Energy in Waves - 1

Objective: Learning about different physical properties of waves and wave propagation.

Key concepts:

- ❖ Wavelength
- ❖ Time period and frequency
- ❖ Wave speed
- ❖ Longitudinal and Transverse waves
- ❖ Interference and Beats
- ❖ Doppler effect

Waves

When discussing waves, whether they are waves of water, **sound**, light or matter, the same terms are used – namely, **wavelength**, **frequency**, and **wave speed**.

Vibrations make waves, for example both sound and light are vibrations that move as waves.

Sound – vibration of matter → Needs a medium to travel cannot travel in vacuum

Light – vibration of Energy → Does not require a medium to travel - can travel in vacuum

Wavelength

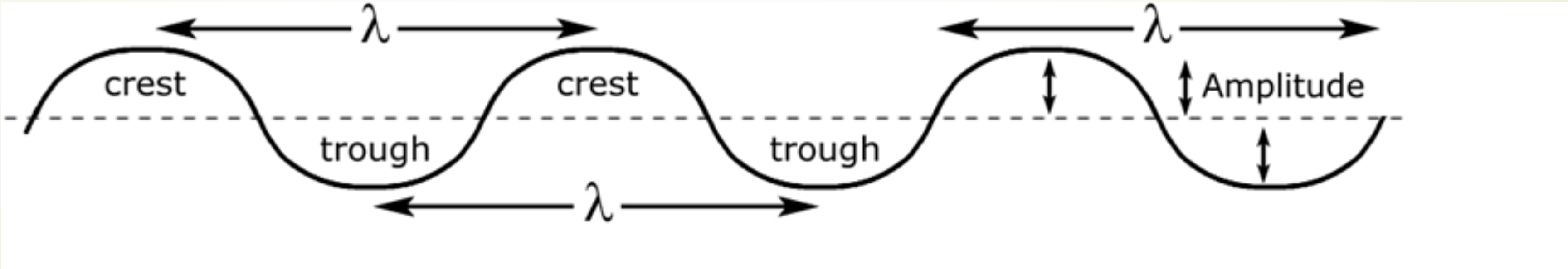
Wavelength:

The ____________________, designated by the Greek letter λ, is the distance between a point on one wave and the corresponding point on the next wave.

λ is pronounced **lambda** and is the Greek "L" for length

The same wavelength would be measured from crest to crest or from trough to trough. The unit is usually given in meters, centimeters, millimeters, nanometers, depending upon the wavelength size.

The wave **amplitude** is half of the "wave height" measured on the ocean. Amplitude is measured from the middle.



