P360 - Optics

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Instructions for Exam II:

- This is a 50-min in-class exam
- Show all your work on these sheets
- You may use your text (Hecht) and notes
- Please print your name below
- Part 1 is worth 50 points and consists of 5 short questions
- Part 2 is worth 50 points and consists of 2 problems

You can also take a copy of this exam and work the problems at a more liesurely pace. If as a result you want to change your answers to any of the questions/problems please give me your amended solutions by 9 am Fri - April 9. - Cheers, Alex

Name (please print)

Part 1

Question 1 (10 points)

Circularly polarized light enters a quarter-wave plate along an optic axis perpendicular to the plate.

(a) Describe the polarization of the light which leaves the quarter-wave plate.

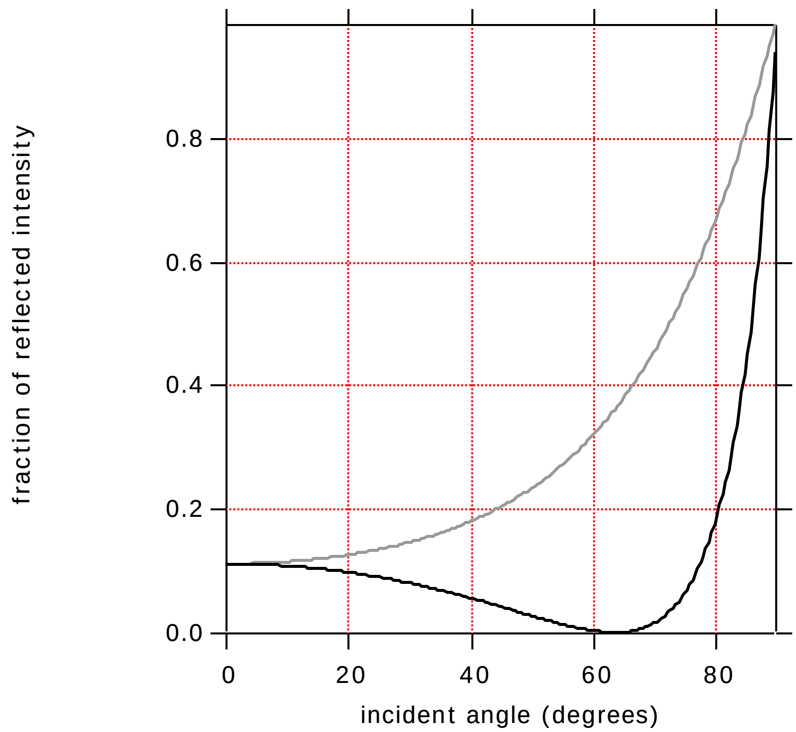
(b) What happens to polarization of the emergent beam as the quarter-wave plate is rotated about the optic axis?

(b) What happens to intensity of the emergent beam as the quarter-wave plate is rotated about the optic axis?

Only brief answers needed - no explanation is necessary.

Question 2 (10 points)

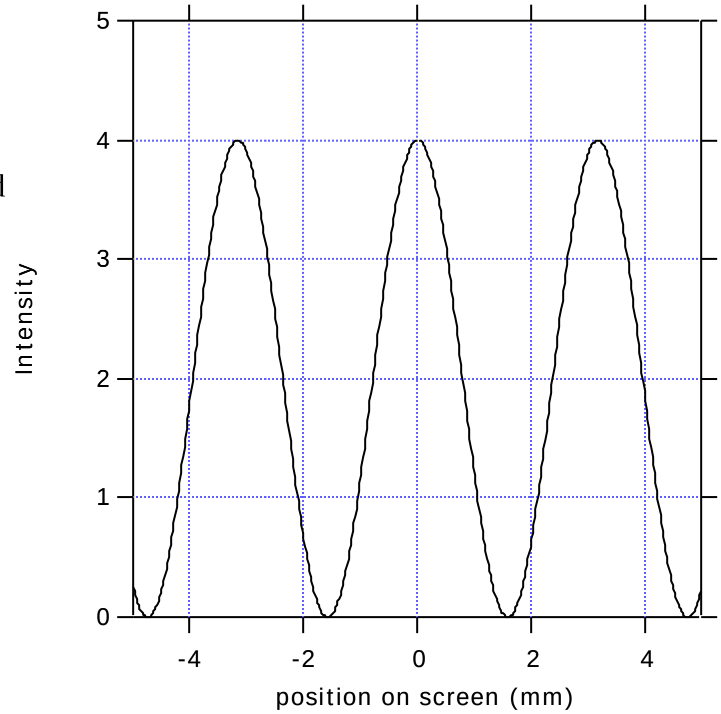
The plot shows fraction of reflected light off on a interface between air and material with index of reflection equal to 2.0. Suppose that circularly polarized light beam is incident on this surface at Brewster's angle and the intensity of the beam is I_o. In terms of I_o, what is the intensity of the reflected light?



