Describing Waves

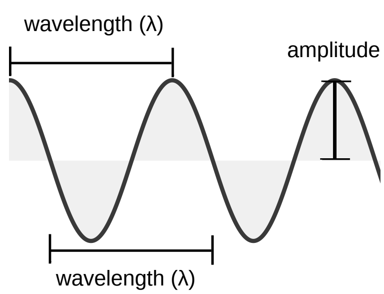
Skills to Develop

- Describe the basic wave properties and resonance
- Distinguish the 2 types of wave interference
- Explain the significance of standing waves

Understanding waves is essential to understand the rest of this section, because we will be talking about many different types of waves. Light has wave properties, and standing electron waves explain many chemical properties.

Basic Properties of Waves

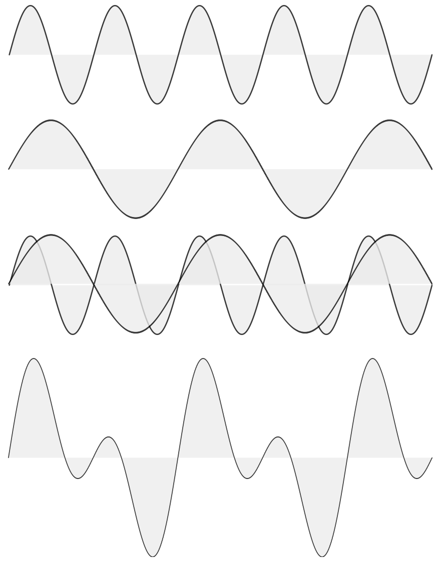
You have probably studied **waves** a little bit in a previous class. Waves include sound waves, ocean waves, and light waves. You have probably also studied sine and cosine waves in math class. Here will will review some of these topics. A wave is defined as "a periodic disturbance that moves through space." The disturbance could mean the high and low parts of an ocean wave, or the high and low pressure parts of a sound wave, etc. **Periodic** means that the disturbance repeats. As an example, consider a graph of y = sin(x). This is a wave. In this case, the **amplitude** is 1, because this is the distance between the average value of y and the maximum value. The **wavelength** is 2π. In non-mathematical waves, wavelength (abbreviated λ) is given in meters. A **cycle** is when the wave goes through one wavelength, so it ends at the same part of the wave where it started. The **frequency** of the wave is the number of cycles/second. So if you look at one position, you will see the wave go up and down at that point. The time it takes for the wave to go through one cycle at that point (from the top to the bottom to the top again) is the **period**. Frequency is 1/period, (we'll abbreviate it ν) and is usually reported in Hertz, which is just s^{-1}. You can think of it as cycles/second, but sometimes people use radians/second instead (you can convert between these using 1 cycle = 2π radians). Because wavelength is meters/cycle and frequency is cycles/second, wavelength x frequency is meters/second or velocity.



A wave, showing wavelength and amplitude.

Wave Interference

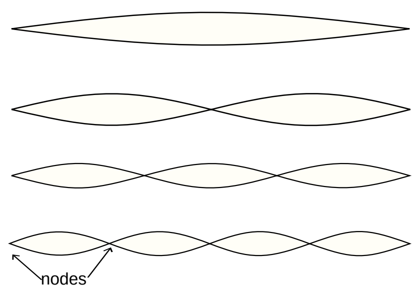
This describes what happens when waves interact with each other, or overlap. The best way to see what this means is to watch: try watching the video on the Double Slit experiment to see waves interacting. Basically, to find the total wave made of several different waves, you just add the amplitude at each point. For instance, if the high part (amplitude 1, say) of one wave overlaps the low part of another (-2, say, this wave is bigger), the result is a smaller wave (-1, here), called **destructive interference**. If the 2 peaks (high parts) overlap, then the wave get bigger, called **constructive interference**. In the graph below, the sum wave has big peaks in regions of constructive interference, and small peaks in regions of destructive interference.



Two sine waves, plotted separately (top), on the same axes (middle), and summed to show the total wave with regions of constructive and destructive interference (bottom).

Standing Waves

An important type of wave for us is a **standing wave**. Standing waves are present in musical instruments, and are how the instrument produces sound of the correct frequency (or pitch, the term used in music). Standing waves don't travel, because they are confined in the instrument. For instance, in a stringed instrument like a guitar or a violin, the whole string vibrates, but the wave doesn't travel because it is trapped in the string, and the string has end points (where it is attached to the instrument, or held down by the musician's finger). Because the ends are fixed in place, the amplitude at these points has to stay zero, but the amplitude in the middle of the string can change. This limits the wavelengths possible to the string. The properties of the string, like its mass/length and tension, will determine the velocity, and the frequency is determined from the combination of wavelength and velocity.



Harmonics, or standing wave frequencies, in a string.

What does velocity mean? The standing wave comes from the wave traveling down the string, reflecting off the fixed ends, reversing direction, reflecting again... when the frequency/wavelength/velocity all match up, the wave reflections reinforce each other, or interfere constructively, which is called **resonance**. Resonance generally describes a vibration that is reinforced by the particular properties of the surroundings because it matches their natural frequencies. When waves with the wrong wavelength bounce back they will cause destructive interference with themselves. The result is that the string can easily vibrate at its natural, resonant frequencies, but can't really vibrate at other frequencies because those waves cancel themselves out. For instance, a harp (an instrument with many strings) will laugh with you, because some of the strings will match some of the frequencies in your laugh and start to resonate, creating sound waves in the air. Here's a 1 min video of using resonance to break a glass. Here's an amazing video showing the location of 2-D standing waves using metal plates and the bow of a violin.

Outside Links

- Khan Academy: Introduction to Waves (13 min)
- Amplitude, Period, Frequency, and Wavelength of Periodic Waves (14 min)
- Brightstorm: Wave Interference (8 min)

- Veritasium: The Original Double Slit Experiment (8 min)
- Brightstorm: Standing Waves (10 min)

Contributors and Attributions

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