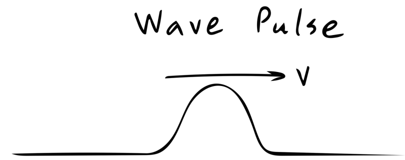
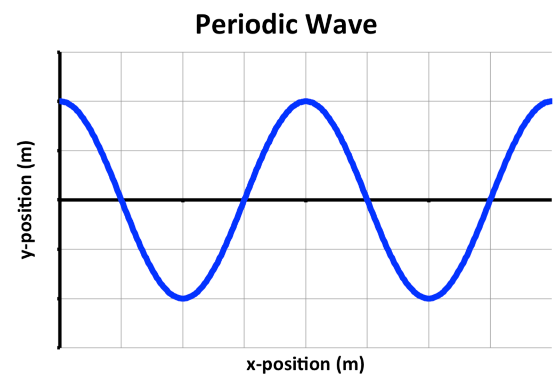
Flipping Physics Lecture Notes:
AP Physics 1 Review of *Waves*
https://www.flippingphysics.com/ap1-waves-review.html



A wave is the motion of a disturbance traveling through a medium not the motion of the medium itself.

- The disturbance of the medium is energy traveling through a medium.
- Wave Pulse: A single wave traveling trough a medium.
- Periodic Wave: Many wave pulses at specific, periodic time intervals.
- The energy moves through the medium as the wave pulse, however, the overall displacement of the medium is zero. $\Delta\vec{x}_{medium} = 0$



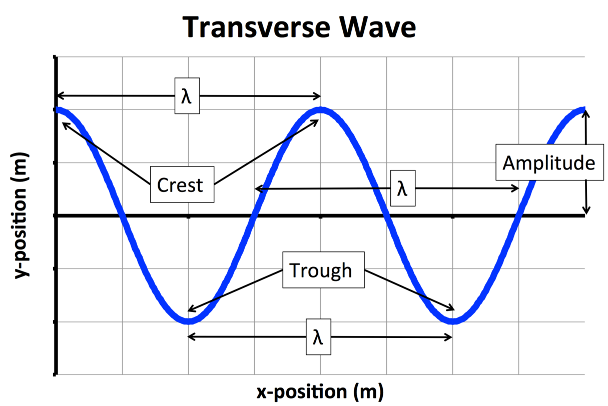
Transverse wave: the disturbance of the medium is perpendicular to the direction of wave propagation. (shown at right)

- Waves in rope, Ripples on a Pond

Longitudinal wave: the disturbance of the medium is parallel to the direction of wave propagation.

- Density on y-axis instead of y-position.
- Sound in Air, Seismic waves in the Earth

Electromagnetic waves are transverse waves that do not need a medium to travel through. They are the only waves we know of that do not need a medium.



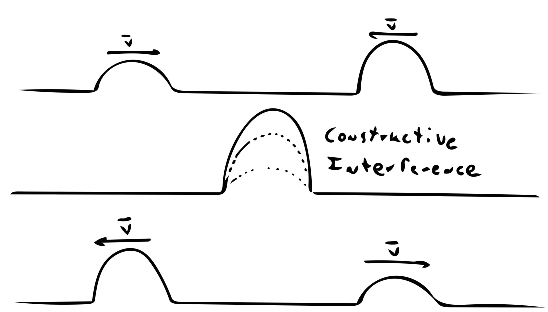
- The distance between two successive crests is called the wavelength, λ.
- The time it takes for one full cycle or for one wavelength to pass a point is called the period, T.

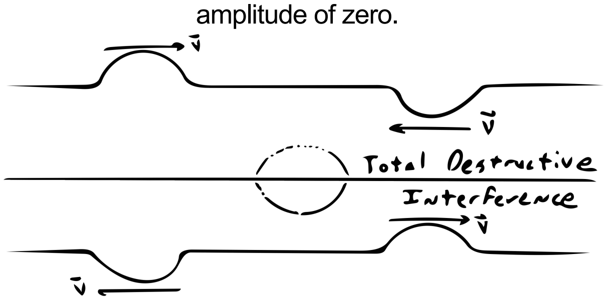
Using the equation for velocity, we can determine the equation for the velocity of a wave:

- $\vec{v} = \frac{\Delta\vec{x}}{\Delta t} = \frac{\lambda}{T}$ & $f = \frac{1}{T} \Rightarrow v = f\lambda$
- Simple Harmonic Motion, SHM, does *not* have a wavelength, so you can *not* use $v = f\lambda$ with SHM.

Waves are not physical objects; they are energy traveling through a medium. Therefore, waves *can* occupy the same space at the same time. We determine their combined amplitude using superposition.

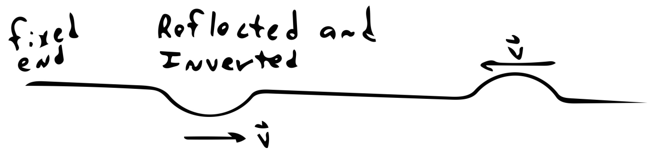
- Constructive Interference
  - Waves add together to create a larger amplitude.
- Total Destructive Interference
  - Waves cancel one another out to create an amplitude of zero.

