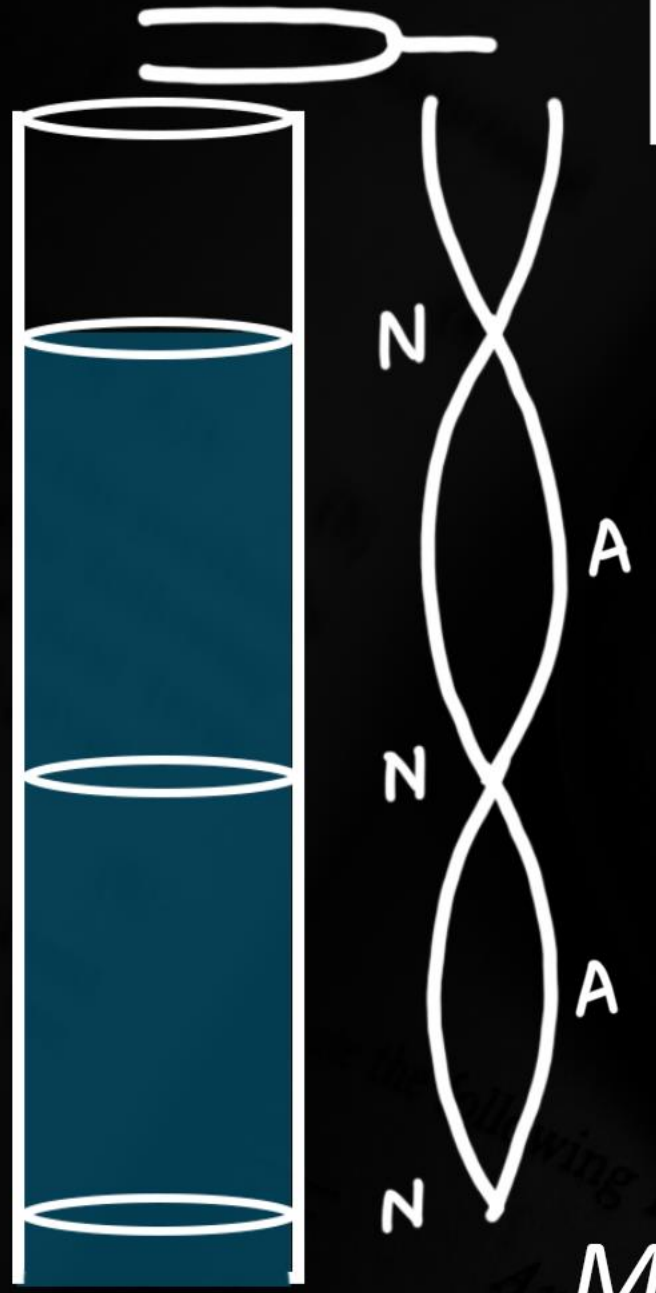
# RESONANCE TUBE ORGAN PIPES




## 'JEE MAIN' CONCEPT PYQs

*Mohit Goenka, IIT Kharagpur*

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.....and many more to come

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# TOPICS COVERED

1. Closed Organ Pipe
2. Open Organ Pipe
3. End Correction
4. Resonance Tube
5. PYQs (Build your understanding)

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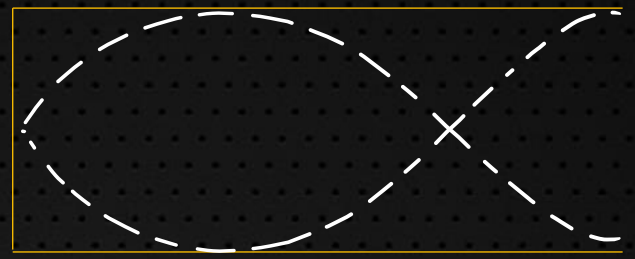
# 1. CLOSED ORGAN PIPE (STATIONARY WAVES)

(a)


$\ell = \lambda/4$

$\therefore \lambda = 4\ell$, $\boxed{f_0 = \frac{v}{4\ell}}$ → fundamental frequency or 1st Harmonic

(b)

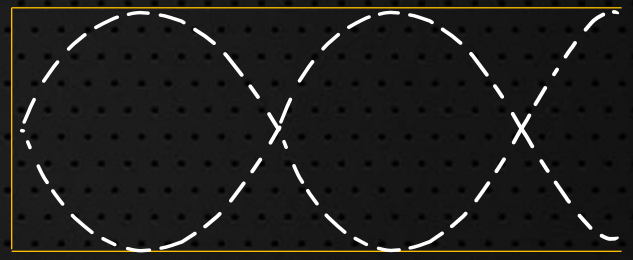


$\ell = 3\lambda/4$

$\Rightarrow \lambda = 4\ell/3$

$\therefore f_3 = \frac{3v}{4\ell}$ → 3rd Harmonic or 1st Overtone

(c)



