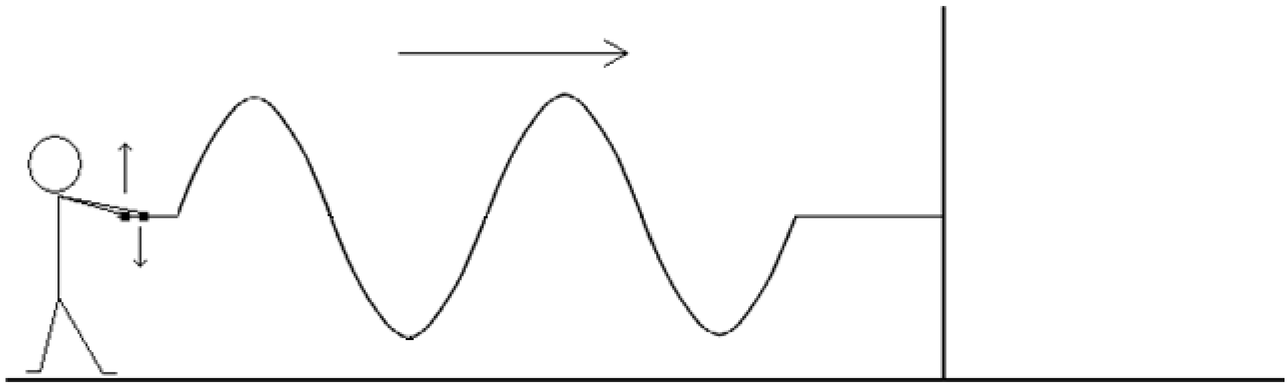
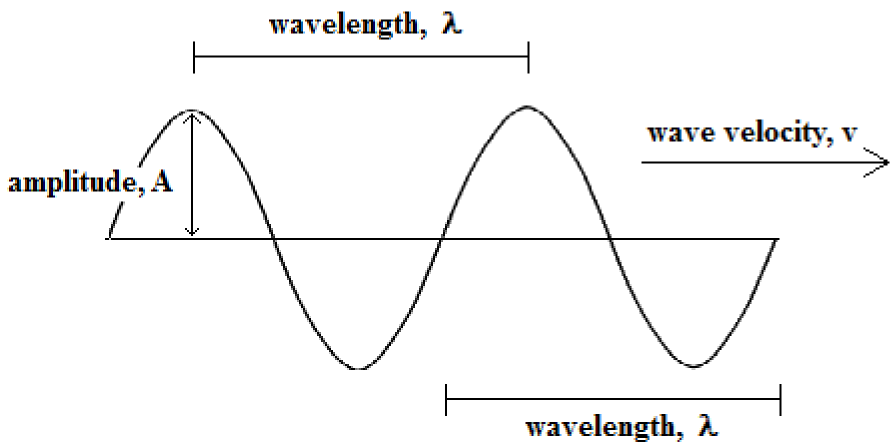
Waves

If you tie a long spring to a post at one end and hold the other end some distance away, you can make waves along the spring by oscillating your hands up and down.



If we extract the wave from the physical situation, it becomes easier to label various components.



Wavelength is symbolized with the Greek letter, λ. It is the distance along the wave from one peak to the next or, more generally, from one point in the wave formation to the next equivalent point.

The amplitude of the wave is the maximum position the wave form has from equilibrium.

The wave velocity is simply the velocity at which the wave propagates through the medium, here the medium of the long spring.

Lastly, suppose you watch the wave formations pass you from the side and you see two waves pass you every second. This would be the frequency of the waves, given the Greek letter nu, υ. In this case, $\upsilon = 2\frac{waves}{second}$ or 2 Hz

The time it takes one wave to pass you is the period of the wave, *T*. If two waves pass you per second, then the period of a single wave is just 0.5seconds. As with oscillators, period and frequency are reciprocals:

$T = \frac{1}{\upsilon}$ and $\upsilon = \frac{1}{T}$

If you then measure each wavelength to be 3m, you can tell immediately that the wave velocity is 6m/s. You seeing two waves pass you per second and each wave occupies a distance of 3m.

So, wave velocity equals wavelength times waves frequency.

$$v = \lambda \cdot \upsilon$$

Answer Webassign Question 1

Answer Webassign Question 2

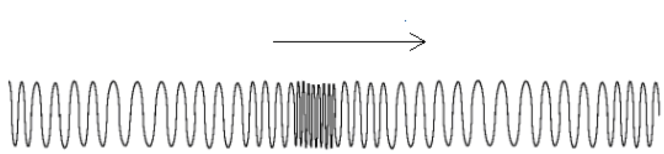
For a wave on a string, the velocity it travels at depends upon the tension in the string, *T*, the mass of the string, *m*, and the length of the string, *L*. Sometimes, this denominator is written as the mass density of the spring, μ = m/L.

