Physics 111

Experiment # 5

GEOMETRIC OPTICS

Objectives

1. To find the focal length of a converging lens by means of imaging;
2. To show that a diverging lens can form a virtual image that can serve as an object for a second converging lens that forms a final real image;
3. To construct a simple telescope and microscope

Basic Ideas

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 equation:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

where d_o and d_i are the object and image distances measured from the lens of focal length *f*. Ray tracing diagrams can also be used to find the image of a lens. The lateral magnification , *M*, of the image is given by:

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

where h_i and h_o are the image and object heights. Remember the set of sign conventions that go with these quantities described in your text.

Tasks

1. Using a white light source, object (marked arrow on paper), converging lens, and screen set up a simple optical arrangement on the optical bench to find a real image of the object on the screen. Measure the object and image distances and heights. Repeat this measurement for a total of 5 different object distances. For each measurement calculate a value for the focal length and magnification and put these results in a table. Try to calculate a best value for the focal length together with an uncertainty based on a statistical analysis of your data. Compare with the "nominal" value stamped on the lens holder.

2. With the same object and 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 your converging lens from part 1 beyond the diverging lens and look for a real image on your screen. For this part, draw a complete ray diagram to scale in your notebook using the "nominal" focal length of the diverging lens. Measure all relevant distances, compare with the image location from your ray diagram, and compute the focal length of the diverging lens using equations. 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.

3. Two lens systems can be used to make both a simple telescope and a simple microscope. Refer to the diagrams in your textbook in the appropriate sections.

A. *Telescope.* Using a “longish” focal length lens as the objective lens (the one closest) to the object, an image of an object at “infinity” is produced at the focal point. In a refracting telescope, the objective lens produces a real image at its focal point that is then magnified by a second short focal length lens that serves as an eyepiece. The eyepiece is positioned so that its focal point is at the first image therefore the total separation of the two lenses is the sum of the two focal lengths. Looking through an eyepiece, one sees an enlarged virtual image that then produces a real image directly on the retina through the lens of the eye. Build a telescope and take it to a window to test it out. You’ll see best by putting your eye as close as you can to the short focal length eyepiece lens. Estimate the magnification of your telescope.

B. *Microscope.* A short focal length converging lens (the objective) is used to produce an enlarged, inverted, real image. The small object is positioned just outside the focal point of the lens. A second converging lens (the eyepiece) with longer focal length is then used to create an enlarged, virtual image by positioning the first image just inside the focal point of the eyepiece. The eye then views this virtual image through the lens of the eye to produce a real image on the retina. Construct a microscope on your optical bench and view a close object such as the print on this page. Estimate the magnification of your microscope.