# <u>Measuring Focal Length of a Thin Lense</u>

Laboratory Experiment #6

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Submitted to:

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**Objective:**

The objective of this experiment, as outlined in the report, is to determine the focal lengths of both a positive (convex) and a negative (concave) lens. Through the process of measuring how parallel rays of light are focused by the lenses onto a screen, the experiment aims to teach the principles of lens optics, including the relationship between object distance, image distance, and focal length, as well as to provide practical experience in handling optical equipment and conducting precise measurements in the context of photonics.

**Materials:**

- Optical Table (SG-22-2)
- Rectangular HeNe Laser (IF-HN15M)
- Laser Diode and power supply
- Laser diode mounting bracket
- Magnetic Base
- 1x Post Holders (VPH-2)
- Lens Kit (E52-305) DCX (+100 mm)
- 1" Diameter Adj. Mirror Mounts. (E55-532)
- Screw Kit, ¼ x 20 (SK-25A)
- Aluminum Square Rule
- Scissor Jack

**Background:**

The background of the experiment on the measurement of the focal length of thin lenses is grounded in the principles of geometric optics. The core theoretical concept at play is the lensmaker's equation for thin lenses, which relates the focal length of a lens to the radii of curvature of its surfaces and the refractive index of the material from which the lens is made.

In a thin lens, the refractive power is concentrated at a central plane, and rays of light are assumed to bend at this plane. For a convex lens, parallel rays of light converge at the focal point, while for a concave lens, they appear to diverge from the focal point. The focal length is positive for converging (convex) lenses and negative for diverging (concave) lenses.

The experiment also considers spherical aberration, a distortion that occurs because lenses do not focus all parallel rays to the same point. This aberration becomes more pronounced for rays further from the central axis. Additionally, chromatic aberration, which is the dispersion of light into its constituent colors due to varying refractive indices for different wavelengths, is also considered. The focal length varies with wavelength, and this experiment may illustrate this phenomenon if monochromatic light sources are not used.

The key governing equation is the lens formula

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

, where $f$ is the focal length, $o$ is the object distance, and $i$ is the image distance. This experiment aims to practically apply these concepts by determining the focal length through direct measurement of object and image distances.

Procedure:

1. **Setup**: Place the helium-neon (HeNe) laser on a scissor jack and position it on an optical table away from any white surfaces to minimize interference from stray reflections.

