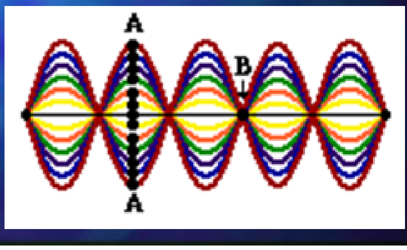
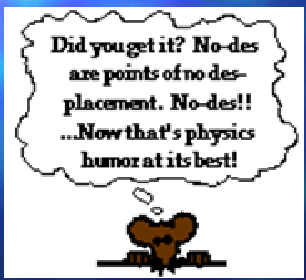
Standing Waves

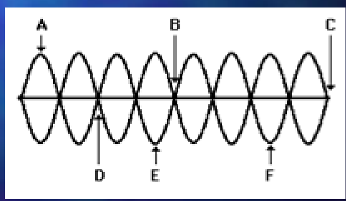
- A **standing wave** *is the result of two identical waves traveling in opposite directions. It has stationary* nodes *and* antinodes.
- Standing Waves
- Animation



- *At a* node, *the medium is not displaced as the waves pass through each other.*

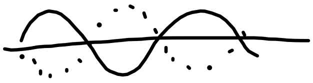


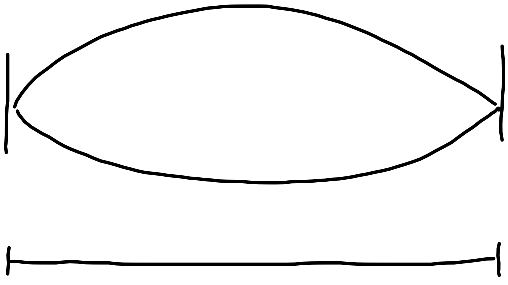
- *At an* antinode, *the displacement caused by the interfering waves is the largest.*
- Nodes: B, C, D
- Antinodes: A, E, F



- *For every medium of fixed length, there are many* **natural frequencies** *of vibration that produce* **resonance**
- **Fundamental frequency** ~ *the lowest frequency (longest wavelength) that will produce resonance*
- **Fundamental mode** ~ *the standing wave pattern for the fundamental frequency; it has the fewest nodes and antinodes*
- **Overtones** ~ *natural frequencies higher than the fundamental frequency*

Finding the frequences for a fixed length:

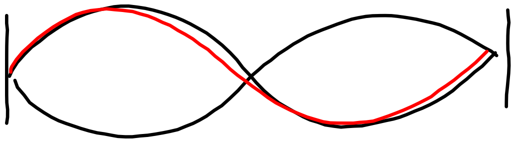




$L = \frac{\lambda}{2}$ $\lambda = 2L$ $v = \lambda f$

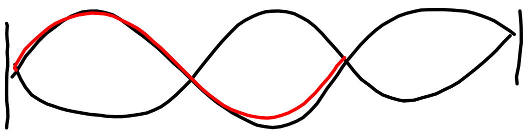
$f = \frac{v}{\lambda}$

$f_1 = \frac{v}{2L}$



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

$f_2 = \frac{v}{L}$



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

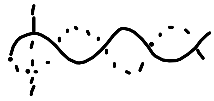
$f_3 = \frac{v}{\left(\frac{2}{3}L\right)}$

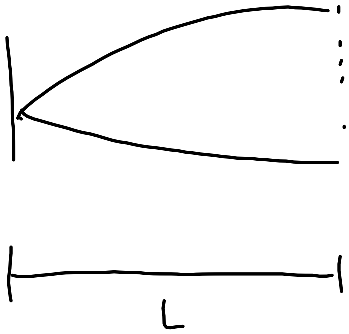
$f_3 = \frac{3v}{2L}$ ($\frac{v}{2L} = f_1$)

$\frac{v}{2L}, \frac{2v}{2L}, \frac{3v}{2L}, \ldots\ldots$

$f_n = n f_1$ (ends are both fixed)

If only 1 end is fixed:



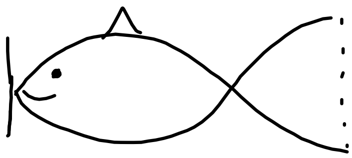


$L = \frac{1}{4}\lambda \quad \lambda = 4L$

$v = \lambda f$

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

$f_1 = \frac{v}{4L}$

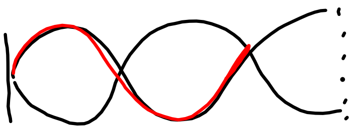


$L = \frac{3}{4}\lambda \quad \lambda = \frac{4}{3}L$

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

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

$f_2 = \frac{3v}{4L}$ ($\frac{v}{4L}$: f_1)

