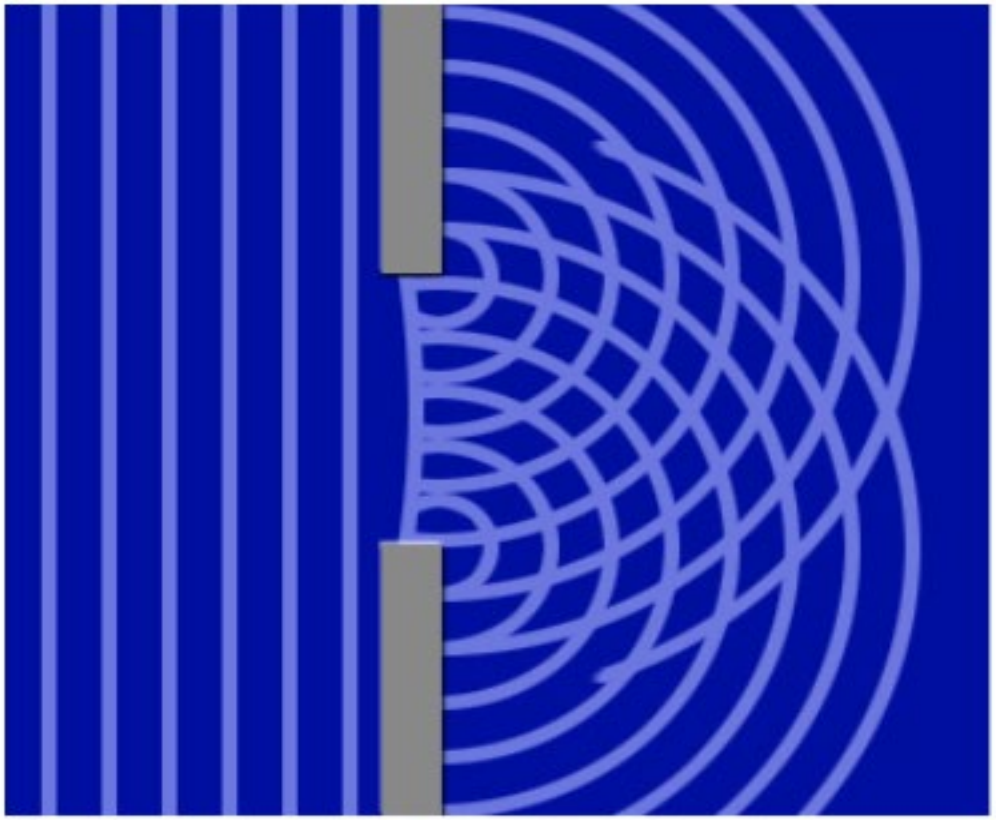
Collision of Waves -- Interference and Resonance



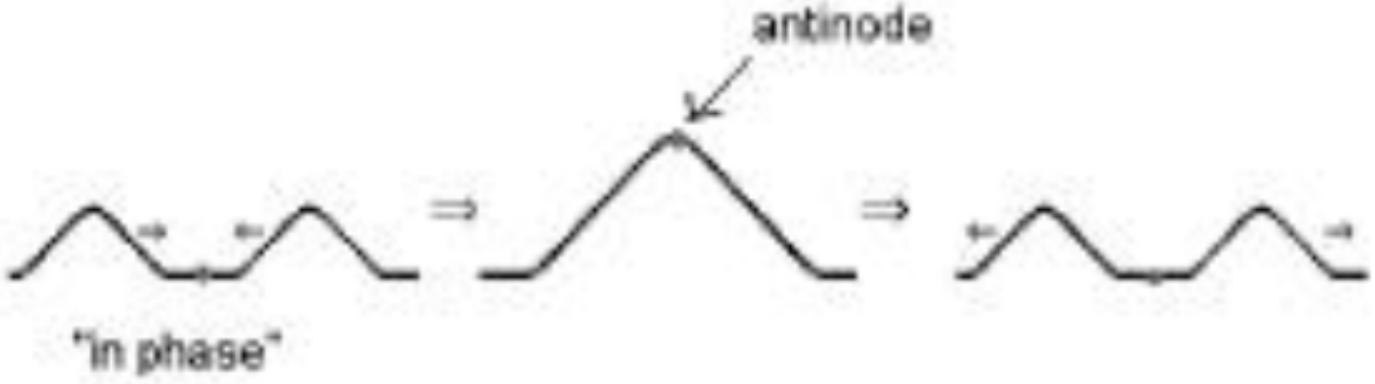
The Principle of Superposition

- When two waves traveling in opposite directions through the same medium collide, the amplitude of the resulting wave will be the sum of the two initial waves.

