PHYS 1040 - General Physics II Lab
Converging Lenses - Imaging

In this lab you will perform an experiment to understand image formation by converging lenses. Converging lenses are used in cameras and several other optical instruments (telescopes, magnifying glass, etc.).

INTRODUCTION AND THEORY:

Lenses work due to the refraction of light as it passes through different media. Converging lenses refract parallel rays of light entering the lens through their focal point on the other side of the lens. When considering image formation by converging lenses, there are essentially three factors that you need to consider, and the purpose of this lab is to study how these factors depend on each other.

The factors that affect/describe image formation are:

- Focal length, f, the distance from the center of the lens to the point at which parallel rays entering the lens are focused.
- The object distance, d_o, is the distance from the object that you are trying to image from the center of the lens.
- The Image distance, d_i, is the distance from the image formed to the center of the lens.
- The magnification, m, is the ratio of the size of the image to the size of the object.

Ray Tracing:

Ray tracing can be used to better understand the size, location and nature of the image formed by a converging lens. As with mirrors, we utilize certain facts about refraction by a converging lens in order to draw a ray diagram. The following three rays are commonly used to study image formation by converging lenses:

1. A ray from the top of the object, parallel to the principal axis, will pass through the focal point on the other side of the lens from the object after refraction.
2. A ray from the top of the object, passing through the focal point on the same side of the lens as the object, will emerge from the lens as parallel to the principal axis.
3. A ray from the top of the object, passing through the center of a thin lens will emerge straight through the lens.

The point at which the refracted rays meet is where the image is formed. In general, any two of the above rays can be used to find the image location.

Thin Lens Equation

The relationship between the focal length (f), object distance (d_o) and image distance (d_i) for a thin lens is given by:

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

The magnification (m) can be represented as the size of the image (h_i) divided by the size of the object (h_o) and is given by:

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

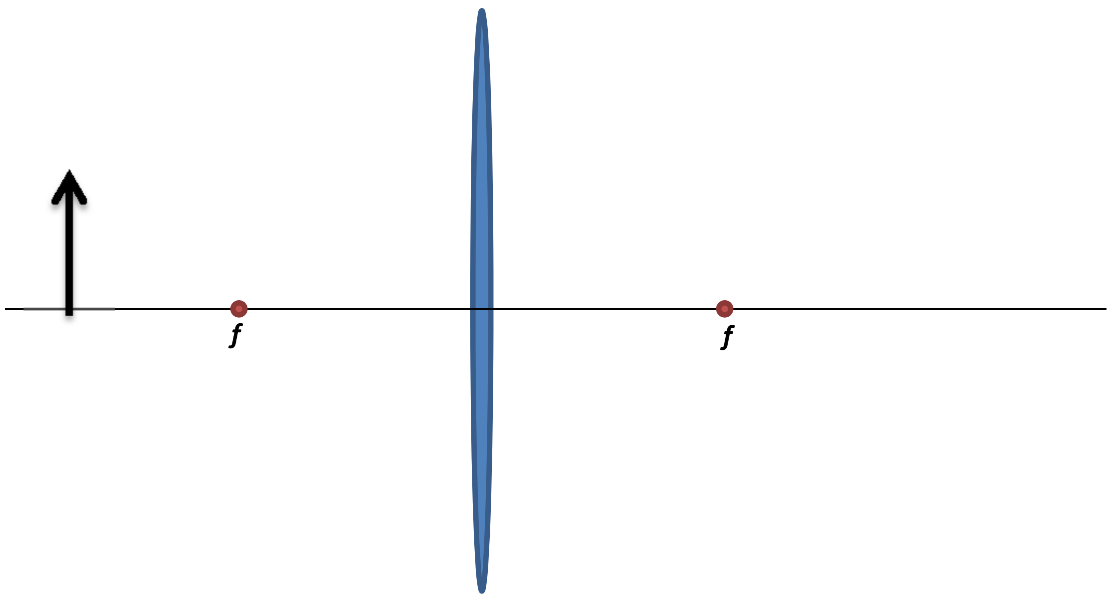
Using the thin lens equation requires the following sign conventions:

1. The focal length, f, is positive for converging lenses and negative for diverging lenses.
2. If the object is in front of the lens, the object distance is positive.

3. If the image is on the opposite side of the lens from where the light enters the lens, the image distance is positive (if the image is formed on the same side of the lens as the object, the image distance is negative).
4. The size (or height, h_o) of the object is upright and positive; the size (or height, h_i) of the image is taken as positive if the image is upright and negative if the image is inverted.

