Waves and Vibrations

Concepts

- Types of waves:
  - Transverse: waves on strings
  - Longitudinal: sound waves
  - water waves are more complex (combination)
- Relationship of wavelength, frequency and velocity of wave ($\lambda f = v$)
- Wave amplitudes can be added together.
- Addition of waves leads to interference: constructive or destructive

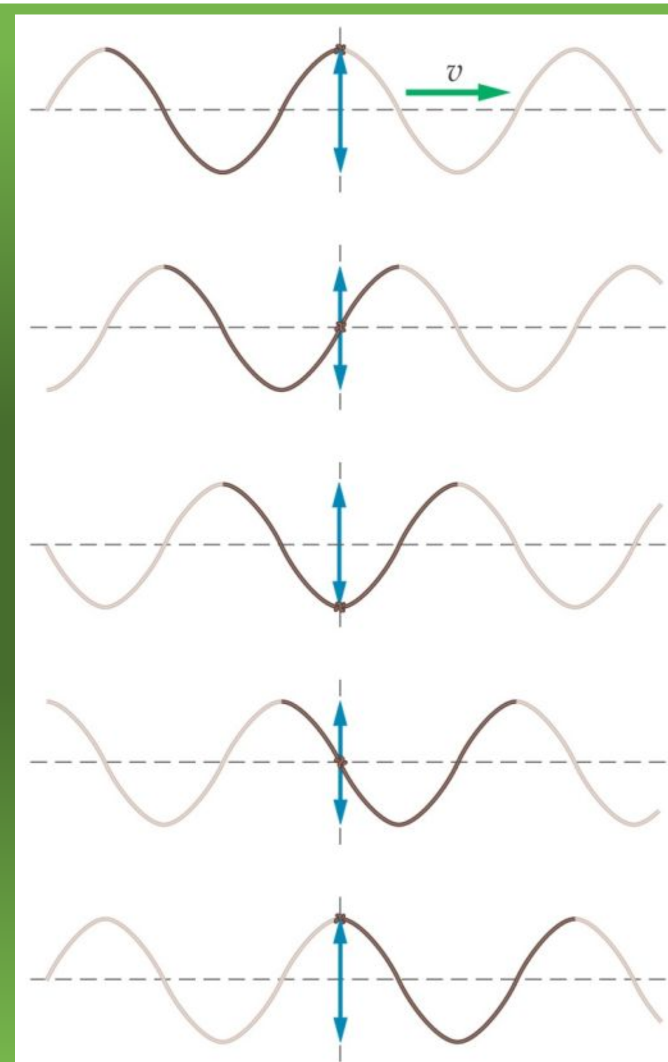
Key characteristic of these waves

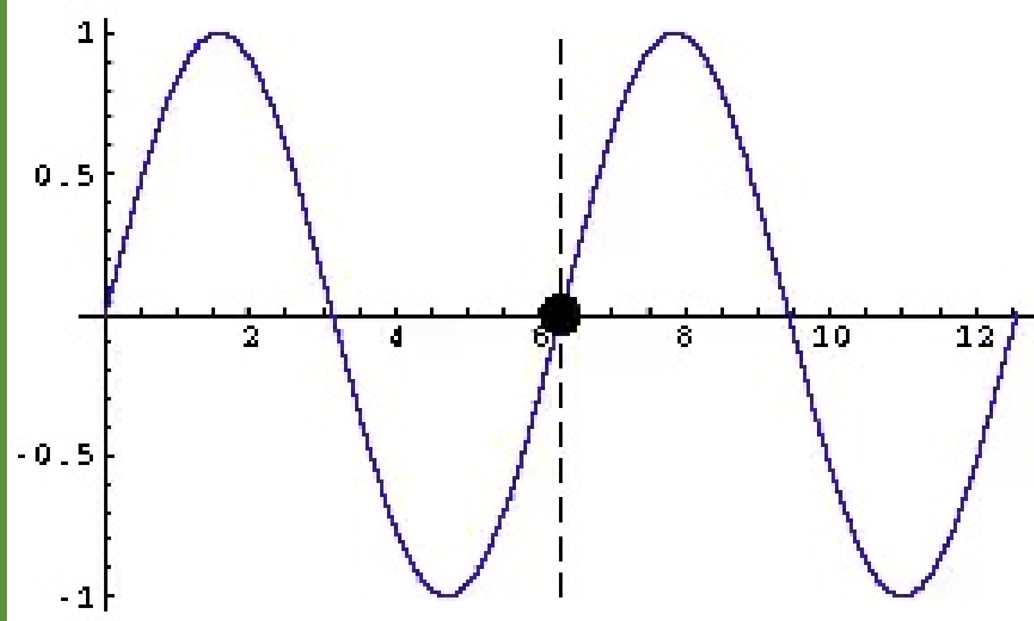
- Energy (in the form of motion) can be transmitted by the wave
- The medium (the string, the air, the water) does not move at the speed of the wave—it essentially “stays put”
- The energy of the wave is transmitted through the medium from one piece of matter to another
- Note that light waves travel without the need for a medium at all!

