EECE4646 Midterm Exam

Prof. Charles A. DiMarzio
Department of Electrical and Computer Engineering
Northeastern University

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Logistics

Schedule In fairness to all, I must insist on adhering strictly to the schedule. The exam is due electronically on Blackboard before 6:00PM Friday 28 February. To avoid any confusion, that is 18:00 Eastern Standard time.

Format: Please email exactly one .pdf file with all the problems answered in sequence. Other formats can lead to font variations, lost artwork, and other unpleasant events.

Filename: Please include some recognizable portion of your name in the filename.

Copy: Please keep a copy yourself, in case any electronic problems occur. I plan to download your work and check that I can open your file shortly after the submission deadline, and I will contact you if there is any problem.

General Instructions

Please do not collaborate with other students or seek help from outside experts. However, you may use any reference book, journal articles, or other readily available resources. Please cite references if you do so.

Please contact me if you are confused about the wording of a problem. I will will clarify the wording of the problems, or correct an error in the questions if someone should find one. Keep an eye on the announcements on the course web site for such updates. Obviously, I cannot give you the level of help I would on homework, but I can clarify or correct.

Draw a figure for each of the problems. Usually in my problems, the first step is to generate a layout of the optical system. I give points for figures.

You will want to use a computer for some of the problems. You may use any language you like, but make sure that the equations and graphs are presented in such a way that I don't need to look at your code. When I ask for a plot, I am looking for a correctly labeled one, with correct numerical values. A sketch is not sufficient.

Present your work as clearly as possible. I give partial credit if I can figure out that you know what you are doing. I do not give credit for putting down everything you know and hoping I will find something correct in it. In the past, some students have typeset the whole exam in Word or LaTeX, which made it easy to follow. Others submitted excellent hand–written exams that were as easy to read as the typeset ones. These exams were the easiest to grade, particularly when I sought to understand the reasoning in order to assign partial credit.

1 Dispersion in a Prism

Look at the website, http://refractiveindex.info/ and find information on the glass, SF10. Consider a prism with an apex angle of 60 degrees. Collimated white light is incident from the left with rays at the minimum deviation angle for green light ($\lambda = 500$ nm).

1.1 Incidence Angle

Calculate the angle of incidence on the first surface to achieve minimum deviation at 500 nm.

1.2 Dispersion

Calculate the deviation angles for wavelengths from 400 nm to 1.5 μm in steps of 100 nm.

1.3 Raytrace

Trace these rays through the prism.

2 Negative Lens

Consider a negative lens with a focal length of $f = -1$ m. This is good model for the convex mirror frequently used on cars and bicycles.

2.1 Imaging

Plot the image distance as a function of object distance from 2 meters to a distance that can be considered infinite. You will know that you've reached it because the image distance won't change much. Is the image real or virtual?

2.2 Magnification

Plot the magnification, m, and the axial magnification as functions of object distance over this same range of values. Use a single plot for both functions and discuss distortion.

3 Laser Scanning Microscope

Let's begin with a commercial infinity–corrected microscope objective specified as having a magnification of 10, and a numerical aperture of 0.53. The aperture stop is a metal ring in the back focal plane of the objective. This manufacturer uses a 160–mm tube lens.

3.1 Stop Diameter

What is the diameter of the aperture stop?

3.2 Field of View

The microscope, consisting of objective and tube lens has a field stop at the back focus of the tube lens, with a diameter of 20 cm. What is the field of view in object space?

3.3 Scanner Optimization

I want to scan a laser beam across the object by reflecting the laser from a rotating mirror, passing it through a lens of focal length, f_s, and delivering it backward through the tube lens and then the objective. The laser beam is initially collimated, and I want it to scan in the image plane (and thus in the object plane) to cover the full field of view.

Consider f_s to be variable and compute (1) the diameter of the pupil at the scanner location and (2) the required scan half–angle from the axis to the edge of the field of view.

Assume that, with the aid of another telescope, I can make the collimated laser beam have any diameter I want, to fill the pupil. Pick a value of f_s that you think is a good compromise between required mirror size and scan angle.

3.4 Conclusion

Draw a dimensioned layout of the complete scanning microscope. Draw rays representing the center and edges of the laser beam when the scanner is set for the center of the field of view. Repeat for the maximum excursion. You may use a different scale for the axial dimension and the transverse dimension for clarity.

4 Aberrations

Consider an afocal telescope consisting of two lenses, $f_1 = 5$ cm and $f_2 = 50$ cm. The lenses are f/5.

4.1 Imaging

If the object is placed 1 km in front of the telescope, where is the image.

4.2 Reducing Aberrations

Given a choice of plano–convex and biconvex lenses with the appropriate focal length, design the best telescope to minimize aberrations for this application. Specify the lens types, orientations, and spacing. The available short focal length lenses have thickness of 5 mm and the longer ones have a thickness of 2 cm. Compute the longitudinal spherical aberration for each lens and add to get the total for the telescope.

4.3 Another Application

Now the goal is to place an object at the front focal plane of the first lens and obtain an image at the back focal plane of the second. Repeat the results above.