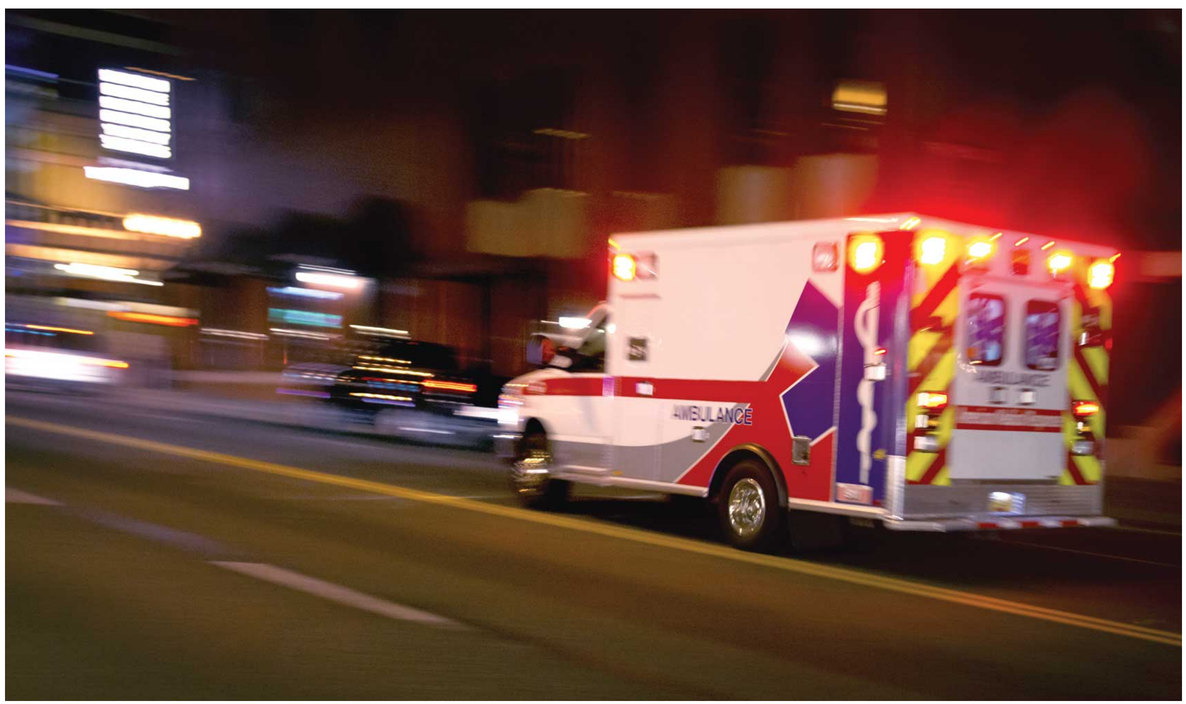
Physics 1240: Sound and Music

<u>Today (7/11/19)</u>: Doppler Effect, Interference, Beats

<u>Next time</u>: Characteristics of Sound, Decibels



Review

- Speed = Wavelength × Frequency   ($v = \lambda f$)

- Frequency = 1 / Period ↔ pitch
- Amplitude ↔ loudness

- Simple harmonic motion:
  - Higher elasticity (stiffness) means ______ frequency
  - Higher inertia (mass) means ______ frequency

- Resonance: amplifying a system's natural frequency

BA

<u>Clicker Question 3.1</u>

What is the speed of sound in air under normal atmospheric conditions in km/s?

A) 343 km/s
B) 34.3 km/s
C) 3.43 km/s
D) 0.343 km/s
E) 343,000 km/s

BA

Clicker Question 3.1

What is the speed of sound in air under normal atmospheric conditions in km/s?

A) 343 km/s
B) 34.3 km/s
C) 3.43 km/s
D) <u>0.343 km/s</u>
E) 343,000 km/s

Conversion: $1\ \text{km} = 10^3\ \text{m}$

$$\left(343\ \frac{\cancel{\text{m}}}{\text{s}}\right)\left(\frac{1\ \text{km}}{1000\ \cancel{\text{m}}}\right) = 0.343\ \text{km/s}$$


BA

Clicker Question 3.2

As you fill a glass with water from the sink, you notice that you can hear a rising pitch. Why?

A) The mass of water in the cup is increasing as the water vibrates
B) The mass of water in the cup is decreasing as the water vibrates
C) The mass of air in the cup is decreasing as the air vibrates
D) The elasticity of the water is increasing as more bubbles form
E) You are tilting the cup less and less as it fills up

BA

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C) The mass of air in the cup is decreasing as the air vibrates
D) The elasticity of the water is increasing as more bubbles form
E) You are tilting the cup less and less as it fills up

BA

Clicker Question 3.3

On a cool summer evening when the air temperature is 20°C, you see a flash of lightning and hear the sound of thunder 2 seconds later. Assuming you saw the light at the same time the sound was produced, how far away was the bolt?