$\ell = 5\lambda/4$

$\Rightarrow \lambda = 4\ell/5$

$\therefore f_5 = \frac{5v}{4\ell}$ → 5th Harmonic or 2nd Overtone

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

$\gamma = C_P / C_V$

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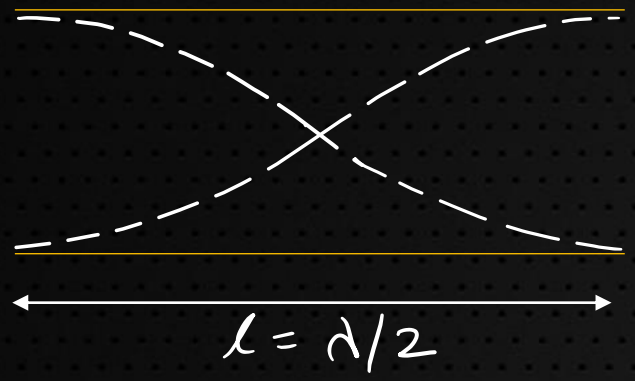
If frequency of tuning fork matches with odd Multiple of fundamental frequency, Resonance occurs

$f_n = (2n+1) f_0$

↳ $n^{th}$ Overtone

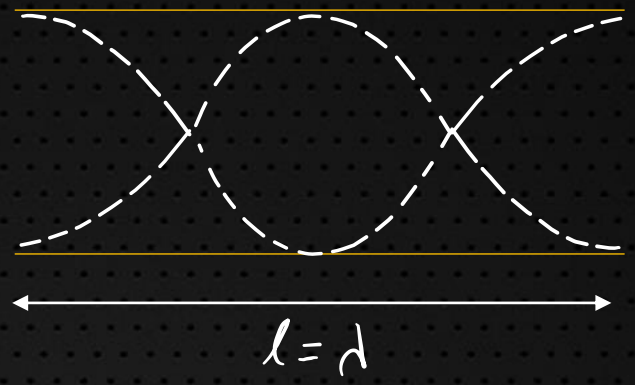
# 2. OPEN ORGAN PIPE (STATIONARY WAVES)

(a)




$\therefore \lambda = 2\ell$, $\boxed{f_0 = \frac{V}{2\ell}}$ → fundamental frequency or 1st Harmonic

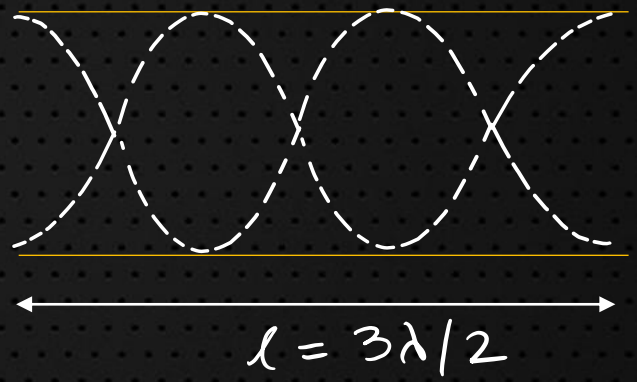
(b)




$\Rightarrow \lambda = \ell$

$\therefore f_2 = \frac{2V}{2\ell}$ → 2nd Harmonic or 1st Overtone

(c)




$\Rightarrow \lambda = 2\ell/3$

$\therefore f_3 = \frac{3V}{2\ell}$ → 3rd Harmonic or 2nd Overtone

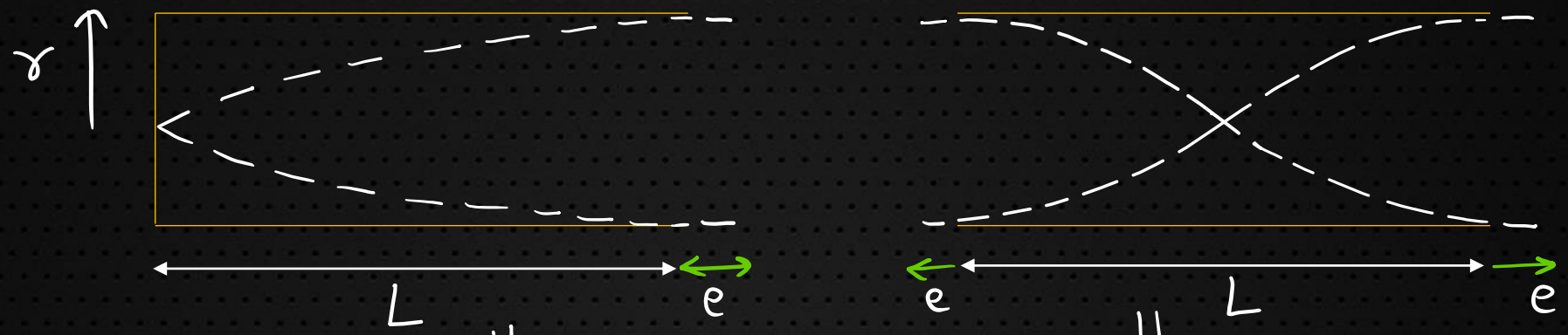
If frequency of tuning fork matches with integer Multiple of fundamental frequency, Resonance occurs

