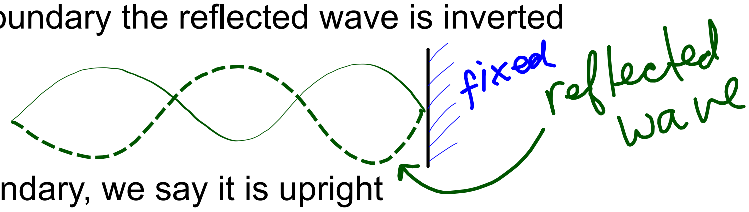
1.5 Resonance

When a wave passes from one medium to another its speed changes depending mostly on the density of the mediums. As a result the wavelength changes proportionally with the velocity change. Frequency, however, remains constant. Thus,

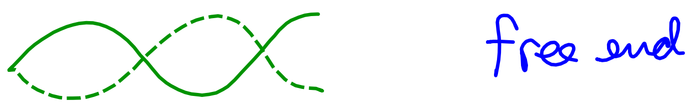
$$\frac{v_1}{v_2} = \frac{\lambda_1 f}{\lambda_2 f} \quad \text{since } f \text{ is constant} \Rightarrow \frac{V_1}{V_2} = \frac{\lambda_1}{\lambda_2}$$

When a wave pulse is reflected at a

- fixed (hard) boundary the reflected wave is inverted



- free (soft) boundary, we say it is upright



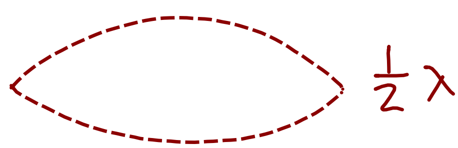
Mechanical Resonance: When an input force has the same frequency as the natural frequency of the object it acts on, the result is called mechanical resonance.

ex. Tacoma Narrows bridge, pushing a car out of the snow, swing,

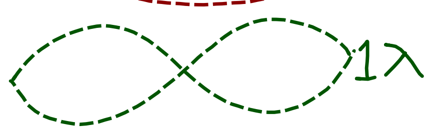
Acoustic Resonance: Whether it's a string or wind instrument, all are designed to produce standing waves. These standing waves produce distinct notes in the instrument.

The lowest frequency on a string is called its fundamental frequency or first harmonic (f_0). Harmonics or overtones, are integer multiples of f_0.

