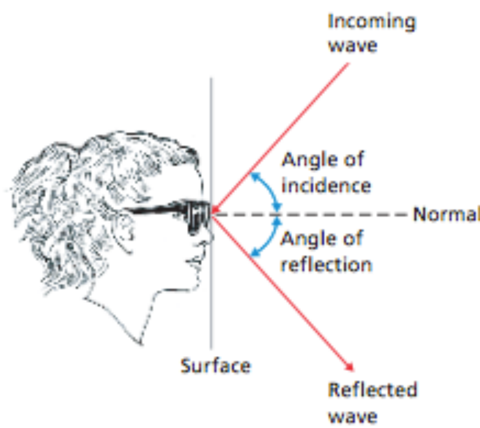
Interactions of Waves

It is a hot, sunny day. You are the first person to enter the calm water of the swimming pool. To test the temperature of the water, you dip one foot in first. Your foot causes a series of ripples to travel across the water to the far wall of the pool. As each ripple hits the wall, it bounces off the wall and travels back toward you.

Reflection



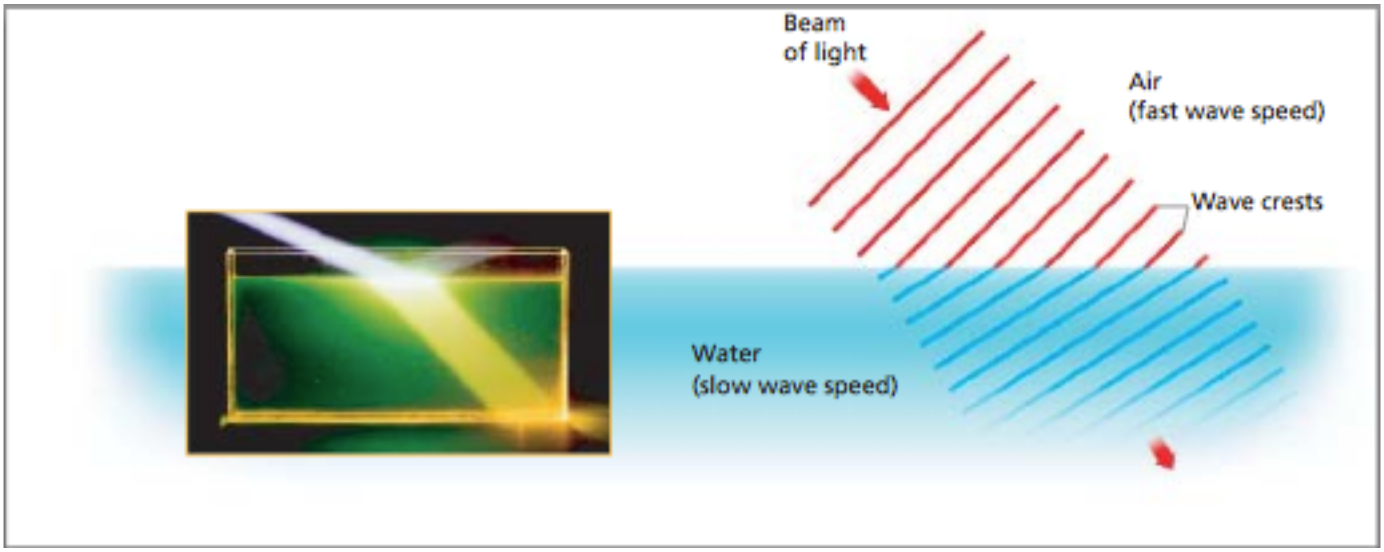
When water waves hit the side of a swimming pool, they bounce back. **When an object or wave hits a surface though which it cannot pass, it bounces back.** This is called **reflection**.

To show the reflection of a wave, draw a line to represent a surface. Draw another line to show a wave moving toward the surface at an angle. Now imagine a line perpendicular to the surface. The **angle of incidence** is the angle between the incoming wave and the imaginary perpendicular line. The **angle of reflection** is the angle between the reflected wave and the imaginary line. <u>The law of reflection states that the angle of reflection equals the angle of incidence</u>. All wave obey the law of reflection.

There are many examples of reflection in your everyday life. A ball that hits a wall bounces back, or is reflected. When you look in a mirror, you use reflected light to see yourself. An echo is an example of reflected sound.

