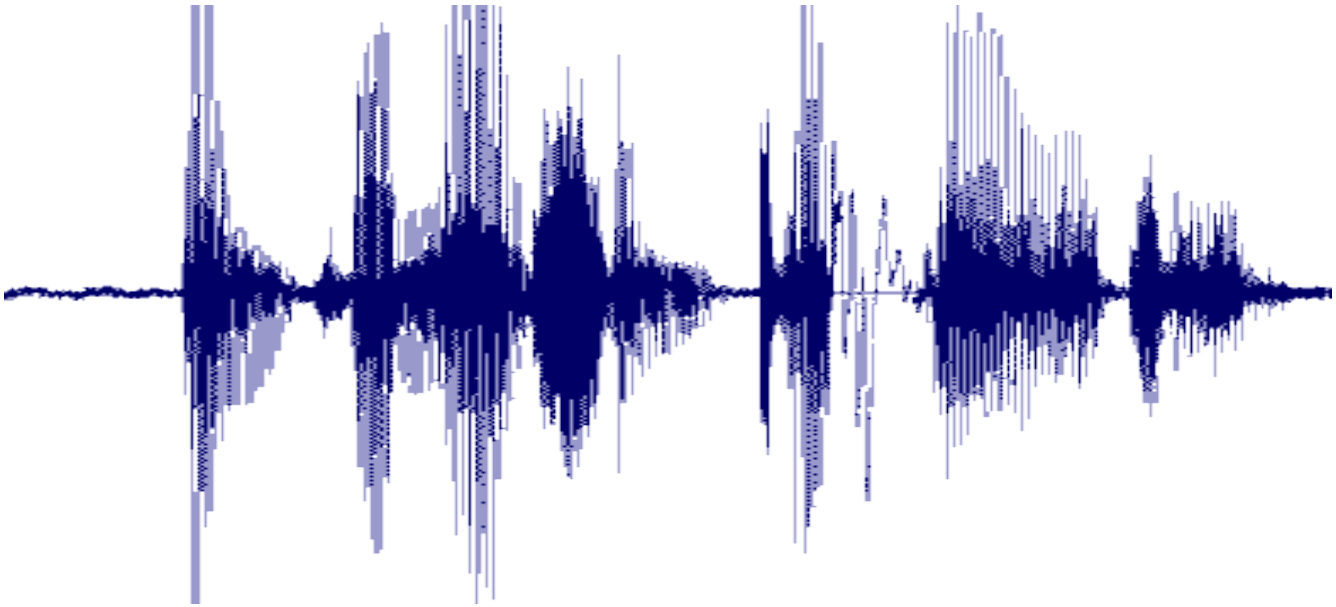
Physics 1240: Sound and Music

Today (7/12/19): Complex Waves: Beats, Timbre

Next time: Harmonics, Decibels

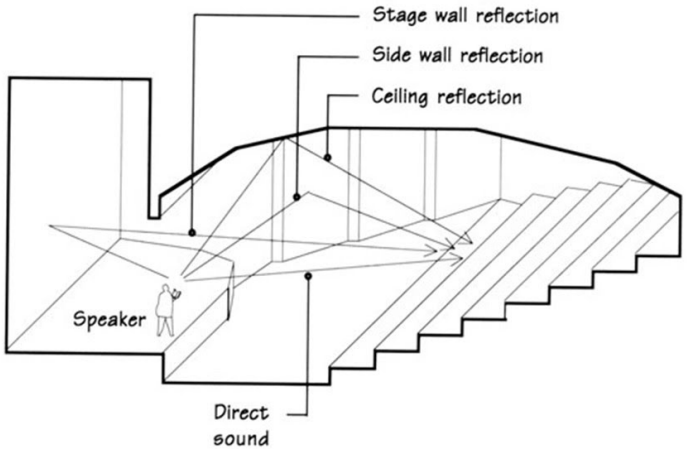


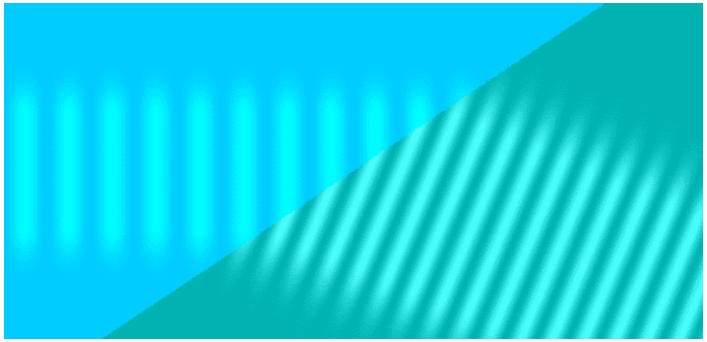
Review

- Speed of sound increases with temperature:

$$v[\mathrm{m/s}] = 331 + 0.6\,T[^{\circ}\mathrm{C}]$$

- How sound can propagate:
  - Reflection (diffuse or spectral)
  - Absorption (greater for softer surfaces)
  - Refraction (when speed of sound changes)
  - Diffraction (greater for larger wavelengths)





BA

Clicker Question 4.1

You can hear a sound in your left ear that came from your right side. There are many physical reasons why this occurs, but which below is best?

A) Because your head is a relatively soft surface so that absorption takes place
B) Because the sound can refract around the hotter air closer to your body heat
C) Because the sound just keeps traveling through your head to your left ear drum
D) Most sound wavelengths are larger than your head so they diffract
E) Most sound wavelengths are smaller than your head so they diffract

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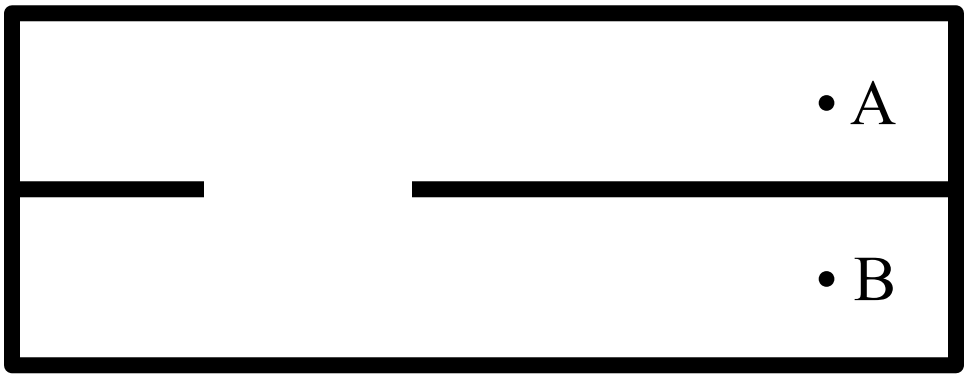
If the walls shown below are hard and smooth, what's the best explanation for how a high-pitched sound produced at A could reach B?



A) Because it reflects once
B) Because it reflects multiple times
C) Because of diffraction through the opening
D) Because of absorption through the wall
E) The sound will not reach B

BA

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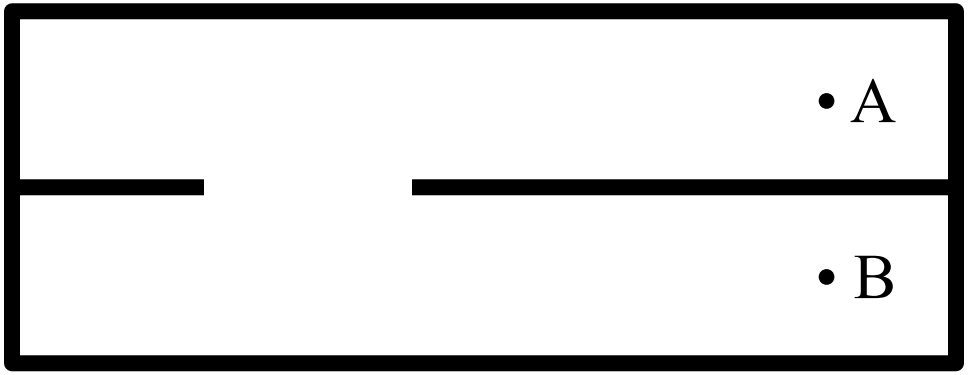

