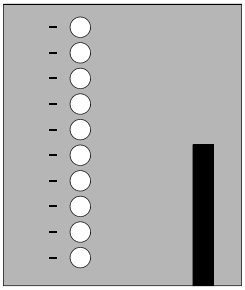
PhyzGuide: Diffraction

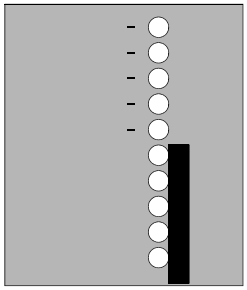
Why is broadcast channel 2 easier to receive than channel 83? Why can you receive AM radio stations—but not FM radio stations—from 100 miles away? Why do fog horns sound the way they do?

SNEAKING AROUND A BARRIER

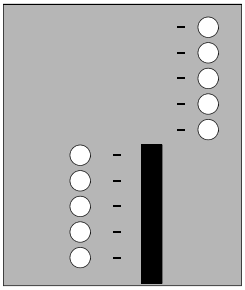
Suppose a line of marbles were traveling through space toward a barrier. What will happen when the marbles hit the barrier?



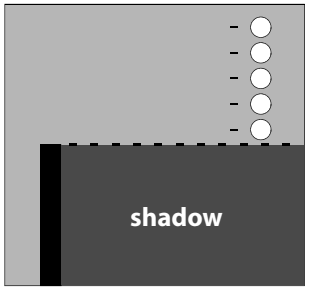
Marbles traveling through space toward a barrier.



Some marbles hit the barrier while others do not.

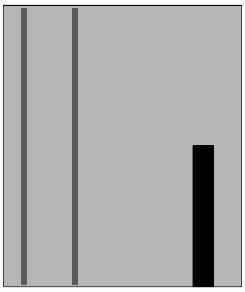


The marbles that hit the barrier bounce back; the others continue unaffected on their way.

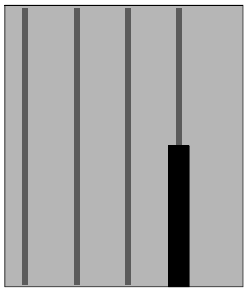


A shadow is formed behind the barrier. No marbles move into the shadow area.

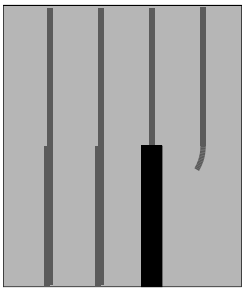
As might be expected, none of the marbles gets behind the barrier in the shadow region. This is the behavior of particles. But waves behave differently. Consider waves traveling through water toward a barrier. What will happen when the waves hit the barrier?



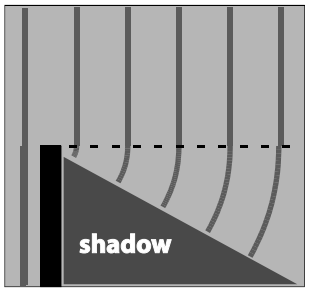
Plane waves traveling through water toward a barrier.



A portion of each wave hits the barrier while another portion does not.



The portion of each wave that hits the barrier reflects; the other portion continues past the barrier but bends around the barrier.

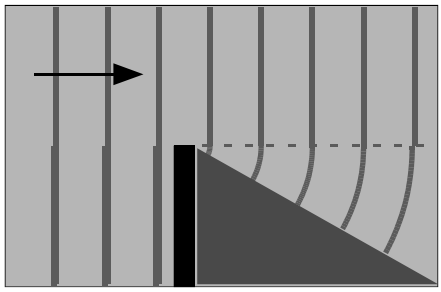


The shadow behind the wave barrier is smaller than the shadow behind the particle barrier.