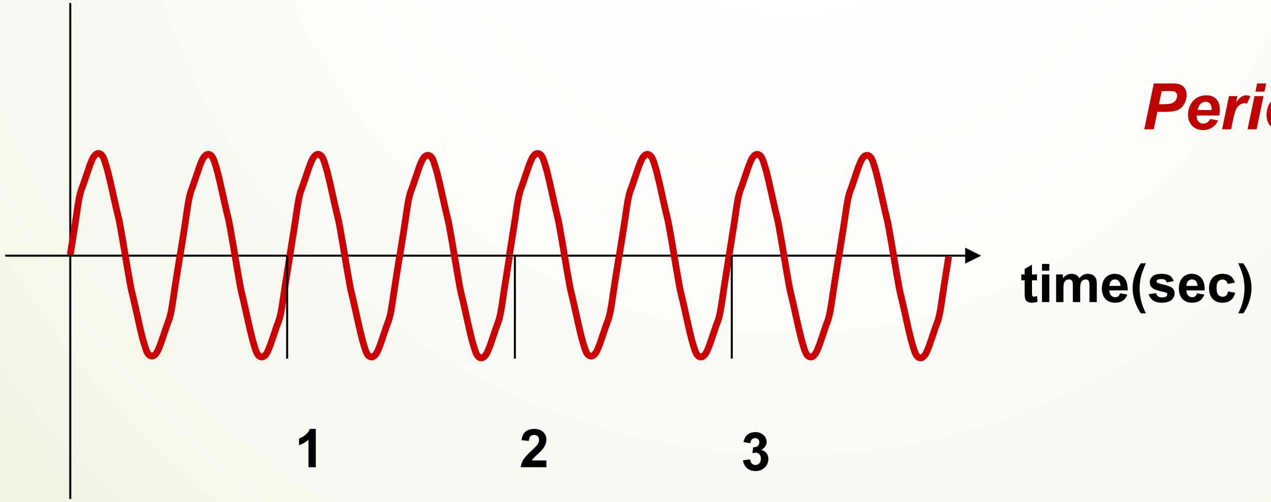
Frequency and Period

Frequency:

The ____________________, designated by the f, is the number of cycles completes per second by a wave.

$$\text{Frequency} = \frac{1}{\text{period}}$$

The ***frequency*** of a wave refers to how often the particles of the medium vibrate when a wave passes through the medium. ***Frequency*** would have units of cycles/second, or vibrations/second. SI unit for frequency is the ***Hertz*** (abbreviated Hz), where 1 Hz is equivalent to 1 cycle/second.



***Period** – time taken for one cycle*

Two cycle per second

Period = ½ s

f = 2 Hz

Wave Speed

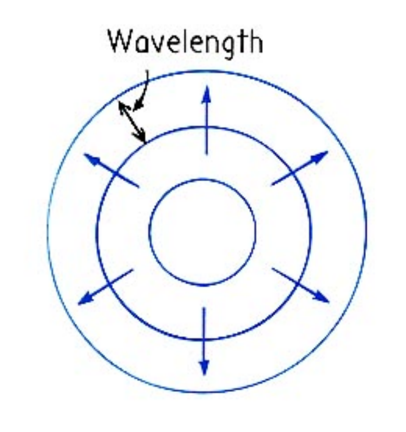
The ________________, designated by the letter **v,** is the speed measured for any point on the wave, such as the crest of a water wave.

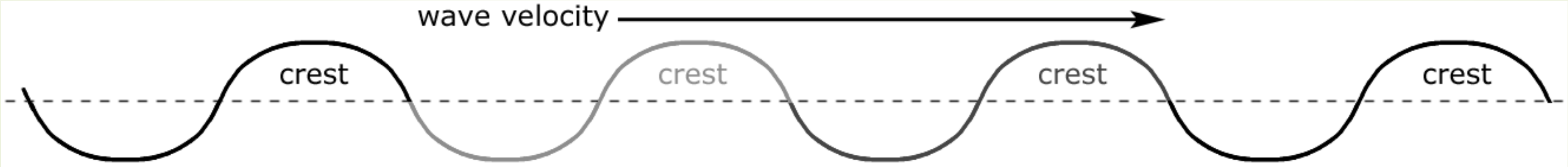
The SI units are m/s, and $\mathbf{v} = \lambda \times f$.

This is true for all waves; sound waves, water waves and light waves.

