Wave Properties

4.2.1 Describe the reflection and transmission of one-dimensional waves at a boundary between two media.

When a wave encounters a boundary it does two things, it reflects backwards and transmits through the medium. Why? That has a relatively complex answer… (And you don't need to know or understand why for the IB exam.)

Waves travel at different speeds in different mediums. Sound travels much faster in metal than in air. Metal is much stiffer than air and can transmit the signal from one atom to the next much quicker. Think of try to push a bowling ball with a flexible stick (air) versus pushing the bowling ball with a stiff rod, which one will allow you to accelerate the ball the quickest (or easiest)?

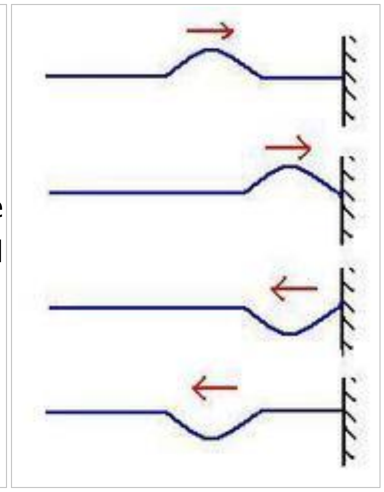
When a wave encounters a boundary its amplitude (energy) is "split" into a transmitted wave and a reflected wave. The ratio of transmitted amplitude to reflected amplitude is a function of the waves velocities in the two medium:

$Ar \propto v2 - v1\ v2 + v1\ AI\ AT \propto 2\ v2\ v2 + v1\ AI$

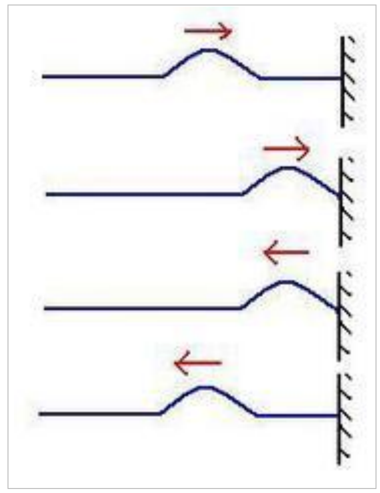
Where AR is the amplitude of the reflected wave, AT is the amplitude of the transmitted wave, AI is the amplitude of the incident wave (original wave), v1 is the velocity in the original material and v2 is the velocity in the second material. Notice that there will always be a reflected wave, but if the wave has a zero velocity in the second material there is no transmission. If a wave has zero speed in a medium, then it can not propagate in that medium…

The equations above work for waves of any type. But let's take two simple, but extreme examples of a half pulse traveling down the length of a rope.

Fixed End: In this case the end of the rope is attached to the end of the wall and can not move. The wave hits the wall and is reflected back, but the peak and become a trough!



Free End: In this case the rope is attached to the wall in such a way as to allow the end of the rope to move up and down but in no other direction. In this case the wave hits the wall and is reflected back, but the peak stays a peak!

