Group Members: Emilie E, Jasmine G, Cyrus X, Pearl O, Cindy T

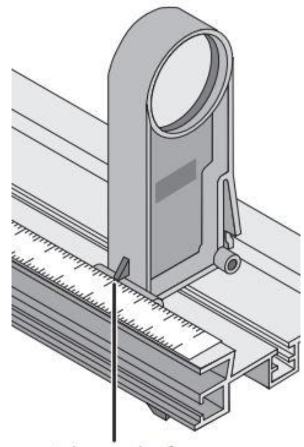
LAB. RAY OPTICS: IMAGES OF LENSES AND MIRRORS

AP PHYSICS II

Driving Questions | Objective

How do you locate real and virtual images of convex/concave lenses/mirrors?

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



Conduct Your Experiment

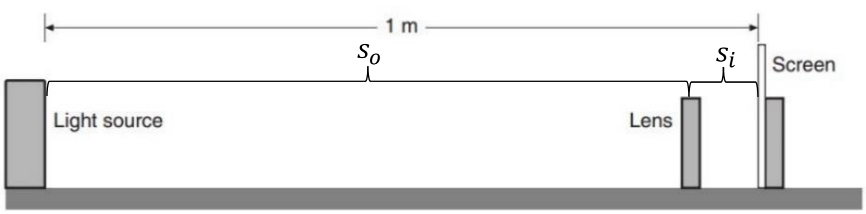
It is your group's responsibility to conduct an experiment whose data will support your answer to the driving question above. Use properties of the Thins Lens Equation $\frac{1}{f} = \frac{1}{s_i} + \frac{1}{s_o}$ to graphically determine the focal length of the lenses and mirrors. Be sure to bring an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

Materials and Equipment

- Light Source (Image Side)
- Optics Bench
- Metric Ruler
- Screen
- Various convex and concave lenses and mirrors

Part 1 – Convex Lenses

In this part, you will determine the focal length of a convex lens by measuring several pairs of object/image distances and plotting $1/s_i$ versus $1/s_o$.



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, adjust 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 distance, which is the distance from the center of the lens to the front of the light source. Also measure the image distance, which is the distance from the center of the lens to 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. Repeat steps 2 and 4, but this time with a difference distance between the light source and screen (for example, you place the light source 0.9 meters from the screen instead of $1m$ and then reposition the lens to the two different locations that produce the image again. Attempt this with 5 different source/screen distances.

Part 1 Data and analysis

Table 1

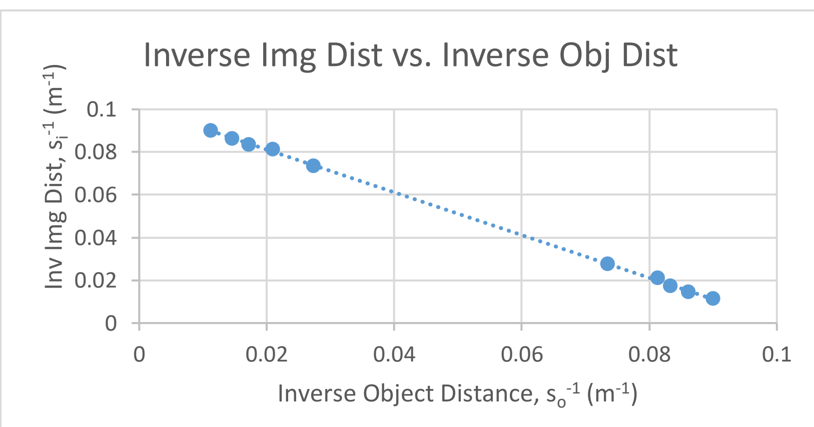
Distance from light source to screen	Position of lens to produce an image	s_o (m)	s_i (m)	$1/s_o$ (m^{-1}) *x*-variable	$1/s_i$ (cm^{-1}) *y*-variable
1 *m*	1st	.11	.89	0.09	0.112
	2nd	0.89	.11	0.0112	0.09
.5 *m*	1st	.136	.364	0.0735	0.0274
	2nd	.364	.136	0.0274	0.0274
.8 *m*	1st	.116	.684	0.0862	0.0146
	2nd	.684	.116	0.0146	0.0862
.7 *m*	1st	.12	.0.58	0.0833	0.01724
	2nd	.58	.12	0.01724	0.0833
.6 *m*	1st	.123	477.	0.0210	0.0813
	2nd	.477	.123	0.0813	0.0210

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 r² value are shown. You can do this by clicking the arrow next to the "Trendline" option and clicking "More Options."



