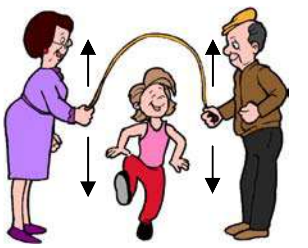
Name: ______________________

Period: ______________________

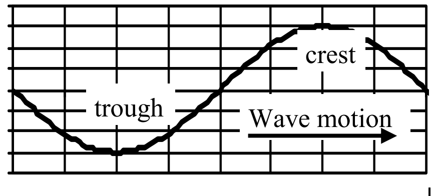
Standing Waves

We know that waves move. Yet waves can be trapped between ***boundaries***. These are known as ***standing waves***.

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



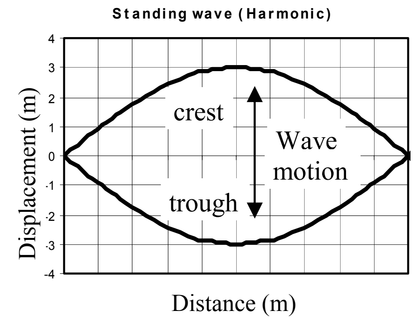
To keep a standing wave going it needs to have a *driven end:* an end that gives energy to the wave. Jump ropes have *two* driven ends.



A moving wave.

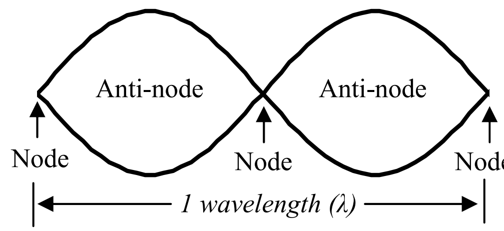
In a *moving* wave, the wave moves away from what drives it. Waves that move away from a rock in a pond are driven by the force of the rock pushing through the water.

Standing waves are TRAPPED between boundaries, so we show both the crest and the trough in the same place at the same time. In reality, though, it alternates: going up and down, just like a jump rope.



A graph of the fundamental wave for this distance.

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



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

1 Anti-node = (1/2)λ

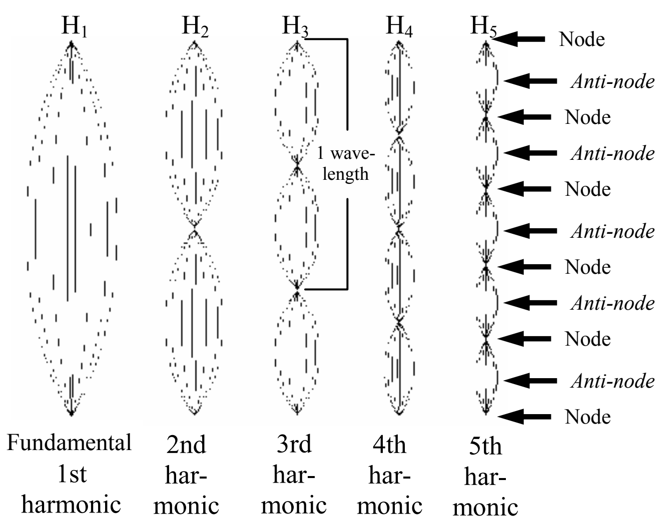
2 Anti-nodes = λ

The largest wave that can be produced in a certain distance is called the ***fundamental***. It is one-half of one wavelength long.

Harmonics

Harmonics are waves that are whole number multiples of the fundamental. ***Harmonics*** have nodes at the boundaries. Harmonics sound louder, keep their energy longer, and take less energy to produce.

First 5 Harmonics of a Vibrating String



Frequency of Harmonics

$$f_{Hx} = f_f(X)$$

Frequency of harmonic x (in *Hz*) → f_{Hx}; Frequency of the fundamental (in *Hz*) → f_f; # of the Harmonic → X

Ex. Find the frequency of the third harmonic (H_3) of a 4 Hz fundamental.

$f_f = 4$ Hz $X = 3$ $f_{H3} = ?$	$f_{Hx} = f_f(X)$ $f_{H3} = (4\text{ Hz}) \times (3)$ $f_{H3} = 12$ Hz

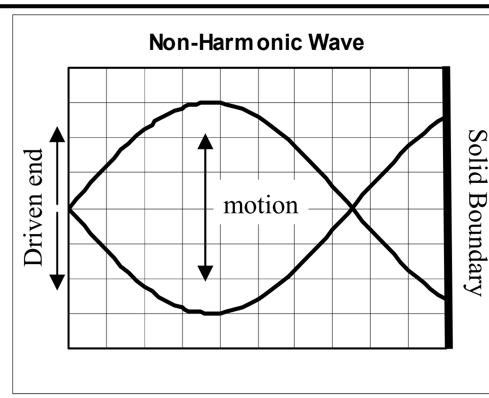
Ex. If the fifth harmonic has a frequency of 55 Hz, find the fundamental frequency.