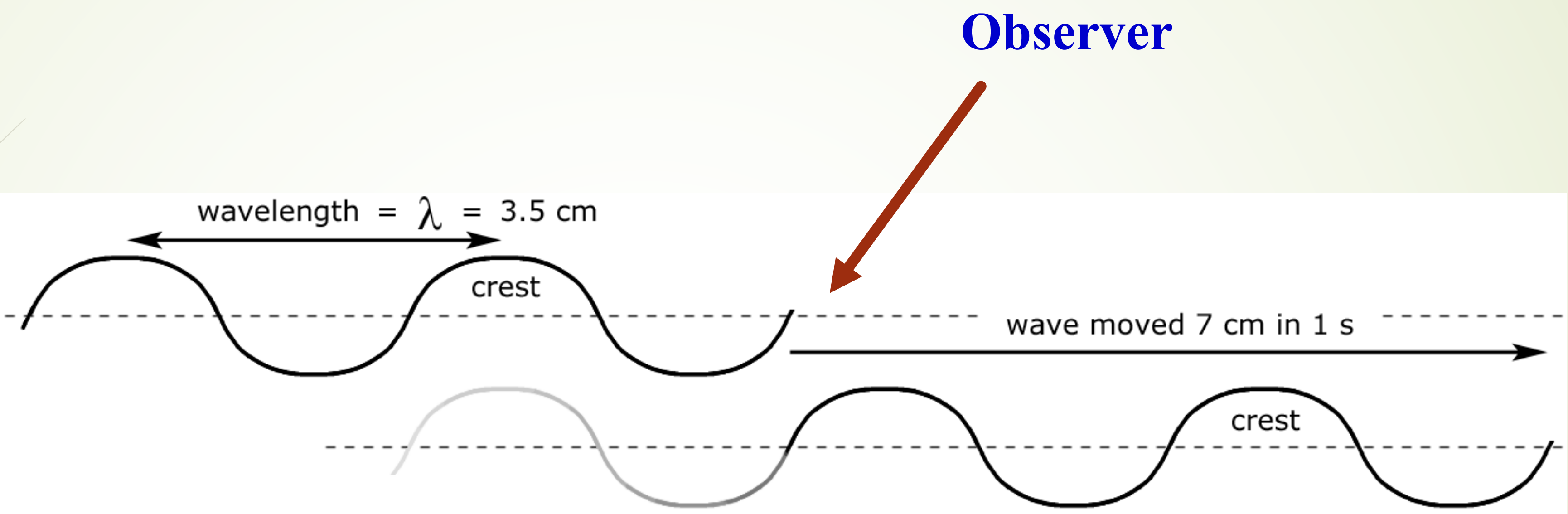
Wave Motion- Transporting Energy

Top view of water waves





Example



1. You can use a ruler to measure the wavelength to be about 3.5___ in cm or 0.035___ in m.

Number of waves that passed the observer in 1 second: _____

Wave frequency in Hz: _______ Velocity of wave: _________

Example

2. Closely related to frequency is **period**.

The Period of a wave is the time (in units of seconds) it takes for one full wave to pass a point.

The period is the inverse of the frequency.

$$\text{Period} = \frac{1}{\text{frequency}}$$

If waves hit the shore every 4 seconds,

what is the period? Period = ____________

What is the frequency? Frequency = ___________

What is the period of a 500 Hz sound wave? _________

Example

3. The wavelength and frequency are related by the wave speed:

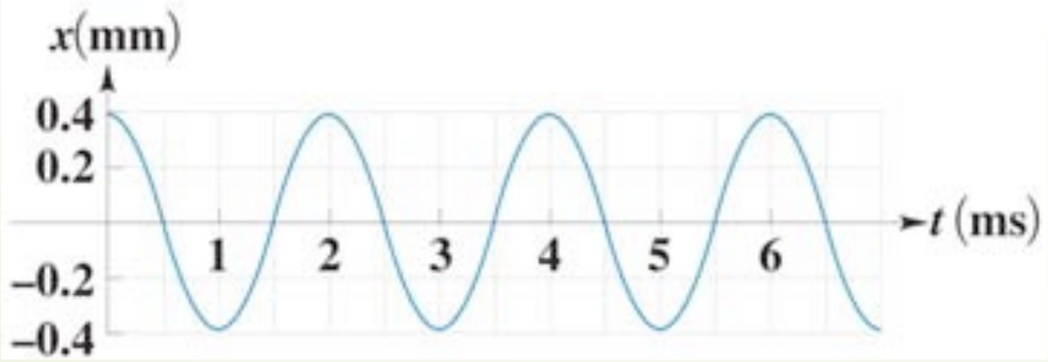
$$v = \lambda \times f \qquad so\ \lambda = v/f \quad and \quad f = v/\lambda$$

Thus, wavelength and frequency are ____________ related.

