

Wave Properties



National Science Foundation
WHERE DISCOVERIES BEGIN

Wave Properties

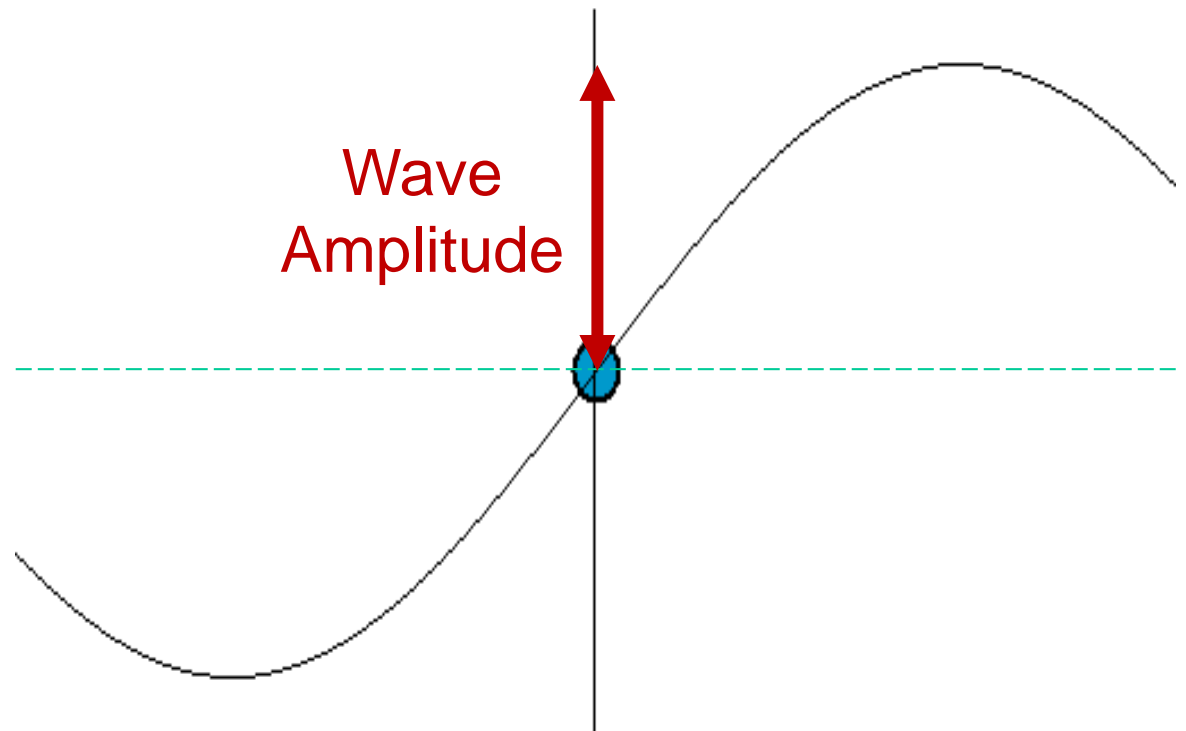
Basic properties of cyclic waves:

