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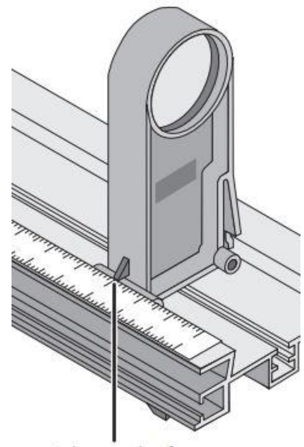
LAB 14. RAY OPTICS: IMAGES OF CONVEX LENSES

AP PHYSICS II

Driving Questions | Objective

How do you find the focal length of an unknown lens? How will a convex lens affect the size and orientation of an image with respect to the object?

Perform an experiment to determine the focal length of a thin lens and measure the magnification for a certain combination of objects and image distances.



Conduct Your Experiment

It is your group's responsibility to conduct an experiment whose data will support your answer to the driving question above. Use properties of the Thins Lens Equation $\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$ to graphically determine the focal length of the lens. Be sure to bring an appropriate graphing calculator for your analysis.

Materials and Equipment

- Light Source (Image Side)
- Optics Bench
- Metric Ruler
- Screen
- Convex Lens of Unknown Focal Length

Experimental Design Pt. 1 – Object at Infinity

In this part, you will determine the focal length of the lens by making a single measurement of d_i with $d_o \cong \infty$.

1. Hold the lens in one hand and the screen in the other hand. Focus the image of a *distant* bright object (such as a window or lamp across the room – at least 20 feet away from you) to the screen.

2. Have your partner measure the distance from the lens to the screen.

3. **Image Distance**: $d_i = 9$ cm

Analysis

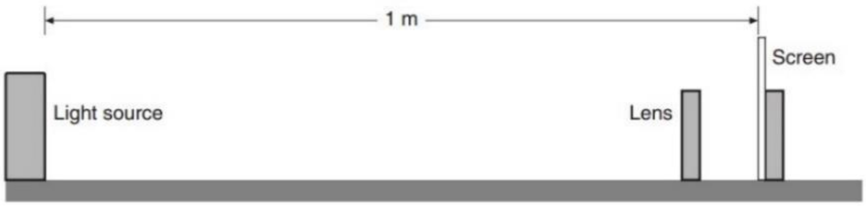
1. If $d_o \cong \infty$, what does $1/d_o$ approximately equal? $\frac{1}{d_o} = 0$

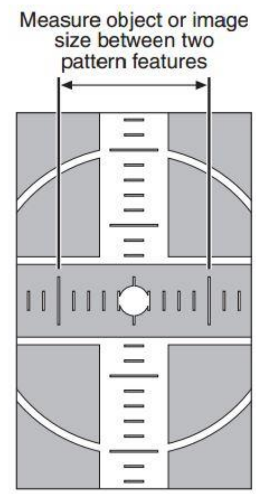
2. Use the Thin Lens Equation to calculate the Focal Length.

3. **Focal Length**: $f = 1/9\ cm$

Experimental Design Pt. 2 – Object Closer Than Infinity

In this part, you will determine the focal length by measuring several pairs of object and image distances and plotting $1/d_i$ versus $1/d_o$.





1. Place the light source and the screen on the optics bench 1 m apart and place the lens anywhere between them.

2. With the screen and light source fixed, make adjustments to the placement of your lens until an in-focus image appears on the screen. Record the object and image distances below in Table 1.

3. Measure the object size and distance as well as the image size and distance for this position of the lens. Look at the figure to the right for assistance with images too large to fit on the screen.

4. Without moving the screen or light source, is there another position along the track for the lens which would also produce an image on the screen?

5. Measure the object size & distance and image size & distance for this position also.

6. Repeat steps 2 and 4, but this time with a difference distance between the light source and screen. Attempt this with 5 different source/screen distances.

7. Record, also, the magnification of the image. $M = -\frac{d_i}{d_o}$ or $M = \frac{image\ size}{object\ size}$ and is negative if the image is inverted.

Table 1

Distance from light source to screen	Position of lens to produce an image	d_o *(cm)*	d_i *(cm)*	$1/d_o$ *(cm⁻¹)*	$1/d_i$ *(cm⁻¹)*	Object Size	Image Size	Mag.
100 *cm*	1st	88.8 cm	11.2 cm	0.011 cm^{-1}	0.089 cm^{-1}	D = 4 cm	D= 1 cm	-0.126
	2nd	11.3 cm	88.7 cm	0.088 cm^{-1}	0.011 cm^{-1}	D = 4 cm	D = 16 cm	7.850
95 *cm*	1st	83.9 cm	11.1 cm	0.012 cm^{-1}	0.090 cm^{-1}	D = 4 cm	D = 0.5 cm	-0.132
	2nd	11.3 cm	83.7 cm	0.088 cm^{-1}	0.012 cm^{-1}	D = 3 cm	D = 15 cm	7.407
90 *cm*	1st	78.7 cm	11.3 cm	0.013 cm^{-1}	0.088 cm^{-1}	D = 4 cm	D = 0.7	-0.144
	2nd	11.5 cm	78.5 cm	0.087 cm^{-1}	0.013 cm^{-1}	D = 3 cm	D = 14 cm	6.826
80 *cm*	1st	68.3 cm	11.7 cm	0.015 cm^{-1}	0.085 cm^{-1}	D = 4 cm	D = 1 cm	-0.171