$f_n = (n+1) f_0$

↳ $n^{th}$ Overtone

# 3. END CORRECTION (e)

↳ At open side, ANTINODE is formed a little outside.




$$f_0 = \frac{V}{4(L+e)}$$

$$f_0 = \frac{V}{2(L+2e)}$$

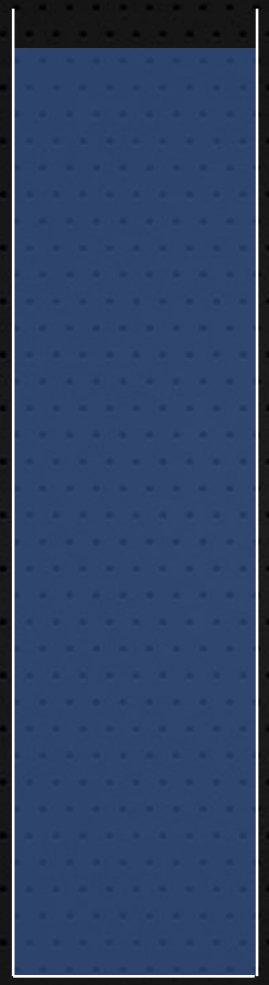
r = Pipe radius. $\boxed{e = 0.6r}$

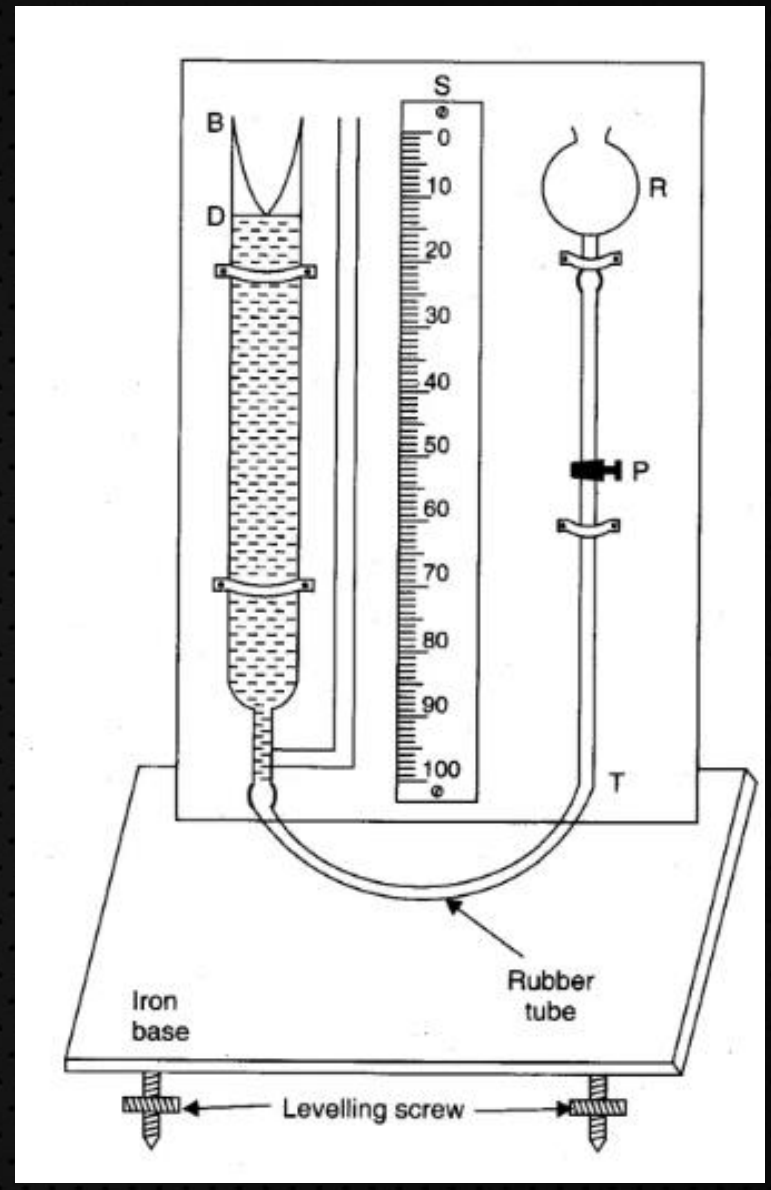
L = Pipe true length

# 4. RESONANCE TUBE

↳ Used to find speed of sound in air.

↳ It is like closed organ pipe.





NOTE: ONCE $f$ is fixed, $\lambda$ is also fixed.

