<u>Diffraction</u>

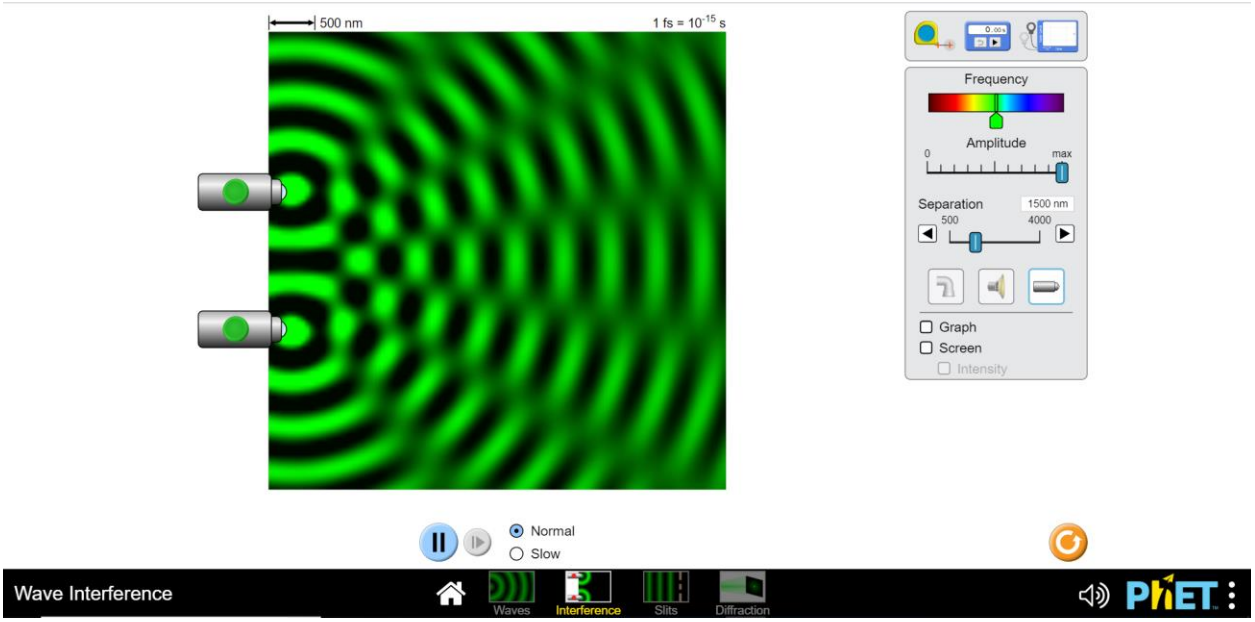
April 20, 2020

When two or more traveling sinusoidal waves are added together, interference phenomena result. If electromagnetic waves travel through objects that have sizes comparable to the wavelength of the waves, then the structural details of the objects can be deduced from the interference patterns. For example, the double helix structure of DNA was deduced from diffraction of X-rays of wavelength about 0.1 nm.

For our exercise, start here:

https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference_en.html

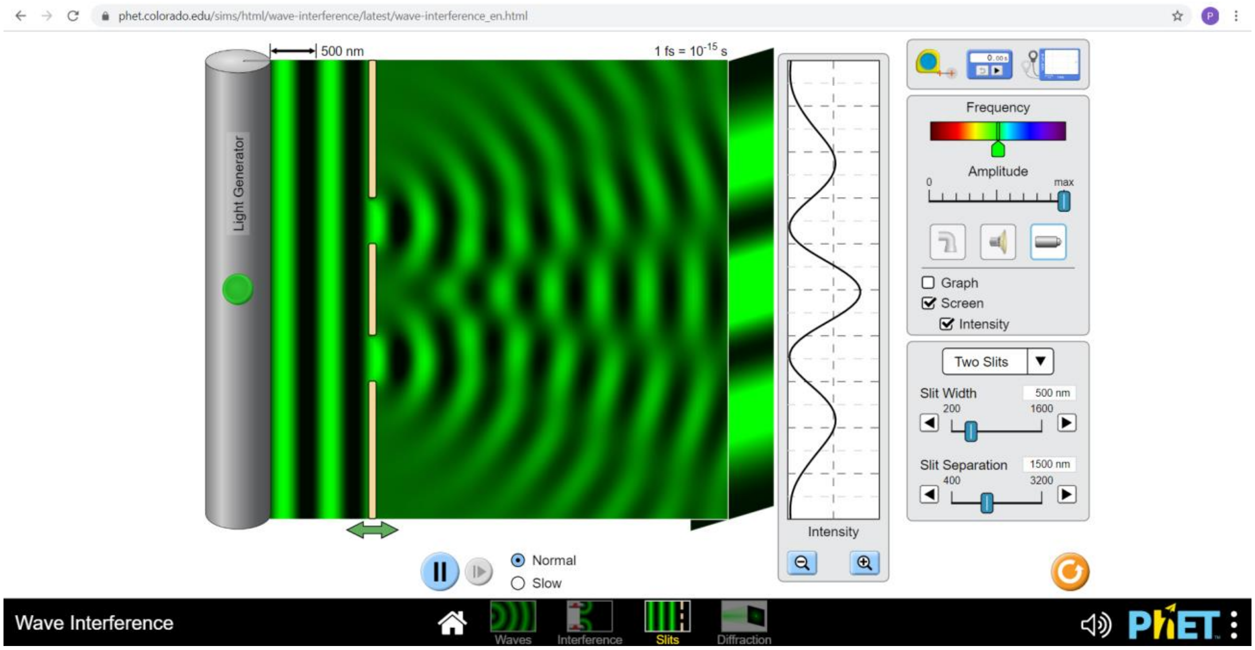
Click twice on the "Interference" icon. On the right side of the screen, select light sources. Then press the buttons on the two light sources to see the effects of interference between the light from the two sources. In particular, look at the dark gaps (I'll call them "fringes") in the pattern where the sinusoidal waves from the two light sources add up to zero.



Slide the frequency setting (upper right part of the screen) to violet (close to the right end of the spectrum) and look at the spacing between the dark fringes. Now slide the frequency setting to red, and look at the spacing between fringes again. Does the spacing between fringes depend on the wavelength of the light?

Now click on the "Slits" icon on the bottom of the interference screen.

First, select the light source in the middle gray box on the right side of the screen. Then turn on the light source by pressing the green button on the left side of the screen. Select "Two Slits" in the bottom gray box on the right side of the screen. Then drag the slits from the center of the screen to the left until they are one-quarter of the way from the source to the screen. Default separation of the slits is 1500 nm and default slit width is 500 nm. In the middle gray box on the right side, click on "Screen" to see what would be seen on a wall. The click on "Intensity" to show a graph of the intensity on the screen.