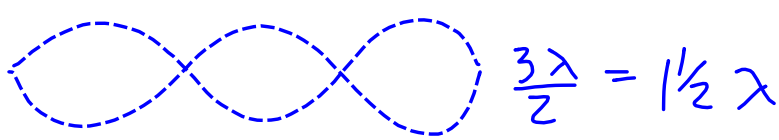
1st harmonic = f_0



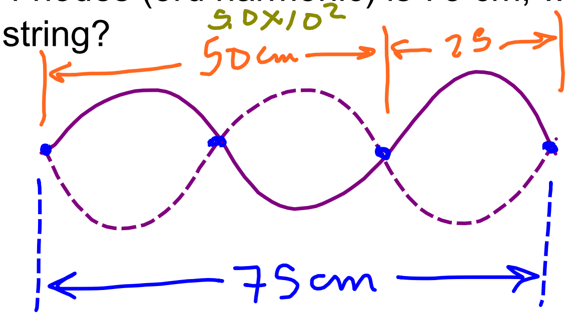
2nd harmonic = $2f_0$



3rd harmonic = $3f_0$



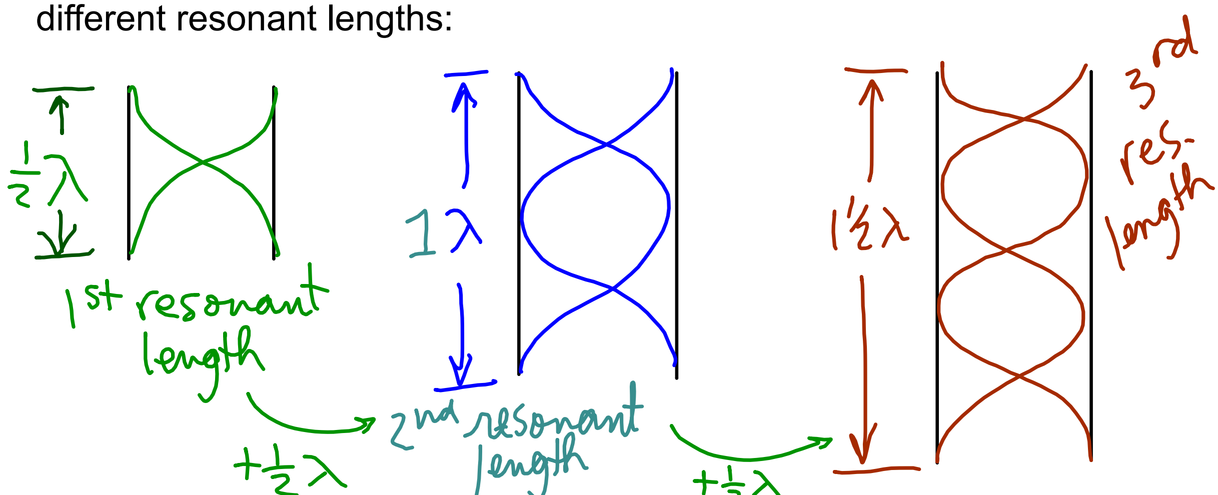
ex. A standing wave on a guitar strings has f = *440 Hz*. If the distance between 4 nodes (3rd harmonic) is 75 cm, what is the wave's velocity through the string?



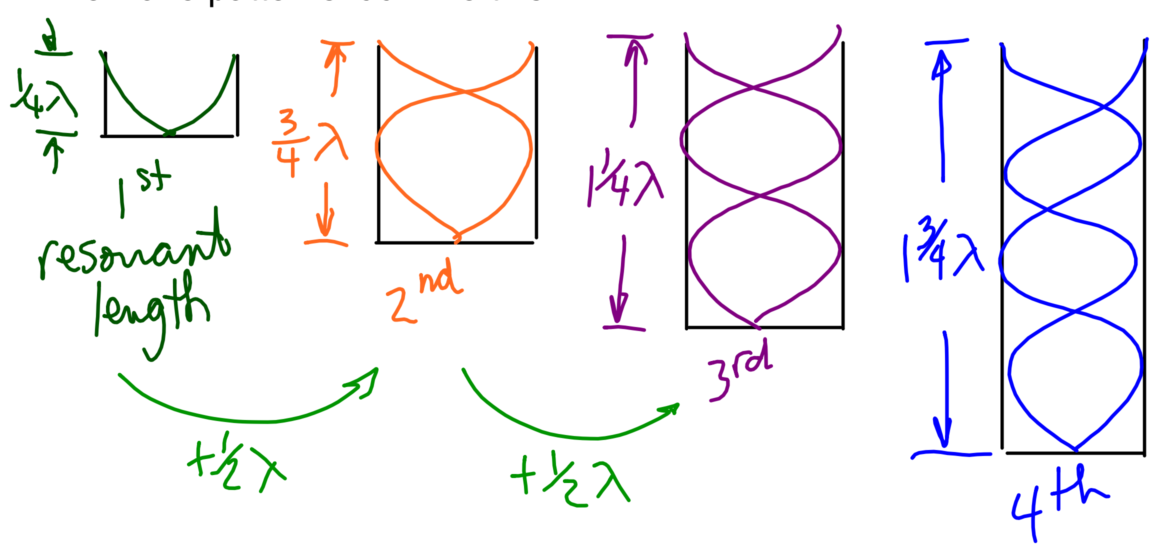
$$v = \lambda f$$
$$= (0.50\,m)(440\ s^{-1})$$
$$v = 220\ m/s$$

For wind instruments the wave pattern is a bit different.