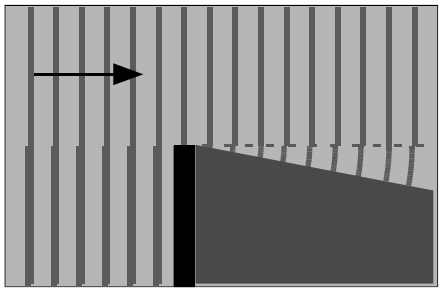
Some of the wave energy appears behind the barrier in what *should* have been a shadow region! This is the behavior of waves called **diffraction**. Diffraction is the bending of a wave around a barrier.

DIFFRACTION AND WAVELENGTH

The extent to which a wave bends around a barrier depends on its wavelength. As shown in the diagrams below, longer wavelength waves diffract to a greater extent than short wavelength waves.



Long wavelength waves are diffracted around the barrier.

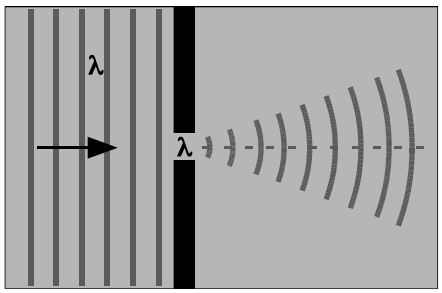


Short wavelength waves are diffracted around the barrier to a smaller extent.

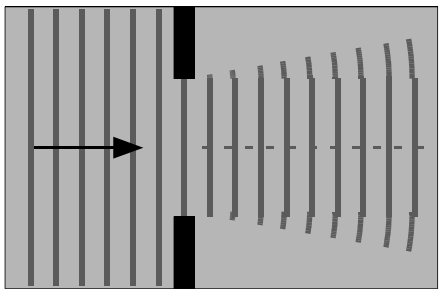
Since longer waves diffract (bend around a barrier) better than short ones, radio waves broadcast with lower carrier frequencies bend around barriers like mountains and the curvature of Earth itself. (Radio waves in the AM band have longer wavelengths than those in FM; television station numbers are related to the frequency of their carrier signals, so lower channel numbers use longer waves). Fog horn sound waves with longer wavelengths (lower frequencies) can bend around coastal irregularities.

DIFFRACTION AND OPENING WIDTH

Sometimes a wave train encounters a narrow opening in a wide barrier. When the opening is as wide as the wavelength of the wave, the wave is diffracted greatly, when the opening is much wider than the wavelength of the wave, the wave is diffracted much less.



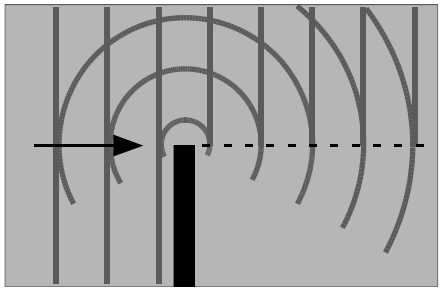
An opening (slit) as wide as the wavelength produces great diffraction.



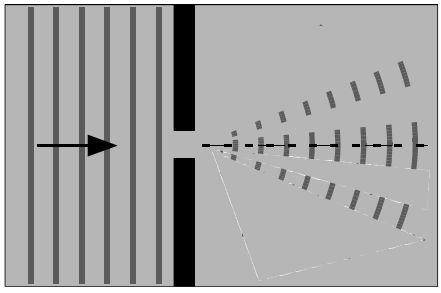
An opening (slit) much wider than the wavelength produces little diffraction.

DIFFRACTION AND INTERFERENCE

The images above never happen quite as shown. There is a complicating factor. A close examination of diffraction around a barrier reveals that the edge of the barrier itself behaves somewhat like a point source of new waves. This effect is exaggerated in the diagram below to the left. When waves pass through a narrow opening, there are two of these apparent point sources close to each other. And you know what happens when two point sources of waves are close together. Interference! So a more realistic image of the diagram above to the left is shown below to the right.



The edge of the barrier acts as a point source of waves.



The interference pattern resulting from waves passing through a narrow slit.