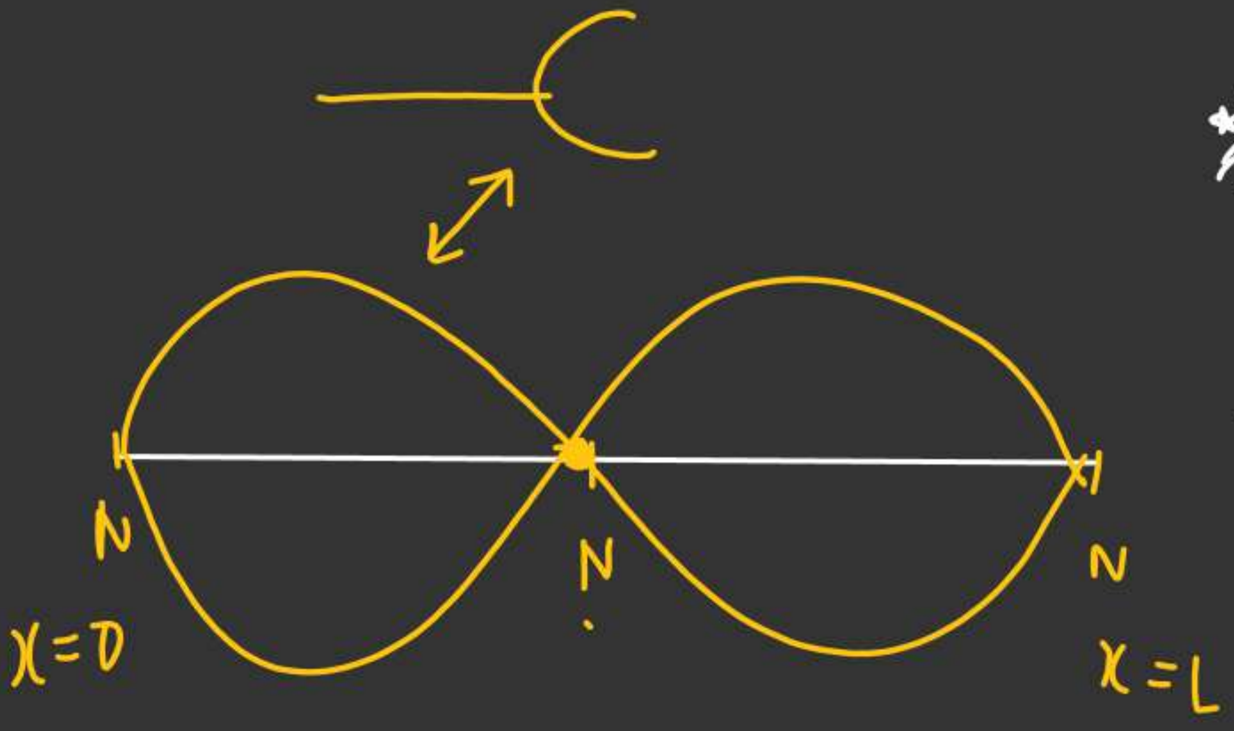
Nishant Jindal

$n=2, \quad L = \frac{2\lambda}{2} \Rightarrow L = \lambda.$



$n=2$

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

2nd harmonic
or
1st overtone

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

$$L = \frac{n}{2}\frac{v}{f}$$

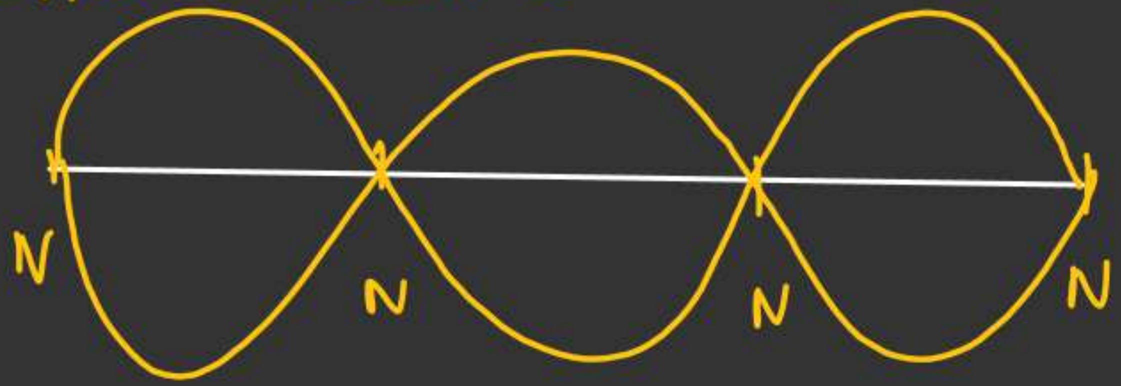
$$\boxed{f = \frac{nv}{2L}}$$

In general.

$n=3$

$$f = \frac{3v}{2L} = \frac{3}{2L}\sqrt{\frac{T}{\mu}}$$

3rd harmonic or 2nd overtone



Note :- In string fixed at both end all the intergral multiple of harmonics are the overtone.

$$f = n\underbrace{\frac{v}{2L}}_{f_0} \Rightarrow \boxed{f = nf_0}$$

Nishant Jindal

Case-2 :- String fixed at one end :-

$$f_0 = \frac{v}{4L} \rightarrow$$ 1st harmonic or fundamental frequency.

