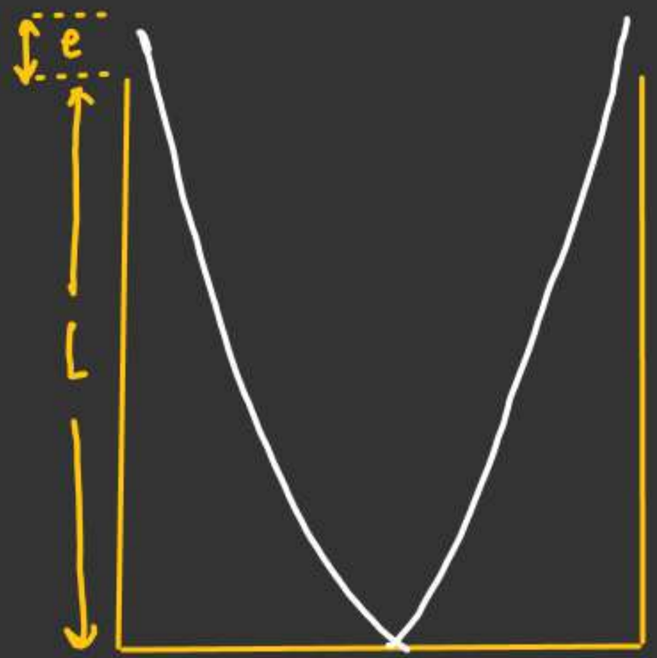
Nishant Jindal

End Correction

Closed organ pipe

e = end Correction $\boxed{e = 0.3d}$

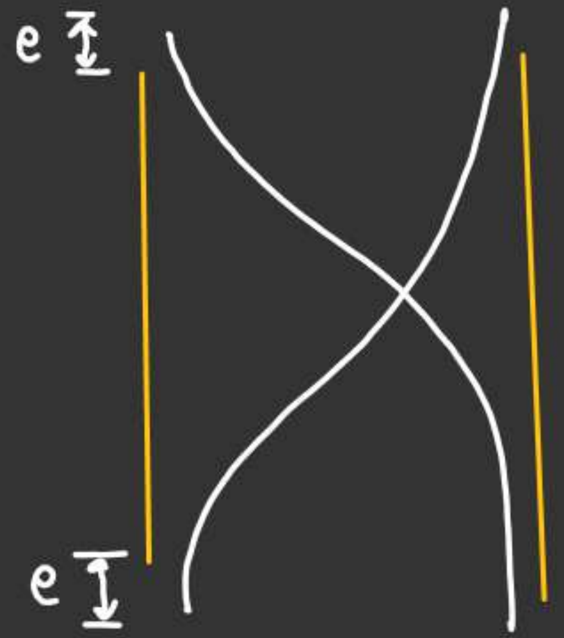


d = diameter of organ pipe

$$L_1 = L + e = \frac{\lambda}{4}$$

$$\boxed{f = (2n-1)\frac{v}{4(L+e)}}$$

Open organ pipe



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

In general.

$$\boxed{f = \frac{nv}{2(L+2e)}}$$

Nishant Jindal

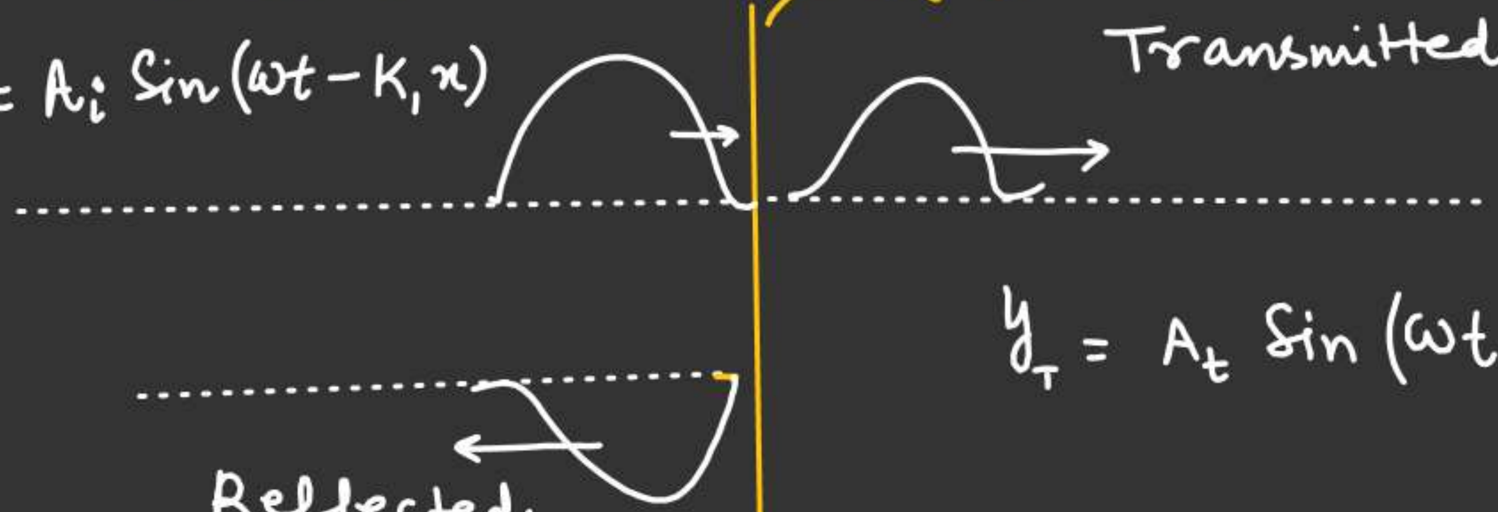
Reflection and transmission of wave

Incident

Rigid boundary.

$y_i = A_i \sin(\omega t - K_1 x)$

Transmitted



$y_T = A_t \sin(\omega t - K_2 x)$

Reflected

$y_R = A_R \sin(\omega t + K_1 x + \pi)$

$y_R = -A_R \sin(\omega t + K_1 x)$

Medium-1

Medium 2

Note Phase change of π when reflection from rigid boundary.