- This is called interference. There are two types of interference:
    1) Constructive
    2) Destructive

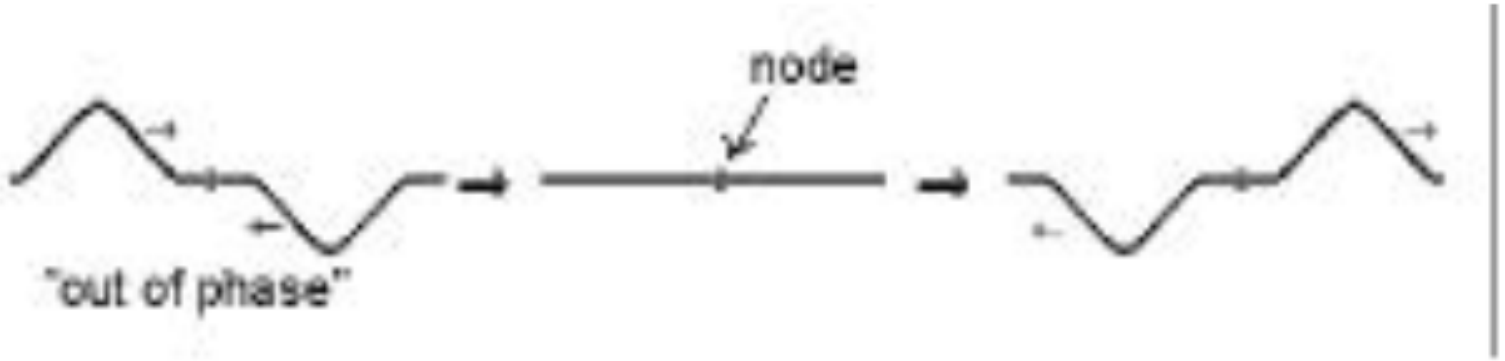
Constructive Interference

- **the amplitudes of the initial waves are in the same direction**
- **the resulting wave will be larger than the original waves**
- **the highest point of a constructive interference is called an *antinode.***



Destructive Interference

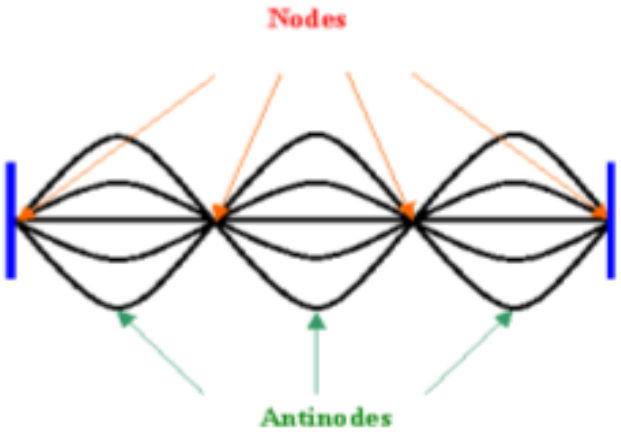
- **the amplitudes of the initial waves are opposite**
- **the amplitude of the resulting wave will be zero**
- **the point in the middle of a destructive interference is called a *node* (it never moves)**



Standing Waves - Resonance

- **When two identical waves travelling in opposite directions interfere with each other, they produce points of maximum amplitude (antinodes) and points of minimum amplitude (nodes).**

- **These nodes and antinodes remain in the same location, causing the wave to appear as if its standing still**

