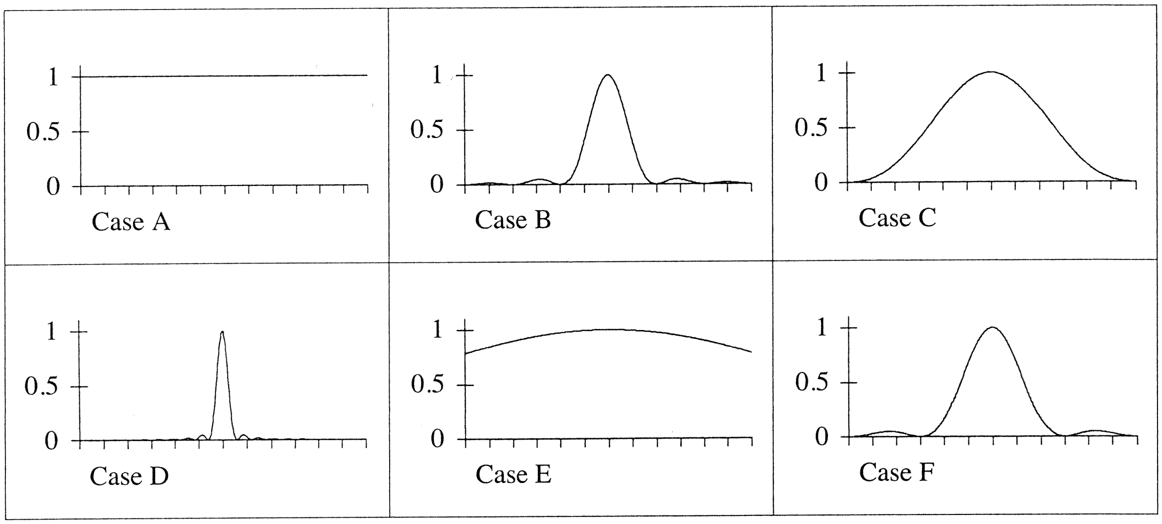
A MODEL FOR SINGLE-SLIT DIFFRACTION

Name ____________________

1. Light from a distant point source is incident on a narrow slit. Each of the graphs below shows the intensity on a distant screen as a function of θ. The only difference among the six physical situations is the width of the slit.

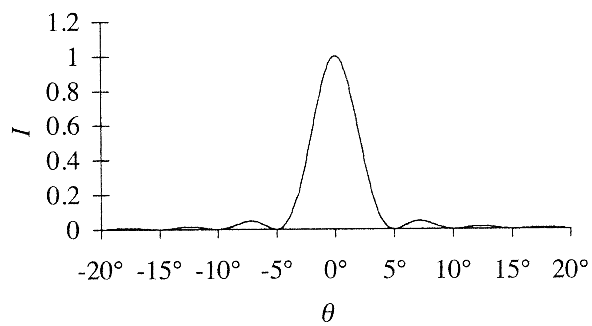
   The horizontal scale is the same for all graphs. The vertical scale has been normalized so that the maximum intensity is the same for all cases.



Rank the cases according to the width of the slit, from largest to smallest. Explain your reasoning.

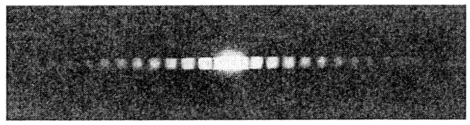
2. The graph at right shows the intensity on a distant screen as a function of θ for a single-slit experiment.

   a. Determine the width of the slit in terms of λ. Show your work.



   b. If $\lambda = 580$ nm, what is the width of the slit in mm? Show your work.

B. The photograph at right shows the diffraction pattern produced by laser light incident on a narrow slit.



Narrow slit

Even narrower slit

Use the model that we have developed to predict how the pattern would change if the slit were made *even narrower*. Explain your reasoning and sketch your prediction in the space provided at right.