$$A_r = \left(\frac{K_1 - K_2}{K_1 + K_2}\right) A_i$$

$$A_t = \left(\frac{2K_1}{K_1 + K_2}\right) A_i$$

$$K_1 = \frac{\omega}{v_1} = \frac{2\pi f}{v_1}$$

$$K_2 = \frac{2\pi f}{v_2}$$

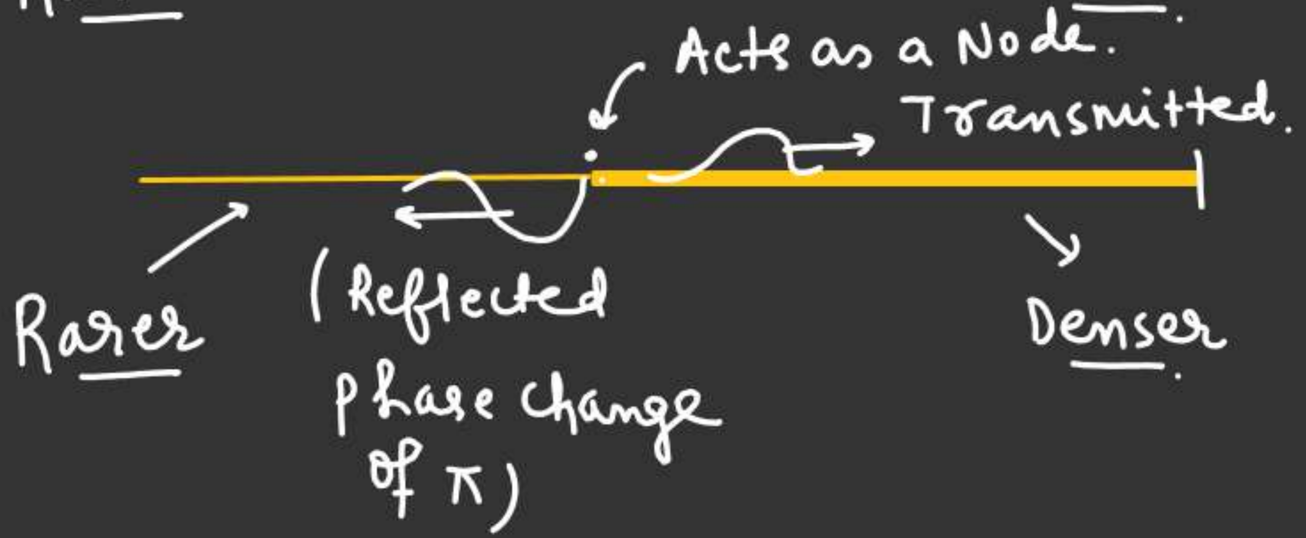
$$A_r = \left(\frac{\frac{1}{v_1} - \frac{1}{v_2}}{\frac{1}{v_1} + \frac{1}{v_2}}\right) A_i = \left(\frac{v_2 - v_1}{v_1 + v_2}\right) A_i$$

$$A_t = \frac{2(1/v_1)}{1/v_1 + 1/v_2} \cdot A_i = \left(\frac{2v_2}{v_1 + v_2}\right) A_i$$

