1 Convex, Concave Lenses and the Lensmaker's Law

1.1 Equipment

light ray source, Pasco convex and concave lens slices, ruler, 1.2m optics track with lens holder and white screen, 10cm lens

1.2 Purpose

1. To measure the focal length of a convex and a concave lens.
2. To predict the focal length of a convex and a concave lens using the lensmaker's law.
3. To examine the behavior of combining the convex and concave lenses.
4. Test the lens equation with error.

1.3 Theory

The lensmaker's law used to calculate the focal length f and f' is:

$$\frac{1}{f} = \frac{1}{f'} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \tag{1.1}$$

It uses the index of refraction n of the lens material along with the radii of curvature of both surfaces to predict the focal length of double-convex, double-concave, plano-convex or plano-concave lenses. It assumes that the lens thickness d can be treated as insignificant and that the lens is surrounded by air.

The Gaussian sign convention indicates that for a double-convex lens, R_2 is negative and for a double-concave lens, R_1 is negative.

The Basic Optics kit contains a pair of lenses that allow the measurement of focal length and radii of curvature is a very quick manner.

1.4 Procedure[1]

1. Place the ray source (three rays) on a large sheet of paper and direct the rays toward the double-convex lens as shown in Figure 1.1. One edge of the lens is more flat and will be more stable and is best in contact with the paper. *Note: Allow room for a total of four trials, two for each lens.*
2. Carefully trace around the lens using pencil. This trace will be used to measure the curvature later.
3. Mark the ray edges or centers and then use a ruler to draw the rays on the paper. Extend the center ray well beyond the focal point. Record the f' distance in mm under the diagram.
4. Put a reasonable error on the focal length value.
5. Repeat steps one to four and average the results for the focal length. Include an error.
6. Use a compass to determine the radius of curvature of both sides. Record them as R_1 and R_2 with surface 1 being the first surface the light hits. If desired you can retrace the lens on a separate trial somewhere.

[1] Explain any changes to procedure you may have made, right on the diagram.

Figure 1.1: Thin lens equipment setup

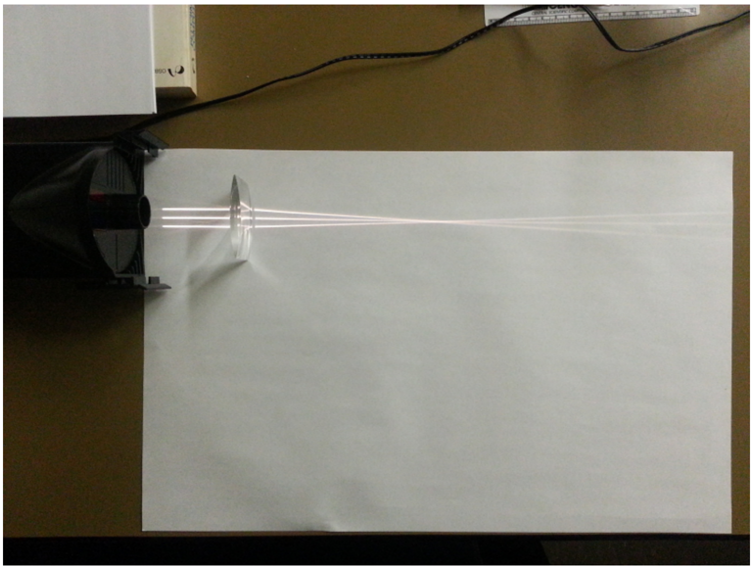
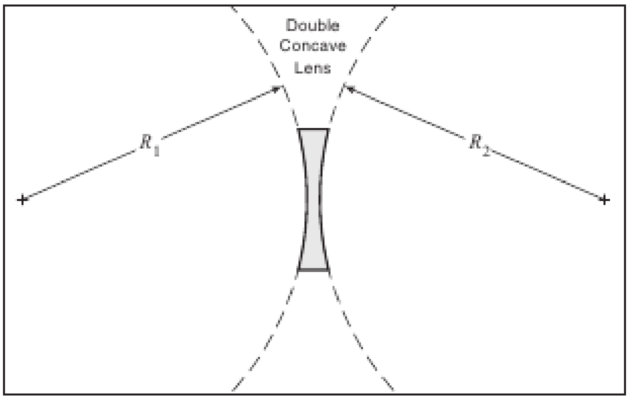


