Standing Waves and Sound Resonance

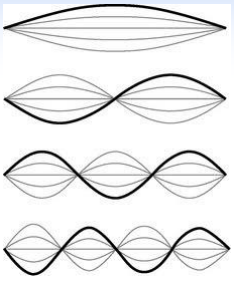
Waves on a String, in an open-ended pipe, and in a closed-ended pipe

Harmonics on a String

- On your whiteboards, sketch the appearance of the string for the following harmonics:
- **1st Harmonic/Fundamental Frequency:**
- **2nd Harmonic/1st Overtone:**
- **3rd Harmonic/2nd Overtone:**
- **4th Harmonic/3rd Overtone:**

- List the equation for wavelength (λ), in terms of the length of the string (L) for EACH of these harmonics.
- If the string is 1.20 m long, and f_0 = 28 Hz, determine the frequency that will cause each harmonic, and determine the wavelength of each harmonic.

Harmonics on a String



1st Harmonic/Fundamental Frequency
Wavelength (λ) = 2L
Frequency = f_o

2nd Harmonic/1st Overtone
Wavelength (λ) = L
Frequency = $2f_o$

3rd Harmonic/2nd Overtone
Wavelength (λ) = $\frac{2L}{3}$
Frequency = $3f_o$

4th Harmonic/3rd Overtone
Wavelength (λ) = $\frac{L}{2}$
Frequency = $4f_o$

Harmonics on a String

- General Relationship for standing waves on a string:

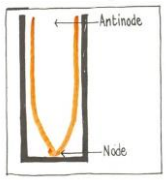
$$L = \frac{n \cdot \lambda}{2}$$

n = harmonic number (1, 2, 3, …)

L = length of string

Closed End Resonance

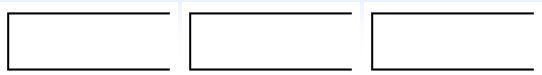
- **Closed End Resonator:**
  - Any column of air that is closed at **one end only**.
    - It is open at the other end
  - **Nodes** will ALWAYS be found at the closed end
  - **Antinodes** will ALWAYS be found at the open end



- At the fundamental frequency:

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

Harmonics in a Closed Pipe



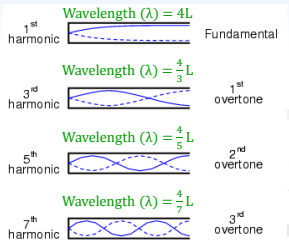
3rd Harmonic 5th Harmonic 7th Harmonic

NOTICE: Only odd harmonics are present!

- Sketch the waveforms that would represent the displacement of the air molecules within the air column. What, in terms of the length of the pipe (L), is the wavelength (λ) for each of these?

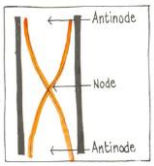
Harmonics in an Closed Pipe

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



Open End Resonance

- **Open End Resonator:**
  - Any column of air that is open at **both ends**
  - **Antinodes** will always be found at both ends



- At the fundamental frequency:

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

Harmonics in an Open Pipe

- 2nd harmonic 3rd harmonic 4th Harmonic
  - Sketch the waveforms that would represent the displacement of the air molecules within the air column. What, in terms of the length of the pipe (L), is the wavelength (λ) for each of these?

Harmonics in an Open Pipe

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