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

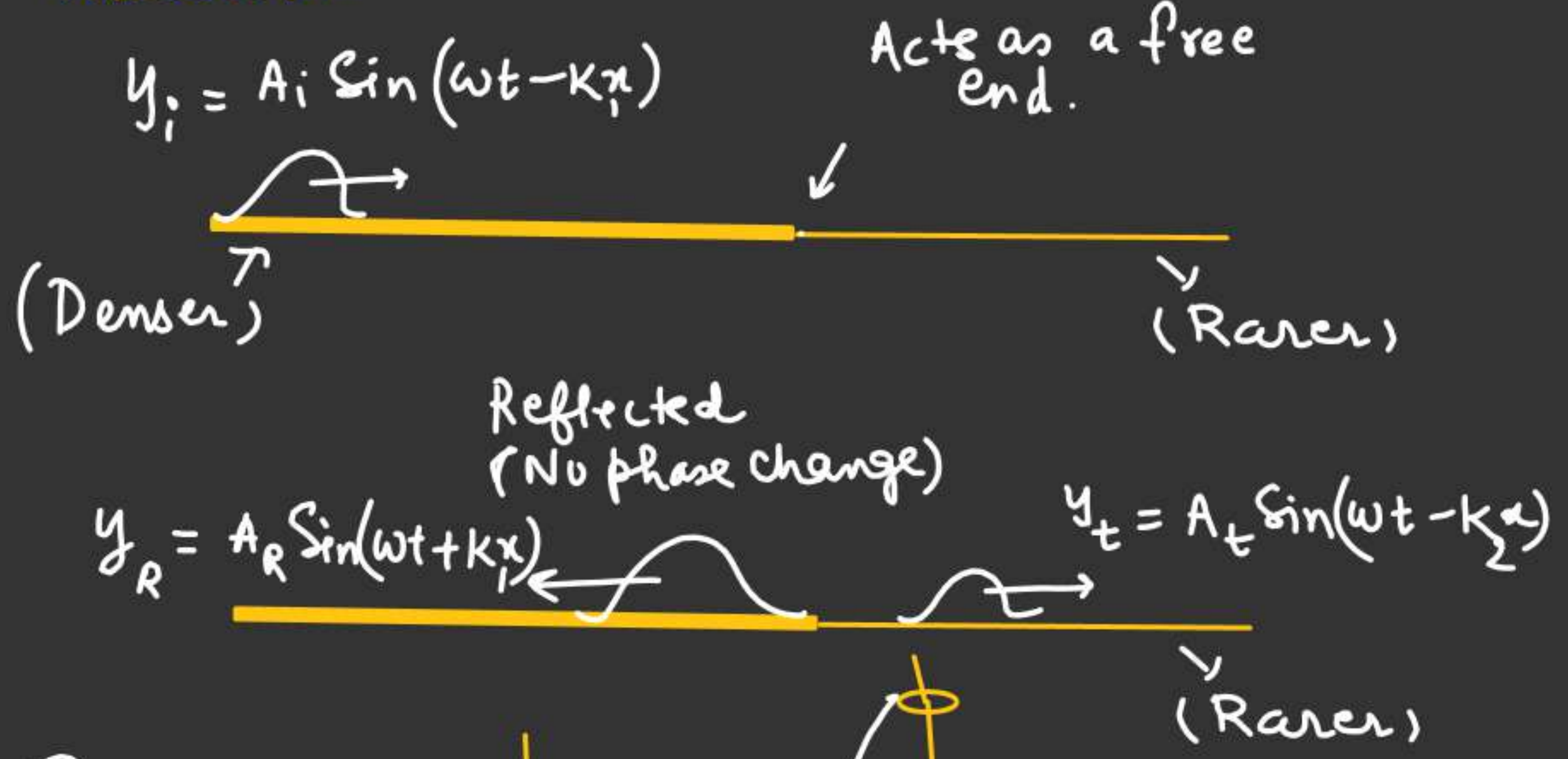
$T \to$ Same

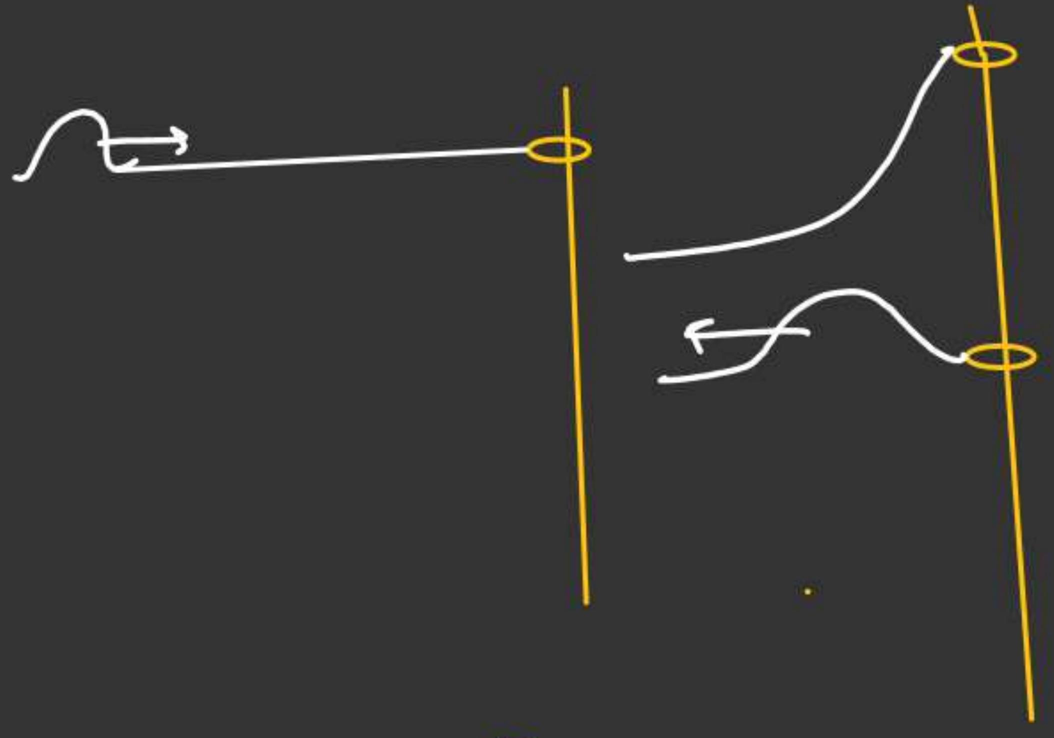
$$\mu = \frac{m}{l}$$



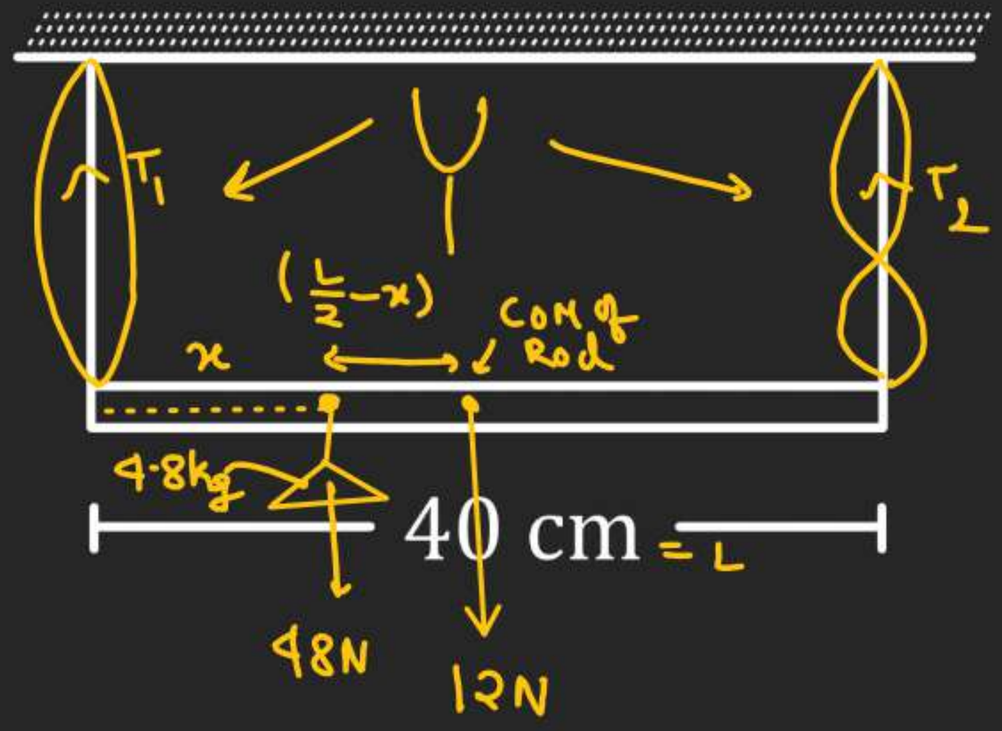
Reflection from free end.

or incident wave pulse in denser medium and reflected wave pulse in rarer medium.





Q.1 A uniform horizontal rod of length $40\ \mathrm{cm}$ and mass $1.2\ \mathrm{kg}$ is supported by two identical wires as shown in figure. Where should a mass of $4.8\ \mathrm{kg}$ be placed on the rod so that the same tuning fork may excite the wire on left into its fundamental vibrations and that on right into its first overtone? Take $\mathrm{g} = 10\ \mathrm{m\ s^{-2}}$.



$T_1 + T_2 = 60$ — ①

$\tau_{net} = 0$ at COM of Rod.

$T_1 \frac{L}{2} = 48(\frac{L}{2} - x) + T_2 \cdot \frac{L}{2}$

$(T_1 - T_2)\frac{L}{2} = 48(\frac{L}{2} - x)$ — ②

$f_{tuning\ fork} = f_{wire-1} = f_{wire-2}$

$\frac{1}{\cancel{\ell}}\sqrt{\frac{T_1}{\mu}} = \frac{2}{\cancel{\ell}}\sqrt{\frac{T_2}{\mu}}$

$T_1 = 4T_2$ — ③

$T_2 = 12N, \quad T_1 = 48N$

$x = \underline{5cm}$.

Q.2 Figure shows an aluminium wire of length $60\ \mathrm{cm}$ joined to a steel wire 'of length $80\ \mathrm{cm}$ and stretched between two fixed supports. The tension produced is $40\ \mathrm{N}$. The cross-sectional area of the steel wire is $1.0\ \mathrm{mm}^2$ and that of the aluminium wire is $3.0\ \mathrm{mm}^2$. What could be the minimum frequency of a tuning fork which can produce standing waves in the system with the joint as a node? The density of aluminium is $2.6\ \mathrm{g\ cm}^{-3}$ and that of steel is $7.8\ \mathrm{g\ cm}$

$l_1, a_1, \rho_1 = 3\rho_2$ Node $a_2 = 3a_1$, ρ_2

let, steel and Aluminium resonate in n_1 & n_2 mode for joint to be node

$f_{\text{tuning fork}} = f_{steel} = f_{Al}$

$$\frac{n_1}{2L_1}\sqrt{\frac{T}{\rho_1 a_1}} = \frac{n_2}{2L_2}\sqrt{\frac{T}{\rho_2 a_2}}$$

$$\frac{n_1}{n_2} = \frac{L_1}{L_2}\sqrt{\frac{\rho_1}{\rho_2}\times\frac{a_1}{a_2}} = \frac{80}{60} = \frac{4}{3}$$

