Lab # 5
IMAGE FORMATION WITH MIRRORS
(Exit Interview)

I. Introduction
In this lab you will form images with several different types of spherical mirrors, some large and some small. In each case you will use the mirror equation

\[ \frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \]  

relating the object distance \( s \), the image distance \( s' \), and the focal length \( f \). We will also see if the relationship between the focal length and radius of the curvature \( f = R/2 \) holds for the mirrors we are using.

We have only a few samples of each type of mirror; so, you and your lab partners will need to cycle through the procedures II. and III. given below. You may begin with either one.

Fundamental Laws of Experimental Optics:
1. Do not Drop!
2. Do not Touch (keep your fingers off optical surfaces)!

II. Large Mirrors
A. For either one of the two large mirrors, determine the radius of curvature \( R \) by the following method: Assume that the mirror surface is part of a sphere. A cross-section is shown in the figure below. Measure both \( h \) and \( p \), including some estimate of the associated uncertainty. Derive an expression for \( R \) in terms of \( h \) and \( p \). (Note: the mirror surface is at the back of the glass - your ruler goes only to the front of the glass, so presumably you need some estimate of the thickness of the glass.) Show your result for \( R \) to the instructor.

B. Use a variety of objects such as a light bulb, the sun (if available), the Holyoke range. Also try a small arrow carved out of a black screen illuminated from behind at a series of fixed intervals (maybe 10 or 20 cm), and so on. You can form the (real) image on a sheet of paper or index card. For each object, measure the object distance and image distance. Don’t worry about really high precision, but in each case estimate an uncertainty arising
not only from the limitations of rulers and the like, but also from the range of distances over which the sharpness of the image is visually indistinguishable.

C. To see if your results are described by Eq. (1), we want you to plot a graph of your data in such a way that if Eq. (1) is the appropriate relationship between the various distances, the data will all fall on a straight line. From that line you will determine a value for the focal length to be compared with the value determined from the radius of curvature of the mirror. You want \( f \) to appear as either the slope or the intercept of the straight line (NOT \( 1/f \)). Once you decide the appropriate data format, use a spreadsheet program to find \( f \). For fun, you may also wish to check your result for the focal length by producing parallel incident rays with the HeNe lasers and measuring the location of the point at which the reflected rays cross. You may use a little chalk dust to illuminate the rays, but avoid getting too much on the big mirrors.

D. We usually imagine that your eye is far away when doing our ray tracings. But what happens when your eye is at a finite distance? Sit about two or three meters away from the mirror and calculate how far from the mirror an object would have to be to form an image at your position. Have your lab partner move his/her thumb from the surface of the mirror to the center, noting the point at which the image should be where your eye is. Record your qualitative observations. Can you explain them? Place a meterstick along the optical axis and look at the image of the scale. Explain qualitatively what you see. Place your eye along the optic axis and move toward and away from the mirror. Where does the image become unclear? Can you estimate the range over which it is unclear? Can you quantitatively predict over what that range should be unclear?

III. Small Mirrors and an Optical Illusion

A. In this section you will concentrate on understanding image formation semi-quantitatively. No need for great precision or uncertainty estimates here. First determine the approximate focal length of one of the small mirrors from the optical illusion “Mirage” by the following (useful) trick: Hold a card illuminated from behind in front of the mirror. Form the image of the bulb on the card, and find the point at which \( s = s' \). If \( s = s' \), then from Eq. (1) \( s = s' = 2f \).

B. The Illusion. Put the two “Mirage” spherical mirrors (they have the same focal length) together to form the illusion using a small 6-volt light bulb as the object (also try the little pig). How many images do you see? Are they upright or inverted? Facing forward or backward? Work out a simple argument to understand what you see. Try both ray tracing and a more formal argument based on the mirror equation. Show your results to the instructor.
IV. A Pair of Large Mirrors

If time is available, place the two large mirrors facing each other about 5 to 6 feet apart. Put a high-power light bulb as an object, approximately at the focal point of one of the mirrors. What images do you see in front of the other mirror? How do you account for them in terms of the mirror equation? Of the two images, is one brighter than the other? Is it bright enough to set fire to a piece of paper? Does the color of the paper make a difference?

V. Exit Interview

For your exit interview, be prepared to explain to the instructor your results from parts II. and III. above.