- Amplitude
- Wavelength
- Frequency
- Wave speed

These 3 are related

Wave Amplitude

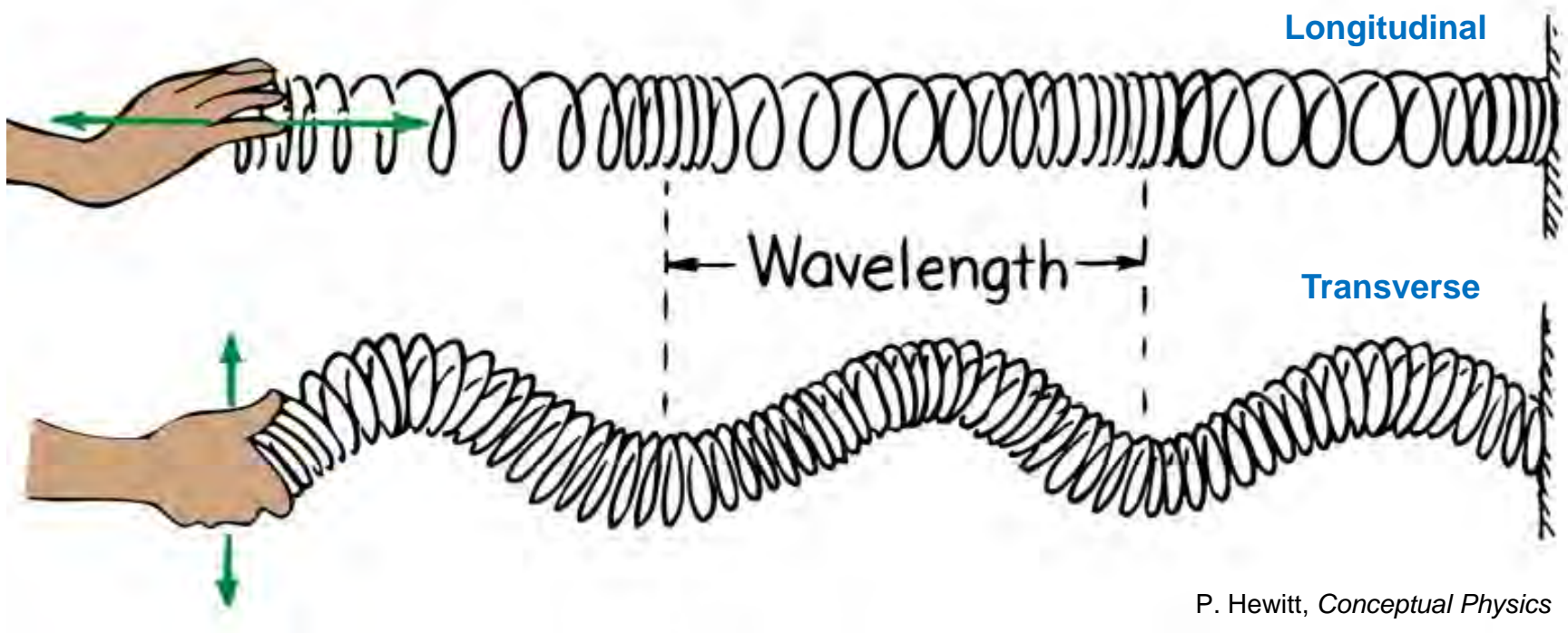
Cyclic wave motion has an amplitude, similar to that of vibrations and oscillations.



From Wikipedia

Wavelength

Wavelength is distance between the wave crests or between the troughs of waves.