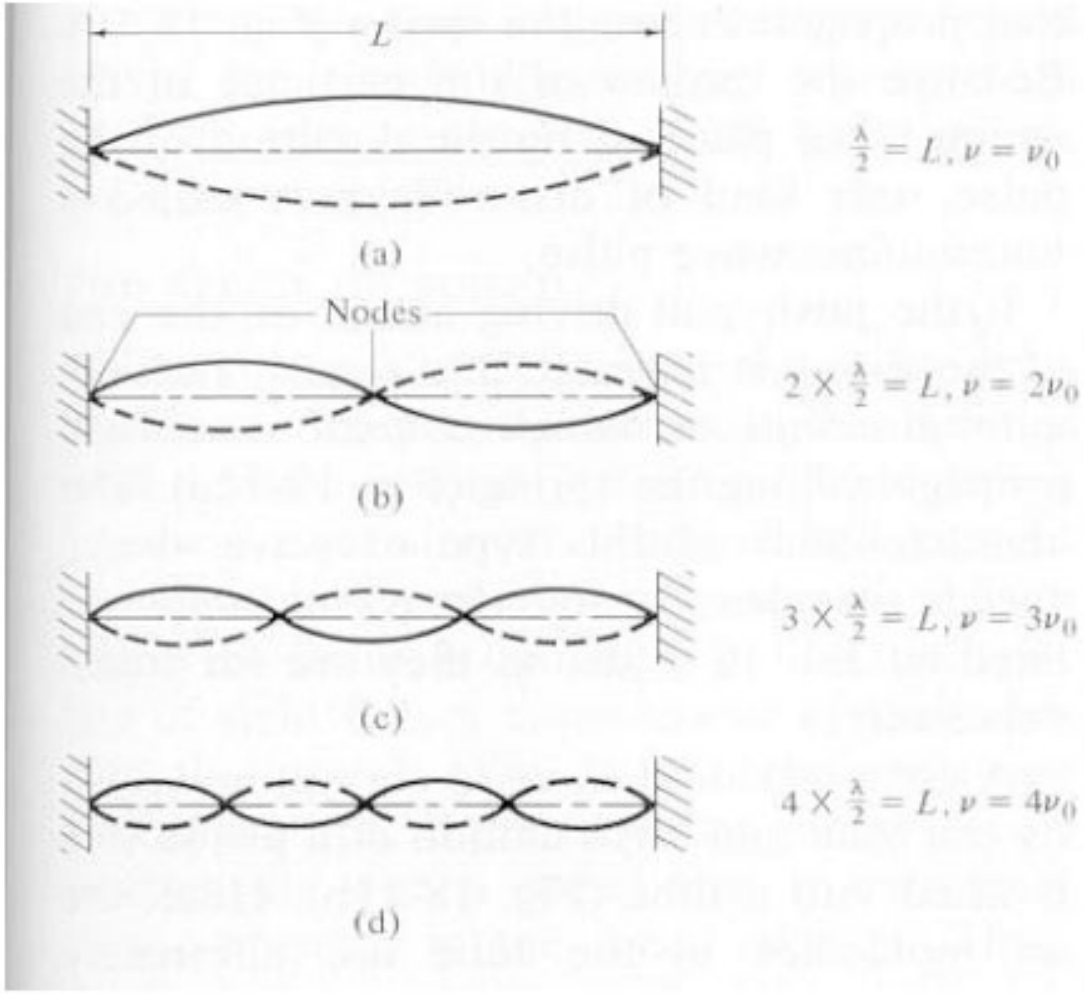


Standing Wave

Wave Transmission

http://www.rmcybernetics.com/images/main/pyhsics/standing_wave.gif

Standing Waves - Stretched Strings



$\frac{\lambda}{2} = L, \nu = \nu_0$

$2 \times \frac{\lambda}{2} = L, \nu = 2\nu_0$

$3 \times \frac{\lambda}{2} = L, \nu = 3\nu_0$

$4 \times \frac{\lambda}{2} = L, \nu = 4\nu_0$

Fundamental Frequency

- **The fundamental frequency is the natural frequency with which an object will vibrate.**
- **It is defined as the frequency when the wavelength is one-half of the length of the string.**

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

- **We can use the universal wave equation to help us find the frequency here:**

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

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

Non-fundamental Frequencies: Harmonics

- **For strings not vibrating at the fundamental frequency, the wavelength has changed.**

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

where:

λ = wavelength (m)
L = length of string (m)
n = frequency # (harmonic)

