Name: _____

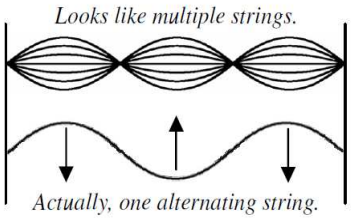
Period: _____

Standing Waves

5.4

Sometimes waves are trapped in boundaries. If the length of a wave matches the space it is in, **resonance** occurs, causes maximum amplitude. The wave seems to stand still. **Standing waves occur only at certain frequencies.**

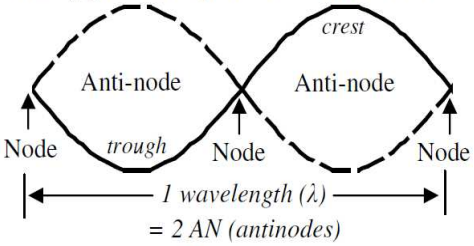
A jump rope looks like a standing wave, but is not because it moves in a circle and can exist at any frequency (you can speed up a little at a time). A standing wave can't exist at any frequency.

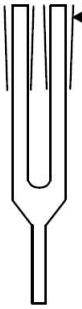


Resonance—When an object vibrates sympathetically and amplifies the energy of a wave.

Guitar strings would be quiet without the resonance (amplification) of the guitar's body.

*The places of no amplitude are called **nodes**. The places of greatest amplitude are called **anti-nodes**.*

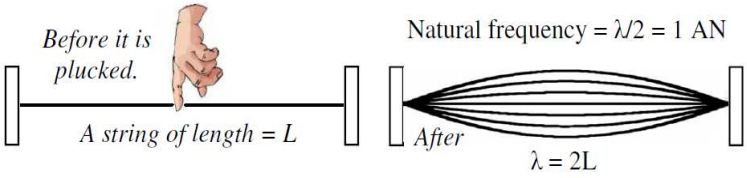




Some standing waves have open boundaries, like a tuning fork. ***Open boundaries move and must be anti-nodes.***

Natural Frequency

When a string is plucked it will vibrate with only **one anti-node**. This is known as **the natural frequency** and always equals **one half of a wavelength**. The natural frequency is also called the fundamental frequency (f_f) or harmonic one (H_1).

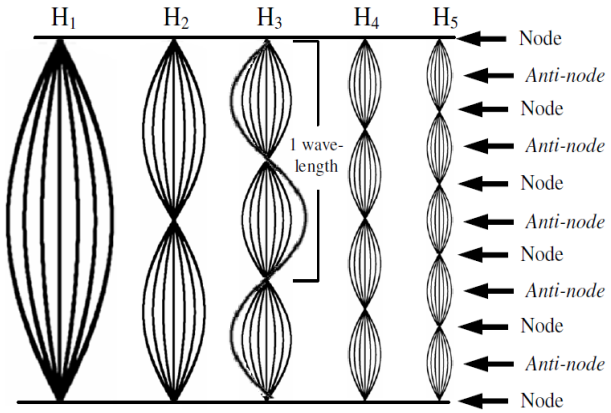


The wavelength of the fundamental always equals 2L!

Harmonics

Harmonics are standing waves that fit in the same boundaries as the fundamental (natural frequency). As with any wave, changing the frequency does not change the wave speed. So if f changes, λ changes, not v.

First 5 Harmonics of a Vibrating String



Fundamental 1st harmonic	2nd har-monic	3rd har-monic	4th har-monic	5th har-monic
$f = f_f$	$f_2 =$	$f_3 =$	$f_4 =$	$f_5 =$
=H	=2H	=3H	=4H	=5H

Examples of Fundamentals and their Harmonics				
$H_1 (f_f)$	H_2	H_3	H_4	H_5
H	2H	3H	4H	5H
2 Hz	4 Hz	6 Hz	8 Hz	10 Hz
5 Hz	10 Hz	15 Hz	20 Hz	25 Hz
10 Hz	20 Hz	30 Hz	40 Hz	50 Hz

Frequency of a Harmonic

Frequency of the harmonic N (in *Hz*) → $f_{HN} = N(H)$ ← # of the harmonic

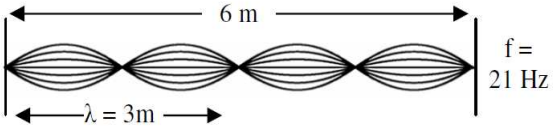
Frequency of the fundamental (in *Hz*)

Ex. Find the frequency of the third harmonic (H_3) of a 4 Hz fundamental.	
H = 4 Hz N = 3 H_3 = ?	$f_{Hn} = N(H)$ $f_{H3} = 3(4)$ f_{H3} = 12 Hz

Ex. If the fifth harmonic has a frequency of 55 Hz, find the fundamental frequency.	
f_{H5} = 55 Hz N = 5 f_{H1} = H = ?	$f_{Hn} = N(H)$ 55 = 5H H = f_{H1} = 11 Hz

Speed of a Standing Wave

To find the speed of a fixed string you would need to know the frequency of any harmonic and that harmonic's wavelength.



