**Introduction**

Of the many items used in optical arrangements, one of the most common are thin converging lenses. These are lenses with relatively thin thicknesses, and with opposing spherical surfaces. In this lab we’ve taken to investigating the properties of such a lens, and considering the effect that measurement error has on calculated results. Though conceptual comments are made regarding this type of optic, our goal is to determine both radii of curvature, the focal length, and ultimately to calculate the index of refraction for a single converging lens.

**Procedure**

To measure the focal length of the lens, an object and a screen on which to project the focused image are needed. A ceiling light at the end of a hallway was chosen as it was easy to identify on the screen and considered far enough away that the term in the thin lens equation would trend to zero. With the lens held intercepting the path from the light to the paper screen, a poorly focused image was observed. By adjusting the position of the lens with respect to the paper, the image was put into focus and kept in focus as the distance between the paper and the center of the lens was measured. What we measured was the image distance in the Thin Lens equation:

As the term can be approximated to be zero, the measured image distance was taken as being equal to the lenses focal length: . The +/- 0.2 cm comes from the standard deviation observed on successive measurements of 17.9 cm and 18.3 cm, errors well above 1/10th of a mm.

A Spherometer, in conjunction with the Spherometer Equation below, was then used to find the radius of curvature, R1 and R2, for both sides of the lens. By placing the spherometer squarely onto a surface, one can measure the height displacement of a centrally aligned needle in the device. As two points are needed to measure any displacement, we first placed the device onto what we considered to be a flat surface—our laboratory table—and calibrated the meter to read this position as being exactly zero. Then we measured the displacement of the needle with respect to zero—with respect to a flat surface—by placing the device squarely against each side of our lens ensuring the calibration of our device before and after both measurements: , and . However, generally the error of h, . This displacement from zero to our measured values represent the ‘h’ values seen in the Spherometer Equation, and physically represent the height of the lens sphere that penetrated the imaginary plane made by the Spherometer’s circular base. The radius of the base, measured to be 8.0 +/- 0.1mm, being the value ‘b’ in both equations.

,

,

A series of measurements were performed for re-calculating the lens’ focal length. A lamp with two stark black lines on it’s surface as our object. Again, a piece of paper was used as a screen, but this time was clipped securely to a metal plate. The positions of the lamp’s surface, the converging lens, and screen were secured to a metal railing using clamps. The image distance, and object distance were each measured for four separate arrangements each differing from the previous measurement in overall distance—from lamp to screen, or object to image—by about 2cm. Using the Thin Lens equation from before, and these measured distances, we re-calculate the focal length for each positional arrangement.

|  |  |  |  |
| --- | --- | --- | --- |
|  | (cm) | (cm) | (cm) |
| 1st | 51.0 | 29.7 | 18.77 |
| 2nd | 53.9 | 29 | 18.855 |
| 3rd | 56.5 | 27.8 | 18.632 |
| 4th | 59.2 | 27.3 | 18.684 |

With the radii of curvature, and the focal length determined, the Lensmaker’s Equation can be used to calculate the index of refraction.

**Analysis and Discussion**

**Q1 The orientation of the object was inverted in the image because the magnification comes out as being negative.**

**Q2 Any error in the Spherometer’s readings could not be seen in repeated measurements. As such, the error for this is 1/10 of the smallest discretization of measurement, or +/-0.001mm. Meaning the error for h on either of the lens’ sides is no more than +/- 0.001mm.**

**Q3 An Iris wouldn’t help sharping our image as our object is flat, it’s depth of field is not an issue.**

**Q4 The mean of my focal lengths in the four measurements seen in the above table is 18.73525, with a standard deviation of . The percent error of the initial estimate with respect to this calculated value is .**

**Q5** Placing the light source at a distance of less than the lens’ focal length made the image impossible to focus. What seems to be happening is that as the object approaches and surpasses the focal length of the lens, light rays exiting the opposite side of the lens become parallel and then even somewhat divergent.