Experiment 11: Focal Length and Magnification of a Thin Lens

Required Equipment from Basic Optics System

Light Source
Bench
Converging lens of unknown focal length
Screen

Other Equipment

Metric ruler
Optics Caliper (optional, for measuring image sizes), PASCO part OS-8468

Purpose
The purpose of this experiment is to determine the focal length of a thin lens and to measure the magnification for a certain combination of object and image distances.

Theory
For a thin lens:

(eq.12.1)
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

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. By measuring d_o and d_i the focal length can be determined.
Magnification, M, is the ratio of image size to object size. If the image is inverted, M is negative.

Part I: Object at Infinity

In this part, you will determine the focal length of the lens by making a single measurement of d_i with $d_o \approx \infty$

Procedure

1. Hold the lens in one hand and the screen in the other hand. Focus the image of a *distant* bright object (such as a window or lamp across the room) on the screen.

2. Have your partner measure the distance from the lens to the screen. This is the image distance, d_i.

d_i = _______________

Analysis

1. As d_o approaches infinity, what does $1/d_o$ approach?

2. Use the Thin Lens Formula (Equation 12.1) to calculate the focal length.

f = _______________

Part II: Object Closer Than Infinity

In this part, you will determine the focal length by measuring several pairs of object and image distances and plotting $1/d_o$ versus $1/d_i$.

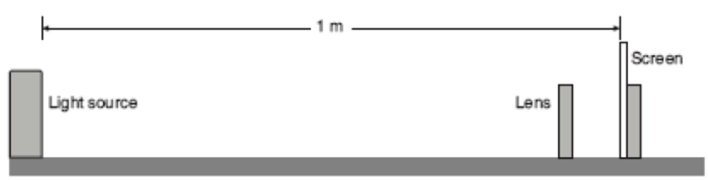

Figure 12.1

Procedure

1. Place the light source and the screen on the optics bench 1 m apart with the light source's crossed-arrow object toward the screen. Place the lens between them (see Figure 12.1).

2. Starting with the lens close to the screen, slide the lens away from the screen to a position where a clear image of the crossed-arrow object is formed on the screen. Measure the image distance and the object distance. Record these measurements (and all measurements from the following steps) in Table 12.1.

3. Measure the object size and the image size for this position of the lens.

4. Without moving the screen or the light source, move the lens to a second position where the image is in focus. Measure the image distance and the object distance.

5. Measure the object size and image size for this position also. Note that you will not see the entire crossed-arrow pattern. Instead, measure the image and object sizes as the distance between two index marks on the pattern (see Figure 12.2 for example).

6. Repeat steps 2 and 4 with light source-to-screen distances of 90 cm, 80 cm, 70 cm, 60 cm, and 50 cm. For each light source-to-screen distance, find *two* lens positions where clear images are formed. (You don't need to measure image and object sizes.).

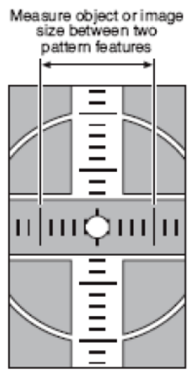

Figure 12.2

Analysis Part A: Focal Length

1. Calculate $1/d$o and $1/d$i for all 12 rows in Table 12.1.

2. Plot $1/d$o versus $1/d$i and find the best-fit line (linear fit). This will give a straight line with the x- and y-intercepts equal to $1/f$. Record the intercepts (including units) here:

y-intercept = $1/f$ = _______________

x-intercept = $1/f$ = _______________

Note: You can plot the data and find the best-fit line on paper or on a computer.

Table 12.1: Image and Object Distances

Distance from light source to screen	d_o	d_i	$1/d_o$	$1/d_i$	Image Size	Object Size
100 cm						
90 cm						
80 cm						
70 cm						
60 cm						
50 cm						

3. For each intercept, calculate a value of f and record it in Table 12.2.

4. Find the percent difference between these two values of f and record them in Table 12.2.

5. Average these two values of f. Find the percent difference between this average and the focal length that you found in Part I. Record these data in Table 12.2.

Table 12.2: Focal Length

f

Result from x-intercept	
Result from y-intercept	
% difference between results from intercepts	
Average of results from intercepts	
Result from Part 1	
% difference between Average of results from intercepts and result from Part1	

Analysis Part B: Magnification

1. For the first two data points only (the first two lines of Table 12.2), use the image and object distances to calculate the magnification, *M*, at each position of the lens. Record the results in Table 12.3.

(eq. 12.1)

$$M = -\frac{d_i}{d_o}$$

2. Calculate the absolute value of *M* (for each of the two lens positions) using your measurements of the image size and object size. Record the results in Table 12.3.

(eq. 12.3)

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

3. Calculate the percent differences between the absolute values of *M* found using the two methods. Record the results in Table 12.3.

Table 12.3: Magnification

	Point 1	Point 2
M calculated from image and object distances		
[M] calculated from image and object distances		
% difference		

Questions

1. Is the image formed by the mirror upright or inverted?

2. Is the image real or virtual? How do you know?

3. By looking at the image, how can you tell that the magnification is negative?