For AntiNode.

$$x = (2n-1)\frac{\lambda}{2}.$$

$x = L$, → AntiNode

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

$$v = f\lambda$$

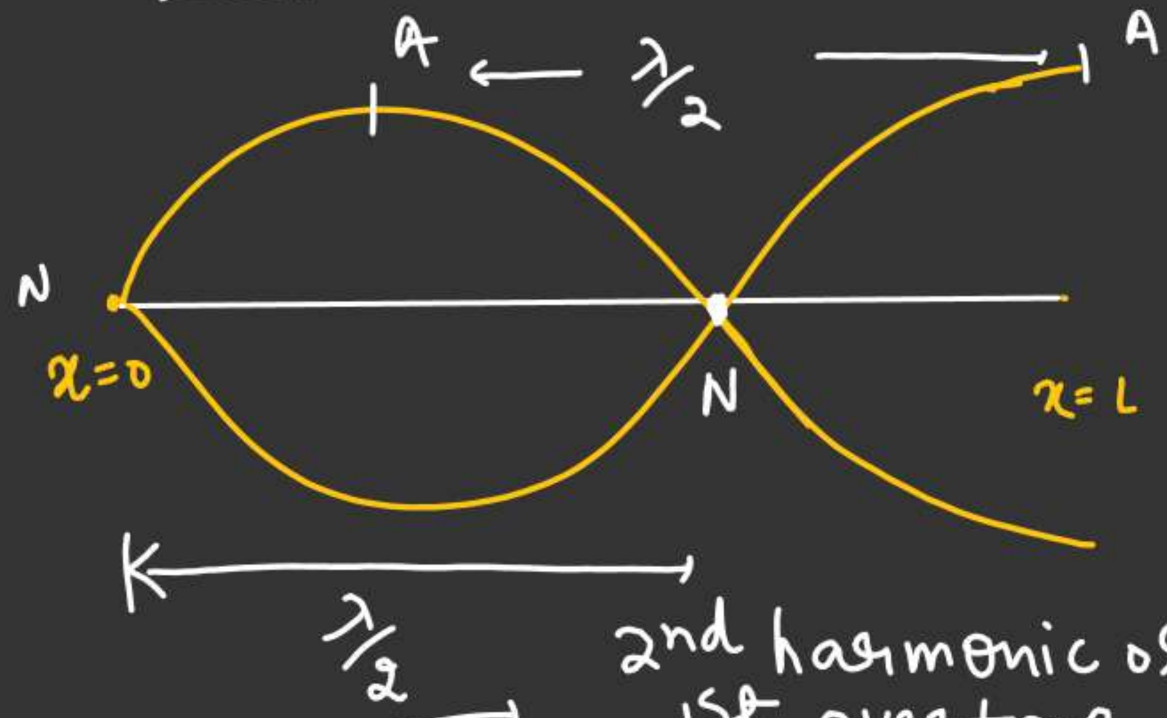
$$\lambda = \frac{v}{f}$$

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

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

$n = 1, 2, 3, 4, \ldots$

$\underline{n=2}$.



2nd harmonic or 1st overtone.

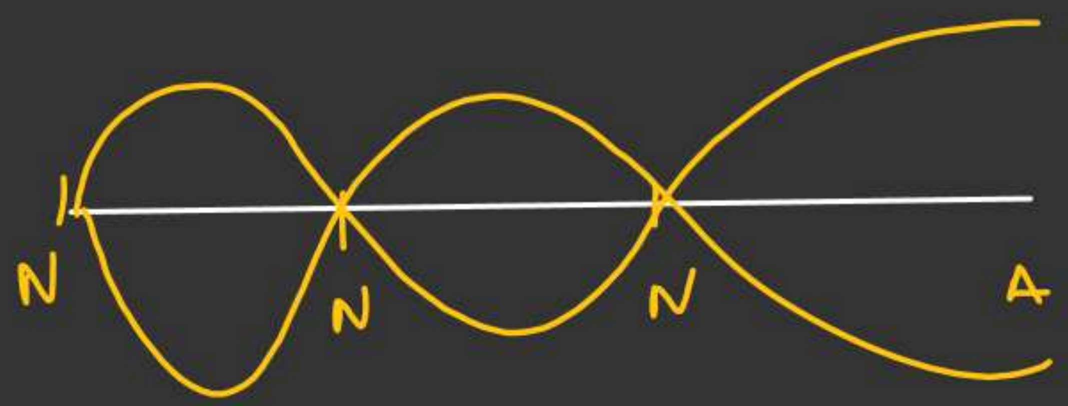
$$f = \frac{3v}{4L} = 3f_0$$

$$L = (2\times2-1)\frac{\lambda}{4}$$

$$L = \frac{3\lambda}{4}.$$

$$L = \frac{\lambda}{2} + \frac{\lambda}{4}$$

$\underline{n=3}$.



$$L = (2\times3-1)\frac{\lambda}{4}$$

$$L = \frac{5\lambda}{4} = \lambda + \frac{\lambda}{4}$$

$$f = \frac{5v}{4L} = 5f_0$$

3rd harmonic or 2nd overtone

$\Rightarrow$ Note :- [Only odd multiple of harmonics are the overtone]

Nishant Jindal

Standing wave in organ pipes

Case-1 :- Closed organ pipe → (Same as string fixed at one end)