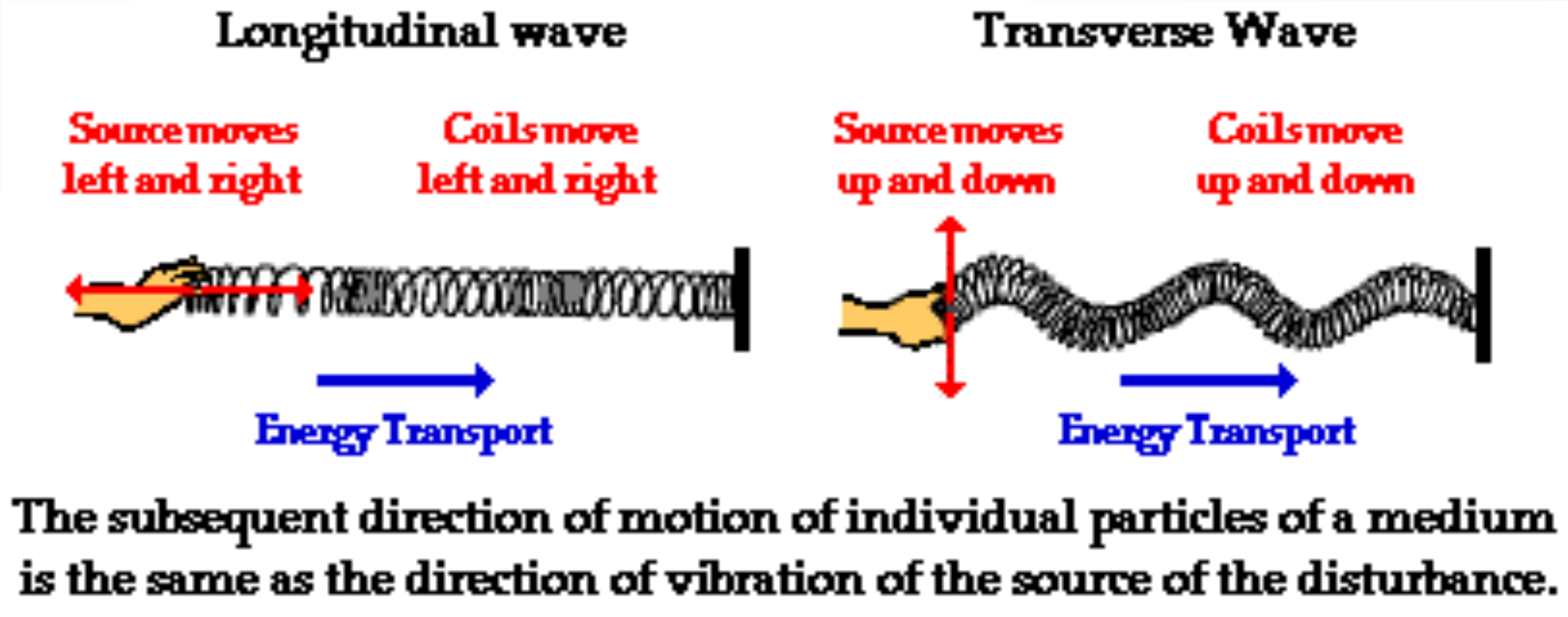
4. **Higher** frequencies correspond to _______ wavelengths

while **lower** frequencies correspond to ______ wavelengths.

Practice: The graph shows the displacement x of a tuning fork as a function of time t as it is playing a single note. What are the amplitude, period and frequency.



Types of waves



Sound – Longitudinal wave → Vibrations are **along** the direction of the wave

Light – Transverse wave → Vibrations are **perpendicular** to the direction of the wave

Click on the Sound and Light waves to explore animations of those waves!