$n_1 = 4 \to$ Steel resonate in 4th harmonic

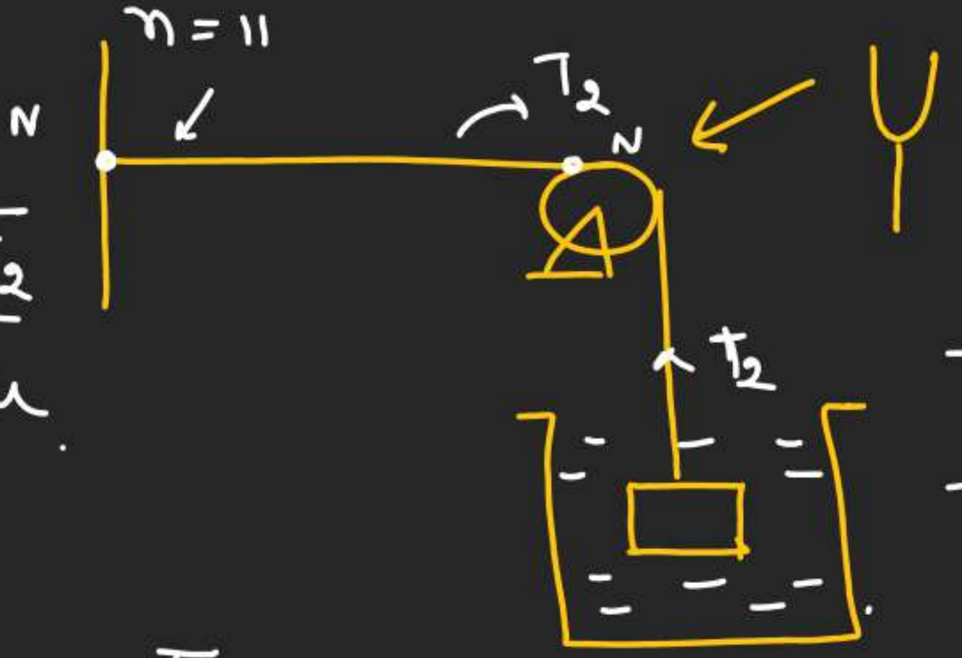
$n_2 = 3 \to$ Al resonate in 3rd harmonic

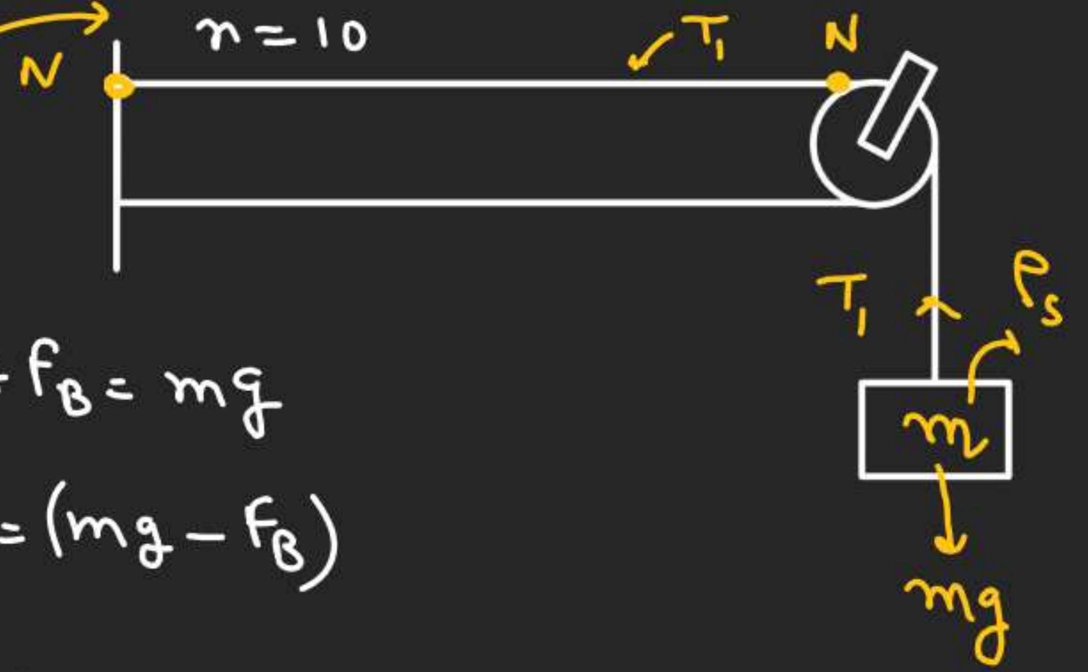
$$f_{\text{tuning fork}} = \left(\frac{4}{2L_1}\sqrt{\frac{T}{\rho_1 a_1}}\right) = \left(\frac{3}{2L_2}\sqrt{\frac{T}{\rho_2 a_2}}\right)$$

Q.3 Figure shows a string stretched by a block going over a pulley. The string vibrates in its tenth harmonic in unison with a particular tuning fork. When a beaker containing water is brought under the block so that the block is completely dipped into the beaker, the string vibrates in its eleventh harmonic. Find the density of the material of the block.

Resonance.

$\rho_{water} = 1\,\text{gm/cc} = 10^3\,\text{kg/m}^3$





$T_2 + F_B = mg$

$T_2 = (mg - F_B)$

$$\frac{10}{\cancel{2L}}\sqrt{\frac{T_1}{\mu}} = \frac{11}{\cancel{2L}}\sqrt{\frac{T_2}{\mu}}$$