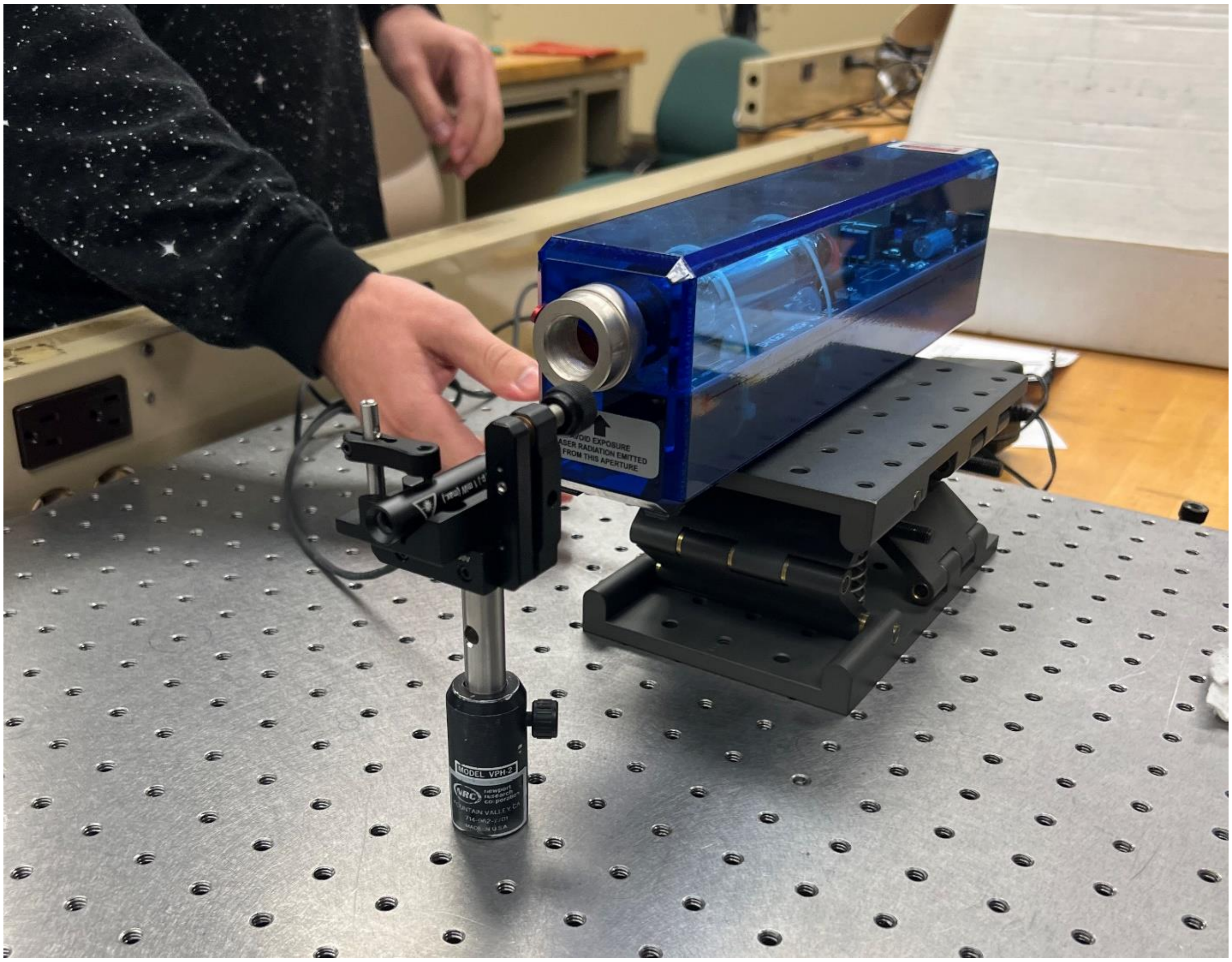


*Figure 1 - Laser Set up*

2. **Laser Alignment**: Mount the laser diode to the magnetic base and align it directly in front of the HeNe laser aperture. Power on both lasers, ensuring the beams are parallel and at the same height.

*Figure 2 - Laser Alignment*

3. **Beam Manipulation**: Install a post holder on the optical table and use it to hold a mirror mount without the mirror, positioned so both beams pass through the center of where the mirror would be, indicating alignment.