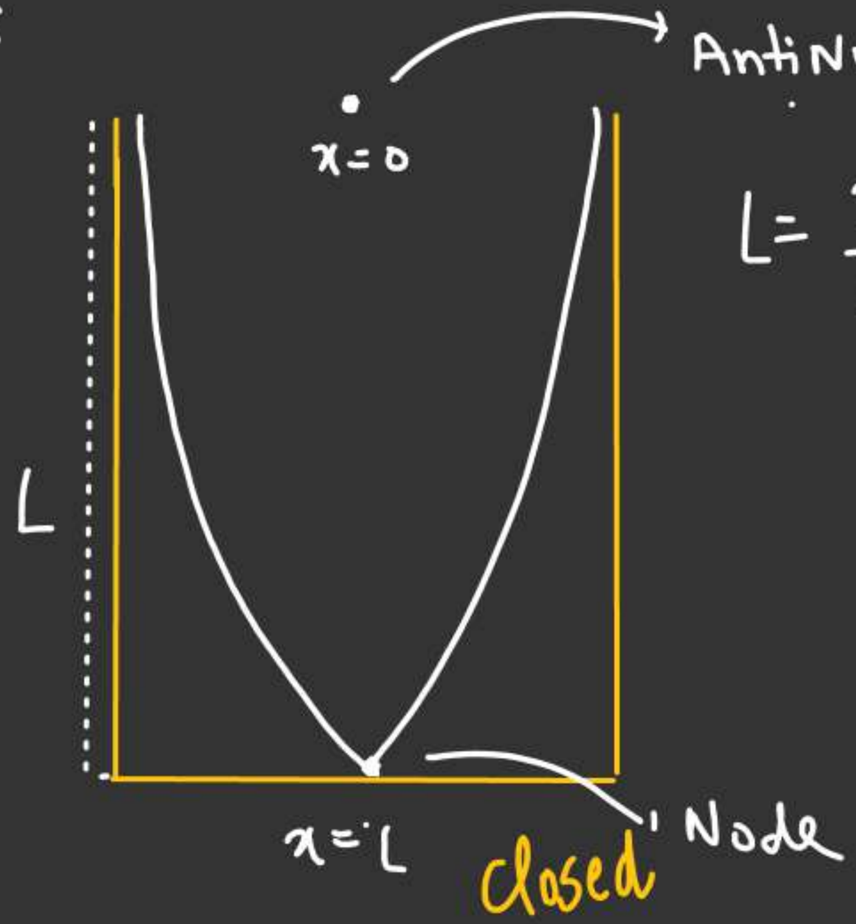
$$\boxed{f = (2n-1)\frac{v}{4L}}$$

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

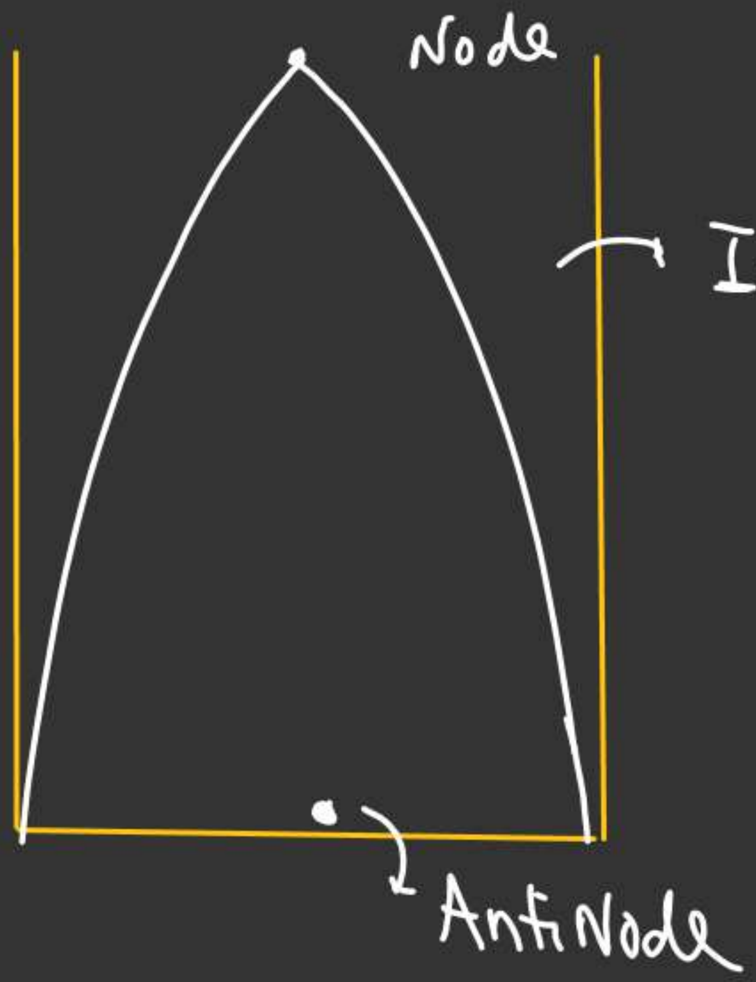
For sound wave

$$\boxed{v = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}}$$

In terms of displacement of particles



$$L = \frac{\lambda}{4}$$



In terms of excess pressure

$$PV = \frac{\omega}{M}RT$$

$$P = \left(\frac{\omega}{V}\right)\frac{RT}{M}$$

$$\frac{P}{\rho} = \left(\frac{RT}{M}\right)$$

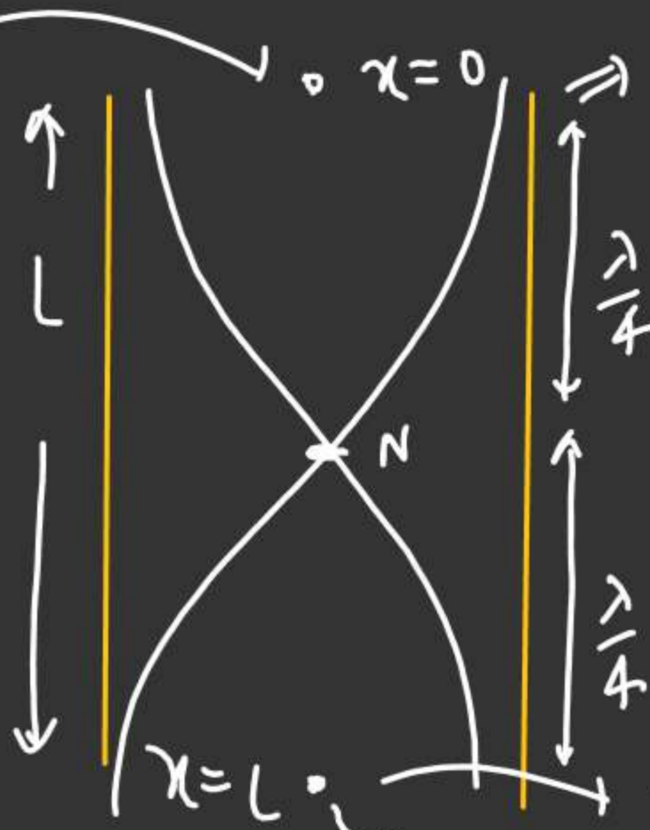
Open organ pipe (Same as string fixed at both end)