$$\frac{T_1}{T_2} = \left(\frac{121}{100}\right)$$

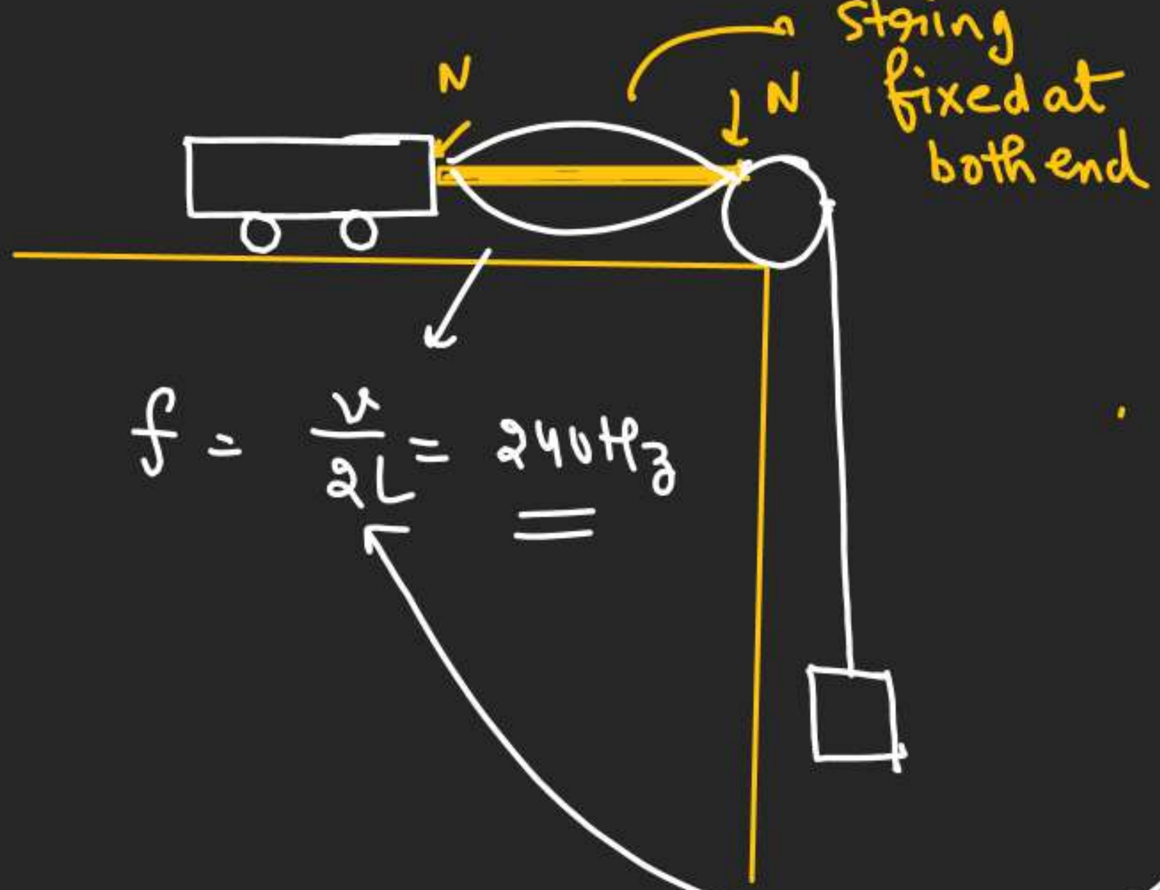
$$T_1 = mg$$

$$T_2 = W_{app} = mg\left(1 - \frac{\rho_L}{\rho_s}\right)$$

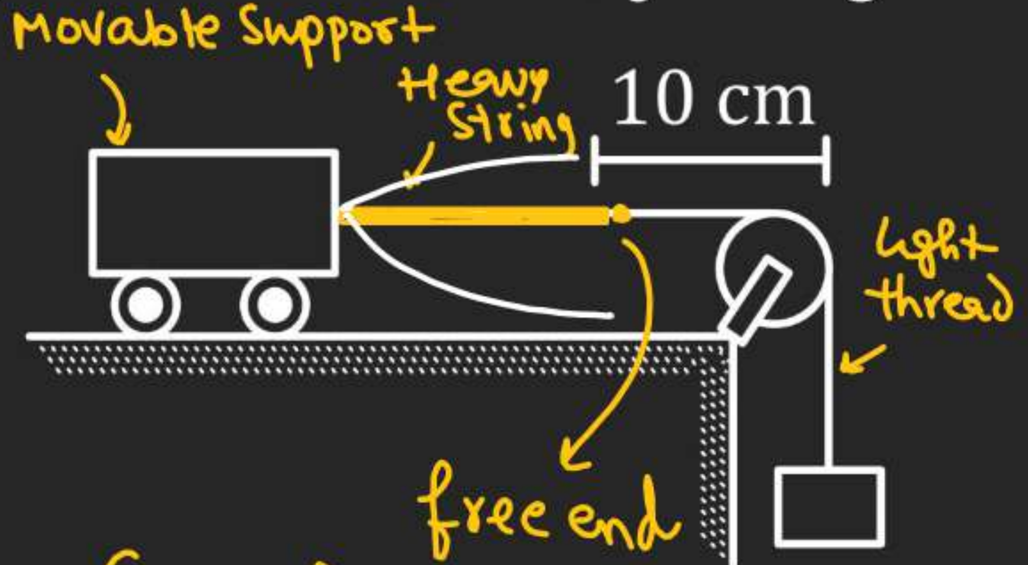
$$\frac{1}{1-\frac{\rho_L}{\rho_s}} = \frac{121}{100}$$

$$\Rightarrow \rho_s = ??$$

Q.4 A heavy string is tied at one end to a movable support and to a light thread at the other end as shown in figure. The thread goes over a fixed pulley and supports a weight to produce a tension. The lowest frequency with which the heavy string resonates is 120 Hz. If the movable support is pushed to the right by 10 cm so that the joint is placed on the pulley, what will be the minimum frequency at which the heavy string can resonate?



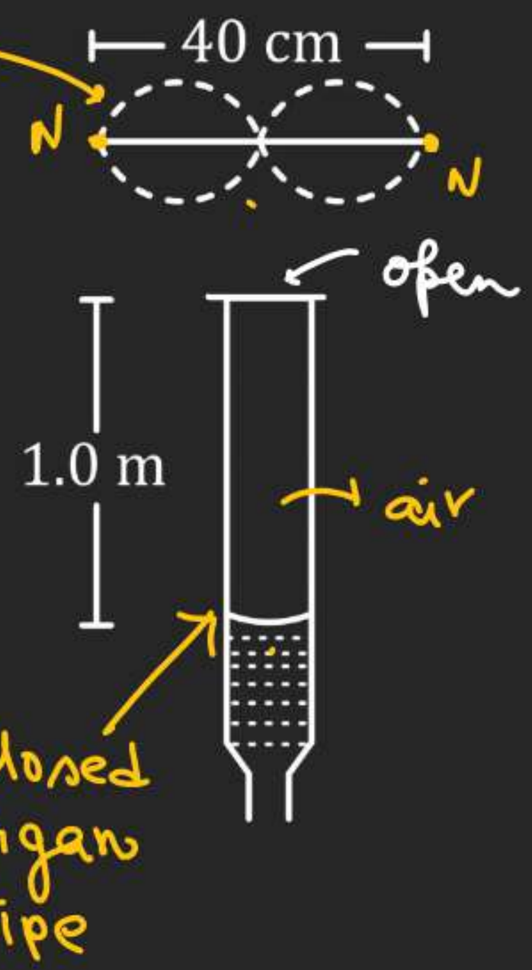
$f = \frac{v}{2L} = 240Hz$



Case of string fixed at one end.

$\frac{v}{4L} = 120Hz. \quad \text{--- (1)}$

Q.5 Consider the situation shown in figure. The wire which has a mass of $4.00\ \mathrm{g}$ oscillates in its second harmonic and sets the air column in the tube into vibrations in its fundamental mode. Assuming that the speed of sound in air is $340\ \mathrm{m\,s^{-1}}$, find the tension in the wire.



