Name: ______________________________ Date: ______________

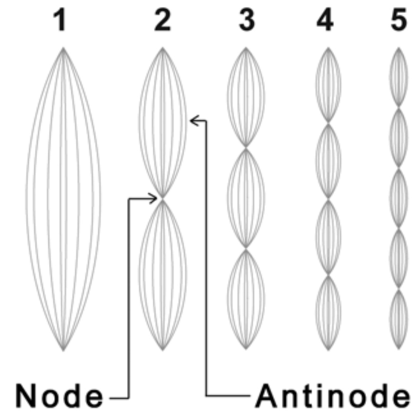
20.1

Standing Waves

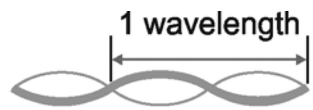
A wave that is confined in a space is called a **standing wave**. Standing waves on the vibrating strings of a guitar produce the sounds you hear. Standing waves are also present inside the chamber of a wind instrument.

A string that contains a standing wave is an oscillator. Like any oscillator, it has natural frequencies. The lowest natural frequency is called the **fundamental**. Other natural frequencies are called **harmonics**. The first five harmonics of a standing wave on a string are shown to the right.

There are two main parts of a standing wave. The **nodes** are the points where the string does not move at all. The **antinodes** are the places where the string moves with the greatest amplitude.

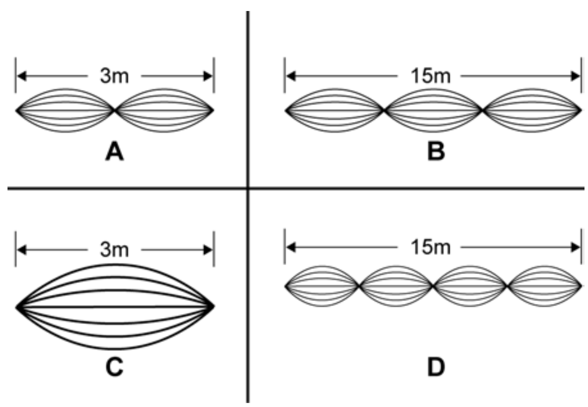


The wavelength of a standing wave can be found by measuring the length of two of the "bumps" on the string. The first harmonic only contains one bump, so the wavelength is twice the length of the individual bump.

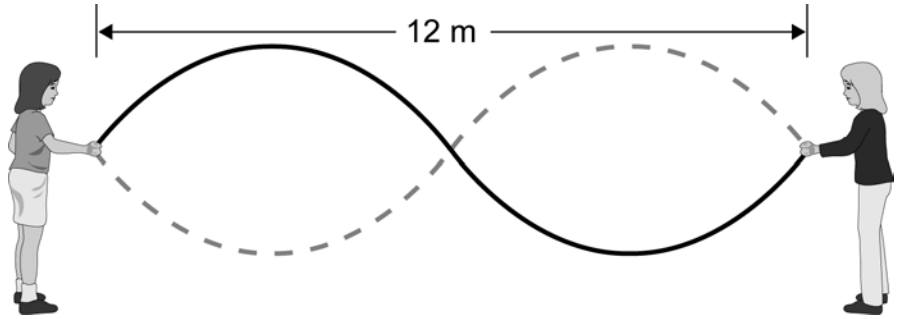


PRACTICE

1. Use the graphic below to answer these questions.
   a. Which harmonic is shown in each of the strings below?
   b. Label the nodes and antinodes on each of the standing waves shown below.
   c. How many wavelengths does each standing wave contain?
   d. Determine the wavelength of each standing wave.



2. Two students want to use a 12-meter long rope to create standing waves. They first measure the speed at which a single wave pulse moves from one end of the rope to another and find that it is 36 m/sec. This information can be used to determine the frequency at which they must vibrate the rope to create each harmonic. Follow the steps below to calculate these frequencies.



a. Draw the standing wave patterns for the first six harmonics.

b. Determine the wavelength for each harmonic on the 12 meter rope. Record the values in the table below.

c. Use the equation for wave speed ($v = f\lambda$) to calculate each frequency.

Harmonic	Speed (m/sec)	Wavelength (m)	Frequency (Hz)
1	36		
2	36		
3	36		
4	36		
5	36		
6	36		

d. What happens to the frequency as the wavelength increases?

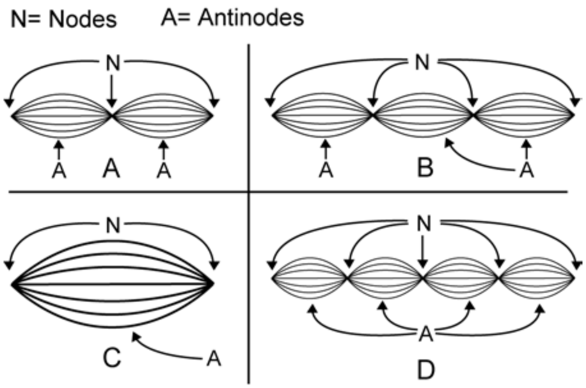
e. Suppose the students cut the rope in half. The speed of the wave on the rope only depends on the material from which the rope is made and its tension, so it will not change. Determine the wavelength and frequency for each harmonic on the 6 meter rope.

Harmonic	Speed (m/sec)	Wavelength (m)	Frequency (Hz)
1	36		
2	36		
3	36		
4	36		
5	36		
6	36		

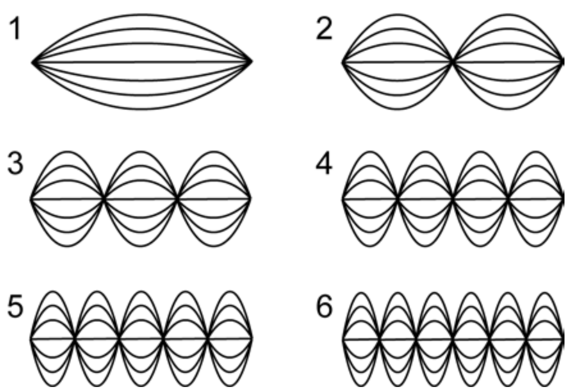
f. What effect did using a shorter rope have on the wavelength and frequency?

20.1 Standing Waves

1. Answers are:
   a. A = 2nd; B = 3rd; C = 1st or fundamental; D = 4th (You can easily determine the harmonics of a vibrating string by counting the number of “bumps” on the string. The first harmonic (the fundamental) has one bump. The second harmonic has two bumps and so on.)
   b. Diagram:



   c. A = 1 wavelength, B = 1.5 wavelengths, C = half a wavelength, D = 2 wavelengths
   d. A = 3 meters, B = 10 meters, C = 6 meters, D = 7.5 meters
2. Answers are:
   a. Diagram:



   b. See answer for (c).
   c. See table below:

Harmonic	Speed (m/sec)	Wavelength (m)	Frequency (Hz)
1	36	24	1.5
2	36	12	3
3	36	8	4.5
4	36	6	6
5	36	4.8	7.5
6	36	4	9

   d. The frequency decreases as the wavelength increases. They are inversely proportional.
   e. See table below.

Harmonic	Speed (m/sec)	Wavelength (m)	Frequency (Hz)
1	36	12	3
2	36	6	6
3	36	4	9
4	36	3	12
5	36	2.4	15
6	36	2	18

   f. The shorter rope resulted in harmonics with shorter wavelengths. The second harmonic on the short rope is equivalent in terms of wavelength and frequency to the 4th harmonic on the longer rope.