Sound and Light waves

There are some similarities between **SOUND** and **LIGHT**:
The same terms – namely, **wavelength**, **frequency**, and **wave speed** are used for all waves, including both sound and light.

Also, both sound and light produce the effects of **interference**, **diffraction**, **reflection**, **refraction**, and the **doppler effect**.

Some differences:

1. (a) **SOUND does not travel through a vacuum**, and travels much faster in dense materials, such as water or steel, than it does in air.

   (b) **LIGHT** travels fastest in a vacuum and travels slower in materials such as water or glass.

2. (a) **SOUND** travels slowly, at about **340 m/s in air** or about 1500 m/s in water.

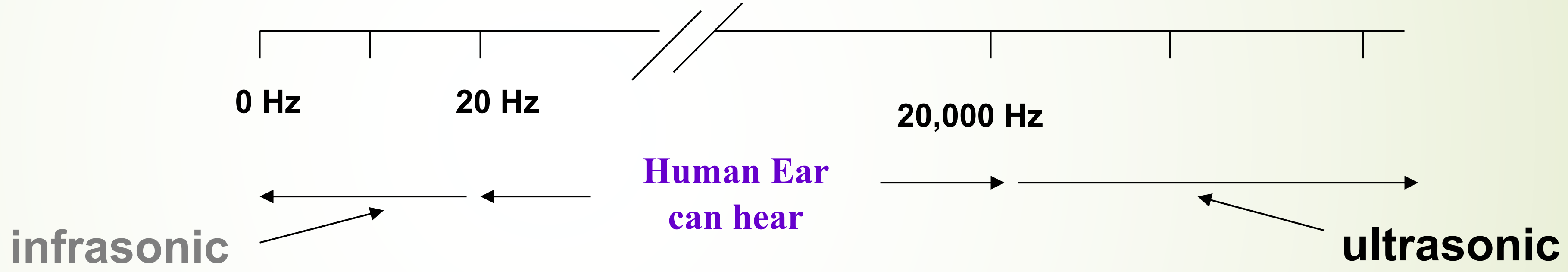
   (b) . **LIGHT** travels extremely fast, at 3 x 10^8 m/s in a vacuum.

Sound and Light waves

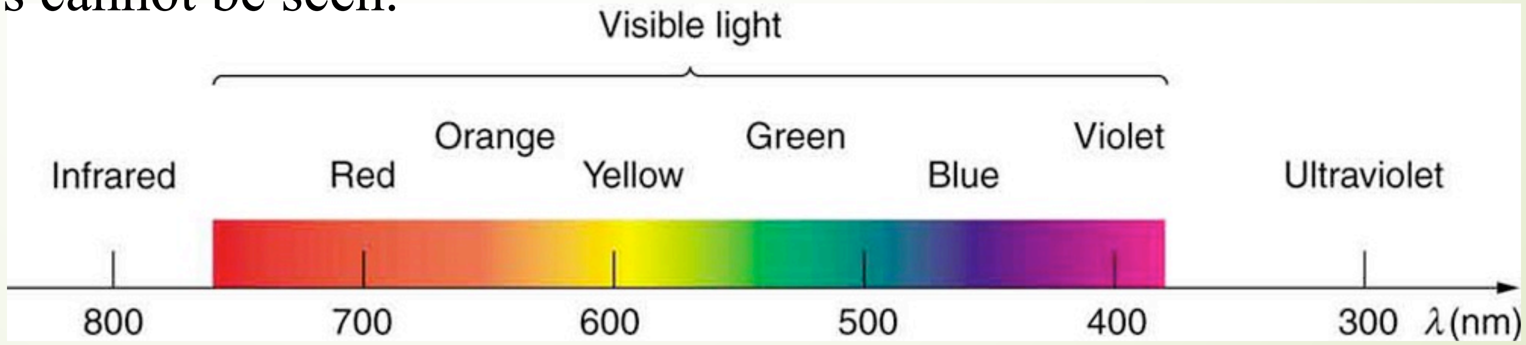
Other differences:

3. (a) Our range of **hearing** is from 20 Hz to 20,000 Hz when we are young.

