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 referred 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 distance 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 projected 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 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. Move the screen back and forth and try to find a sharp image. If you cannot, 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 cannot be used to measure the focal length of a diverging lens because 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 $\geq 10\text{ cm}$) 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

\[
\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}
\]  

(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 cal-
culated 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).

\[
M = \frac{\text{image size}}{\text{object size}} = \frac{h_i}{h_o}.
\]  

(2)

4. Calculate the magnification using the equation

\[
M = -\frac{d_i}{d_o}.
\]  

(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 

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 

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

<table>
<thead>
<tr>
<th>Object size $h_o =$</th>
<th>Lens I focal length $f_1 =$</th>
<th>Lens II focal length $f_2 =$</th>
</tr>
</thead>
</table>

| Object Distance $d_o$ (cm) | Measured Image Distance $d_i$ (cm) | Calculated Image Distance $d_i$ (cm) | Description of Image of Image
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>$d_o &gt; 2f_1$</td>
<td></td>
<td></td>
<td>Real or Virtual</td>
</tr>
<tr>
<td>$2f_1 &gt; d_o &gt; f_1$</td>
<td></td>
<td></td>
<td>Upright or Inverted</td>
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<tr>
<td>$f_1 &gt; d_o$</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
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</tr>
<tr>
<td>$f_2 &gt; d_o$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conv Lens I</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Conv Lens II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conv Lens</td>
<td>Div Lens</td>
<td>Div Lens</td>
<td>Div Lens</td>
</tr>
<tr>
<td>Image Dist</td>
<td>Object Dist</td>
<td>Image Dist</td>
<td>Focal Length</td>
</tr>
<tr>
<td>$d_{i1}$ (cm)</td>
<td>$d_{o2} = d_{i1} - x$ (cm)</td>
<td>$d_{i2}$ (cm)</td>
<td>(cm)</td>
</tr>
<tr>
<td>(cm)</td>
<td></td>
<td>(cm)</td>
<td>(cm)</td>
</tr>
<tr>
<td>Diverging Lens</td>
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</tr>
<tr>
<td>Object Size</td>
<td>Image size</td>
<td>Magnification</td>
<td>Magnification</td>
</tr>
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<td>-------------</td>
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<td>---------------</td>
</tr>
<tr>
<td>$h_0$ (cm)</td>
<td>$h_i$ (cm)</td>
<td>$M = \frac{h_i}{h_o}$</td>
<td>$M = -\frac{d_i}{d_o}$</td>
</tr>
<tr>
<td>Converging Lens I</td>
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</tr>
<tr>
<td>Converging Lens II</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Conv / Div Lens Combination</td>
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<td>XXXXXXXXXXX</td>
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