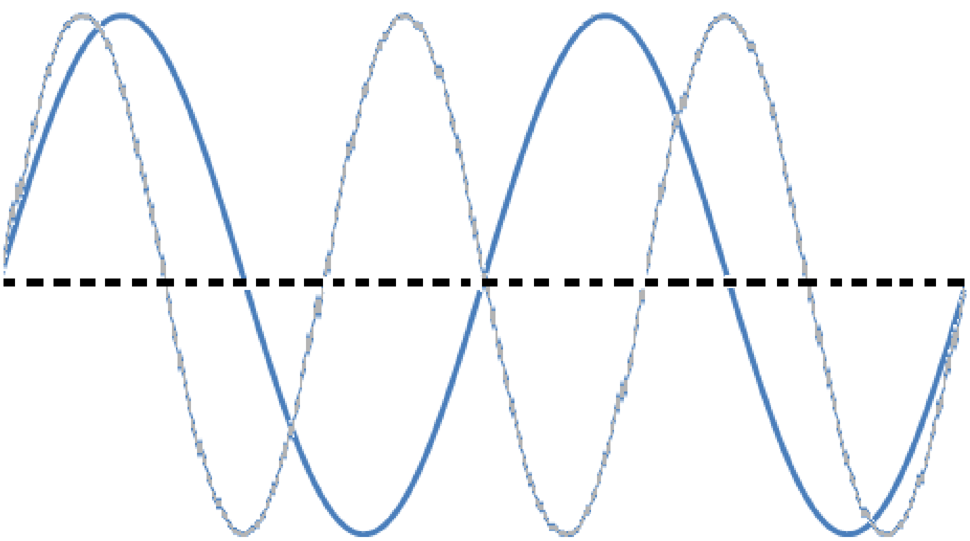
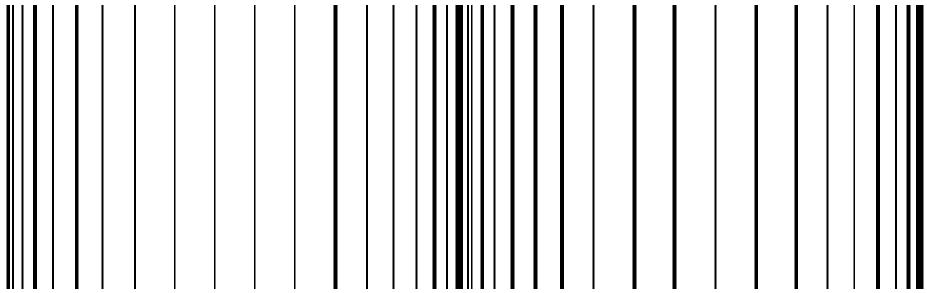
Mechanical Waves

A mechanical wave is a rhythmic disturbance in a medium produced by mechanical energy applied to the medium. Wave motion starts with a vibration or an oscillation. To start with let's look at a simple oscillator in time – the pendulum. A pendulum is simply a string with a mass at the end that is allowed to swing back and forth under the influence of gravity. A pendulum has a natural rate of swing based on its length. The time it takes to make one complete back and forth swing is its period. Period is simply time and is measured in units of time, seconds in the SI system. The number of complete swings a pendulum makes in a certain amount of time is known as the frequency. The frequency of a pendulum is the inverse of its period and the units are the inverse time units, 1/second or Hertz (Hz). So a pendulum represents a simple oscillation or repeating motion. A wave, then, starts with this regular repeating motion and also transmits energy through a substance (medium) or even through empty space.

There are two types of waves, transverse and longitudinal. The main characteristics of any wave are its frequency and period, as defined with the pendulum, as well as its amplitude, wavelength, and wave speed. The picture of a wave that may be most familiar to you is that of a transverse wave. The visible parts of a ***transverse*** wave include the **crest, trough, wavelength, amplitude, and rest position.** The frequency and period are not as obvious, however, a higher frequency transverse wave picture would have more wave crests in the same space. and a resulting shorter wavelength. The picture below shows two transverse waves of different frequency.