Figure 1.2: Double-concave lens radii



7. Repeat the above steps for the double concave lens with the following changes. Assign reasonable $\pm$ errors to measurements of f and the values of R. This time:
   a) The rays will have to be extended back to a focal point after removing the lens.
   b) The radius of curvature can be determined using the faint ray that reflect off the first surface. Trace these rays too and use them to measure R_1.
   c) The manufacturer states that for the double-concave lens $R_2 = R_1$.
8. On the paper, table your values and averages with their errors.
9. Determine and report the thickness at the center of each lens in a table.
10. Nest the two lenses together (touching) and examine the resulting ray pattern that is produced by rays exiting both the lenses. Note this step as Step #10 on the paper and your report. Indicate if the rays are: diverging, converging or parallel after going through both lenses.
11. Now gradually pull the lenses apart horizontally, and note any changes to the rays exiting the lens pair.
12. Reverse the positions of the two lenses and repeat steps 10 and 11.

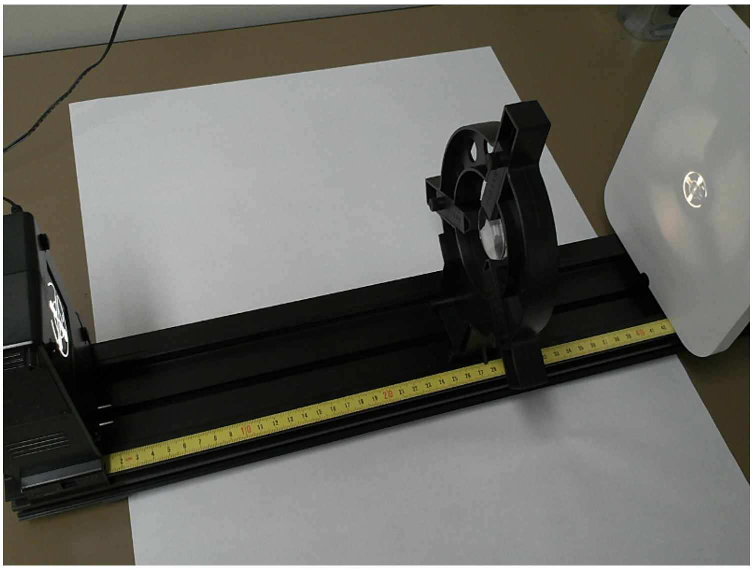


Figure 1.3: Len's equation test setup

1.5 Calculations

1. Use the lensmaker's law with the measured radii and focal lengths of both lenses to calculate the index of refraction n for each lens.

2. What does the test is step 10 tell you about the lenses?

3. Do the rays do anything different comparing steps 11 and 12?

1.6 Lens Equation

The standard lens equation employed to calculate image and object positions or the focal length of a lens is:

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

Often f will be shown as f', which is the focal length on the image side of a converging lens.

1.6.1 EXERCISE: Verification of Lens Law, Graphing and Measuring Error, plot of 100mm = 10cm lens data

The main goals of this exercise to *generate reasonable errors on values of s and s'* and to see the lens equation in action. The actual values of *s* and *s'* used are given and are to be confirmed not determined again.

1. Set up the lens holder and light source and the white screen as shown in Figure 1.3. Set the light source to illuminated object.

2. For the rows in Table 1.1 with a *, set *s* to be the value shown.

3. Verify that the *s'* value record in Table 1.1 is similar to yours.

4. Determine a reasonable error in *mm* for both *s* and *s'*. Record these values in the table. *Watch how the error changes as you move down the table and account for this change.*

5. In xmgrace, enter the values of *s* and *s'* with error bars. Use set type XYDXDY with s in the X column.

6. Create a graph of *s'* as a function of *s* in your report.

Table 1.1: 100*mm* lens data

object distance *s* *[mm]*	image distance *s'* *[mm]*	error in *s* *[mm]*	error in *s'* *[mm]*	calculated f
600	118			
*500	121			
450	125			
*400	130			
350	135			
*300	146			
250	160			
*200	193			
*150	272			
100	1058 (?)			
75	no focus			

7. Use xmgrace to calculate values and plot a second graph of $1/s'$ as a function of $1/s$ with error. This set will also be of type XYDXDY. Consult the appropriate tutorial sections for assistance.

8. List three sources of error for *s* and *s'*.

1.6.2 Question

1. Why does the s=75mm distance not provide a focused image?