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Review

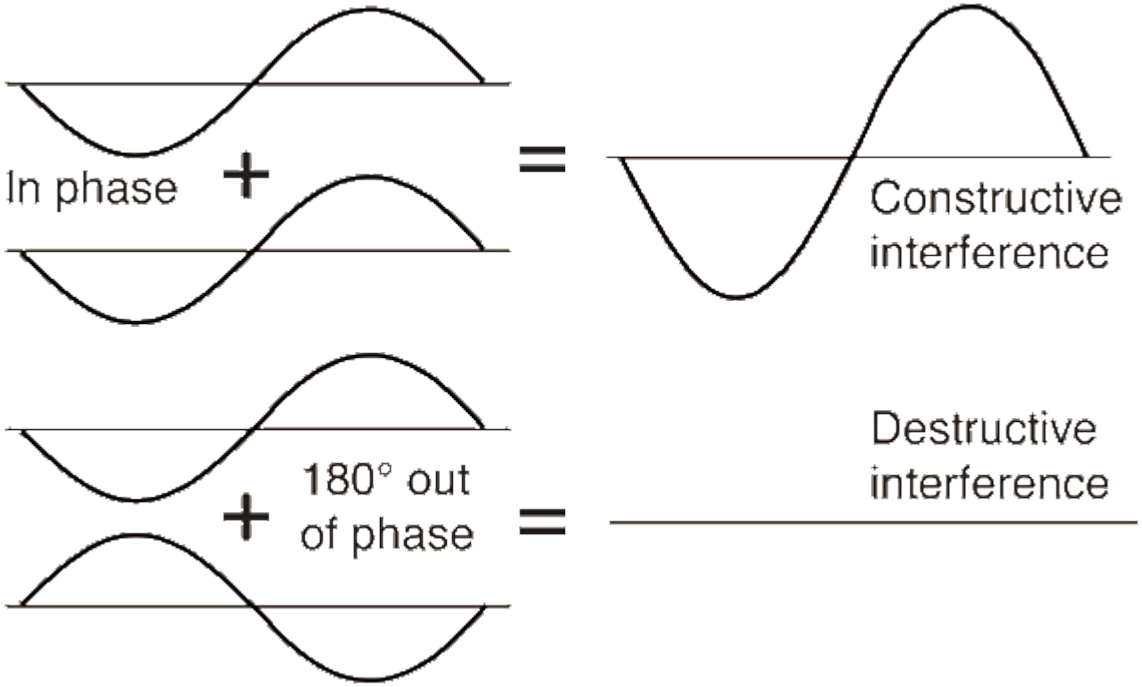
- Physics sound phenomena:
  - Sonic boom (shock wave when going over Mach 1)
  - Doppler effect (frequency increases when sources travels towards you):

$$\%\ \text{change in}\ f \cong \frac{\Delta v}{v_{\text{sound}}}$$

  - Two-source interference (waves cancel when separated by half a wavelength)