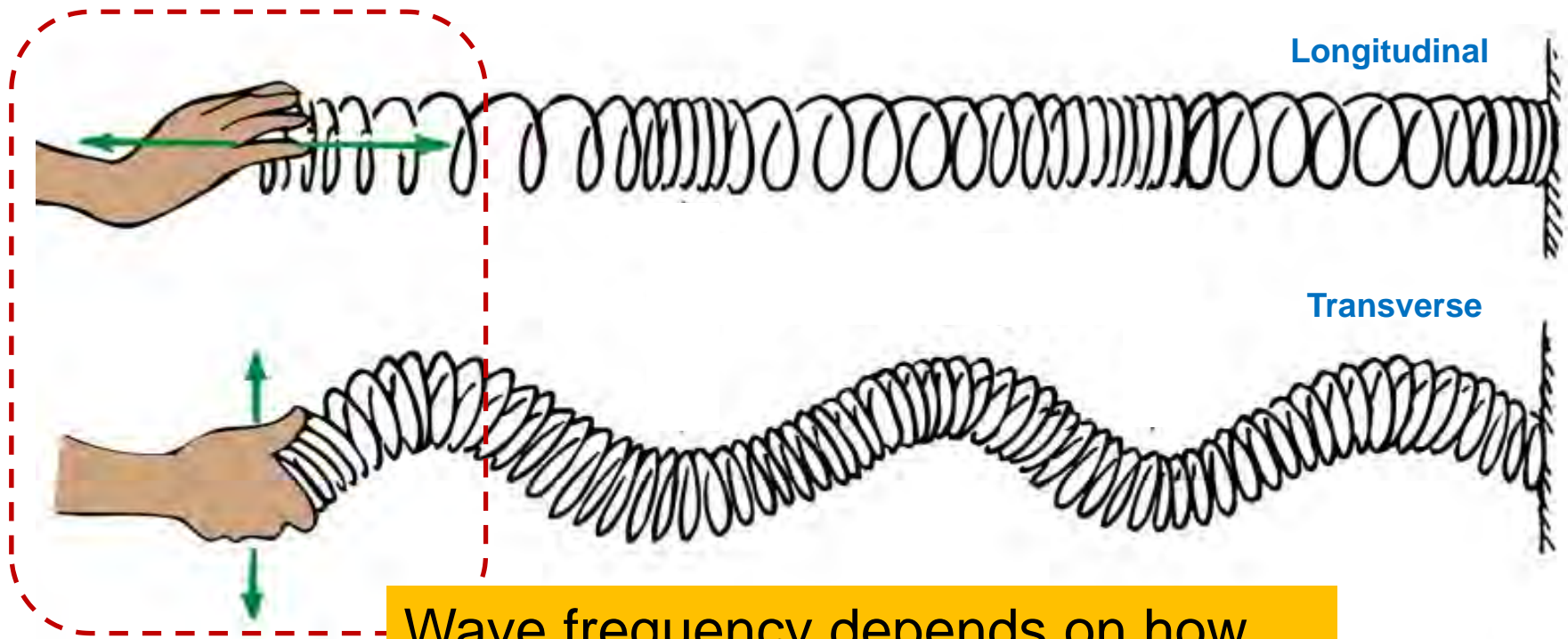
CGI Water Waves

This image has wavelengths ranging from short ripples to long rolling waves.



Frequency

Frequency is the number of oscillations per second for the wave's material motion.