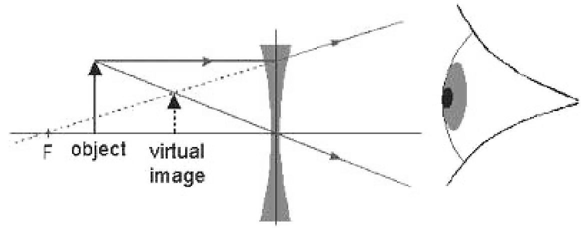
4. Consider the thin lens equation: $\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{f}$, which can be rewritten as $\begin{cases} \frac{1}{s_i} = -\frac{1}{s_o} + \frac{1}{f} \\ y = m\,x + b \end{cases}$. Which physical quantities of the lens would the x-intercept and y-intercept be? What should be the value of your slope?

They are both the inverse of the focal length of the lens. This means that the slope should be -1.

5. At this point, you should know how to evaluate the focal length once you have the *x* and *y*-intercepts. Please record your calculated focal lengths in the table below.

	f
Result from *y*-intercept	
Result from *x*-intercept	
Average	

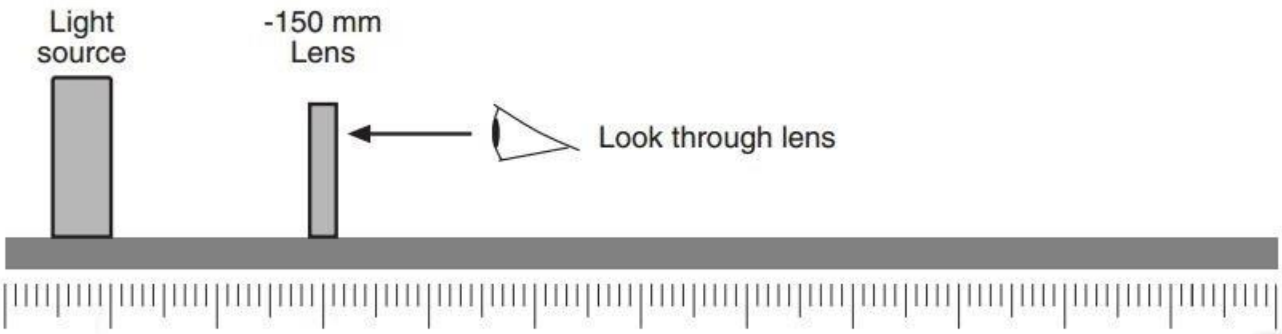
Part 2 – Concave Lenses



1. Place the light source (extended object side) somewhere near the beginning of the bench, but not at the 0 cm mark (example: 10 cm or 15 cm).

2. Place the -150 mm lens on the bench at a position greater than 150 mm, but less than 300 mm away from the light source.

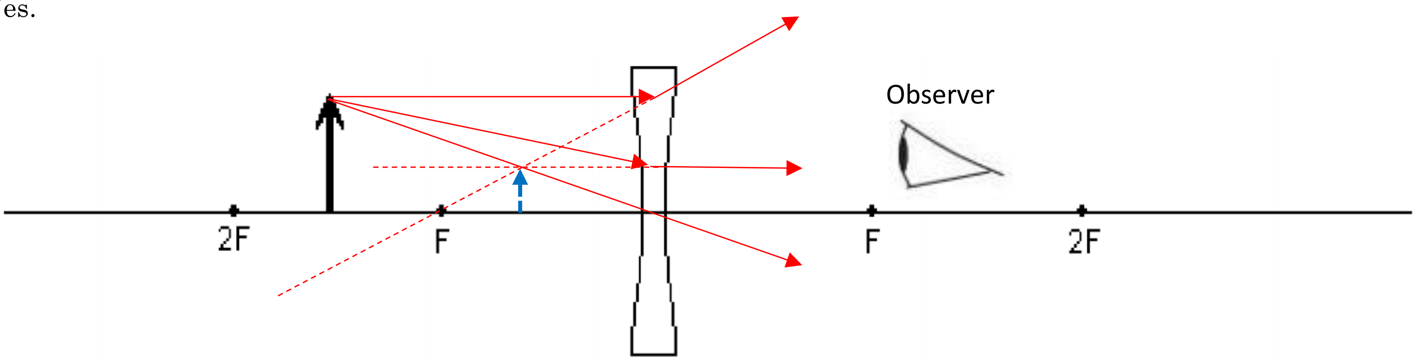
3. Record the object distance s_o in the Table on the next page



4. Looking through the lens toward the light source, describe the image. Is it upright or inverted? Smaller or Larger? Is the image closer or farther to you than the object? Is the image real or virtual? How do you know?

Virtual, upright, minified, closer. We know because we can't see a real image on the screen.

