

Lens Optics – Revised Version Spring 2008

Introduction

In this experiment, you will examine the optical properties of *converging* (convex or positive) and *diverging* (concave, or negative) lenses.

I. Images of distant objects.

1. *Converging lens observations:*

- Remove all of the lenses from the optical bench. Take the +200 mm converging (convex) lens, hold it at arms length, and look at a distant object outside the window. Now, hold this lens about 8 to 10 cm from your hand or your text (*not* your eye!). Briefly sketch what you see in each case, noting the difference in the magnification and orientation of the images.
- Place the +200 mm lens back in the optical bench, between the light source and plastic screen. Remove the light source and aim the front of the optical bench at the window. Move the screen back and forth until you get a sharply focused (*real*) image of a distant object (e.g. a tree) through the window.
- Remove the screen, and look through the lens at the image from the window. Again sketch the image you see.
- Now take the -150 mm diverging (concave) lens, and place it in the bench about 10 cm from the converging lens. Look through the diverging lens, and adjust the distance between the two lenses until the image is focused. Sketch the appearance of a distant object through the window as viewed through your simple telescope.

2. *Measurement of focal length:*

- Remove the diverging lens from the bench, leaving the converging lens in place. Place the screen back in the bench.
- Again move the screen until you see a sharp image of a distant object; at this point the screen is located at the *focal point* of the lens. Measure the distance between the lens and the screen, and compare this distance to the actual focal length of the lens. Calculate the % difference between these values.
- Repeat this procedure to measure the focal length of the other two converging lenses, and compare the measured value to the actual value.

3. *Diverging lens observations:*

- Repeat step (1a) using -150 mm diverging (concave) lens. Sketch the appearance of a distant and close object, and compare these images to those seen using the converging lens.
- Repeat step (1b). Explain what the difference is when using the diverging lens to perform this step.

II. Comparison of image distances determined theoretically and by measurement.

1. *Theoretical location of an image:*

First you will examine the relationship between the position of an object, and the location of its image with respect to a converging lens. It is interesting to note that the relationship between object and image location is *the same* for all converging lenses; for example, an object that is 2 focal lengths from a converging lens will always produce an image that is 2 focal lengths away.

- a. Set up a table like the one at the end of these instructions. Your calculations of image distance will be based on object distances that are multiples of a focal length of 1.0. These calculations will then be applied to the converging lens you will measure on the optical bench. Quantities with a *prime* (') denote distances calculated for *any* converging lens of focal length 1; those without a prime denote distances calculated and measured using a *real* converging lens.
- b. Calculate i' for each o' value using the Thin Lens equation: $\frac{1}{f'} = \frac{1}{o'} + \frac{1}{i'}$.
- c. You may note that there seems to be a problem with your calculations when the object is 1.0 focal length away. What do you suppose your calculations are telling you about the image in this case? You'll check your assumption later on the optical bench.
2. *Measurement of the image location:*
- a. Now calculate the *expected* distances from the theoretical distances just calculated. Using the focal length of the converging lens (in *cm*), calculate the lens-to-object distance ($o = o'f$) and the expected lens-to-image distance ($i = i'f$) for each object distance given in your table.
- b. Put the light source and the +200 mm lens in the optical bench. Set the object distance to the value indicated in the (o) column of your table. Measure i , the image distance, for each case. The last two cases will result in a virtual image; your instructor will show you how to use the virtual image detector to estimate the location of these virtual images.
- c. Find the % difference between the expected and measured values for i .
3. *Calculation of focal length:*
- a. Use KaleidaGraph to plot $1/o$ (the *actual* object distance on the optical bench) vs. $1/i$ (the *measured* image distance). Calculate the focal length (and its uncertainty) of the lens from the parameters of the best-fit line. How does your measured value compare to the actual value?

$$f = +20.0 \text{ cm}$$

Object distance, o'	Image distance, i'	Actual object distance, $o = o'f$ (cm)	Expected image distance, $i = i'f$ (cm)	Measured image distance, i (cm)	% difference
1.0					
1.5					
2.0					
3.0					
0.5					
0.7					

Sample:
Create your own table!

Discussion:

- Summarize what you have learned about the difference between converging and diverging lenses.
- Explain what happens to the image when you place an object 1 focal length from a converging lens.