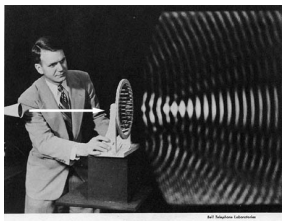
What was that that you said?



Class 25:
Sound

Reminders/Updates:
MT3 optional Long Answer Due Thurs
Reading posted; RQ Thurs
Total Scores w/Drops to be posted online

1

Sound waves

Everyday Life Experience at the Ballpark

You are at Coors Field sitting in the bleachers in the outfield (~325 ft from the batter). You **see** the bat hit the ball. About how long will it take before you **hear** the bat hit the ball?

a. About 10 seconds
b. About 2 seconds
c. About 0.3 seconds
d. About 0.03 seconds
e. There will be no delay between seeing ball hit and hearing ball hit.

What causes the delay between seeing and hearing?

- Light (carrying sight information) and sound (carrying noises) travel in totally different ways and at totally different speeds from the event to your eyes/ears.
- Light is an electromagnetic wave.
  - It travels absurdly fast – 3×10^8m/s or 670 million mph!
  - Virtually no delay between bat hitting ball and you seeing it occur
- A sound wave involves the motion of air molecules
  - It travels or propagates much more slowly – 330m/s or 740 mph
  - Sound takes a noticeable amount of time to get from bat to your ear!

What is air anyway?

a) There's nothing there – can you see anything?
b) Load of stationary atoms of all types
c) Primarily oxygen molecules fixed in a rigid matrix
d) Primarily nitrogen and oxygen molecules bouncing around and colliding with each other and anything else they bump into
e) There's something out there but its got nothing to do with atoms or molecules

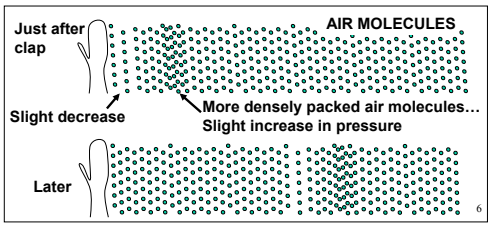
What is sound?

When you hear the crack of the bat with your ear, what is it that your ear is detecting?

a. Electromagnetic radiation that was produced when the bat hit the ball.
b. A small change in the pressure of the air that is the result of the bat hitting the ball.
c. A wave that travels through the air from the bat to your ear.
d. a. and c.
e. b. and c.

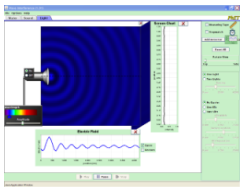
What produces the sound?

What is it that your ear is detecting?



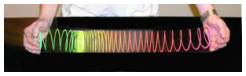
6

Wave Interference Sim.



http://phet.colorado.edu/en/simulation/wave-interference

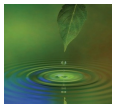
Longitudinal wave



Direction of wave propagation

Displacement of medium

Transverse wave



Direction of wave propagation

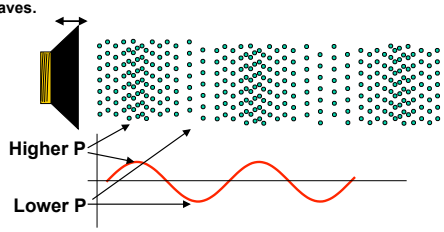
Displacement of medium

Movement of air molecules:

- Displaced ~10^{-5}m for loudest bearable sound
- Displaced ~10^{-11}m for faintest audible sound
- Back to original position after sound wave passes

Creating Musical Tones

To create a pure sustained tone (like concert A), the speaker pushes on the air at regular intervals creating a series of pressure waves.

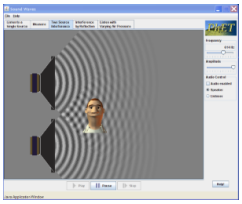


All instruments work with same principle... push on air at regular intervals.