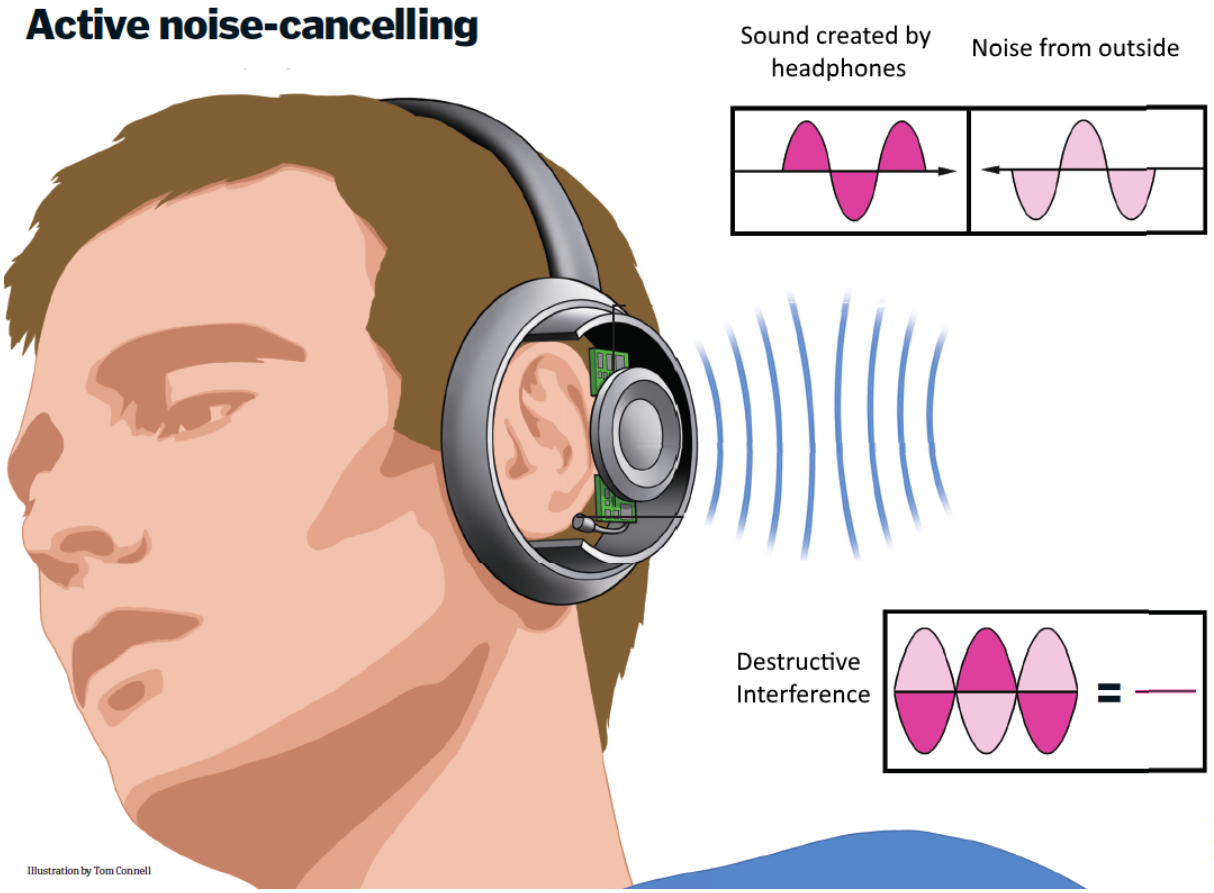
Sound Propagation

- Interference:
  - Waves just add
  - Adding two waves can be constructive or destructive



Sound Propagation

- Interference:



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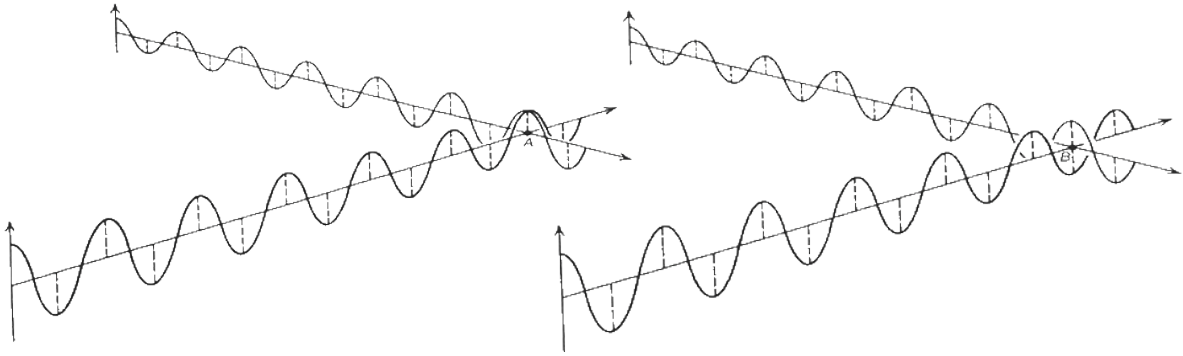

