PHYS 1402
General Physics II

EXPERIMENT 8
SPHERICAL LENSES

I. OBJECTIVE

The objective of this experiment is the study of the image formation properties of spherical thin lenses. The student will measure the focal lengths of two converging lenses and, for the proper choice of object distances, will measure image distances and study the nature of the images formed. The measured image distances will be compared to those predicted by the thin lens equation to verify the validity of this equation. The student will also measure the focal length of a diverging lens.

II. APPARATUS

Two converging lenses of different focal lengths, one diverging lens, optical bench with light source and other accessories.

III. EXPERIMENTAL PROCEDURE

PROCEDURE (1): Measurement of Focal Length of a Converging Lens

1. A converging lens forms a real image at its focal point of an object located very far away (infinitely far away). This fact can be used to measure the focal length of a converging lens quickly, easily and with reasonable accuracy.

2. Place one of the converging lenses in the lens holder and place it near one end of the optical bench. Place the small plastic screen on the optical bench behind the lens. Stand at one end of the hallway (outside the lab) and point the end of the optical bench with the lens toward the window on the other end of the hallway. Move the screen back and forth until you see a sharp image of the window projected on the screen. The distance between the lens and the screen is the focal length of the lens. Read it off the scale and record it in the data table.

3. Repeat step (2) for the other converging lens.

PROCEDURE (2): Measurement of Image Distance

1. Place the plate with the arrows on one end of the optical bench and place the light right behind it. Place the cardboard cover around both of them. Tighten the screws to fix them on the optical bench. When you turn the light on, you will see a lit arrow and it will serve as the object. The plate which has the arrows will be refered to from now on as the object plate.

2. Place lens #(1) in the lense holder and place it on the optical bench. You will use three distinct object distances as shown in the data table. For the first case, choose an object distance larger than twice the focal length and move the lens until the ditance between it and the object plate is equal to this distance. Tighten the screw to fix the position of the lens and record this distance in the data table as the object distance.

3. Place the screen on the other side of the lens and move it back and forth until you see a sharp image of the arrows projectd on the screen. When you are satisfied that this is the sharpest image you can get, fix the position of the screen. The distance between the lens and the screen is the image distance. Read it off the scale and record it in the data table.

4. Describe the image: a) measure its size, b) is it real or virtual and c) is it upright or inverted?

5. For the second case, choose an object distance in the middle of the specified range and move the lens until the distance between it and the object plate is equal to this distance. Fix the position of the lens and record the object distance in the data table. Find a sharp image, record its distance and describe its nature as you have done in case (1).

6. For the third case, choose an object distance smaller than the focal length and move the lense until the distance between it and the object plate is equal to this distance. Fix the position of the lens and record the object distance in the data table. Move the screen back and forth and try to find a sharp image. If you can not, the image could be virtual. A virtual image is located on the same side of the lens as the object. Look through the lens (as if you are looking at yourself in the mirror) and try to find an image. If you find one, describe its nature. You will not be able to measure its distance.

7. Repeat steps 2, 3, 4, 5 and 6 for converging lens #(2).

PROCEDURE (3): Measurement of the Focal Length of a Diverging Lens

1. The procedure you used to measure the focal length of a converging lens can not be used to measure the focal length of a diverging lens bcause a diverging lens does not form a real image (an image on a screen). Here you will measure the focal length of a diverging lens with the help of a converging lens. This is accomplished by using a converging lens to project a real image, and then use the diverging lens to alter its position a measurable distance. The diverging lens is then forming a real image of a virtual object.

2. As you have done above, use the converging lens which has the larger focal length (preferably $\geq 10\,\mathrm{cm}$) to project a real image on a screen. You can duplicate the first case you did earlier where $d_o > 2f$. Measure the image distance and record it in the data table. Call it d_{i1}.

3. Place the diverging lens in the lens holder and place it on the optical bench between the converging lens and the image. The diverging lens will form an image of the image. Move the screen back and forth until you find a sharp image. If you can not find a sharp image, move both the diverging lens and the screen until you find a sharp image. Make sure the distance between the two lenses remains less than the distance d_{i1}. When you are satisfied you have located a sharp image, measure the distance between the two lenses and call it x and the distance between the diverging lens and the final image and call it d_i. Record these distances in the data table.

4. Describe the image: a) measure its size, b) is it real or virtual and c) is it upright or inverted?

IV. ANALYSIS

1. For each converging lens, use the thin lens equation

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

and the measured values of d_o and f to calculate the image distance d_i.

2. Calculate the largest percent difference between the measured d_i and the ones calculated using the thin lens equation. Is this percent difference reasonable (less than 10%)?

3. Calculate the magnification using the equation (if the image is inverted, h_i should be taken as a negative number).

$$M = \frac{\text{image size}}{\text{object size}} = \frac{h_i}{h_o}. \tag{2}$$

4. Calculate the magnification using the equation

$$M = -\frac{d_i}{d_o}. \tag{3}$$

5. Calculate the focal length of the diverging lens using the data obtained in procedure (3). Since the diverging lens forms a real image of a virtual object (the intermediate image), according to the sign convention, the object distance must be entered in the thin lens equation as a negative number. Recall that the focal length of a diverging lens is a negative number.

6. For one of the converging lenses, draw 3 ray tracing diagrams for the three cases you considered. Each ray tracing diagram must contain the three principal rays. Diagrams must be drawn to scale as far as d_o and d_i and f. Don't worry about the size of the lens and the size of the object being to the same scale.

7. In your conclusion, comment on the accuracy of this experiment. What is the largest percent difference? What are the two most important sources of error?

Experiment (8) Data Table
Object size $h_o =$
Lens I focal length $f_1 =$
Lens II focal length $f_2 =$

	Object Distance d_o (cm)	Measured Image Distance d_i (cm)	Calculated Image Distance d_i (cm)	Description of Image Real or Virtual Upright or Inverted
Converging Lens I	$d_o > 2f_1$			
	$2f_1 > d_o > f_1$			
	$f_1 > d_o$			
Converging Lens II	$d_0 > 2f_2$			
	$2f_2 > d_o > f_2$			
	$f_2 > d_o$			

	Conv Lens Image Dist d_{i1} (cm)	Lens Separation x (cm)	Div Lens Object Dist $d_{o2} = d_{i1} - x$ (cm)	Div Lens Image Dist d_{i2} (cm)	Div Lens Focal Length f_{div} (cm)
Diverging Lens					

<table>
<tr><th colspan="5">Experiment (10) Data Table (cont'd)</th></tr>
<tr><th></th><th>Object Size
h_0
(cm)</th><th>Image size
h_i
(cm)</th><th>Magnification
$M = \frac{h_i}{h_o}$</th><th>Magnification
$M = -\frac{d_i}{d_o}$</th></tr>
<tr><td rowspan="2">Converging
Lens
I</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Converging
Lens
II</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Conv / Div Lens
Combination</td><td></td><td></td><td></td><td>XXXXXXXXX</td></tr>
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