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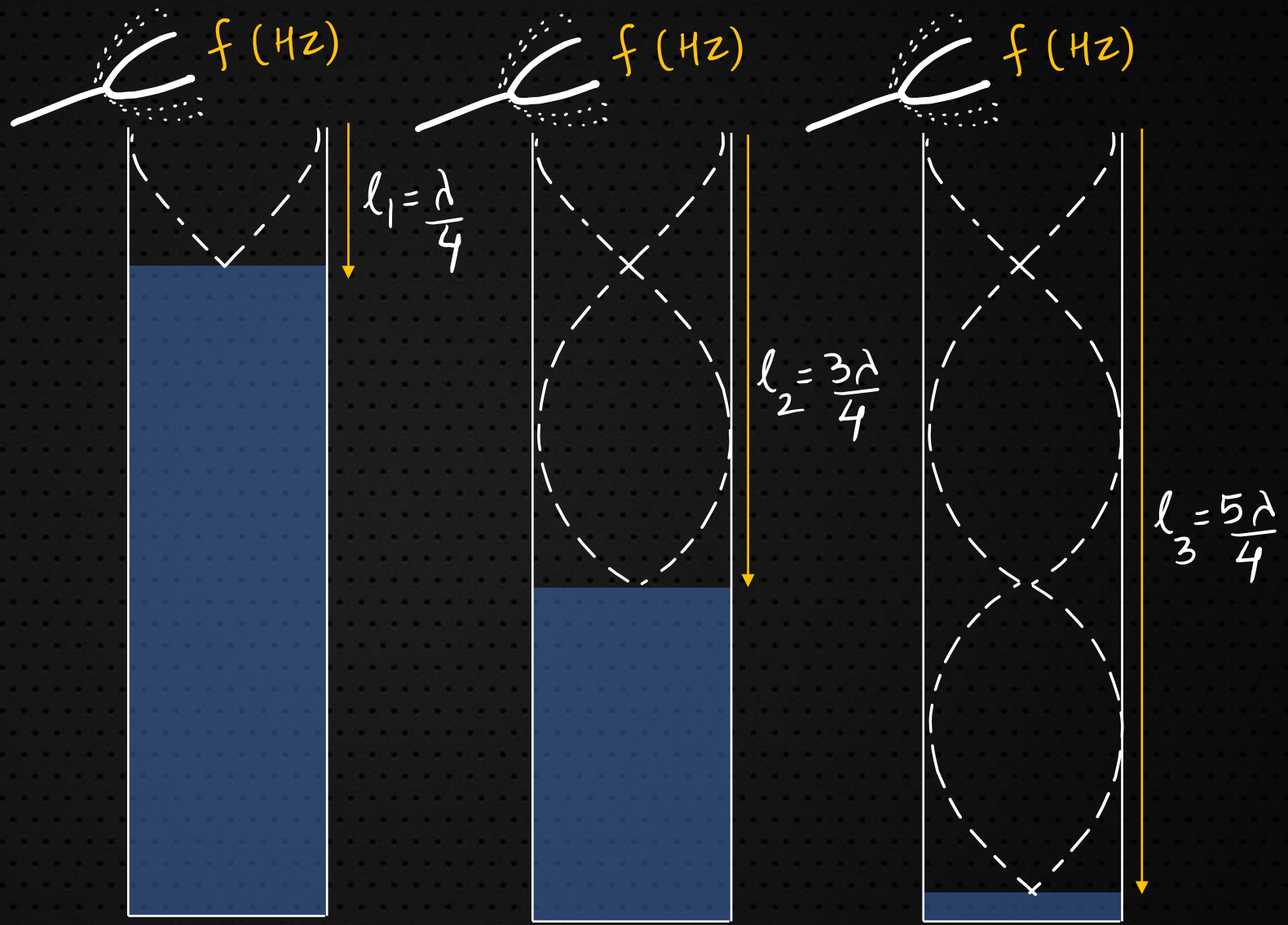