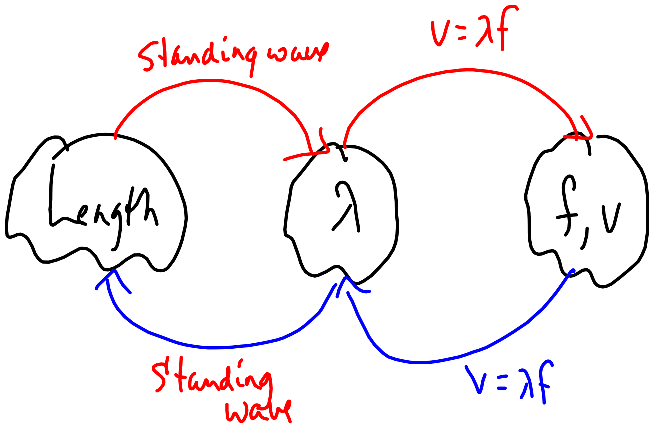


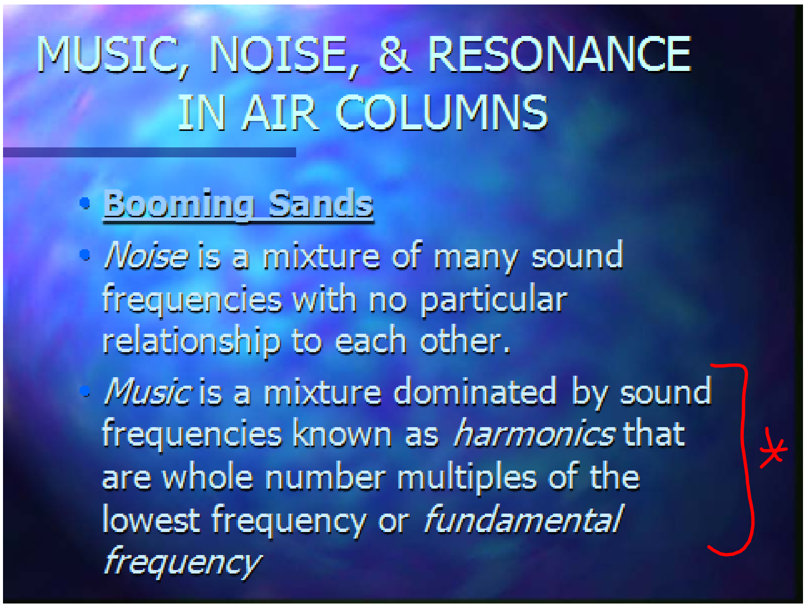
$L = \frac{5}{4}\lambda \quad \lambda = \frac{4}{5}L$