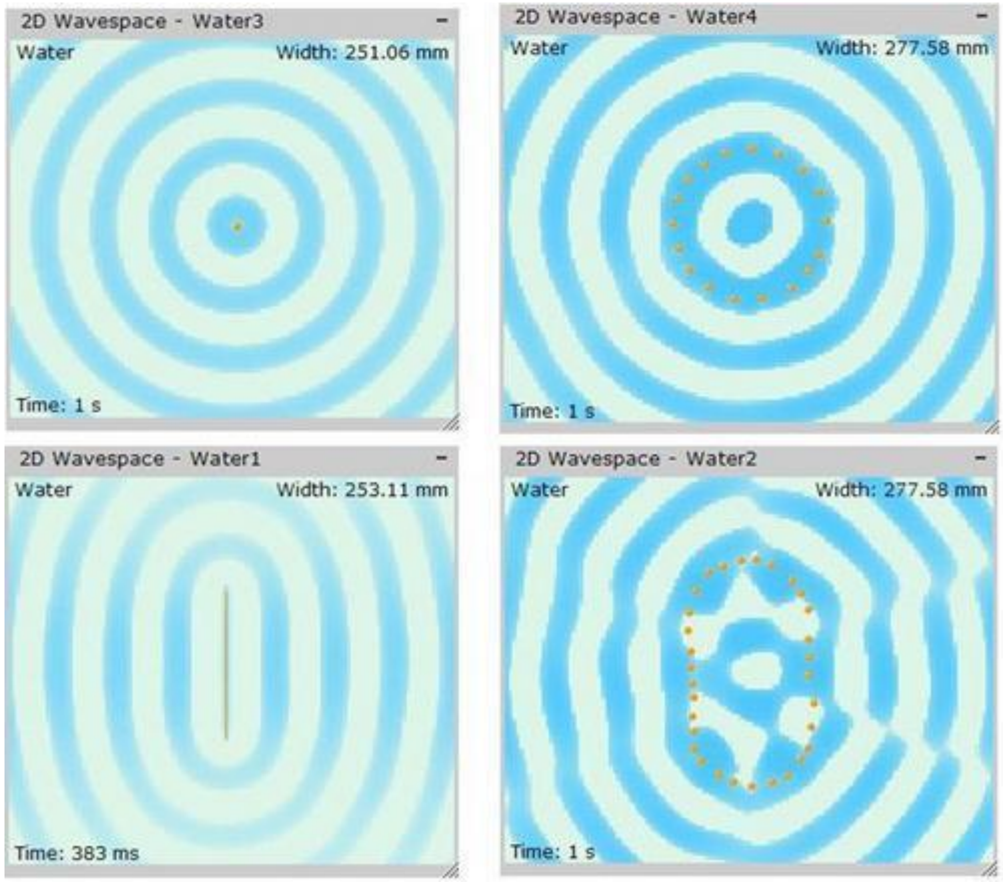


4.2.2 State Huygens' Principle

Huygens' Principle:

Every point on an advancing wavefront can be considered a source of secondary waves called wavelets. The new position of the wavefront is the envelope of the wavelets emitted from all points of the wavefront in it previous position.

What this means is that we can view the "next" peak or crest of an advancing wave as having been created by point sources lying on the previous peak or crest…