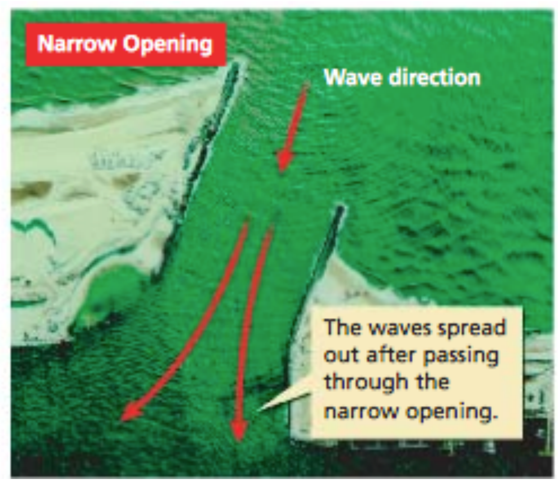
Refraction

Perhaps you have tried to grab a sinking object when you are in a swimming pool, only to come up empty-handed. Yet you were sure you grabbed right where you saw the object. You missed grabbing the object because the light rays from the object changed direction as they passed from the water into the air. **When a wave moves from one medium into another medium at an angle, it changes speeds as it enters the second medium, which causes it to bend.** The bending of waves due to a change in speed is called **refraction**. Bending occurs only when one side of the wave enters the new medium before the other side of the wave.



Diffraction

Sometimes waves can bend around an obstacle in their path. For example, waves can pass through a narrow entrance to a harbor and then spread outside the harbor. The picture on the right shows water waves that are diffracting as they enter a harbor.



When a wave passes a barrier or moves through a hole in a barrier, it bends and spreads out. The bending of waves around the edge of a barrier is known as **diffraction**. The picture above shows a water wave passing through a hole in a barrier and another bending around a barrier. In each case, you see the wave diffracting on the other side of the barrier.

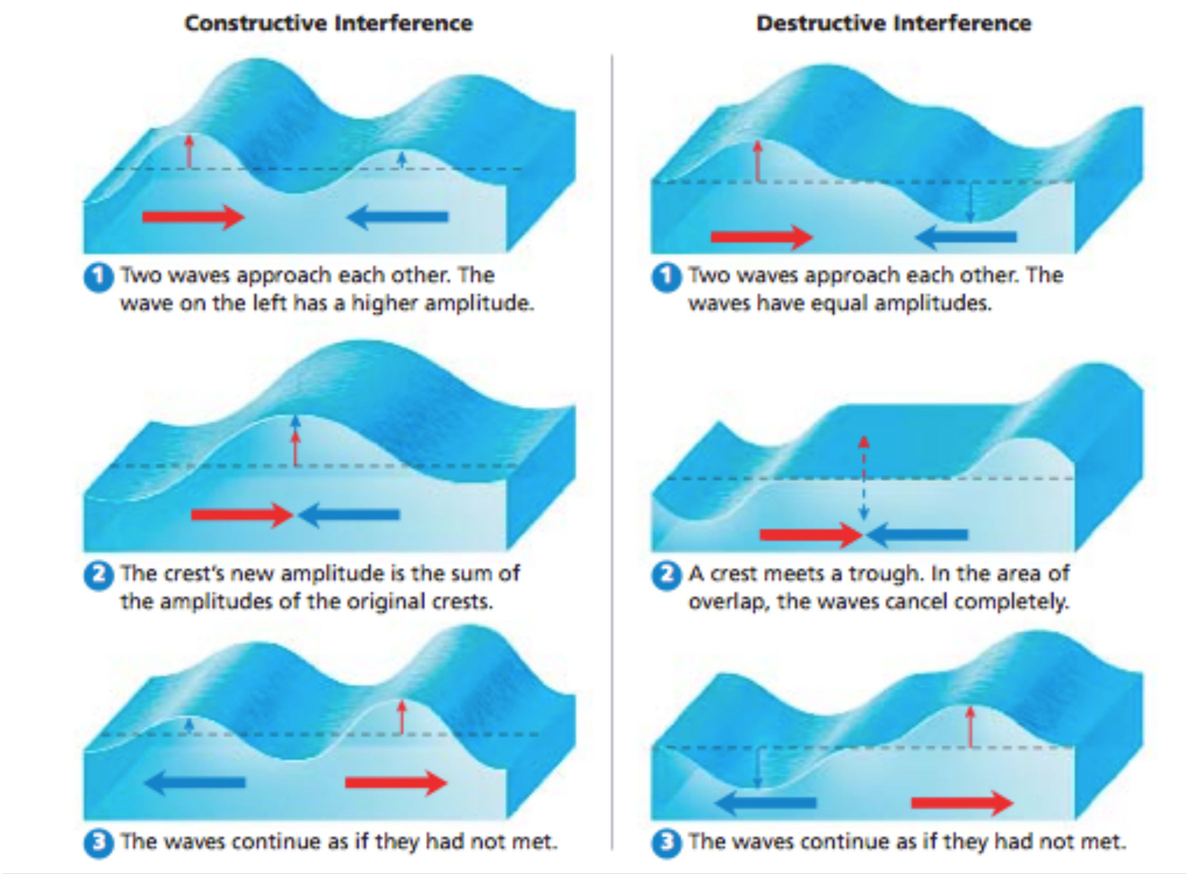
Interference

Suppose that you and a friend are each holding one end of a rope. If you both flick the ends at the same time, you send two waves towards each other. What will happen when those two waves meet? When two or more waves meet, they have an effect on each other. This interaction is called **interference**. There are two types of interference: constructive and destructive.