$$\boxed{f = \frac{nv}{2L}}$$

$$v = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}$$

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

free end
Anti Node



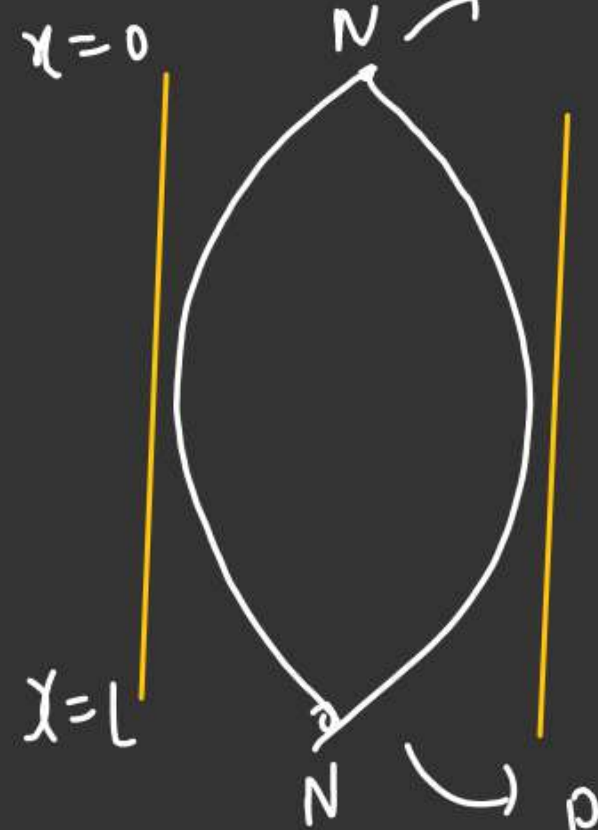
free end
AntiNode

In terms of displacement of Medium particles

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

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

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



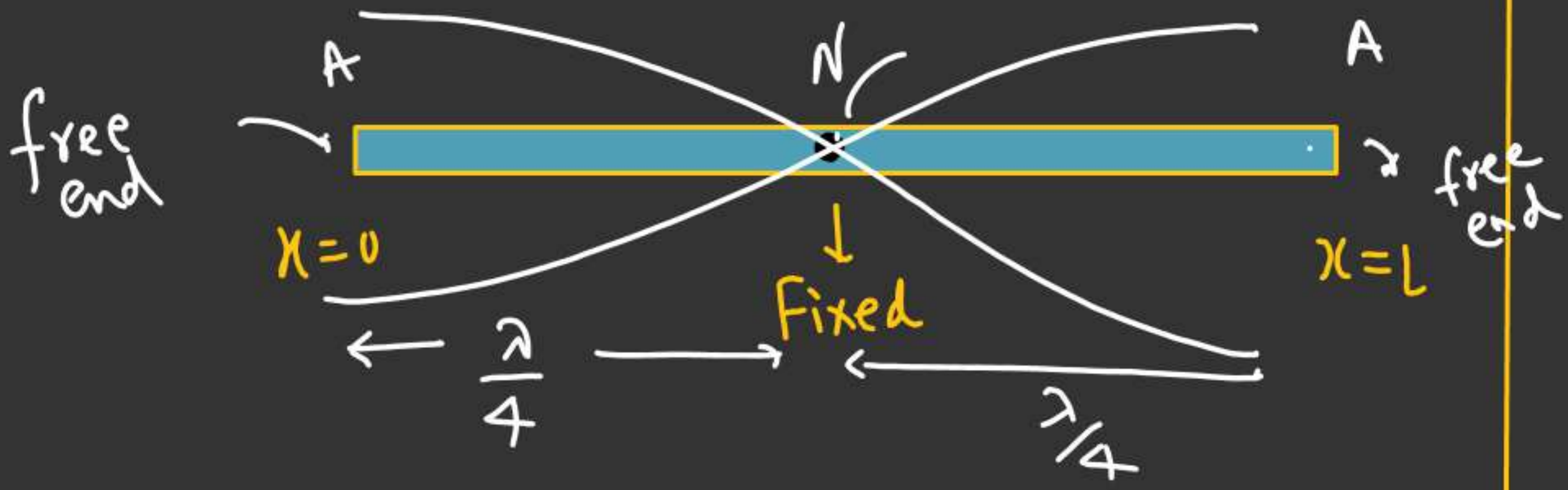
Pressure Node

Pressure Node

Nishant Jindal

Rod Vibrating when fixed at its Mid point

$n = 1$



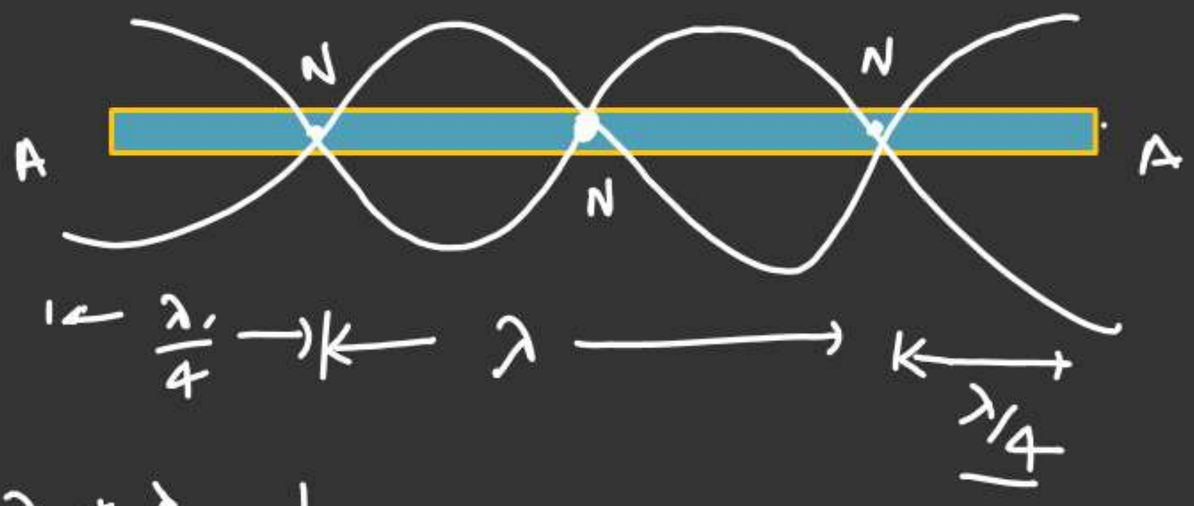
$$L = \frac{\lambda}{2}.$$

$$\lambda = \frac{v}{f_0}$$

$$L = \frac{1}{2}\frac{v}{f_0} \qquad \left(v = \sqrt{\frac{Y}{\rho}}\right)$$

$$\left(f_0 = \frac{v}{2L}\right) \rightarrow$$ Fundamental or 1st harmonic

$n = 2$ 2nd harmonic or 1st Overtone



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