Vibrating String

Motion of a Transverse Wave on a string

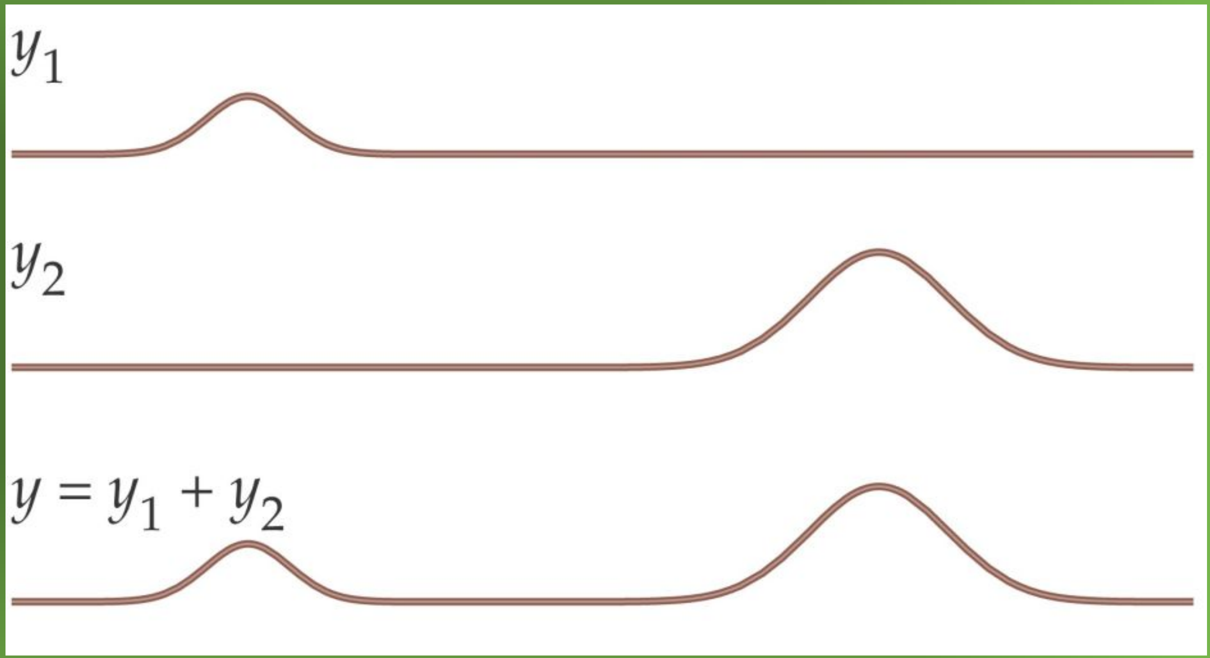
- Wave amplitude is $y=y_m \sin(kx - wt)]$
  - $k = 2\pi / \lambda$, $w = 2\pi/T$
- If you sit at one location *x*, the wave oscillates in time.
- If you stop the action at a time *t*, the wave oscillates as a function of distance *x*.
- The wave crest travels a distance l in one period of time, 1/f. Thus the speed is the distance over the time, or $\lambda f = v$




1
0.5
-0.5
-1
2
4
6
8
10
12

Superposition (addition) of waves

When two waves or more occupy the same region of a medium at the same time, they will interfere with each other.

