WORLD OF LIGHT LABORATORY

LAB 3

Lenses and Mirrors

INTRODUCTION:

This lab investigates the behaviors of lenses and mirrors. Lenses and mirrors are the central elements of essentially all optical instruments, including microscopes, telescopes, and cameras. They have also had enormous influence in scientific history. Galileo's development of the telescope enabled him to discover the phases of Venus (like the phases of the moon), the moons of Jupiter, and the rings of Saturn (which he misattributed to being moons). These discoveries were the first steps in modern astronomy. Similarly, Van Leeuwenhoek's development of the microscope enabled him to discover single-celled organisms, bacteria, sperm cells, and blood flow in capillaries. These were the first steps in modern microbiology. Telescopes, microscopes, and many other optical instruments are still being actively developed.

We will investigate the relationship between the position of an object and the position of its image for a lens and a curved mirror. In some cases, the image will be a real image, meaning that the light is actually at the image location, enabling it to be projected onto a screen. In other cases, the image will be a virtual image, meaning that the light appears to come from the location of the image, but there is no light really at that location. We will also see that the image can be larger or smaller than the object, and that it can be oriented the same way or inverted relative to the object.

In this lab, we will measure all distances relative to lens or mirror. To do so, we will define the location of the lens or mirror to be position 0.

EQUIPMENT:

This lab requires the use of several pieces of equipment.

• An optical rail, on which you can attach pieces of optical equipment. Do not use the rail's built-in ruler because you can't adjust its zero position, which makes it annoying to use.

• A light source, which is the object. This source has arrows so you can see if the image is upright or inverted. The source can get hot, so an oven mitt is provided to handle it.

• A lens and mirror. Clamp the appropriate one into a lens/mirror holder.

• White cardstock. This is your projection screen.

• A meter stick, 2-meter stick, and calipers. Use these as needed to measure distances and image sizes.

PROCEDURES:

Part 1. Lens, real image

Put the lens near the middle of the optical rail. Put the light source a modest distance away on one side. Using the white card, find the image. The light is actually here, so this will be a real image. Measure and record: the distance from lens to object, d_o, the distance from lens to image, d_i, the width of the image arrow in the image (the left-right arrow, which has a circle on one end), and whether the image is upright or inverted. Also, measure and record the width of the object arrow. Then, move the object and repeat. Do this about 6 times.

object width: _________

object d_o (m)	image d_i (m)	width (cm)	inverted (y/n)

Draw a lens ray diagram.

Using your ray diagram and prior data:

• Can you find the positions where $d_o = d_i$? What are they?

• From the prior result, what is the lens focal length?

• Can you find the object focal point, where $d_o = f$ and $d_i = \infty$? What is it?

• Where do you think the image focal point is, where $d_o = \infty$ and $d_i = f$?

Part 2. Concave mirror, real image

Do the same thing with the mirror. Put the mirror towards the left end of the optical rail, with the concave side on the right. Put the object a modest distance away to the right. It helps to make the object as low as possible and the mirror up a little. Using the white card, find the image, which is a real image. Measure and record: the distance from mirror to object, d_o, the distance from mirror to image, d_i, the width of the image arrow in the image, and whether the image is upright or inverted. Do this about 6 times. Make sure that some of your results are for $d_o < d_i$ and some are for $d_o > d_i$.

object d_o (m)	image d_i (m)	width (cm)	inverted (y/n)

Draw a ray diagram for a concave mirror, for the object beyond the focus.

Using your ray diagram and prior data:

- Can you find the positions where $d_o = d_i$? What are they?
- From the prior result, what is the mirror focal length?
- Can you find the focal point, where $d_o = f$ and $d_i = \infty$? What is it?

Part 3. Concave mirror, virtual image

Leaving the mirror where it is, move the source closer to the mirror than the focal distance (it helps to put it quite close to the mirror). Looking in the mirror, you should see a virtual image. Have your partner hold the meter stick where the virtual image appears to be. Measure and record: the object distance, the image distance, the image width, and whether the image is inverted. Do this at least 3 times.

object d_o (m)	image d_i (m)	width (cm)	inverted (y/n)

Draw a ray diagram for a concave mirror, with the image placed closer than the focal length.

Using your ray diagram and prior data:

- Can you find the positions where $d_o = d_i$? What are they?
- What is d_i when $d_o = f$?

Part 4. Convex mirror, virtual image

Leaving the mirror in place (or possibly sliding it to the right along the rail if needed), move the object over to the left side of the mirror. It should produce a virtual image, which will appear to be on the right side of the mirror. As above, do your best to estimate the virtual image position and magnification. Record these values for at least 3 object positions.

object d_o (m)	image d_i (m)	width (cm)	inverted (y/n)

Draw a ray diagram for a convex mirror.

Using your ray diagram and prior data:

• Can you find the positions where $d_o = d_i$? What are they?

• What is d_i when $d_o = \infty$?

Data analysis

Using Excel, compare your results with theory. There are two theory equations. First, the object distance, image distance, and focal length are related through the equation

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

Secondly, the magnification should equal

$$M_i = -\frac{d_i}{d_o}$$

We will discuss these equations some in class.

Lab report

As usual, this lab explanation and worksheet is purely for your own use and does not need to be turned in. Instead, turn in a more polished report, prepared using Microsoft Word or equivalent. It should have five clearly labeled sections: Introduction, Methods, Results, Discussion, and Conclusions.

Introduction

• Write a few sentences about why mirrors and lenses are important.

• Present and briefly discuss your four ray diagrams (lens, concave mirror with source beyond focus, concave mirror with source within focus, and convex mirror). *These should be your own drawings, not copied from elsewhere.*

Methods

• Briefly describe what you did in this lab. One paragraph should be adequate.

Results

• Present your four data tables.

• Present all graphs, plotted in Excel, with the theory lines. Label which points arose from which experiment. Please keep data tables and graphs in a reasonably small size, provided that they are still legible.

• Describe your results in paragraph form, referring to figures as they come up. Focus on the facts of what you found, not the interpretation.

Discussion

• Answer all of the questions that are posed above. Lens: find positions where $d_o = d_i$, focal length, focal points. Concave mirror: find the positions where $d_o = d_i$, focal length, focal point. Concave mirror virtual image: positions where $d_o = d_i$, find d_i when $d_o = \infty$. Convex mirror: positions where $d_o = d_i$, find d_i when $d_o = \infty$.

• Explain how these results agree (or disagree) with the ray diagrams.

• Discuss how well your results agree with the theory lines.

• What were the main sources of error? (These may be different for different data points.) This is not about what mistakes you made, but what errors were unavoidable.

Conclusions

• Summarize your results and primary conclusions from them in 4-5 sentences. Include the key qualitative results and how well your experimental results agreed with theory. This section should not include new material, but should summarize the key findings from above. This is about the science results that you determined, not about how much you learned.