Assignment 2
Due September 15, 2011

Text readings

Geometric optics of simple lenses [Pages 153-170].
Spherical mirrors in the paraxial approximation [Pages 181-187].
Please read through the derivation of these relationships.

Problems

The equipment will be available in Room 212B. Please work on these problems right away, so we can discuss your conceptual understanding, any needed theory and work out any problems.

Problem 1

Methods to Determine the Focal Length of Convex lenses: In class you will be given a convex lens. Determine its focal length using the following methods.

1. Object at infinity: Use the idea that images of objects that are far away from the lens will be formed at the location of the focus (or focal plane). Position a light source 2-3 meters away from the positive lens then adjust the lens-screen distance until you see the sharpest, brightest, and smallest image.

2. Thin lens formula: Determine the focal length of the positive lenses using the image formation technique. Find the object distance S_o and the corresponding image distance S_i for, at least, 4 cases. Recall that the thin lens formula is given by

$$\frac{1}{f} = \frac{1}{S_i} - \frac{1}{S_o}$$

(a) Plot $1/S_i$ vs. $1/S_o$ and determine the focal length f.
(b) At what object distance (in terms of lens focal length) the magnification is one. What does this mean? In some cases in optical spectroscopy this configuration becomes important. Why?

3. Bessel Method: In this case the distance between the object and the screen, L, is fixed. If the lens is moved back and forth, the image will be in focus at two positions of the lens. The focal length f is given by

$$f = \frac{L^2 - d^2}{4L}$$

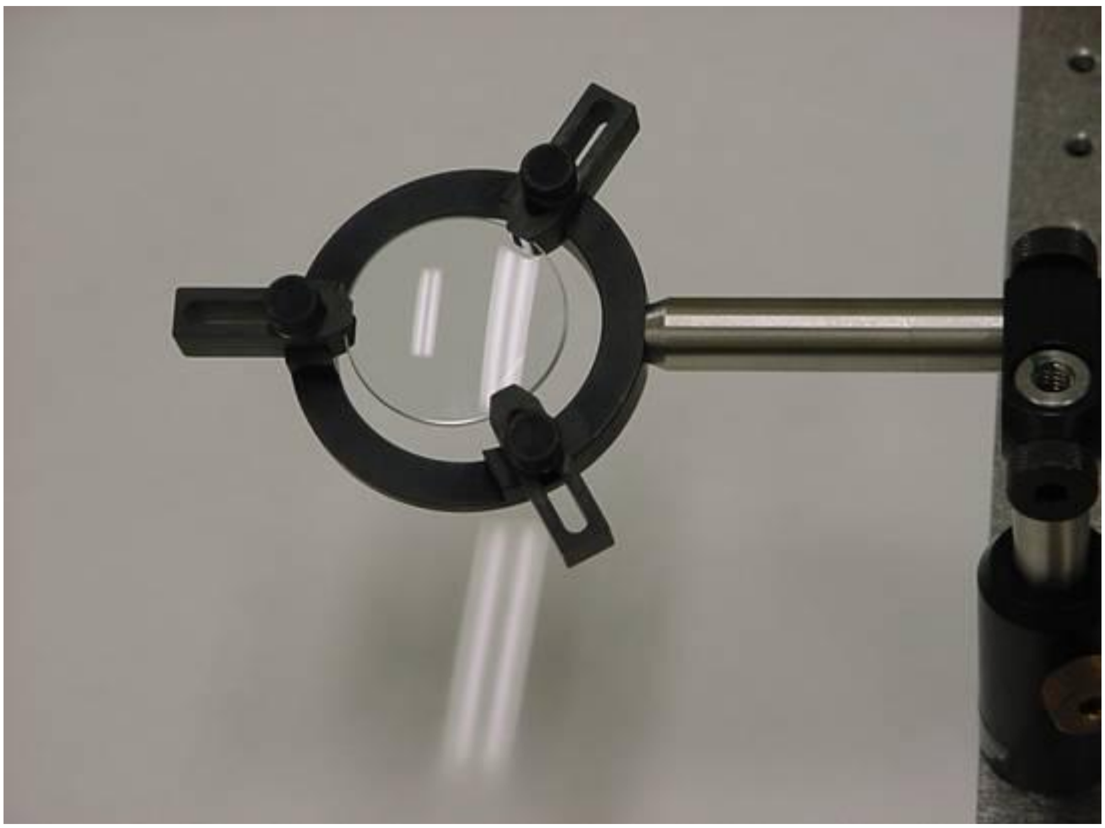
Here, *d* is the distance that the lens moved. The distance *L must be greater than four times the focal length* as you can see from the above equation.