Remember that λ (wavelength) = 2 antinodes!	λ = 3m f = 21 Hz v = _____	v = fλ v = 21(3) v = 63 m/s

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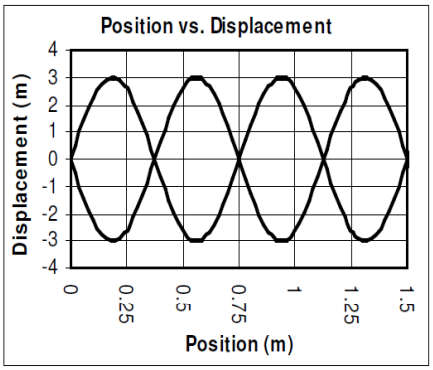
1. Standing wave	A. Where wave's amplitude is greatest.
2. Harmonic	B. Where the wave has no motion.
3. Fundamental	C. A wave that is a multiple of another wave.
4. Natural Frequency	D. A wave that is trapped within boundaries.
5. Node	E. The first harmonic of a standing wave, equal to 1/2 its wavelength.
6. Anti-node	F. The frequency at which any space will vibrate when disturbed.



# of cycles: _____

Wavelength: _____

Amplitude: _____

# of Anti-nodes: ____

Harmonic #: _____

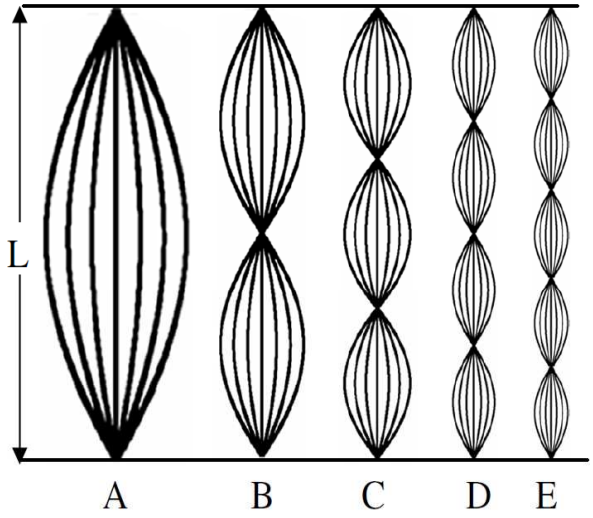
Why does a violin have a wood body instead of just strings?

Sometimes when talking or singing in a room, certain notes get very loud. Why?

A string has a fundamental (first harmonic) of 15 Hz, find the frequency of harmonic 3 (H_3).

If 20 Hz is the fundamental, find H_6.

If 35 Hz is H_7, what is the fundamental frequency?



____ Is the second harmonic.

____ Has 4 anti-nodes.

____ Has 3 nodes.

____ Has a length of 1.5λ.

____ Is the fundamental.

_____Has a wavelength of L.

_____Is the highest frequency.

_____Longest wavelength.

_____Fastest wave speed.

_____Is the natural frequency.

String A has a fundamental with a period of 0.25 seconds.

A) What is the fundamental's frequency?

B) How many antinodes does it have?

C) If the fundamental is on a 6 m long string, what is its wave length?

D) Find the speed of the wave on that string.

E) What would be the frequency of the third harmonic?

F) What is the wave speed of the fourth harmonic?

The following table shows the frequencies of the first 5 harmonics of different strings. Fill in the blank spaces.

1	2	3	4	5
4 Hz				
6 Hz				
	4 Hz			
		36 Hz		
			44 Hz	

A fellow student shows you the frequencies of four harmonics of a string. Which one would you question and why?
Frequencies: 12 Hz; 24 Hz; 29 Hz; 48 Hz

Find its period: _____

Mark the nodes and anti-nodes.

What harmonic is this? _____

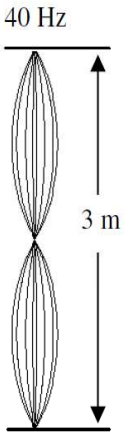
Fundamental frequency = _____

3rd harmonic frequency = _____

Wavelength = _____

Speed of the wave =

Speed of 5th harmonic =



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