We lose the ability to hear high frequency sounds as we age (damaged by loud sounds). Most adults cannot hear above 15,000 Hz and many have additional hearing loss in particular frequency ranges.



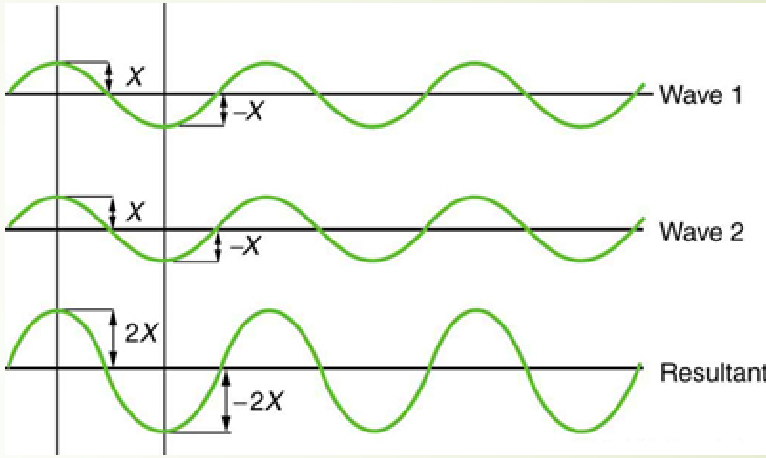
(b) Visible **light** frequency ~ 4×10^{14} to 8×10^{14} Hz is perceived as color by our eyes. Other kinds of "electromagnetic waves" include microwaves, radio waves and X rays cannot be seen.



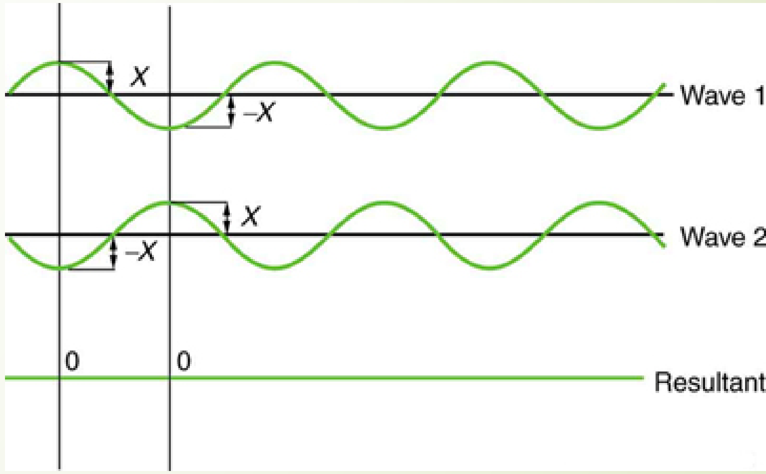
Interference

When two or more waves arrive at the same point, they superimpose themselves on one another. More specifically, the disturbances of waves are superimposed when they come together—a phenomenon called **superposition**.

- Constructive Interference: two identical waves that arrive at the same point exactly in phase.