A) 172 m
B) 343 m
C) 686 m
D) 1.7 km
E) 20 km

BA

Clicker Question 3.3

On a cool summer evening when the air temperature is 20°C, you see a flash of lightning and hear the sound of thunder 2 seconds later. Assuming you saw the light at the same time the sound was produced, how far away was the bolt?

A) 172 m
B) 343 m
C) 686 m
D) 1.7 km
E) 20 km

$$(343\ \text{m/s}) \times (2\ \text{s}) = 686\ \text{m}$$

BA

Clicker Question 3.4

You are standing outside on a pleasant day, playing a recorder. You play A_4 ("concert A", also known as A440); i.e., during one second, 440 compressions of air move outwards. If the speed of sound in air on that day is 343 m/s, what is the approximate wavelength of the sound wave?

A) A couple of mm
B) A couple of cm
C) A little under one meter
D) A little over one meter
E) More than a km

BA

Clicker Question 3.4

You are standing outside on a pleasant day, playing a recorder. You play A_4 ("concert A", also known as A440); i.e., during one second, 440 compressions of air move outwards. If the speed of sound in air on that day is 343 m/s, what is the approximate wavelength of the sound wave?

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$$\frac{(343\ \mathrm{m/s})}{(440\ \mathrm{Hz})} \approx 0.78\ \mathrm{m}$$

$$\left(v = \lambda f \quad \Rightarrow \quad \lambda = \frac{v}{f} \right)$$

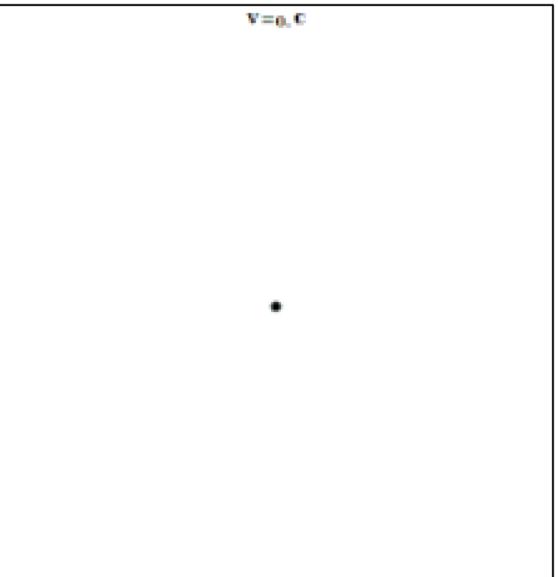
Sound Propagation

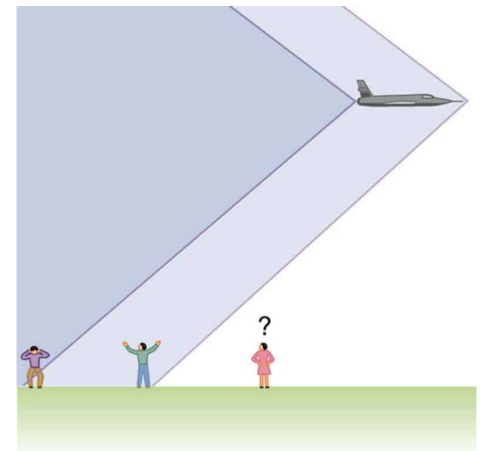
- Speed of sound in air at 20°C:
  v = 343 m/s = 767 mph = Mach 1

- Muzzle velocity of rifle: 120 m/s – 1200 m/s
- Speed of commercial airplane = 250 m/s = 560 mph
- Land speed record = 341 m/s = 763 mph = Mach 1.02
- Speed of fastest jetfighter = 2,000 m/s = Mach 6.7
- Speed of light = 299,792,458 m/s = 670 million mph

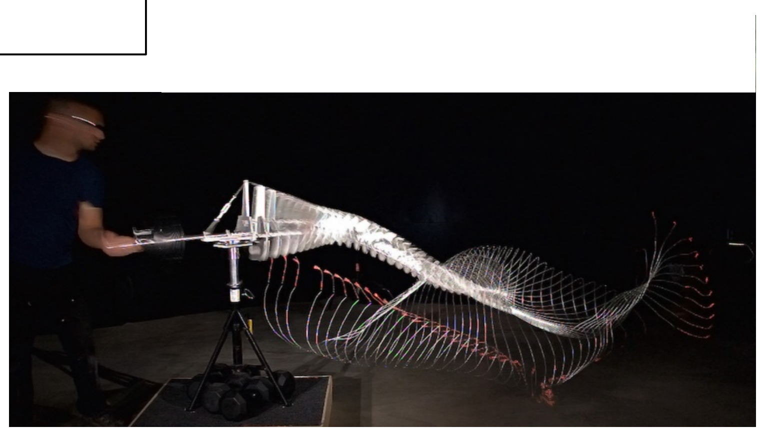
Shock waves

- “Sonic boom” occurs when object travels faster than the local speed of sound (waves can’t get out of the way fast enough)





