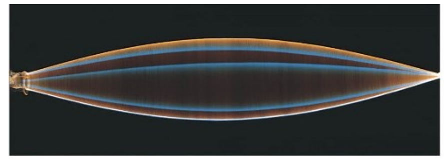
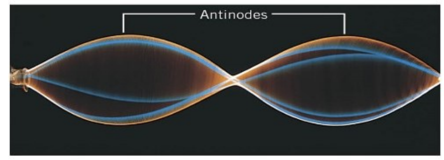
Physics 10-06 Resonance *Name:* ________________________

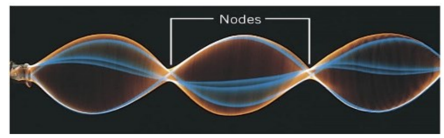
String Attached at Both Ends



- The ______________ wave is formed.
- Nodes – ______________
- Antinodes – ______________



- The wave ______________ along the string until it hits the other ____________
- The wave ______________ off the other end and travels in the ______________ direction, but ______________
- The returning wave hits the ______________ end and ______________ again (this side the wave is ____________________)
- Unless the timing is just right the reflecting wave and the new wave will not ______________



- When they do coincide, the waves add due to ______________ interference
- When they don't coincide; ______________ interference

Harmonics

- When you vibrate the string faster, you can get standing waves with ______________ nodes and antinodes
- Standing waves are named by number of ______________
- 1 antinode → 1st harmonic (fundamental frequency)
- 2 antinodes → 2nd harmonic (1st overtone)
- 3 antinodes → 3rd harmonic (2nd overtone)

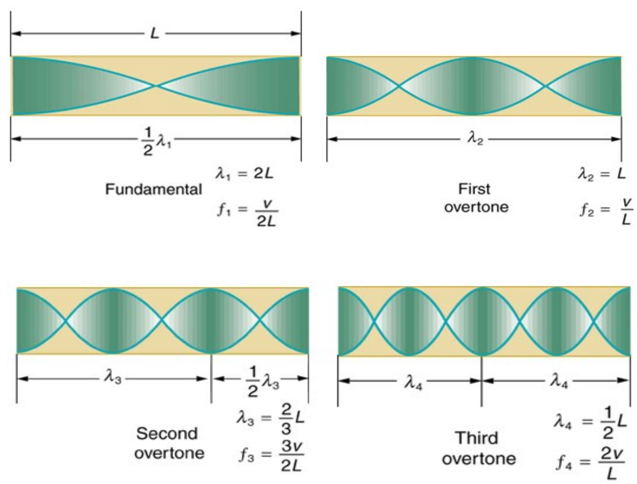
- f_1 = fundamental frequency (1st harmonic)
- $f_2 = 2f_1$ (2nd harmonic)
- $f_3 = 3f_1$ (3rd harmonic)

- To find the fundamental frequencies and harmonics of a string fixed at ______________ ends

$$f_n = n\left(\frac{v_w}{2L}\right)$$

- Where f_n = frequency of the n^{th} harmonic, n = integer (harmonic #), v_w = speed of wave, L = length of string

Tube open at both ends



- Wind instruments rely on standing _________________ sound waves in ______________
- The waves ______________ off the open ends of tubes
- One difference at the ends are ______________ instead of nodes

Formula for Tube Open at Both Ends

$$f_n = n\left(\frac{v_w}{2L}\right)$$

What is the lowest frequency playable by a flute that is 0.60 m long if that air is 20 °C.

