ECE 181
Spring 2008
Final Exam

Instructions:

Closed book; two pages of notes are allowed.
Calculators OK, but not cellphones or collaboration.
You have 3 hours.

You must SHOW YOUR WORK to receive full credit.

Careful: There is no such thing as a 'trick question.'
Read each question carefully. If you need clarification, ask.

You must ANSWER THE QUESTION POSED to receive credit.

Draw a box around your answer to make it clear to the grader.

Name: ________________________________

Problem 1: The magnifying glass (20 points)

You have a simple spherical lens which is 50mm in diameter and also has a 50mm focal length. The lens has the same curvature on both sides, and is made of window glass with an index of refraction of 1.6 for green (550nm) light.

(A)What is the radius of curvature of the lens faces?
(B)The lens has a flat edge which is 1mm wide. Calculate the total center thickness (justify any approximations)
(C)What are the F/# and numerical aperture of this lens? (do not assume paraxial)
(D)What is the diffraction limit for an ideal lens of this diameter (diameter of the airy disk) for green light?
(E)Will this lens be diffraction limited? Why or why not?

Problem 2: Using the magnifying glass (20 points)

Treating the lens from P1 as a thin ideal lens, use it to examine in detail a tiny 1mm high symbol shaped like this: 

(A)Make a scale drawing of the lens being used as a magnifying glass (held near the eye) including the position of the object, position and orientation of any intermediate image, and position and orientation of the image on the retina.

(B)Making the apparent position of the object at standard viewing range (10”), label distances and sizes. Your drawing of the eye’s lens and image should just be approximate.

(B) What is the magnifying power of this system?

(C) Assuming your eyes are typical, what is the smallest linear detail which you can resolve on the symbol?

Problem 3: Using the magnifying glass some more (20 points)

Now you use the SAME LENS in a different position to look at the SAME OBJECT, now with the lens far from your eye.

(A) Make a rough (not scale) drawing of the optical system, showing the position of the object, the position and orientation of any intermediate image, and the position and orientation of the image on the eye's retina.

(B) Calculate the distances from object to lens, and lens to eye, needed to put the apparent object position at 10" from the eye and provide exactly the same apparent magnification as before.

(C) From the GEOMETRICAL OPTICS perspective, is there any limit to the magnifying power with this arrangement?

Problem 4: Diffraction Gratings (20 points)

(A) A diffraction grating is illuminated at normal incidence by red light at 632nm and blue light at 474nm. We see the red light that is diffracted into the M^{th} diffraction order comes out at the same angle as blue light diffracted into the N^{th} order, where M and N differ by one (e.g., the 1^{st} and 2^{nd} orders, or the 3^{rd} and 2^{nd} orders). What are N and M?

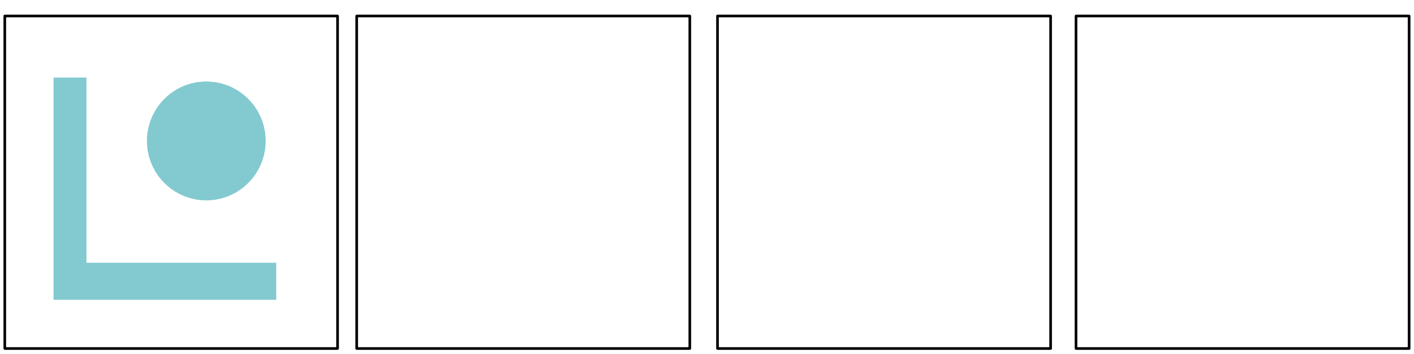
(B1) A diffraction grating with a 7μm grating period is illuminated at normal incidence by light at 1064nm. What is the highest diffraction order, M_{max}, which can be emitted from the grating?