Visible parts of a ***longitudinal*** wave include the **compression, rarefaction, and rest position.**

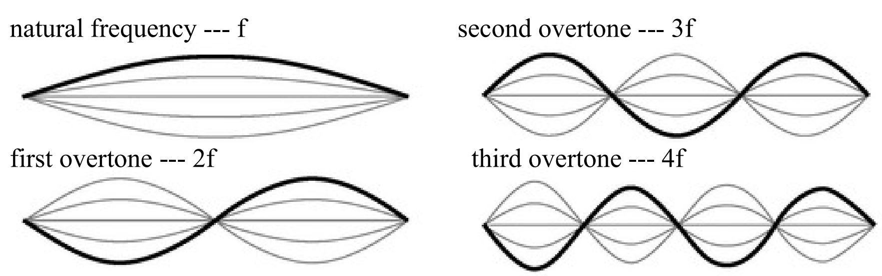


Be aware that we are looking at still pictures of energy in motion. Each wave above is showing the medium's response to that energy.

In a **transverse wave** the medium (the substance, represented by the curved line) is displaced along a line perpendicular to the direction of energy travel. The direction of energy travel is known as the wave's **propagation**. Each successive particle in the path of the energy is displaced proportional to the amount of the energy. This displacement is measured as the amplitude. The most distinct features of the transverse wave are the crests and troughs, which are basically the same parts simply opposing each other. The distance between two successive crests/troughs is the wavelength. The wavelength can be measured from any point along the wave to the same point where the wave begins to repeat itself.
With the **longitudinal wave** the medium is displaced along a line parallel to the wave's propagation. Each successive particle in the path of the energy is forced to oscillate back and forth along the wave's propagation. The medium being used for a longitudinal wave has areas of high and low density due to the oscillations. The areas of high density are called **compressions** and the areas of low density are **rarefactions**. The amplitude is the difference between the rest density of the medium and the density of the compressed or rarefacted areas of the medium. The amplitude can also measured as the displacement of the actual particles from their rest position, just as a transverse wave.
One last, and important quantity is how fast the wave is travelling. The most obvious way to find the speed of a wave is no different than any other speed calculation: you need a distance and a time for that distance. To be more specific to waves the most obvious distance is the wavelength and the time for that distance is the period. SO…the wavelength divided by the period is the wave speed. Or more conventionally…the wavelength times the frequency gives you the **wave speed**.

$$\mathbf{v = \lambda \cdot f}$$

The speed of a wave is constant so long as the medium does not change. With this in mind we can look at the two transverse waves above along with the wave equation and recognize that wavelength and frequency are inversely proportional...as the wavelength decreases as the frequency increases.
In addition to observing waves travelling through an unchanging medium it is also useful to observe how waves behave as the medium and its environment change. Reflection occurs when there is a barrier through which the wave cannot travel completely, if at all. The wave will bounce off similarly to a tennis ball off the floor according to the law of reflection. Wave interference occurs when two or more waves combine to produce a new wave pattern. This shows up in a simple transverse wave produced in a spring with two fixed ends (attached and unable to move). When a wave is generated in the spring it reflects off one end and travels back to the other end, repeating over and over as long as the wave is generated. At the ends the wave reflects and flips over, or the crest becomes a trough. When the wave is produced at the natural frequency of the spring you will observe a wave that appears to be simply oscillating up and down and no longer travelling along the medium. This is known as a standing wave where the wave is travelling back and forth between the ends of the spring. The oscillating crest is called an anti-node and the points between them where the is no oscillation is called a node. This picture shows four standing waves, the first is the natural frequency and the other three are overtones. The frequency of each overtone is a multiple of the natural frequency.



Refraction occurs when the speed of a wave changes due to a change in the medium, a light string to a heavy spring. This change in speed results in a change in direction if the wave is at an angle to the change in medium boundary. Diffraction is the bending of a wave around a barrier or through an opening. When the wavelength close to or larger than the barrier or opening the diffraction will be more noticeable. The Doppler shift is the apparent change in the frequency of a wave due to the relative motion of the wave source to the receiver. The frequency appears higher if the two are moving towards each other and appears lower if the two are moving away from each other.