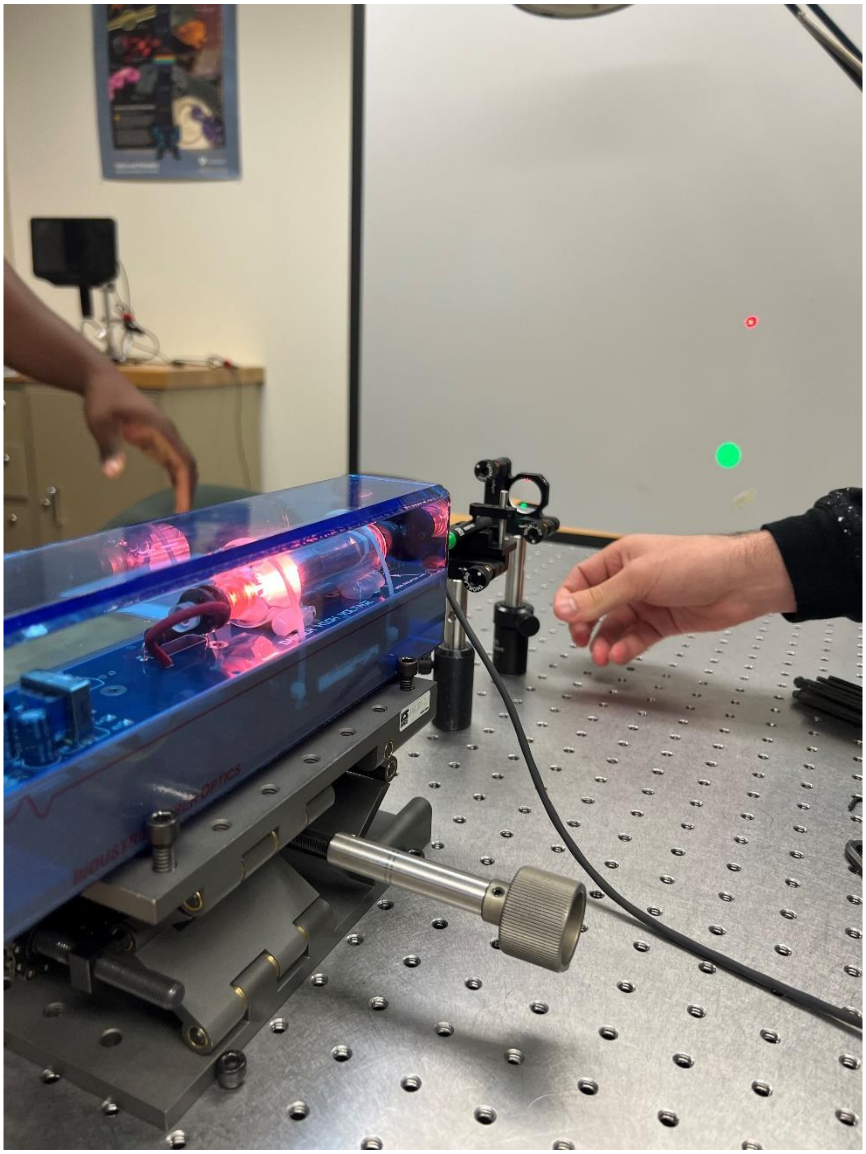

*Figure 3 - Insuring Beam is as aligned as possible.*

4. **Lens Insertion**: Replace the empty mirror mount with a +100 mm double convex lens (DCX) mounted in a post holder, positioned to intersect both beams.

5. **Beam Convergence**: Place a screen at the far end of the table and move it until the two laser beams converge into a single point, then measure the distance between the lens and the screen where the beams converge to determine the focal length.

6. **Data Collection**: Adjust the screen's position at measured increments and record the beam separation at each point. This data will be used to plot the relationship between the object distance (screen to lens) and the image distance (beam separation).