Ask a tutorial instructor for the photograph showing diffraction patterns produced by light incident on a narrow slit and on an even narrower slit so that you may check your predictions.

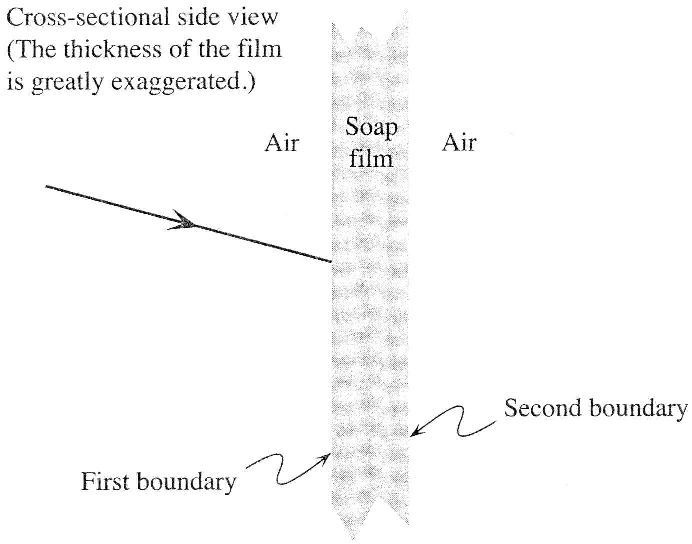
C. Describe what you would see on the screen if the width of the slit were gradually decreased to zero. Discuss your predictions with your partners.

D. If a diffraction pattern has several minima (like the patterns shown in this tutorial), is the width of the slit *greater than, less than,* or *equal to* λ? Explain your reasoning.

C. Consider light incident on a *thin* soap film, as illustrated in the cross-sectional side view diagram at right.

The soap film is supported by a loop (not shown), which is held vertically. Only a small portion of the film has been shown; the thickness of the film is greatly exaggerated.

In answering the following questions, use an analogy between this situation and the connected springs in parts A and B.



1. Reflection and transmission at the first boundary

   a. On the diagram, draw rays that correspond to the light that is transmitted and reflected at the first boundary (on the left).

   b. Is the frequency of the transmitted wave (in the film) *greater than, less than,* or *equal to* the frequency of the incident wave (in the air)?

   c. Is the wavelength of the transmitted wave (in the film) *greater than, less than,* or *equal to* the wavelength of the incident wave (in the air)?

   d. For light incident on the first boundary, would the reflection at this boundary be more like reflection from a *fixed end* or from a *free end?* Explain.

   e. On the basis of your answers above:

   At the first boundary, would the reflected wave be *in phase* or *180° out of phase* with the incident wave (*i.e.,* is there a phase change upon reflection)?

   At the first boundary, would the transmitted wave be *in phase* or *180° out of phase* with the incident wave (*i.e.,* is there a phase change upon transmission)?

2. Reflection at the second boundary

   a. Continue the transmitted ray (from part 1) through the film to the second boundary (on the right). Then draw rays that correspond to the light that is transmitted and reflected at the second boundary.

   b. For light incident on the second boundary, would the reflection at this boundary be more like reflection from a *fixed end* or from a *free end?* Explain.

      At the second boundary, would the reflected wave be *in phase* or *180° out of phase* with the incident wave (in the film)?

3. Transmission at the first boundary

   Continue the reflected ray from part 2 through the film back to the first boundary. Then draw rays that correspond to the light that is transmitted and reflected at this boundary.

   Would there be a phase change on transmission at this boundary?

D. Light of frequency $f = 7.5 \times 10^{14}$ Hz is incident on the left side of the soap film.

   Determine the numerical values of the:

   - frequency of the wave in soap film (in Hz)
   - wavelength in air (in nm)
   - wavelength in film (in nm)

E. Suppose that an observer were located on the left side of the soap film in part C.

   Which of the rays that you drew could reach this observer?

   How would these rays be different if the light were incident at essentially normal incidence?