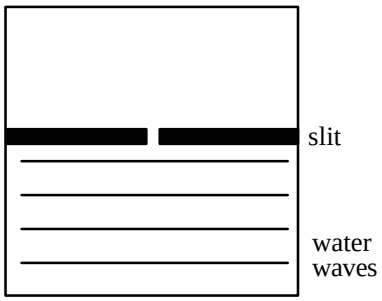
Wave Particle Duality

I. Water Waves

Consider linear water waves incident on a slit that is narrower than the wavelength of the waves. (See figure at right.) Sketch your prediction for the appearance of the water on the other side of the slit.

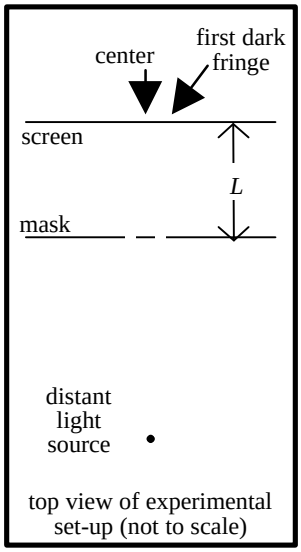


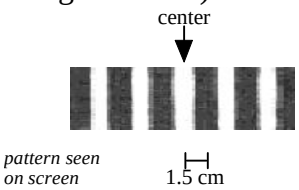
After sketching your prediction, obtain a photograph of this experiment from a staff member. If necessary, resolve any discrepancies.

II. Light

A. Wave Properties

1. Consider light with wavelength l = 500 nm incident on two identical narrow slits. The widths of the individual slits are less than l, the slits are separated by a distance d = 30 μm, and a screen is located a distance L from the slits (see figure at right). An interference pattern is observed on the screen with the location of the first dark fringe 1.5 cm from the center (see figure below).





How much farther is the left slit from the first dark fringe than the right slit? Explain how you know.

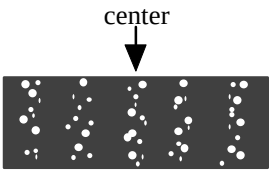
Use your result to calculate the distance L. Show all work.

2. Suppose the left slit is covered so that light can only pass through the right slit. Describe how, if at all, the appearance of the screen would change. Explain your reasoning.

Is your answer consistent with your description of water waves in Section I? If not, resolve the discrepancy.

B. Particle Properties

1. The experiment described in part A1 is repeated except that the intensity of light is lowered so that only one photon at a time is incident on the slits. Furthermore, the screen is replaced by photographic film. The resulting pattern on the film is shown at right.



   Discuss what aspects of this experiment are consistent with light acting like a wave.

   Discuss what aspects of this experiment are consistent with light acting like a particle.

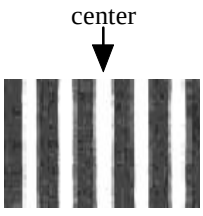
2. Suppose one of the slits is covered so that photons can only pass through one of the slits (one at a time). Describe how, if at all, the appearance of the film would change. Explain your reasoning.

III. Electrons

A. Wave Properties

1. Consider electrons with energy E = 24 eV incident on two identical narrow slits.

   An interference pattern is observed on a screen located on the other side of the slits (see figure at right). Discuss what this observation suggests about the properties of electrons. Explain.



Suppose that the slits are separated by a distance d = 0.5 μm; the distance between the center of the pattern and the first bright region is 1.0 mm; and the distance between the screen and the slits is 2.0 m. Use the results of this experiment to determine the wavelength of the electrons. Explain how you arrived at your answer.

You may find some of the following information useful:

$\hbar c$ = 200 eV-nm
$(Ke^2/\hbar c) = 1/137$
mc^2 = 511 KeV

Is your answer consistent with de Broglie's relations? Explain.

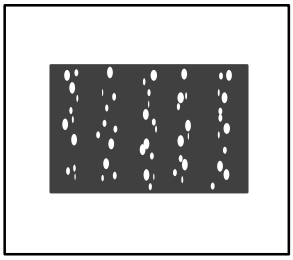
2. How would the appearance of the screen change if the energy of the electrons were doubled? Explain.

3. Suppose the experiment in part 1 is repeated except that one of the slits is covered so that electrons can only pass through one of the slits. Describe how, if at all, the appearance of the screen would change. Explain your reasoning.

Is your answer consistent with your description of light going through one slit? If not, resolve the discrepancy.

B. Particle Properties

1. The experiment described in section III part A1 is repeated except that the flux of electrons is lowered so that only one electron at a time is incident on the slits. The resulting pattern is shown at right.



   Discuss what aspects of this experiment are consistent with electrons acting like a wave.

   Discuss what aspects of this experiment are consistent with electrons acting like a particle.

2. Suppose one of the slits is covered so that electrons can only pass through one of the slits (one at a time). Describe how, if at all, the appearance of the screen would change. Explain your reasoning.

IV. Comparison

In what way do electrons behave like light? Support your answer with evidence.

In what ways are electrons different from light? Support your answer with evidence.