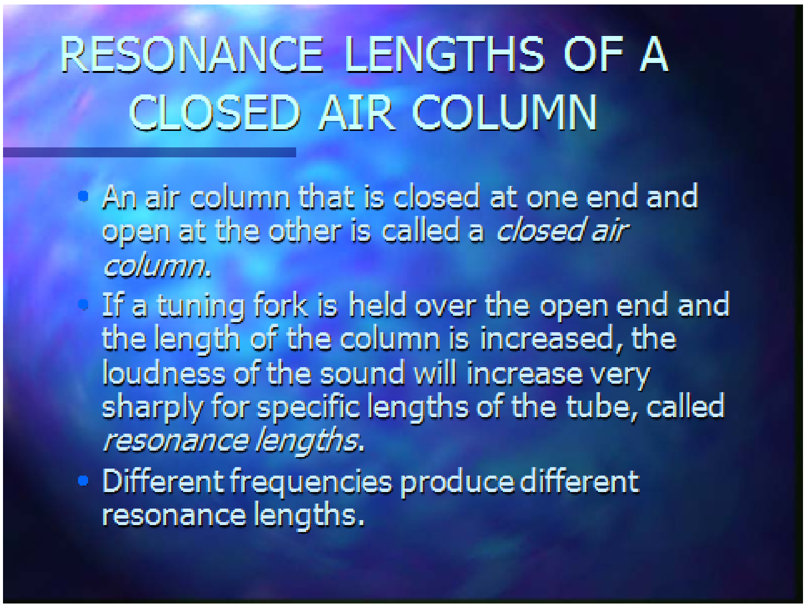
$f_3 = \frac{5v}{4L}$

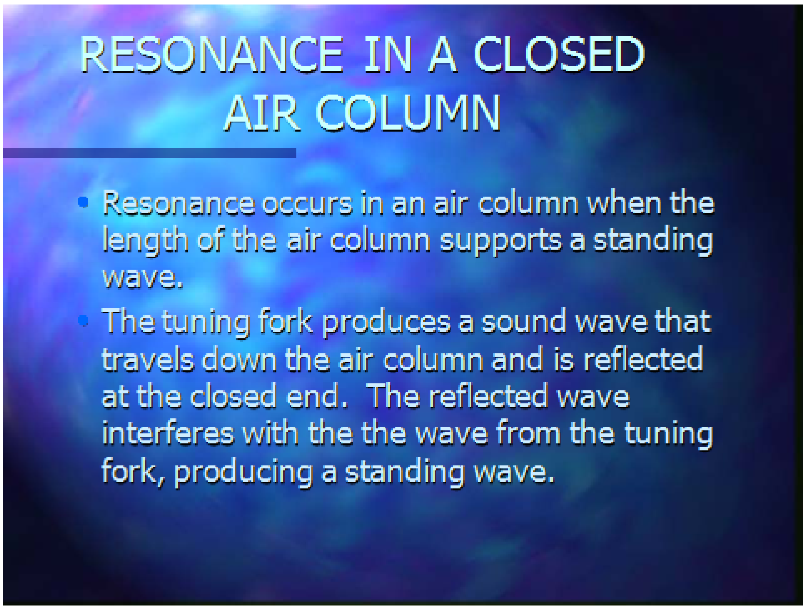
$\frac{v}{4L}, \frac{3v}{4L}, \frac{5v}{4L} \ldots\ldots$

