Experiment 9

Converging and Diverging Lenses

Preparation

For this week's experiment read about the thin lens equation for converging and diverging lenses. Be sure you understand the sign conventions for d_o, d_i, f and m.

Principles

Lenses follow the same rules as mirrors. The thin lens equation is:

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

The equation for magnification is:

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

Convex lenses can produce real images if the object is placed outside the focal point or virtual images if the object is inside the focal point. Concave lenses always produce virtual images. With lenses the object distance, d_o, is positive if the object is in front of the lens and negative if it is in back of the lens. The image distance, d_i, is positive if the image is in back of the lens and negative if it is in front of the lens. In other words, if the rays from the object pass through the lens and converge, the object and image will be on opposite sides of the lens, d_o and d_i will have the same sign, and the image will be real. If the rays from the object diverge, the object and image will be on the same side of the lens, d_o and d_i will have opposite signs, and the image will be virtual.

In this experiment you will use four methods to find the focal length of a converging lens. The first is the same infinite object method that was used in the mirror experiment. The object is placed so far away that d_o can be assumed to be infinity. As d_o approaches infinity, $1/d_o$ approaches zero and d_i approaches f. In the second method the object is placed near the lens, but outside the focal point, the image is projected onto a screen, the object and image distances are measured and the thin lens equation is used to calculate f.

The third method is called the method of coincidence. This method relies on the fact that the paths of light rays through lenses are reversible. If parallel rays enter a converging lens they will converge at the focal point. If rays originate at the focal point and pass through the lens, the rays that emerge will be parallel. If an object is placed at the focal point of a lens and the image is reflected back through the lens, the reflected image will be focused at the same place as the source.

If the object is inside the focal point of a converging lens, the lens acts as a simple magnifier. The image can be located using the method of parallax. This is the same procedure that was used with the diverging mirror. The method of parallax will also be used to determine the focal length of the diverging lens.

Equipment

1 optical bench
3 optical bench carriages
1 lens holder
1 screen holder
2 short rods
1 longer rod
1 thin rod
1 large object lamp
1 small object lamp
1 converging lens
1 diverging lens
1 plane mirror
1 index card

Procedure

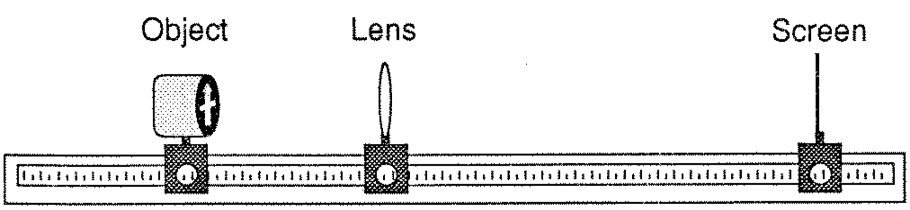
In each case, record the positions of the object, image, and lens to the nearest .1 cm.
Remember; keep track of the signs of your measurements. The sign of an upright image is positive; the sign of an inverted image is negative.

Distant Object

1. Set the large object lamp at the opposite end of the table from the optical bench. Set the lens and index card in holders and place them on the bench. Form a sharp image. Characterize the image as real or virtual, upright or inverted, enlarged or reduced.

Nearby Object

2. Place the small object light on the bench and project a sharp image onto the card. Record all positions. Also measure the size of some feature on the object lamp and measure same feature on the image. Characterized the image.



Optical bench arrangement

3. Change the object distance a few time and notice how the image distance and the magnification change.

Method of Coincidence

4. Place the plane mirror in a holder and place it on the bench. Hold the index card next to the object light and place the object on the opposite side of the lens from the mirror. Move the object and card together until a clear image forms on the card. Record the positions of the object and lens, as well as the sizes of the object and image. Characterize the image.

Parallax Method

5. Place one of the aluminum support rods in a holder and place it on the bench, on the same side of the lens so that its distance from the lens is less than the focal length. The lens will create a virtual image. Place the thin rod in a holder behind the lens on the other side of the aluminum rod.

6. Look at the image of the thick rod through the lens. Look directly at the thin rod. Move the two rods until there is no parallax between the pin and the image. Record the positions of the object rod (the one viewed through the lens), the image rod (the thin one that was viewed directly), and the lens. Characterize the image.

7. Repeat the above procedure with the diverging lens. This time the object rod can be farther away from the lens than the focal length and the image rod must be between the object rod and the lens.

Analysis

1. For the first set of data, calculate the focal length.

2. For the second set of data, calculate the focal length. Also, calculate the magnifications using both equations for m and find the percent difference between them.

3. Find the focal length from the third set of data. Find the magnifications and the percent difference between them.

4. Find the focal length of the magnifier. Remember that the image distance will be negative in this case.

5. Find the focal length of the diverging lens.