PHYS 2426

Engineering Physics II

EXPERIMENT 10

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 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 which has 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. Let us get an estimate of the uncertainy in your reading of the focal length. You should have noticed that there is a range of distances over which you could move the screen and still call the image of the window a "sharp image". Move the screen close to the lens until the image gets out of focus and move the screen back and watch as the image gets sharp and then fuzzy again. The distance between the two points where the image got fuzzy is the range of distance mentioned above. We will take the uncertainty in the reading of the focal length as one half of this range. Record this uncertainty in the data table.
4. 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 lens 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 of the lens 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. Estimate the uncertainty in the reading of the image distance the same way as you did the uncertainty in the focal length in procedure (1).
5. Describe the image: a) measure its size, b) is it real or virtual and c) is it upright or inverted?
6. 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).

7. For the third case, choose an object distance smaller than the focal length of the lens 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.
8. Repeat the above steps 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. 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 converging lens #(1) to project a real image on a screen. You can duplicate one of the cases you have already recorded in your data table. Measure the image distance and record it in the data table. Call it S''.
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 S''. 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 S'. Record these distance 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 and the experimental values of S and f to calculate the theoretical image distance S'.
2. Calculate the largest percent difference between the experimental and theoretical S'. State whether this percent difference is reasonable (less than 10%).
3. Calculate the experimental magnification

$$M \equiv \frac{\text{image size}}{\text{object size}} = \frac{h_i}{h_o}$$

   In the above equation, h_i is a negative number if the image is inverted.
4. Calculate the theoretical magnification, $M = -\frac{S'}{S}$.
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, you must be careful about the sign of the object distance when used in this calculation.
6. Calculate the relative uncertainty in the calculated image distance, $\frac{\delta S'}{S'}$, (4 cases). Round it off to one significant figure and give it as %.
7. Calculate the relative uncertainty in the calculated focal length of the diverging lens, $\frac{\delta f}{f}$. Round it off to one significant figure and give it as %.
8. 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 S and S' and f. Don't worry about the size of the lens and the size of the object being to the same scale.
9. In your conclusion, comment on the accuracy of the thin lens equation.

Lens I Focal Length	=
Lens II Focal Length	=

Converging Lenses

	Obj Distance s(cm)	Meas Image Distance s'(cm)	Calc Image Distance s'(cm)	Description of Image	h_0 (cm)	h_i (cm)
Lens I						
2f < s						
2f > s >f						
f >s						
Lens II						
2f < s						
2f > s >f						
f >s						

Diverging Lens

s'' (cm)	x (cm)	s=s''-x (cm)	s' (cm)	f (cm)	h_0 (cm)	h_i (cm)

Magnification

	Magnification: $M = h_i / h_o$	Magnification: $M = - s' / s$
Lens I		
Lens II		
Conv & Div		$M = -\frac{s''}{s_o}\left(\frac{-s'}{s}\right)$