Wave frequency depends on how quickly you shake your hand.

Frequency & Pitch

Musical notes are sound waves of different frequencies.

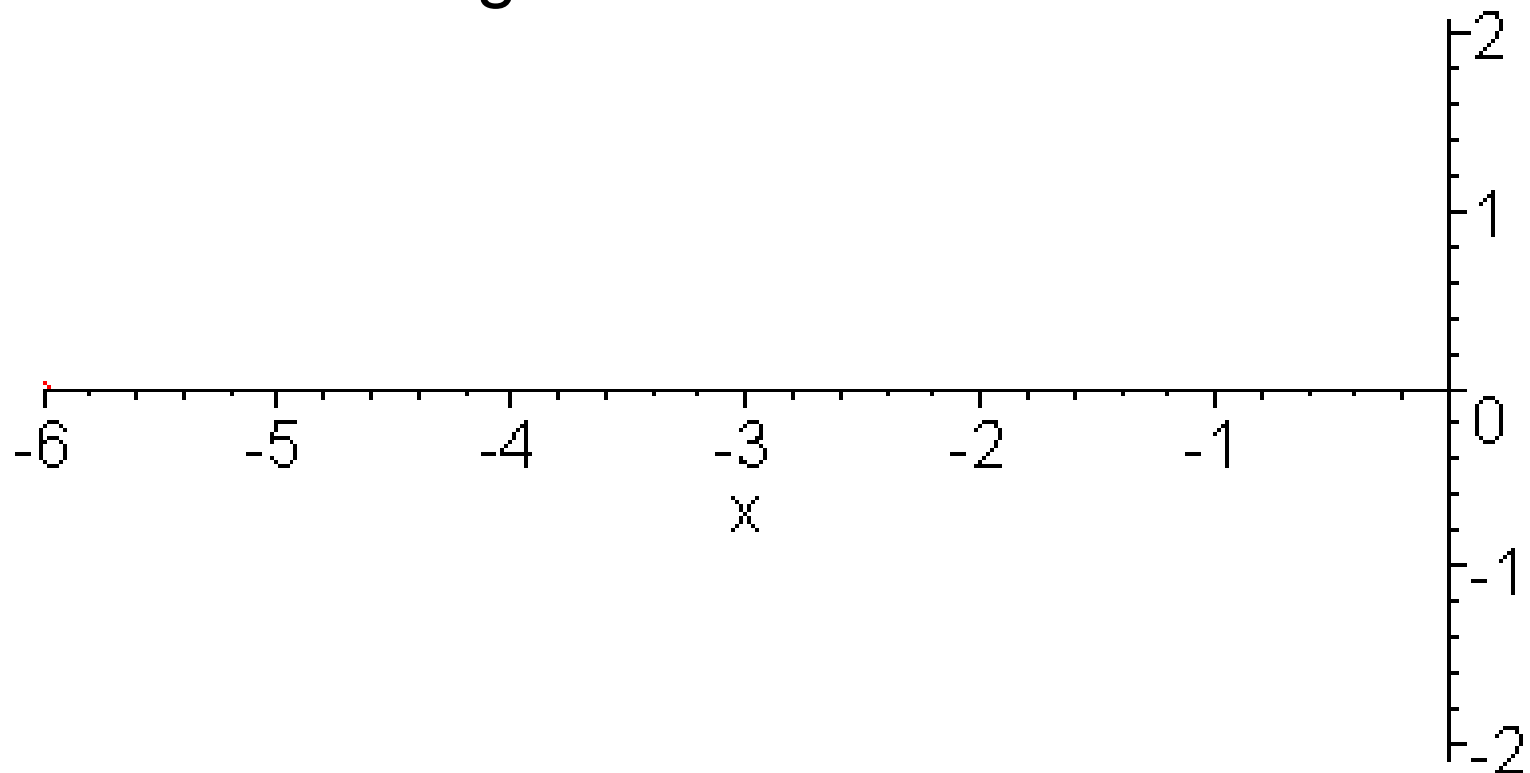
The faster vibrations, have higher frequency. Higher frequencies results in higher pitch for the musical note.