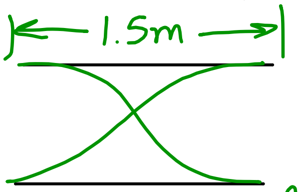
- For open ended instruments (such as horns, clarinets,...) both ends of the wave are free (soft boundaries). The standing wave looks like this for the different resonant lengths:



- For closed ended instruments like flute, one end is fixed (hard boundary). The wave patterns look like this:



ex. An open air collumn is 1.5 m long. What is the longest wavelength and its associated frequency for resonance to occur? $v = 345\ m/s$ given



1st res. length

for an open collumn

$1.5\ m = \frac{1}{2}\lambda$

$3.0\ m = \lambda$

$f = \frac{v}{\lambda} = \frac{345\ m/s}{3.0\ m} = 115\ Hz = \boxed{120\ Hz}$

Ex. A closed air column resonates at 94.0 cm then at 156 cm. What is the resonant frequency if the speed of sound is 3.50 x 10^2 m/s?

$\frac{1}{2}\lambda$ = resonant length$_2$ − resonant length$_1$

$\frac{1}{2}\lambda = 156 - 94$

$2\left(\frac{1}{2}\lambda\right) = (62\ cm) \times 2$

$\boxed{\lambda = 124\ cm} = 1.24\ m$

$f_0 = \frac{v}{\lambda}$

$= \frac{350\ m/s}{1.24\ m}$

$= 282\ Hz$

<u>Beat Frequency</u>: refers to the frequency of a pulsating noise, not the frequency of the sound source.

beat frequency (f_b) = $|f_2 - f_1|$

ex. A guitar player plucks a string that gives a frequency of 440 hz. She then plucks a note on a different string and hears 6 beats in 2.0 seconds. What are the possible frequencies of the 2nd note?

$\frac{6\ \text{beats}}{2.0\ \text{sec.}} = 3$ beats/second

$= 3\ Hz$

<u>case 1</u>

$440\ Hz - 3\ Hz$

$= 437\ Hz$

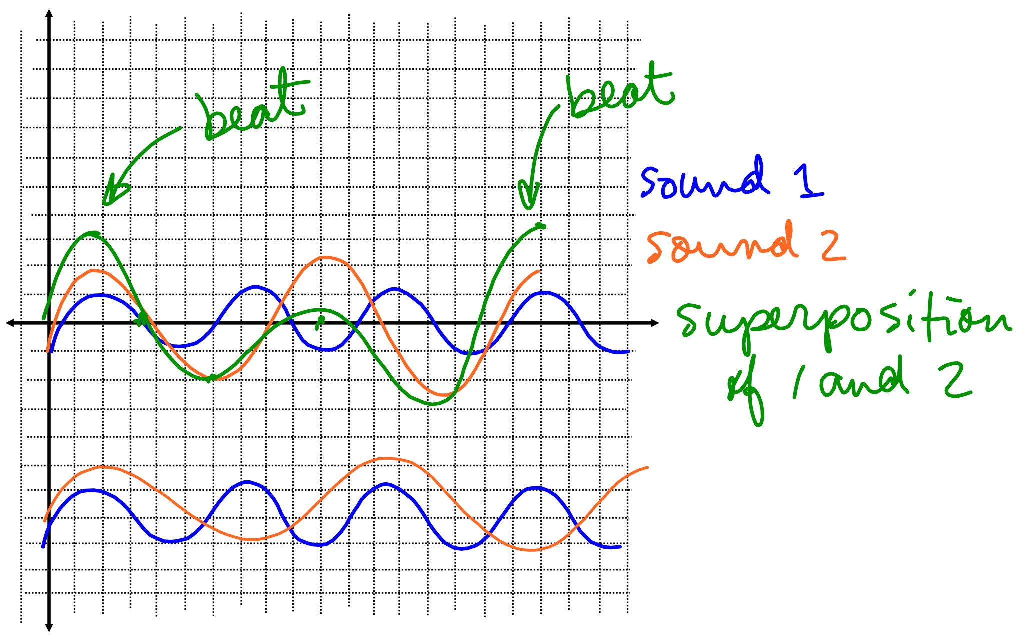
<u>case 2</u>

$440 + 3\ Hz$

$= 443\ Hz$

https://www.youtube.com/watch?v=V8W4Djz6jnY

Beat frequencies with tuning forks... what's happening?



Can you hear it on a guitar?

pg. 416 #19, 20 your book
Handout: #13, 15, (19-25)odd, 36, 37, 39

Quiz: Thursday
- resonance
- beat frequency
- superposition