = 4 \text{ Hz}$

Now, number of beats per minute

$= 4 \times 60$

$= 240$ beats/minute

Question11

A boy standing on a platform observes the frequency of a train horn as it passes by. The change in the frequency noticed as the train approaches and recedes him with a velocity of 108 kmph is (speed of sound in air $= 330 \text{ ms}^{-1}$)

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Options:

A. 18.33%

B. 16.67%

C. 21.27%

D. 15.23%

Answer: B

Solution:

Give velocity of train, $v_t = 108\text{kmph}$

$= 108 \times \frac{5}{18} = 30 \text{ m/s}$

Speed of sound in air, $v_s = 330 \text{ m/s}$

From Doppler's effect,

$f_0 = \frac{v_s + v_{\text{obberver}}}{v_s + v_{\text{train}}} \times f_s$

When train is going way

$$\Rightarrow \quad f_1 = \frac{330}{330 + 30} f_s$$

$$f_1 = \frac{330}{360} f_s$$

$$f_1 = 0.9166 f_s$$

When train is closing in

$$f_2 = \frac{330}{330 - 30} f_s$$

$$= 11 f_s$$

$\therefore$ % change in frequency observed

$$= \frac{11 f_s - 0.9166 f_s}{11 f_s} \times 100\%$$

$$= 0.1667 \times 100\%$$

$$= 16.67\%$$

Question12

If three sources of sound of frequencies $(n-1), n$ and $(n+1)$ are vibrated together, the number of beats produced and heard per second respectively are

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Options:

A. 4 and 2

B. 4 and 4

C. 2 and 2

D. 2 and 4

Answer: A

Solution:

Number of beats produced between n and $n-1$

$=n-(n-1)$

$=1$

Number of beats produced between n and $n+1$

$=(n+1)-(n)$

$=1$

Number of beats produced between $n+1$ and $n-1$

$=(n+1)-(n-1)$

$=2$

Total number of beats produced

$=1+1+2=4$

Number of distinguishable beat per second,

$(n+1)-(n-1)=2$

Question13

A car travelling at a speed of 54 kmph towards a wall sounds horn of frequency 400 Hz . The difference in the frequencies of two sounds, one received directly from the car and other reflected from the wall noticed by a person standing between the car and the wall is (speed of sound in air is $335 \mathrm{~m/s}$)

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Options:

A. 35.9 Hz

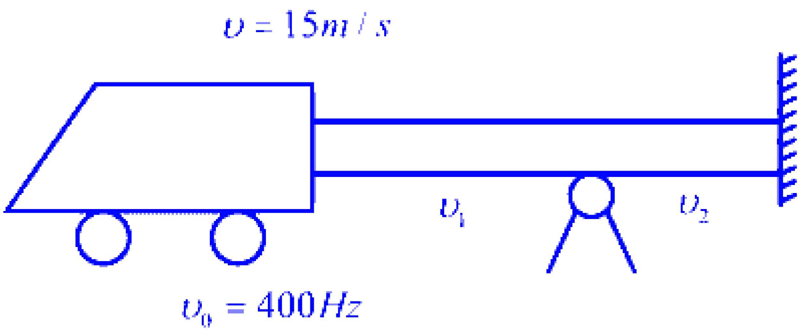
B. 20 Hz

C. 70 Hz

D. zero

Answer: D

Solution:



$$\mathrm{v}_1=\mathrm{v}_0\left[\frac{v-v_0}{v-v_t}\right]$$

$$=400\left[\frac{335-0}{335-15}\right]=\frac{400\times335}{320}\ \mathrm{Hz}$$

$$v_2=v_0\left[\frac{v-v_0}{v-v_1}\right]$$

$$=400\left[\frac{335-0}{335-15}\right]=\frac{400\times335}{320}\ \mathrm{Hz}$$

$$v_1-v_2=0$$

Question14

The speed of a transverse wave in a stretched string A is v. Another string B of same length and same radius is subjected to same tension. If the density of the material of the string B is 2% more than that of A then the speed of the transverse wave in string B is

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Options:

A. $\sqrt{1.04}$ V

B. $\sqrt{1.02}$ V

C. $\frac{v}{\sqrt{1.04}}$

D. $\frac{v}{\sqrt{1.02}}$

Answer: D

Solution:

Given,

Speed of a transverse wave in a

stretched spring $A = v$

In a stretched spring $B = ?$

The speed of transverse wave in a

stretched spring, $v_A = \sqrt{\frac{T}{\mu}}$

where, $v =$ speed of the wave

$T =$ tension in the spring

$\mu =$ linear mass density of the spring

Speed of wave in string B,

$$v_B = \sqrt{\frac{T}{\mu_B}}$$

$$v_B = \sqrt{\frac{T}{1.02\mu_A}}$$

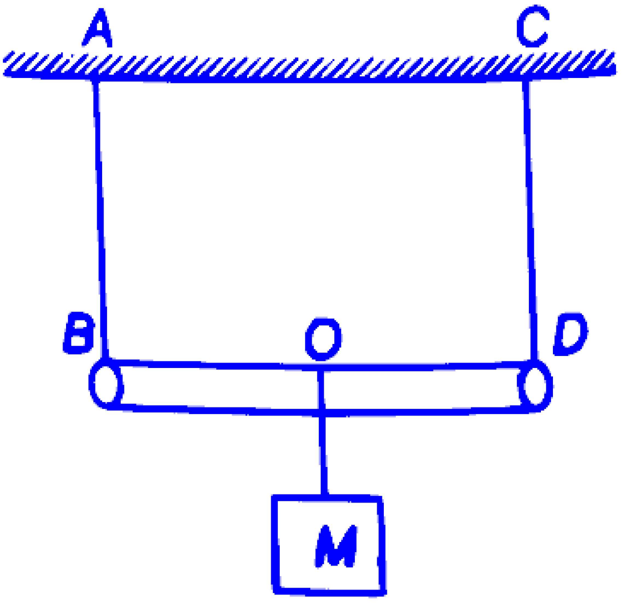
Since, tension T is same for both strings, it cancels out

$$v_B = \sqrt{\frac{1}{1.02} \cdot \frac{T}{\mu_A}}$$

$$v_B = \frac{1}{\sqrt{1.02}} \cdot v$$

Question15

A rod of length L and negligible mass is suspended by two identical strings AB and CD as shown in the figure A mass M is suspended from point O which is at a distance x from B. If the frequency of the first harmonic of AB is equal to the frequency of the second harmonic of CD, then the value of x is



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Options:

A. $\frac{L}{5}$

B. $\frac{2L}{7}$

C. $\frac{3L}{10}$

D. $\frac{L}{g}$

Answer: A

Solution:

Given,

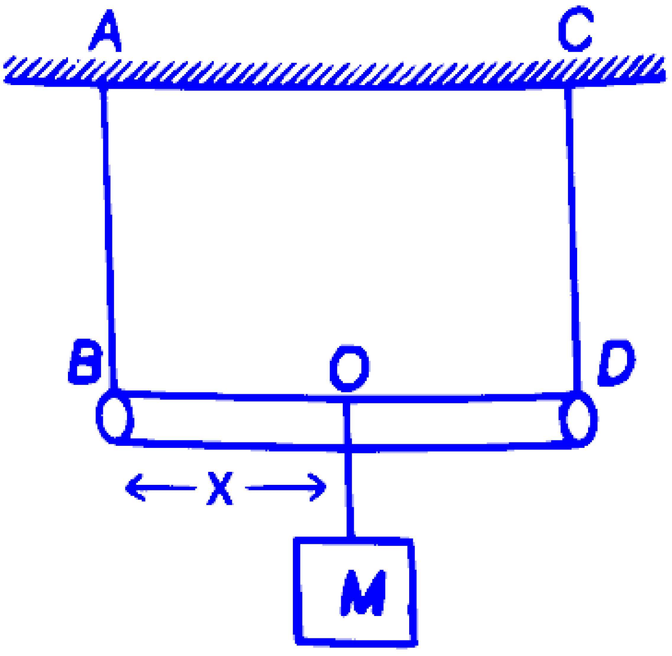
Length of rod $BD = L$

Length of string $AB = CD = 1$

Mass suspended $= M$

Length of $BO = x$

Length of $OD = L - x$



Frequency of 1st harmonics of $AB =$ Frequency of 2nd harmonics of CD. Let T_{AB} is tension in string AB. T_{CD} is the tension in string CD.

Frequency of 1st harmonics of AB is given by

$f = \frac{1}{2l}\sqrt{\frac{T_{AB}}{m}}, l =$ length of string $\quad \ldots (i)$

Frequency of 2nd harmonics of CD

$f = \frac{2}{2}\sqrt{\frac{T_{CD}}{m}} = \frac{1}{l}\sqrt{\frac{T_{CD}}{m}} \quad \ldots (ii)$

Eq. (i) = Eq. (ii) (given)

$$\Rightarrow \frac{1}{2l}\sqrt{\frac{T_{AB}}{m}} = \frac{1}{l}\sqrt{\frac{T_{CD}}{m}}$$
$$\Rightarrow T_{AB} = 4T_{CD} \quad \ldots (iii)$$

For rotational equilibrium of massless rod, taking torque at point O.