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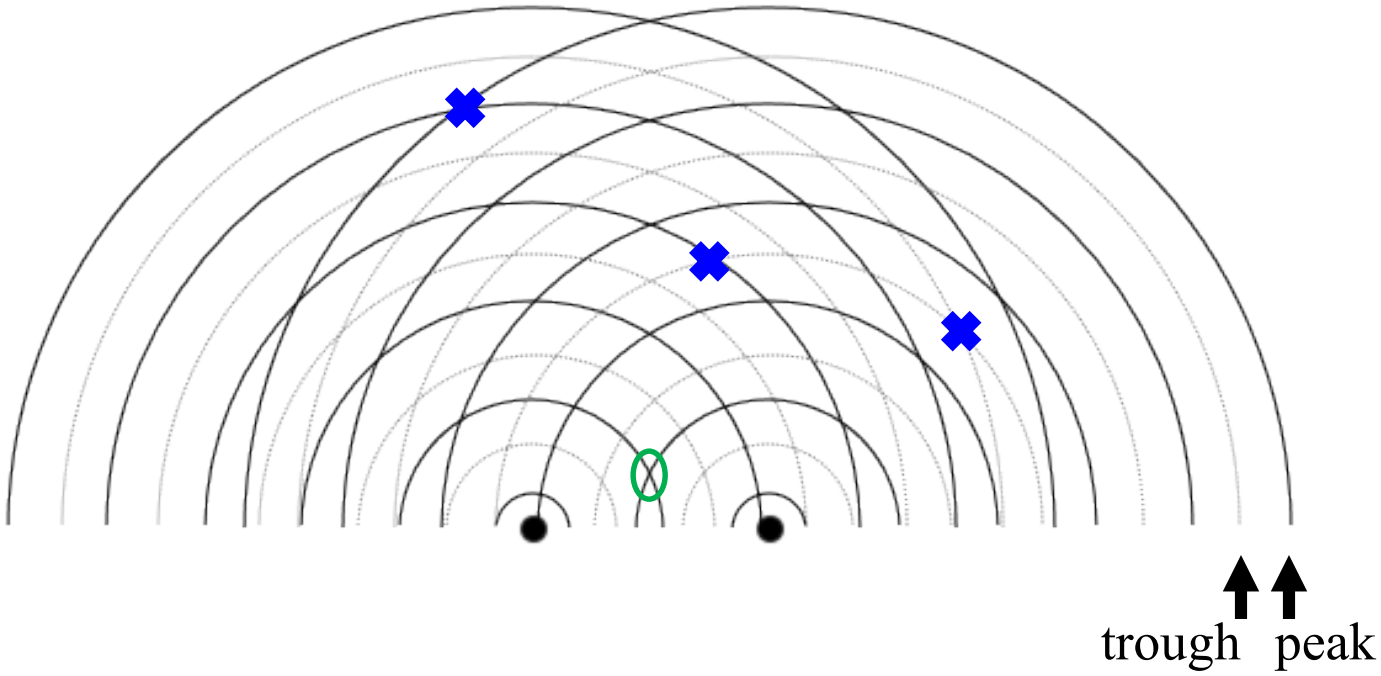

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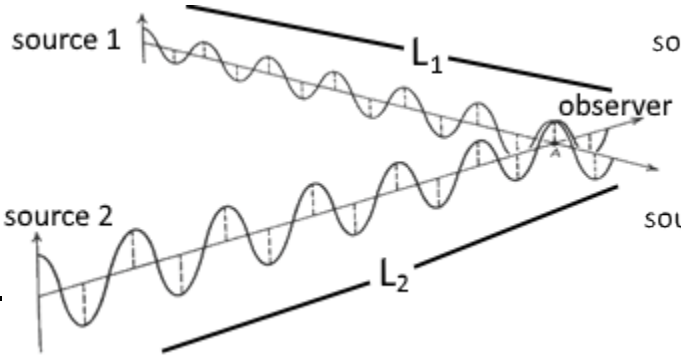

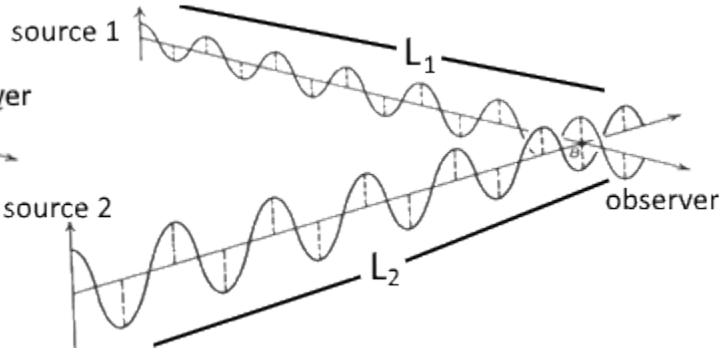

  - Adding two waves can be constructive or destructive
  - For $\Delta L = L_2 - L_1$ = difference between your distance from one source and your distance from a second source:
  - Constructive: $\Delta L = n\lambda$ (where n is an integer)
  - Destructive: $\Delta L = n \times \frac{\lambda}{2}$ (where n is an integer)

Clicker Question 4.3

If you are in a room with two speakers each producing sine waves with a wavelength of 2 meters, where should you stand if you don't want to hear any sound?