2nd harmonic or 1st overtone

$$\mu = \frac{4\times10^{-3}}{40\times10^{-2}}$$

$$\mu = \frac{1}{100}$$

At Resonating condition

$$f_{wire} = f_{air\,column}$$

$$\frac{\cancel{2}}{\cancel{2}L}\sqrt{\frac{T}{\mu}} = \frac{v_{air}}{4\times L_1}$$

$$\frac{1}{40\times10^{-2}}\sqrt{\frac{T}{\left(\frac{1}{100}\right)}} = \left(\frac{340}{4\times1}\right)$$

$$T =$$

WAVE

Q.1 In the wave equation $y = 0.5\sin\frac{2\pi}{\lambda}(400t - x)$m the velocity of the wave will be :

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

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

[28, July 2022]

$v = \left(\frac{\omega}{K}\right)$

(A) 200 m/s

(B) $200\sqrt{2}$ m/s

(C) 400 m/s

(D) $400\sqrt{2}$ m/s

$$y = A\sin\left(\frac{2\pi}{T}t - \frac{2\pi}{\lambda}x\right)$$

$$= A\sin\frac{2\pi}{\lambda}\left(\frac{\lambda}{T}t - x\right)$$

$$= A\sin\frac{2\pi}{\lambda}(vt - x)$$

WAVE

Q.2 Which of the following equations correctly represents a travelling wave having wavelength $\lambda = 4.0$ cm, frequency $v = 100$ Hz and travelling in positive x-axis direction?

$y = A\sin(kx - \omega t)$ $\quad k = \frac{2\pi}{\lambda}$, $\omega = 2\pi f$.

[30, June 2022]

(A) $y = A\sin[(0.50\pi cm^{-1})x - (100\pi s^{-1})t]$ $\quad k = \frac{2\pi}{4}$, $\omega = 200\pi$

(B) $y = A\sin 2\pi[(0.25\ cm^{-1})x - (50\ s^{-1})t]$ $\quad k = 0.5\pi$

(C) $y = A\sin\left[\left(\frac{2\pi}{4} cm^{-1}\right)x - \left(\frac{2\pi}{100} s^{-1}\right)t\right]$

(D) $y = A\sin \pi[(0.5\ cm^{-1})x - (200\ s^{-1})t]$

WAVE

Q.3 Two travelling waves produces a standing wave represented by equation,

$\pi/2$

$y = 1.0\ \mathrm{mm} \cos\left(1.57\ \mathrm{cm}^{-1}\right) x \sin\left(78.5\ \mathrm{s}^{-1}\right) t.$

1cm

The node closest to the origin in the region $x > 0$ will be at $x =$ cm.

[26, Aug 2021]

Amplitude.

$A = 1 \times 10^{-3} \cos\left(\frac{\pi}{2} x\right)$

For Node

$A = 0$.

$\frac{\pi x}{2} = \frac{\pi}{2}$

$x = 1$

WAVE

Q.4 A progressive wave travelling along the positive x-direction is represented by $y(x, t) = A\sin(kx - \omega t + \phi)$. Its snapshot at $t = 0$ is given in the figure.

[12 April 2019 I]

For this wave, the phase ϕ is:

(A) $-\frac{\pi}{2}$

(B) π

(C) 0

(D) $\frac{\pi}{2}$

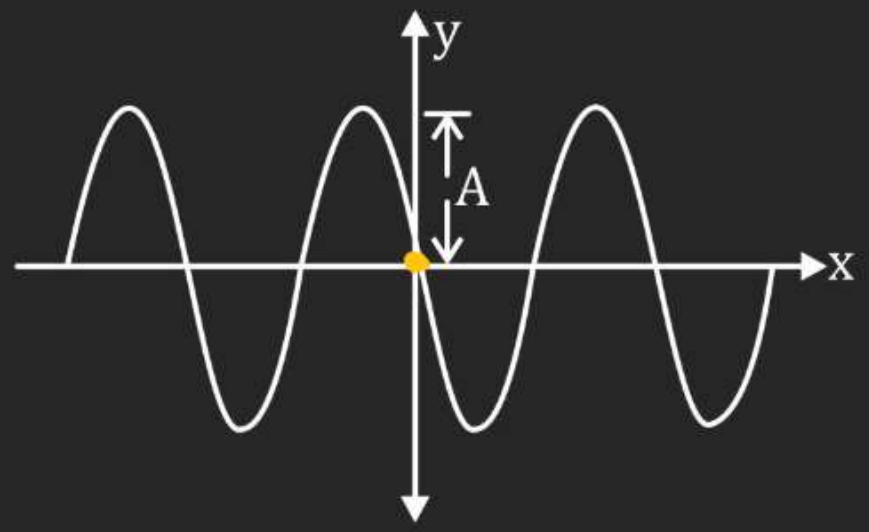
At $x = 0$, $t = 0$

$y = 0$

$0 = A\sin(\phi)$

$\sin\phi = 0$

$\phi = \pi$



WAVE

Q.5 A sound absorber attenuates the sound level by 20 dB. The intensity decreases by a factor of **[2007]**

decreases.

(A) 100 (B) 1000 (C) 10000 (D) 10

$\beta_1 = 10\log\left(\frac{I_1}{I_0}\right)$ $\beta_1 - \beta_2 = 20$ (given)

$\beta_2 = 10\log\left(\frac{I_2}{I_0}\right)$

$\beta_1 - \beta_2 = 10\left[\log\left(\frac{I_1}{I_0}\right) - \log\left(\frac{I_2}{I_0}\right)\right]$

$20 = 10\log\left(\frac{I_1}{I_2}\right)$

$2 = \log\left(I_1/I_2\right)$

$\frac{I_1}{I_2} = 10^2$

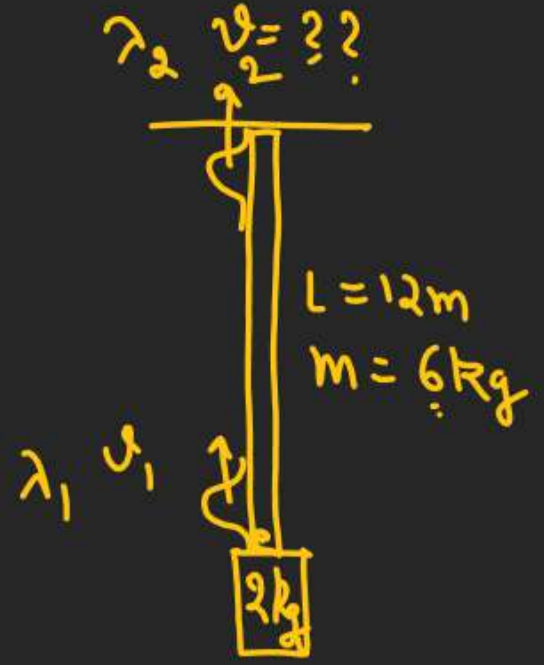
$I_2 = I_1/100$

WAVE

Q.6 A uniform thin rope of length $12 \mathrm{~m}$ and mass $6 \mathrm{~kg}$ hangs vertically from a rigid support and a block of mass $2 \mathrm{~kg}$ is attached to its free end. A transverse short wave-train of wavelength $6 \mathrm{~cm}$ is produced at the lower end of the rope. What is the wavelength of the wave train (in cm) when it reaches the top of the rope?