$$v = \sqrt{\frac{T}{m/L}} = \sqrt{\frac{T}{\mu}}$$

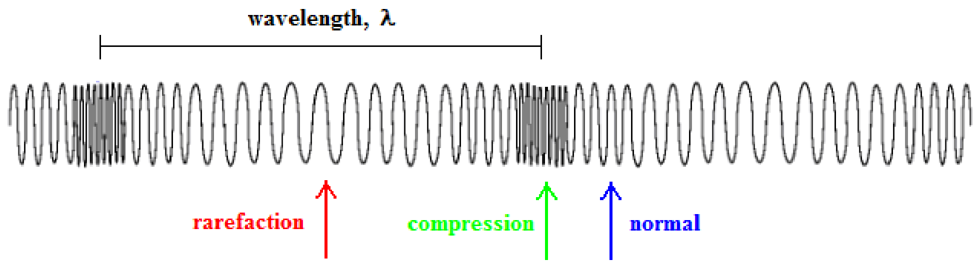
Answer Webassign Question 3

The example above is called a *transverse wave* because each little piece of the spring is oscillating up and down while the wave itself moves right, perpendicular to the motion of the spring segments.

The other common type of wave is a *longitudinal wave*, in which the components of the medium move parallel to the wave velocity. An example of something like this would be if you stretch out a Slinky, pull back a small segment at the end, and let it go. This little compression of coils will propagate down the Slinky with the coils moving parallel to the direction in which the pulse is traveling.



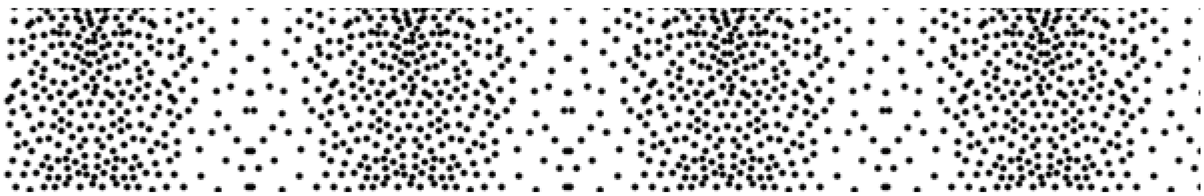
Segments of the Slinky that are closer together than normal are called *compressions*. Sections which are farther apart than normal are called *rarefactions*.



If you were holding the left end of this spring and the right end was attached to a block on a frictionless surface, you could send down waves and make the block slide back and forth. So waves are a means of transferring energy and momentum without an overall displacement of the medium (the Slinky itself does not move as a whole from left to right). And because the energy of a spring is proportional to how far it is stretched squared ($U_{spring} = \frac{1}{2} \cdot k \cdot x^2$), the energy in a wave is proportional to the square of the wave's amplitude ($E_{wave} \propto A^2$).

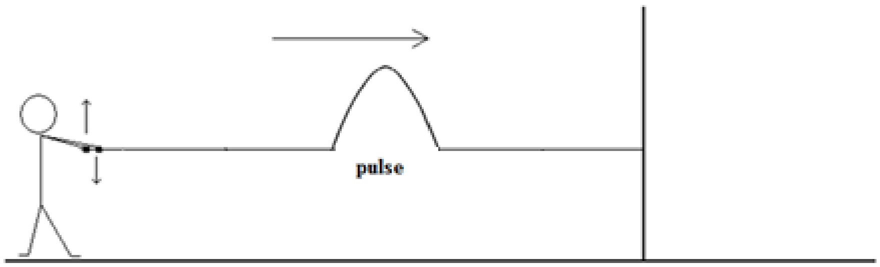
Answer Webassign Question 4

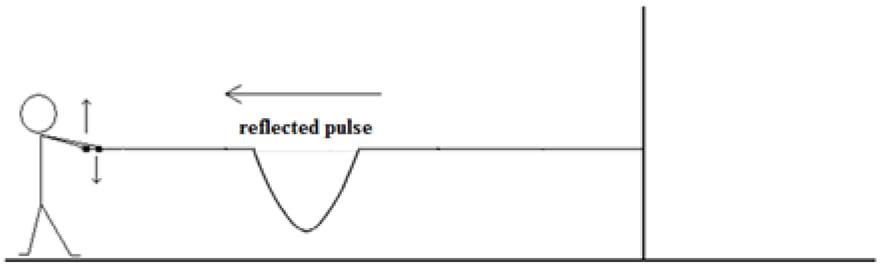
Sound waves are also longitudinal waves. Instead of compressed and expanded Slinky coils, they are made of high and low densities of air molecules.



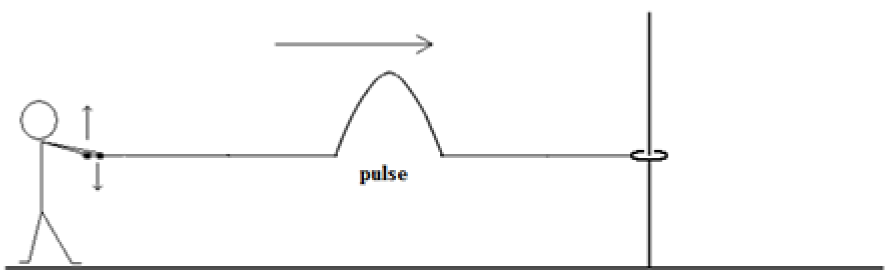
The frequency of the waves is related to the pitch we hear; the loudness is related to the amplitude of the compressions and rarefactions (how much they vary from normal, atmospheric pressure).