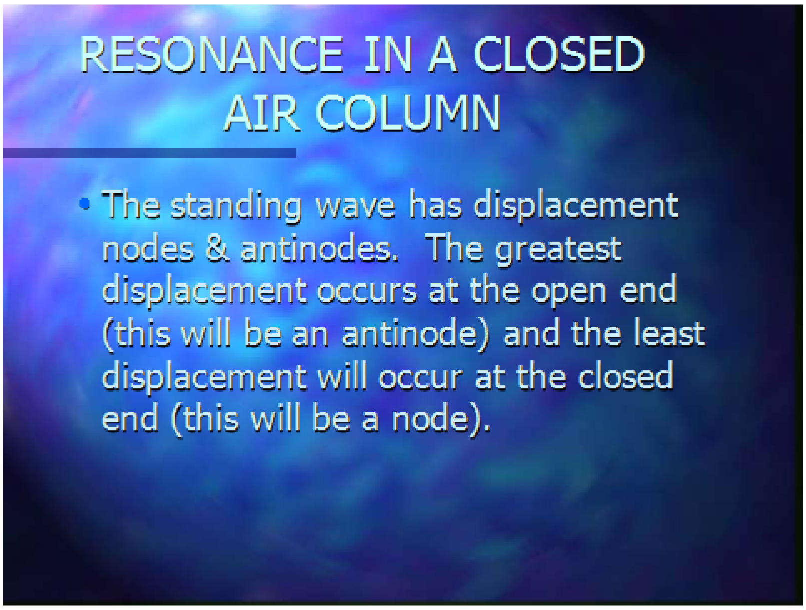
$f_n = (2n-1) f_1$



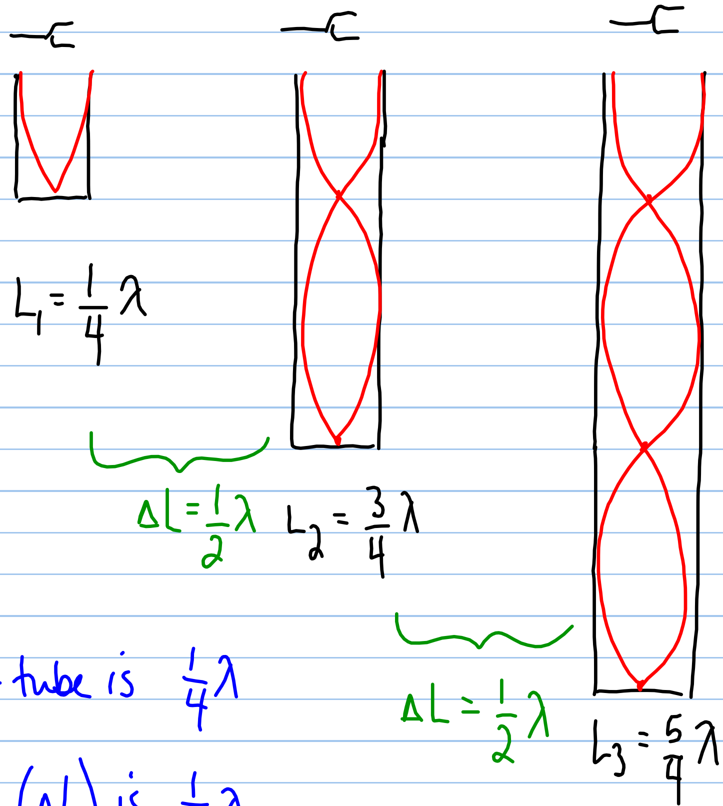

MUSIC, NOISE, & RESONANCE IN AIR COLUMNS
• Booming Sands
• Noise is a mixture of many sound frequencies with no particular relationship to each other.
• Music is a mixture dominated by sound frequencies known as harmonics that are whole number multiples of the lowest frequency or fundamental frequency


RESONANCE LENGTHS OF A CLOSED AIR COLUMN
• An air column that is closed at one end and open at the other is called a closed air column.
• If a tuning fork is held over the open end and the length of the column is increased, the loudness of the sound will increase very sharply for specific lengths of the tube, called resonance lengths.
• Different frequencies produce different resonance lengths.

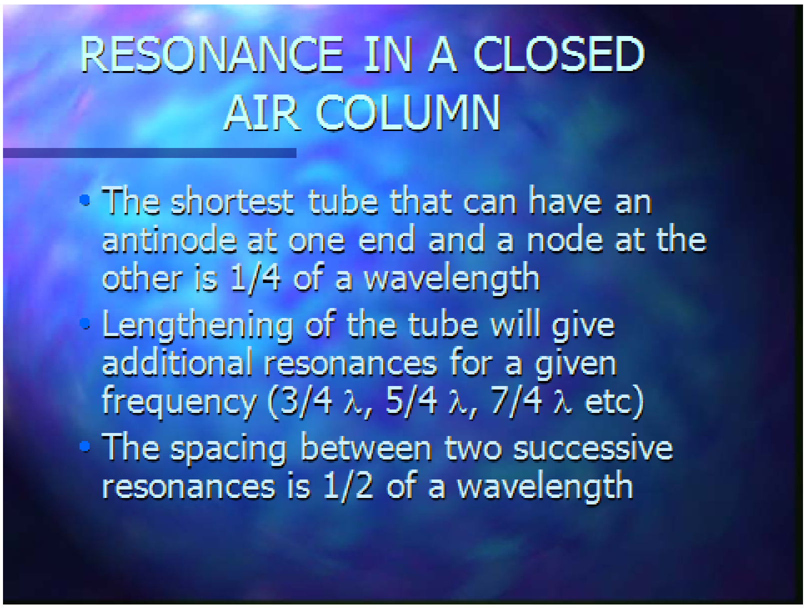

RESONANCE IN A CLOSED AIR COLUMN
Resonance occurs in an air column when the length of the air column supports a standing wave.
The tuning fork produces a sound wave that travels down the air column and is reflected at the closed end. The reflected wave interferes with the the wave from the tuning fork, producing a standing wave.