$$L = \frac{3\lambda}{2}$$

$$L = \frac{3}{2}\frac{v}{f}$$

$$f = \left(\frac{3v}{2L}\right) \qquad \left(v = \sqrt{\frac{Y}{\rho}}\right)$$

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

In general $\quad n = 1, 2, 3, 4 \ldots$

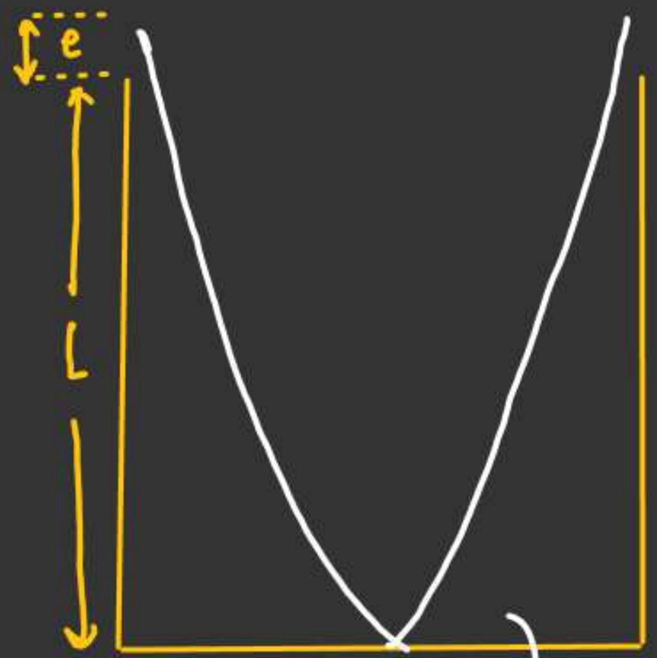
Nishant Jindal

End Correction

Closed organ pipe

e = end Correction

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



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

e = end Correction

$$\boxed{e = 0.3\,d}$$

d = diameter of organ pipe.

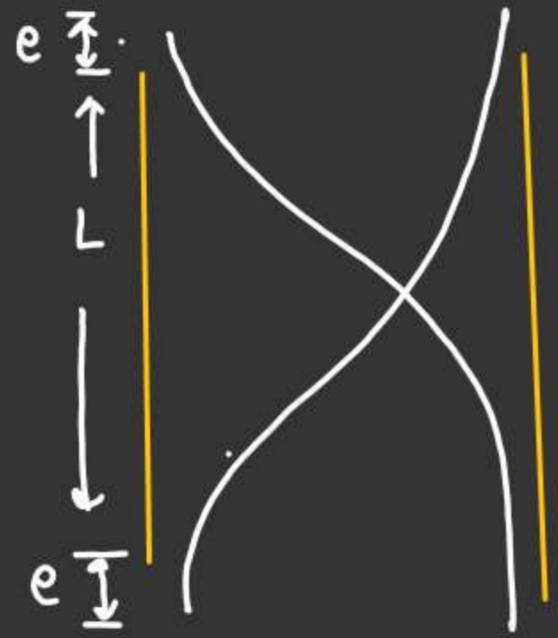
Open organ pipe

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

In general

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

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

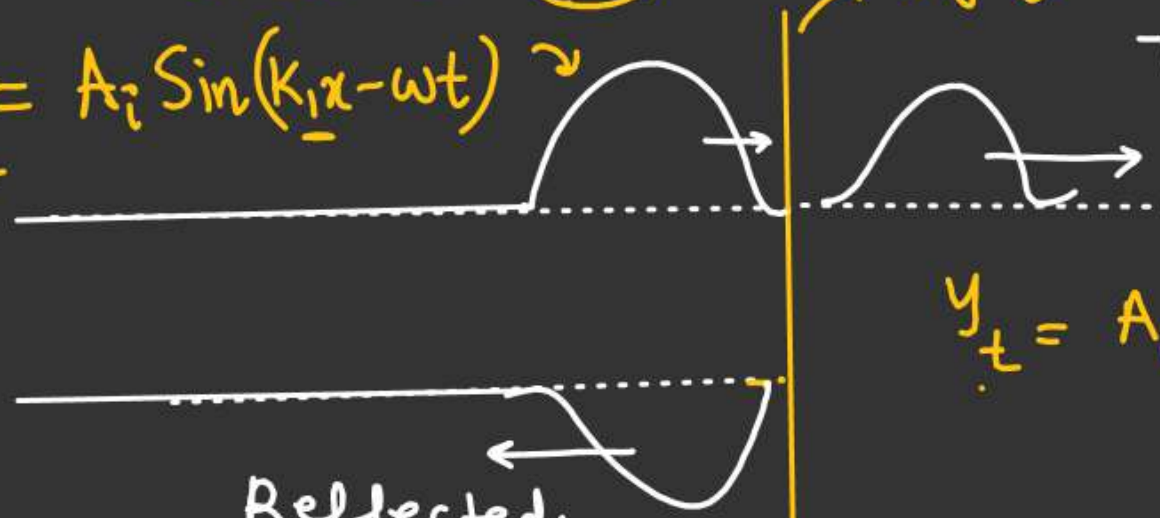


Nishant Jindal

Reflection and transmission of wave

Incident (K_1) Rigid boundary. (K_2)