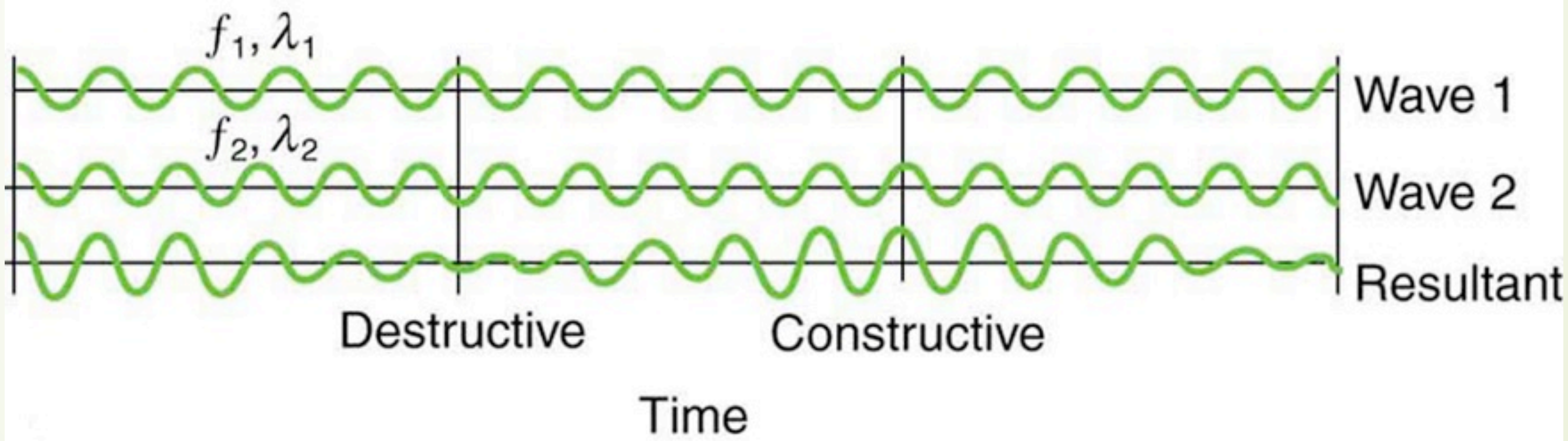
- Destructive Interference: two identical waves that arrive exactly out of phase



Beats

Beats: When two tones of slightly different frequencies are sounded together a fluctuation of loudness occurs.

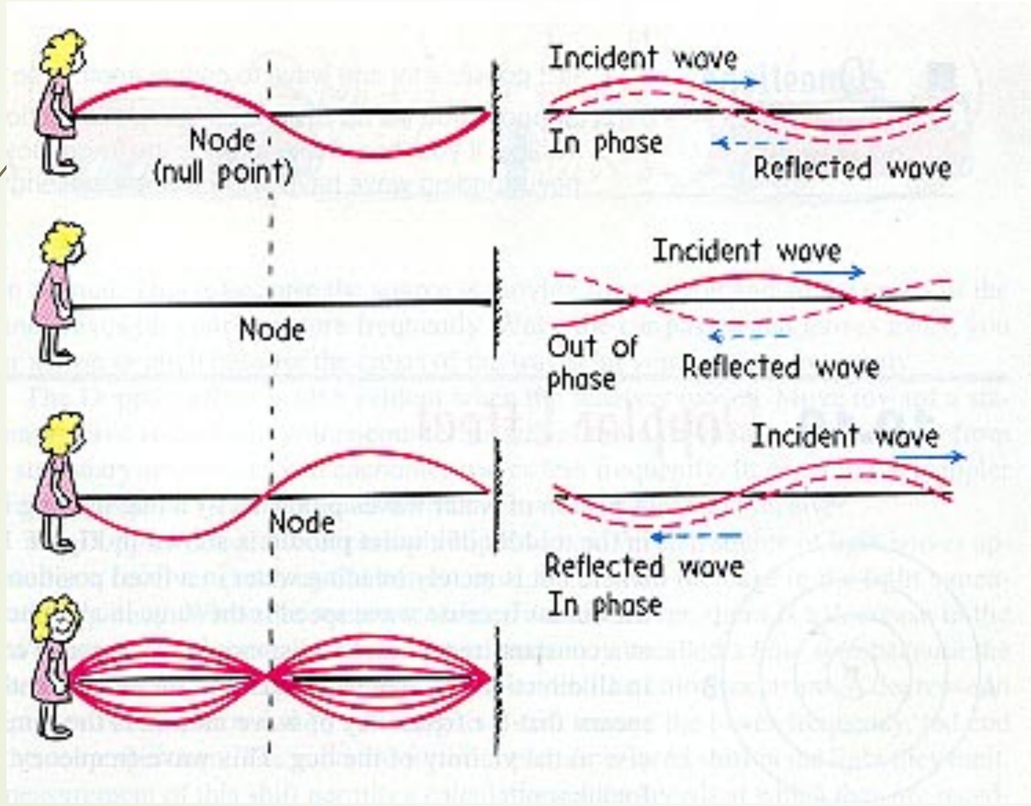
- The wave resulting from the superposition of two similar-frequency waves has a frequency that is the average of the two. This wave fluctuates in amplitude, or *beats*, with a frequency called the *beat frequency*, $f_{B.} = |f_1 - f_2|$

