Experiment 27
Thin Lenses

Advanced Reading:
(Serway) Chapter 36 section 36-3 & 36-4

Equipment:
1 Optical Bench
3 lenses holders
3 optical bench clamps
1 cross-haired light source
1 screen
1 Bi-convex lens
1 Bi-concave lens

Objective:
The object of this experiment is to measure the focal lengths of various lenses alone and in combinations.

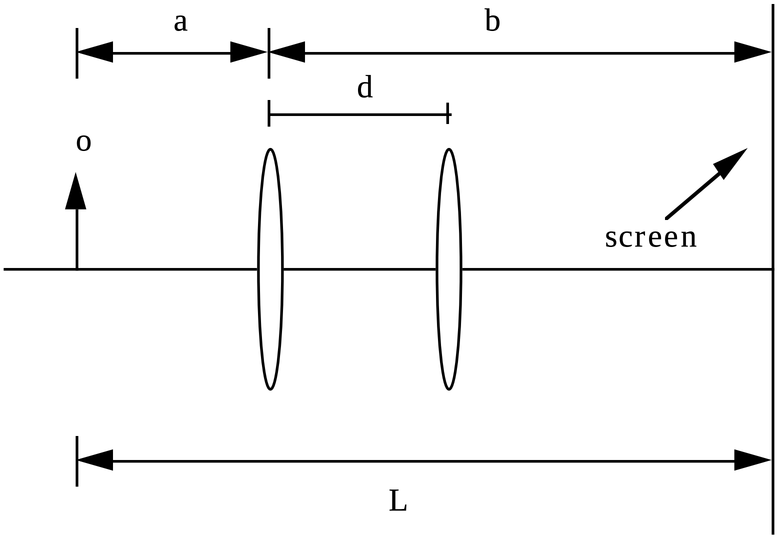
Theory:

In a previous experiment light was found to deviate when it passed between media with different indices of refraction. This property can be utilized to bend light in useful ways. A convex lens (made of glass $n \approx 1.5$) can be used to focus parallel light rays and form a real image as the light travels from air ($n \approx 1$) to glass and back to air. A real image is one that can be projected on a screen. A concave lens forms a virtual image that can not be projected on a screen.

An important property of a lens is its focal length. The focal length of a thin lens is given by:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f} \quad \text{eq. 27-1}$$


figure 27-1



27-2 Conjugate Foci

where p is the object distance and q is the image distance. For an object that is infinitely far away, the image distance and the focal length are the same. For lenses used in the lab ($f<30$ cm) objects over 20 meters away can be considered infinitely far away.

A convenient method of measuring the focal length of a positive lens (forms a real image) is to use the conjugate foci method. If an object and the image are located a distance greater than 4f apart, then the following equation can be used:

$$f = \frac{L^2 - d^2}{4L} \quad \text{eq. 25-2}$$

(See figure 27-2.) This equation arises from equation 27-1 by noting that the object and the image distance can be switched and the focal length will stay the same. While this (switching) in itself is an interesting phenomena, the utility of this method is that it yields *a smaller uncertainty* than the other two methods used in this experiment.

Procedure:

Part 1: Measurement of the focal length of a converging lens

This will be done three ways:
(1) Using distant objects
(2) Using the lens formula
(3) Using the conjugate foci method

Distant Object method

1. Hold the lens by the edges between your fingers and project an image of a distant object on a piece of white paper. (Stand at the door to the lab and project the image of the outside doors on the opposite end of the hall on the paper.)

2. Have your lab partner measure the distance from the lens to the screen. If we assume that the object distance is very large compared to the image distance, then the image distance is equal to the focal length of the lens. Note the character of the image. (Is it inverted or not? Is it magnified [bigger than the object itself] or minified [smaller than the object itself]?

Lens Equation Method

3. Mount the lens, the screen and the light source as they appear in figure 27-1. Adjust the set-up so that a clear image of the object falls on the screen.

4. Measure the image and the object distances. Use equation 27-1 to find the focal length of the lens. Measure at least 5 image/object distances and calculate an average focal length.

Conjugate Foci Method

5. Set-up the optical bench as in figure 27-1. Place the screen as close to one end of the optical bench as possible and the lamp as close to the other end as possible.

6. There are two places in which the lens can be placed in order to form an image. One of the images will be small and bright while the other image will be large and dim. Find these two places. Measure the appropriate distances as shown in figure 25-2 and equation 25-2 to find the focal lengths using the conjugate foci method.

7. Compare the focal lengths measured from the three different methods.

Part 2: Measurement of the focal length of a diverging lens

In this part of the experiment a real image will be used as a virtual object.

8. Place the light box at some position O_c. Form the image of the light box on the screen with the converging lens. Record this position as I_c . This image will serve as a virtual object for the next part of the experiment.

9. Place the diverging lens in the system at some point between convex lense and the location where image I_C was formed on screen. (See figure 27-3.) Keeping the diverging lense stationary, form a clear image on the screen by moving it away from the lenses.

Record the distances p and q. Note that q is the *image distance* and is the distance from the concave lense to the screen at I_D and that p is the *object distance* and is the distance from the concave lense to the object at O_D (which is at the same location as I_C since the diverging lense object is the image of the convex lense. See figure 27-3.) Calculate the focal length of the diverging lens. Move the lense arrangement, repeat three times and calculate the average.

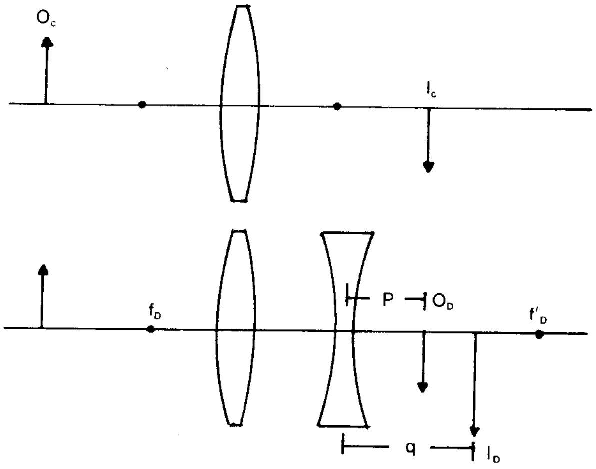


figure 27-3

Questions/Conclusions:

1. Draw ray diagrams for the distant object and conjugate foci methods. used to determine the focal lengths of the lenses.

2. A concave lens made out of air is immersed in water (two watch glasses glued to a piece of pipe to that air is inside). Will it form a real image that can be focused on a screen? Why or why not? Look for clues in the advanced reading section.

3. If a convex lens with an index of refraction of 1.5 and a focal length of 20 cm were immersed in a fluid whose index of refraction is also1.50, what is the new focal length of the lens. (hint: trick question)

4. What are the major sources of uncertainty in this experiment?