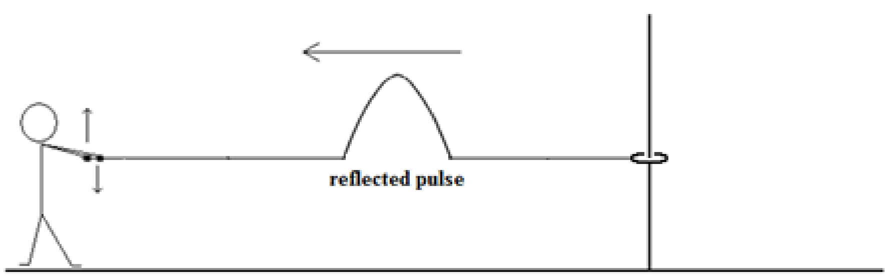
Suppose you send an upward pulse down a string towards a post the other end is tied to. When the pulse strikes the post, it will pull up on the post with its tension. By Newton's third law, the post will pull down on the rope, creating its own pulse that travels back towards you. This is called reflection from a *fixed boundary*.



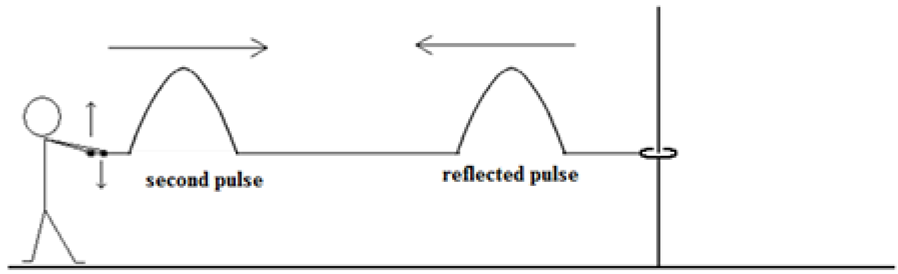


If the rope at the right end is not tied to the post, but is instead tied to a ring which is free to slide up and down, this is called a *free boundary*. When the upward pulse strikes the free boundary, it is reflected back toward you, but not inverted.

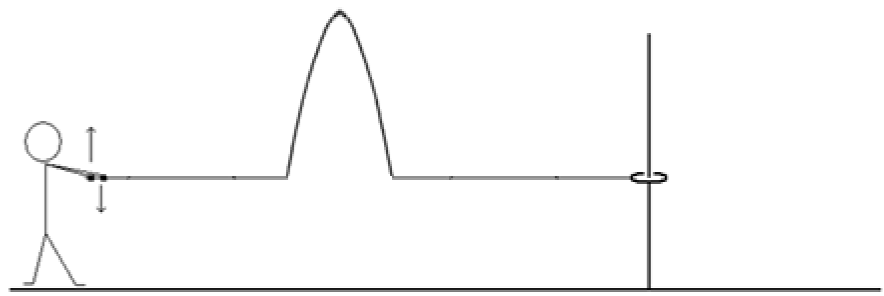




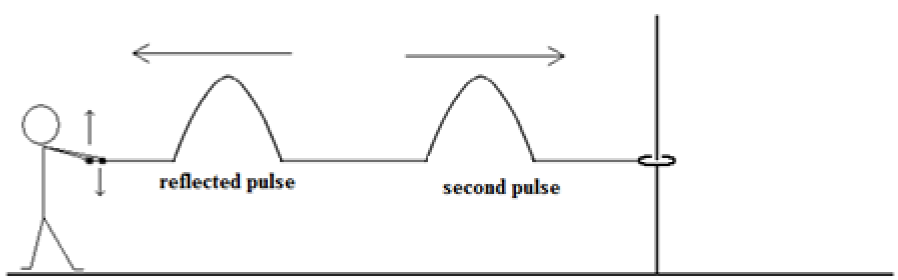
Lastly, if you send down a second pulse while the reflection of the first is heading back towards you, the two waves will strike each other.



When they do, there is *wave interference* and what you see is simply the superposition of the two waves added together. At the instant they overlap exactly, you would see this:



The two pulses would then continue through each other:



Answer Webassign Question 5

To review:

$$v = \lambda \cdot \upsilon$$

where v is wave velocity
λ is wavelength
υ is wave frequency

The wave period is the time of one wave and is reciprocal to the wave frequency.

In a transverse wave, particles of the wave move perpendicular to the wave velocity.
In a longitudinal wave, particles of the wave move parallel to the wave velocity.

A fixed boundary will reflect waves with an inversion.
A free boundary will reflect waves without an inversion.

Wave forms can be added together with the principle of superposition.