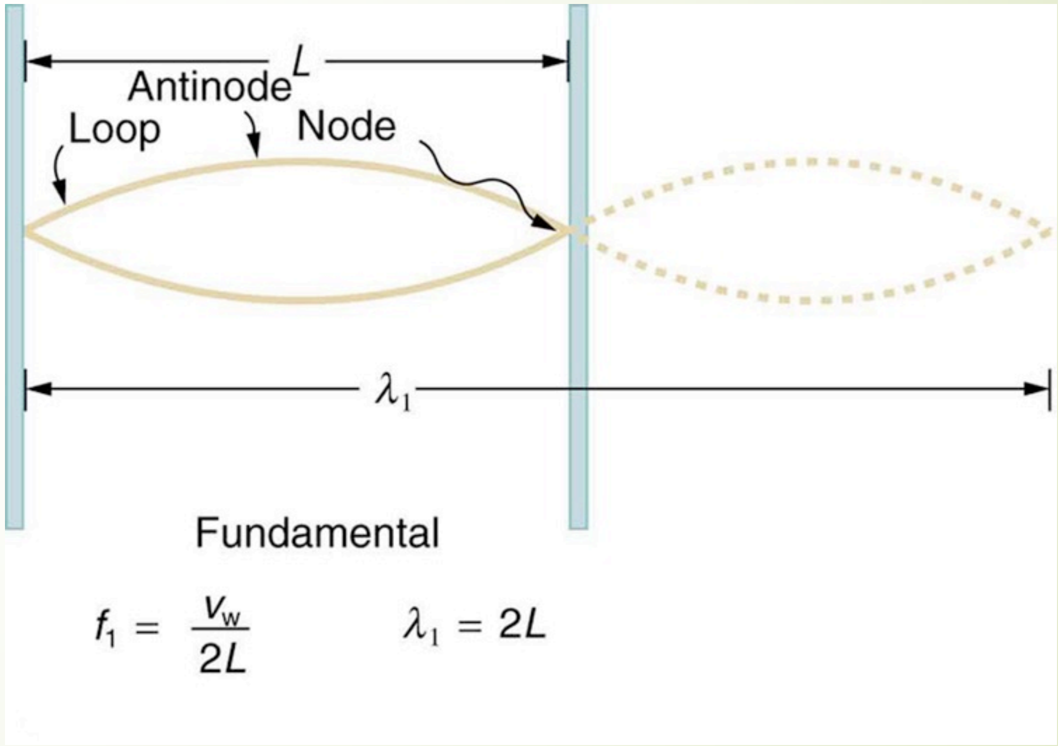


Standing waves

Standing wave: If the incident and the reflected waves have the same amplitude and wavelength, then they alternate between constructive and destructive interference. The resultant looks like a wave standing in place and, thus, is called a **standing wave**.

- Standing waves are commonly found on the strings of musical instruments





Doppler Effect

Doppler Effect happens due to changes in frequency due to motion