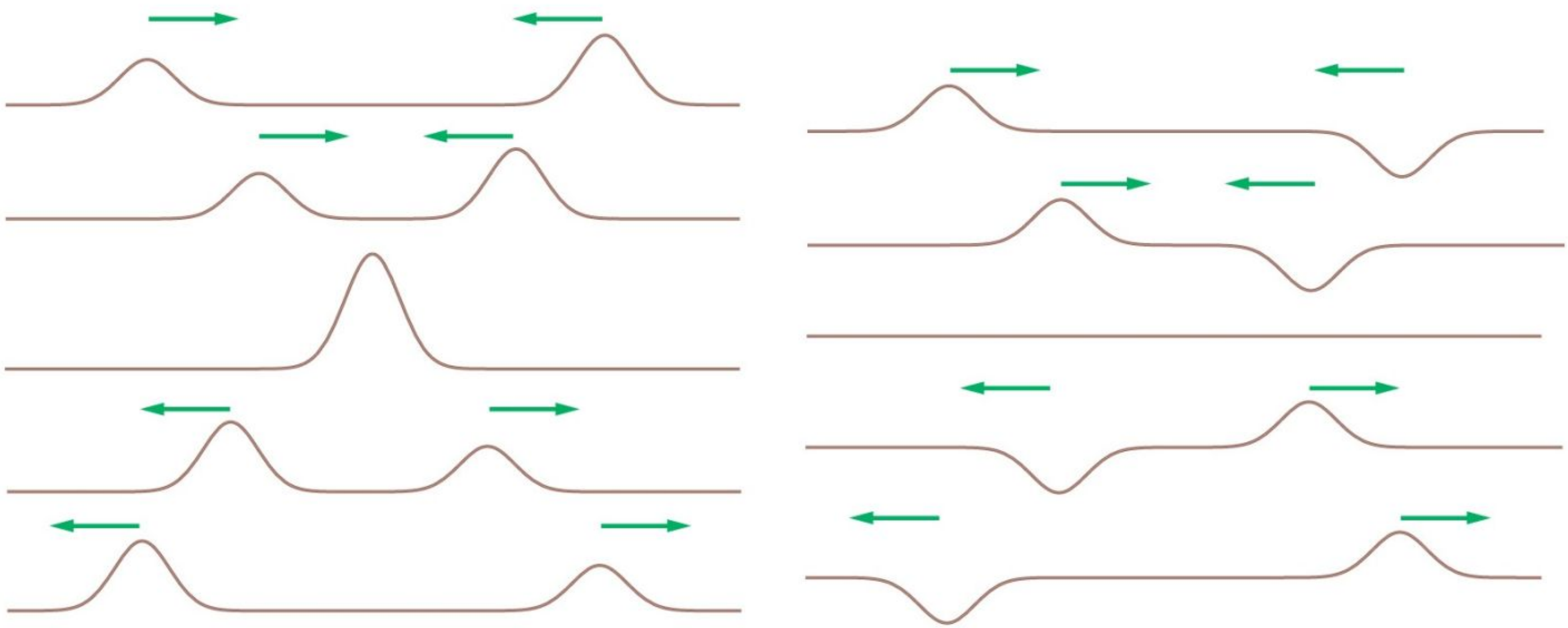


Wave amplitudes are added. They can get larger (constructive) or smaller (destructive) interference when they are superposed.

