Standing Waves

If two periodic waves with the same amplitude and wavelength travel in opposite direction, the resulting interference pattern is particularly interesting. This pattern can be viewed at the link below:

http://ngsir.netfirms.com/englishhtm/TwaveStatA.htm

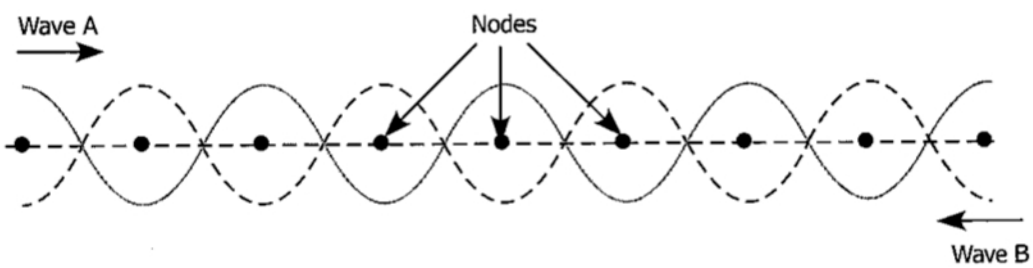
This pattern is interesting because, despite the fact that the medium vibrates up and down, the wave itself appears to stand still. It is, therefore, known as a **standing wave**.

Notice that there are points on the wave that remain perfectly at rest throughout the entire event. These points are called **nodes**. Nodes will occur every half wavelength on a standing wave.

Midway between two nodes is a point that experiences the maximum displacement from the rest position. This point is known as an **antinode**. Antinodes will occur exactly halfway between every pair of nodes.

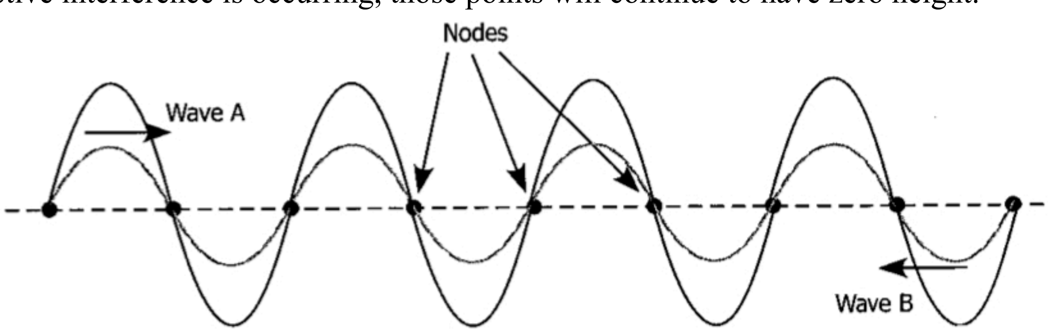
Formation of a Standing Wave

In the diagram below, wave A (solid line) is moving to the right while an identical wave B (dashed line) is moving to the left. At the moment shown, the two waves are directly on top of one another. In this case, destructive interference occurs at every point on the medium. The resultant shape of the whole medium is that of a flat horizontal line.

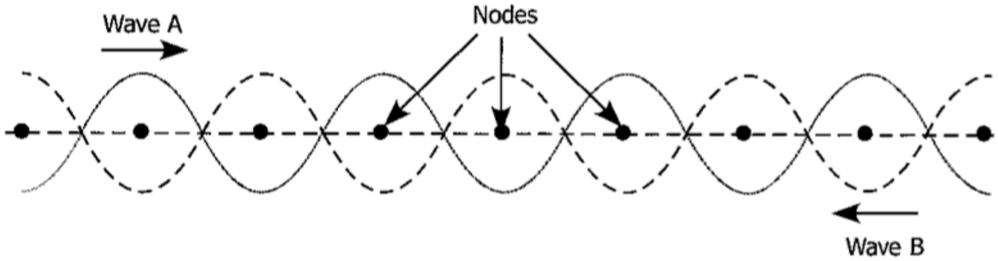


The two waves continue to move in such a way that troughs are soon over other troughs, and crests over crests. Constructive interference occurs and the magnitude of the resultant displacement is twice that of the individual waves.

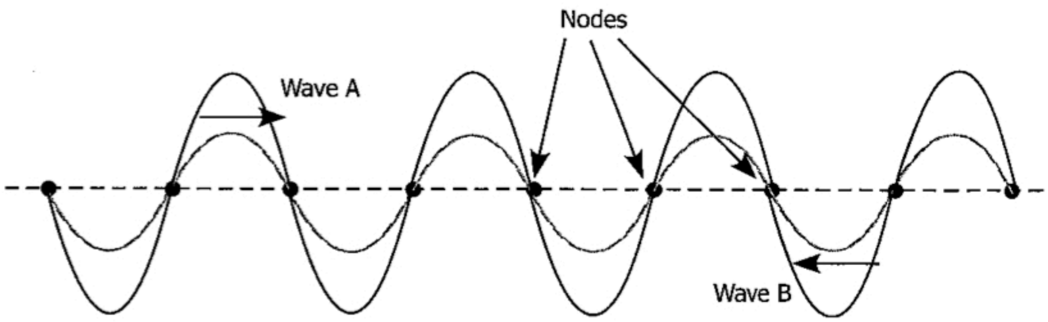
Note that at the points labeled as nodes, the height of both waves is zero. Even though constructive interference is occurring, those points will continue to have zero height.