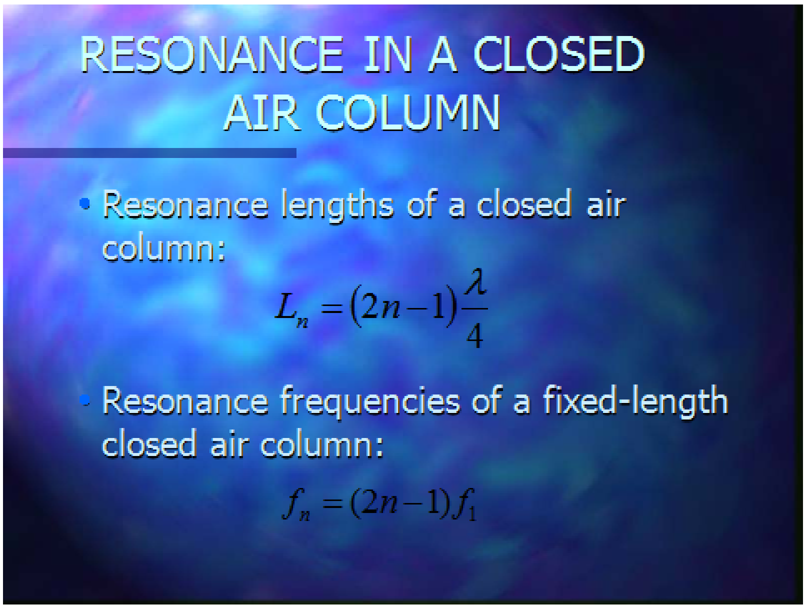

RESONANCE IN A CLOSED AIR COLUMN
The standing wave has displacement nodes & antinodes. The greatest displacement occurs at the open end (this will be an antinode) and the least displacement will occur at the closed end (this will be a node).

Closed Tube Resonance

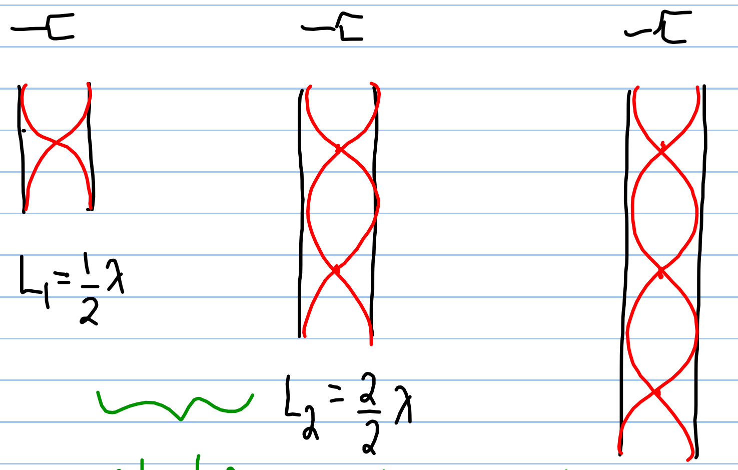


- Shortest tube is $\frac{1}{4}\lambda$
- Spacing (ΔL) is $\frac{1}{2}\lambda$


RESONANCE IN A CLOSED AIR COLUMN
The shortest tube that can have an antinode at one end and a node at the other is 1/4 of a wavelength
Lengthening of the tube will give additional resonances for a given frequency (3/4 λ, 5/4 λ, 7/4 λ etc)
The spacing between two successive resonances is 1/2 of a wavelength


RESONANCE IN A CLOSED AIR COLUMN
Resonance lengths of a closed air column:
$L_n = (2n-1)\frac{\lambda}{4}$
Resonance frequencies of a fixed-length closed air column:
$f_n = (2n-1)f_1$