SHOW SPEAKER IN ACTION

9

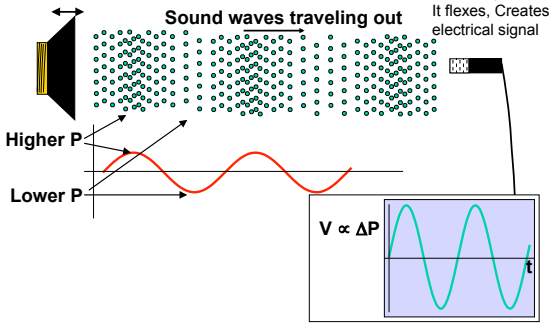
Sound Sim



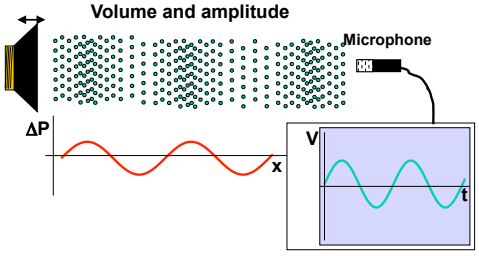
http://phet.colorado.edu/en/simulation/sound

Looking at a soundwave:

Microphone detects changes in pressure.



Volume and amplitude



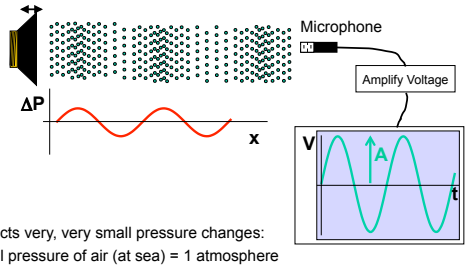
Question: If I increase the volume, what will happen to the signal from the microphone?

a. **The peaks will go up and the valleys will go down.**
b. **The peaks will get closer together.**
c. **The whole signal will go up.**
d. **Both a and b.**
e. **Nothing will happen**

DO EXPERIMENT…

12

What is the amount of over / under-pressure is that we hear?



Ear is detects very, very small pressure changes:

Normal pressure of air (at sea) = 1 atmosphere

Minimum pressure change detectible by ear = 2×10^{-10} atmospheres
minimum change is 1 part in 5 billion,

Maximum pressure change detectible by ear = 3×10^{-4} atmospheres
maximum is 1 part in 3600.
More than max === OUCH!!!!!

13

What if we wanted to change the pitch of the tone produced by the speaker?

To get a higher pitch sound, we need to adjust the speaker so that:

a. It vibrates back and forth more rapidly, taking a smaller amount of time for each cycle
b. It vibrates back and forth at the same rate as before, but the range of it's back and forth motion is larger.
c. It receives more power
d. It vibrates back and forth more slowly, taking a longer amount of time for each cycle
e. It vibrates back and forth at the same rate as before, but the range of it's back and forth motion is smaller.

Frequency (f) of a sound wave

- Controls pitch of sound
- The number of times per second that the speaker goes through one complete pushing motion
- The number of times per second that the pressure in my ear goes through rise-fall cycle.
- Units: Hz (s^{-1}) 1 Hz = 1 cycle per second

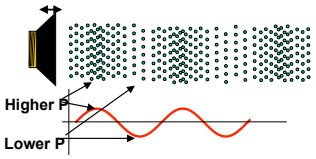
The frequency of Concert A is 440 Hz

FGAB | CDEFGAB | CDEFGAB |

Octave below Concert A (220 Hz)	middle C (256 Hz)	Concert A (440 Hz)	Octave above Concert A (880 Hz)

Range of Human Hearing : 20 Hz to 20,000 Hz
Dogs : 40 Hz to 60,000 Hz
Mice : 1000 Hz to 90,000 Hz

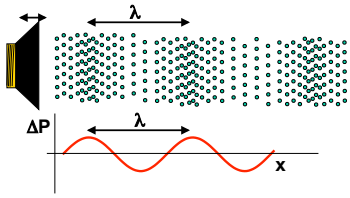
Period of a sound wave



If the speaker vibrates back and forth 200 times each second, (has a frequency of 200 Hz) how much time passes between each time it produces a maximum in pressure?

