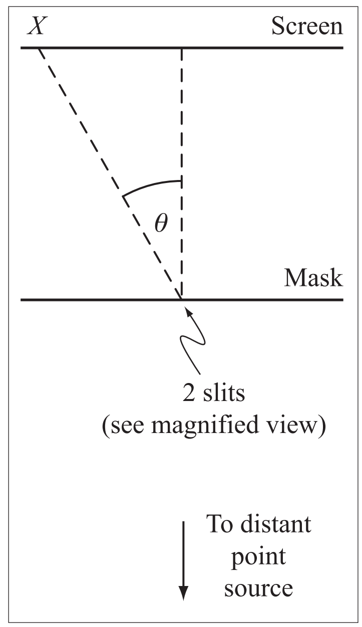
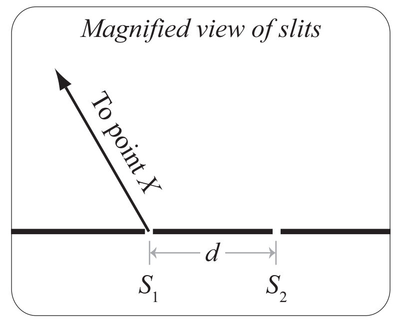
I. Review of two-slit interference of light

Light of wavelength λ from a distant point source is incident on two very narrow slits, S_1 and S_2, a distance d apart. (See illustrations below.) The diagram at right shows the pattern seen on a distant screen.

Pattern on distant screen

In the magnified view of the slits, an arrow is drawn showing the direction from slit S_1 to an arbitrary point on the screen, point X.





A. On the magnified view:

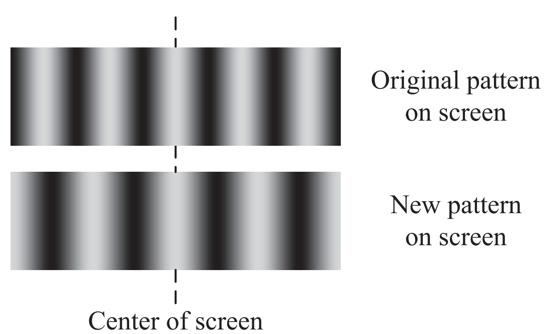
- Draw an arrow to show the approximate direction from slit S_2 to the *distant* point X.
- Identify and label the line segment that represents the path length difference from the slits to point X.

For small angles θ (where θ is measured in radians), what is the approximate path length difference?

B. For what values of the path length difference (in terms of λ) will there be:

- maximum constructive interference *(i.e.,* a *maximum)?*
- complete destructive interference *(i.e.,* a *minimum)?*

C. Suppose that a *single* change were made to the apparatus (keeping the distance between the mask and the screen fixed), resulting in the new pattern shown.



1. Are the angles to the interference maxima in the new pattern *greater than, less than,* or *equal to* those in the original pattern? Explain how you can tell from the diagrams.

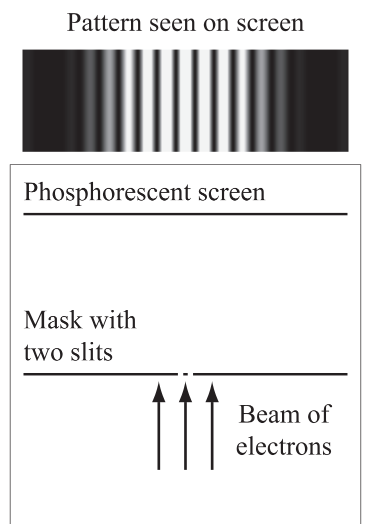
2. If the wavelength of light *(λ)* was the *only* quantity changed, determine (i) whether λ was *increased* or *decreased,* and (ii) whether it was changed by a factor that was *greater than, less than,* or *equal to* 2. Explain how you can use your results from parts A and B to justify your answer.

3. If the slit separation *(d)* was the *only* quantity changed, determine (i) whether *d* was *increased* or *decreased,* and (ii) whether it was changed by a factor that was *greater than, less than,* or *equal to* 2. Explain how you can use your results from parts A and B to justify your answer.

➪ Check your reasoning with a tutorial instructor.

II. Two-slit interference of electrons

A beam of electrons is accelerated through a potential difference, V_o. The beam is incident on two narrow slits. The diagram shows the pattern seen on a phosphorescent screen placed far from the slits. (When an electron hits a small portion of the screen, that portion of the screen glows.)



Top view (not to scale)

A. Which is a better model for the behavior of electrons in this case: that they propagate in straight lines through the slits, or that they propagate like waves? Explain how you can tell.

B. Suppose that the above experiment were repeated but with the electrons accelerated through a potential difference of $0.5V_o$ instead of V_o.

1. Predict whether the bright regions on the screen would *move closer together, move farther apart,* or *stay at the same locations*. Discuss your reasoning with your partners.

Obtain a figure that shows how the interference pattern would change if the accelerating voltage were halved so that you may check your prediction.

2. On the basis of the figure, would you conclude that halving the accelerating voltage changes the wavelength of the electron wave?

   If so: Does the wavelength increase or decrease?
   Does the wavelength change by a factor that is *greater than, less than,* or *equal to* 2? Explain how you can tell from the figures.

   If not: Explain how you can tell that the wavelength did not change.

3. How, if at all, would *halving* the accelerating voltage affect each of the quantities listed below? In particular, determine (i) whether each quantity would *increase* or *decrease,* and (ii) whether each quantity would change by a factor that is *greater than, less than,* or *equal to* 2. Explain your reasoning in each case.

   - the kinetic energy of each electron that reaches the slits

   - the momentum of each electron that reaches the slits

   - the de Broglie wavelength associated with each electron that reaches the slits

4. Are your answers to parts 2 and 3 regarding the de Broglie wavelength of the electrons consistent? If not, resolve any inconsistencies.

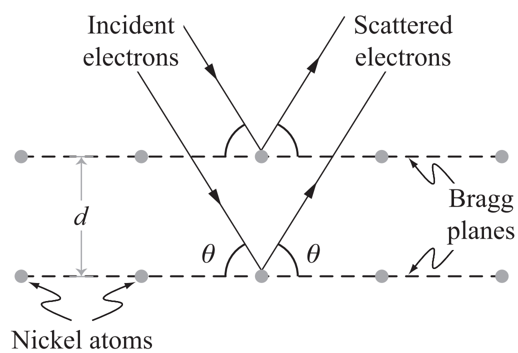
   Now that you have worked through parts 2 and 3, review your answer to part 1. Do you still agree with your earlier reasoning? If not, how would you revise it?

C. Suppose you were to perform the electron interference experiment described in part A.

Describe two independent methods that you could use in order to determine the de Broglie wavelength of the electrons. Include in your descriptions the measurements you would need to make and the steps you would need to follow in each case.

III. Application: Davisson-Germer experiment

Monoenergetic electrons are incident on a nickel crystal. It is observed that intense scattering occurs at angles θ according to the Bragg condition, $2d \sin\theta = n\lambda$. (See diagram at right.)



A. Use trigonometry to show that the path length difference between the two scattered beams shown is equal to $2d \sin\theta$. Show all work.

B. Suppose that this experiment were repeated, each time with a *single* change made to the apparatus. For each change below, determine whether each of the angles θ at which intense scattering occurs would *become larger, become smaller,* or *stay the same*. Explain your reasoning in each case.

1. The kinetic energy of the incident electrons is decreased.

2. The electrons are replaced with neutrons, with each neutron having the same speed as each of the original electrons.