Wave interference

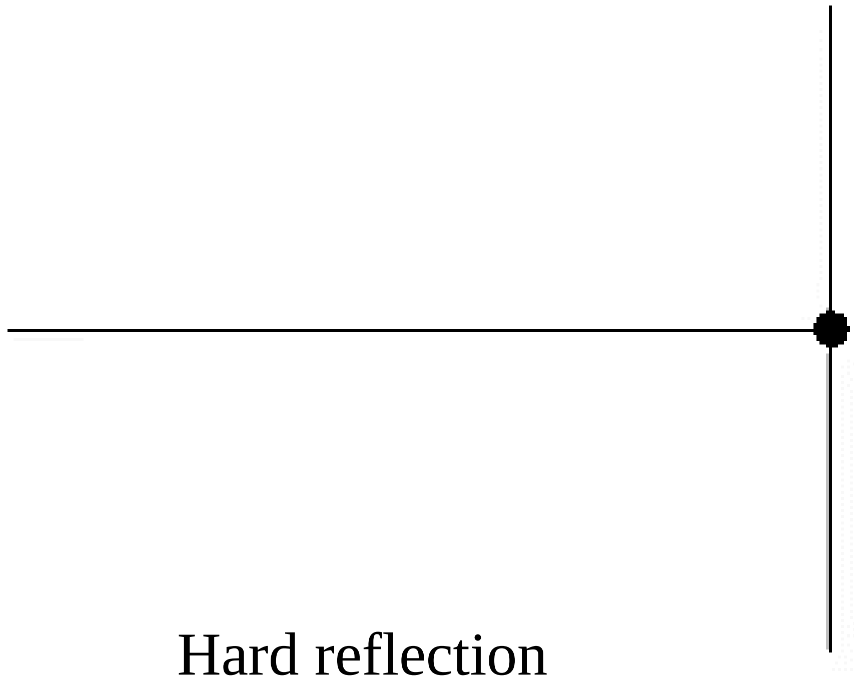
$$\sin\alpha + \sin\beta = 2\sin\left[\frac{1}{2}(\alpha+\beta)\right]\cos\left[\frac{1}{2}(\alpha-\beta)\right]$$