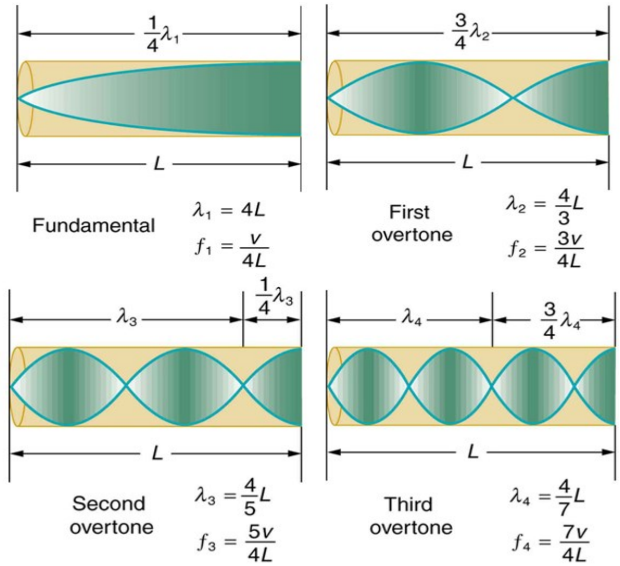
Physics 10-06 Resonance	*Name:* ________________________

Tube open at one end

- Node at the _______________ end
- Antinode at the _______________ end
- Lengths are *odd integer* multiples of ¼ λ

$$f_n = n\left(\frac{v_w}{4L}\right)$$

- Only _______________ harmonics



Practice Work

1. A rope is hanging vertically straight down. The top end is being vibrated back and forth. Standing waves can develop on the rope analogous to those on a horizontal rope. There is a node at the top end. Is there a node or an antinode at the bottom end? Try it.
2. How does an unamplified guitar produce sounds so much more intense than those of a plucked string held taut by a simple stick?
3. What is the difference between an overtone and a harmonic? Are all harmonics overtones? Are all overtones harmonics?
4. (a) What is the fundamental frequency of a 0.672-m-long tube, open at both ends, on a day when the speed of sound is 344 m/s? (b) What is the frequency of its second harmonic? (OpenStax 17.42) **256 Hz, 512 Hz**
5. If a wind instrument, such as a tuba, has a fundamental frequency of 32.0 Hz, what are its first three overtones? It is closed at one end. (The overtones of a real tuba are more complex than this example, because it is a tapered tube.) (OpenStax 17.43) **96.0 Hz, 160 Hz, 224 Hz**
6. What are the first three overtones of a bassoon that has a fundamental frequency of 90.0 Hz? It is open at both ends. (The overtones of a real bassoon are more complex than this example, because its double reed makes it act more like a tube closed at one end.) (OpenStax 17.44) **180 Hz, 270 H, 360 Hz**
7. How long must a flute be in order to have a fundamental frequency of 262 Hz (this frequency corresponds to middle C on the evenly tempered chromatic scale) on a day when air temperature is 20.0 °C? It is open at both ends. (OpenStax 17.45) **65.4 cm**
8. What length should an oboe have to produce a fundamental frequency of 110 Hz on a day when the speed of sound is 343 m/s? It is open at both ends. (OpenStax 17.46) **1.56 m**
9. What is the length of a tube that has a fundamental frequency of 176 Hz and a first overtone of 352 Hz if the speed of sound is 343 m/s? (OpenStax 17.47) **0.974 m**
10. (a) Find the length of an organ pipe closed at one end that produces a fundamental frequency of 256 Hz when air temperature is 18.0 °C. (Speed of sound is 342 m/s.) (b) What is its fundamental frequency at 25.0 °C? (Speed of sound is 346 m/s.) (OpenStax 17.48) **0.334 m, 259 Hz**
11. The G string on a guitar has a fundamental frequency of 196 Hz and a length of 0.62 m. This string is pressed against the proper fret to produce the note C, whose fundamental frequency is 262 Hz. What is the distance L between the fret and the end of the string at the bridge of the guitar? (Cutnell 17.25) **0.46 m**
12. Sound enters the ear, travels through the auditory canal, and reaches the eardrum. The auditory canal is approximately a tube open at only one end. The other end is closed by the eardrum. A typical length for the auditory canal in an adult is about 2.9 cm. The speed of sound is 343 m/s. What is the fundamental frequency of the canal? (Interestingly, the fundamental frequency is in the frequency range where human hearing is most sensitive.)(Cutnell 17.36) **3000 Hz**