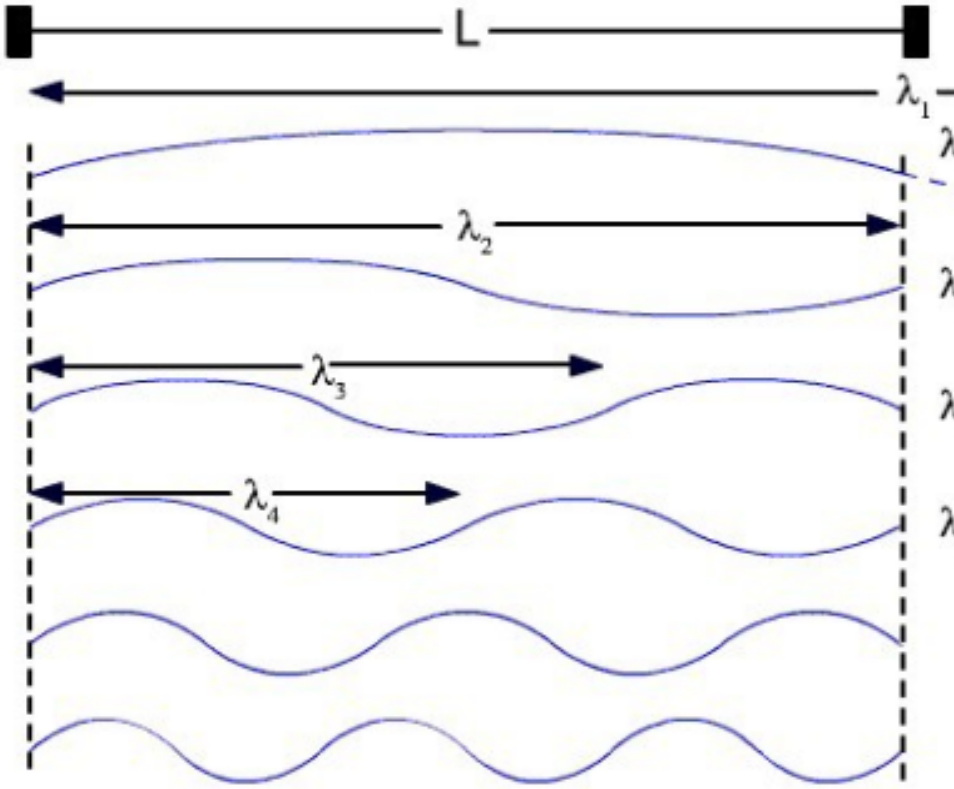
Harmonics

- **1st Harmonic : $\lambda = 2L$ (fundamental)**

- **2nd Harmonic: $\lambda = L$**

- **3rd Harmonic: $\lambda = \frac{2L}{3}$**

Harmonics



$\lambda_1 = 2L \quad f = \frac{v}{\lambda_1} = \frac{v}{2L} = f$ Fundamental

$\lambda_2 = L \quad f_2 = \frac{v}{\lambda_2} = \frac{v}{L} = 2f$ 2nd Harmonic

$\lambda_3 = \frac{2}{3}L \quad f_3 = \frac{v}{\lambda_3} = \frac{3v}{2L} = 3f$ 3rd Harmonic

$\lambda_4 = \frac{1}{2}L \quad f_4 = \quad = \quad = 4f$ 4th Harmonic

$f = 5f$

$f = 6f$

Note: For strings, each end of the string ends in a NODE

Finding Frequency

- **Frequency can be found for any harmonic using:**

$$f_n = nf_1$$

or

$$f_n = \frac{nv}{2L}$$

ex) What is the speed of a wave that vibrates with a frequency of 2.5×10^3 Hz in the 4th harmonic of a guitar whose strings are 0.85 m long?

Air Columns - Resonance

- **Air columns can vibrate with frequencies that are similar to strings. However, there are 2 types of air columns:**