[03, Sep. 2020]

(A) 3 (B) 6 (C) 12 (D) 9



$v = f\lambda$

$\frac{v}{\lambda} = f = \text{Constant.}$

$\frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2} \Rightarrow \lambda_2 = \frac{v_2}{v_1} \times \lambda_1$

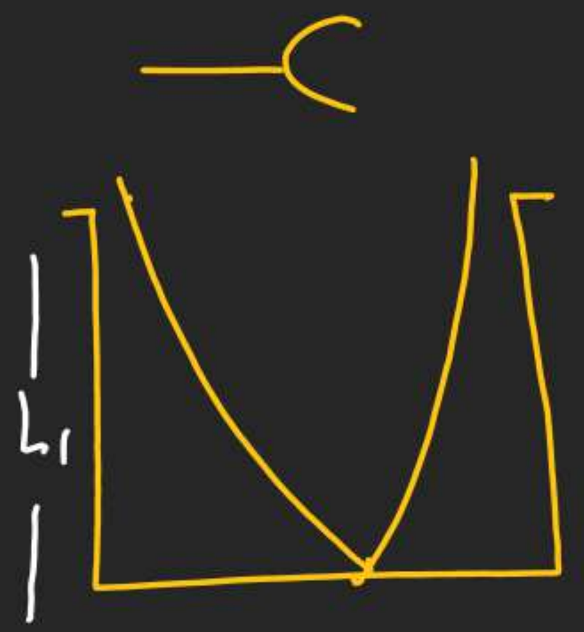
$\lambda_2 = \sqrt{\frac{T_2}{T_1}} \times \lambda_1 \Rightarrow \lambda_2 = \sqrt{\frac{80}{20}} \times \lambda_1$

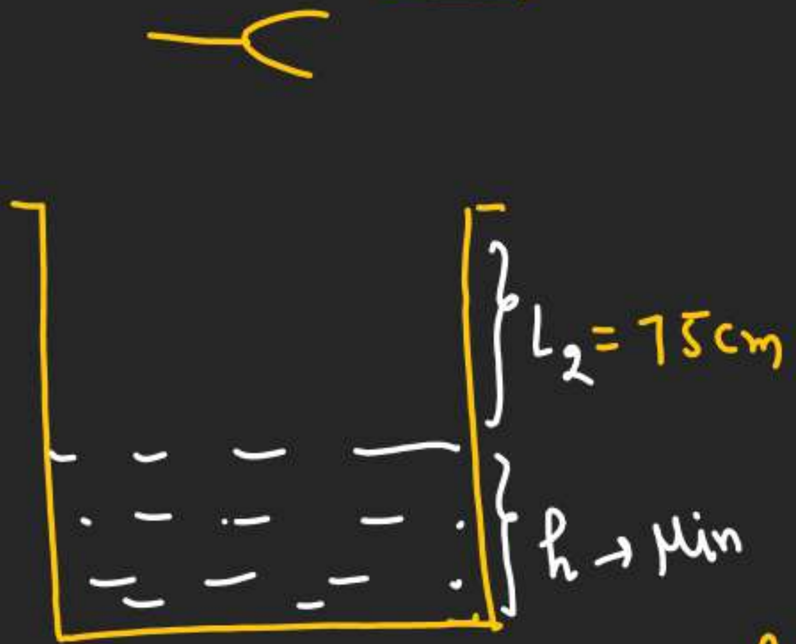
$\lambda_2 = 2\lambda_1 = 2 \times 6 = 12\text{cm}$

WAVE

Q.7 A tunning fork of frequency 340 Hz (= f) resonates in the fundamental mode with an air column of length 125 cm in a cylindrical tube closed at one end. When water is slowly poured in it, the minimum height of water required for observing resonance once again is cm. 50cm.

(Velocity of sound in air is $340\ ms^{-1}$) **[June 28, 2022]**





$v = f\lambda$.

$\lambda = \frac{v}{f} = \frac{340}{340} = 1m$.

$L_2 = \frac{3\lambda}{4} = \frac{3}{4} \times 1$

$L_2 = \underline{75cm}$

$h = (125-75)\ cm$

$= \underline{50}\ cm.$

WAVE

$K = \frac{1}{B}$.

Q.8 A closed organ pipe of length L and an open organ pipe contain gases of densities ρ_1 and ρ_2 respectively. The compressibility of gases are equal in both the pipes. Both the pipes are vibrating in their first overtone with same frequency. The length of the open pipe is $\frac{x}{3} L \sqrt{\frac{\rho_1}{\rho_2}}$ where x is (Round off to the Nearest Integer). **[16, March 2021]**

$f_{open} = \frac{nv}{2L}$

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

$f_{open} = f_{closed}$

$v = \sqrt{\frac{B}{\rho}}$

$\frac{2}{2L_2}\sqrt{\frac{B}{\rho_2}} = \frac{3}{4L_1}\sqrt{\frac{B}{\rho_1}}$

$L_1 = L$ (given)

$L_2 = \frac{4}{3}\sqrt{\frac{\rho_1}{\rho_2}}\, L$

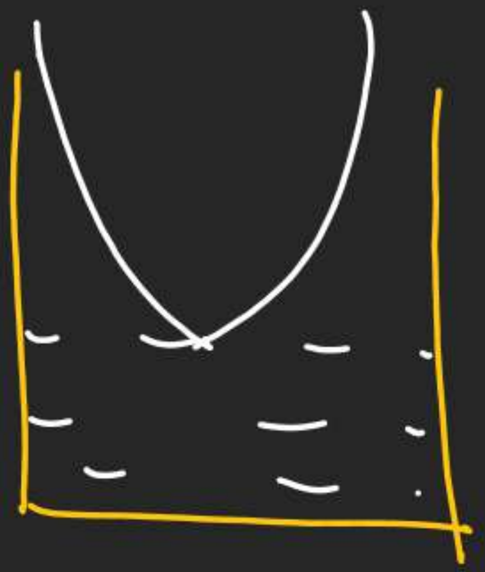
$x = 4$

WAVE

End Correction

Q.9 A tuning fork of frequency $480\ \mathrm{Hz}$ is used in an experiment for measuring speed of sound (v) in air by resonance tube method. Resonance is observed to occur at two successive lengths of the air column, $l_1 = 30\ \mathrm{cm}$ and $l_2 = 70\ \mathrm{cm}$. Then, v is equal to: **[12 April 2019 (II)]**