Open-Tube Resonance



$L_1 = \frac{1}{2}\lambda$

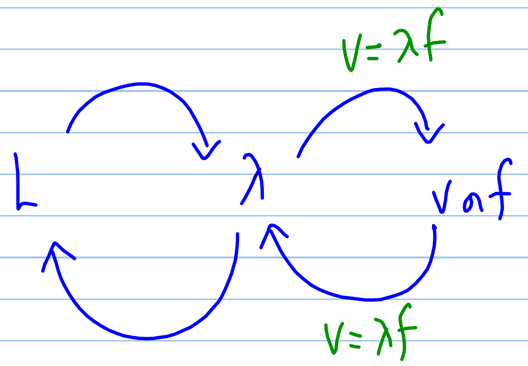
$L_2 = \frac{2}{2}\lambda$

$L_3 = \frac{3}{2}\lambda$

$\Delta L = \frac{1}{2}\lambda$

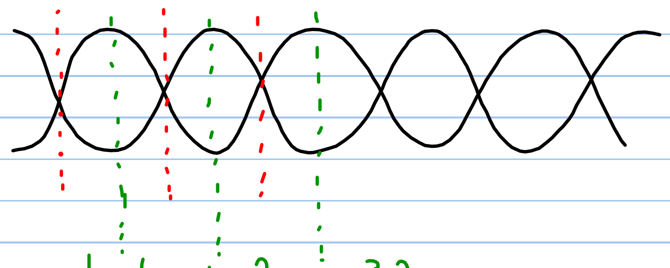
$\Delta L = \frac{1}{2}\lambda$

- shortest tube is $\frac{1}{2}\lambda$
- spacing (ΔL) is $\frac{1}{2}\lambda$



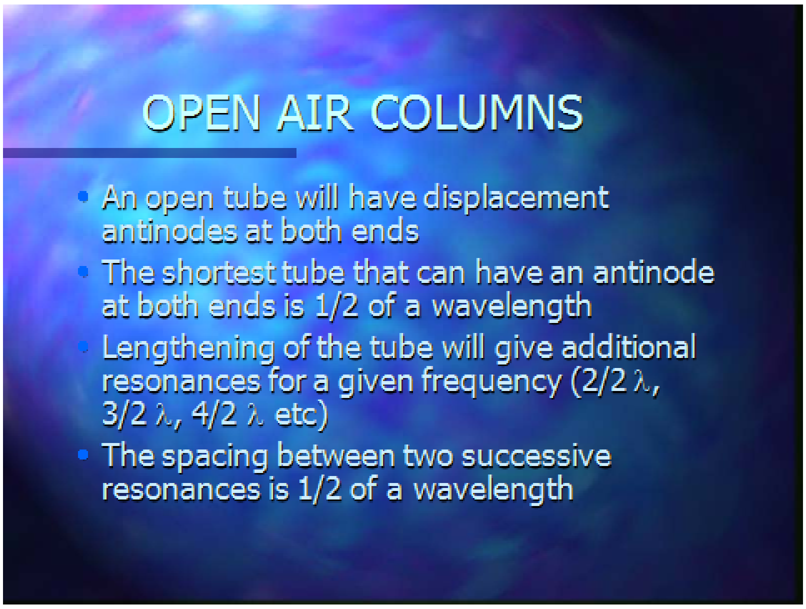
closed

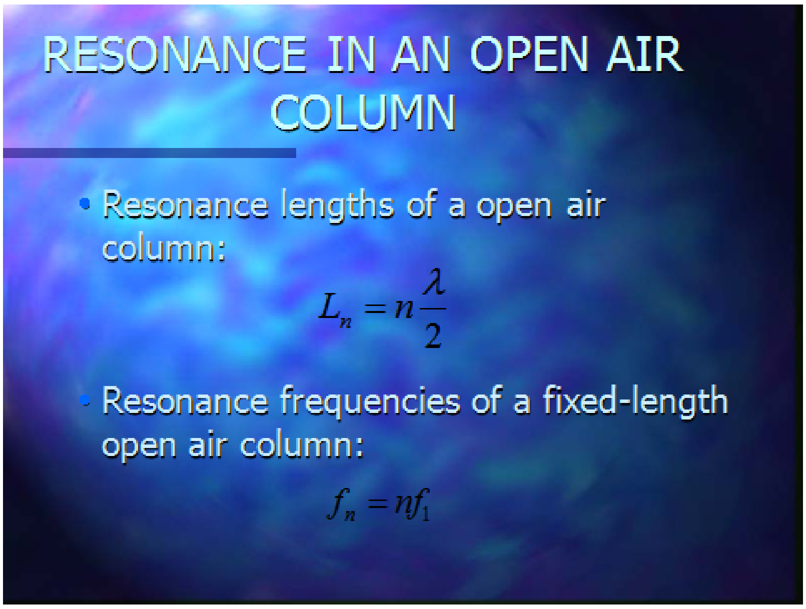
$L_1 = \frac{1}{4}\lambda$ $L_2 = \frac{3}{4}\lambda$ $L_3 = \frac{5}{4}\lambda$



open

$L_1 = \frac{1}{2}\lambda$ $L_2 = \frac{2}{2}\lambda$ $L_3 = \frac{3}{2}\lambda$


OPEN AIR COLUMNS
An open tube will have displacement antinodes at both ends
The shortest tube that can have an antinode at both ends is 1/2 of a wavelength
Lengthening of the tube will give additional resonances for a given frequency (2/2 λ, 3/2 λ, 4/2 λ etc)
The spacing between two successive resonances is 1/2 of a wavelength


RESONANCE IN AN OPEN AIR COLUMN
Resonance lengths of a open air column:
$L_n = n\frac{\lambda}{2}$
Resonance frequencies of a fixed-length open air column:
$f_n = nf_1$