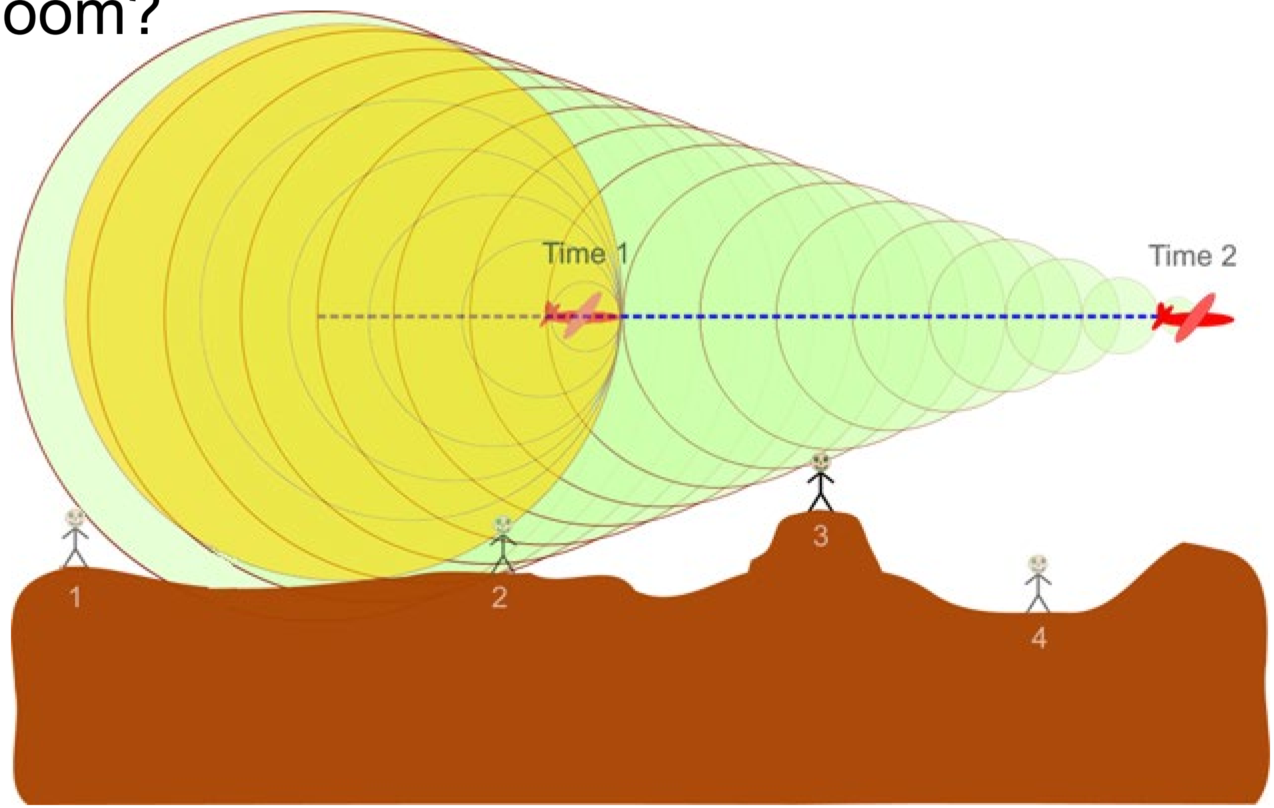
- F-18 over beach
- Atlas V rocket launch
- Bullets
- Whip Crack
- Apatosaurus tail



BA

Clicker Question 3.5

At Time 1, an accelerating plane crosses the sound barrier, and then continues at a constant speed greater than the speed of sound until Time 2. At Time 2, who has heard a sonic boom?



