

Optics II: Lenses

Spring 2008

Introduction

In this experiment, you will examine the optical properties of lenses. Your report will be graded on the care you take with your measurements and diagrams.

I. Images of distant objects.

1. Observations:

- Hold a *converging* lens at arms length, and look at a distant object outside the window. Now, hold this lens very close to your hand or your text. Note the difference in the magnification and orientation of the images. Sketch the image that you see for the close and far objects.
- Tilt the light bulb and arrow object to the side. Place the converging lens in the optical bench and move the plastic screen back and forth until you get a sharply focused (*real*) image of a distant object through the window. Again sketch the image that is formed.
- Looking from *behind* the screen, tilt the screen out of the way to see the image without the screen. Keep in mind that it is this image that is projected on the screen.

2. Measurement:

- The screen is located at the *focal point* of the lens, the position where a sharp image of a distant object is formed. The *focal length* is the distance between the lens and the focal point. Measure the distance between the lens and the image, and note the focal length marked on the lens (see notation explanation below). Your measured focal length should agree with the value printed on the lens.

Lens notation: The lenses you will be using are marked with a *series number* (the last three digits, e.g. 400 or 800). These series numbers were invented as a way of grouping the lenses in our collection by focal length. The corresponding focal length (in centimeters) is determined by taking the inverse of the series number, and multiplying by a factor of 10^4 . So, for an 800 series lens:

$$f = (1/800) \cdot 10^4 = 0.00125 \cdot 10^4 = \mathbf{12.5 \text{ cm.}}$$

Note that most of our lenses follow this notation scheme, but you may find some that you have to multiply the inverse by 10^3 , or are marked incorrectly.

- Repeat this procedure to measure the focal length of two or three other lenses.

3. Diverging Lens:

- Repeat step 1a using a *diverging* lens. What's the difference? Sketch the appearance of the distant object, and compare it to that seen using the converging lens.
- Why can't you repeat step 1b or 1c with the diverging lens?

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

1. Theoretical Location of the Final Image:

- Set up a table like the one at the end of these instructions. The *primed* (') quantities are calculated values; *unprimed* values are measured directly on the optical bench.
- Graphical*: You will now construct a series of ray diagrams that show how light rays are refracted through *any* converging lens (a sample of these diagrams will be made available). These *generic* ray diagrams are constructed with $f' = 1.0$ units; that is, the focal length of the generic lens is 1.0, and the object and image distances that appear on the left side of the table below are in multiples of the focal length.

Draw your ray diagrams carefully, and find i' for the given values of o' for each lens. Record your results in the second column of your table. The last two cases will produce *virtual images*, so i' should be entered as a **negative** number.

- Thought question*: Why isn't there a table entry to calculate the image for an object at $o' = 1$ unit?

- Algebraic*: Use the thin lens equation $\left(\frac{1}{f'} = \frac{1}{o'} + \frac{1}{i'} \text{ or } i' = \frac{o'f'}{o' - f'} \right)$ to calculate i' for each generic object distance. Record your results in the third column of your table, then calculate the % difference between the graphical and algebraic image distances.

2. Measurement of the Final Image:

- Record the focal length you measured in part I, step 2 for the 800-series lens at the top right of your table. Use *this* measured focal length to calculate the *expected* lens-object distance (column 5: $o = o'f$) and the expected lens-image distance (column 6: $i = i'f$) for each generic object distance given in your table.
- Put the 800-series lens in the optical bench, measure the *actual* lens-image distance (i) in each case, and record in column 7. Your instructor will show you how to locate the virtual images using a virtual image detector.
- Find the % difference between the expected and measured image distances, and enter in the last column of the table. Comment on the agreement between these values. What are some sources of error?

| | | | | $f = \underline{\hspace{2cm}} \text{ cm}$ | | | |
|-------------------------------|------------------------------|------------------------------|--------|---|------------------------------------|----------------------------|--------|
| Generic object distance, o' | Generic image distance, i' | Generic image distance, i' | % diff | Actual object distance, $o = o'f$ | Expected image distance, $i = i'f$ | Actual image distance, i | % diff |
| (units) | <i>graphical</i> (units) | <i>algebraic</i> (units) | | (cm) | <i>algebraic</i> (cm) | <i>measured</i> (cm) | |
| 1.4 | | | | | | | |
| 2.0 | | | | | | | |
| 3.0 | | | | | | | |
| 4.0 | | | | | | | |
| 0.5 | | | | | | | |
| 0.7 | | | | | | | |