**Lab 2. Ray and GEOMETRICAL Optics**

**FALL 2017**

*Objective* To understand the principles of ray tracing as they apply to systems of optical components. The student should have acquired the ability to quickly find the image plane of a multiple-lens system. The student should understand the differences between real and virtual images.

prelab

1. Explain why a beam of light passing through the center of a lens at an arbitrary angle will not be deflected (i.e. will emerge at the same angle). Explain using Snell’s Law principles.

**(2 points)**

1. Sketch out the ray-tracing diagram for the image formed by a system of two lenses of equal focal lengths, and an object two focal lengths away from the first lens. The two lenses are two focal lengths apart. Do you encounter any problems?

**(2 points)**

1. Describe, in principle, how a microscope works. Draw its ray-tracing diagram, and label all focal lengths and components. What is the total magnification of your system in terms of focal lengths (show your work)? *THIS IS IMPORTANT, AS YOU WILL REFER TO THIS PRELAB QUESTION IN THE LAB. YOU MAY REFER TO THE RAY TRACING DIAGRAM IN PART IV.*

**(4 points)**

PART I INTRODUCTION TO OPTICS

*Discussion* The purpose of this exercise is to become familiar with setting up optical experiments. By using the imaging equation, we will determine the focal length of a lens.

*Procedure* Mount a lens of unknown focal length. Using a white light source, form an image of a slide on a screen using your lens (see figure). If the image of the filament is causing problems, place a diffusive object at the output. Measure the object and image distances from the center of the lens. Measure the object and image heights using a meter stick to determine the magnification M. Is the image upright or inverted? Move the lens relative to the object and move the screen to find the new image plane. Measure several object/image distance pairs. Plot 1/z1 vs. 1/z2 and fit a line through the data. What is the focal length?

**(3 points)**

z2

Object

Lens

Light Source

**A**

z1

Image in Focus

PART II ESTIMATING THE FOCAL LENGTH OF A LENS

*Discussion* Often, it is necessary to quickly determine the focal length of a lens. Here, we will investigate a quick method to estimate the focal length of a lens.

*Experiment*

1) Using the room lights, a piece of white paper, and a meter stick, come up with a way to estimate the focal length of lens. If you have trouble with this, see the TA. Justify your method with a mathematical expression.

**(2 points)**

2) Now apply your method to the lens sued in Part I. How does your result compare?

**(1 points)**

PART III VIRTUAL IMAGES

*Discussion* In Part I, we formed a real image of an object slide and used it to measure the focal length of a lens. In this part of the lab, you will form a virtual image and study its characteristics.

*Experiment*

1) A ray-tracing diagram for the formation of a virtual image is shown below. Select a lens from your optical components drawer and set up a virtual image of an object slide (provided by the TA). You should illuminate the object slide from the back, and you can use a diffuse slide to avoid imaging the light source, as depicted in the figure. *Hint: You may have to use the results of your Part II estimates.*



2) Look into the lens towards the object slide. Describe the image. If you move your head, does the image change size or location? Explain.

**(2 points)**

3) Try to obtain an image using the viewing screen (white piece of paper taped to the black wooden beam stop. Describe what you see, and explain what happens.

**(2 points)**

PART IV SYSTEMS OF MULTIPLE LENSES

*Discussion* In many imaging and optical applications, a system of several lenses is needed to form a desired image. Here, we will construct a 2-lens imaging system that will be a fundamental part of our unit on Fourier Optics.

*Experiment*

1) While retaining the lens from Part III, select an additional lens from the optical components drawer.

2) Place the lenses in magnetic bases and set their separation to be greater than the sum of the focal lengths. You should use the meter stick.

3) Arrange the mag-lite/diffuse glass (diffuse glass optional)/object slide combination such that a real image will be produced at an image plane beyond both of your lenses. You should use the wooden beam-stop with a piece of white paper taped to it at the image plane (i.e. “the screen”). Is the image inverted or upright?

**(1 points)**

4) Record all the relevant distances (i.e. distance between lenses, distance from the first lens to the object plane, and distance from the second lens to the image plane), and the estimated focal lengths of the lenses. Estimate the magnification of the system using a ruler. How does this compare with the expected magnification?

**(3 points)**

PART V THE COMPOUND MICROSCOPE

*Discussion* Compound microscopes are very useful tools for a broad range of applications. In this part of the lab, you will build such a microscope using the principles you have learned in this lab. Only here, the viewing direction will be parallel to the table top, in contrast to top-down for a commercial microscope.

*Experiment*

1) A ray tracing diagram for a simple compound microscope is shown in the figure below. Please note the locations of the eyepiece lens and microscope objective lens relative the real and virtual images that are formed. From the optics in the drawers, select a lens to serve as the eyepiece, and one as the objective. Before you begin, sketch the position of the lenses. You may use a commercial microscope objective (if you find one) or a simple singlet lens with short focal length. You also may need to estimate the focal length using the procedure from Part I. Sketch the ray diagram and note the components used in your final setup.

**(1 points)**



2) Select an object to magnify. A ruled grating, or any image slide (both provided by TA) illuminated from the back works quite well.

3) Align the parts of the compound microscope and observe an image through it. *Hint: You may need to adjust the focus of the eyepiece (distance d) as you would in a real microscope.* Be sure to show your TA that you made your microscope work. Comment on the smallest feature you are able to observe. How would you make the microscope better?

**(2 points)**

WRITEUP QUESTIONS

1) A 10-*cm* focal length lens is used to image a ceiling light onto a piece of white paper on the floor. If the light is 3 *m* from the lens, what is the % error in estimating the focal length of the lens (such as in Part I)? Show your work.

**(1 points)**

2) Describe the origins of a virtual image in your own words. What is it? Limit your response to two sentences.

**(1 points)**