**AP Physics: Lab #11**

**Images & Converging Lenses**

Name ________________________ Hour ______

Lab Partners ________________________________________

## Purpose:

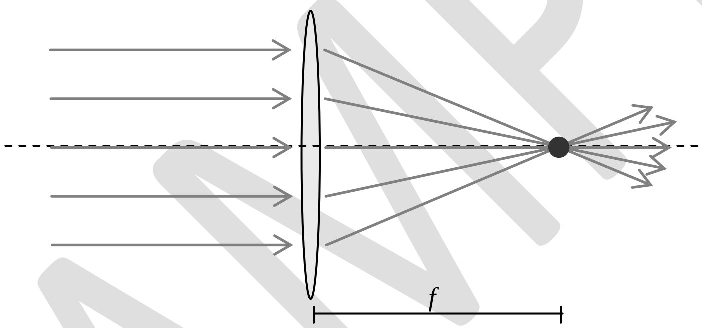
* Determine the focal length of a converging lens using various object and image distance combinations.
* Calculate the magnification of an image formed by a converging lens.
* Predict the location of the final image formed by 2 converging lenses in combination.

## Equipment:

Optical Bench and Screen
Illuminated Object
Converging Lenses

## Introduction:

A converging lens uses refraction to focus all parallel rays of incoming light to a single point, known as the focal point. The distance of this point from the lens is the focal length, *f*. This is demonstrated in the diagram below.




When rays of light illuminate an object and then pass though a converging lens, an image of the object is formed by the refraction of the rays of light. The distance between a given object and the lens, $s_o$, and the distance between the object's image and the lens, $s_i$, are related to the focal length of the lens by the equation:

$$\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{f}$$

In addition, the ratio of the size of the object's image to the size of the original object is known as the magnification. It can be found by comparing either the object and image heights or the object and image distances from the lens. The magnification of an image, then, can be calculated by the equation:

$$M = \frac{h_i}{h_0} = -\frac{s_i}{s_0}$$

The following procedures lead to the experimental determination of the focal length, *f*, of a given converging lens, and the magnification, *M*, of various images formed by the lens.

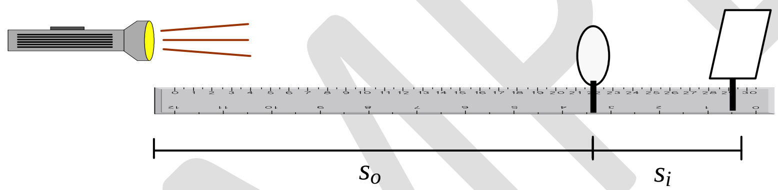
## Procedures:

Set up the optical bench by mounting a cardboard screen near one end of the bench, as shown in the diagram below. Choose a biconvex lens and mount it near the middle of the optical bench. Mount the illuminated object at a large distance from the lens *(approximated as ∞ for purposes of finding the focal length.)* Adjust the position of the screen until rays from the illuminated object are focused as clearly as possible on a single point on the screen. Record this combination of object distance and image distance on Data Table A for $s_o$ at ∞. Use your measurements to calculate an estimated focal length of the lens, which will be used in the remainder of the lab.

Using the estimated focal length calculated in the previous step as a guide, adjust the position of the illuminated object so that the object distance is somewhat greater than $2f$. Then adjust the position of the screen until rays from the illuminated object are focused as clearly as possible in an image on the screen. Record this combination of object distance and image distance on Data Table A. Also record the height of the illuminated object, $h_o$ and the height of the object image, $h_i$. Repeat these procedures for object distances of approximately $2f$ and somewhere between $f$ and $2f$. Record all measurements on Data Table A.

Obtain a second biconvex lens of a different focal length. Repeat the procedures above, recording all measurements on Data Table B.

Using the previously measured focal lengths, determine an arrangement in which the two biconvex lenses together will create a final focused upright image on the screen. Record the distances to be used on Data Table C. Then set up the arrangement of the two lenses, using a longer optics bench if necessary. Observe the magnification and orientation of the final image on the screen.




## Calculations:

Use the thin lens equation to calculate and record the focal length of each lens, $f$, from each combination of object and image distances. Calculate the average focal length of each lens.

Use the measurements of object and image heights to calculate and record an experimental magnification, $M_E$, of each image formed by the lens. Use the measurements of object and image distances to calculate and record a calculated magnification, $M_C$, of each image formed by the lens.

## Analysis:

To summarize the lab report, answer the application questions below in complete sentences. In addition, include a brief statement of the overall results for the lab.

- Are the images formed on the screen real or virtual? Explain your answer.
- Draw a ray diagram for an object that is inside the focal point. Label an appropriate combination of object and image distance values on your diagram. Why was this situation not part of your experimental procedures?
- Draw a ray diagram showing your arrangement for the two biconvex lenses together. Label all object and image distance values used on your diagram. Did this arrangement create a final focused image? If so, what did you observe about the magnification and orientation of the final image? If not, what errors could account for the failure to create an image?
- For which situations in the experimental procedures is the absolute value of the image magnification . . . greater than 1? . . . equal to 1? . . . less than 1? Theoretically, how does this magnification change as the object distance is increased to a very large length?
- What does the sign of the magnification represent? Are the magnifications of the images in this lab positive or negative? Is this true for all situations in the experiment or does the sign of the magnification vary? Explain your answer.

Data Table A: Lens #1

| | Object Distance ($s_o$) | Image Distance ($s_i$) | Focal Length ($f$) | Object Height ($h_o$) | Image Height ($h_i$) | Measured Mag ($M_E$) | Calculated Mag ($M_C$) |
|---|---|---|---|---|---|---|---|
| $s_o = \infty$ | | | | --- | --- | --- | --- |
| $2f < s_o < \infty$ | | | | | | | |
| $s_o = 2f$ | | | | | | | |
| $f < s_o < 2f$ | | | | | | | |

Average Focal Length *(f)* = _______________

Data Table B: Lens #2

| | Object Distance ($s_o$) | Image Distance ($s_i$) | Focal Length ($f$) | Object Height ($h_o$) | Image Height ($h_i$) | Measured Mag ($M_E$) | Calculated Mag ($M_C$) |
|---|---|---|---|---|---|---|---|
| $s_o = \infty$ | | | | --- | --- | --- | --- |
| $2f < s_o < \infty$ | | | | | | | |
| $s_o = 2f$ | | | | | | | |
| $f < s_o < 2f$ | | | | | | | |

Average Focal Length *(f)* = _______________

Data Table C: Lens Combination

| Object Distance #1 ($s_o$) | Image Distance #1 ($s_i$) | Distance Between Lenses | Object Distance #2 ($s_o$) | Image Distance #2 ($s_i$) | Total Distance (Original Object to Final Image) |
|---|---|---|---|---|---|
| | | | | | |

## Lab Report:

Title Page, Objectives, & Overall Report – 5 pts
Procedures – 3 pts
Data Table – 6 pts
Calculations – 7 pts
Analysis – 13 pts