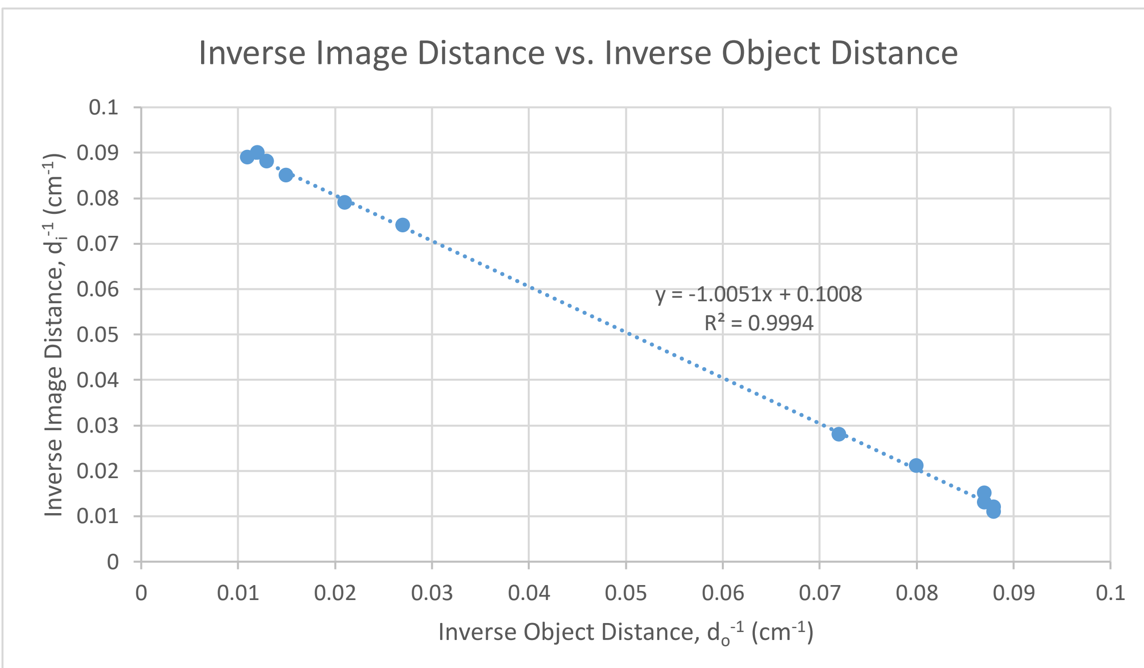
	2nd	11.5 cm	68.5 cm	0.087 cm^{-1}	0.015 cm^{-1}	D = 3 cm	D = 12 cm	5.957
60 cm	1st	47.4 cm	12.6 cm	0.021 cm^{-1}	0.079 cm^{-1}	D = 4 cm	D = 1.5 cm	-0.266
	2nd	12.5 cm	47.5 cm	0.080 cm^{-1}	0.021 cm^{-1}	D = 3 cm	D = 9.5 cm	3.800
50 cm	1st	36.4 cm	13.6 cm	0.027 cm^{-1}	0.074 cm^{-1}	D = 4 cm	D = 1.7 cm	-0.374
	2nd	13.8 cm	36.2 cm	0.072 cm^{-1}	0.028 cm^{-1}	D = 3 cm	D = 6.7 cm	2.623

Analysis

1. Plot the Inverse Image Distance vs. the Inverse Object Distance in the chart below.

2. To enter your data, right click on the graph and click "Edit Data"

3. Once you have entered your data, place the appropriate regression by clicking the "+" symbol next to the graph and checking "Trendline." Make sure the regression equation and r^2 value are shown. You can do this by clicking the arrow next to the "Trendline" option and clicking "More Options."



4. Consider the thin lens equation: $\frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{f}$, which can be rewritten as $\begin{cases} \frac{1}{d_i} = -\frac{1}{d_o} + \frac{1}{f} \\ y = m\,x + b \end{cases}$. What would you ***expect*** the slope of this graph to be? -1.0051
5. What does the y-intercept represent? Focal length

6. Determine the focal length using the y-intercept.

   - **Focal Length**: $f =$ 0.1008

7. What does the x-intercept represent? Focal length

   - **Focal Length**: $f =$ 0.1002

8. Lastly, now that you have determined the focal length of the lens through these different methods, let's make some comparisons on your values.

	f
Result from *y*-intercept	0.1008
Result from *x*-intercept	0.1002
% difference between results from intercepts	0.597%
Average of results from intercepts	0.1005
Focal Length Result from Part 1 – Object at Infinity	0.1111
% difference between Average of results from intercepts and results from Part 1	10.019%

Analysis

❓ 1. Are the images formed by the lens upright or inverted?

Inverted

❓ 2. Are the images formed in this experiment real or virtual? How do you know?

Real

❓ 3. What do you believe would happen to this image if you were to cover the top half of this lens with your hand? Feel free to try it and see. Why does this happen?

The image gets dimmer. Light still passes through the lens, just less, so the image still forms

❓ 4. Explain why, for a given screen-to-object distance, there are two lens positions where a clear image forms.

One appears when the light source/object is at the focal length, the other appears when the screen/image is at the focal length

❓ 5. What does a negative magnification mean?

The image is inverted

❓ 6. You made three separate determinations of ***f*** (by measuring it directly with a distant object, from the *x*-intercept of your graph, and from the *y*-intercept). Were these three values equal? If not, what might account for

Recording the incorrect measurements when determining where the clearest image forms

the variation?

❓ 7. What do you believe is the "true" focal length of the lens is?

0.1005 cm

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