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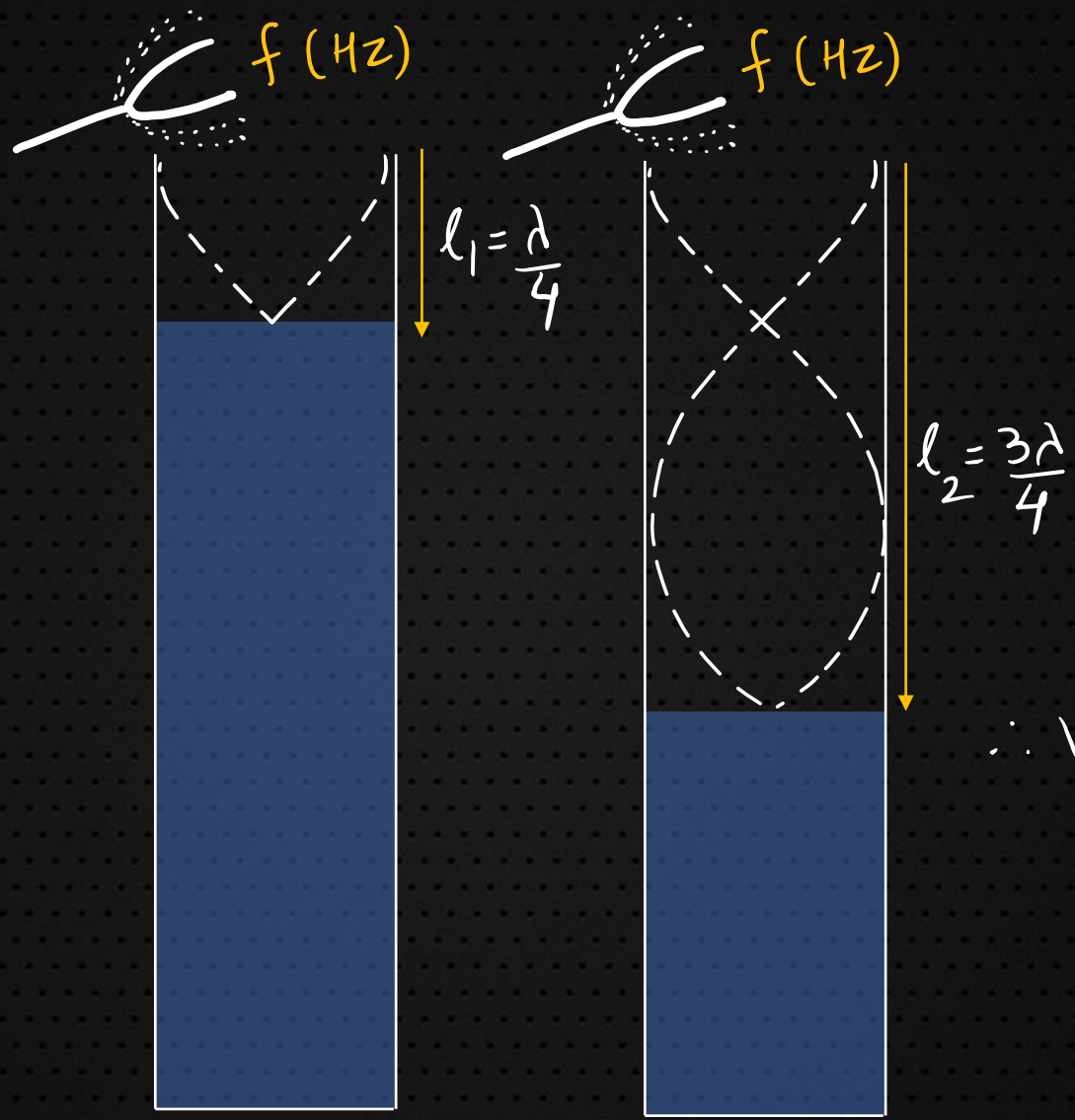



(1.) Difference betⁿ any two consecutive Resonance/harmonic is $\lambda/2$.