256 Hertz
C₄ (Middle C)



Standing Waves

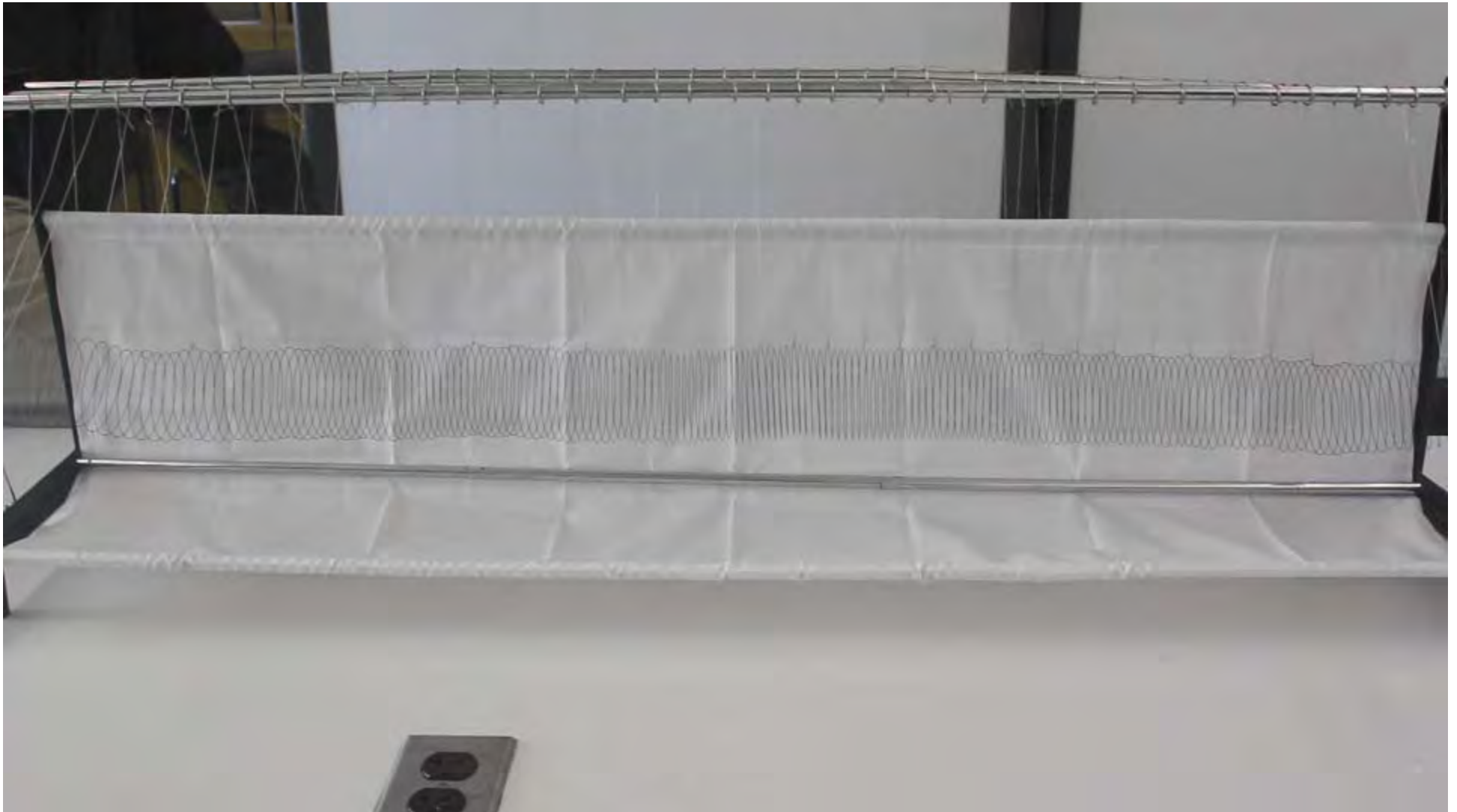
When a wave interferes with its reflection, this may create a standing wave.



