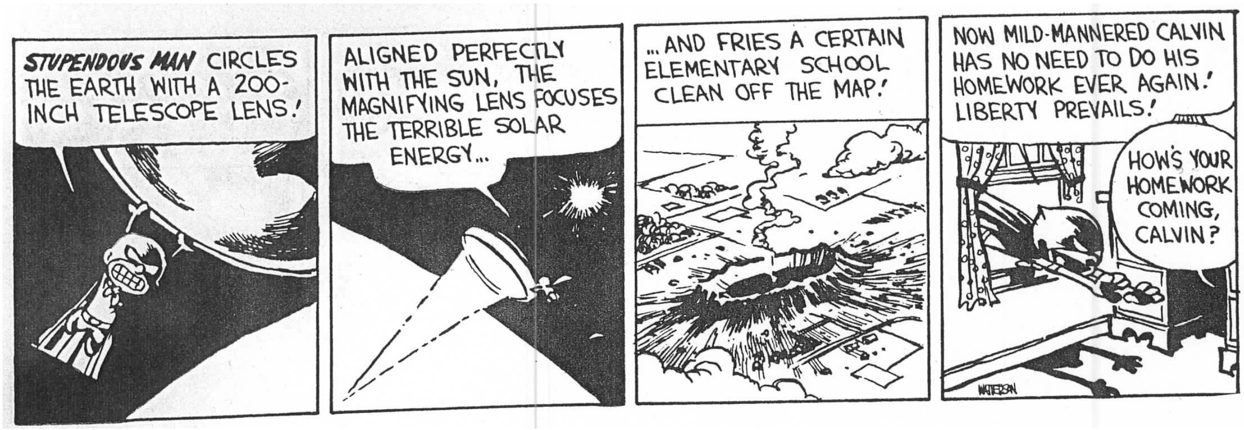
Physics 4L, Spring 2010 — Problem set 13 (last one!)
Due Wednesday May 5 at Catherine Crouch's office by 5 p.m.
Problem sessions will meet Thurs-Mon as usual plus probably a session Tuesday evening May 4



In addition to the problems listed below, please complete the attached worksheet.

Chapter 32: problems 52, 65

Additional problems

1. You are ordering lenses for a microscope and you want the lenses coated with a thin anti-reflective coating to minimize reflection of 500 nm light. The coating has index of refraction 1.38 and the glass used for the lenses has an index of refraction of 1.52. How thick should you tell the factory to make the coating? Would you need a different coating thickness if the glass used for the lenses had an index of refraction of 1.60? Explain your answers briefly. (Note: to solve this problem, just consider reflections from the air-coating interface and the coating-glass interface, as discussed in class; do not worry about the Maxwell's equation treatment mentioned by Wolfson.)

2. You are using a microscope equipped with a 60x objective lens with NA (numerical aperture) = 1.4 to examine a specimen using fluorescence from blue fluorescent protein, which emits 445 nm light.

(a) What is the smallest resolvable distance between features in your sample?

(b) If your microscope is connected to a CCD camera and the 60x magnified image is detected by the CCD sensor, how large is the image of the smallest resolvable distance?

(c) If you were examining a specimen in which the structures of interest were marked with yellow fluorescent protein (emits 527 nm light) instead of blue fluorescent protein, would the smallest resolvable distance in your sample increase or decrease? Explain briefly.

(d) The 60x, 1.4 NA objective is extremely common in biological microscopy. Typical research-grade CCD cameras for use in microscopy have square pixels that are 6.25 μm on each side. Explain why this is a wisely chosen size.

For extra credit:

3. The size of one pixel in the sensor for a digital camera is about 2 μm x 2μm. If the camera lens has a diameter of 40 mm and a focal length of 30 mm, is the smallest feature visible in the resulting image determined by diffraction through the lens or by the pixel size on the sensor? (Pick a reasonable value for the wavelength of the light forming the image.) Hint: find the size of the diffraction-limited spot produced when the lens focuses light from a point source, and compare it to the size of the pixel.)

