

EXPERIMENT 6

OPTICS: FOCAL LENGTH OF A LENS

The following website should be accessed before coming to class.

Text reference: pp189-196

[Optics Bench](#)

a) For convenience of discussion we assume that the light passes through the lens from left to right. Ray diagrams will follow this convention.

(b) The **focal point** of a lens is found by allowing a bundle of mutually parallel rays to enter the lens (i.e., from an object infinitely far from the lens). The lens alters the direction of these rays, making them emerge as a convergent or divergent bundle. The point to which they converge (or from which they diverge) is called the **focal point**. The diagrams illustrate this; F labels the focal points.

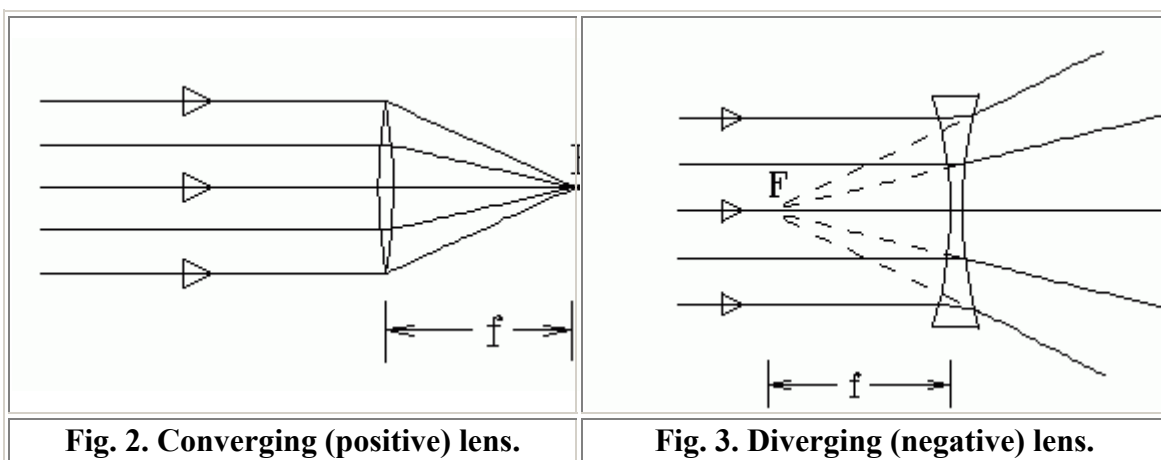


Fig. 2. Converging (positive) lens.

Fig. 3. Diverging (negative) lens.

(d) A lens which **converges** a bundle of parallel rays is called a **converging lens**, or **positive lens** (its focal length is taken as positive.) The converging lens is thicker at its center than at its edge.

(e) A lens which **diverges** a bundle of parallel rays is called a **diverging lens**, or a **negative lens** (its focal length is taken as negative.) The diverging lens is thicker at its edge than at its center.

(f) Light rays from a point source (object) passing through a lens emerge convergent to a point or divergent from a point. In either case, that point is called the **image** of the source.

(g) When the emergent rays **converge** to a point, the image is called **real**.

(h) When the emergent rays **diverge** from a point, the image is called **virtual**. Such images can be seen only by looking through the lens, toward the light source. By our convention, with the rays passing through the lens from left to right, you must have your eye to the right of the lens and look through the lens to see the image which is to the left of the lens.

EQUIPMENT NEEDED

- Bench (OS-8518)
- Convex lens

- Light source (object) (OS-8517)
- Screen

Purpose

To determine the focal length of a thin lens and to explore the difference between convex and concave lenses and to determine their focal lengths.

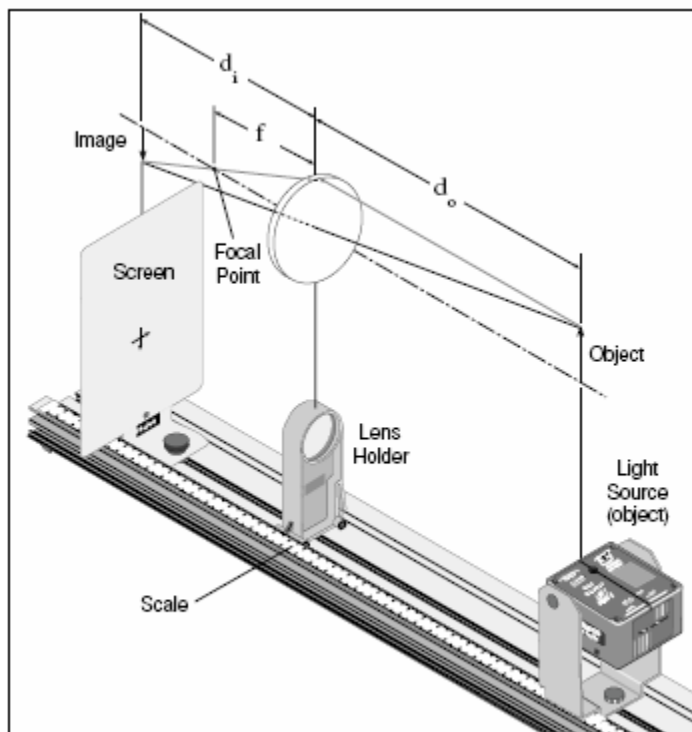


Figure 9.1

Theory

For a thin lens:
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

where f is focal length, d_o is the distance between the object and the lens, and d_i is the distance between the image

and the lens. See Figure 9.1.