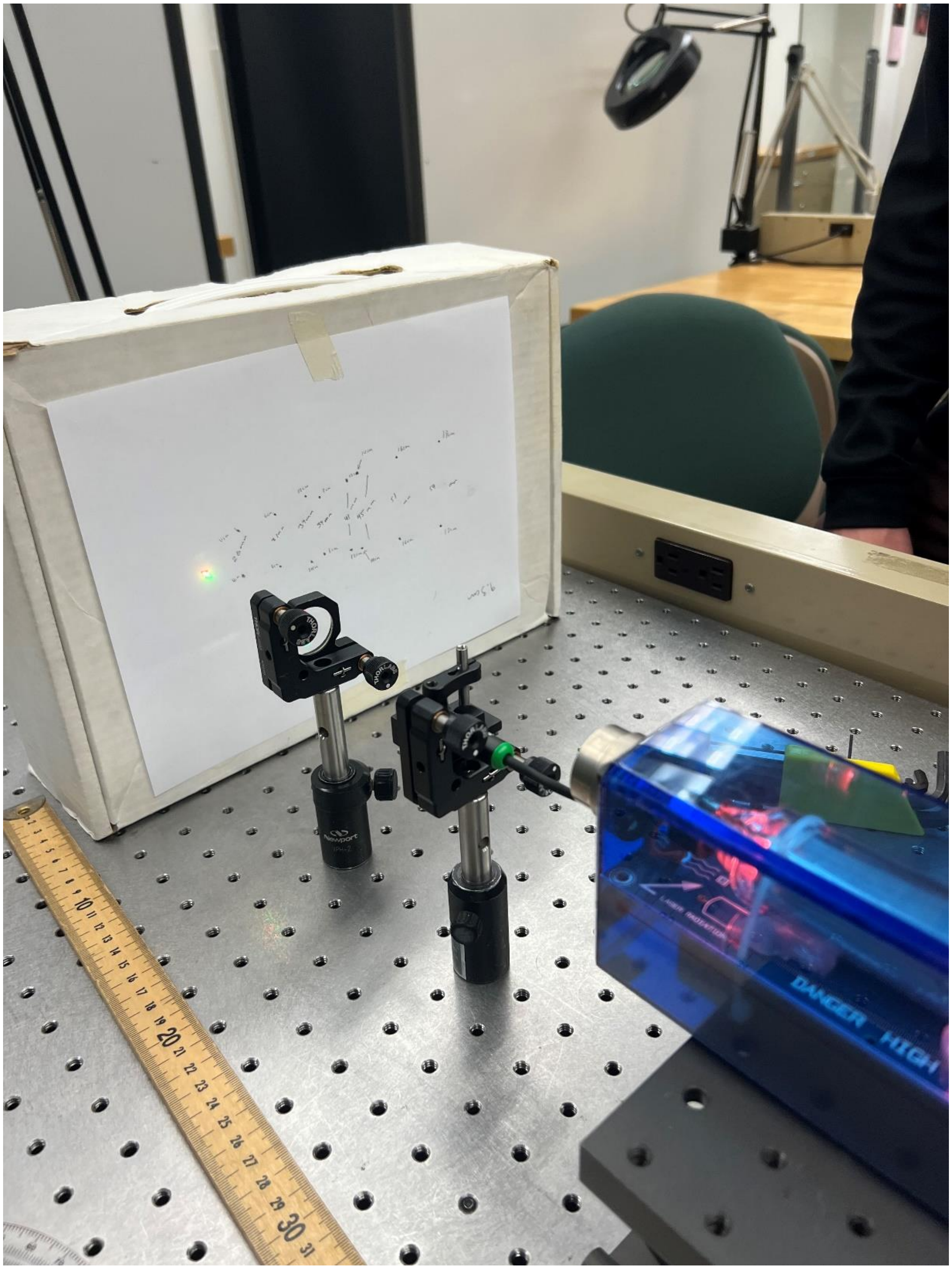


*Figure 4 -Data Collection.*

7. **Power Down**: After completing the measurements, turn off both lasers.

8. **Analysis**: Use the collected data to plot a graph of beam separation against screen distance. This graph will provide a visual representation of how the focal length can be determined from the convergence point of the beams.

**Data & Observations:**

The data and observations from the experiment provide insight into the focal lengths of thin lenses. The measured distances between the lens and the point of beam convergence were recorded at various positions of the screen. These values were then used to calculate the separation between the two laser beams at each position.

The results were tabulated, displaying the screen distance (object distance) alongside the corresponding beam separation (image distance). This tabular data shows a clear inverse relationship between the object distance and the image distance, which is expected from the thin lens equation:

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

**Table 1**

| X (cm) | 18 cm | 16 cm | 14 cm | 12 cm | 10 cm | 8 cm | 6 cm | 4 cm |
|---|---|---|---|---|---|---|---|---|
| Y (cm) | 5.4 cm | 5.1 cm | 4.5 cm | 4.1 cm | 3.9 cm | 3.4 cm | 3.1 cm | 2.6 cm |

Virtula focal point = **-9.36**.

A graph was plotted using the measured values, with the screen distance on the x-axis and the beam separation on the y-axis. The graph illustrates how the beam separation changes with the distance of the screen from the lens, providing a visual representation of the focal length's effect on the convergence of light.

