3.6.10.2: Diffraction Simulation

The simulation shows what happens to a planewave light source (below the simulation, not shown) as it passes through an opening. The wavelength (color for light, pitch for sound) of the waves and the size of the opening, a, are in the same arbitrary units (meters, cm, μm, etc.) and can be adjusted. The waves in the simulation represent light, sound or any other type of linear wave.

Simulation Questions:

1. Leave the opening width fixed and experiment with the wavelength of the waves. Describe what you see.
2. You should have noticed that for a long wavelength the opening basically becomes a point source of waves. The waves on the other side of the opening move outward in all directions. But once the wavelength is much smaller than the opening the waves do not spread as much and appear to be more like plane wave all headed in the same direction. Light, with it's very small wavelength, passes through a doorway without bending because the door is much larger than the wavelength. Sound, however, is a wave with wavelengths close to the size of the opening of a door. Explain why we can hear noise through a doorway to another room even though the source (a person, radio, TV. etc.) is not in our direct line of sight.
3. All optical instruments (telescopes, microscopes, even radio telescopes which look at radio waves instead of light waves) have openings to allow light in. This means diffraction will be a problem for that instrument for some sizes of waves. If you want to reduce the effects of diffraction for a particular instrument, would you want to try to use longer or shorter wavelengths? (Hint: Electron microscopes can provide much higher magnification because electron waves can be much smaller than light.)
4. Reset the simulation and leave the wavelength fixed while changing the size of the opening. Describe what you see. How does the opening size affect the diffraction pattern?

Advanced Questions:

Diffraction can also be explained as a type of interference resulting from a path difference from multiple sources. Recall in the ripple tank simulation of two sources waves from the source on the left must travel a longer path to get to a point at the top right of the simulation than waves from the source on the right. This path difference changes depending on how far to the right we look resulting in spots of destructive and constructive interference along the top. For a single opening instead of two separate sources we can imagine a row of many sources filling up the single opening. Again there will be a path difference from the different sources but the pattern will look different because there are now many sources lined up next to each other.

1. The formula for the location of destructive interference in the case of single slit diffraction is given by $\sin\theta_{dark} = m\lambda/a$ where a is the opening size and $m = 0, \pm 1, \pm 2, \pm 3 \ldots$ where a is the width of the opening and θ is the angle to each successive dark spot, labeled with the number m.
2. For 600 nm light and an opening of 0.01 mm, what is the angle (in radians) to the first minimum?
3. For the previous question, how far away would the screen have to be in order to have a 2 mm separation between the central maximum ($\theta = 0$) and the first minimum?
4. Red light has a longer wavelength than green light. Which color bends the least when going through a small opening, red or green?
5. What would be the result of shining white light through a small opening?