Lab 10 – Focal Length of Lenses (revised “Lab 41”)

Overview

The objective of this lab is to investigate the properties of images formed by lenses. We will determine experimentally the focal length of both a converging and a diverging lens.

Prelab

Turn in the questions (1-9) from the prelab assignment for lab 41 (pg 473).

Lab activities

See the following pages. The last page contains tables for your data and the questions to be answered in your report. The lab is pretty much the same as is described in Lab 41 except that we will only use two lenses (converging and diverging) and a slightly different lab setup.

Introduction

The lab manual and these notes use a different convention than our textbook does, identifying the object distance as p (rather than s) and the image distance as q (rather than s'). One way to remember this is to note that p follows o (object) in the alphabet. The thin lens equation

\[
\frac{1}{p} + \frac{1}{q} = \frac{1}{f}
\]

relates these distances to the focal length of the lens. Note that when the object is at infinity, the image is formed at the focal length of a converging lens. A diverging lens (negative value for f) does not form a real image. The magnification is given by

\[
M_{\text{actual}} = \frac{\text{image height}}{\text{object height}} = \frac{h'}{h} = M_{\text{theory}} = -\frac{q}{p}
\]

Finally, a combination of two lenses that are right next to each other is given by

\[
\frac{1}{f_{\text{combo}}} = \frac{1}{f_a} + \frac{1}{f_b}
\]

Equipment

- Optical bench with illuminated object
- Lens set (one is about +10cm, the other about –20 cm)
- Meter stick and ruler
**Procedure**

1. Estimate the focal length of the converging lens as follows: Form an image of the overhead lights on the floor and measure the distance from the lens to the floor. Since the object distance is large, the image distance is an approximation to f. Record this estimate in Table 1.

2. Measure the object height and record it in Table 1.

3. Place the image screen **about 80 to 85 cm from the object** with the lens between them.

   (A) Slide the lens closer to the object until an image forms on the screen. Measure p (object distance), q (image distance), and h’ (height of image) and record them in Table 1. Calculate f and the theoretical and actual magnifications and the percent error in the magnification and enter them in Table 1.

   (B) Slide the lens closer to the screen until an image is formed. (The position of the lens in parts 3A and 3B are called conjugate points, where p and q are simply reversed.) Complete the second line in Table 1.

4. Find another set of data points by moving the screen to **about 55 to 60 cm from the object** with the lens in between. Move the lens until an image is formed. Complete the third line in Table 1. Get the final set of data points by moving the lens (keeping the screen at the same location) and finish Table 1.

5. Determine the best value for the focal length by averaging the four values you have obtained. Find the percent difference between this value and your estimated value. Also calculate the standard deviation along with the average and quote it as the uncertainty in the focal length.

6. We will now determine the focal length of a diverging lens by finding the focal length of a lens made by combining it with the lens just studied. Tape the two lenses together to form a combined lens and estimate the focal length as in step 1. Record the combined focal length and the object height in Data Table 2.

7. Repeat steps 3 through 5 for this combination lens, but this time start with the image screen **about 90 to 95 cm from the object** with the lens between them, and move the screen further away (to **about 100 to 110 cm** from the object) for the second pair of measurements.

8. Calculate the focal length of the diverging lens by setting up and solving equation (3). Show your work for this calculation on the data sheet.

**Answer the 3 questions on the last page** to complete your report.