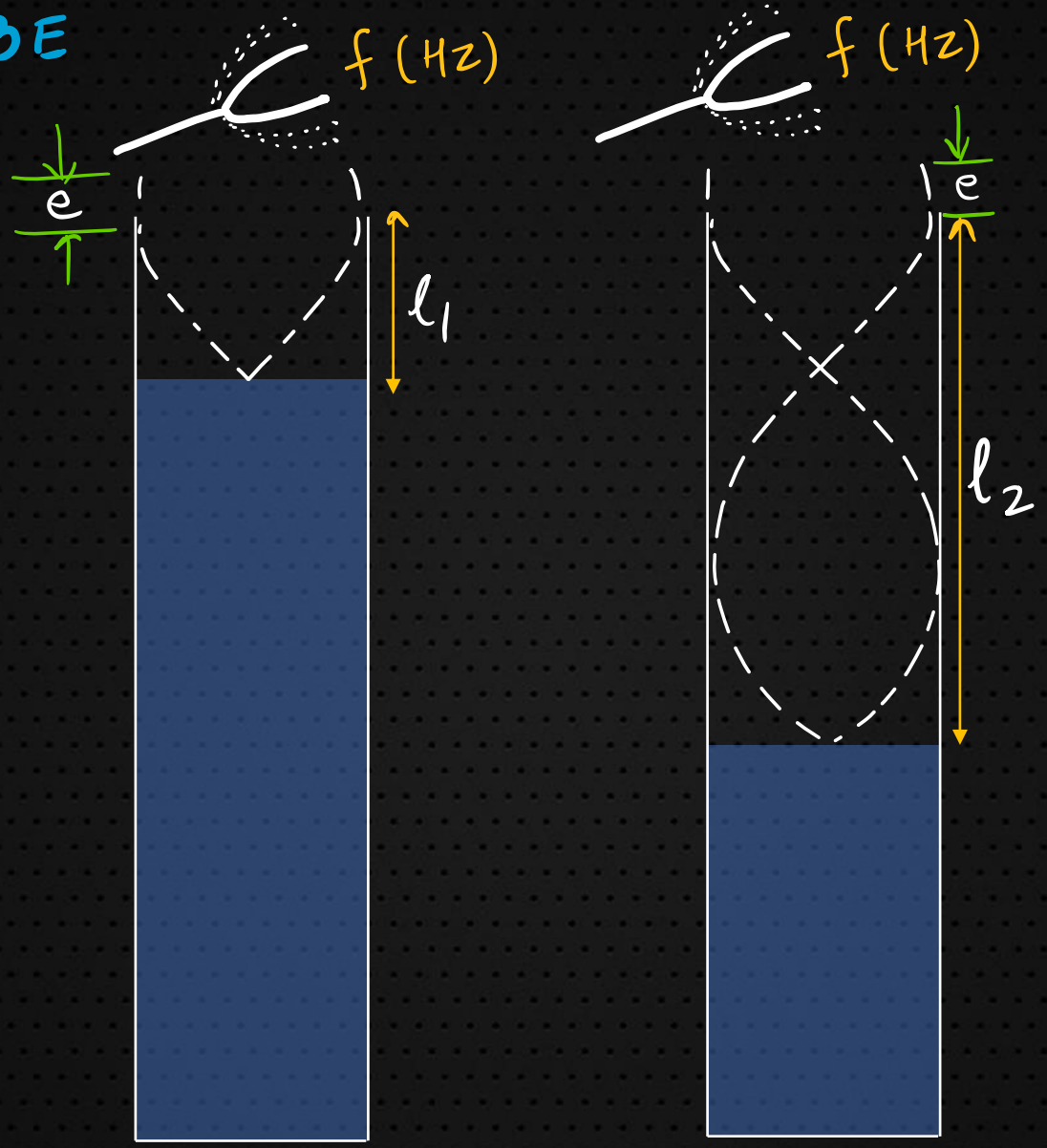
$$l_2 - l_1 = \lambda/2$$

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

$$\therefore V = \lambda f = 2f(l_2 - l_1)$$

# 4. RESONANCE TUBE

$l_1$ and $l_2$ are length measured on scale.




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

$$\Rightarrow l_2-l_1=\frac{\lambda}{2}$$

$$\therefore v=f\times 2(l_2-l_1)$$

Hence end correction has no effect on final result of experiment.

# 5 PYQs For UNDERSTANDING

1. 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 Main)**

(a) $\frac{f}{2}$ (b) $\frac{3f}{4}$ (c) $2f$ (d) $f$

*JEE Main 2016*

Solution on Next Page

1. 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 Main)**

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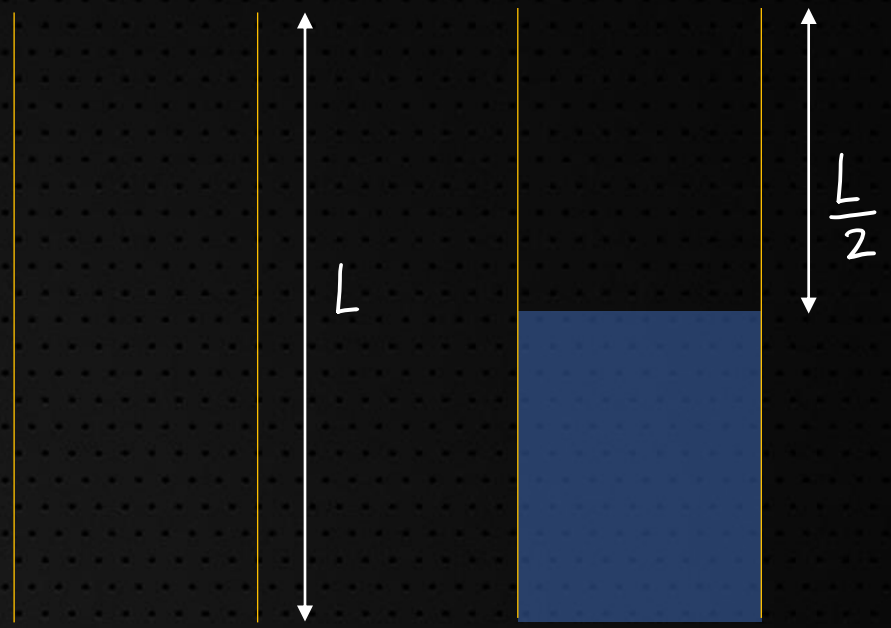


$f = \frac{V}{2L}$

$f' = \frac{V}{4 \times \frac{L}{2}}$

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

$= f$

2. A closed organ pipe has a fundamental frequency of 1.5 kHz. 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 20000 Hz)

(a) 6 (b) 4

(c) 7 (d) 5

*JEE Main 2019*

Solution on Next Page

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(a) 6 (b) 4
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*JEE Main 2019*

$f_0 = 1500$ Hz

$n^{th}$ overtone:

$f_n = (2n+1) f_0$

$(2n+1) \times 1500 = 20000$

$\Rightarrow n = 6.17$

$\therefore$ 6 overtones can be heard distinctly.