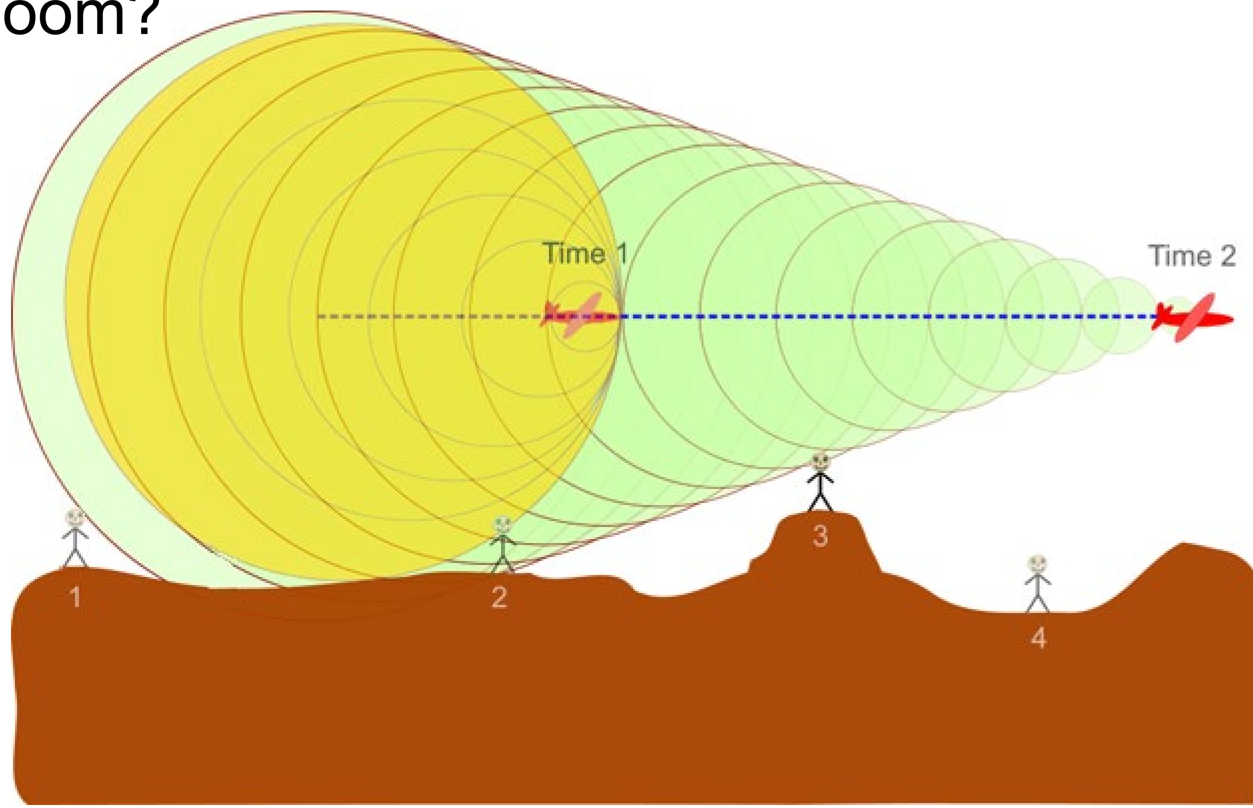
A) 1, 2, 3, 4
B) 1, 2, 3
C) 1, 2
D) 2, 3
E) 2

BA

<u>Clicker Question 3.5</u>

At Time 1, an accelerating plane crosses the sound barrier, and then continues at a constant speed greater than the speed of sound until Time 2. At Time 2, who has heard a sonic boom?

A) 1, 2, 3, 4
B) 1, 2, 3
C) 1, 2
D) <u>2, 3</u>
E) 2



Sound Propagation

- Doppler effect: the shift in frequency of a wave where the source and the observer are moving relative to one another (higher frequency if moving toward each other)

$$\boxed{\frac{\Delta v}{v_{\text{sound}}} \cong \%\ \text{change in}\ f} = \frac{f_1 - f_0}{f_0}$$

Δv = source velocity – observer velocity

-
- f_1=received frequency

f_0=emitted frequency

BA

Clicker Question 3.6

A fire truck travels away from you at 67 mph (30 m/s). If the speed of sound is 343 m/s, do you hear a lower- or higher-pitched note from the siren than the driver? What’s the percent change in the frequency?

A) You hear 8.75% lower
B) You hear 8.75% higher
C) You hear 19.5% lower
D) You hear 19.5% higher
E) You hear the same pitch as the driver


BA

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$$\%\text{ change in } f \cong \frac{\Delta v}{v_{\text{sound}}} = \frac{30\text{ m/s}}{343\text{ m/s}} \cong 0.0875$$

Applications

- Demo: I-beams, whirling ball

- Sirens
- Radar guns
- Leslie speaker for Hammond organ (tremolo & vibrato): https://www.youtube.com/watch?v=GkgQ6jU-4G4

Sound Propagation

What factors affect the speed of sound?

- *Composition of medium*: generally faster in solids and liquids than in gases
- *Temperature of medium*: $\boxed{v[\mathrm{m/s}] = 331 + 0.6\,T[°\mathrm{C}]}$
- *Weather*: speed increases with humidity, wind, pressure
- NOT dependent on frequency, amplitude, or wavelength

BA

Clicker Question 3.7

On a hot summer evening when the air temperature is 30°C, you see a flash of lightning and hear the sound of thunder 1 second later. Assuming you saw the light at the same time the sound was produced, how far away was the bolt?

A) 331 m
B) 341 m
C) 343 m
D) 346 m
E) 349 m

BA

Clicker Question 3.7

On a hot summer evening when the air temperature is 30°C, you see a flash of lightning and hear the sound of thunder 1 second later. Assuming you saw the light at the same time the sound was produced, how far away was the bolt?

A) 331 m
B) 341 m
C) 343 m
D) 346 m
E) 349 m

$v = 331 + (0.6 \times 30°C)$

$= 349 \text{ m/s}$

$(349 \text{ m/s}) \times (1 \text{ s}) = 349 \text{ m}$

BA

Clicker Question 3.8

A sound wave with a specific pitch and volume travels through air at atmospheric pressure and 20°C. What change will cause the sound speed to increase?

A) Increasing the volume
B) Traveling through a wall instead of air
C) Doubling the frequency
D) Lowering the temperature
E) Removing all the air

BA

Clicker Question 3.8

A sound wave with a specific pitch and volume travels through air at atmospheric pressure and 20°C. What change will cause the sound speed to increase?

