lPhysics 4L, Spring 2010 — Problem set 12
Due THURSDAY April 29 in class (note change)

Chapter 29 problem 42
Chapter 32 "For Thought and Discussion" 6, 7
problems 10, 18, 20 (with problem 20, also explain how the second-order angular separation between the wavelengths compares to the angular separation in first order and thus which of first or second order allows you to distinguish more closely spaced wavelengths), 35, 45 (with problem 45, also explain what change to the grating would increase the angular separation between the two wavelengths), and the following additional problems:

Additional problems

1. Linear (rod-shaped) antennas for detecting and transmitting electromagnetic radiation usually are roughly a quarter of a wavelength long. Measure your cell phone antenna and from this measurement determine the approximate frequency of your cell phone carrier's signal in Hz. How does this compare to your favorite radio station's frequency? (AM frequencies are in kHz, FM frequencies are in MHz. Keep in mind that the graders need to be able to tell if you've done this correctly, so clearly present your measurement and the logic of your solution.)
If you don't have a cell phone or your phone doesn't have a visible antenna, measure someone else's, or estimate that the length of the antenna is comparable to the length of the phone.

2. X-ray diffraction from a crystal of potassium chloride gives a first-order maximum when the X-rays strike the crystal plane at 8.5° from the surface of the crystal (NOT from the normal to the crystal surface). The X-ray wavelength is 0.097 nm. Find the spacing between the crystal planes.

3. In fluorescence microscopy, one color of light is used to illuminate ("excite") the sample; a dye that is attached to molecules or structures of interest within the sample absorbs a photon of the exciting light, changing its energy, and then emits a photon of a *different* color of light. Colored filters are used between the sample and the eyepiece or camera so that only the emitted color of light is observed. The specific combination of excitation and emission colors is specific to the particular dye. One such combination is for a dye called Texas Red, which is excited by light with wavelength 596 nm (an orange color) and emits light with wavelength 615 nm (a red color).

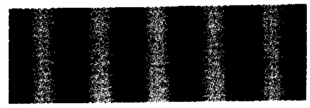
(a) Is the energy of a single exciting photon higher or lower than the energy of a single emitted photon?

(b) Do you think there exist dyes for which the energy of an exciting photon is lower than the energy of an emitted photon? Explain why or why not. Any answer will get full credit — the goal is for you to think about this, and then we'll discuss it the last day of class. If you already understand how fluorescence works, great! :-)

(c) In a special type of laser-based fluorescence microscopy called two-photon microscopy, *two* photons of the exciting light are absorbed by the sample for every single photon emitted. How does the energy of *two* exciting photons compare to that of one emitted photon? How does the energy of *one* exciting photon compare to that of one emitted photon?

Also complete the attached worksheet (third page of polarization homework). For part 3a, you should specify a quantity related to the red light such as electric field, magnetic field, or intensity.

3. Unpolarized red light is incident on two identical, narrow vertical slits. The photograph at right shows the interference pattern that appears on a distant screen.



Double-slit pattern produced by *unpolarized* red light

a. Specify the quantity or quantities that are adding to zero at the interference minima. ("The light waves from the two slits are adding to zero" is *not* a sufficient answer.)

b. A polarizer is placed directly in front of both slits, so that the light is *vertically* polarized before passing through the slits. It is observed that the intensity at each point on the screen decreases by a factor of two.

How can you account for the decrease in intensity at the interference maxima?

c. The polarizer is slowly rotated through 360°. As the polarizer is rotated, it is observed that the interference pattern does not change.

Consider the following *incorrect* prediction:

> *"If the direction of polarization of the polarizer were horizontal, I don't think any light would reach the screen. In that case the light that reaches each slit would be polarized horizontally, so the light would be blocked by each of the vertical slits."*

What is the flaw in the reasoning? Explain.

d. Now imagine that one polarizer is placed in front of each slit: one polarizer with its direction of polarization vertical; the other, horizontal.

Would there still be locations on the screen at which the intensity is *zero?* Explain why or why not.