

3.) Standing Waves in Open-Open (and Closed-Closed) Organ Pipes:

Open Ends: \Rightarrow **Pressure nodes** and **displacement anti-nodes** at $x = 0$ and $x = L$.

Closed Ends: \Rightarrow **Pressure anti-nodes** and **displacement nodes** at $x = 0$ and $x = L$.

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1st harm.	$L = \frac{1}{2}\lambda_1$	$\lambda_1 = \frac{2}{1}L$	$f_1 = \frac{1}{2} \frac{V}{L} = 1 f_1$	
2nd harm.	$L = \frac{2}{2}\lambda_2$	$\lambda_2 = \frac{2}{2}L$	$f_2 = \frac{2}{2} \frac{V}{L} = 2 f_1$	
3rd harm.	$L = \frac{3}{2}\lambda_3$	$\lambda_3 = \frac{2}{3}L$	$f_3 = \frac{3}{2} \frac{V}{L} = 3 f_1$	
...
nth harm.	$L = \frac{n}{2}\lambda_n$	$\lambda_n = \frac{2}{n}L$	$f_n = \frac{n}{2} \frac{V}{L} = n f_1$	

(*n.b.* open-open standing wave modes drawn)

$$f_n = \frac{v}{\lambda_n} = n f_1; \quad f_1 = \frac{v}{2L}; \quad n = 1, 2, 3, \dots$$

- First harmonic also known as the fundamental
- Second harmonic also known as the first overtone, *etc.*
- Replace L by $L + 2 \delta$ for “exact” answer.
- Note: Since $v_{\text{helium}} \gg v_{\text{air}}$, $f_1(\text{helium}) > f_1(\text{air})$