3. In a resonance tube experiment when the tube is filled with water up to height of 17.0 cm from bottom, it resonates with a given tuning fork. When the water level is raised the next resonance with the same tuning fork occurs at a height of 24.5 cm. If the velocity of sound in air is 330 m/s, the tuning fork frequency is

(a) 1100 Hz (b) 3300 Hz

(c) 2200 Hz (d) 550 Hz

*JEE Main 2020*

Solution on Next Page

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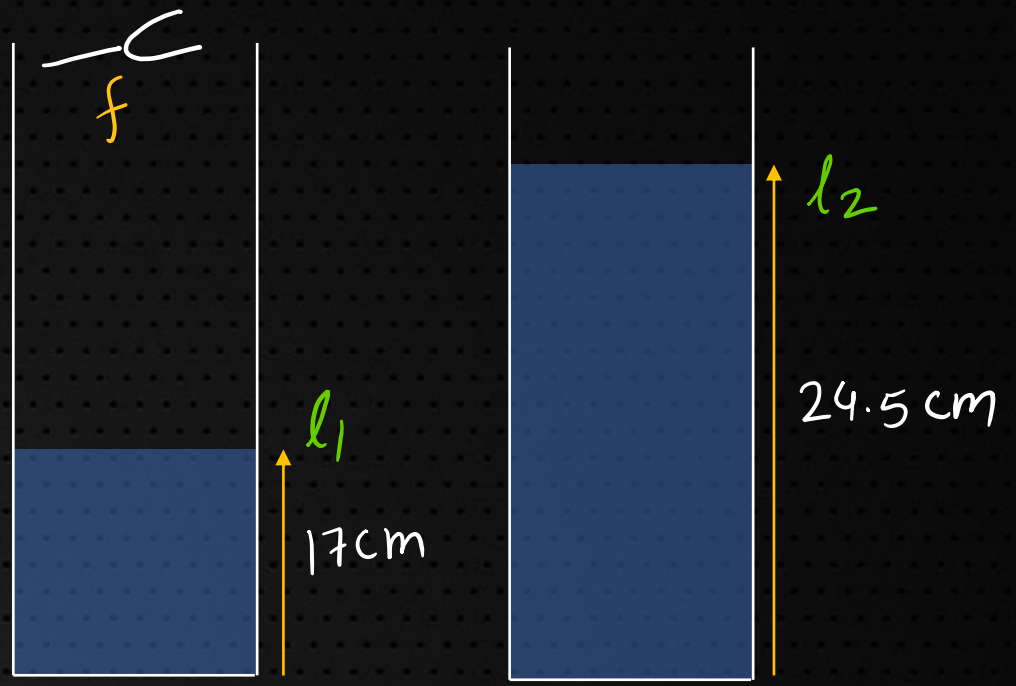


$$\ell_2 - \ell_1 = \frac{\lambda}{2} \Rightarrow \lambda = 2(\ell_2 - \ell_1)$$

$$\therefore f = \frac{v}{\lambda} = \frac{330}{2(24.5-17)\times 10^{-2}}$$

$$= \boxed{2200\ \text{Hz}}$$

4. A resonance tube is old and has jagged end. It is still used in the laboratory to determine velocity of sound in air. A tuning fork of frequency 512 Hz produces first resonance when the tube is filled with water to a mark 11 cm below a reference mark, near the open end of the tube. The experiment is repeated with another fork of frequency 256 Hz which produces first resonance when water reaches a mark 27 cm below the reference mark. The velocity of sound in air, obtained in the experiment, is close to