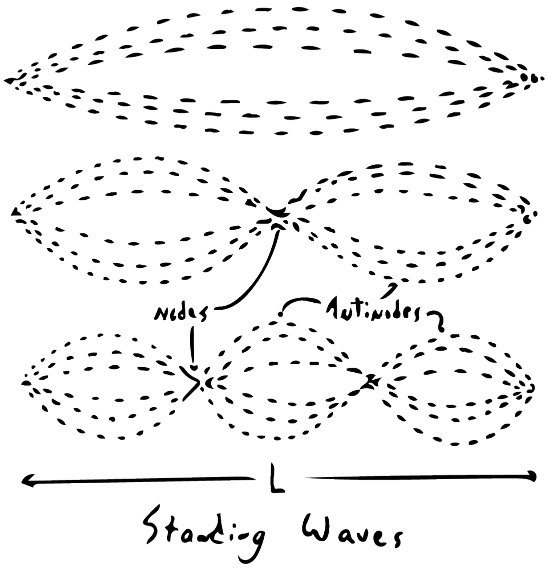




Standing waves: Periodic waves are reflected and inverted and interfere with one another creating standing waves.

- Nodes: Locations of total destructive interference.
- Antinode: Locations of constructive interference.





- n is called the Harmonic Number. n = 1 is the fundamental frequency and the 1st harmonic. n = 2 is the 2nd harmonic, etc.
- Pitch is our brain's interpretation of frequency. 440 Hz is typically concert pitch and is the A above middle C.
- Open pipe instrument (like the flute) is open at both ends and has the same equation for frequency as a stringed instrument.
- Closed pipe instrument (like the clarinet) is open on one end and closed on the other, therefore, it has a slightly different equation as derived on the next page.

Standing waves will only occur at specific wavelengths and the wavelengths are determined by the length of the string or air column in the wind instrument!

An open end of a wind instruments creates an antinode and a closed end creates a node.

Stringed Instrument and Open Pipe:

- Fundamental Frequency or 1st harmonic: $\frac{1}{2}\lambda = L \Rightarrow \lambda = 2L$ & $v = f\lambda \Rightarrow f = \frac{v}{\lambda} = \frac{v}{2L} = 1\left(\frac{v}{2L}\right)$
- 2nd harmonic: $\lambda = L$ & $f = \frac{v}{\lambda} = \frac{v}{L} = 2\left(\frac{v}{2L}\right)$
- 3rd harmonic: $\frac{3}{2}\lambda = L \Rightarrow \lambda = \frac{2L}{3}$ & $f = \frac{v}{\lambda} = \frac{v}{\left(\frac{2L}{3}\right)} = \frac{3v}{2L} = 3\left(\frac{v}{2L}\right)$
- $f = n\left(\frac{v}{2L}\right);\ n = 1, 2, 3, \ldots$

Closed Pipe Instrument:

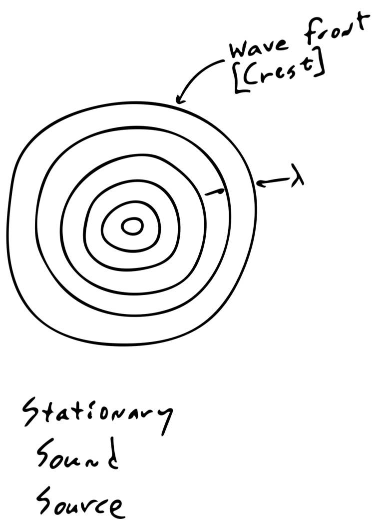
- Fundamental Frequency or 1st harmonic: $\frac{1}{4}\lambda = L \Rightarrow \lambda = 4L$ & $v = f\lambda \Rightarrow f = \frac{v}{\lambda} = \frac{v}{4L} = 1\left(\frac{v}{4L}\right)$
- 3rd harmonic: $\frac{3}{4}\lambda = L \Rightarrow \lambda = \frac{4L}{3}$ & $f = \frac{v}{\lambda} = \frac{v}{\left(\frac{4L}{3}\right)} = 3\left(\frac{v}{4L}\right)$
- 5th harmonic: $\frac{5}{4}\lambda = L \Rightarrow \lambda = \frac{5L}{3}$ & $f = \frac{v}{\lambda} = \frac{v}{\left(\frac{5L}{3}\right)} = 5\left(\frac{v}{4L}\right)$
- $f = m\left(\frac{v}{4L}\right); m = 1,3,5,\ldots$

Beat Frequency: $f_{beat} = \left|f_1 - f_2\right|$

- When two notes are played that have frequencies that are close to one another, the constructive and destructive interference pattern creates “beats” in the sound.
- For example, $f_{beat} = \left|440 - 441\right| = 1hz$, will sound with 1 “beat” per second.

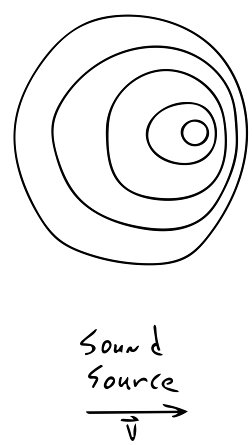
Doppler Effect: The change in the wavelength and therefore frequency and therefore pitch we hear of a moving sound source. (The observer can also move to cause the same effect.) Pictures!

- As the sound source moves towards the observer the crests are closer to one another and therefore the wavelength is decreased. $v = f\lambda$, therefore the frequency is increased and we hear a higher pitch.
- As the sound source moves away from the observer the crests are farther apart and therefore the wavelength is increased. $v = f\lambda$, therefore the frequency is decreased and we hear a lower pitch.



$v = f\lambda \Rightarrow f = \frac{v}{\lambda}$

Away from Observer:
$\lambda \uparrow$ & $f \downarrow$



Toward Observer:
$\lambda \downarrow$ & $f \uparrow$