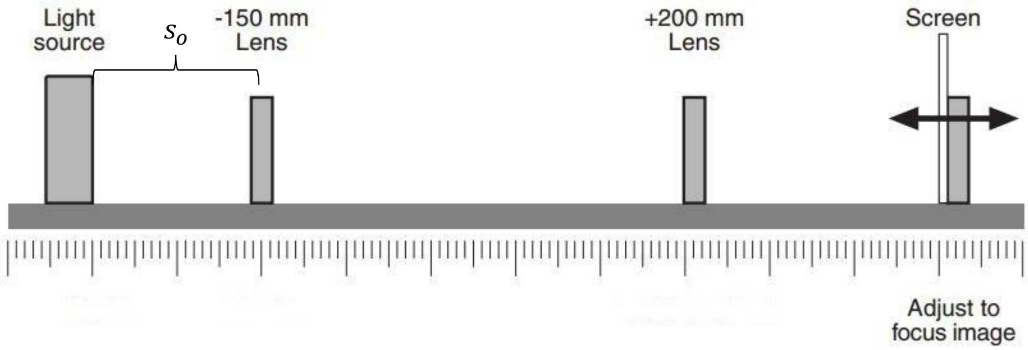
5. Using what you know about ray tracing at this point, does the location of the image match your prediction? Yes.



Unfortunately, since this kind of image is virtual, we will not be able to project it onto a screen like we could for a real image from the convex lens. We're going to have to get a bit more creative to locate this image!l

6. Place the +200 mm lens on the bench anywhere a distance greater than 200 mm from the -150 mm lens.

7. Place the viewing screen behind the +200 lens and slide the screen to a position where a clear image is formed on it.

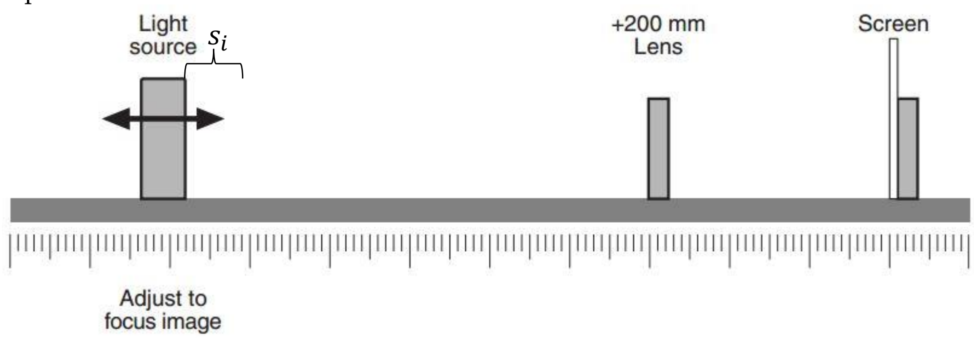


8. The image you see on the screen is the "*image*" from the +200 mm lens. But what acts as the +200 mm lens' "*object*"?

The "object" is the virtual image formed by the concave lens.

9. Remove the -150 mm lens from the bench. You should notice that the image on the screen comes out of focus.

10. While leaving the +200 mm lens and Screen in place, attempt to get your image back by moving the light source around to a new position.



11. Once you have formed a clear image on the screen again, record the new position of the light source. This new location must be the location of the virtual image that was produced by the concave lens before it was removed!

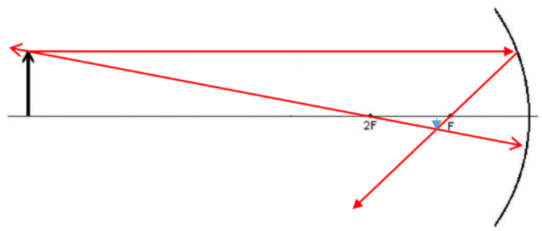
12. Record the object distance, focal length, and image distance from this experiment in the table below and check your results with the thin lens equation.

Object Distance, s_o	66-16.6 = 49.4
Focal Length. f	20.17
Image Distance, s_i	100-65.9 = 34.1

Part 3 – Concave Mirrors

1. This time, we will determine focal length of a concave mirror by measuring several pairs of object and image distances and plotting $\frac{1}{s_i}$ $vs. \frac{1}{s_o}$.

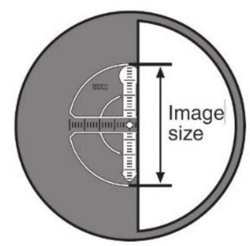
2. Using what we know about ray tracing for a concave mirror, estimate where you believe the image of an object located will be located.



3. Is the image **real/virtual, upright/inverted, magnified/minified**? Will it be possible to project this image onto a screen because of these conditions?

Real, inverted, minified. It will because it is a real image.

