

## Standing Waves

Let's assume that electromagnetic waves travel a way for trapped between two mirrors. There are standing waves.

A jump rope is a good example of a standing wave.



The jump is made negative going down to form a disturbance and then goes away to the wave. Jump rope is like a string wave.

The places of zero amplitude are called nodes. The places of greatest amplitude are called antinodes.



A standing wave.

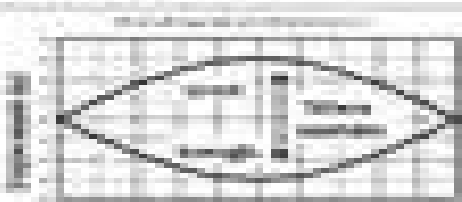
Standing waves are created by two waves traveling in opposite directions. The wave has the same amplitude at the same time. In reality, though, it's a wave going up and down, just like a jump rope.

In a standing wave, each antinode is one-half of a wavelength.

$$1 \text{ Antinode} = \frac{1}{2} \lambda$$

$$2 \text{ Antinodes} = \lambda$$

Two jump ropes, the same length, same frequency, same  $\lambda$ . Notice that wave away to the right is in phase with the wave at the end, both pushing through the wave.



Uniform ball

A graph of the fundamental wave for the string.

The longest wave that can be produced in a uniform string is called the fundamental. It is one-half of one wavelength long.

### Standing Waves

Standing waves occur between objects whose lengths are multiples of the fundamental. Standing waves occur in the harmonics. Harmonics are the first, second, third, fourth, and fifth, and so on, standing waves.

#### Part 1: Harmonics of a Vibrating String



#### Frequency of Harmonics

Frequency of the  $n$ th harmonic is  $f_n = \frac{v}{\lambda_n}$  and the wavelength is  $\lambda_n = \frac{2L}{n}$ .  
 Frequency of the fundamental is  $f_1$ .

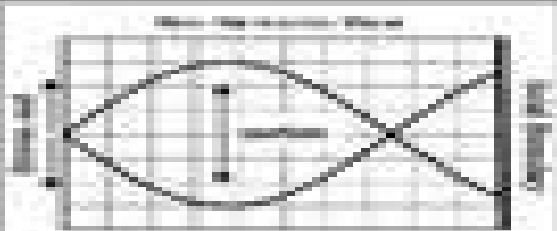
If you know the frequency of the first harmonic,  $f_1$ , and the length of the string,  $L$ , you can find the frequency of the  $n$ th harmonic.

$$f_n = n f_1$$

If you know the frequency of the first harmonic,  $f_1$ , and the length of the string,  $L$ , you can find the frequency of the  $n$ th harmonic.

$$f_n = n f_1$$

Standing waves can be formed in a tube. The wave in the tube is a sound wave, and it's a longitudinal wave.



Harmonic	Wavelength	Frequency
1st	$\lambda_1 = 2L$	$f_1 = \frac{v}{2L}$
2nd	$\lambda_2 = L$	$f_2 = \frac{v}{L}$
3rd	$\lambda_3 = \frac{2}{3}L$	$f_3 = \frac{3v}{2L}$
4th	$\lambda_4 = \frac{1}{2}L$	$f_4 = \frac{2v}{L}$
5th	$\lambda_5 = \frac{2}{5}L$	$f_5 = \frac{5v}{2L}$

# Standing Waves Answers Stephen Murray

**Anthony S. Fauci**



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