CHECKPOINT 1:
Discuss the following questions with your group and write your expectations and answers.

1. Complete the ray diagram below. Label the object distance, object size, image distance, image size, and principal axis.

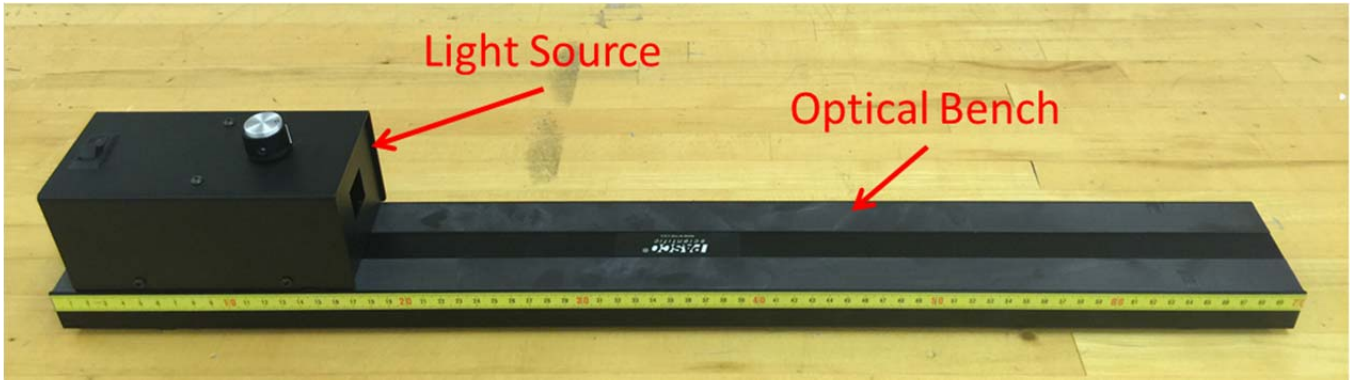


2. What is the difference between a real and virtual image? When standing in front of a mirror how far away from your eyes does your image appear to be? Is this image virtual? Or real? How can you tell?

3. Hold your hand up roughly ten inches from your face and look at it; is the rest of the room clear? Or blurry. Now spread your fingers and lock eyes with a friend, are your fingers blurry? Or clear. How does your eye make some things clear and other things blurry?

Show your TA your expectations before proceeding.

EQUIPMENT:



Optical Bench: Provides a stable platform to mount optical elements.

Other Elements: Light source, viewing screen, arrow target, convex lens, concave lens (not shown)

EXPERIMENT

Part 1 – Conduct an experiment to verify the thin lens equation for a convex (converging lens).

You need to create a data table in your lab notebook, deciding on number of columns to be included in the table. Record all the data you take, even though some data may not be within the expected value. This is an experiment and hence uncertainty is associated with any measurement.

Analyze your data performed in part 1 of the experiment:

- How does the image change based on object distance?
- Is the image formed by a convex lens always real? How does the magnification of the image change?
- Use your data to verify the thin lens equation.

CHECK POINT 2:
Show your TA your experimental data and conclusions for part-1 of the experiment.

Part 2 – Conduct an experiment to investigate image formation by a diverging (Concave) lens.

CHECK POINT 3:

- Can you use just a concave lens to form a real image?

Part 3 – Investigate image formation using the Box-Lens Setup Provided

The aim of this part of the experiment is to develop an intuitive understanding of how a camera works. Develop a procedure that investigates the following aspects:

- Describe the image formed? Real or virtual? Upright or inverted? What does this depend on?
- Where the camera film / sensor should be placed to capture the image?
- What needs to change to be able to take focused images of objects at different distances?
- Investigate the magnification as a function of object distance.

CHECK POINT 4:
Show your TA your experimental data and your conclusions for the above listed questions.

Post Lab Questions

1. Think about what “focusing” a camera really means, how far away is the lens from the detector in a camera when the camera is focused on a distant mountain? On a friend close by? How does your eye accomplish this?
2. How far would you have to place the screen to see an image of the target placed at the focal point of a converging lens?

LAB REPORT – due one week after the lab.

The procedure you followed should be clearly written and all the analysis should be included. Ray tracing is required. Make sure you address the questions posed at the beginning of this handout, your expectations before conducting the experiment and use to your experimental data to support your conclusions. Your conclusion should indicate whether or not you were able to confirm your expectations.