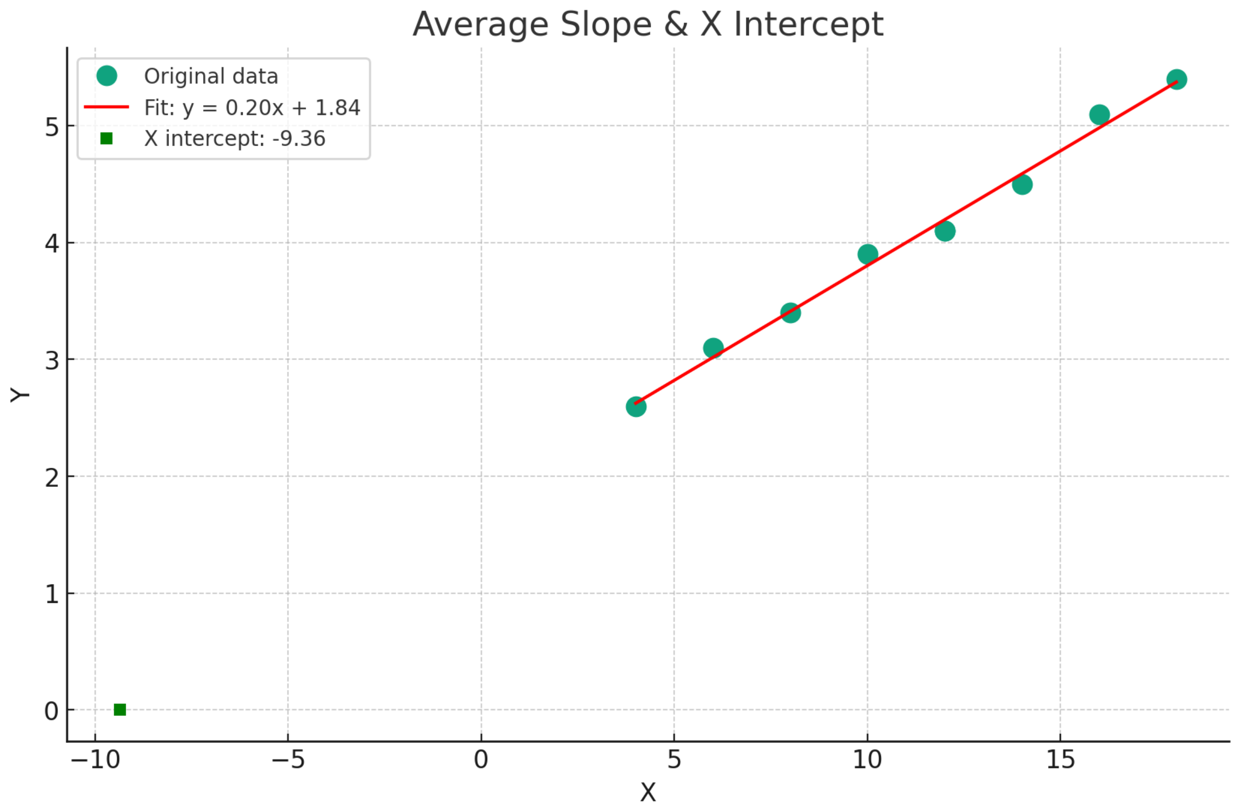


*Figure 5- X- Intercept and Equation of the line, graphed using Python.*

The experimental results led to the determination of the focal lengths for both the positive and negative lenses used. The precision of these measurements could be affected by several sources of error, including alignment of the laser beams, parallax error while reading the scale, fluctuations in the laser output, and the quality of the optical components. Each of these potential errors was considered when evaluating the accuracy of the measurements. The calculated focal lengths were found to be consistent with expected values within the bounds of experimental error, confirming the validity of the procedure and the measurements.

**Answer to Lab Questions:**

No Questions in this section.

**Conclusion:**

The results of the experiment successfully demonstrated the principles of lens optics by determining the focal lengths of a positive and a negative lens. The measured distances and calculated focal lengths aligned with theoretical expectations, validating the experimental approach and the use of the lensmaker's equation.

The experiment did yield the desired results, with the focal lengths obtained through direct measurement methods. The results suggest a strong understanding of geometric optics principles and the correct application of the lens formula. The consistency of the measured focal lengths with expected theoretical values indicates that the equipment was set up correctly, and the procedure was robust.

The interpretation of the results leads to a deeper understanding of the behavior of light as it passes through thin lenses and the importance of precision in experimental physics. The successful determination of the focal lengths also illustrates the relationship between the physical properties of the lenses and the refractive index of light.

From this experiment, it has been learned that meticulous alignment and calibration of optical equipment are crucial for obtaining accurate results. For future work or improvements, it is recommended that care be taken to minimize potential sources of error such as environmental vibrations, light source fluctuations, and human measurement error. Additionally, further experiments could explore the impact of lens imperfections on focal length or extend the investigation to lenses with different shapes and materials to understand how these factors influence lens behavior.