Question 3 (10 points)

Two sources of light are emitting light with $\lambda = 632.8\ \text{nm}$ - the sources are in phase and coherent. The intensity of each source is I_o. The sources are separated by distance d. A screen is placed 1 meter away and the intensity pattern is plotted in the figure. There are no diffraction effects. The intensity is plotted in units where $I_o = 1$.

What is the separation d in mm ?



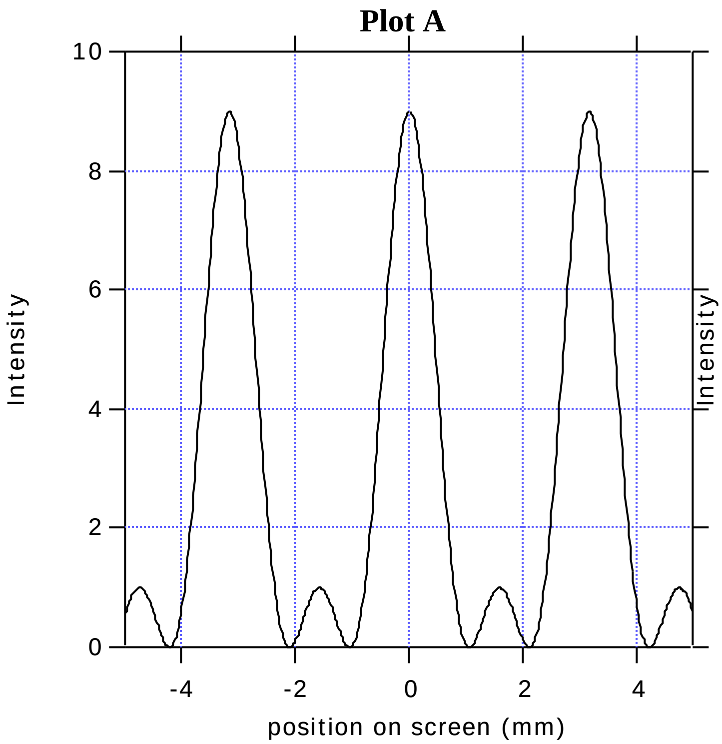
Question 4 (10 points)

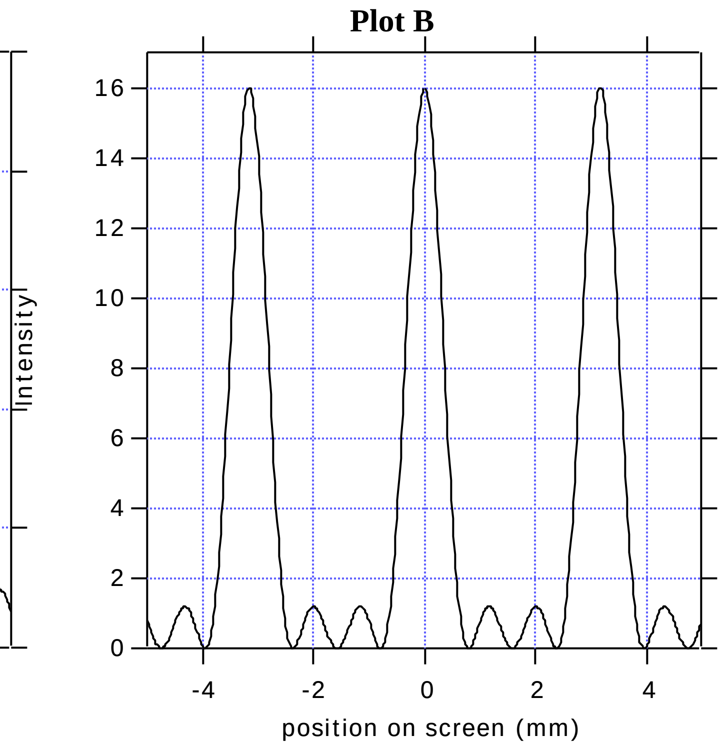
Recall the situation in Question 3. The difference now is that there are more than two sources. The sources are still in phase and coherent and each has intensity I_o. The separation between adjacent sources is the same as in Question 3. There is no diffraction. The same convention is used for the intensity scale.

