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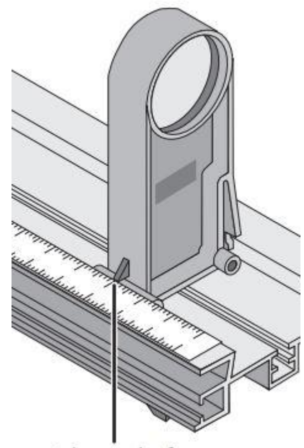
LAB 14. RAY OPTICS: IMAGES OF CONVEX LENSES

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**: $d_i = 8.5$ cm

Analysis

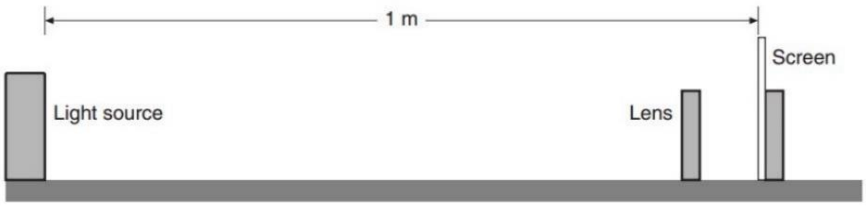
1. If $d_o \cong \infty$, what does $1/d_o$ approximately equal? $\frac{1}{d_o} = 0$

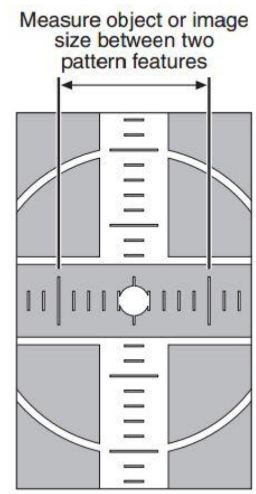
2. Use the Thin Lens Equation to calculate the Focal Length.

3. **Focal Length**: $f = 8.5$ 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? YES

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 $M = \frac{\text{image size}}{\text{object size}}$ and is negative if the image is inverted.

Table 1

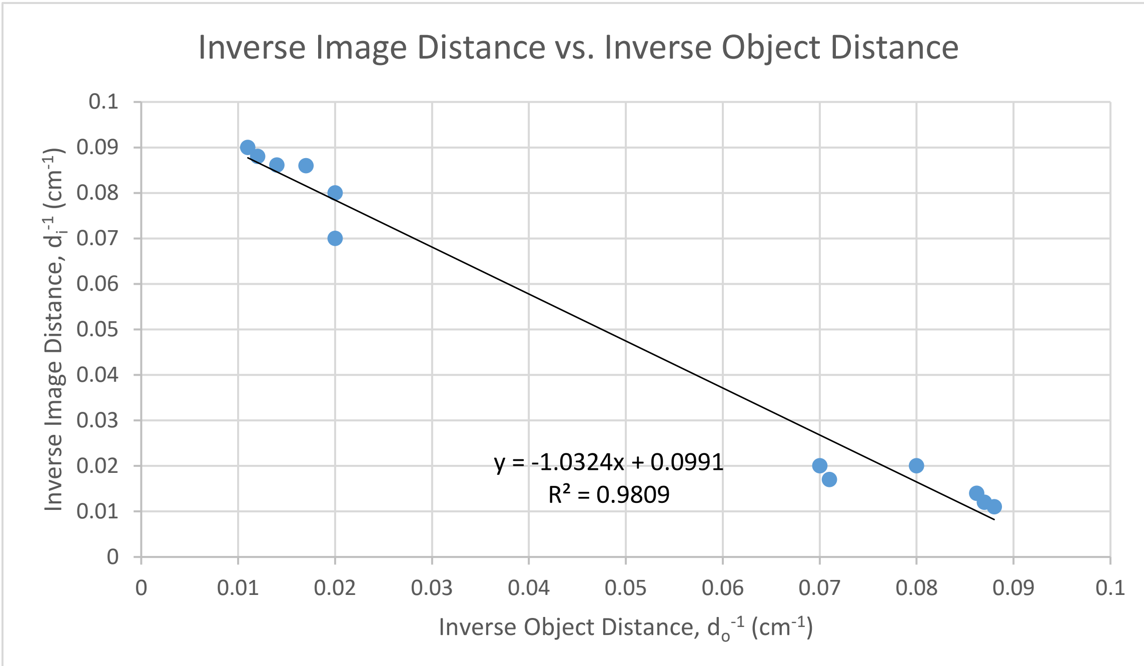
Distance from light source to screen	Position of lens to produce an image	d_o (cm)	d_i (cm)	$1/d_o$ (cm^{-1})	$1/d_i$ (cm^{-1})	Object Size	Image Size	Mag.
100 cm	1st	11.3	88.7	.088	.011	2	16	-8
	2nd	89	11	.011	.09	4	.5	-1/8
90 cm	1st	78.7	11.3	.012	.088	4	.6	-.15
	2nd	11.5	78.5	.087	.012	2	13.5	-6.75
80 cm	1st	68.5	11.5	.014	.0861	4	.7	-.175
	2nd	11.6	68.4	.0862	.014	2	11.5	-5.75
70 cm	1st	14	58	.071	.017	2	9	-4.5
	2nd	58.5	11.5	.017	.086	4	.8	-.2
60 cm	1st	12.5	47.5	.08	.02	4	15.5	-3.875
	2nd	47.6	12.4	.02	.08	4	1	-.25
50 cm	1st	13.7	36.3	.07	.02	4	10.7	-2.675
	2nd	36.4	13.6	.02	.07	4	1.5	-.375

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

5. What does the y-intercept represent? The inverse of the focal length

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

   - **Focal Length**: $f =$ 1/.0991= 10.09cm

7. What does the *x*-intercept represent? W*hen* d_0 *is equal to* f, so it would represent 1/*f*.

   - **Focal Length**: $f =$ 1/0.096= 10.42 cm

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	10.09
Result from *x*-intercept	10.42
% difference between results from intercepts	~3.3%
Average of results from intercepts	10.26
Focal Length Result from Part 1 – Object at Infinity	8.5 cm
% difference between Average of results from intercepts and results from Part 1	~21%

Analysis

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

They are inverted.

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

They are real images, because the light rays all converge on the screen.

❓ 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 would get less bright, but still remain completely visible. This is because light from all points of the object still reaches the lens.

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

Because bending the light either as it leaves the light source, or as it approaches the screen, at the right distance and angle, will allow all light rays to intersect on the screen.

❓ 5. What does a negative magnification mean?

The image of the object has been 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 fo the variation?

No, they were not equal. The x and y intercepts differ because our measurements were done by hand, with human error involved. The one from optical infinity had even larger measurement error, because it was difficult to determine exactly when the projector screen was focused.

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

We think the true focal length of this lens is 10 cm, because it is a round number, and therefore more likely to be used in manufacturing, if the manufacturers pick arbitrary sizes.

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