4. Determine the power and the f-number (f/#) of the lens. Recall that the power of a lens is defined as $(1/f)$ *where f is the focal length in meters*. The $f/\#$ of a lens with a circular aperture of diameter D is defined as the ratio of the focal length to the lens diameter, f/D. The f-number is also referred to as the relative aperture and the $f/$stop.

Problem 2

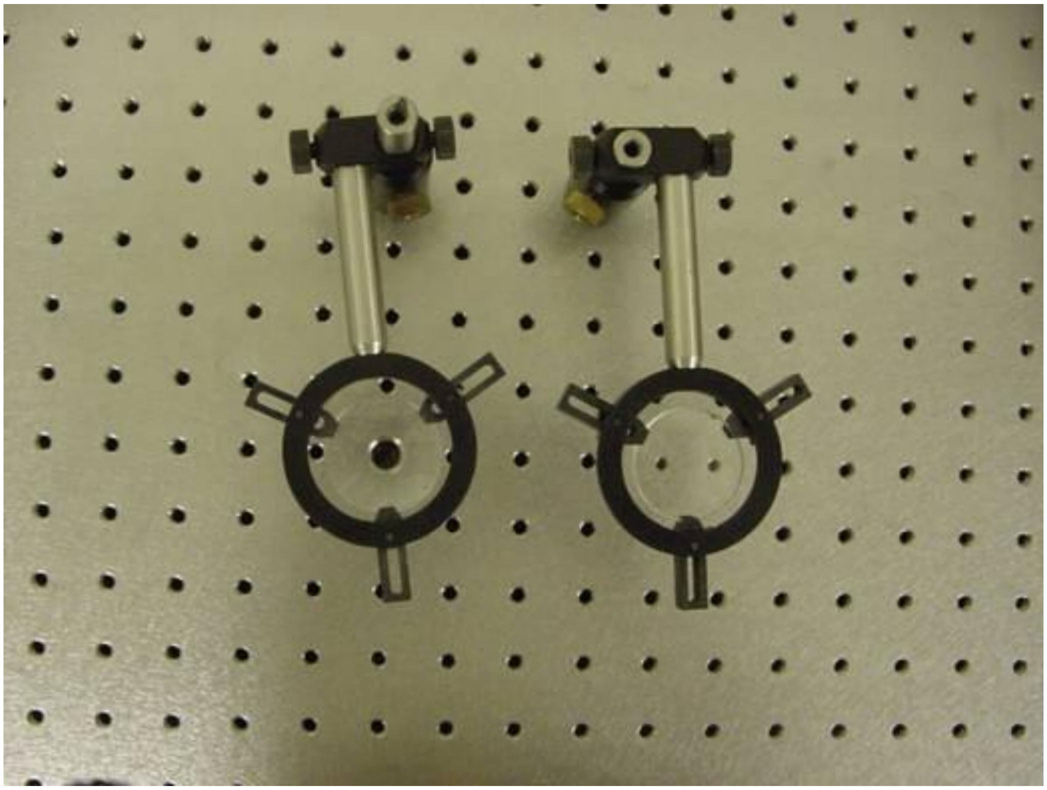
Focal Point: The picture shown below is a converging lens. The overhead fluorescent lights reflect from the glass surface(s) of the lens and the lens projects an image of these lights on a white paper below the lens.

(a) What is the focal length of this lens? You will be able to manipulate the lens in class to make whatever measurements needed.
(b) Clearly describe how you determine the focal length. Use ray diagrams to support your arguments.
(c) From which glass surface does each of the two reflections seen below comes. Support your answer by using ray diagrams.