$f_{H5} = 55$ Hz $X = 5$ $f_f = ?$	$f_{Hx} = f_f(X)$ $f_f = f_{Hx}/X = 55\text{ Hz}/5$ $f_f = 11$ Hz

Examples of Fundamentals and their Harmonics

H_1 (f_f)	H_2	H_3	H_4	H_5
1 Hz	2 Hz	3 Hz	4 Hz	5 Hz
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

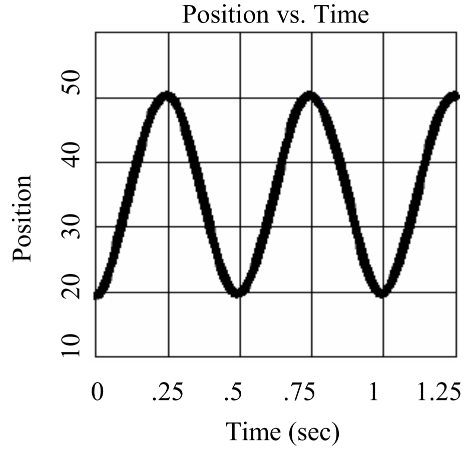
Non-harmonic waves can be forced into boundaries, too. The wave will to die out quickly, sound quieter (if a sound wave), and take more energy to produce.



Name: ____________________

Period: ____________________

1. Boundary	A. The part that is moved to give energy.
2. Standing wave	B. Where wave's amplitude is greatest.
3. Harmonic	C. Where the wave has no motion.
4. Fundamental	D. A wave that is a multiple of another wave.
5. Driven end	E. A wave that is trapped within boundaries.
6. Node	F. The first harmonic of a standing wave, equal to 1/2 its wavelength.
7. Anti-node	G. A place that limits a wave's motion.



# of cycles: ________

Period: ________

Frequency: ________

Amplitude: ________

1. f = ____________	8 m/s
2. v = ____________	8 sec
3. λ = ____________	8 Hz
4. T = ____________	8 m

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

If 20 Hz is the fundamental, find H_6.

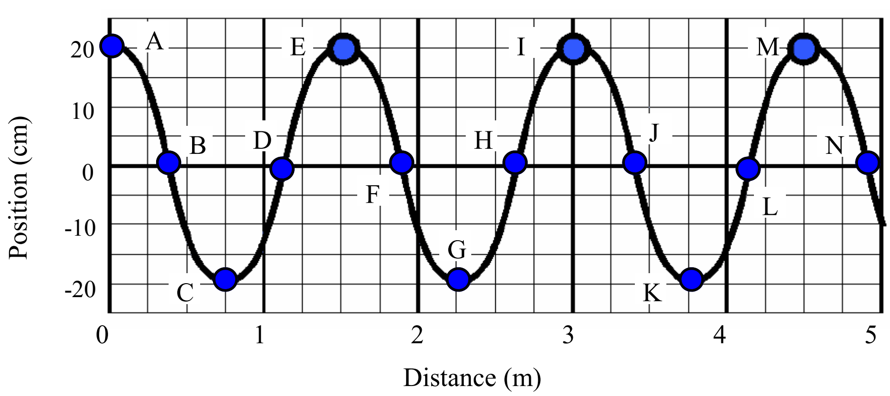
If 35 Hz is H_7, what is the fundamental frequency?

If a wave's frequency is 25 Hz, what is its period?

If a wave's period is 0.1 sec, find its frequency.

If a wave has a frequency of 50 Hz and a wavelength of 2 meters. Find its speed.

A wave's velocity is 20 m/sec with a wavelength of 40 m. What is it's frequency?



One cycle: A to ____; C to ____; F to ____.

Half cycle: H to ____; J to ____; B to ____.

Two cycles: B to ____; D to ____; E to ____.

Total cycles: ____________

Wavelength: ____________

Amplitude: ____________

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: ____________

What harmonic is this? ____________

Mark the nodes and anti-nodes.

Find the fundamental frequency:

____

3rd harmonic frequency:

____

40 Hz