A) 2 meters from one speaker and 2 meters from the other
B) 2 meters from one speaker and 4 meters from the other
C) 2 meters from one speaker and 3 meters from the other
D) 3 meters from one speaker and 5 meters from the other
E) 1 meter from one speaker and 0.5 meters from the other

BA

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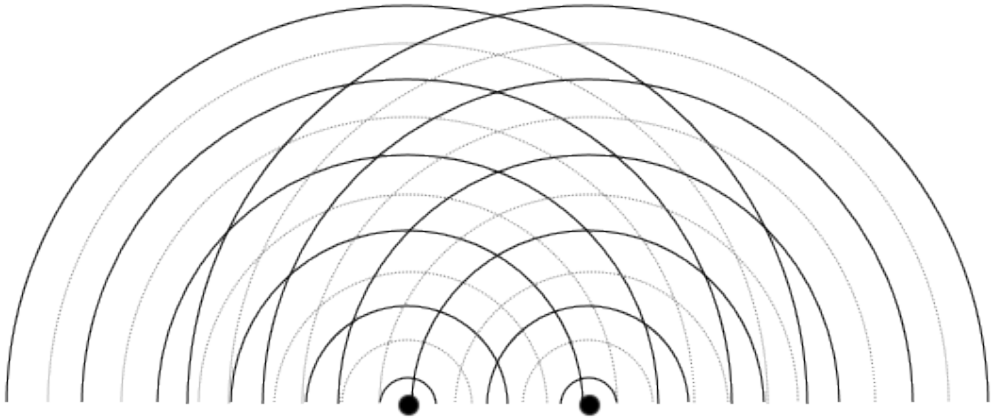
Sound Propagation

- What if the two speakers have different wavelengths?

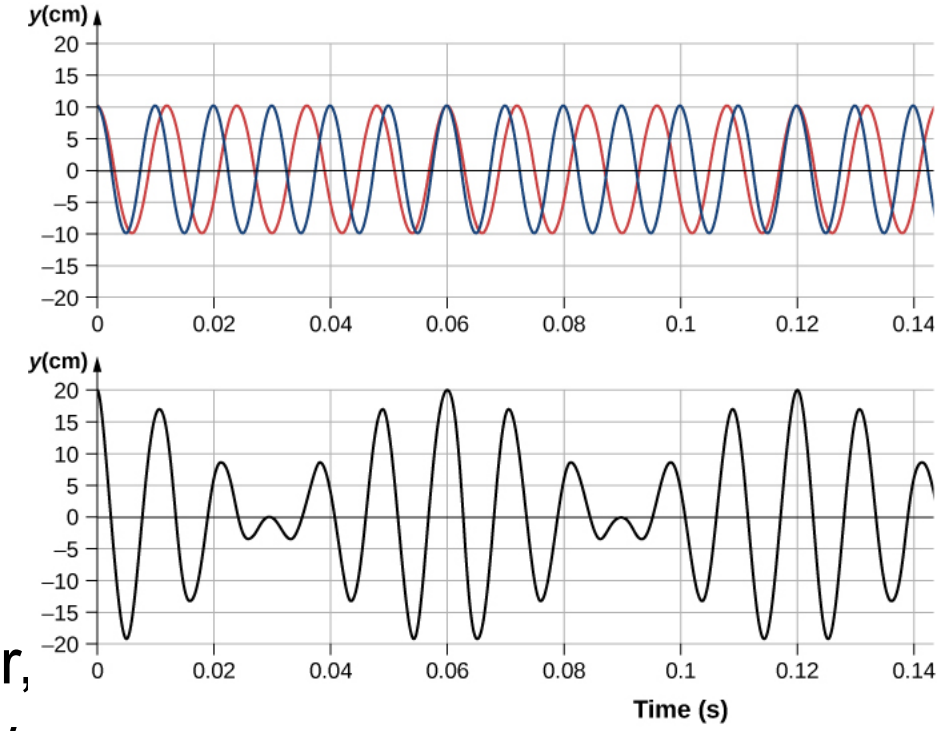


- http://www.falstad.com/ripple/

Sound Propagation

- Beats: adding two waves with different frequencies produces a periodic oscillation in the amplitude

$$f_{\text{beat}} = f_2 - f_1$$



- Ex. 440 Hz and 441 Hz produce beats with a frequency of 1 Hz

- Used for tuning—as 2 pitches get closer together, do beats speed up or slow down?

BA

Clicker Question 4.4

When you pluck two guitar strings, they have an almost identical pitch, but their volume together throbs at a rate of about 3 times every second. If one string is tuned to a pitch of E_2 (f=82 Hz), what's the frequency of the other?