A) Increasing the volume
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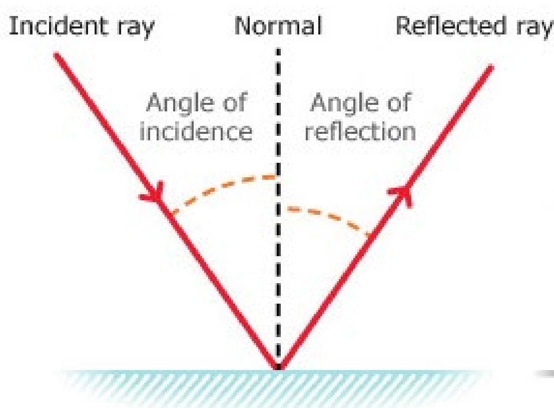
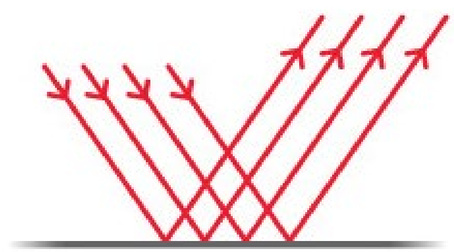
<u>Sound Propagation</u>

- <u>Reflection</u> (echoes)
  - How bumpy is bumpy? Needs to be similar size to the wavelength
  - accompanied by some <u>absorption</u> for softer surfaces

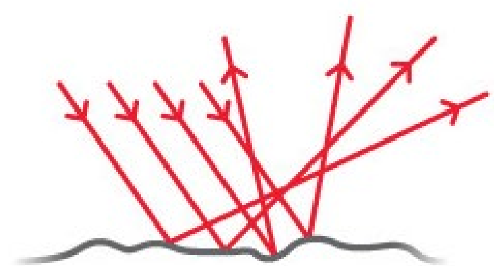
Law of reflection



Specular



Diffuse



BA

Clicker Question 3.9

If the bumps and irregularities on the wall are about 30 cm wide (or smaller), which frequencies of sound are most likely to reflect diffusely? (i.e. what’s the “cutoff”?)

A) Frequencies above 10 Hz
B) Frequencies below 10 Hz
C) Frequencies above 1000 Hz
D) Frequencies below 1000 Hz

BA

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If the bumps and irregularities on the wall are about 30 cm wide (or smaller), which frequencies of sound are most likely to reflect diffusely? (i.e. what's the "cutoff"?)

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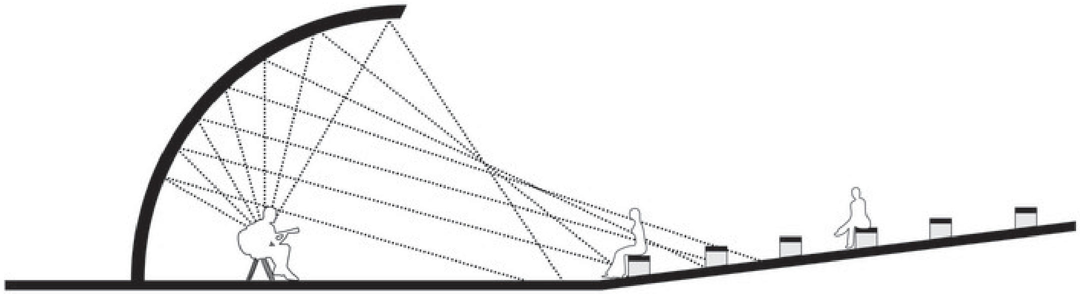
B) Frequencies below 10 Hz
C) Frequencies above 1000 Hz
D) Frequencies below 1000 Hz