(A) $332\ \mathrm{ms}^{-1}$ (B) $384\ \mathrm{ms}^{-1}$ (C) $338\ \mathrm{ms}^{-1}$ (D) $379\ \mathrm{ms}^{-1}$



$$l_1 + e = \frac{\lambda}{4}$$

$$l_2 + e = \frac{3\lambda}{4}$$

$$v = f\lambda$$

$$(l_2 - l_1) = \frac{\lambda}{2}$$

$$\lambda = 2(l_2 - l_1)$$

$$v = f\lambda$$

$$= 480 \times 2 \times (70-30)$$

$$= \underline{\qquad\qquad}$$

WAVE

H.W

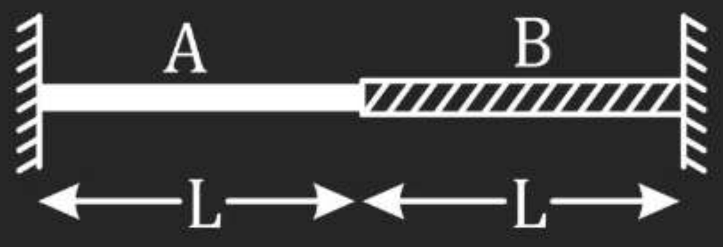
Q.10 A string $2.0 \mathrm{~m}$ long and fixed at its ends is driven by a 240 Hz vibrator. The string vibrates in its third harmonic mode. The speed of the wave and its fundamental frequency is: [9 April 2019 (II)]

(A) $180 \mathrm{~m/s}, 80 \mathrm{~Hz}$
(B) $320 \mathrm{~m/s}, 80 \mathrm{~Hz}$
(C) $320 \mathrm{~m/s}, 120 \mathrm{~Hz}$
(D) $180 \mathrm{~m/s}, 120 \mathrm{~Hz}$

WAVE

H.W

Q.11 A wire of length $2\,L$, is made by joining two wires A and B of same length but different radii r and $2r$ and made of the same material. It is vibrating at a frequency such that the joint of the two wires forms a node. If the number of antinodes in wire Q A is p and that in B is q then the ratio $p:q$ is : **[8 April 2019 (I)]**



(A) $3:5$

(B) $4:9$

(C) $1:2$

(D) $1:4$

WAVE

H.W

Q.12 A closed organ pipe has a fundamental frequency of 1.5kHz. The number of overtones that can be distinctly heard by a person with this organ pipe will be: (Assume that the highest frequency a person can hear is $20,000\ \text{Hz}$)

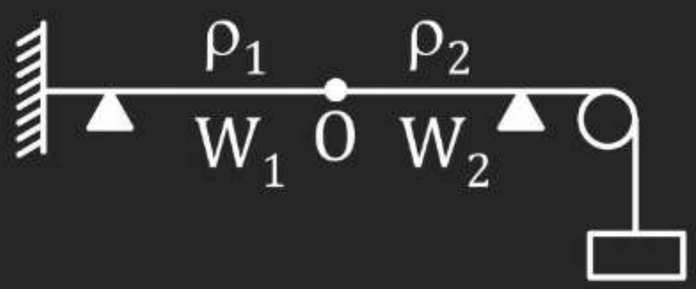
[10 Jan. 2019 (I)]

(A) 6 (B) 4 (C) 7 (D) 5

WAVE

H.W

Q.13 Two wires W_1 and W_2 have the same radius r and respective densities ρ_1 and ρ_2 such that $\rho_2 = 4\rho_1$. They are joined together at the point O, as shown in the figure. The combination is used as a sonometer wire and kept under tension T. The point O is midway between the two bridges. When a stationary waves is set up in the composite wire, the joint is found to be a node. The ratio of the number of antinodes formed in W_1 to W_2 is: **[8 April 2017]**



(A) $1:1$

(B) $1:2$

(C) $1:3$

(D) $4:1$

WAVE

H.W

Q.14 A uniform string of length $20\ \mathrm{m}$ is suspended from a rigid support. A short wave pulse is introduced at its lowest end. It starts moving up the string. The time taken to reach the supports is :

(take $g = 10\ \mathrm{ms^{-2}}$) [2016]

(A) $2\sqrt{2}\ \mathrm{s}$ (B) $\sqrt{2}\ \mathrm{s}$ (C) $2\pi\sqrt{2}\ \mathrm{s}$ (D) $2\ \mathrm{s}$

WAVE

H-W

Q.15 A pipe open at both ends has a fundamental frequency f in air. The pipe is dipped vertically in water so that half of it is in water. The fundamental frequency of the air column is now:

[2016]

(A) $2f$ (B) f (C) $\frac{f}{2}$ (D) $\frac{3f}{4}$

Nishant Jindal

WAVE

H.W

Q.16 The total length of a sonometer wire between fixed ends is $110\ \text{cm}$. Two bridges are placed to divide the length of wire in ratio $6:3:2$. The tension in the wire is $400\ \text{N}$ and the mass per unit length is $0.01\ \text{kg/m}$. What is the minimum common frequency with which three parts can vibrate? [19 April 2014]

(A) $1100\ \text{Hz}$ (B) $1000\ \text{Hz}$ (C) $166\ \text{Hz}$ (D) $100\ \text{Hz}$

WAVE

Q.17 A tuning fork A of unknown frequency produces 5 beats/s with a fork of known frequency 340 Hz. When fork A is filed, the beat frequency decreases to 2 beats/s. What is the frequency of fork A ? **[26, Feb. 2021]**

(A) 335 Hz (B) 338 Hz (C) 345 Hz (D) 342 Hz

A

f_A


B

$f_B = 340$

$|f_A - f_B| = 5$

$|f_A - 340| = 5$

$f_A - 340 = \pm 5$

$f_A = 345$

$f_A = 335$ ✓

filing → Tuning fork frequency increases

Waxing → Tuning fork frequency decreases

$|f_B - f_A \uparrow| =$ Beat frequency ↓.

f_B fixed

WAVE

Q.18 A tuning fork of known frequency $256\ \mathrm{Hz}$ makes 5 beats per second with the vibrating string of a piano. The beat frequency decreases to 2 beats per second when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was **[2003]**

(A) $(256+2)\mathrm{Hz}$ (B) $(256-2)\mathrm{Hz}$

(C) $(256-5)\mathrm{Hz}$ (D) $(256+5)\mathrm{Hz}$

$\uparrow f_{wire} = \frac{n}{2L}\sqrt{\frac{T}{\mu}}\uparrow$

$f_{tuning fork} = 256\ \mathrm{Hz}$ ✓

$f_{wire} = f$

$|f-256| = 5$

$256 - f_{wire}\uparrow = \text{Beat}\downarrow$

$f \rightarrow 256+5 =$

$f \rightarrow 256-5$

WAVE

Q.19 A tuning fork arrangement (pair) produces 4 beats/ sec with one fork of frequency 288cps. A little wax is placed on the unknown fork and it then produces 2 beats /sec. The frequency of the unknown fork is **[2002]**

(A) 286cps (B) 292cps (C) 294cps (D) 288cps

Let, Unknow frequency be f

$|f - 288| = 4$

$f - 288 = \pm 4$

$f \rightarrow 292$, 284

$f - \underbrace{288}_{\text{fixed}} = \text{Beat}$

$f = 292$