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



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

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

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

Medium-1   Medium 2

Note. Phase change of π when reflection from rigid boundary.

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

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

Note :- When wave reflected from rigid Support it suffer a phase change of π or path difference of $\frac{\lambda}{2}$.

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

$$\downarrow$$

$$\pi = \frac{2\pi}{\lambda}\cdot\Delta x$$

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

Nishant Jindal

Reflection and transmission of wave

Incident (K_1)

Rigid boundary. (K_2)

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

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

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

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

Medium-1

Medium 2

Note. Phase change of π when reflection from rigid boundary.

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

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

$$K_1 = \frac{\omega}{v_1}, \quad K_2 = \frac{\omega}{v_2}$$

ω = Same

$\omega = 2\pi f$

$\downarrow$

Frequency depends on source only not on medium

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

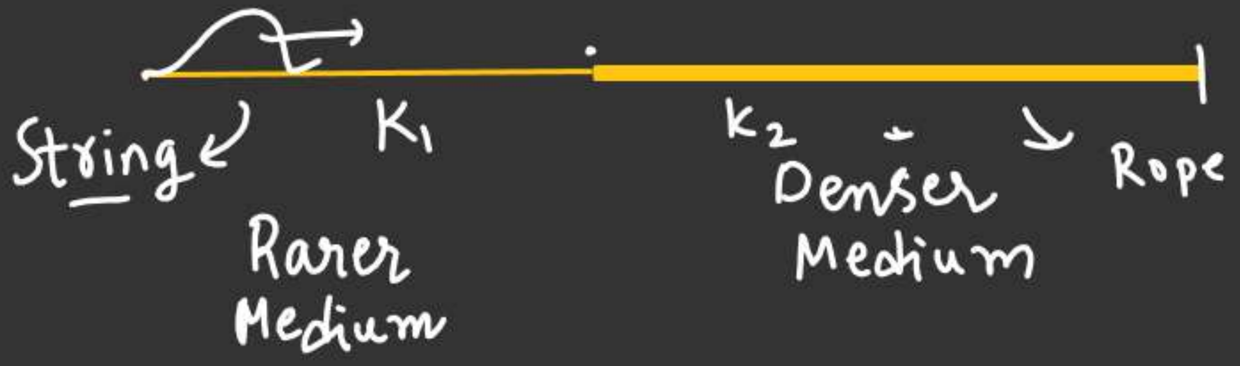
$$\boxed{A_r = \left(\frac{v_2 - v_1}{v_2 + v_1}\right) A_i}$$

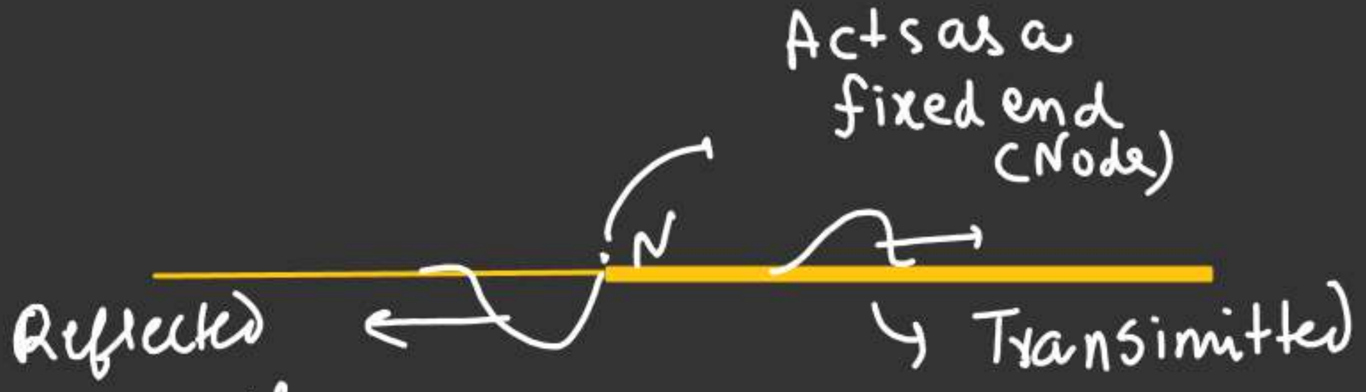
$$\boxed{A_t = \frac{2v_2}{v_1 + v_2} A_i}$$