$$(30\text{ cm})\left(\frac{1\text{ m}}{100\text{ cm}}\right) = 0.3\text{ m}$$

$$f = \frac{343\text{ m/s}}{0.3\text{ m}} = 1143\text{ Hz}$$

Sound Propagation

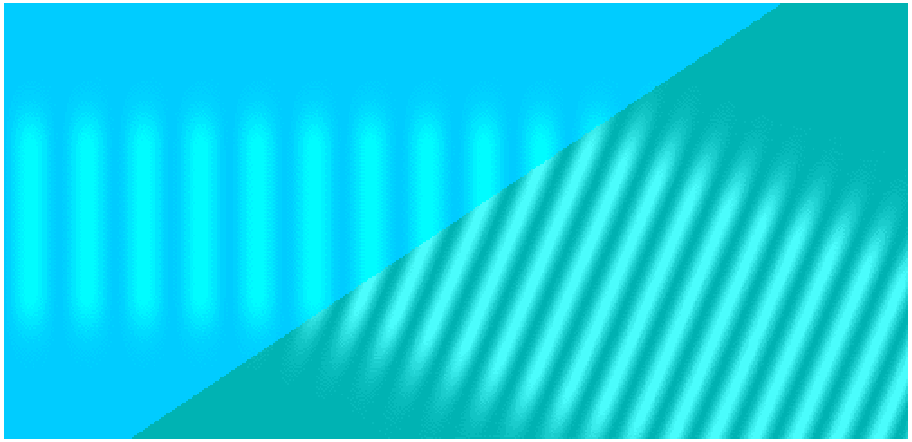
- Provides basics for **acoustics**



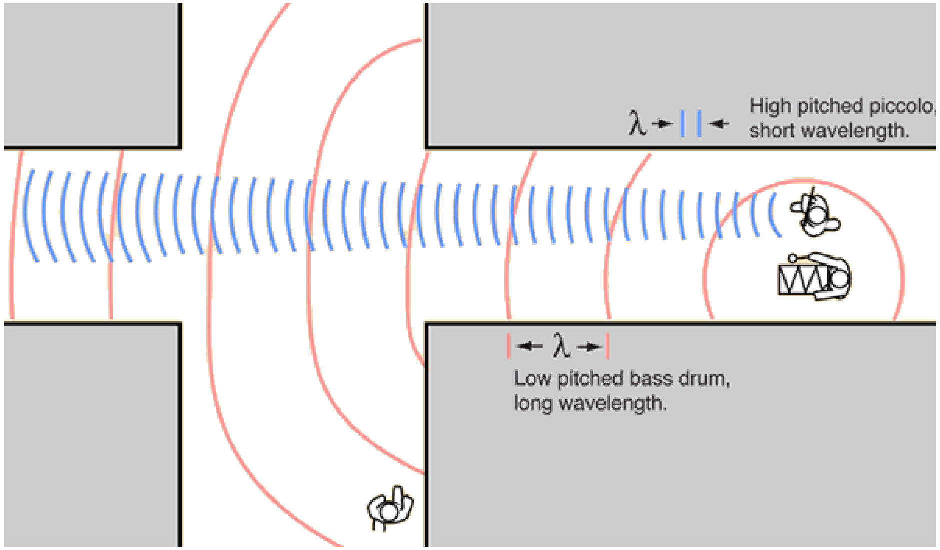
Sound Propagation

- Sound waves can also bend!

