SIMG-215: LABORATORY #2

1 Imaging with Lenses

1.1 Objective:

To investigate the use of lenses to form images, including the imaging equation, transverse magnification, magnifiers, and telescopes. Many of the tasks in this experiment follow the first four experiments shown on the cards in the OSA "Optics Discovery Kit"

1.2 Materials:

1. Three lenses from the OSA "Optics Discovery Kit"
2. Spring Clothespins (to hold the lenses upright)
3. Light source (such as a desk lamp or a flashlight)
4. Meter stick or tape measure (to measure distances up to one meter)

Figure 1: Lenses in the OSA Optics Discovery Kit

1.3 Experimental Procedure:

1. Estimate the focal lengths of the two positive lenses ("A" and "B") by forming images of a bright object located a long distance away and measuring the distance between the lens and the image; this is approximately the focal length.
2. Set Lens "A" and your light source on a table as in Figure 2:

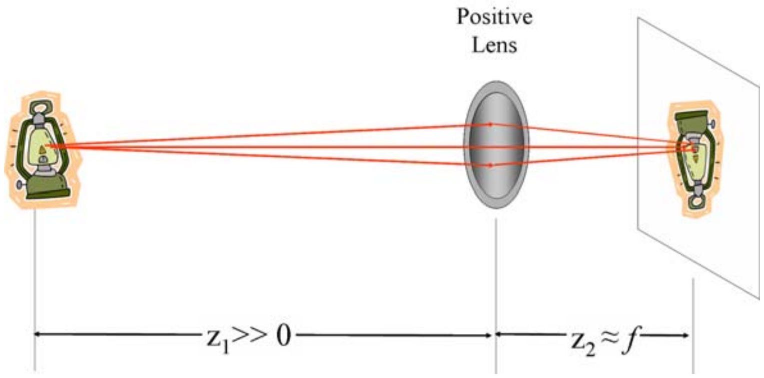

Figure 2: Imaging with a single positive thin lens

3. Measure the size of the object (the light bulb or the lamp shade) (this is the object height h_1)
4. Set the distance between the light source and the lens (the object distance z_1) to 150 mm
5. Use a piece of paper or plain index card as an observation screen. Hold it to the right of the lens as shown in Figure 2. Move it closer or farther from the lens until you find a distance where there is a sharp image of the light source on the piece of paper.
6. Measure the distance between the lens and the paper (the image distance z_2)
7. Measure (or estimate if necessary) the size of the image (the image height h_2)
8. Note the orientation of the image; if the image is inverted, record h_2 as negative (e.g. an upside down image that is 10 mm high would be recorded as "−10 mm"
9. Repeat steps 1 - 7 above to fill in Table 1 for Lens A. Check to see if your measurements confirm the *imaging equation* for single thin lenses:

$$\frac{1}{z_1} + \frac{1}{z_2} = \frac{1}{f}$$

and the equation for the *transverse magnification of the image:*

$$M_t \equiv \frac{h_2}{h_1} = -\frac{z_2}{z_1}$$

Lens A: Estimated focal length $f_A =$ ___________ mm

Object Distance z_1	Object Height h_1	Image Distance z_2	Image Height h_2	$\frac{z_2}{z_1}$	$\frac{h_2}{h_1}$
100 mm					
200 mm					
250 mm					
500 mm					
750 mm					
1000 mm					

10. Repeat steps 2-9 for Lens B; fill in the table

    Lens B: Estimated focal length $f_B =$ ___________ mm

Object Distance z_1	Object Height h_1	Image Distance z_2	Image Height h_2	$\frac{z_2}{z_1}$	$\frac{h_2}{h_1}$
30 mm					
50 mm					
100 mm					
200 mm					
500 mm					
1000 mm					

11. In this section, you use the lenses along with your eye.

    (a) For the large positive lens ("A") first, hold the lens "close to" an object (such as your finger to look at your fingerprint). View the object through the lens with your eye. Sketch the layout of object and lens and trace rays to see where the image is formed.

    (b) Repeat for the other two lenses. Note the characteristics of the image you see in the three cases.

12. In this section, you use the lenses in pairs along with your eye to make two different telescopes. A telescope is a "system" of (usually) two lenses: a positive lens (the "objective") that usually has a large diameter and long focal length, combined with a negative OR positive lens with a smaller diameter and a shorter focal length (the "eyepiece" or "ocular"). Telescopes are used to image objects located far away, so that the incoming rays are approximately *parallel.* The objective lens brings these lens to a *focus* (location where the rays *converge*) at the focal point of the lens. The eyepiece is placed at a distance equal to its focal length away from the focal point; this distance is "positive" if the eyepiece has a positive focal length and negative if the eyepiece is a negative lens.