$$\rightarrow \sin[kx-\omega t] + \sin[kx+\omega t] = 2\sin[kx]\cos[\omega t]$$

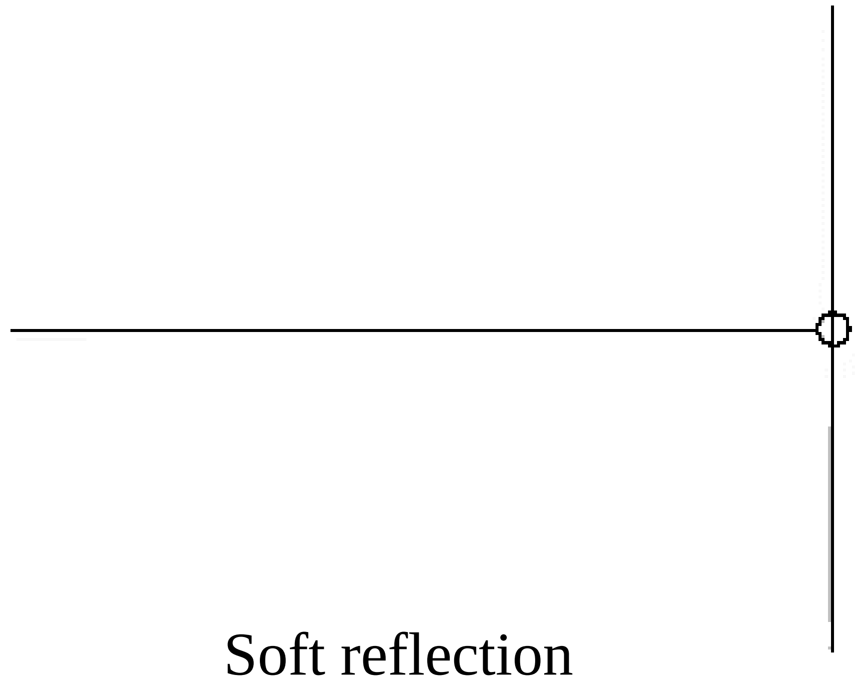


(a) Constructive (b) Destructive

Wave Reflection



Hard reflection



Soft reflection

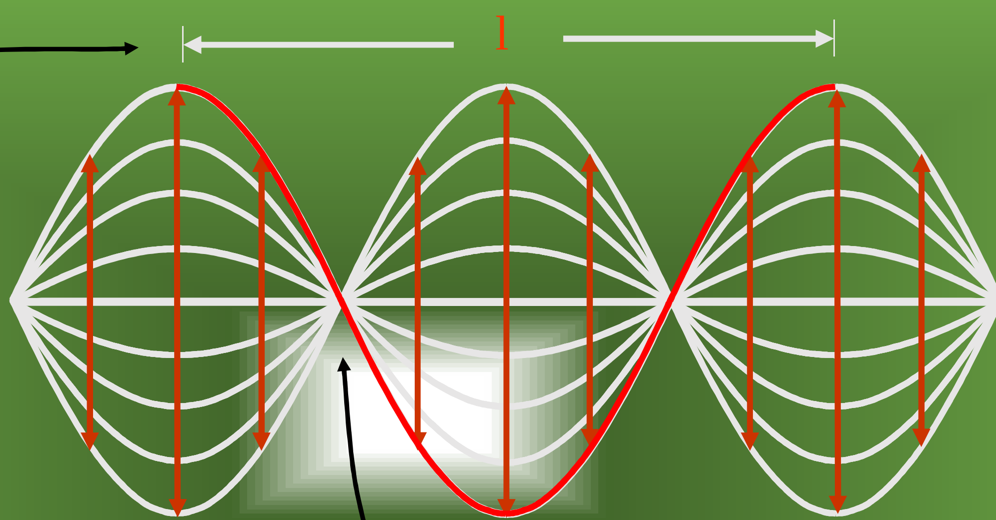
Standing waves on strings (Resonance)

When two sets of waves of equal amplitude and wavelength pass through each other in opposite directions, it is possible to create an interference pattern that looks like a wave that is "standing still."

It is a changing interference pattern.

Standing waves occur when both ends of a string are fixed. In that case, only waves which are motionless at the ends of the string can persist. There are nodes, where the amplitude is always zero, and antinodes, where the amplitude varies from zero to the maximum value.

Parameters of a Standing Wave



There is no vibration at a node.

There is maximum vibration at an antinode.

l is twice the distance between successive nodes or successive antinotes.