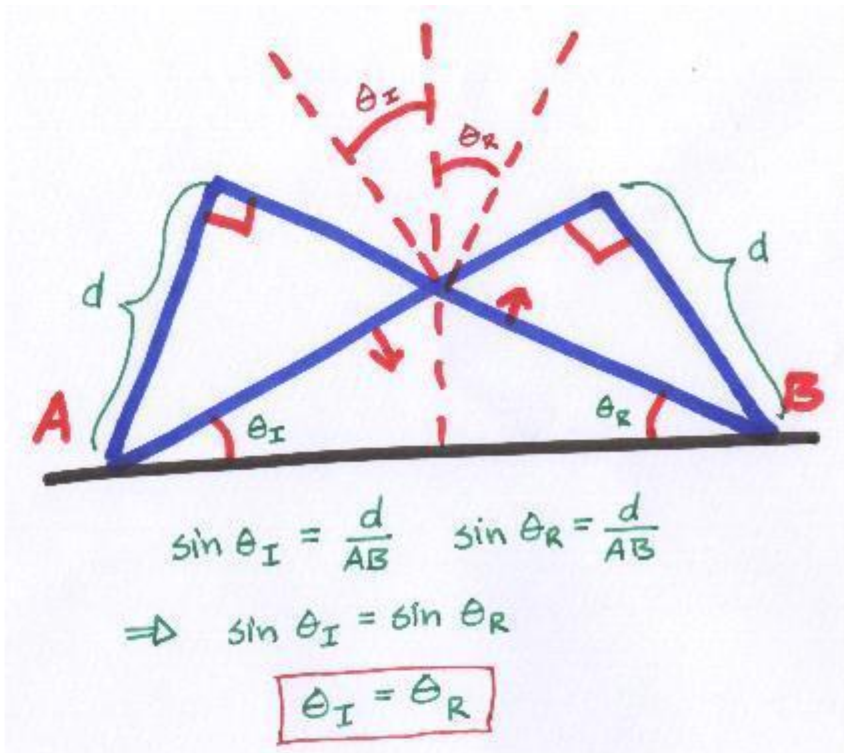


Images made using Crocodile Physics

The wavefronts generated by a point source are shown in the upper left. In the upper right; Using Huygens' Principle we can replicate the advancing waves of a point source by several point sources arranged in a circle, i.e. in the same shape as a wavefront generated by the point source. In the bottom left; a line source is generating wave fronts. Again the advancing wave fronts can be duplicated by several point sources arranged in an oval as shown in the lower right.

4.2.3 Apply Huygens' Principle to two-dimensional plane waves to show that the angle of incidence is equal to the angle of reflection.

We can use Huygens' Principle to demonstrate that when a wave reflects it will reflect at the same angle that it hit the obstacle.

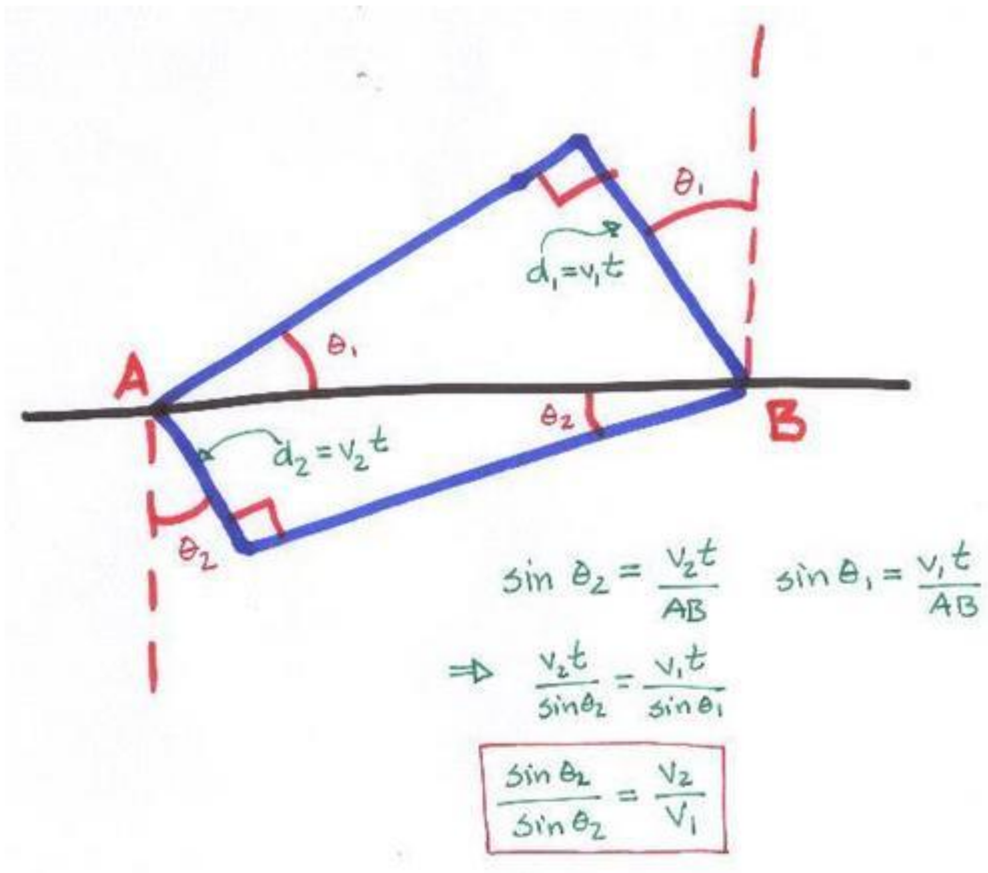


In the diagram to the left an incoming wavefront (ray) is incident to the reflective surface at an angle θI, When the wavefront reaches the surface at point A, the wave front must still travel the distance d to reach point B. When the wavefront reaches A, a new wavefront is formed by the wavelets generated at the reflective surface. When the original wavefront reaches B, the wavelet from point A is now a distance d from the reflective surface. Doing a little algebra and we get the result:

Or that the angle of incidence is equal to the angle of reflection.

