

PHYS222 Experiment 27

Thin Lenses

(Spring 2021 version)

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 observe the characteristics of (thin) convex and concave lenses and to measure the focal lengths of these two types lenses.

Theory:

In a previous experiment light was found to change direction when it passed (at an angle) between media with different indices of refraction. This property can be utilized to bend (refract) light in useful ways. A convex lens (made of glass with $n > 1$) can be used to focus 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 cannot be projected on a screen.

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

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f} \quad \text{Eq. 27-1}$$

where o is the object distance and i 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 ($f < 30\text{cm}$) objects over 20 meters away can be considered infinitely far away.

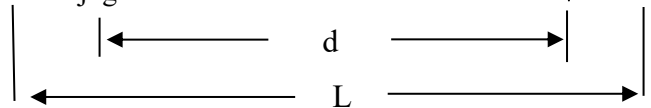
A convenient method of measuring the focal length of a positive lens (forms a real image) is to use the conjugate foci method. If an object and the image are located a distance greater than $4f$ apart, then the following equation can be used:



Figure 27-1
Conjugate Foci Method - 1st measurement



Figure 27-2
Conjugate Foci Method - 2nd measurement



$$f = \frac{L^2 - d^2}{4L} \quad \text{eq. 27-2}$$

(See figures 27-1 & 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) Conjugate Foci Method

Distant Object method

1. Place a lens and screen on the optical rails. Point the apparatus towards the window. Move the screen until a clear image is formed of something outside the window. You should determine a range of uncertainty. Your TA will explain this.

2. Measure the distance from the lens to the screen. This is i or image distance. 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 the magnification > 1 (i.e., image size larger than the object itself) or magnification < 1 (i.e., image size smaller than the object itself)?

Lens Equation Method

3. Plug in the light source. Adjust the set-up so that a clear image of the object falls on the screen. See data table given in uncertainty website).

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

Conjugate Foci Method

5. Place the light source and screen as far apart as the optical bench allows (maximum value is 180 cm). **First** find one image when the lens is near the screen. Record this location. **Next** move lens where is the same distance from the light source as it was from the screen. This is the conjugate position. Record this location. See Figs 27-1 & 27-2.

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. *Before starting step 8 below explore the behavior of a negative lens by looking at an object from various distances. Note what you observe. Can you project an image on a screen? Does image ever go out of focus? Is it always upright?*

If you have questions about how to do this part see video below. It is less than 2 minutes long.

<https://www.youtube.com/watch?v=hRCzNbs1wrw>

6. **Record all positions in part 2 in your lab data notebook.** Place the light box at some position O. Form an image of the light box on the screen with the converging lens. **Record this image position as I.** *This image will serve as a virtual object for the next part of the experiment.*

7. Next, place the diverging lens in the system at **some point between convex lens and the location where image I was formed on screen.** (See figure 27-2.) While keeping the diverging lens stationary, form a clear image on the screen by **moving the screen away** from the lenses to a new position I' .

The distance from the **concave lens** to the new screen position (at I') is the **image distance i** . The distance from the **concave lens** to position of the **first image formed** (at position I) is the (virtual) **object distance o** . See figure 27-3.

Calculate the focal length of the diverging lens. Please note that **o is a negative value.**

8. Move the lens arrangement and repeat two more times. Calculate the average focal length.

Ray diagram

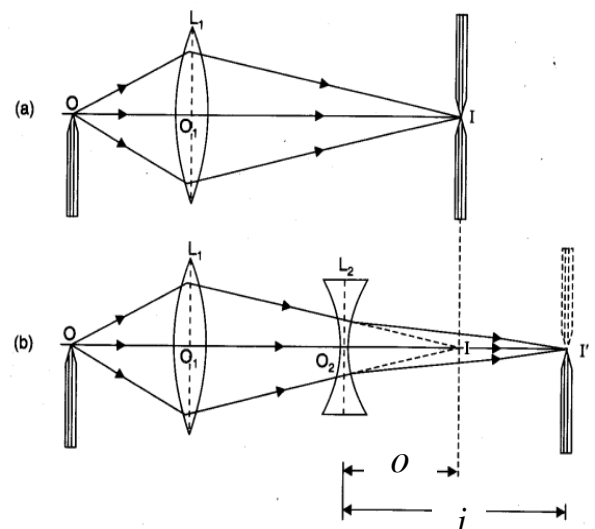


Fig. Focal length of a concave lens.

Figure 27-3.

Questions/Conclusions:

1. Draw one ray diagram each for when the object distance is located at two times the focal length of a lens. Draw a 2nd diagram for when the distance to the object is located at a distance that is $1\frac{1}{2}$ times the focal length.
2. In Pitfall Prevention 36.1 of Serway & Jewett 8th Edition the authors state “Magnification does not necessarily imply that enlargement.” Explain what this means in the context of what you observed in the experiment.
3. Were the focal lengths you determined by the different methods the same (when uncertainty is considered)?

Which method gave the most precise answer (i.e., which method had the smaller [or smallest if you did conjugate foci method]).

Explain your answers.

4. A diopter is defined as $1/\text{focal length}$ when the focal length is given in meters. For instance, a positive lens with a focal length of 40 cm is 2.5 diopters since $1/0.40 = 2.5$. Eyeglass prescriptions are given in diopters.

Calculate how many diopters both your positive and negative lenses are. Show all work.