(B2) Can the same 7μm period grating be used to diffract light into the next higher $(M+1)^{st}$ order? Why or why not?

Problem 5: Phase Microscopy (20 points)

Your microscope has a 10x eyepiece and a 20x objective. Both of these optics are F/2.
(A)Draw the basic optical system (sample, objective lens, eyelens, and eye) labeling the focal lengths and diameters of the lenses, and the approximate distances between the elements.
(B)A thin phase filter is used at the lens focal plane to enhance contrast for thin phase objects. Assuming the filter provides a positive delay at center, created using a thin layer of coating with index 1.6, designed for 500 nm light. Calculate the diameter and the thickness of the filter's central spot.

(C) Sketch the detected image intensity pattern when the microscope is used to look at the object at left, a very thin phase object , using the conventional (unfiltered) operation, phase contrast, and differential interference contrast.



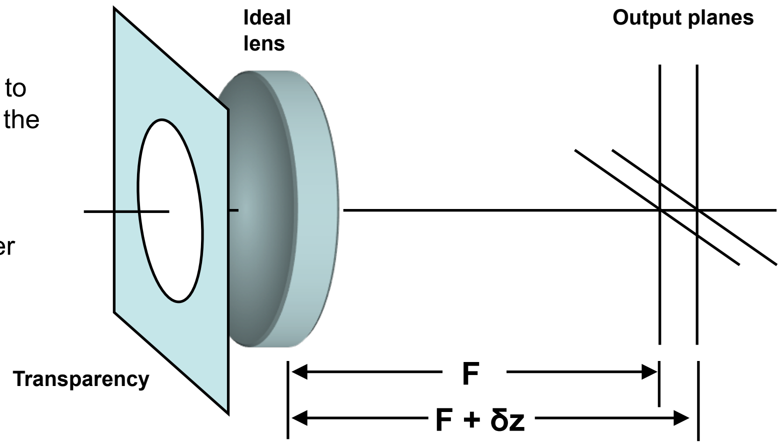
Problem 6: Spot intensity distribution of focused and defocused images (20 points)

A **1cm diameter** input transparency is illuminated with a plane wave, and the transmitted light is focused by an ideal lens to the output plane which is located at exactly the focal length from the lens, or slightly defocused: shifted along z by **δz = 1mm**.

The diameter of the ideal lens is much larger than the size of the transparency.

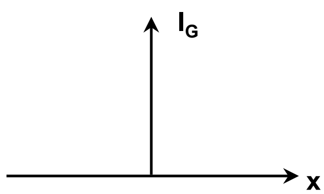
The wavelength of the light is **0.5 µm**

The focal length of the lens is **1 m**

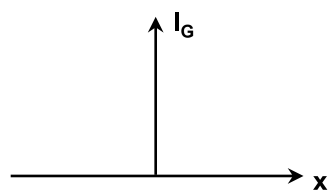


(1) Under the **geometrical optics approximation**, sketch the approximate intensity distribution at the output plane when the input is a circular aperture 1 cm in diameter. Label the horizontal scale.

In focus: I_G (x, y=0, z=F)

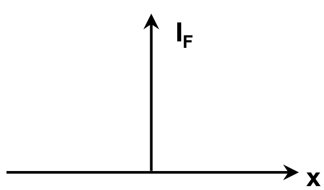


Defocused: I_G(x, y, z=F+δz)

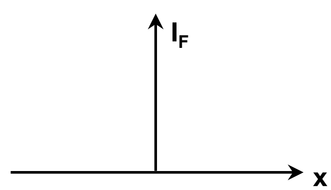


(2) Using **Fresnel propagation**, sketch the approximate intensity distribution at the output plane when the input is a <u>circular aperture</u> 1 cm in diameter. Label the horizontal scale.

In focus: I_F (x, y=0, z=F)

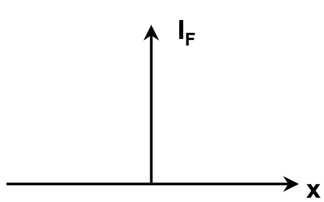


Defocused: I_F(x, y, z=F+δz)



(3) Using **Fresnel propagation**, sketch the approximate intensity distribution at the output plane when the input is a <u>Gaussian transmission function</u> with a mode radius of 5 mm. Label the horizontal scale.

In focus: I_F (x, y=0, z=F)



Defocused: I_F(x, y, z=F+δz)