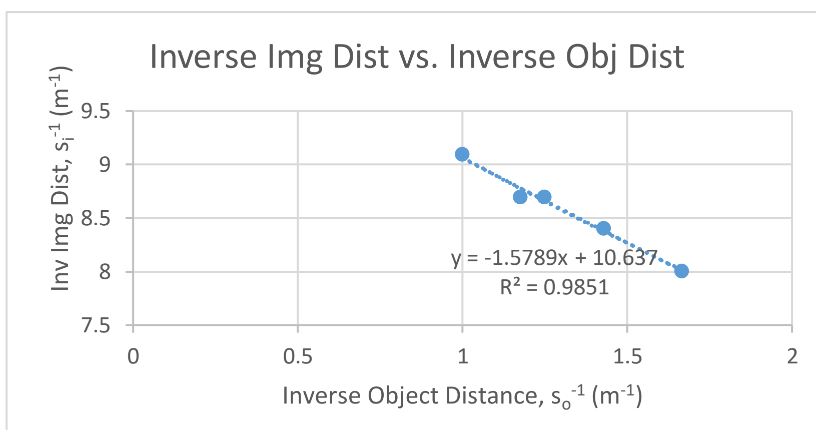
4. Place the light source and the mirror $1m$ apart on the optics bench. Place the half-screen between them and adjust its position until an image is formed as seen the figure below. Record the object distance (distance from light source to mirror) and image distance (distance of mirror to half-screen) in the table below.



5. Using the Table below, collect data with 5 distinct values of the object distance, s_o and record the corresponding image distances. Plot your inverse image distance vs inverse object distance graph

Table

		x-variable	y-variable
s_o (m)	s_i (m)	$1/s_o$ (m^{-1})	$1/s_i$ (m^{-1})
1.0	0.11	1.0	9.091
85	85-73.5 = 0.115	1.176	8.696
80	80-68.5 = 0.115	1.25	8.696
70	70-58.1 = 0.119	1.429	8.403

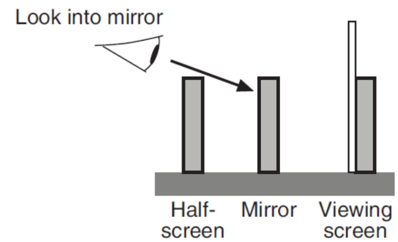


60	60-47.5 = 0.125	1.667	8

6. What is the focal length of the mirror? What aspect of the graph did you use to determine this?

9.4 cm. We took the inverse of the y-intercept and then converted it to cm.

Part 4 – Convex Mirrors



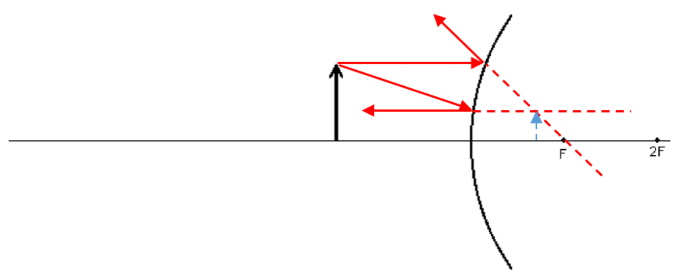
1. In this part, you will attempt to find the location of a virtual image formed by a convex mirror. You will not be using the light source in this part.

2. Place the half-screen on the bench near one end. Turn the screen so its edge is vertical. Place the convex mirror on the bench such that the convex side faces the half-screen.

3. Look through the half screen into the mirror. Is it **upright/inverted**, **minified/magnified**? Using parallax, is the image of the half-screen **in front/behind** the mirror?

Upright, minified, behind

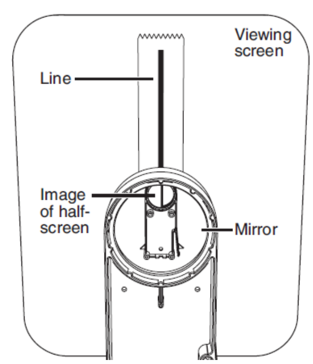
4. Using what we know about ray tracing, we can estimated a position for the image of an object.



5. Is the image **real/virtual, upright/inverted, magnified/minified**? Will it be possible to project this image onto a screen because of these conditions?

This image is virtual, upright, and minified. This means that it will not be possible to project this image.

6. Make an educated approximation as to the location of the image on the bench. Place the full-size screen at this location, as seen in the figure on the top right of this page.



7. Look over the top half of the half-screen so you can see the image of the half-screen and the line drawn on the viewing screen at the same horizontal location (see figure to the right).

8. Use Parallax and move your head side to side. If you guessed the right spot, the line on the tape should stay lined up with the middle of the image of the half-screen. Make adjustments if needed until you have located the image position.

9. What similarities do convex mirrors share with concave lenses?

Convex mirrors form virutal, upright, and minified images, just as concave lenses do.