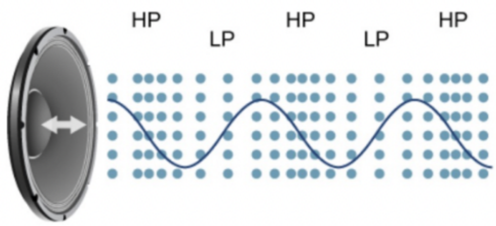
CAS PY 106

InClass Note 21

1. Sometimes waves make circular patterns
    a. Notice how waves move outward from their emission point to form concentric circles (smaller circles centered inside of larger circles)
    b. They form circles because the waves travel outward at the same wave speed v in all directions
2. Sound
    a. Speed of sound waves determined by the medium - you can't change the speed
    b. V = f * lambda (nature decides this)
    c. Typically, choose the vibration frequency f and then the wavelength lambda is fixed by this equation
    d. For example, if you choose to use a speaker vibrating at f = 600 Hz in a room filled with air (20 degrees Celsius) then you'll get a wave with a speed of v = 343m/s and a wavelength of 0.57 meters (about 2 ft)



e.

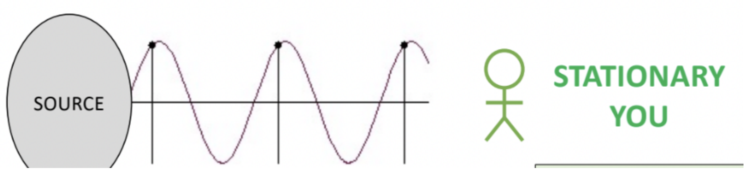
Medium	Speed of sound
Air (0°C)	331 m/s
Air (20°C)	343 m/s
Helium	965 m/s
Water	1400 m/s
Steel	5940 m/s
Aluminum	6420 m/s

f. Range of human hearing: f = 20Hz to 20,000 Hz

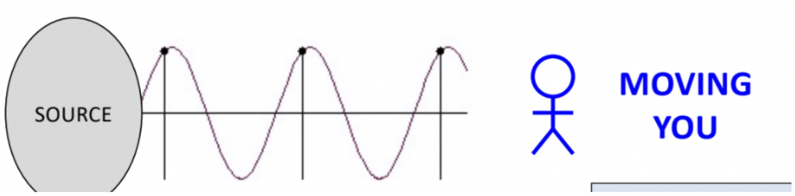
g. Wavelengths of sounds we hear: lambda = 17m - 17cm

h. Important to understand that the absolute speed of waves from the source remains constant

3. Stationary or moving you, relative to source

a. 

b. When stationary, you observe sound wave peaks at the same frequency they are emitted

c. 

d. When you move toward a source, you observe sound wave peaks more frequently

    e. When you stop, you are stationary again, and you observe sound wave peaks at the same frequency they are emitted
4. Doppler Effect
    a. The Doppler effect is the shift in frequency of a wave that occurs when the wave source, or the observer/detector of the wave, is moving
    b. Applications range from medical tests using ultrasound to police speed traps using radar to astronomy
    c. Example of source moving toward stationary observer
5. Doppler Effect: moving observer
    a. Stationary source and stationary observer
    b. Stationary source and moving observer
    c. When you move toward the source, you encounter more waves per unit time than you did before
    d. Stationary source and moving observer (who feels as if the waves are moving toward them)
    e. When you move toward the source, from your perspective, it's almost as if the waves are moving toward you
6. Other obvious scenarios
    a. Stationary source and moving observer (away in the other direction)
    b. When you move away the source, you encounter fewer waves per unit time than you did before
    c. Stationary observer and moving source

   d. Another case where the source moves toward you, passes by, and then moves away from you

7. What are we calculating?
   a. Typical Doppler effect problem: if a source emits sound waves at a particular frequency f, how do you calculate the observed frequency f' of the waves if the source, and/or observer, are moving?
   b. **General Doppler Equation for Sound**

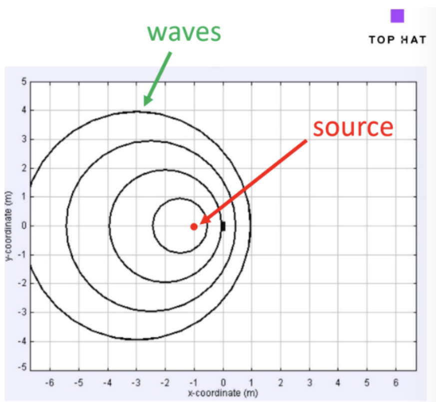
      $$f' = f\left(\frac{v \pm v_o}{v \mp v_s}\right)$$
   c. f' = observed frequency
   d. f = source frequency
   e. v = speed of sound in particular medium (water, air, etc)
   f. v_o = speed of observer
   g. v_s = speed of source
   h. **The $\pm$ and $\mp$ are in this equation because the signs used will depend on the exact situation described in the problem!**

8. How do we determine which signs to use?
   a. Determine what the scenario is and use the table below to determine the right equation

b.

	Stationary **Observer** ($v_o = 0$)	**Observer** moving toward source *+ in numerator*	**Observer** moving away from source *– in numerator*
Stationary **Source** ($v_s = 0$)	$f' = f$	$f' = f\left(\frac{v + v_o}{v}\right)$	$f' = f\left(\frac{v - v_o}{v}\right)$
Source moving toward observer *– in denominator*	$f' = f\left(\frac{v}{v - v_s}\right)$	$f' = f\left(\frac{v + v_o}{v - v_s}\right)$	$f' = f\left(\frac{v - v_o}{v - v_s}\right)$
Source moving away from observer *+ in denominator*	$f' = f\left(\frac{v}{v + v_s}\right)$	$f' = f\left(\frac{v + v_o}{v + v_s}\right)$	$f' = f\left(\frac{v - v_o}{v + v_s}\right)$

9. Doppler Effect example question

a. 

b. The source of sound waves are moving to the right at the speed of v = 340 m/s

c. At what x-coordinate did the source emit the first wave?

Hint: source emitted the first wave at x = -3m, and the source moved 2m to the right while the first wave traveled 4m

$T = x_s / v_s = x_w / v_w \rightarrow 2\text{m} / v_s = 4\text{m} / (340\text{ m/s})$

$v_s = 2 * 340 / 4 = 170\text{m/s}$

Source traveled 2 m in the same amount of time it took the wave to travel 4m. So, the source speed is ½ the wave speed