$\tau = r \times F($ Here $F =$ Tension $)$
$T_{AB} \times (X) = T_{CD}(L - X)$

Put value of T_{AB}, then

$X = L/5$

Question16

An observer moves towards a stationary source of sound with a speed $\frac{1}{5}$ th that of sound. The frequency of $^{\text{th}}$ sound emitted by the source of f. The apparent frequency recorded by the observer is

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Options:

A. $1.2f$

B. f

C. $0.8f$

D. $2f$

Answer: A

Solution:

When an observer moves towards a stationary sound source, the apparent frequency they perceive increases. This is due to the observer's motion, which causes them to encounter sound waves more frequently than if they were stationary.

In this scenario, the observer's speed is $\frac{1}{5}$ of the speed of sound. The key parameters are:

Observer's speed, $v_0 = \frac{v}{5}$

Source speed, $v_s = 0$ (stationary)

Frequency of the sound emitted by the source, f

Speed of sound, v

The formula to calculate the apparent frequency (f') when the observer is moving towards a stationary source is:

$f' = \left(\frac{v+v_0}{v}\right) f$

Substituting the given values:

$f' = \left(\frac{v+\frac{v}{5}}{v}\right) f$

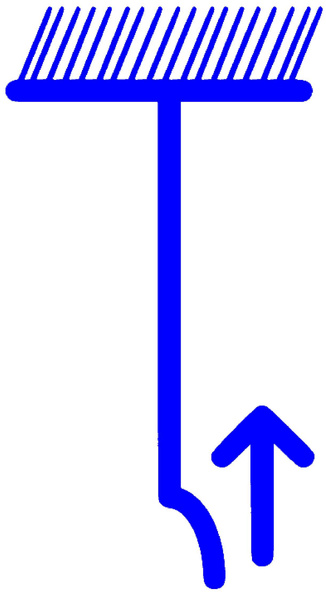
Simplifying the equation:

$f' = \left(\frac{6v}{5v}\right) f = \frac{6}{5} f = 1.2f$

Therefore, the apparent frequency recorded by the observer is $1.2f$.

Question17

A heavy uniform rope is suspended vertically from a ceiling and is in equilibrium. A pulse is generated at the bottom end of the rope as shown. As the pulse travels up the rope, its acceleration at any instant is(g is acceleration due to gravity



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Options:

A. constant and equal to $\frac{g}{2}$

B. variable but equal to $\frac{g}{2}$ when the pulse is exactly at the middle of the string

C. Constant and equal to g

D. variable but equal to g when the pulse is exactly at the middle of the string

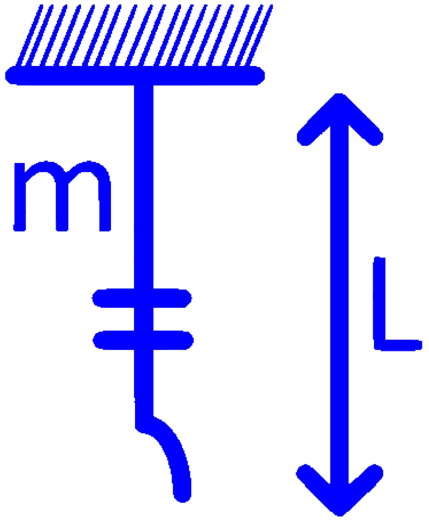
Answer: A

Solution:

Speed of wave on the string is given by

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

where T is tension, μ is linear mass density.



Mass of the rope $=m$

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

, iii)

Put the value of T and μ in Eq. (i),

$$v=\sqrt{\frac{mg}{\frac{m}{L}}}=\sqrt{gL}$$

Now, using equation of motion,

$$v^2=u^2+2as$$

($v=0$, rope is connected to ceiling)

$$a=\frac{U^2}{2S} \Rightarrow \frac{gL}{2L}$$

(because $S=L$)

$$a=\frac{g}{2}$$

Hence, the value of acceleration is constant.

Question18

A wave is given by the equation $y = (0.02) \sin(\pi x - 8\pi/$ then the velocity of the wave is (y and x are in metre and t is in second)

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Options:

A. 16 ms^{-1}

B. 2 ms^{-1}

C. 8 ms^{-1}

D. 18 ms^{-1}

Answer: C

Solution:

Let's analyze the given wave equation. The equation is:

$y = (0.02) \sin(\pi x - 8\pi t)$

Here, the wave is in the standard form:

$y(x, t) = A \sin(kx - \omega t)$

where:

$A = 0.02$ is the amplitude.

k is the wave number.

ω is the angular frequency.

From the given equation:

The wave number is: $k = \pi$.

The angular frequency is: $\omega = 8\pi$.

The wave velocity v (also called the phase velocity) is given by the formula:

$v = \frac{\omega}{k}$

Substitute the known values:

$v = \frac{8\pi}{\pi} = 8\,\text{ms}^{-1}$

Thus, the velocity of the wave is $8\,\text{ms}^{-1}$, which corresponds to Option C.