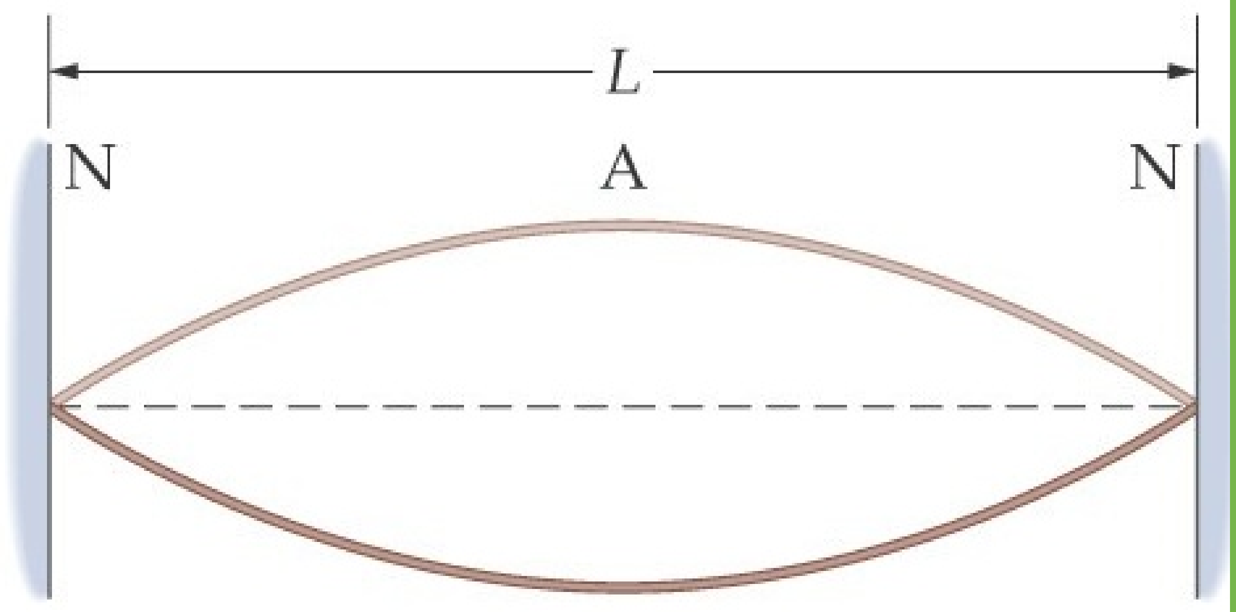
Standing waves on strings

First harmonic

$L = \lambda/2 \rightarrow \lambda = 2L$

$\lambda f = v \rightarrow f = v / \lambda \rightarrow$

$f = v / 2L$



(a)

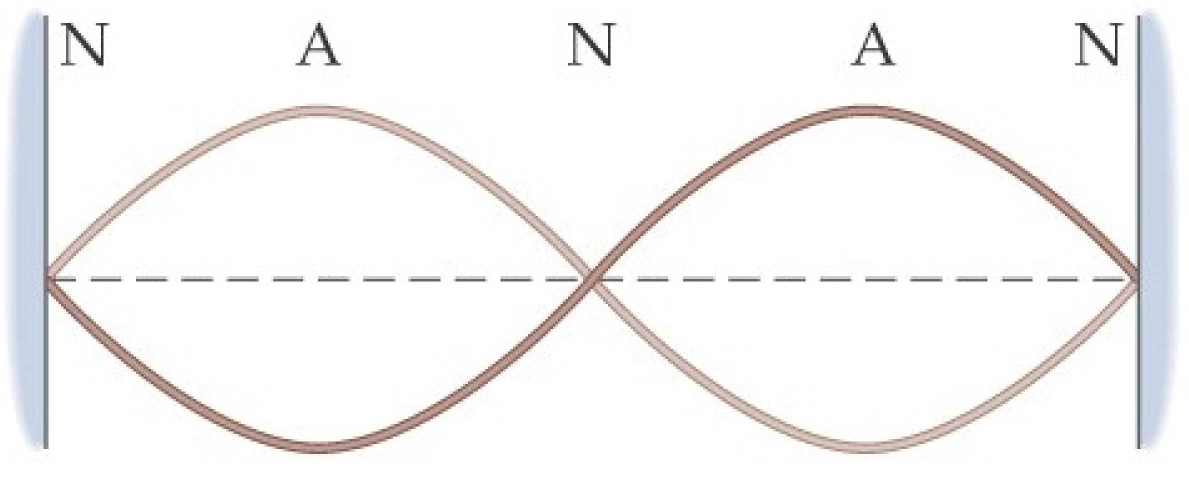
Standing waves on strings

Second harmonic (one octave)

$L = \lambda$

$\lambda f = v \rightarrow f = v / \lambda \rightarrow$

$f = 2\ (v/2L)$



(b)

