Experiment 7

Geometrical Optics

Equipment List: Simulation (phet.colorado.edu) Geometrical Optics

In this experiment you will determine the focal lengths of different virtual lenses by various methods, comparing the results. The focal lengths of a lens are governed by the shape of the lens and the material of the lens (also by the material that the lens is residing). The lens in the simulation is a bi-convex lens. Slide buttons located near the top of the screen allow you to change the radius of curvature of the lens (both radii change by the same amount in this simulation), the refractive index of the lens, and the diameter of the lens.

Check “Screen” on. A dark screen on which the image will appear. The distance from the lens to the sharply formed image on this screen is the image distance. Also, an illustration of a desk lamp is considered as the object in this experiment. The distance from the point the rays of light emit from the desk lamp to the lens is the object distance.

Check “Ruler” on. This ruler can be dragged about the screen so as to measure the focal length, the object distance, and the image distance.

Click on “Principal Rays”. This will show the three principal rays. With this chosen you can see where the light rays start in the desk lamp.

The long, horizontal blue line is the optical axis. On the optical axis are two yellow x marks. These show the positions of the two focal points of the lens.

The first method of determining the focal length of the lens is to use the ruler and measure from one focal point to the other focal point. Because the two radii of curvature are equal in the simulation the two focal points are equidistant from the center of the lens. Divide the distance between the two focal points by two and you have the measured focal length.

The second method is to set an object distance on one side of the lens (left side). This is done by moving the desk lamp to the position requested. Use the ruler to measure out the distance and drag the desk lamp such that the point from which the rays of light emit from coincides with that position. Then, mover the screen until you have as sharp an image as can be formed. Use the ruler to measure from the lens to the image on the screen. This distance is the image distance. Both of these measurements are considered positive.

f

f

do

di

Object

Image

Figure 1

Once you have the object distance set and the image distance measured use the Thin Lens Equation to determine the focal length of the lens.

You will be given three object distances by your lab instructor. Determine the image distance for all three object distances to determine three focal lengths. These three focal lengths should, ideally, be the same value. Average the 3 values together.

The third method is to determine the focal length of the lens using the Lens Maker’s Equation.

In the above equation f is the focal length of the lens, n1 is the index of refraction of the medium that the lens is in (for our experiment this is air, where n = 1.00), n2 is the index of refraction of the lens, R1 is the radius of curvature of the first surface of the lens that the light strikes, and R2 is the radius of curvature of the second surface of the lens that the light strikes.

f

f

R1

R2

Direction of light

Figure 2

If a surface of the lens is convex towards the source of the light (the object), then the radius of curvature is considered to be a positive value. If a surface of the lens is concave towards the source of the light (the object), then the radius of curvature is considered to be a negative value. In the above illustration, R2 has a negative value, and R1 has a positive value.

In each of the following parts apply the three methods as stated above to determine the focal length of each part’s lens. The object distances and calculations are to be done on the worksheet.

Part 1

Curvature Radius: 0.8 meters

Refractive Index: 1.53

Diameter: 1.3 meters

Part 2

Curvature Radius: 0.5 meters

Refractive Index: 1.53

Diameter: 1.3 meters

Part 3

Curvature Radius: 0.5 meters

Refractive Index: 1.33

Diameter: 1.3 meters

Results

In your Results section state if the focal lengths determined by each of the methods are in agreement with each other. Use the percent error equation to compare a.) The focal length determined by the Thin Lens Equation to the Measured focal length, b.) The focal length determined by the Lens Maker’s Equation to the Measured focal length.

Questions for Discussion

1. The focal length determined in Part 1 is different from the focal length in Part 2, even though the index of refraction was not changed. State how the focal length changed from Part 1 compared to Part 2 and explain why the focal length changed.
2. The radius of curvatures in Part 2 and Part 3 are the same, but the indices of refraction are different. State how the focal lengths for each part changed from Part 2 to Part 3 and explain why the focal length changed. State in your explanation how this is different from the change in focal lengths discussed in question 1?
3. Derive the Thin Lens Equation using Figure 1 and similar triangles. Show all step-by-step work. There will be several steps. Note: the distances from the center of the lens to each of the focal points are **equal** to each other. The object distance is **not equal** to the image distance. Similar triangles share an equal sized angle.

Let the height of the object be ho, and the height of the image be hi.

1. The magnification of the image by a lens is equal to the negative of the ratio of the size of the image to the size of the object. This ratio is also represented as:

If the magnification results in a negative value, then the image is inverted. If it results in a positive value, then the image is upright. For the three object distances in Part 1 determine the corresponding magnifications. Write these three magnification values as part of your answer to this question. Comment on how the magnification changes as the object distance changes.