- **Open Air Column (both sides open)**

- **Closed Air Column (one side open)**

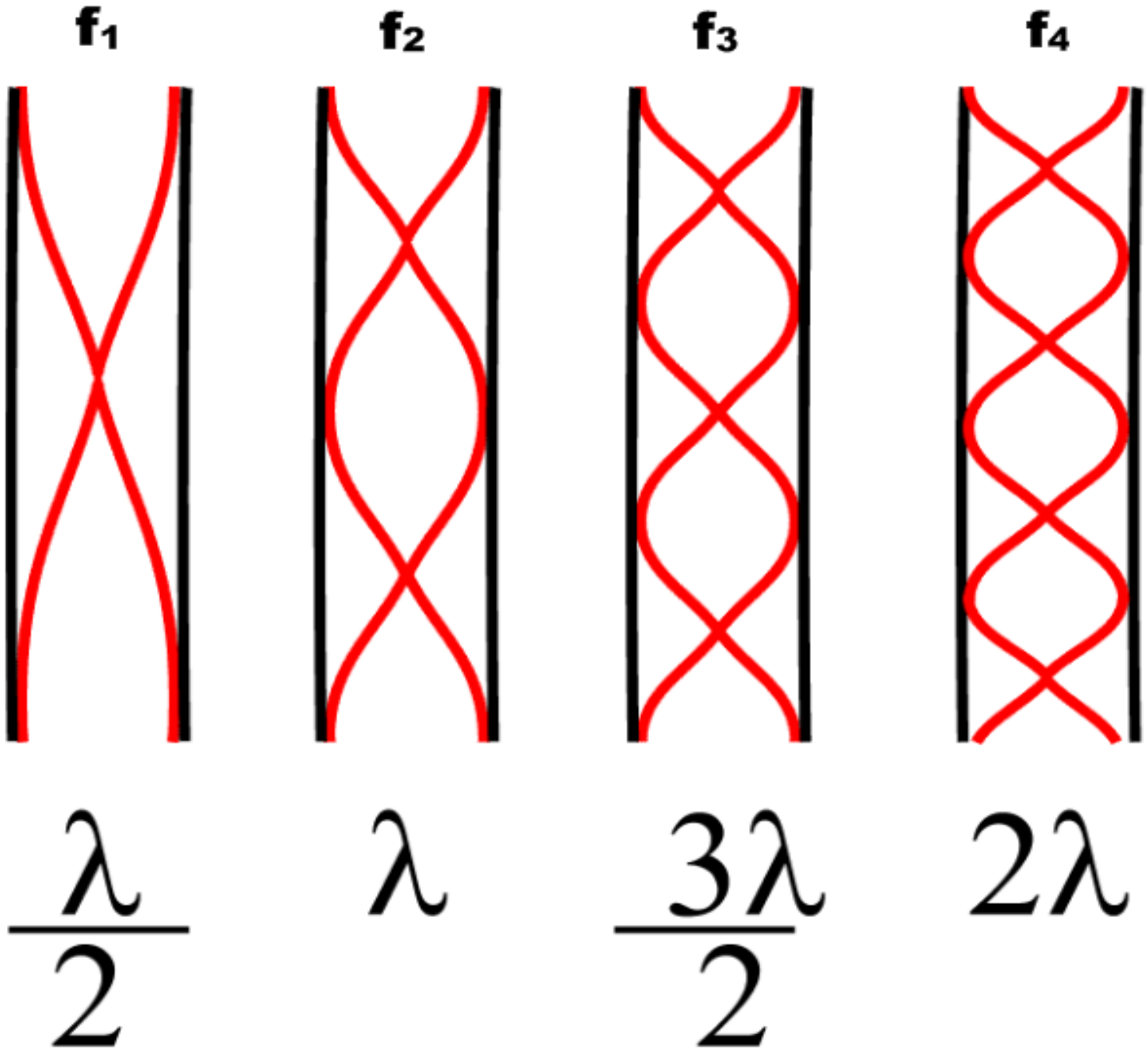
Open Air Columns

- **When sound waves form in a column (such as a wind instrument) the sound waves form points of constructive and destructive interference. This is a resonant effect**

Fundamental Frequency is the same as for strings:

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

Note: Both ends of the column end in an ANTINODE

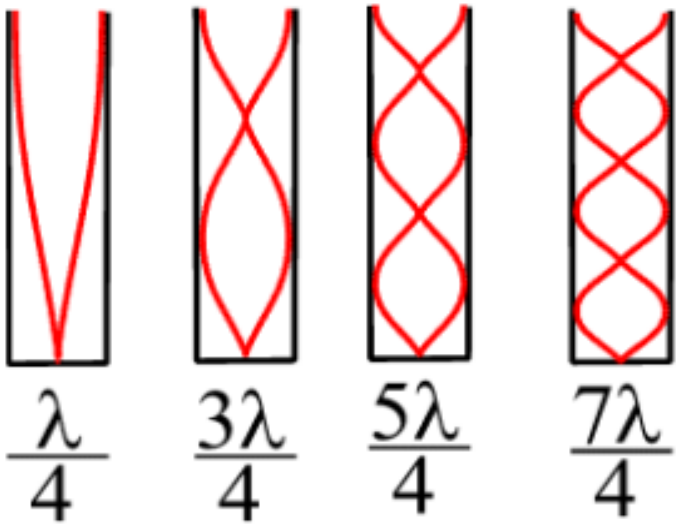

f1
f2
f3
f4
λ/2
λ
3λ/2
2λ

Closed Air Columns

- **Fundamental Frequency is NOT the same as for strings:**

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

Note #1: $f = \frac{nv}{4L}$



Note #2: One end of the column ends in an ANTINODE and the other ends in a NODE

Note #3: There are only odd numbers of harmonics!

ex) A closed air column is 55cm in length. If the 3rd harmonic vibrates at 156 Hz, what is the speed of the wave?

Loudness vs. Pitch

- **Pitch is a property of waves that results from the FREQUENCY of a wave.**
  - **the lower the frequency (higher wavelengths), the lower the pitch**
  - **the higher the frequency (lower wavelengths), the higher the pitch**

- **Loudness is a property of waves that results from the AMPLITUDE of a wave.**
  - **the lower the amplitude, the quieter the sound**
  - **the higher the amplitude, the louder the sound**
  - **wavelength is independent of amplitude!!**