A short time later, the waves have moved again to produce a net vertical displacement of zero. While this is the same as our first picture, note that wave A and wave B have traded places.



Finally, after another short bit of time, constructive interference will occur again. We again have the opposite of our last instance of constructive interference: a large trough occurs where we used to have a large crest, and a large crest occurs where we had a large trough.



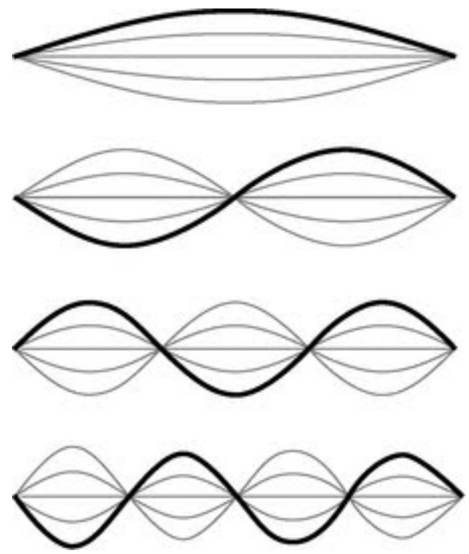
Notice that the nodes remain undisturbed throughout this entire process. The pattern described above continues for as long as the periodic waves continue to interfere.

Note: One of the easiest ways to produce a standing wave is by having a periodic wave interfere with its own reflection from a fixed end. The reflected wave acts exactly like wave B in our description above.

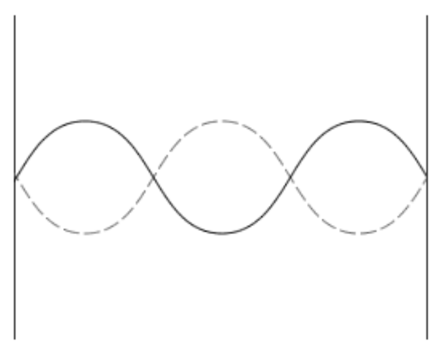
For a given length of rope (or any other medium), only certain wavelengths will produce standing waves. This is because the ends of the medium must be nodes or antinodes.

Standing Wave Pattern

When drawing standing waves, we usually represent them as shown below:



In each image, the darker line represents the current position of the wave, while the lighter lines represent the position of the wave at various other times. It is also acceptable to only show the position of the wave at the two extremes of its vibration, as shown below.



In each diagram, the positions of the nodes are clearly evident. You can also see where the antinodes occur.

Example

A wave is produced on a spring by shaking one end back and forth 15 times in $3.0\ s$. The waves travel down the spring and reflect from the fixed end. The incident and reflected waves interfere to produce a standing wave with nodes that are $0.40\ m$ apart.

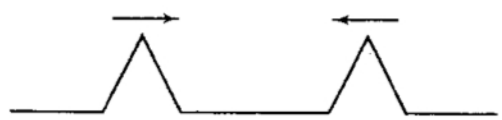
a) What is the frequency of these waves?

b) What is the wavelength of these waves?

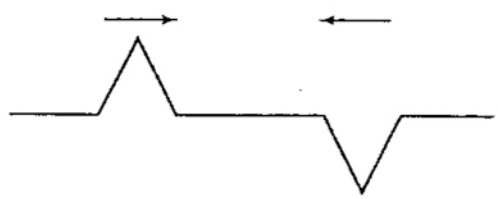
c) What is the speed of these waves?

Waves Worksheet #3

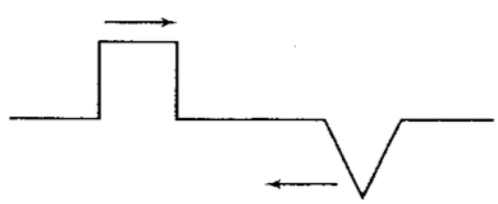
1. Two triangular pulses, each 2 cm high and 1 cm wide, were directed toward each other on a spring, as shown. Sketch the appearance of the spring at the instant that they met and completely overlapped. What kind of interference is this?



2. Two triangular wave pulses, each 2 cm high and 1 cm wide, were directed towards each other along the same spring. However, the pulse approaching from the left was upright and the one approaching from the right was inverted. Sketch the appearance of the spring at the instant that the two pulses met and completely overlapped. What kind of interference is this?



3. An upright square pulse and an inverted triangular pulse were directed toward each other on a spring, as shown below. Sketch the appearance of the spring at the instant the two pulses met and completely overlapped. What principle did you use in constructing the shape of the spring for the instant at which the two pulses met? What does this principle state about how waves combine?



4. Describe what you would see when a standing wave was set up in a spring. Why is it called a standing wave?

5. What is a node? What is an antinode? Describe how the nodes and antinodes are distributed along the length of the standing wave pattern.

6. A string instrument vibrates at a frequency of $4.0\ Hz$, and the distance between the nodes is $0.30\ m$. What is the speed of the waves on the string?

7. The speed of a wave on a guitar string is $350\ m/s$. If the frequency of the standing waves is $420\ Hz$, how far apart are the nodes?