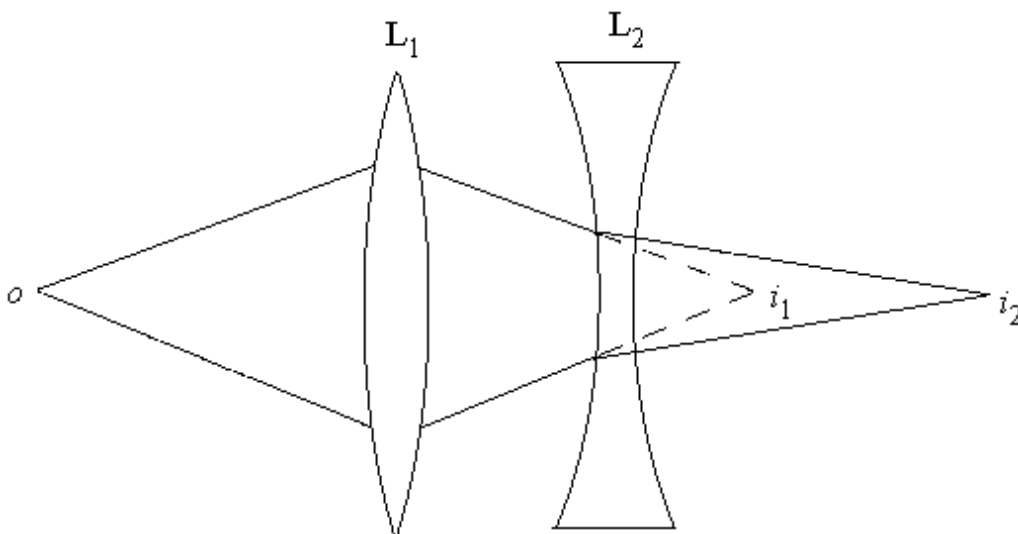


For a divergent lens, all principles and conventions used for a convergent lens will apply equally well. The key difference is that a divergent lens cannot by itself form a real image of a real object. Hence, in this experiment we will measure f using a virtual object. The virtual object and real image 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 the laser. We all know that a laser has a well-defined wavelength. This will remove a source of blurring known as chromatic aberration, and 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.

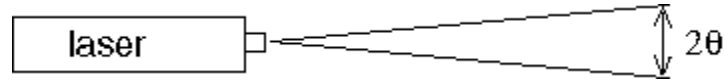
Procedure:

- A. Use a spherometer to measure the radius of curvature of a divergent lens.
- 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.



- 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 He-Ne laser onto a distant wall and measure the radius of the maximum spot size that can be discerned.



- Q1.** Is the spot of uniform brightness? Calculate 2θ in degrees and radians.
- E. Using the converging and diverging lenses and the equation for a Galilean telescope 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 may need to change the converging lens 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?
- Q2.** 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 result agree with your measurements?
- Q3.** Does the beam diverge beyond the objective? Using your measurements estimate its divergence angle there.

Before leaving the laboratory, make rough estimates of all quantities that need to be calculated or included in your report.

Appendix: Galilean Telescope Configuration

The image position for a two lens combination is

$$s_i = \frac{f_2 d - \frac{f_2 s_o f_1}{(s_o - f_1)}}{d - f_2 - \frac{s_o f_1}{(s_o - f_1)}}$$

where s_o is the position of the object (before either lens), and d is the distance between the lenses. If $s_o = \infty$, and $d = f_1 + f_2$, then $s_i = \infty$. This is the Galilean telescope case.