Problem 3

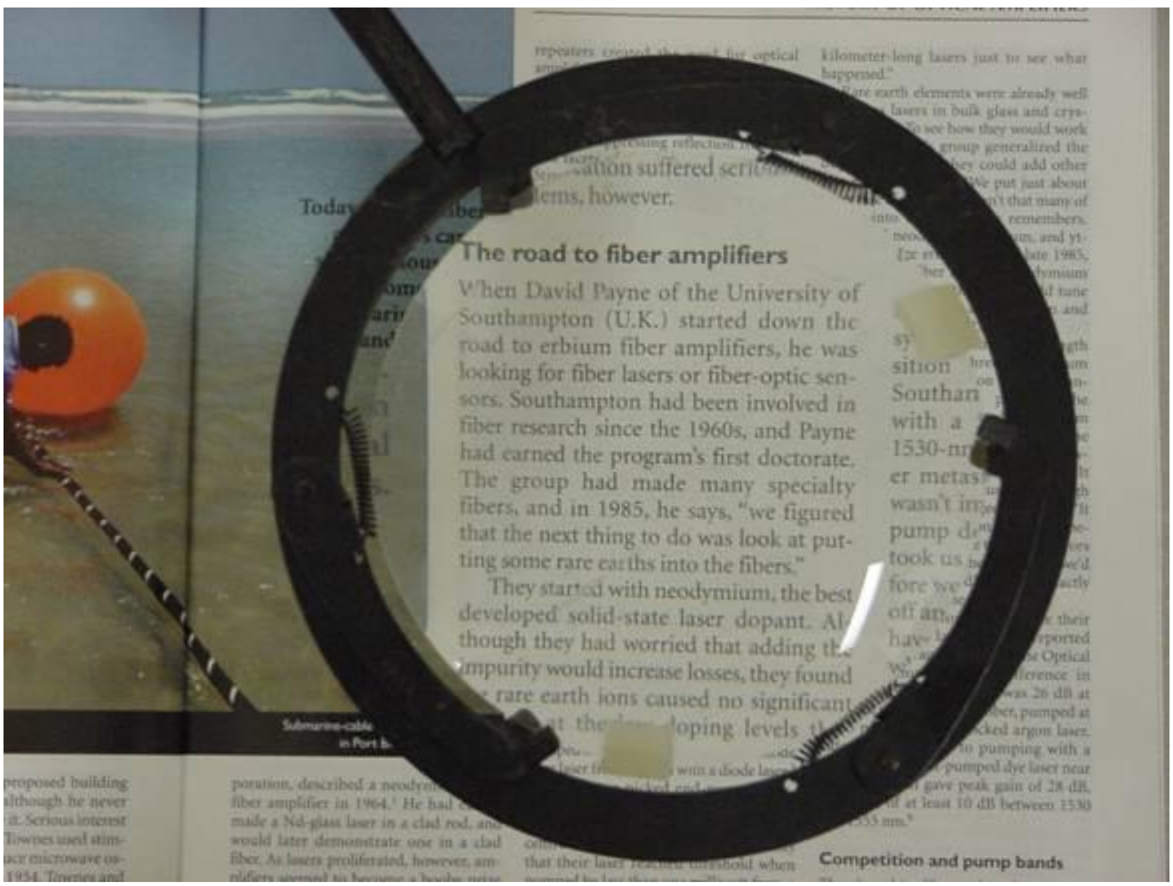
Spherical Lenses: Can you determine the type of the lenses shown in the picture? If you have no clue don't be discouraged you will be able to play with them in class. Is it possible that both lenses have the same sign but not the same focal length? If yes, explain with diagrams and mention conditions.



Problem 4

Magnifier: The picture shows a lens used as a magnifier.

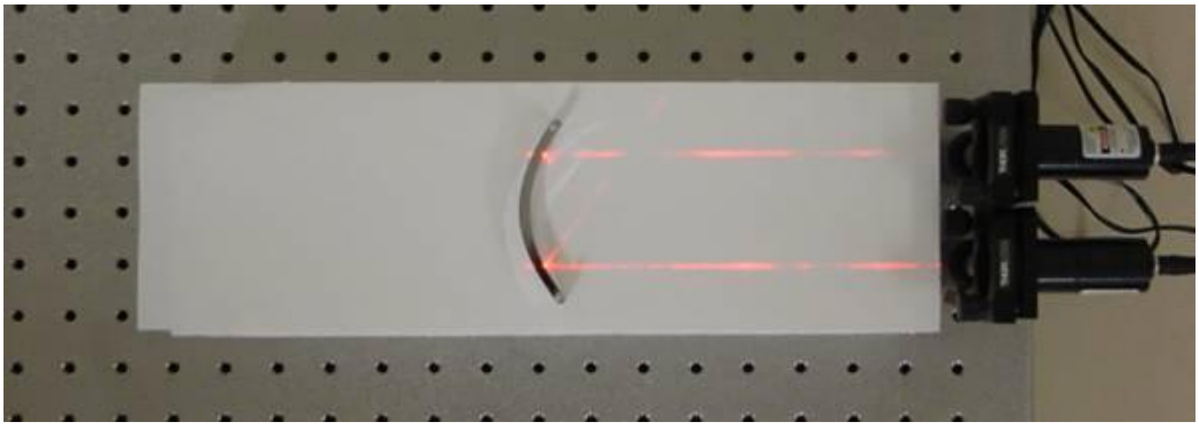
(a) What is the focal length of the lens?
(b) How far must this lens be from the page to give a magnification of 3 times?
(c) What is the object (virtual or real) and object distance
(d) What is the image (virtual or real) and image distance
(e) Do calculations to show that all these numbers work out.
(f) Draw a ray diagram.