Transverse Standing Waves



Longitudinal Standing Waves



Wave Speed

The speed at which waves travel is called the **wave speed**.

Speed of sound waves =
 $\frac{1}{5}$ mile per second

Speed of light waves =
186,000 miles per sec.



Water waves at the beach move a few miles per hour

Wave Relations

Wave speed, wavelength & frequency related:

$$(\text{Wave speed}) = (\text{Wavelength}) \times (\text{Frequency})$$

Hold Fixed	Change	Result
Wave speed	Frequency ↑	Wavelength ↓
Wave speed	Wavelength ↑	Frequency ↓
Wavelength	Wave speed ↑	Frequency ↑
Frequency	Wave speed ↑	Wavelength ↑

For Change ↓, flip the Result direction

Pan Pipes

Hold Fixed	Change	Result
Wave speed	Wavelength \uparrow	Frequency \downarrow

The short pipes produce sound waves with short wavelengths so that sound has a high frequency.

The long pipes produce long wavelength sound waves; those waves have a low frequency.



Pipe with a Piston

Hold Fixed	Change	Result
Wave speed	Wavelength \uparrow	Frequency \downarrow

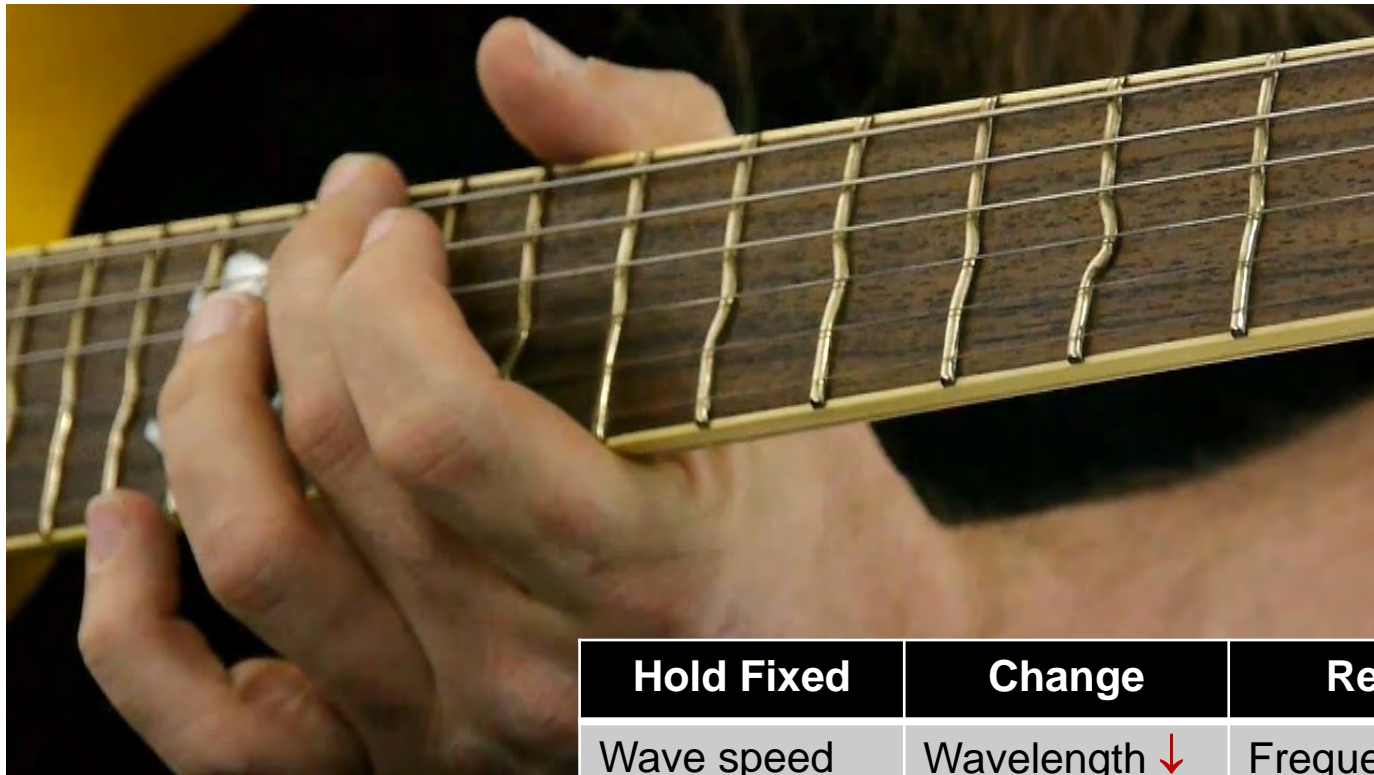
The pipe has a high pitch when the piston is pushed in, since the pipe is short.

The pipe has a low pitch when the piston is pulled out, since the pipe is long.



Fretting a Guitar

Shortening the length of a guitar string produces a note with a higher pitch.



Hold Fixed	Change	Result
Wave speed	Wavelength ↓	Frequency ↑

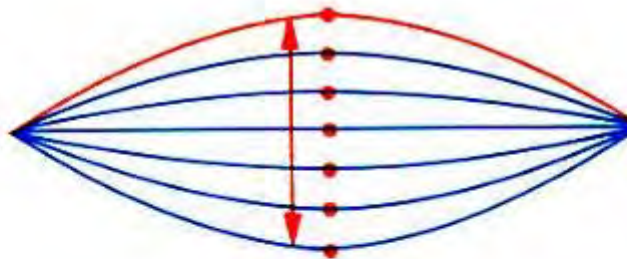
Fundamental & Overtones

The Fundamental is the lowest frequency standing wave.

The Overtones are twice, three times, etc., the frequency of the Fundamental.

256 Hz
(C₄)

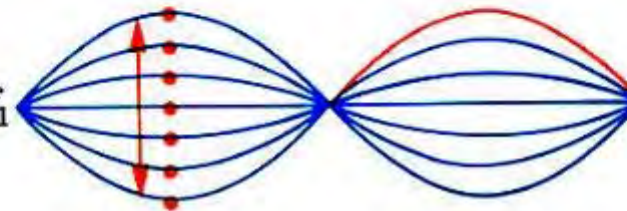
Frequency = f_1



Fundamental

512 Hz
(C₅)

Frequency = $2f_1$



First
Overtone

Hold Fixed	Change	Result
Wave speed	Wavelength ↓	Frequency ↑

Guitar Strings

Each guitar string has a different wave speed due to its thickness and the string's material.