Continued on next page

Please also complete an **online electricity and magnetism diagnostic test** worth 10 points of problem set credit (linked on the web site under "Assignments"; use the login information provided in the link, not your course web site login information). The purpose of this test is to help me benchmark the class's progress on core concepts; you will get full credit for answering all the questions regardless of correctness. I think you'll find it most useful to you if you do it after reviewing electricity and magnetism up through and including induction.

Problems 18 and 31 pertain to topics we have not covered (you can skip those if you wish) but the rest are relevant. After you complete it and submit your answers, you will see a screen indicating that your answers have been stored.

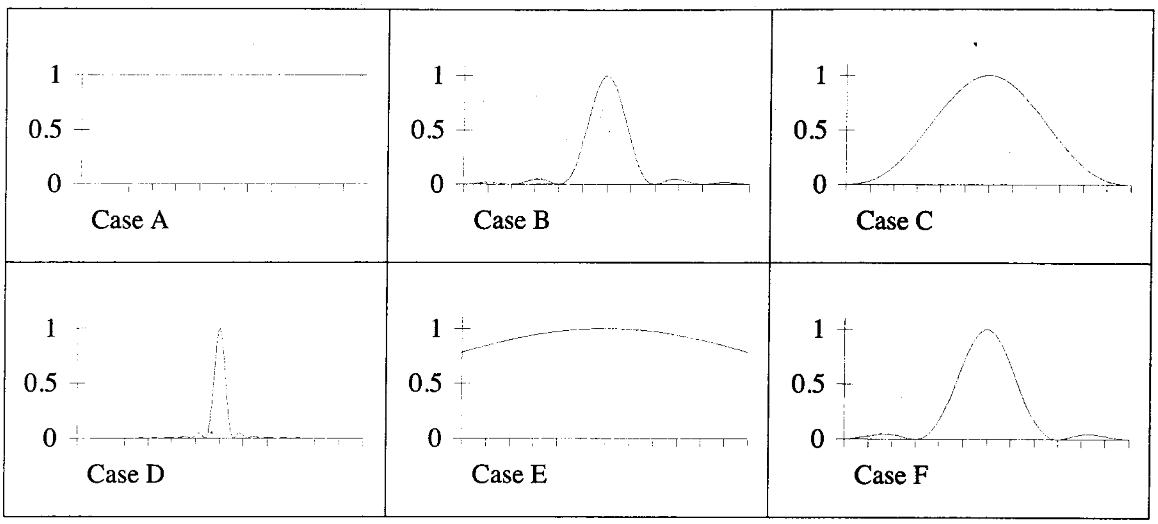
You can complete it any time by Monday, May 17 at 10 p.m.; if you do it before the final, you can go over a copy of the test answers at one of the SA sessions or office hours (for copyright reasons, I can't distribute solutions).

There will be a final course evaluation posted under "Assignments", worth 15 points of problem set **extra credit**, that needs to be completed by Monday, May 17 in order to receive the extra credit. As always, your feedback is valued! You can complete it anonymously or turn it in with your name, whatever you are comfortable with. Instructions will be provided on the form.

Finally, Ch. 32 "For Thought and Discussion" #5 is very interesting, though pretty sophisticated to answer accurately. You don't have to hand it in, but I encourage you to think about it (after the semester is over if necessary :-)) and I will provide an explanation with the problem set solutions.

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.

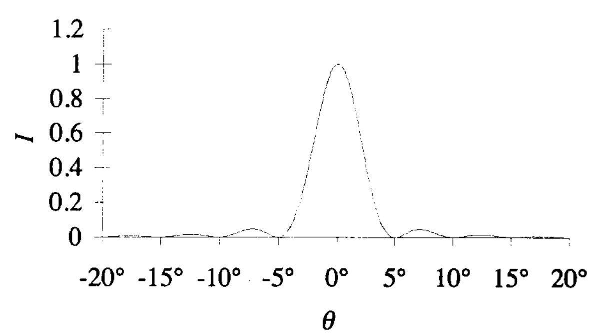
   The horizontal scale is the same for all graphs. The vertical scale has been normalized so that the maximum intensity is the same for all cases.



   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.