Lab 8

Simple Lenses

Experimental Objectives

Through the various arrangements suggested below, you should be able to...

- ... figure out the definition of the following terms based on the images you observe
  - magnified versus minified
  - upright versus inverted
  - real versus virtual
- ... figure out the relationships between the measurable quantities:
  - the magnification, defined in terms of the image height and the object height: $M = \dfrac{h_i}{h_o}$
  - the image distance (from the lens) q
  - the object distance (from the lens) p
  - the focal length, f.

Anybody who has looked through glasses, microscopes, telescopes, a magnifying glass, or even a window has experienced a lens. We see images through lenses.

8.1 Procedure with Questions for the Analysis

Warning 8.1.1. The data you take in Subsection 8.1.2 will also be used in Subsection 8.1.3, so tabulate it in a coherent and clear format.

8.1.1 Defining Your Terms

As a group, take one of the three lenses and your white screen into a dark room so that you can see a brighter room through a doorway. Have one person in the group go stand in the bright room and move around while another person looks through the lens. Then trade places until everybody has a chance to look through the lens.

Exercise 8.1.2.

1. As a group, decide how to describe the image in the terms above: **Magnified** or **minified**? **upright** or **inverted**? **real** or **virtual**?

2. While still in the darker room, notice that if you hold up your lens in front of a white screen (or a tee shirt) so that the lens is between the screen and the person in the other room, the image of the brighter room appears on the screen. (Have somebody dance and jump in the bright room while you watch the image on the screen.)

Take that same lens back into the room and have each person view this text through the lens.

Exercise 8.1.3.

1. As a group, decide how to describe the image in the terms above: **Magnified** or **minified**? **upright** or **inverted**? **real** or **virtual**?

2. Notice this time that the text appears to be on the same side of the lens as the actual text is. There is no place that you can put your white screen to have the words from the page appear on the screen.

Compare and contrast the image of the room to the image of the text.

Exercise 8.1.4.

1. If you had to choose between the names real and virtual, which image would you call real? which would you call virtual? why?

2. Decide if either of the images change based on the location of the lens relative to the object being viewed.

8.1.2 Quantify the Magnification

In order to make precise measurements, attach the screen to one end of the optical bench and the light source to the other side. The illuminated cross-hairs on the light source will be the object observed. Place a converging lens[1] on the optical bench between the object and the screen. Keep the screen and the light source fairly far apart (the convenient distance will depend on which lens you are using). Adjust the position of the lens until a clear image is formed on the screen.

Exercise 8.1.5.

1. Describe the image formed in the terms defined above.

Measure the distances between the lens and the image (image distance, q), and between the lens and the object (object distance, p). Measure the height of the image on the screen h_i and the height of the object on the light source h_o. (If the image is inverted, then h_i is a negative value.) Calculate the magnification factor of the image, $M = \dfrac{h_i}{h_o}$.

For this same lens, without changing the position of the screen or the light source, find a second image that has a different description using the defined terms above. Again, measure p, q, h_i, and h_o and calculate M.

Exercise 8.1.6.

1. Describe this second image in the terms defined above.

Repeat this for each of the other two lenses.

Exercise 8.1.7.

1. Determine the relationship between M, q, and/or p. Verify that your relationship works (to about two significant figures) for all six data sets separately.

[1] Converging lenses, also called convex lenses, bulge in the middle. Diverging lenses, also called concave lenses, bulge at the edges.

8.1.3 Quantify the Focal Length

The lens equation, $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$, shows the relationship between the image distance, q, object distance, p, and the focal length of the lens, f. Using your data from Subsection 8.1.2, determine the focal length of each lens. Each lens should have two values for f (one for each image).

Exercise 8.1.8.

1. For each lens separately, compare the average of these numbers to the accepted value.

The focal length of a lens may also be determined by forming the image of a very distant object on a screen. In this case, the object distance, p, becomes very large and therefore $1/p$ becomes very small. When this is the case, the lens equation may be written as $1/q = 1/f$, or more conveniently, $q = f$. Using a distant object in an adjacent room, measure the image distance and thereby determine the focal length for each lens.

Exercise 8.1.9.

1. Compare this with your results for f from the data in Subsection 8.1.2.

2. Describe the image formed by this distant object.

In principle, an object needs to be infinitely far away for this second method to be true. In practice, the object only needs to be "far enough." Determine, theoretically or experimentally, how far an object needs to be to get an accurate measurement of the focal length in this manner. If the day is sunny, ***under strict instructor supervision*** take a lens outside and, using the sun as "an infinitely far away object," measure the focal length by forming an image of the sun on your lab notebook. Take a minute or so to really visualize the sun on your paper. Predict the results.

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