Nishant Jindal

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

$y_i = A_i \sin(k_1 x - \omega t)$



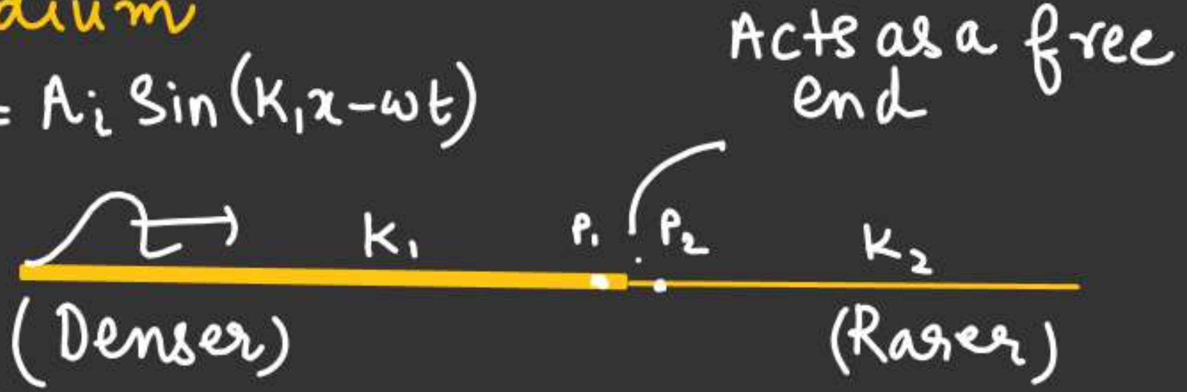


$y_R = A_R \sin(k_1 x + \omega t + \pi)$

Reflection from free end.

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

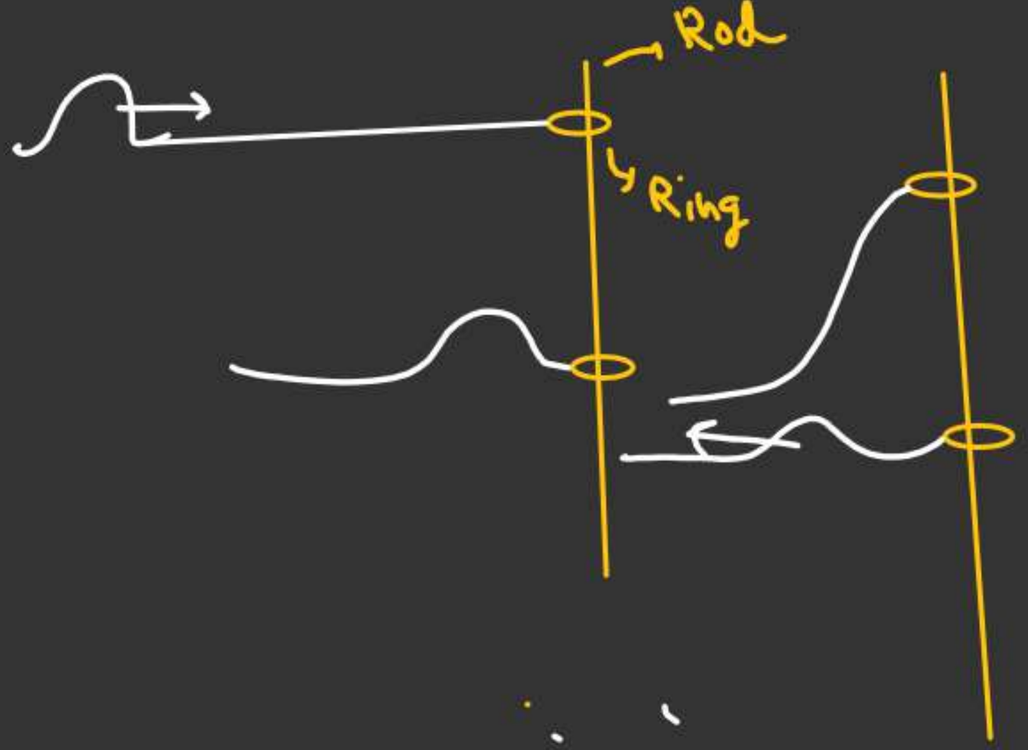
$y_i = A_i \sin(k_1 x - \omega t)$



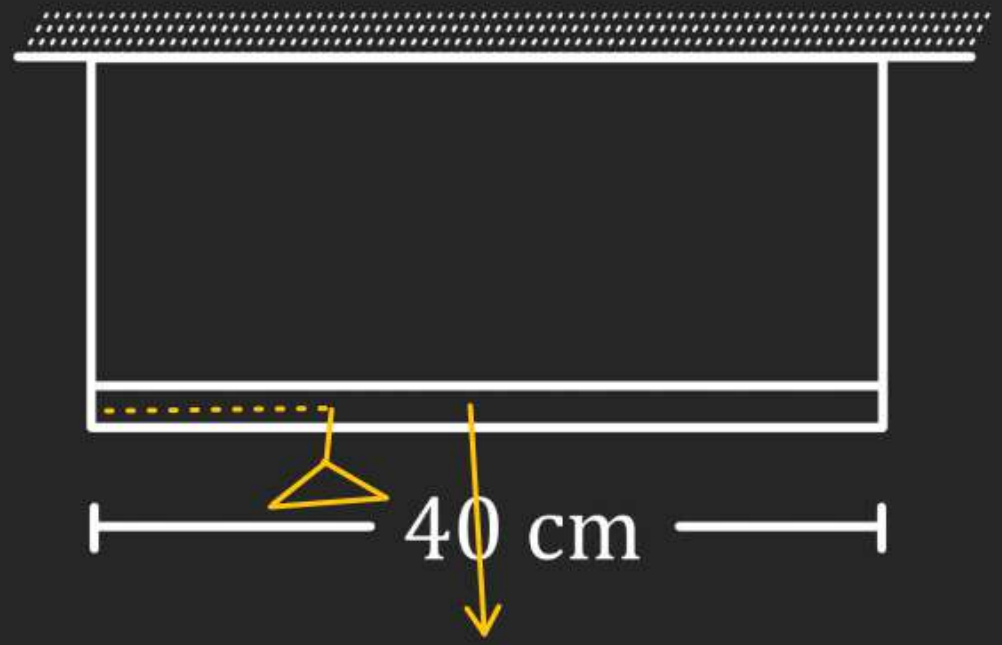
$y_R = A_R \sin(k_1 x + \omega t)$ Reflected wave