a. 0.2 seconds b. 200 seconds c. 0.005 seconds
d. 0.02 seconds e. 0.05 seconds

Wavelength



Question: If the speaker oscillates at 200 Hz (remember that is completing one cycle in 0.005 seconds), what is the wavelength (distance between the pressure maximums)
Recall: the speed of sound = 330 m/s

a. 0.6 m b. 1.65 m c. 66,000 m d. 3.3 m

If the speaker vibrates back and forth twice as fast (so 400 times per second), then the *period* of the sound wave (the time between producing each peak in pressure) is

a. twice as long b. half as long c. unchanged

What happens to the wavelength of the sound wave when we double f ?
The distance between each peak in pressure is

a. twice as far b. half as far c. unchanged

Thinking about waves:

Frequency (f)	**# of oscillations/sec**	**(Hz = 1/s)**
Wavelength (λ)	**Distance of one complete cycle** (e.g. distance between pressure maximums)	**(m)**
Period (T)	**Time for one complete oscillation**	**(s)**
Speed (v)	**Distance traveled per second**	**(m/s)**

Relationships among these variables:

$v = \lambda \times f$

Distance per second = distance per oscillation × # of oscillations per second

$f = 1/T$

oscillations per second = 1/time for one oscillation

$v = \lambda / T$

Sound and stringed instruments

- How does a violin (or other stringed instrument) produce sound?
- How do we get different notes from a violin?
- Why is the sound of each instrument unique?

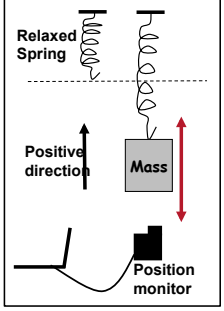
Remember that a musical note is a periodic variation of the air pressure

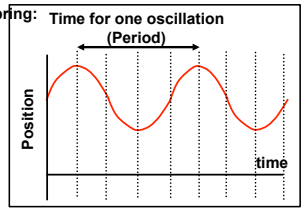
Therefore to create musical notes, all musical instruments have something that oscillates back and forth in periodic fashion.

Consider the violin. Each piece of string is like a little mass hooked to spring.

First lets think about springs a little bit

Start a mass bouncing on a spring:



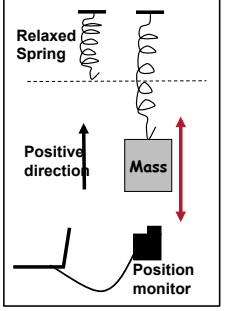


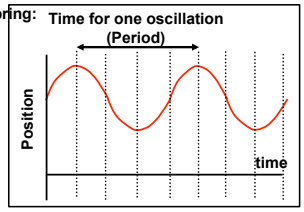
If the spring is stiffer, then …

a. the time per oscillation will increase
b. the time per oscillation will decrease
c. the time per oscillation unchanged

First lets think about springs a little bit

Start a mass bouncing on a spring:



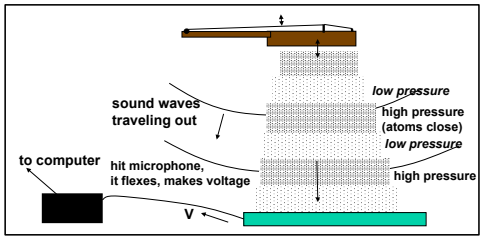


If the mass is heavier, then …

a. time per oscillation will increase
b. time per oscillation will decrease
c. time per oscillation unchanged

How a violin makes sound

- Strings oscillate up and down at certain frequency
- Make wooden body oscillate in and out,
- Body pushes air to make sound waves



Note that we now have 2 types of 'waves' going on:

1. Oscillatory (wave) motion of the string
3. Sound wave (pressure wave in the air) coming out from violin

Both waves have same frequency but different wavelengths and speeds