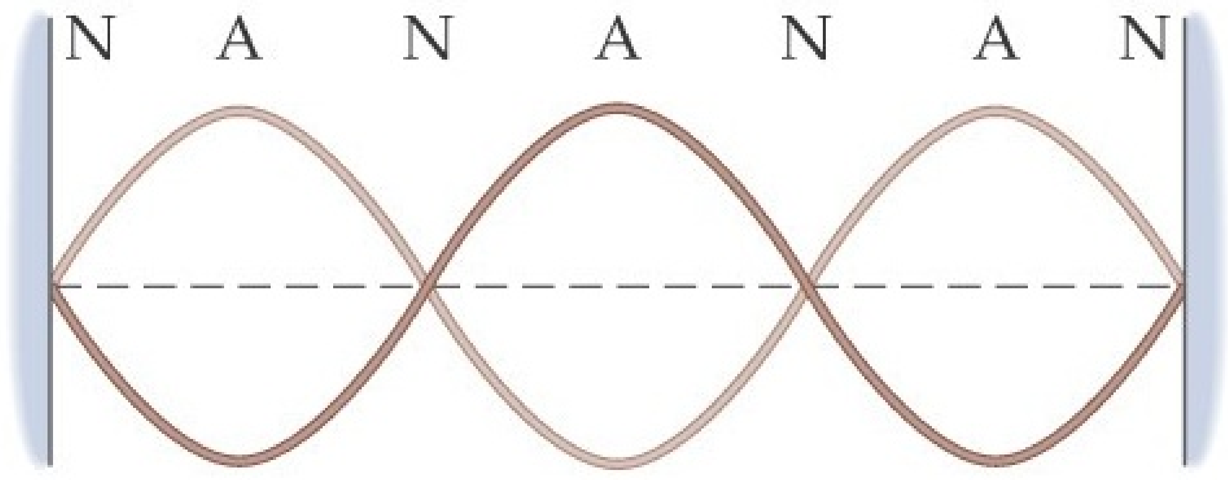
Standing waves on strings

Third harmonic

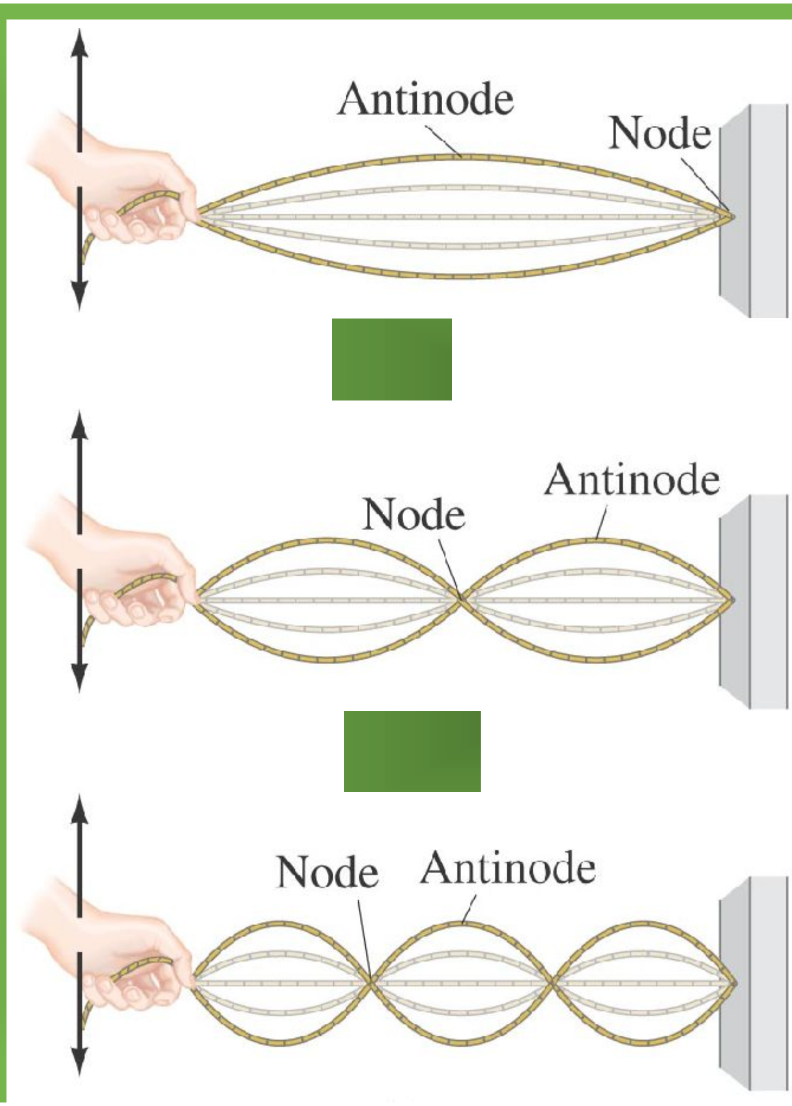
$L = 3\lambda/2 \rightarrow \lambda = 2L/3$

$\lambda f = v \rightarrow f = v/\lambda \rightarrow$

$f = 3v/2L$



(c)



$$\lambda_n = \frac{2L}{n} \quad , \quad n = 1\,,\,2\,,\,3\,,\ldots$$

$$f_n = \frac{v}{\lambda_n} = n\frac{v}{2L} = nf_1$$

$$v = \sqrt{\frac{\tau}{\mu}}$$

- In the experiment today you will adjust the tension in a vibrating string so that you create different standing wave patterns.