Transmitted

$y_t = A_t \sin(k_2 x - \omega t)$

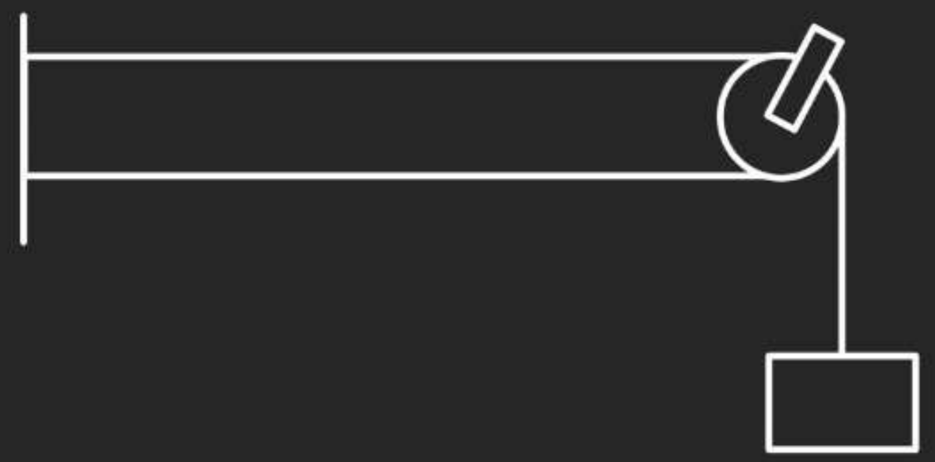


Q.1 A uniform horizontal rod of length $40\ \mathrm{cm}$ and mass $1.2\ \mathrm{kg}$ is supported by two identical wires as shown in figure. Where should a mass of $4.8\ \mathrm{kg}$ be placed on the rod so that the same tuning fork may excite the wire on left into its fundamental vibrations and that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

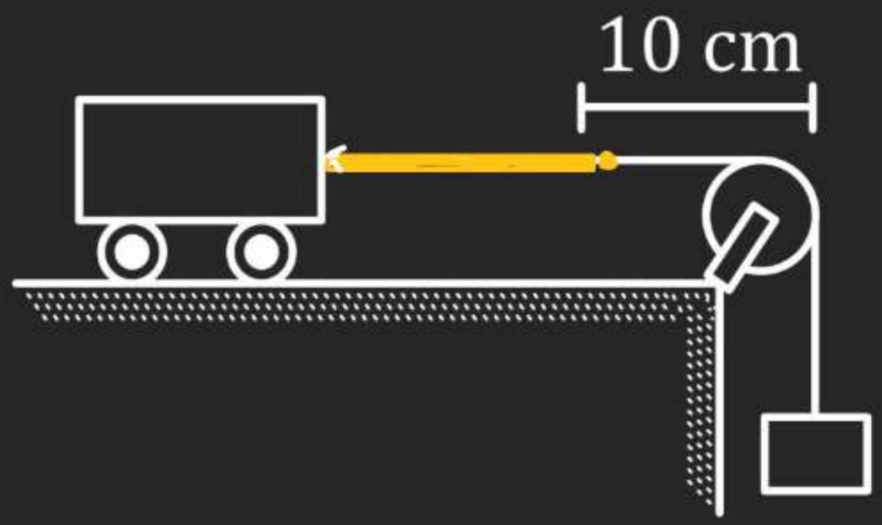


Q.2 Figure shows an aluminium wire of length $60\ \mathrm{cm}$ joined to a steel wire 'of length $80\ \mathrm{cm}$ and stretched between two fixed supports. The tension produced is $40\ \mathrm{N}$. The cross-sectional area of the steel wire is $1.0\ \mathrm{mm}^2$ and that of the aluminium wire is $3.0\ \mathrm{mm}^2$. 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 $7.8\ \mathrm{g\ cm}$

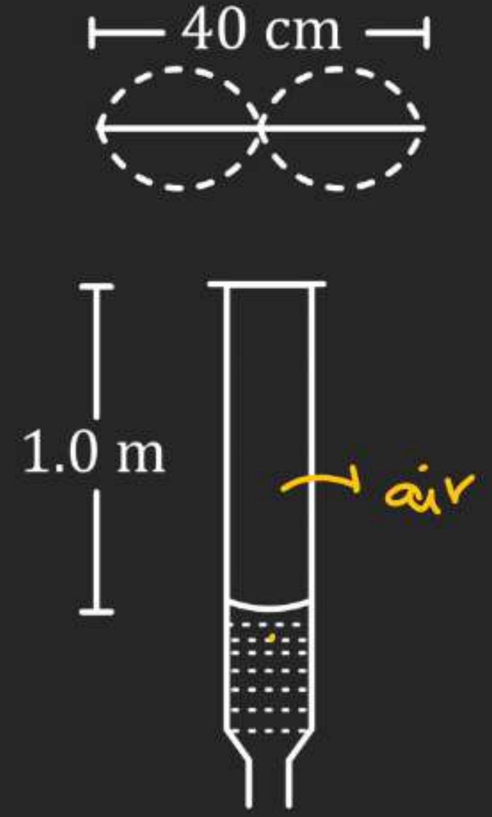
Q.3 Figure shows a string stretched by a block going over a pulley. The string vibrates in its tenth harmonic in unison with a particular tuning fork. When a beaker containing water is brought under the block so that the block is completely dipped into the beaker, the string vibrates in its eleventh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



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 $120\ \text{Hz}$. If the movable support is pushed to the right by $10\ \text{cm}$ so that the joint is placed on the pulley, what will be the minimum frequency at which the heavy string can resonate?



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.



WAVE

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

(A) $335\ \mathrm{Hz}$ (B) $338\ \mathrm{Hz}$ (C) $345\ \mathrm{Hz}$ (D) $342\ \mathrm{Hz}$

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) $(256 + 5)\mathrm{Hz}$

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 $/\text{sec}$. The frequency of the unknown fork is [2002]

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