A) 82 Hz
B) 83 Hz
C) 84 Hz
D) 85 Hz
E) Cannot determine

BA

Clicker Question 4.4

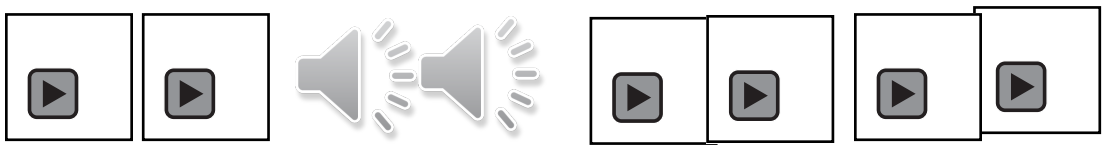
When you pluck two guitar strings, they have an almost identical pitch, but their volume together throbs at a rate of about 3 times every second. If one string is tuned to a pitch of E_2 (f=82 Hz), what's the frequency of the other?

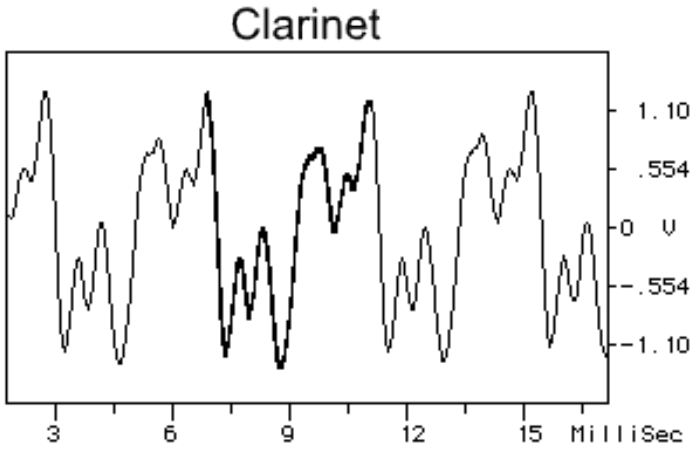
A) 82 Hz
B) 83 Hz
C) 84 Hz
D) 85 Hz
E) Cannot determine

Could be 85 Hz or 79 Hz
(82±3 Hz)

Characteristics of Sound

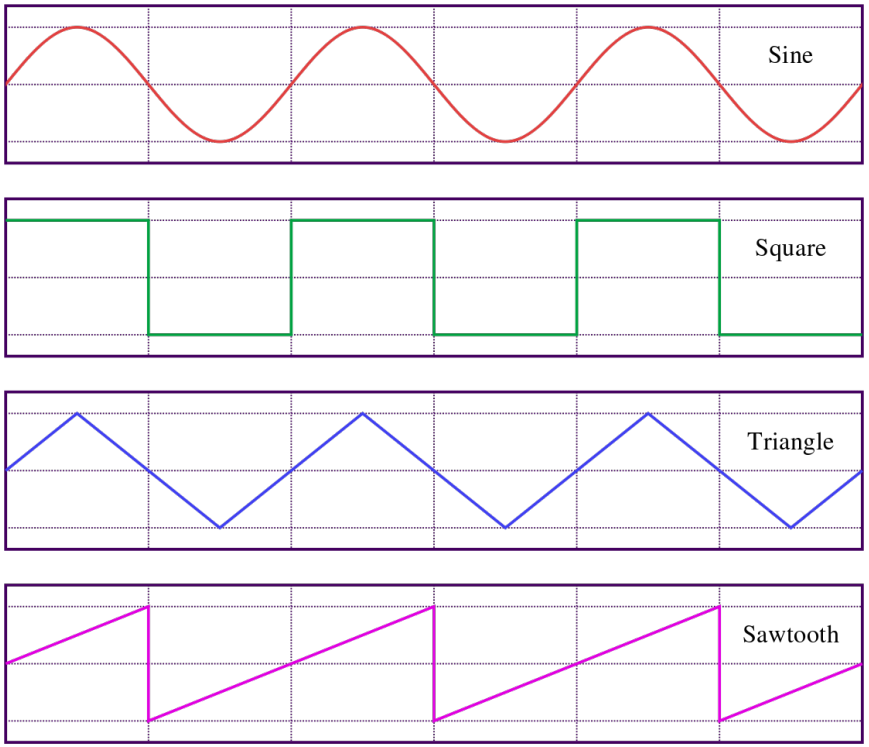
- What do we need to completely describe a single, steady tone?
  - Frequency ↔ pitch
  - Amplitude ↔ loudness
  - Duration ↔ note length
  - Waveform ↔ timbre