    (a) Hold the two positive lenses in your hand with the longer focal-length lens ("A") farther in front of you (Figure 3). Aim the lenses at a distant (and bright) object and look through the second lens ("B"). Change the distance between the lenses until you see an image of the distant object. Characterize this image, including its orientation and size compared to the actual object seen without the lenses. You may want to draw two copies of the image on paper: one that seems to be the same size as the image you see with and without the lenses. You can measure these images to estimate the *angular magnification* of the telescope. This is a *Keplerian telescope*, named after Johannes Kepler.

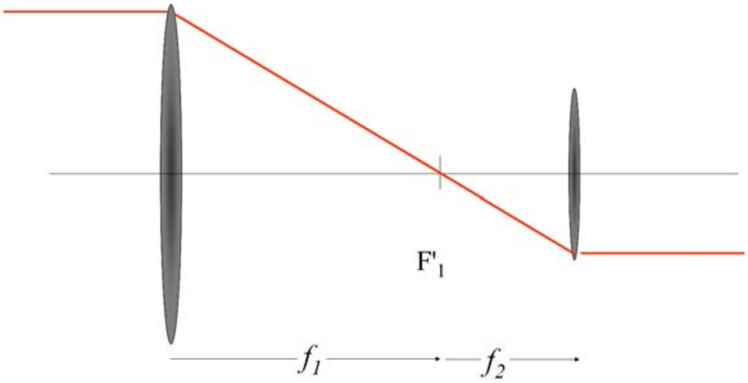

Figure 3: Telescope formed from two positive lenses

(b) Now substitute the negative lens ("C") for the smaller positive lens ("B") and repeat the process (Figure 4). This has the form of the original telescope used by Galileo (hence a *Galilean telescope*). Characterize the images obtained with this telescope and compare to the images obtained with the Keplerian telescope. For information, the angular magnification of Galileo's original telescope was about 15X.

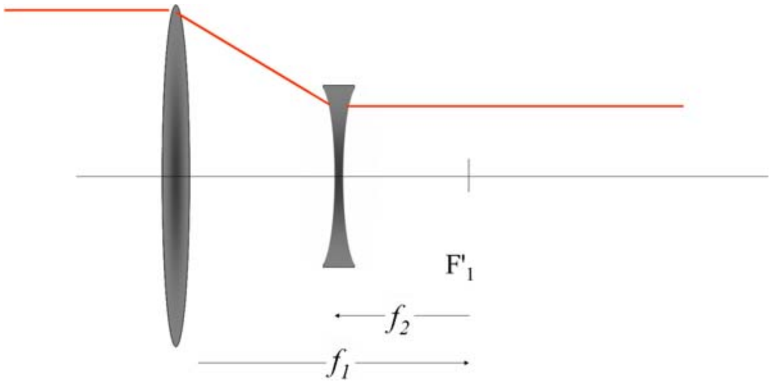

Figure 4: Galilean telescope formed from a positive objective lens and a negative eyepiece lens.

1.4 Data Analysis

1. Graphing object and image distance

   Graph the relationship between object distance z_1 on the horizontal axis and image distance z_2 on the vertical axis for lens A.You may make the graphs on a computer using Microsoft Excel$^{\mathrm{TM}}$ or similar program.

2. Repeat for Lens B.

3. Determine the focal length of the lens from the data using the imaging equation:

$$\frac{1}{z_1} + \frac{1}{z_2} = \frac{1}{f}$$

4. Image Magnification

$$M_t \equiv \frac{h_2}{h_1} = -\frac{z_2}{z_1}$$

   Calculate the ratios of image distance z_1 to object distance z_2 and the ratios of the image height h_2 to object height h_1

1.5 Estimate the Uncertainty of Measurements

Experimental measurements always carry some degree of uncertainty, often called "experimental error". Perfect precision is not possible. Therefore, experimental results should always be reported with some estimate of the degree of uncertainty of the measured results. There are many advanced techniques for estimating experimental uncertainty, involving statistical evaluations of data.

You used two methods to determine the focal length of two lenses. It is unlikely that you found exactly the same value using the two methods. Describe the uncertainty in your measurements. Which measurement do you think is probably most correct? Why?

1.6 Lab Report

Submit a typed lab report including your measurements, graphs, and answers to all the questions posed in the lab.

1.7 Optional Questions Based on Your Experiments

The following are examples of practical applications of the geometric theory of lens focal point and magnification.

1. In an overhead projector, where is the overhead slide located relative to the focal point of the projector lens? (Answer something like: "At the lens", or "At the focal point", or "Between the lens and twice the focal point", or "Between zero and twice the focal point", etc.)
2. In a digital camera, where is the image sensor located relative to the focal point of the camera lens when you take a picture of a distant object? (Answer something like: "At the lens", or "At the focal point", or "Between the lens and twice the focal point", or "Between zero and twice the focal point", etc.) Hint: What magnifications are useful for overhead projectors and cameras?