Procedure

I. FOCAL LENGTH USING AN OBJECT AT INFINITY

1. Using one of the positive lenses focus a distant light source on a paper.
2. Measure the distance from the lens to the paper. This is the image distance.
3. Take the limit as the object distance (d_o)* goes to infinity in the Thin Lens Formula:

* d_o is measured by focusing the image on a piece of paper of the lights and measuring that distance. This is the focal length experimental for that particular lens. Compare this value with your graphical solution.

* d_o = _____ (cm)

II. FOCAL LENGTH BY PLOTTING $1/d_o$ vs. $1/d_i$

- a. On the optical bench, position the lens between a light source (the object) and a screen. Be sure the object and the screen are at least one meter apart.
- b. Move the lens to a position where an image of the object is formed on the screen. Measure the image distance and the object distance. Record all measurements in table 9.1.
- c. Measure the object size and the image size for this position of the lens.
- d. Move the lens to a second position where the image is in focus (Do not move the screen or Light Source). Measure the image distance and the object distance.
- e. Measure the image size for this position also.
- f. Move the screen toward the object until you can no longer find two positions of the lens where the image will focus. Then move the screen a few centimeters further away from the object. Repeat Parts b and d for this position of the screen and for 4 other intermediate positions of the screen. This will give you 6 sets of data points.
- g. Plot $1/d_o$ vs. $1/d_i$ using the 6 data points. This will give a straight line and the x- and y-intercepts are each equal to $1/f$. Determine the focal length (f).

- h. Find the percent difference between the two values of the focal length found from the intercepts. Then average these two values and find the percent difference between this average and the focal length found in Part I.
- i. For the first two sets of data points ONLY, use image and object distances to find the magnification at each position of the lens.

$$\text{Magnification} = M = \frac{d_i}{d_o}$$

Then, using your measurements of the image size and object size, find the magnification by measuring the image size and the object size.

$$|M| = \frac{\text{image size}}{\text{object size}}$$

Find the percent differences.

Table 9.1

Object distance	Image distance	Image size	1/d _o	1/d _i
1				
2				
3				
4				
5				
6				

x – intercept (1/f₁) _____ y – intercept (1/f₂) _____

Solve for: f₁ _____ f₂ _____

f average = (f₁ + f₂)/2 _____

$$\text{percent difference} = \left| \frac{*do - f \text{ average}}{*do} \right| \times 100$$

1. Remove the ray box from the optical bench and place the ray box on a white piece of paper. Using five white rays from the ray box shine the rays straight into the convex lens. See Figure 6.1.

NOTE: Concave and Convex lenses have only one flat edge. Place flat edge on surface. Trace around the surface of the lens and trace the incident and transmitted rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions.

2. The place where the five refracted rays cross each other is the focal point of the lens. Measure the focal length from the center of the convex lens to the focal point. Record the result in Table 6.1.

Table 6.1 Results

	Convex Lens	Concave Lens
Focal Length		

3. Repeat the procedure for the concave lens. Note that in Step 2, the rays leaving the lens are diverging and they will not cross. Use a ruler to extend the outgoing rays straight back through the lens which is called a **virtual** focus. The focal point is where these extended rays cross.
4. Place the convex and concave lenses together and place them in the path of the parallel rays. Trace the rays. What does this tell you about the relationship between the focal lengths of these two lenses?
5. Slide the convex and concave lenses apart to observe the effect of a combination of two lenses. Then reverse the order of the lenses. Trace at least one pattern of this type.

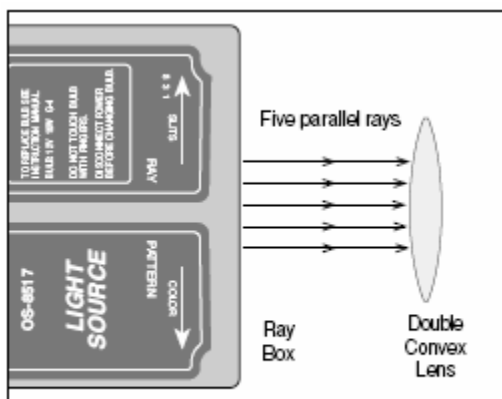


Figure 6.1