EECE5646 Midterm Exam

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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 11:59:59pm (23:59:59) Tuesday 21 October.

Format: Please submit 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.

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 sought to understand the reasoning in order to assign partial credit.

1 Reverse Engineering A Lens

We have found an interesting lens in the "junk drawer" in the lab, which might be useful for a project. From what we can see, the lens is built in a black metal tube 22 cm. long, and consists of multiple glass elements. The front element has a convex outer surface and the back element has a planar one.

1.1 Focal Points

We begin by using autocollimation to locate the back focal point. For this, we place a white card with a pinhole where we think the back focal point is located, and use a flashlight to deliver light through the pinhole. We place a slightly tilted mirror at the front of the lens to return the light to the card. Then we move the card and flashlight until we have a good image of the pinhole on the card. We then measure the distance from the back of the lens to the card as 4.000 cm.

When we try to do the same for the front focal point, it appears that the focal point is inside the lens. Therefore, we build an auxiliary lens system shown in Figure 1, that relays the pinhole to a location which can now be used as a virtual object for autocollimation to find the front focus of the original lens. We see a good image on the card when the back vertex of the auxiliary lens is placed 7.2 cm in front of the lens being tested.

Draw and label the front (F) and back (F') focal points of the original lens, and show dimensions on the drawing indicating their exact position relative to the lens ends.

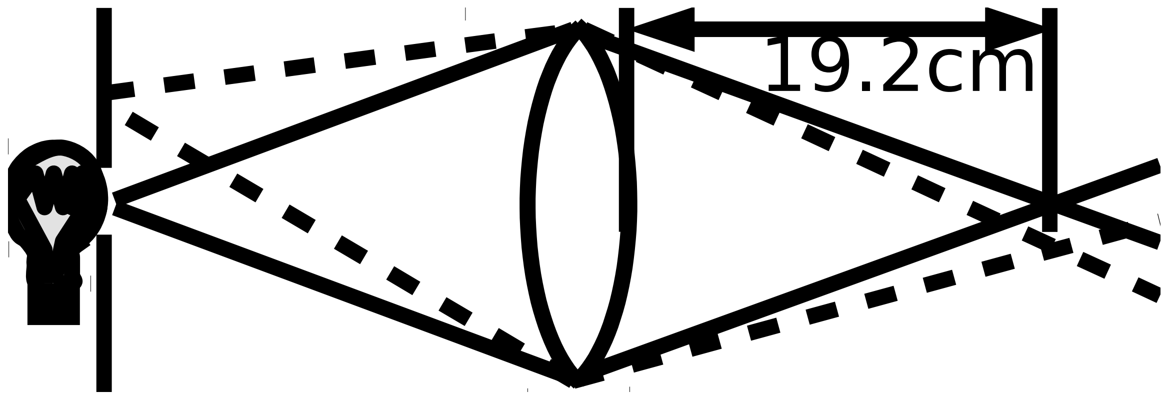

Figure 1: Auxiliary Relay System to Generate a Virtual Object. The distance from the back vertex of the lens to the focal point is measured to be 19.2 cm.

1.2 Principal Planes and Focal Length

So, now we know the focal points, but we still don't know the focal length, because we don't know the locations of the principal planes. Specifically, we've made two measurements, but we have three unknowns, h, h', and f. We need one more measurements. We place a ruler as an object in front of the lens and a white card after it, and adjust to obtain a well–focused image. We measure the object distance from the front of the lens as 3.400 cm., and the image distance as 6.404 cm. Measuring the height of the ruler in the image, we determine that the magnification is -0.4808.

Compute the focal length and principal plane distances. Add the principal planes to the drawing.

1.3 Optimization

Would you suspect this lens is optimized for (a) a long object distance and short image distance, (b) a short object distance and long image distance, or (c) a symmetric imaging system? Why?

2 Spherical Mirror

In class (Slide 5r1–2)and in the text, I showed a raytrace through a cylindrical refracting surface. Do the same for a concave spherical reflecting surface with a focal length of 10 cm. Assume the object is at infinity. From your results, measure the width of the smallest spot, and the distance from the vertex at which it occurs.

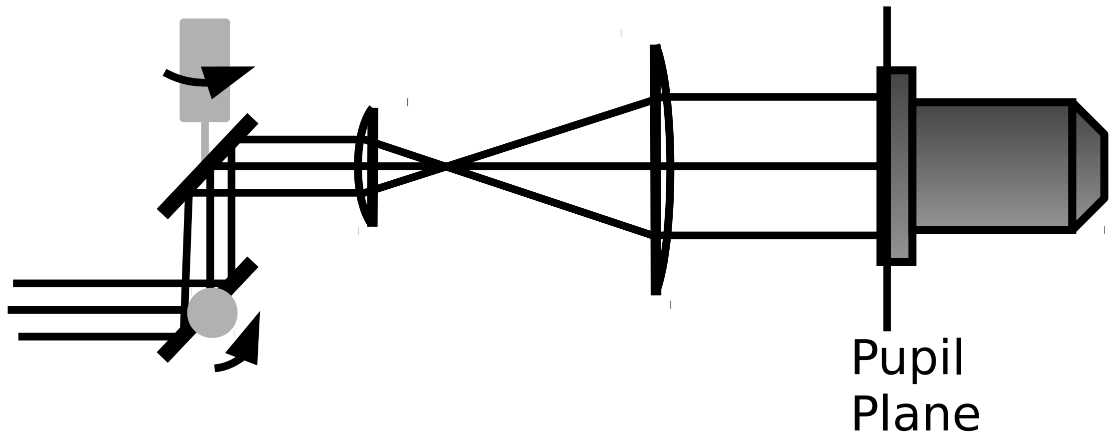

Figure 2: Scanning Microscope (The right figure this time)

3 Stops

Here we consider a scanning microscope. Rather than aim for a perfect system, we will accept some compromises. Rather than place both scanning mirrors at pupils, and thereby use two relay telescopes, we try to place the two mirrors "close" to a pupil as shown in Figure 2. The field of view as measured in the "infinity space" before the objective, viewed from the pupil is three degrees.

We use a 3X telescope to expand the beam to fill the pupil of the objective.

3.1 Optical Design

Pick suitable focal lengths and determine lens positions.

3.2 Mirror Control

Through what angle does each mirror move. **Warning:** This is a bit of a trick question.

3.3 Beam Truncation

Suppose that the source produces a beam of light with nearly parallel wavefronts one third the size of the pupil. Thus, with the scan mirrors in the nominal positions to produce an axial beam, the beam after the beam–expanding telescope just fills the pupil. At the extreme edges of the scan in each direction, what fraction of the beam is obscured? You may use approximations.

4 Thick Lenses

Here we explore a very simple and obvious lens, consisting of a perfect sphere of transparent material in air. The index can be anywhere between 1 and 4. As you do the plots, be careful about the lowest value of n when you generate the plots. Make sure that your plots are an aid to understanding the problem.

4.1 Matrix

For now, keep the index of refraction and radius perfectly general and write the matrix of a perfect sphere, from vertex to vertex.

4.2 Principal Planes and Focal Planes

Now calculate the focal length. Normalize to the radius and plot.

Plot the front and back vertices (trivial), the front and back principal planes and the front and back focal planes, as functions of the index of refraction.

4.3 Imaging

For what values (if any) of n is it possible to obtain a real image of a real object through such a sphere?