

Physics 111
Experiment # 5
Geometric Optics

Geometric Optics

Geometric optics treats light as rays that travel in straight lines and refract at the boundaries between different optical media. In a simple thin lens, the law of refraction combined with some simple geometry yields the lens and magnification equations:

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \quad (1)$$

and

$$m = -\frac{d_i}{d_o} = \frac{h_i}{h_o} \quad (2)$$

As shown by equations (1) and (2) above and in figure 1 below, d_o is the distance from the lens to the *object* (in this case a light bulb); d_i is the distance from the lens to the *image* (the screen); f is the *focal length* of the lens; and m is the *magnification*, i.e. the ratio of the image size to the object size (along with the associated sign conventions). In addition, the object has a size h_o and its image will also have a size given by h_i .

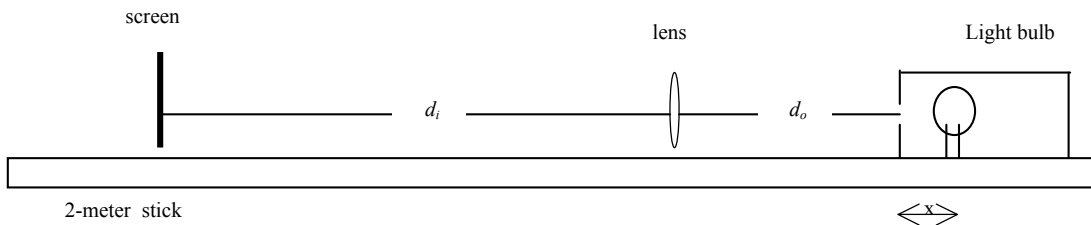


Figure 1: A schematic showing the basic setup for determining the focal length of a converging lens.

Part 1. Determining the focal lengths of your converging lenses

- a. Select 2 converging lenses with labels A & B.
- b. Starting with the light source and screen far apart along the scale and one of your converging lenses find two different locations where the lens can be placed so that a focused image appears on the screen. Record the location of all three (the two locations that the lens can be placed and the location of the screen.) Now move the screen closer to the light source in increments of your choice. Repeat for a total of 5 screen locations. Each time you move the screen, again find two lens locations that produce a focused image. In the end you will have 10 object distances and 10 image distances. Repeat this procedure for lens B.
- c. Determine a way to plot your data such that the result is linear. Add a trend-line and record the slope and intercept. What values do you get for the focal length of the lens and of the slope of the line?
- d. You may find that the slope of your graph is significantly different from -1. The reason is that your measurement of d_o does not include the distance x that is seen figure 1. We can correct that. First make and record in the spread sheet a rough estimate of the distance x .

Then modify your spreadsheet so that it adds that value to each d_o . Keep changing the value of x until the slope of your graph is as close as possible to -1. Determine the new value of the focal length of the lens.

- e. Repeat this process for the remaining converging lenses that you have using your best value of x and plot the data on your initial graph. There should be only one plot.

Part 2: Determining the focal length of a diverging lens

- a. The method described above will not work with the diverging lens (this is the lens that is thinner at the middle), as it does not focus light. Mathematically, diverging lenses are treated as if they have a negative focal length.
- b. With the same light source, put a diverging lens on the optical bench and verify that there is no real image. Look through the lens and observe the virtual image. Now put one of your converging lenses from part 1 beyond the diverging lens and look for a real image produced on the screen. When you have a real image produced, measure all relevant object and image distances, and compute the focal length of the diverging lens using equation (1) twice. You will need to do the calculations in steps, first computing the virtual image location, then the object distance for the second lens, and finally the final real image location.
- c. The actual value of the focal length stamped on the diverging lens is $f_D = -2.2\text{cm}$. Using this and the positions of the diverging (from the light source) and converging lens (from the diverging lens), draw a complete ray diagram *to scale* and determine the location (with respect to the converging lens) of the real image. How does this distance compare to what you measured in the last step? Note: You will need to select a convenient scale for the drawing and you will need to use a whole sheet of paper and a ruler to actually draw the ray diagram.

Part 3: Measuring the size of the light bulb filament

How large is the light bulb filament in your light box? Using one of your converging lenses, determine and write a procedure that you can use to measure the curly part of the light bulb filament. Comment on how good you believe your method to be. What are your sources of uncertainty?

Part 4: Another method to determine converging lens focal lengths

There is another method that is sometimes used to measure focal length. From your work in part 1, you found that for each position of the screen, there are two different positions of the lens that will bring an image into focus. Let D be the light bulb to screen distance, and let s be the distance between the two different lens positions. See figure below. Working from equation (1) it is possible to find a relation between D , s and f . Derive the relationship between these variables D and f first. Then using the relationships you find between D and f , determine relationship between D , f , and s .

You already have the data you need to calculate f in this way. Modify your Excel spreadsheet by adding new columns for s and D then calculate a value for f for each row using the formula that you have derived. Calculate the average f for each of your converging lenses.