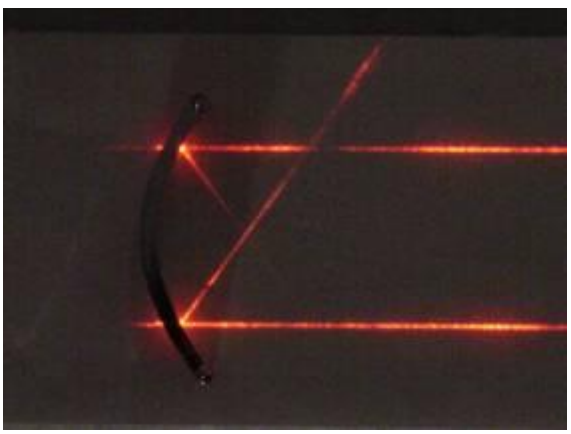


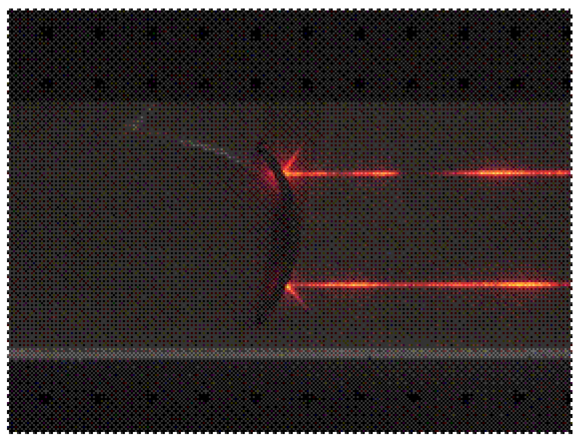
Problem 5

Circular Mirrors: Trace rays to determine the focal length for the two mirrors shown below. Use these values to determine the radius of curvature for each mirror. Your answer should include:

(a) a copy of your ray diagram,
(b) measurements,
(c) a clear theoretical explanation using the paraxial theory for mirrors, and
(d) the mirror radius.







Problem 6

Disappearing Bulb: The picture below shows an empty light bulb socket. However, at other times a lit bulb appears in the socket. This is a trick! Examine the apparatus to determine what is going on.

Answer the following questions clearly and completely. You will be able to determine some answers by direct measurement in class and others from theoretical calculations.

(a) Make a ray diagram for this system.
(b) What are the object and image distances?
(c) What is the radius of the mirror?
(d) Is the object real or virtual?
(e) Is the image real or virtual?
(f) Is the mirror convex or concave?

Problem 7

Determination of the focal length of a negative lens: In class you will be given a negative lens in order to determine its focal length. Can you do this by combining or using a positive lens of any focal length? Explain clearly with ray diagrams. If the two lenses are separated by a distance d then the back focal length measured from the closest surface of the second lens is given by.

$$f_{back} = \frac{f_2(f_1 - d)}{(f_1 + f_2) - d}$$

To use this result you need to have the object at a distance more than $10f^2$ (f is the focal length of the positive lens) or use a collimated laser beam. In this formula either f_1 or f_2 could be the focal length of the diverging lens. If the first lens is the positive lens then the separation distance d must be less than f_1=f_p (i.e., $d < f_p$) regardless the power of the lenses. If the first lens is the negative lens then the separation distance d must be larger than f_1+f_2 (i.e., $d > f_p+f_N$) for $|f_N| < f_p$. If the first lens is the negative lens and $|f_N| > f_p$ then the separation distance d can take any value.

A simple and accurate way of determining the focal length of a negative lens can be done using the thin lens formula. Although this can be done with any positive lens it is more appropriate to use a strong one. Fix the distance between the positive lens and the object (make sure that this distance is larger than the focal length. Why?). Find the image of the object on a screen and record the image distance. Now insert the negative lens between the screen and the positive lens as close as possible to the screen. Move the screen until you find the image and record the image distance relative to the center of the negative lens. Now you can use the lens formula to find the focal length of the negative lens. Notice that the object distance relative to the negative lens is the image distance formed by positive lens minus the separation between the lenses.

Bonus Problems

Problems 5.32 and 5.40