4.2.4 Explain refraction using Huygens' Principle.

Refraction occurs when a wave enters a new medium, with a different propagation speed. This causes the wave to change direction. This is easily demonstrated by putting a meter stick in a fish tank, the stick does not appear straight, but appears to be kinked at the surface of the water.



Refraction can be explained using Huygens' Principle. It is a very similar argument used for reflection, but this time we are considering only the wave that is transmitted not reflected.

When the wave hits a surface at point A with an angle of θ1, the wave front still must travel the distance , where v1 is the speed of the wave in the first medium. When the wavefront reaches point B, the wavelets from point A have traveled a distance . Doing a little algebra we find that:

The angle of refraction, θ2, is dependent on the ratio of the velocities in the two mediums.

4.2.5 State and apply Snell's Law.

Light has a maximum speed in a vacuum, which the speed we are usually referring to when we say "the speed of light." In physics we give the speed of light in a vacuum the symbol, c. In every medium the speed of light will decrease. So we can define the index of refraction as:

(1)
$n = cv$

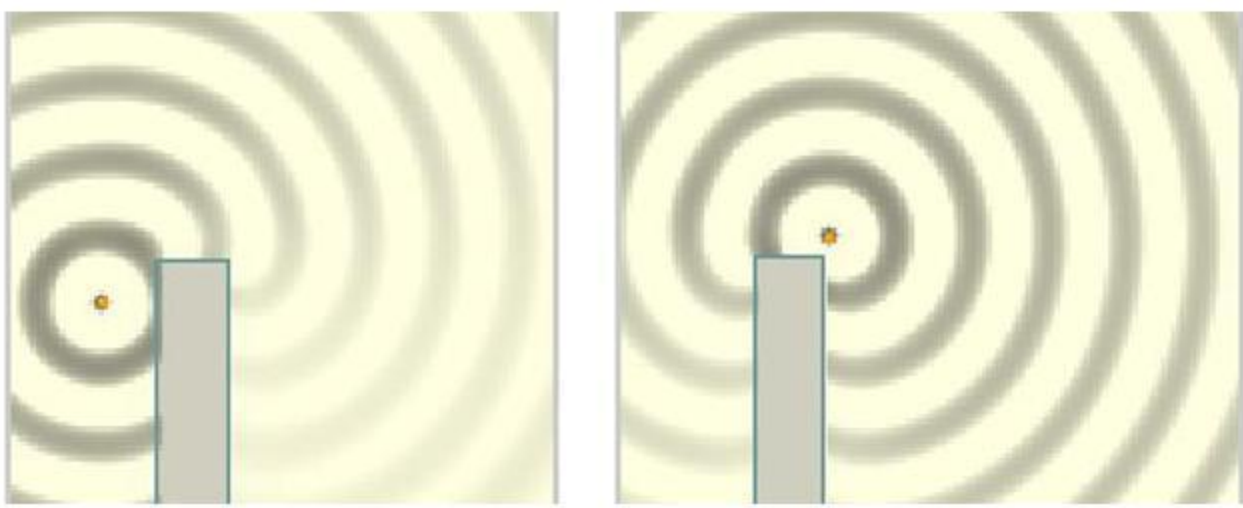
Since v can not be larger than c, n is always larger than 1. If we use this information along with the result from refraction we find what is now called Snell's Law:

(2)
$n1 \sin\theta = n2 \sin\theta$

4.2.7 Explain and discuss qualitatively, using Huygens' principle, the diffraction of waves by apertures and obstacles

4.2.8 Describe example of diffraction.

Diffraction is the phenoma of a wave "bending" around an obstacle. If you look at shadows the edges are not always sharp or well defined. The farther the object casting the shadow is from the shadow the less defined or the more blurred the edges of the shadow… This is because of diffraction. Diffraction can be explained by Huygens' principle:



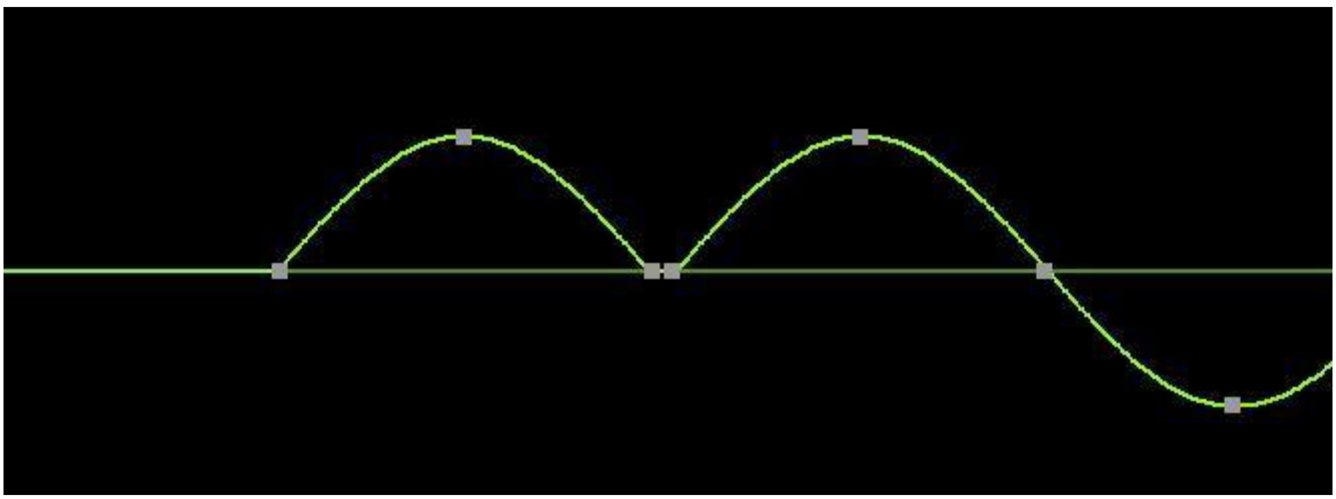
Images made using Crocodile Physics

On the left a point source is generating waves that diffract around the obstacle (simulated vaccum). If we instead imagine that at the corner of the obstacle there is a point source generating wavelets.

4.2.9 State the principle of superposition and explain what is meant by constructive and destructive interference.

4.2.10 Apply the principle of superposition and explain what is meant by constructive and destructive interference.

When two or more waves are at the same place at the same time, the net displacement is the sum of the amplitudes of the waves at the given point in space. The amplitudes can add to create a large displacement, this is called constructive interference. This occurs when two peaks or two toughs overlap. If a peak and a trough overlap the amplitudes subtract and create a small (or zero) amplitude, this is called destructive interference.



