Experiment 7: Converging Lens – Image and Object Relationships

EQUIPMENT NEEDED:

- -Optics Bench
- -75 mm Focal Length Convex Lens
- -Component Holders (3)
- -Light Source
- -Crossed Arrow Target
- -Viewing Screen.

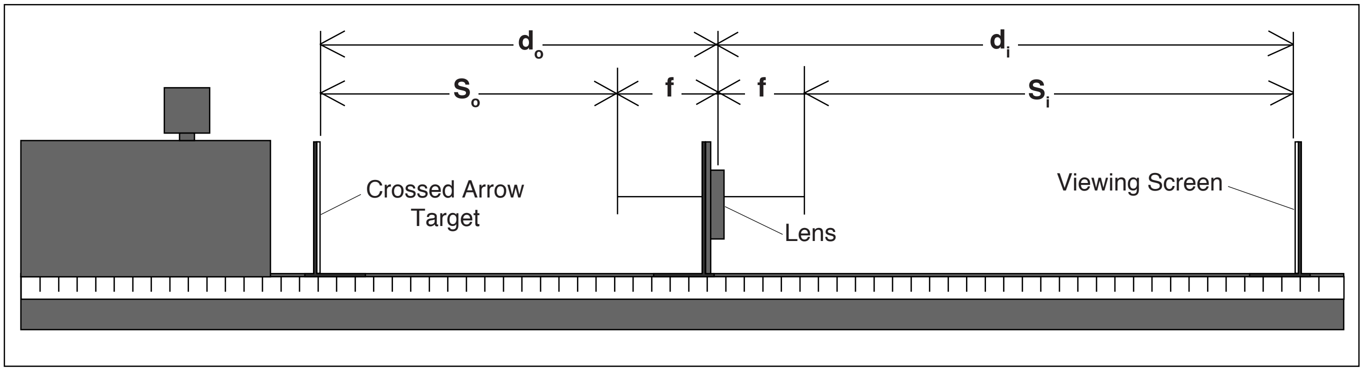

Figure 7.1: Equipment Setup

Introduction

Given a lens of any shape and index of refraction, you could determine the shape and location of the images it forms based only on the Law of Refraction. You need only apply the law along with some of the ray tracing techniques you have already used. However, for spherical lenses (and for spherical mirrors as well), there is a more general equation that can be used to determine the location and magnification of an image. This equation is called the Fundamental Lens equation:

$$1/\mathbf{d_o} + 1/\mathbf{d_i} = 1/\mathbf{f}$$

where **f** is the focal length of the lens, and $\mathbf{d_o}$ and $\mathbf{d_i}$ are the distance from the mirror to the image and object respectively (see Figure 7.1). The magnification of the image is given by the equation:

$$\mathbf{m = -d_i/d_o}$$

In this experiment, you will have an opportunity to test and apply these equations.

➤**NOTE:** Instead of the above equation, you may have learned the Fundamental Lens Equation as $\mathbf{S_oS_i = f^2}$, where $\mathbf{S_o}$ and $\mathbf{S_i}$ are the distances between the principle focus of the lens and the object and image, respectively. If so, notice that $\mathbf{S_o = d_o - f}$, and $\mathbf{S_i = d_i - f}$ (see Figure 7.1). Using these equalities, convince yourself that $1/\mathbf{d_o} + 1/\mathbf{d_i} = 1/\mathbf{f}$ and $\mathbf{S_oS_i = f^2}$ are different expressions of the same relationship.

Procedure

Set up the equipment as shown in Figure 7.1. Turn on the Light Source and slide the lens toward or away from the Crossed Arrow Target, as needed to focus the image of the Target onto the Viewing Screen.

① Is the image magnified or reduced? ____.

② Is the image inverted? ____.

③ Based on the Fundamental Lens Equation, what would happen to $\mathbf{d_i}$ if you increased $\mathbf{d_o}$ even further? ____.

Table 7.1: Data and Calculations

Data			Calculations			
d_o (mm)	d_i	h_i	$1/d_i + 1/d_o$	1/f	h_i/h_o	$-d_i/d_o$
500						
450						
400						
350						
300						
250						
200						
150						
100						
75						
50						

④ What would happen to $\mathbf{d_i}$ if $\mathbf{d_o}$ were very, very large? ________________________________.

⑤ Using your answer to question 4, measure the focal length of the lens. Describe how to experimentally measure the focal length of a converging lens.

Focal Length = ____.

Now set $\mathbf{d_o}$ to the values (in millimeters) listed in the table above. At each setting, locate the image and measure $\mathbf{d_i}$. Also measure $\mathbf{h_i}$, the height of the image. ($\mathbf{h_o}$ is the height of the arrow on the crossed arrow target.)

Using the data you have collected, perform the calculations shown in the table.

⑥ Are your results in complete agreement with the Fundamental Lens Equation? If not, to what do you attribute the discrepancies?____
____.

⑦ For what values of $\mathbf{d_o}$ were you unable to focus an image onto the screen? Use the Fundamental Lens Equation to explain why. ____.

Additional Questions

① For a lens of focal length f, what value of d_o would give an image with a magnification of one?

② Is it possible to obtain a non-inverted image with a converging spherical lens? Explain.

③ For a converging lens of focal length f, where would you place the object to obtain an image as far away from the lens as possible? How large would the image be?