  (Adjusting the tension in the string changes the speed of the wave.)

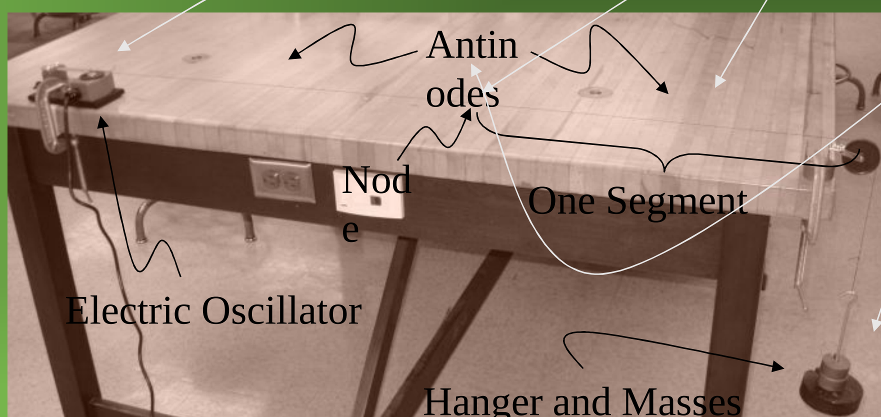
- Important Note:

  The frequency of vibration on your string will remain constant.

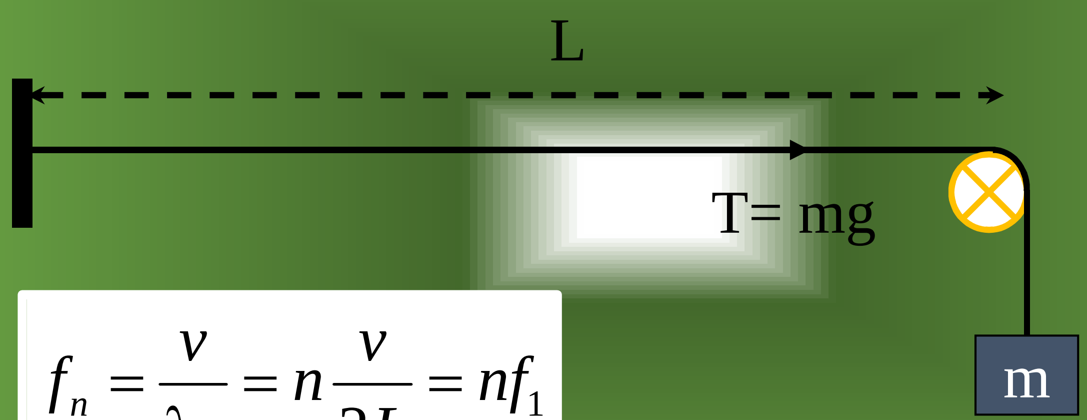
  By changing the wave speed you will be changing the wavelength and therefore the harmonic number of the standing wave.

The lab assistant will now give you an overview of the experimental apparatus

The electric oscillator is located here.
Masses are added here.
When the apparatus is turned on and with the proper mass on the hanger, standing waves can occur.
This is considered to be one segment.
Points of no vibration are called nodes.
Three are shown here. (Where are they?)
The large vibration areas are called antinodes.



By varying the mass on the mass hanger one can create standing waves with differing numbers of segments.



$$f_n = \frac{v}{\lambda_n} = n\frac{v}{2L} = nf_1$$

$$v = \sqrt{\frac{\tau}{\mu}}$$

$f = constant \rightarrow T = variable$

n= $variable$