Refraction:
bending due to a change in the speed of sound

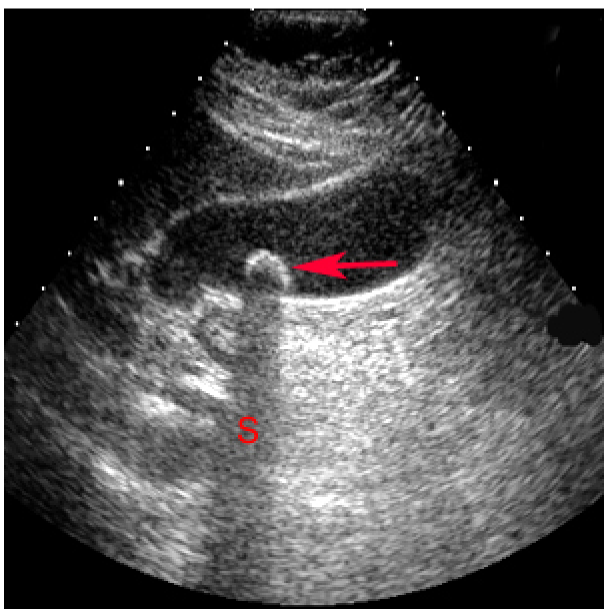


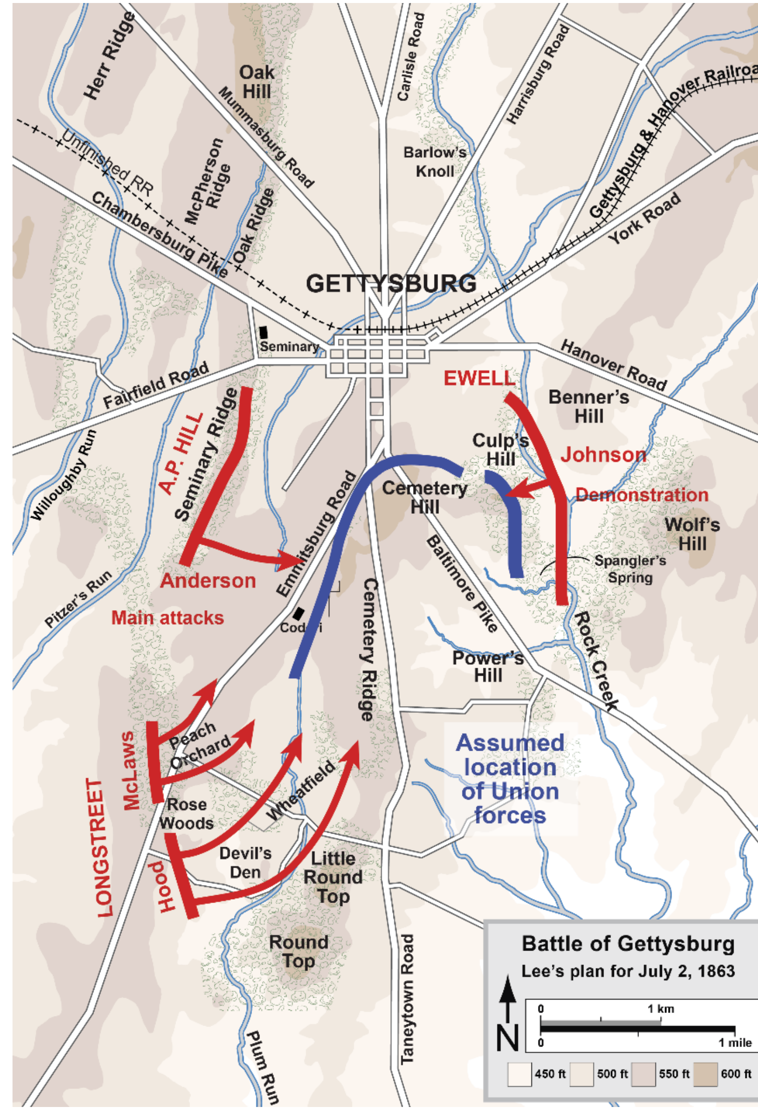
Diffraction:
bending around a corner



- <u>Acoustic shadows</u>

(regions where sound has failed to propagate)



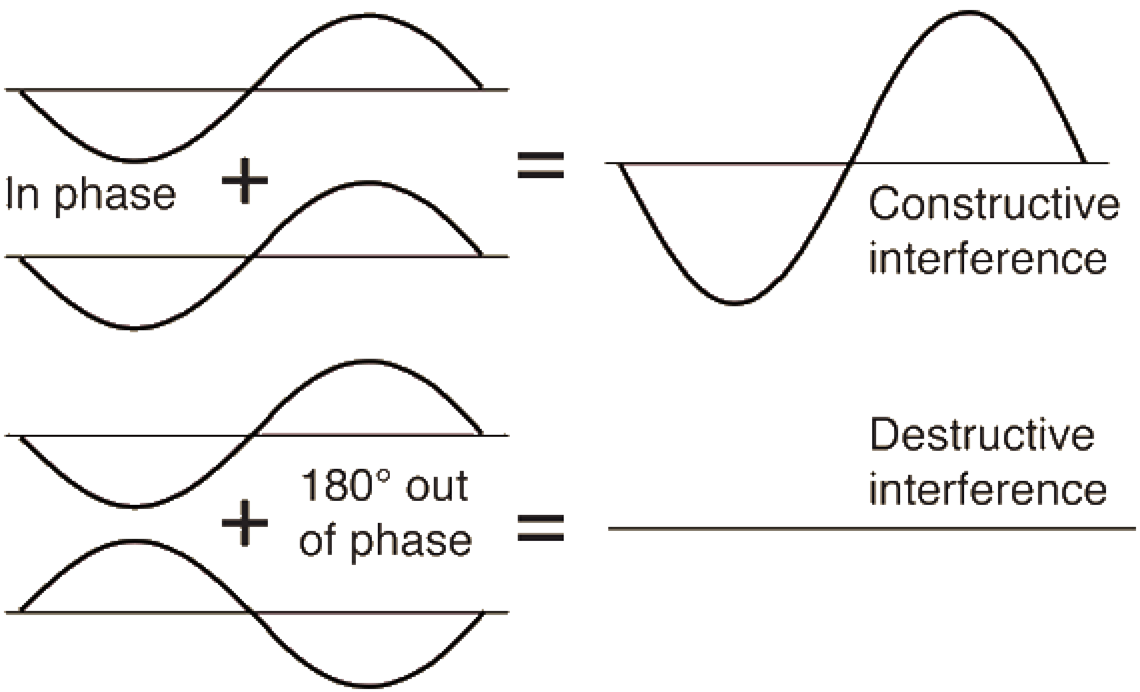


Sound Propagation

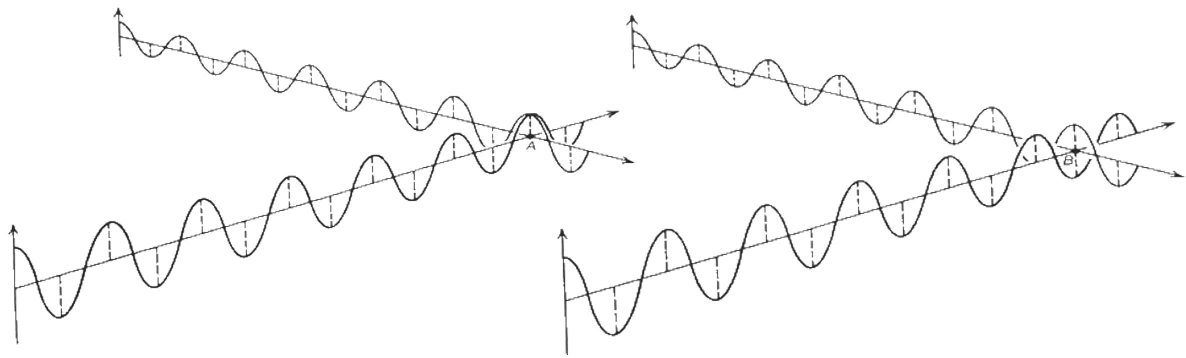
- Ripple tank simulation: http://www.falstad.com/ripple/