For plot A - how many sources?

For plot B - how many sources ?

Explain how you arrived at your answers.

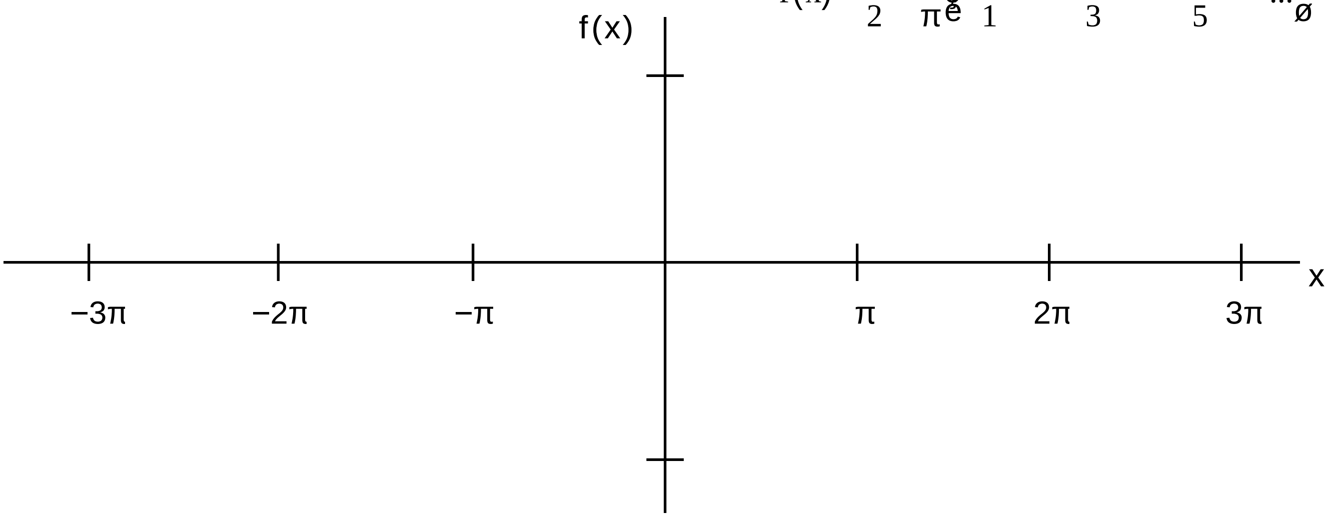




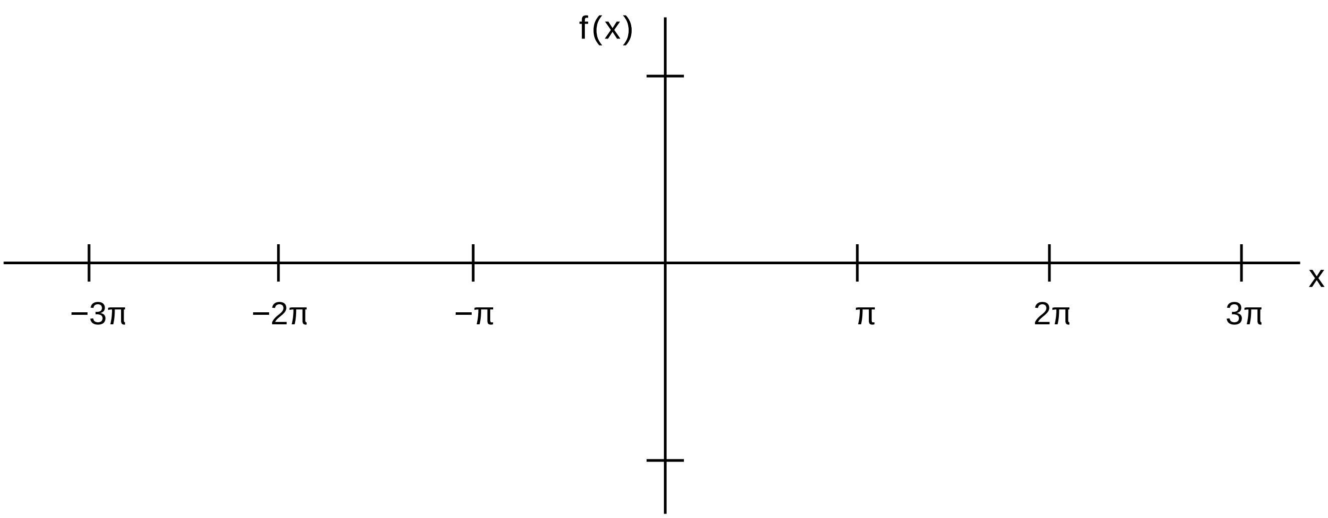
Question 5 (10 points)

A square-wave function is periodic over the interval $[-\pi, +\pi]$. The Fourier Series for two such functions is given below. Plot the functions on the axes provided and be sure to indicate the scale of the vertical axis *in each case.*

$$f(x) = \frac{1}{2} - \frac{2}{\pi}\left(\frac{\sin x}{1} + \frac{\sin 3x}{3} + \frac{\sin 5x}{5} + \ldots\right)$$



$$f(x) = 1 + \frac{4}{\pi}\left(\frac{\sin x}{1} + \frac{\sin 3x}{3} + \frac{\sin 5x}{5} + \ldots\right)$$



Part 2

Problem 1 (25 points)

Suppose that we have a set of linear polarizers which are *perfect*. If the light incident on the polarizer is polarized along the axis, all of the light is passed through and if the incident light is polarized at right angles to the axis, all of the light is blocked.

I want to take linearly polarized light and rotate the polarization of the light through 45^o by passing it through a set of our *perfect* polarizers. However - I want the final intensity of the light to be at least 90 % of the initial intensity.

What is the minimum number of polarizers that I need and how should they be arranged ?

Hint: When doing this problem - you might want to consider using the series expansion:
$\cos\theta = 1 - \frac{\theta^2}{2!} + \frac{\theta^4}{4!} - \ldots$ and the binomial expansion: $(1+z)^n \approx 1 + nz$ when z <<1.

Note: Problem 2 is on page 9

Problem 2 (25 points)

The figure shows a Michelson interferometer for measuring the index of refraction of air. For air, at STP, n = 1.000293. That's pretty close to 1. We usually are more interested in the difference from 1 and so we write: $(n-1)\times 10^6 = 293$.

Here's the idea. The mirrors of the interferometer are made perpendicular to the two arms of the interferometer. The tube in one of the arms has windows for the light to pass through and is initially open to air. The thickness of the windows is taken into account in the design so that the optical path length for both arms is the same. In fact one uses a He-Ne laser $(\lambda = 632.5\ \text{nm})$ and observes the pattern on the screen. Adjustments can be made to the position of the mirror so that one sees a bright spot indicating that the light traveling from one path is in phase with the light traveling from the other path.

Now one starts pumping air out of the tube.

(a) <u>Qualitatively</u> describe what you will observe at the viewing screen as all the air is pumped out of the tube. Explain.

(b) Now <u>quantitatively</u> describe what you should see. For example, CO_2 gas has $(n-1)\times 10^6 = 400$ at STP. If the tube had originally been filled with CO_2 instead of air, what would be different.