AP Phys 1 Unit 12.5 Notes - Doppler Effect

12.5 - Sound Phenomena, The Doppler Effect

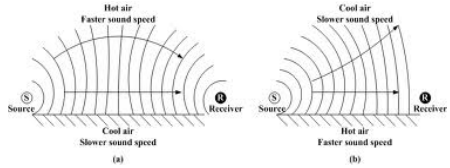
A bad day to be on the water.

Reflection vs. Refraction

We talked about the story of Echo, who is responsible for sound reflection.

Refraction is the bending of sound waves. As sound passes from an area of high v_{sound} to low v_{sound}, it turns toward the area of slower speed.

Ex: voices on a lake on a warm night: cool air by the water has lower v_{sound}: sound bends to the ground.

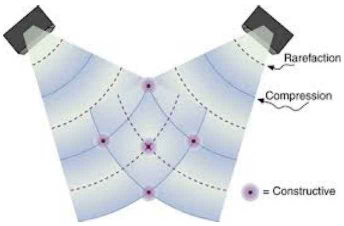


Interference

We talked about constructive (waves add) and destructive (waves subtract) interference: the principle of superposition.

Sound has discernible interference patterns.

Speaker Demo (E_5):



Beats

We got the beat!

When two simultaneous tones are very close in frequency the ear senses pulsations of intensity.

Ex: In jets, sometimes the engines aren't in sync, and there's a whum-whum-whumimg sound.

The human ear can hear up to seven beats a second. Beyond that, the resulting sound is smooth.

Beat Calculations

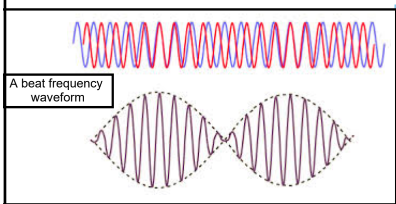
Calculating beats is easy:

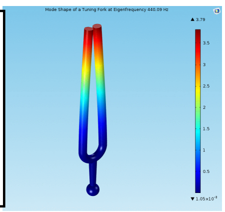
$$f_b = |f_1 - f_2|$$

fb = beat frequency
f1, f2 = different frequencies

Note: Absolute value is specified because it's impossible to have negative frequency, even if $f_1 < f_2$.

Ex: Two tuning forks (256 Hz - B_3), piano (on your own).

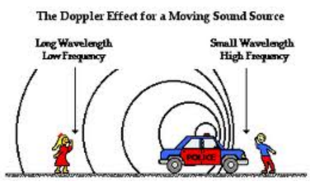




The Doppler Effect

When two objects, one that's making sound, move towards (or apart from) each other, a different pitch (perceived frequency) will be heard.

Example: if an emergency vehicle with a siren drives past, it will have a lowering of pitch as soon as it passes. (Jumping on a trampoline too.)



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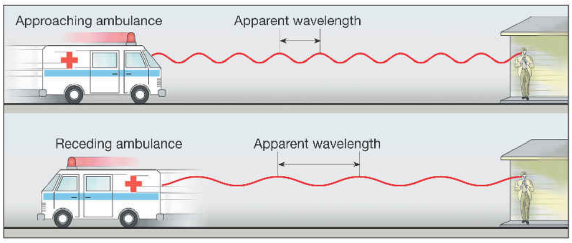
Doppler Effect Explanation

Sound waves in front of a moving objects get bunched up; those behind the object will spread out. (Assumption that the air is fairly still.) Since wavelengths change, you hear different pitches.



Doppler Calculations

The Doppler effect is calculated, depending on what is moving:

Moving Source: $f_o = \left(\frac{v}{v \pm v_s}\right) f_s$

+ source moving from observer
- source moving toward observer

f_o = observed frequency (Hz)
v = speed of sound (m/s)
v_s = source velocity (m/s)
f_s = source frequency (Hz)
v_o = observer's velocity (m/s)

Moving Observer: $f_o = \left(\frac{v \pm v_o}{v}\right) f_s$

+ observer moving toward source
- observer moving from source

Doppler Example

A truck traveling 27 m/s blows its 400 Hz horn as it passes a hitchhiker.

What frequency does the hitchhiker hear:
1. before, and
2. after the truck passes?
(Use a speed of sound of 346 m/s)

Doppler Answer

v_s = 27 m/s
f_s = 400 Hz
v = 346 m/s

- for source moving toward stationary observer
+ for source moving away from stationary observer

1: Approaching:

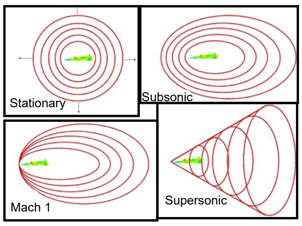
$$f_o = \left(\frac{v}{v - v_s}\right) f_s = \left(\frac{346 m/s}{346 m/s - 27 m/s}\right) 400\,Hz = 434\,Hz$$

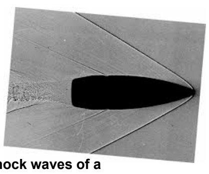
2: Moving away:

$$f_o = \left(\frac{v}{v + v_s}\right) f_s = \left(\frac{346 m/s}{346 m/s + 27 m/s}\right) 400\,Hz = 371\,Hz$$

Sonic Booms

Objects exceeding the speed of sound make a sonic boom.
At the speed of sound, sound waves pile up in front of the object. Beyond that, these form a pressure ridge (shock wave) propagating in a radiating cone.





Shock waves of a supersonic bullet.

Sonic Boom Examples

Aircraft make sonic booms, which leave a higly visible signature when atmospheric conditions are right.

A recent meteor in Russia broke windows & caused panic.
https://www.youtube.com/watch?v=tq02C_3FvFo

Whips make a small boom,

as the tip is accelerated past the speed of sound.

Homework
12.5 Problems
Due: Next Class