Experiment 2: Thin Divergent Lens PHY 431

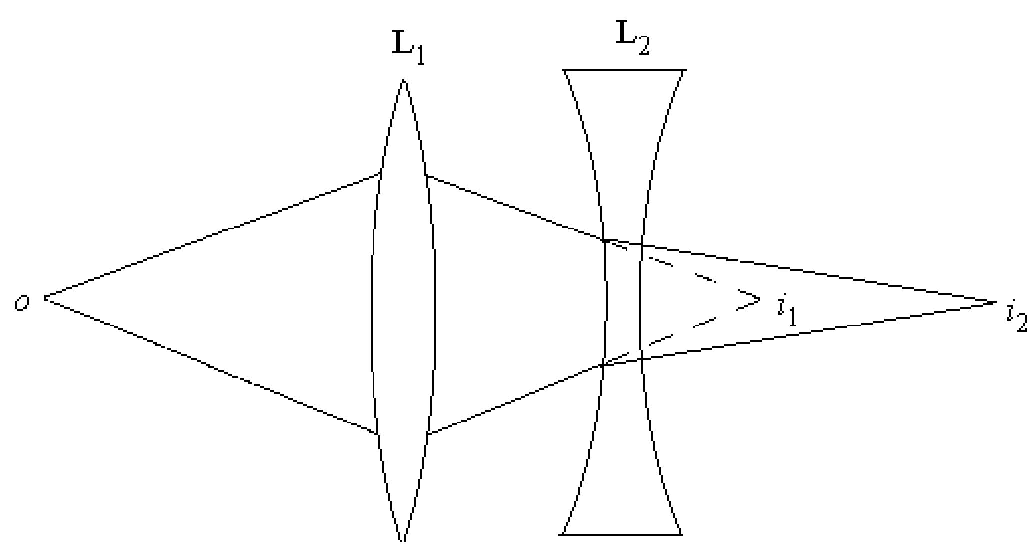
For a divergent lens, principles and conventions used for a convergent lens will apply equally well. The key difference is that a divergent lens cannot by itself form a real image of a real object. Hence, in this experiment we will measure *f* using a virtual object. The virtual object and real image are on the *same* side of the lens. You will measure the radius of curvature and focal length, then calculate the index of refraction of the glass. Don't forget to determine errors for your measurements and derived quantities.

In this experiment you will gain some familiarity with another important optical tool, the laser. Remember, never look directly into a laser. Direct the laser away from the eyes of others, including people unrelated to the lab, potentially present in the outside corridor. We all know that a laser has a well-defined wavelength. This laser characteristic will remove a source of image blurring known as chromatic aberration and will allow for more precise measurements. The laser also appears to produce a well-defined beam of parallel rays. That is to say, it appears to be a collimated source. You will see if this is really the case. Then you will use a telescope to expand or reduce the beam.

Procedure:

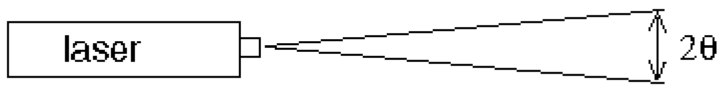
A. Use a spherometer to measure the radius of curvature of a divergent lens. **Q1.** Which edge of the spherometer head is active when determining the curvature of a concave surface?

B. Use a convergent lens L_1 to form a sharp image i_1 of your object on a screen, using the lamp as a source. Next, place a divergent lens L_2 between L_1 and i_1 as indicated below. Measure the distances to i_1 and i_2 to calculate *f* for the divergent lens. Repeat this for 3 positions of i_2 by changing the lens-screen separation in units of about 1 cm. Find your best value for the focal length using the thin-lens equation. Be careful with signs. **Q2.** Relative to which element do you need positions of i_1 and i_2 in order to use the thin-lens equation?



C. Calculate the index of refraction (including uncertainty) for the glass of your lens using the lensmaker's equation. Compare this to the value you found last week.

D. Now switch your light source to the laser. If the beam from the laser is not perfectly collimated, the diverging rays must spread over some angle θ. Aim the beam from the diode laser onto a distant wall and measure the radius of the maximum spot size that can be discerned.



Q3. Is the observed spot of uniform brightness? Calculate 2θ in degrees and radians.

E. Using the converging and diverging lenses configured for a Galilean telescope, see the Appendix for mathematics and discussion, make a laser beam expander (reducer). Note: A Galilean telescope normally utilizes an objective lens with a focal length that is longer than that of an eyepiece (ocular). You will likely need to change the converging lens, used for the objective, in order to arrive at that situation. Measure the beam diameter right before it enters the eyepiece and right after the objective and at a couple of more positions beyond the objective. By what factor does the diameter change across the telescope?

Q4. Derive the beam diameter change (diameter magnification) by considering rays passing through the telescope. For this purpose you can consider parallel incident rays. Does the theoretical result agree with your measurements?

Q5. Does the beam diverge beyond the objective? Carry out suitable measurements to assess its divergence angle there.

Before leaving the laboratory, make rough estimates of all quantities that need to be calculated or included in your report. Check whether these make sense. Once you leave, you have no chance to redo the measurements if any of the recorded results turn out to be incomplete or suspect.

Appendix: Galilean Telescope Configuration

The image position s_i for a combination of two lenses separated by d is given by

$$\frac{1}{s_i} = \frac{1}{f_2} - \frac{1}{d + \frac{f_1\, s_0}{f_1 - s_0}}$$

Here, s_0 is the object position relative to the lens 1 and s_i is relative to the lens 2. The equation above follows from a combination of two thin-lens equations for the two lenses. When the lenses are used as a Galilean telescope, for viewing far-away objects, then $s_0 \to \infty$ and $s_i \to -\infty$. The image formed by lens 1 is formed in practice at its focal point and it is placed for viewing through the lens 2 at the focal point of the latter, so that $s_i \to -\infty$. With this, the utilized lenses get separated by $d = f_1 + f_2$, when configuring the telescope.