Optics for Engineers
EECE4646 — Spring 2017
Exam #1

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

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Name: ______________________________

General Instructions.

Schedule In fairness to all, I must insist on adhering strictly to the schedule. The exam is due at the beginning of class on Thursday, 2 March.

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 clarify the wording of the problems if I can do so without giving away the answer, 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.

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 previous years, many students typeset the whole exam in Word or LaTeX, which made it easy to follow. These exams are usually the easiest to grade, particularly when I seek to understand the reasoning in order to assign partial credit.

1 Dispersion in a Prism

Find the index of refraction as a function of wavelength for the common glass, BK7. Use the N-BK7 (Schott) data. The data is available under the heading "data," at this website.

https://refractiveindex.info/

Consider a prism with a vertex angle of 60 deg.

1.1 Minimum Deviation

Plot the minimum deviation as a function of wavelength from 300 to 2500 nm.

1.2 Actual Deviation

Now we allow white light to enter the prism and want to calculate the dispersion. Select the incident angle that produces minimum deviation for green light, and use it for all wavelengths.

Use Snell's law twice to determine the deviation angle. Plot the deviation angle as a function of wavelength on the same figure.

On a separate figure, plot the difference between the two curves.

1.3 Spectrometer

After the prism, we place a lens and a CCD camera with 1 X 1024 pixels, so that each pixel sees a different wavelength. We put the axis of the focusing system half way between the extremes of deviation angle so that that wavelength falls on pixel 512. Because the light at each wavelength is assumed to be collimated into and out of the prism, it looks like an object at $s \to \infty$, and the CCD is placed at $s' = f$. What is the focal length, f, so that the spectrum just covers the array from zero to 1024?

Plot the wavelength as a function of the pixel number from 1 to 1024.

1.4 Simple Lens

Now, let's assume that the lens is convex–plano (planar side toward the camera), also made of BK7, and designed to have the chosen focal length for green light. Plot the actual focal length as a function of wavelength. Briefly discuss the problem this creates for our spectrometer, and what we might do to eliminate the problem.

2 Compound Lens

Here our goal is to design a very good 2X magnifier with very little aberration and a field of view of a couple centimeters in image space. Given that we haven't studied aberrations yet and we don't want to do an expensive design, we decide to use two old 35 mm camera lenses placed face to face. let's assume that both principal planes of both camera lenses are located at the "back" vertex (the one that would normally be toward the film). The first lens has a focal length of 35 mm and a total length from vertex to vertex of 50 mm. The second has a focal length of 70 mm and a total length from vertex to vertex of 90 mm. The idea is that we use the first lens "backward" to generate a good image at infinity. That image becomes the object for the second lens, with an image at the back focal plane of that lens. Because we are using the lenses in the way they were intended, aberrations will be small.

2.1 Matrix

Place the two lenses as close together as possible. Calculate the matrix for the combination.

2.2 Lens Properties

What is the focal length of the combination and where are the principal planes?

3 Wearable Display

Here we design a simple wearable display as shown in Figure 3.1. The goal is to project the object, a transmissive liquid–crystal display, to a virtual image 55 centimeters in front of the eye. The display is 1 centimeter across and we'd like the image to be 30 centimeters across. We can place the lens, L2, 5 centimeters from the pupil of the eye.

3.1 Image

Find the focal length, f_2, of L2 and the location of the display.

3.2 Illumination

Now we want to place the illumination source, and LED, so that it's image is exactly in the pupil of the eye. In this way, we won't be able to see any structure of the LED. The easiest way to do this is to begin by locating

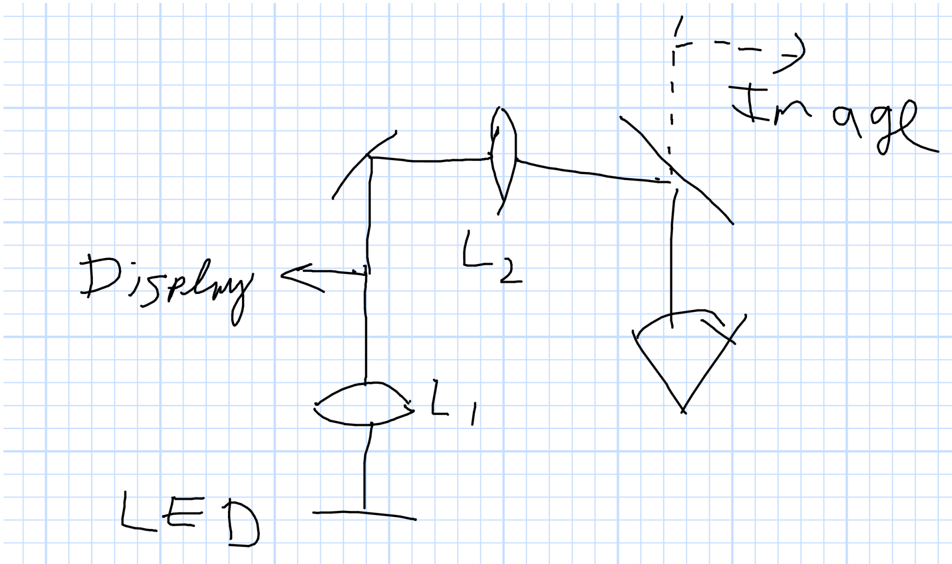

Figure 3.1: Wearable Display

the image of the eye's pupil as seen through L2. Find the location of that image and the diameter, given that the pupil of the eye is 0.6 centimeters in diameter.

Now design an optical system to relay an LED with a diameter of 200 micrometers so that it matches the pupil.

there exists more than one "right" answer (and perhaps no optimal one). Discuss problems you encounter and how they could be mitigated with more work.