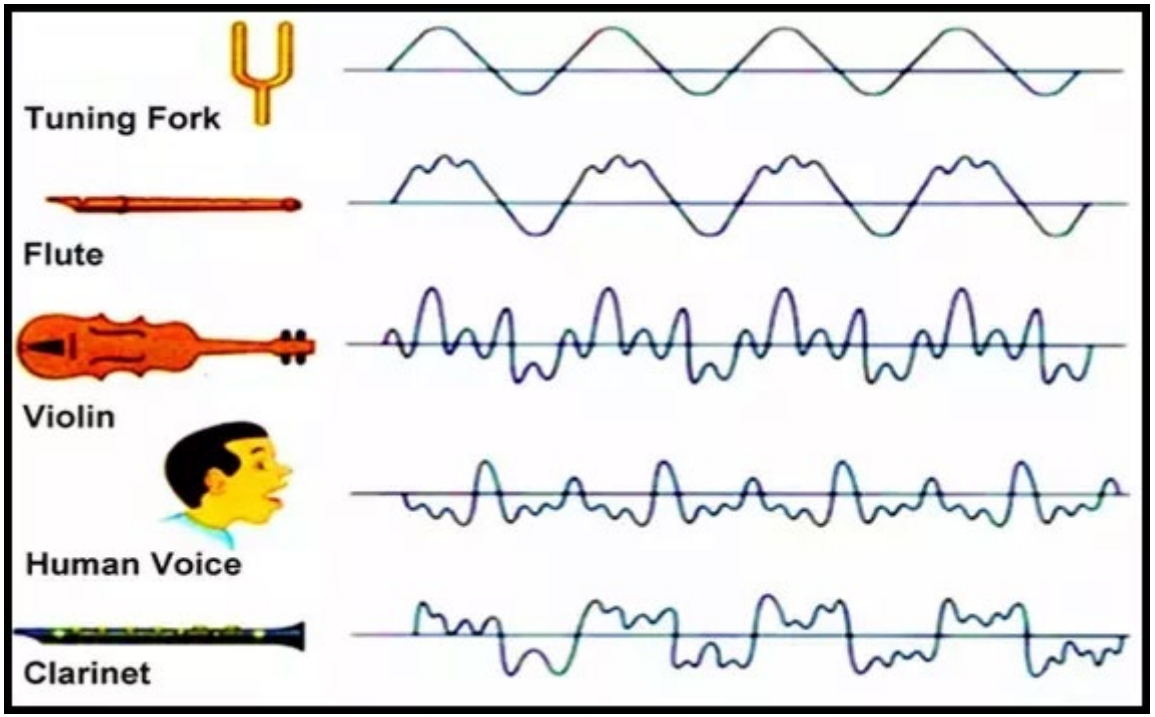
Characteristics of Sound

- Waveform: the shape that forms the repeating pattern of a wave



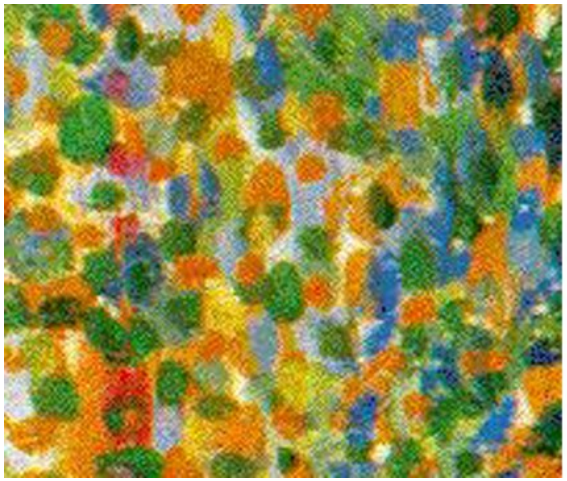
Characteristics of Sound

- Timbre: the musical quality of a sound wave that isn't encompassed by its pitch or loudness



Effects of Timbre

- "Musical pointillism"



J.S. Bach's Cantata BWV 39
https://www.youtube.com/watch?v=ThtSWBZlVuE

Berlioz' *Symphonie fantastique*
https://www.youtube.com/watch?v=598i8b3HGrw