Constructive Interference: **Constructive interference** occurs whenever two waves combine to make a wave with larger amplitude. You can think of constructive interference as waves "helping each other" to give a stronger result, or combining energy.

Sometimes two identical waves (same amplitude, same wavelength) can be traveling in the same direction at the same time. If the two waves join together and travel along the same path at the same time… they will behave as one. What will the combined wave look like? The crests of the first wave will occur at the same place as the crests of the second wave. The energy from these two waves will combine. Thus the amplitude of the new wave will be twice the amplitude of either of the original waves.

If the waves have the same wavelength but *different* amplitudes (as shown here), the crests will still occur at the same place and add together. The resulting amplitude will be the sum of the two original amplitudes. Similarly, the troughs will occur together, making a deeper trough than either wave alone.

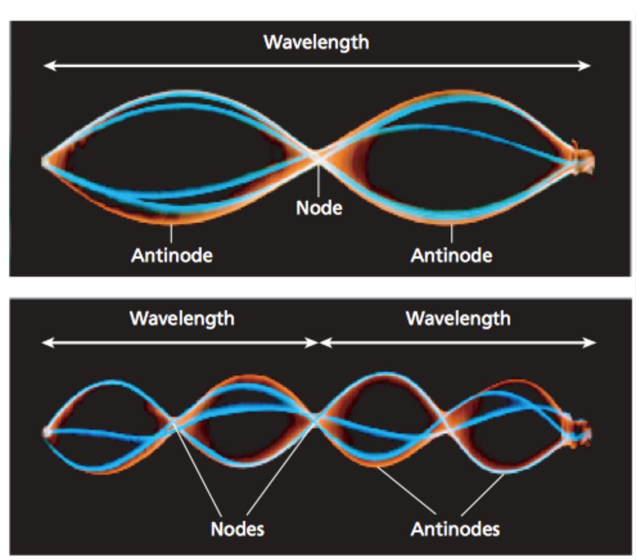


Destructive Interference: When the amplitudes of two waves combine with each other producing a smaller amplitude, the result is called **destructive interference**. What happens if the crests don't meet at the same place? In this case, one wave comes after the other. The picture above (on the right) shows what happens when the crests of the first wave occur at the same place as the troughs of the second wave. The amplitude of the first wave cancels out the amplitude of the second wave. This type of interference produces a wave with amplitude of zero. The original waves seem to be destroyed. If the two waves have different amplitudes, they will not cancel each other out but will combine to produce a wave with smaller amplitude.

Two identical waves can travel along the same path, one a little behind the other. When this happens, the waves combine constructively in some places and destructively in others.

Standing Waves

If you tie a rope to a doorknob and continuously shake the free end, waves will travel down the rope, reflect at the end, and come back. The reflected waves will collide with the incoming waves. When the waves meet, interference occurs. After they pass each other, they carry on as if the interference had never occurred. The same thing occurred when you and a partner made waves on a slinky by pushing on the slinky (from both ends) at the same time.



If the incoming wave and the reflected wave combine at the right places, the combined wave appears to be standing still. A standing wave is a wave that appears to stand in one place, even though it is really two waves interfering as they pass through each other. If you make a standing wave on a rope, the wave looks as though it is standing still. But in fact, waves are traveling along the rope in both directions.

Nodes and Antinodes At certain points, destructive interference causes the two waves to combine to produce an amplitude of zero. These points are called **nodes**. The nodes always occur at the same place on the rope. The diagram (on the previous page) also shows how the amplitudes of the two waves combine to produce amplitudes greater than zero. The crest and troughs of the standing wave are called **antinodes**. These are the points of maximum energy.

Resonance Have you ever pushed a child on a swing? At first, it is difficult to push the swing. But once you get it going, you need only push gently to keep it going. When an object is vibrating at a certain frequency, it takes very little energy to maintain or increase the amplitude of the wave.

Most objects have a natural frequency of vibration. Their particles vibrate naturally at a certain frequency. **Resonance** occurs when vibrations traveling through an object match the object's natural frequency. If vibrations of the same frequency are added, the amplitude of the object's vibrations increases.

An object that is vibrating at its natural frequency absorbs energy from objects that vibrate at the same frequency. Resonance occurs in music and adds a district quality to the sound.

If an object is not very flexible, resonance can cause it o shatter. For this reason, marching troops are told to break steps as they cross a bridge. If they all march across the bridge in perfect step, it is possible that the pounding could match the natural frequency of the bridge. The increased vibration could cause the bridge to collapse.