(a) 322 $ms^{-1}$ (b) 341 $ms^{-1}$

(c) 335 $ms^{-1}$ **(d)** 328 $ms^{-1}$

*JEE Main 2019*

Solution on Next Page

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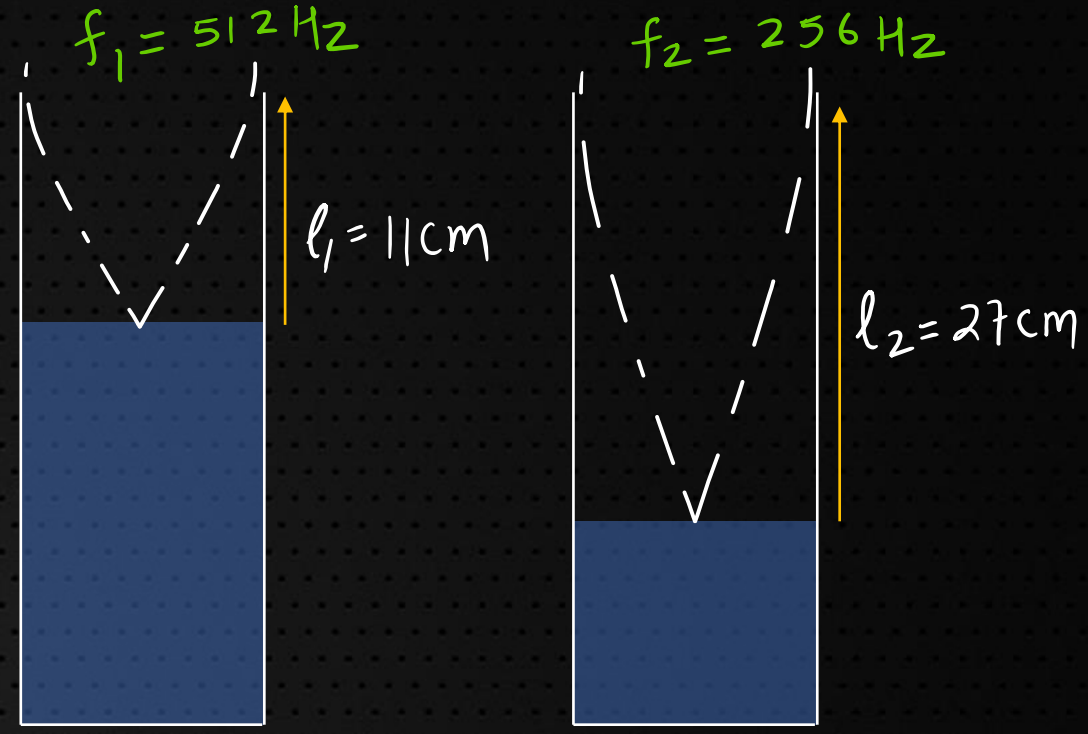


$$l_1 + e = \frac{\lambda_1}{4} \Rightarrow 0.11 + e = \frac{V}{512 \times 4} \quad \text{— (i)}$$

$$l_2 + e = \frac{\lambda_2}{4} \Rightarrow 0.27 + e = \frac{V}{256 \times 4} \quad \text{— (ii)}$$

solving (i) and (ii),

$$V = 328\ m/s$$

5. A student is performing the experiment of resonance column. The diameter of the column tube is 4 cm. The frequency of the tuning fork is 512 Hz. The air temperature is 38° C in which the speed of sound is 336 m/s. The zero of the meter scale coincides with the top end of the resonance column tube. When the first resonance occurs, the reading of the water level in the column is **(2012)**

(a) 14.0 cm (b) 15.2 cm (c) 16.4 cm (d) 17.6 cm

*2012*

Solution on Next Page

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(a) 14.0 cm (b) 15.2 cm (c) 16.4 cm (d) 17.6 cm

2012

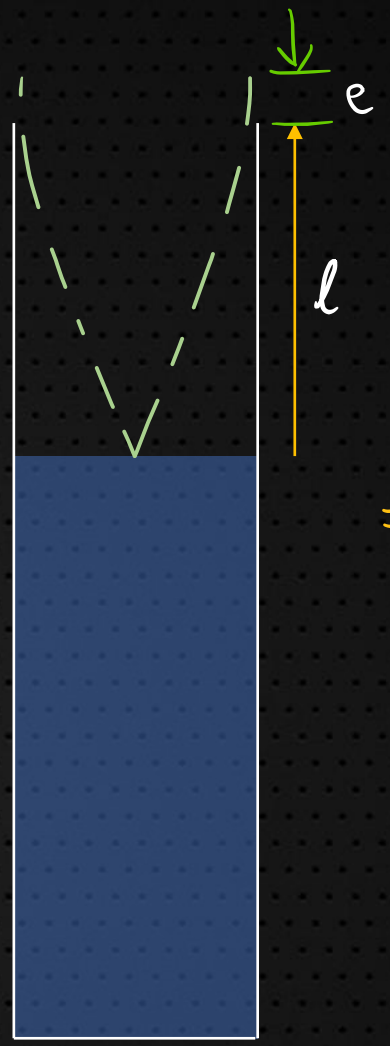
$V = 336\ m/s,\ f = 512\ Hz$

$r = \frac{d}{2} = 2\ cm$

$= 2 \times 10^{-2}\ m$

$e = 0.6r$

$= 1.2 \times 10^{-2}\ m$




$\therefore\ l + e = \frac{\lambda}{4}$

$\Rightarrow l + e = \frac{V}{4f}$

$\Rightarrow l = \frac{V}{4f} - e$

$= \frac{336}{4 \times 512} - 1.2 \times 10^{-2}\ m$

$= \left(\frac{84 \times 100}{512} - 1.2\right)\ cm$

$= \boxed{15.2\ cm}$