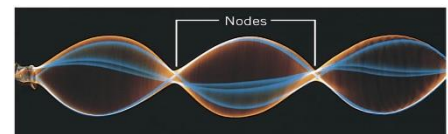
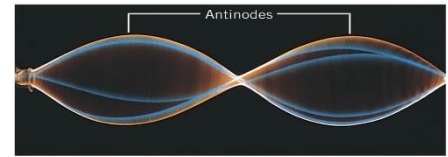
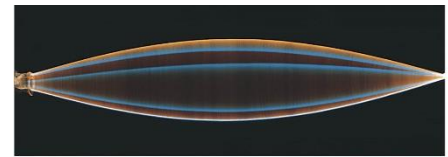


String Attached at Both Ends

- 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 nth 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

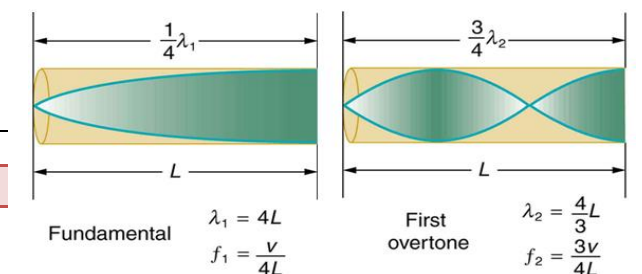
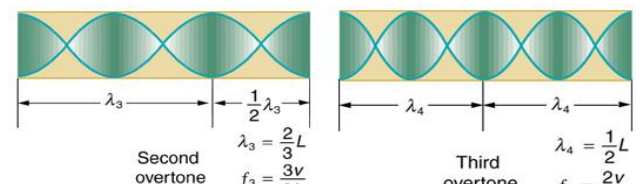
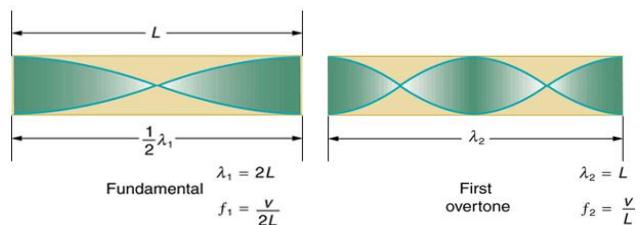
Formula for Tube Open at Both Ends

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

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

Tube open at one end

- Node at the _____ end

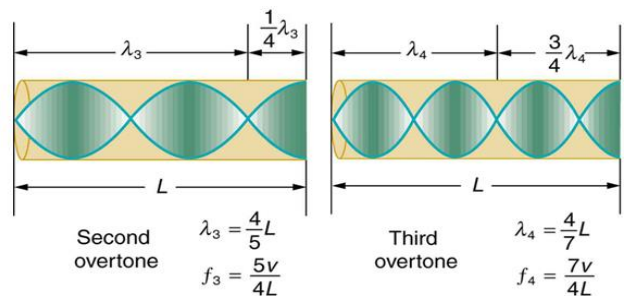


Physics 07-07 Sound Interference and Resonance

- Antinode at the _____ end
- Lengths are *odd integer* multiples of $\frac{1}{4} \lambda$

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

- Only _____ harmonics



Homework

1. A string is vibrating back and forth as in the figure. The tension in the string is decreased by a factor of four, with the frequency and the length of the string remaining the same. Draw the new standing wave pattern that develops on the string. Give your reasoning.
2. 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. (a) There is a node at the top end. Is there a node or an antinode at the bottom end? Try it. (b) The separation between successive nodes is not the same everywhere on the rope, as it would be if the rope were horizontal. Is the separation greater near the top or near the bottom? Try it. Taking into account the mass of the rope, give your reasoning.
3. How does an unamplified guitar produce sounds so much more intense than those of a plucked string held taut by a simple stick?
4. What is the difference between an overtone and a harmonic? Are all harmonics overtones? Are all overtones harmonics?
5. (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**
6. 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**
7. 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 Hz, 360 Hz**
8. 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**
9. 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**
10. 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**
11. (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. (b) What is its fundamental frequency at 25.0 °C? (OpenStax 17.48) **0.334 m, 259 Hz**
12. The A string on a string bass is tuned to vibrate at a fundamental frequency of 55.0 Hz. If the tension in the string were increased by a factor of four, what would be the new fundamental frequency? (Cutnell 17.23) **1.1×10^2 Hz**
13. 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**
14. On a cello, the string with the largest linear density (1.56×10^{-2} kg/m) is the C string. This string produces a fundamental frequency of 65.4 Hz and has a length of 0.800 m between the two fixed ends. Find the tension in the string. (Cutnell 17.27) **171 N**
15. 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**