Sound Propagation

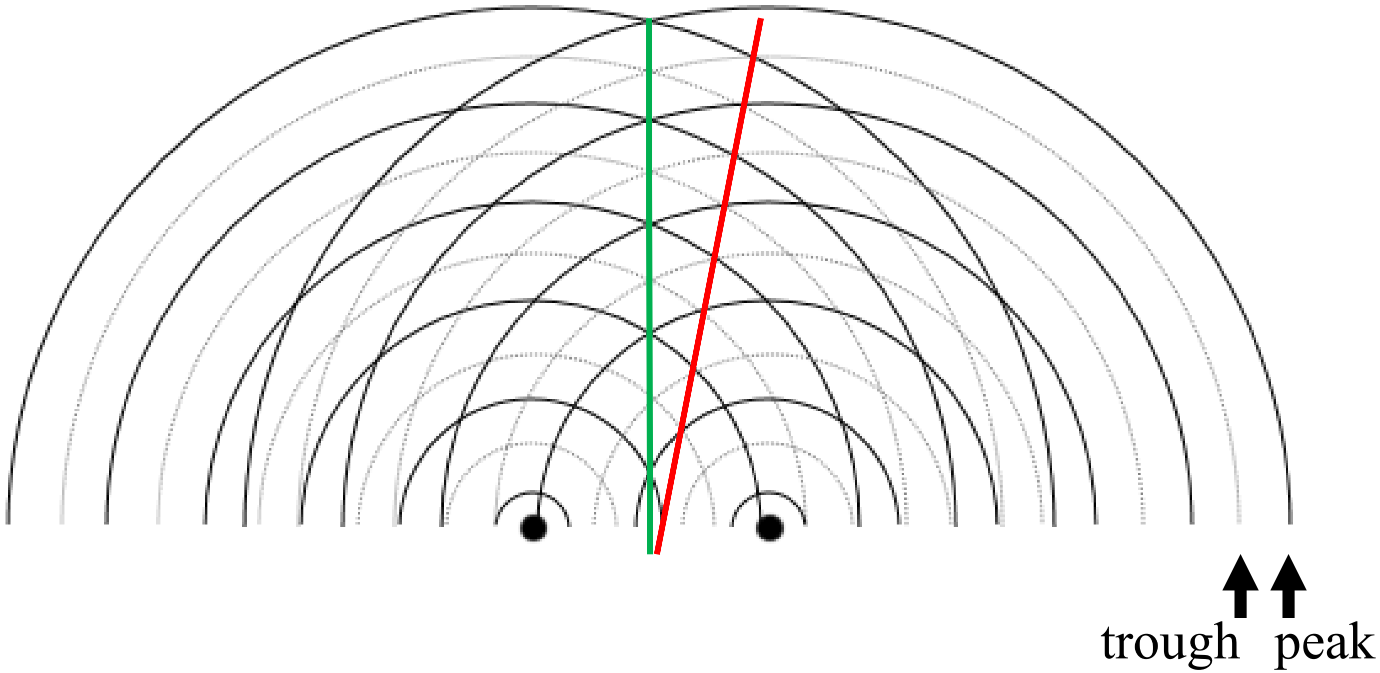
- Interference:
  - Waves just add
  - Adding two waves can be constructive or destructive



- Interference:



  - Adding two waves can be constructive or destructive




BA

Clicker Question 3.10

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

Clicker Question 3.10

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?

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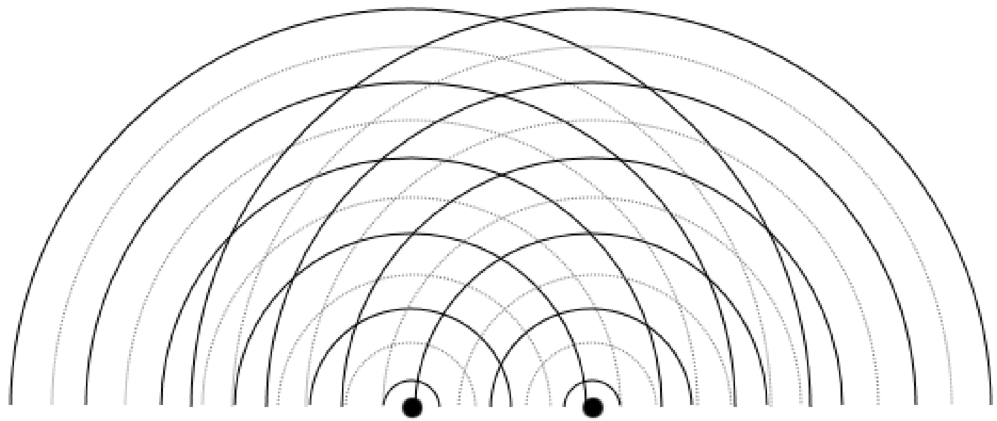
E) 1 meter from one speaker and 0.5 meters from the other

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

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

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

- Used for tuning—beats slow down as pitches approach each other