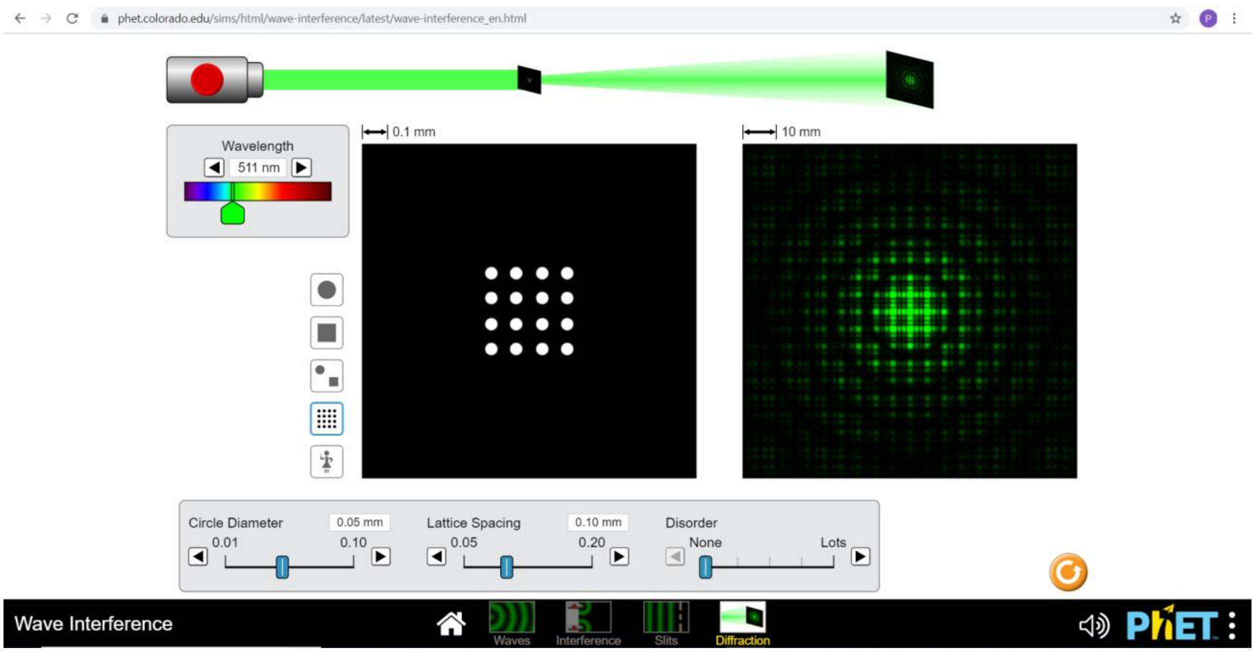


Using the graph, compare the distance between the peak of the central maximum (which I'll refer to as "n=0 maximum" for reasons that will become clear when you start working on problems) to the peak of the n=1 maximum (the first peaks on either side of n=0 maximum) for violet and red. Does the distance to the n=1 maximum depend on the wavelength of the light being diffracted?

Increase slit separation from 1500 nm (default) to 2500 nm. Does separation of n=0 and n=1 depend on slit separation?

Now click on the "Diffraction" icon on the bottom of the screen.

Turn on the light source (red button in the upper left hand corner of the screen), and then choose the lattice pattern of circles from the five patterns available on the left side of the screen. The diffraction pattern on the right side is the result of the interference of the light coming through each of the circles. The diffraction pattern can be altered by changing the lattice spacing (that is, the distance between circles) and the circle diameter. That is, the diffraction pattern can be used to decode the geometry of the feature through which the light is being shown.



British chemist Rosalind Franklin performed a measurement of the diffraction of X-rays of wavelength about 0.1 nm through DNA that led to the discovery of the double helix structure. The famous "Picture 51" from that experiment is shown below. The illustration is taken from a 2018 paper in the *American Journal of Physics*:

https://aapt.scitation.org/doi/10.1119/1.5020051

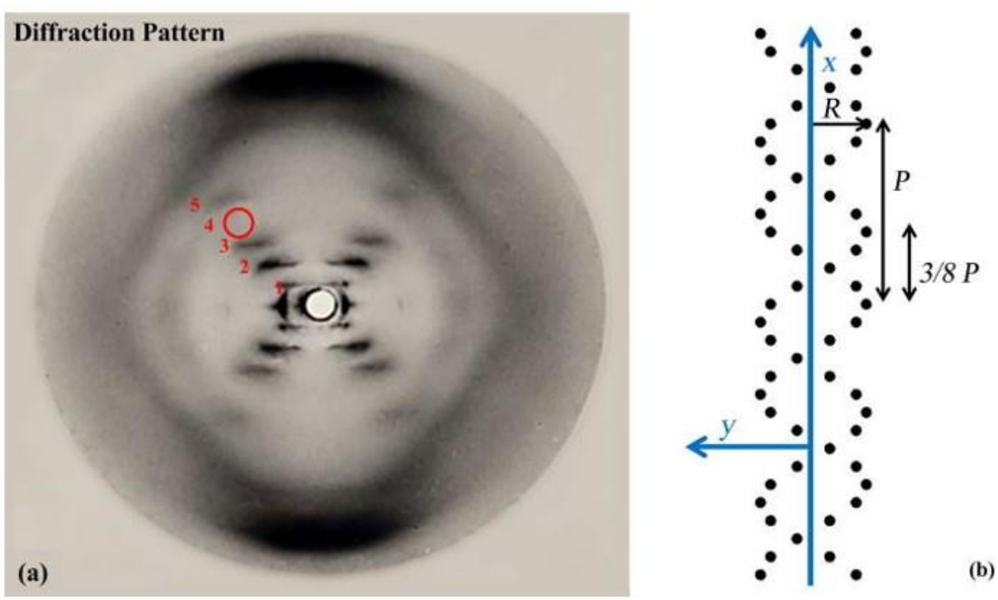


Fig. 1. (a) The well-known Photo 51, the diffraction pattern from DNA in its so-called B configuration. The dimensions of DNA are: pitch P = 3.4 nm, radius R = 1 nm, and a phase difference between the two helices (sine waves) of ΔP = 3P/8. Several important features include the characteristic X-shape or distorted rhombus, the ten diffracted orders per X, and the missing fourth order. (b) A two-dimensional projection of the phosphate molecules in the DNA backbone. The projection outlines two sine waves. We justify this flat model theoretically in Sec. II.