Sound Waves

The Physics of Music

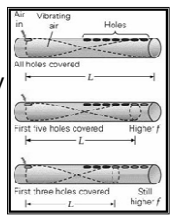
Forced Vibrations and Resonance

- Forced Vibrations
  - The forced transfer of a vibration to other media (Ex: guitar)
- Resonance
  - Occurs when the forced vibration matches the natural frequency of an object
- Resonance can produce a standing wave, creating a louder noise or other results…

https://www.youtube.com/watch?v=uVvnw3MfxkI
https://www.youtube.com/watch?v=rRZT7xO5KN4
https://www.youtube.com/watch?v=sH7XSX10QkM

Resonance

- How it works
  - Certain frequencies will produce standing waves in a given length of pipe or string
  - These standing waves produce the sound we hear in musical instruments.
  - By changing the length of the string or pipe, we can change the frequency that resonates
  - Resonant frequency can also depend on the diameter of the pipe



Resonance

- Fundamental
  - the lowest frequency making up a sound
- Harmonics
  - whole number multiples of the fundamental frequency
- Overtones
  - The first occurrence of resonance above the fundamental frequency

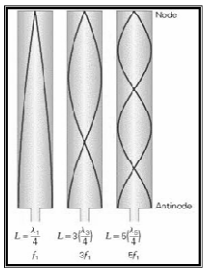
Note on musical vocabulary:
- The fundamental is also the first harmonic
- The first overtone is the second harmonic

Resonance

- Closed pipe resonator
  - resonating tube with one end closed
  - produces a standing wave
  - Minimum length is approx. 1/4 λ

$$\lambda = 4L$$
$$f_n = n\left(\frac{v}{4L}\right) \qquad (n = 1,3,5)$$
$$f_n = nf_1$$

Notice only odd harmonics resonate in a closed tube

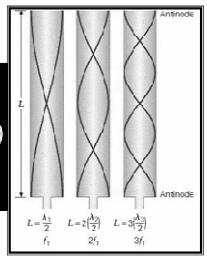


Resonance

- Open-pipe resonator
  - open at both ends
  - produces a standing wave
  - Minimum length is 1/2 λ

$$\lambda = 2L$$
$$f_n = n\left(\frac{v}{2L}\right) \qquad (n = 1,2,3\ldots)$$
$$f_n = nf_1$$

Notice all harmonics resonate in a open tube



Harmonics Sample Problem

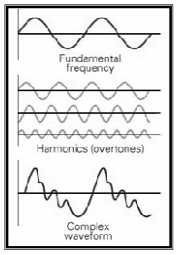
- What are the first two harmonics (resonant frequencies) in a 2.45 m long pipe that is open at both ends? Assume the speed of sound is 345 m/s.

Harmonics Sample Problem

- A 392 Hz tuning fork is used with a closed pipe resonator. The length is 0.32 m when the loudest sound is produced. What is the speed of sound?

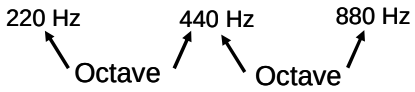
Sound Quality

- Timbre or Quality
  - instrument dependent
  - combined frequencies
  - complex wave forms



Pitch - Octaves

- Pythagoras determined musical scales based on the length of string when plucked.
- Octaves
  - difference in pitch when the two notes' frequencies have a ratio of 2:1



Sound Quality

- Beat
  - pulsing variation of loudness
  - Humans can detect beat frequencies up to approximately 7Hz
  - Over 7Hz we hear a complex wave