Thin Lens Imaging Lab

Thin lens equations: $\frac{1}{s_0} + \frac{1}{s_i} = \frac{1}{f}$ Lensmaker equation: $\frac{1}{f} = \frac{n_2 - n_1}{n_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Magnification: $M_T = \frac{y_i}{y_o} = -\frac{s_i}{s_o}$

Equipment: Lens +100, positive lens with unknown focal length, diopter gauge, negative lens with unknown focal length, target pattern light source, screen, long optical bench; colored pencils, paper;

1. PreLab: Ray Diagram

Draw a complete ray diagram for a 2-cm tall object (h_0 = 2 cm) and label the points *C* (center of sphere), *f* (focal length), *O* (position of object), and *I* (position of image) as well as the distances s_0, s_I, h_0, h_I. Use the exact values below.

1) Assume the object is 15 cm away from a spherical mirror with f = 4 cm.

1. Carefully draw your ray diagram, constructing the image exactly to scale. Carefully measure the distance s_I.
2. Measure the image height, and compute the magnification (sign!).
3. Calculate the values s_I and the magnification *m* from the given quantities.
4. Is the image real or virtual?

2) Repeat 1a-1d) for s_0 = 8 cm and R = -10 cm.

3) Repeat 1a-1d) for s_0 = 1.5 cm and f = 6 cm.

4) Repeat 1a-1d) for s_0 = 5 cm and f = -7 cm.

2. PreLab: Theory on Excel Worksheet: Lens Equation & Magnification

- Create an excel worksheet with the following 6 columns:
  focal length (f), object distance (so), image distance (si), Magnification (M_T), Virtual OR Real image (V/R), Erect OR Inverted image (E/I),
- Use the following three focal lengths: +100, +200, -200
- For each focal length use all 10 object distances: s_o = 1000, 600, 400, 300, 200, 170, 140, 120, 100, 50.
- Calculate s_i and M_T for all combinations.
- Decide if the image is inverted or upright, and if it is real or virtual.

3. Experiment: Lens Equation & Magnification

Determine experimentally the image distance s_i for different object distances s_o for lens with focal lens of f = 100mm. Procedure:

- set the distance s_0 of the light source ("target pattern") to lens
- move the screen until a focused image appears.
- Measure distance s_i of screen to lens.
- Measure the image size (size of arrow in image) and calculate magnification
- Calculate the values of s_i and M_T

s_0 [mm]	Measured s_i [mm]	Calculated s_i (from above)	Measured M_T	Calculated M_T (from above)
600				
400				
300				
200				
170				
140				
120				
100				
50				

4. Experiment: The Lensmaker Equation

OR *Finding focal length and index of refraction*.

Take a convex lens of unknown focal lens:

1. Measure the curvature of both sides of the unknown lens using a diopter gauge. Note that the diopter gauge reads the **curvature (C) of the sphere** in units of diopter 1D = 1/m. with C = 1/(2R).
2. Calculate the radii of both sides.
3. Determine the focal length of the lens by using an object far away (s_0=inf) [for example the ceiling light], bringing image into focus and measuring the distance.
4. From that, determine the index of refraction of the lens.

DATA SHEET: lens with number: _____

Measurement of Curvature of the lens:		
C1=	C2 =	
R1 =	R2 =	
Measurement of focal length		**Calculated focal length:**
s_i =		f =
a) Distances for thin lens equation:		**Calculated index of refraction:**
		n =

5. Experiment: Finding the focal length of a concave lens with the help of a convex lens:

- Place the concave lens with unknown focal length (number 4-6) some distance away from the light source with the grid (the target pattern) (~200-300mm).
- Place the convex lens (f = +100mm) at some distance behind the concave lens. (50-150mm)
- Look for an image on the screen behind the convex lens and, if necessary, adjust the distances.
- Now work your way backwards using the thin lens equation to find the focal length of the first concave lens.

Note that the object of the second lens is the image of the first lens and the distances are related by the following formula:

$$s_i(1st\ lens) = -[s_0(2nd\ lens) - space\ between\ lenses]$$

Data table for experiment 4:

Distance between the lenses: d =	
First lens (concave)	**Second lens (convex)**
s_0 =	s_0 =
s_i =	s_i =
f =	f =

6. Experiment: Finding the focal length of a convex using Bessel's Method.

- Set the object and the screen to a fixed distance L = 1000 mm.
- Move the convex lens with unknown focal length between the object and the screen.
- For two settings of the lens you will produce a focused image.
- For both settings, note the distances s_0 and s_i.
- A) **Calculate the focal lens from the thin lens equation.**

Bessel's method:

- Calculate the difference of the position of the lens $D = s_{02} - s_{01}$.
- B) **Use: $f = (L^2 - D^2)/4L$ to calculate the focal lens.**

Questions:

A) Derive the *thin lens equation* in Newtonian form is valid (See Book on page 163).

B) Assuming Newtonian form of the thin lens equation, what are x_0 and x_i for f=100mm and s_0 = 400mm?

C) Calculate the total magnification of the two lens set-up in Experiment 4.
Note that the total magnification is given by the product of the magnification of the individual lenses $m_{tot} = m_1 * m_2$.

D) Starting from experiment 4, derive a formula of an effective focal length f_{eff} for a two lens set-up, where the distance, d, between the two lenses is small and becomes negligible. [Remember that the focal length is defined as $f = s_i$, for s_0 = infinite].