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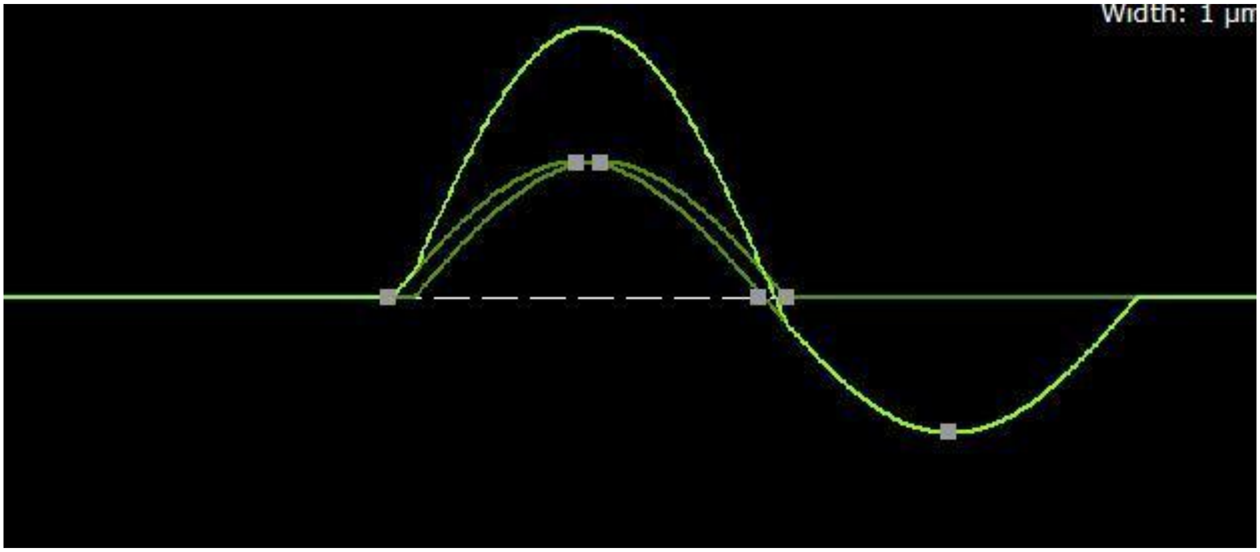
In the picture above a half pulse is traveling left to right and a full pulse is traveling right to left. In the picture above there is no overlap – no interference.



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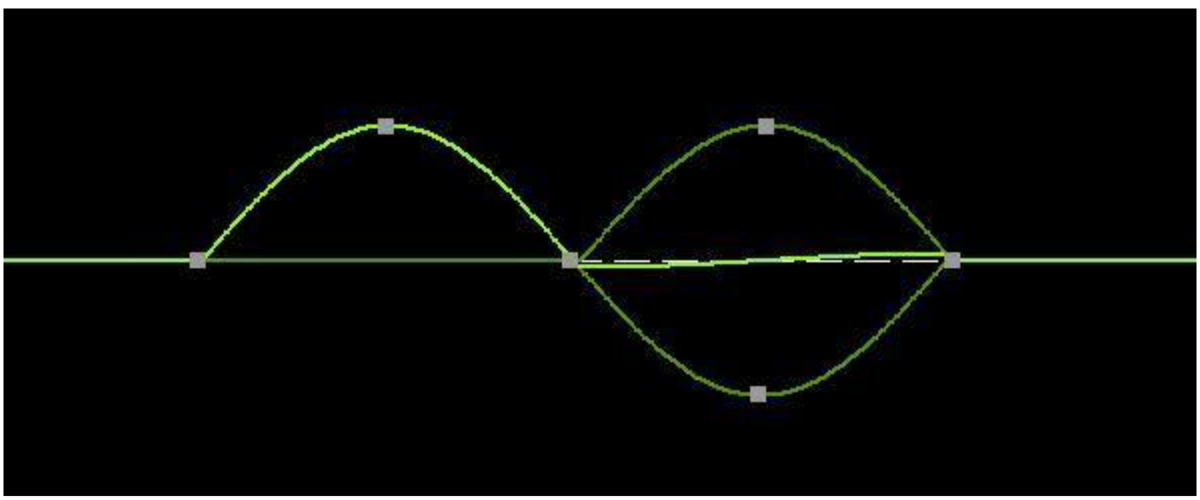
In the picture above the half pulse is overlapping with the peak of the full pulse. The result is shown by the bright green line with a larger amplitude. This is an example of constructive interference.



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In the picture above the half pulse is now overlapping the trough of the full pulse. The net displacement is nearly zero as shown by the bright green line. This is an example of destructive interference.

4.2.11 Describe the Doppler effect.

The Doppler effect is an apparent change in frequency of a source of sound (or other waves) when there is relative motion of the source and the listener. A Doppler effect is observed in all types of waves, however the Doppler effect with regards to light is fundamentally different than for sound or other types of waves that require a medium to propagate. To explain and/or derive the Doppler effect for light we must use Special Relativity. Want more info? Look at the Doppler effect notes.

Source: http://ibphysicsstuff.wikidot.com/wave-properties