Slow wave speed,
low frequency

Fast wave speed,
high frequency



Hold Fixed	Change	Result
Wavelength	Wave speed ↑	Frequency ↑

Tuning a Guitar

Increasing the tension on a guitar string increases the wave speed.

The length of the string doesn't change so increasing the wave speed increases the frequency (i.e., pitch) of the sound waves.



Hold Fixed	Change	Result
Wavelength	Wave speed ↑	Frequency ↑

Helium Voice (1)

Frequency of your voice is higher if you breath helium.

Wavelength of sound is unchanged (size of vocal cords unchanged) but the speed of sound (i.e., wave speed) is higher in helium.



Hold Fixed	Change	Result
Wavelength	Wave speed ↑	Frequency ↑

Helium Voice (2)

Helium atoms are much lighter than air molecules so they travel much faster than air molecules.

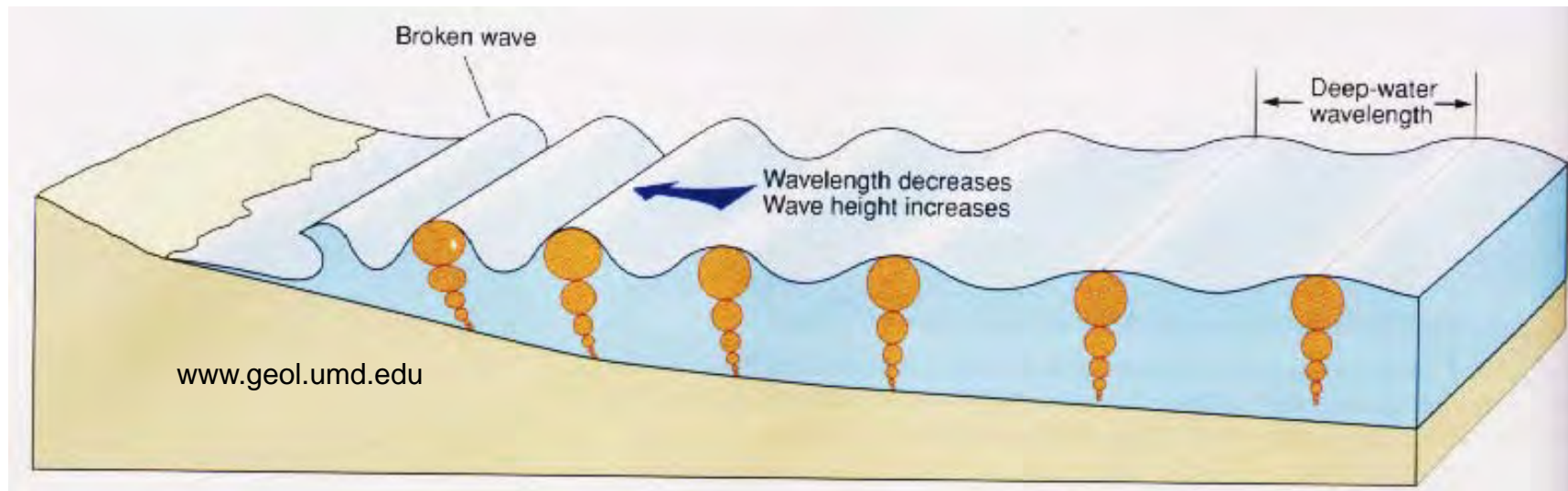
The faster helium atoms transport sound at a higher speed than air molecules..



Hold Fixed	Change	Result
Wavelength	Wave speed ↑	Frequency ↑

Waves Approaching Shore

As ocean waves enter shallow water, they slow down (wave speed decreases).



The frequency stays the same so wavelength shortens and their shape changes.

Hold Fixed	Change	Result
Frequency	Wave speed ↓	Wavelength ↓

Summary

- Wavelength is distance between the wave crests or between the troughs of waves.
- Frequency is the number of oscillations per second for the wave's material motion.
- Wave speed is the speed at which waves move.
- For fixed wave speed, the larger the wavelength the lower the frequency (and vice versa).
- For fixed wavelength, the higher the wave speed the higher the frequency.
- For fixed frequency, the lower the wave speed the shorter the wavelength.