Experiment: Lenses

Introduction

Converging lenses transform a parallel beam into a converging beam. The converging point is known as *focal point.* Converging lenses can produce virtual or real images, depending on the distance between the object and the lens. The distance between the object and the lens (p), the focal distance (f) and the distance between the image and the lens are related as follows:

Equation (1): $$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

In this equation, f is positive for the converging lens; d_i is positive if the image is on the opposite side of the lens (real image) and negative if it is on the same side of the lens as the object (virtual image).

When lenses form an optical system, the image formed by the first lens (whether virtual or real) becomes the object for the second lens. In this experiment, you will investigate the images formed by lenses and combinations of lenses and determine the focal length of a converging lens.

Materials:

- optical bench
- lenses
- object box
- screen

Preliminary Questions:

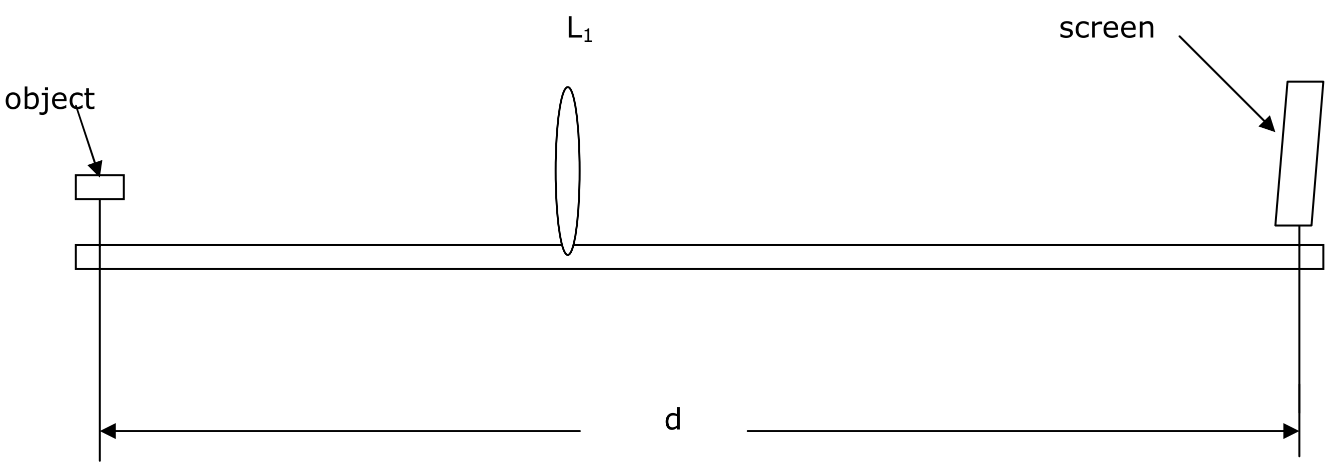
1) An object with a height of 2cm is placed at a distance d=20 cm in front of a converging lens with a focal distance f=5cm.
   a) Trace the significant rays to obtain the image.
   b) Describe the image (real or virtual; greater or smaller than the object; upright or inversed)
   c) Calculate the position and the dimension of the image.

2) Sketch the significant rays to obtain the image produced by a system of 2 converging lenses with focal distances f_1 and f_2. *Note: The image produced by the first lens represents the object for the second lens*.

Procedure:
A) Focal Length of Converging (Positive) Lens

1. Set the object box near one end of the optical bench and the screen at the other end.

2. Locate a position of the lens that will produce a clear image on the screen (L_1 in the drawing below).



3. Measure the object distance and the image distance; Measure the height of the object and the height of the image (including algebraic sign); Enter your measurements in the Table 1.

4. Using equation (1), determine the focal length of the lens and record it in table 1 below.

5. **Leaving the screen and the object in place**, move the lens between the object and the screen until you obtain a new image.

6. Measure the new object distance and the new image distance. Calculate the focal distance again and record the value.

7. Measure a new distance between the object and the screen. Repeat steps 3-6 two times using this new distance. Record the data in table 1.

Table 1						
	d	**d_o**	**d_i**	**h_o**	**h_i**	**f**
1						
2						
3						
4						
				Average f:		

8. Check your result by placing the object at a distance 2f from the lens. In this case, the image should be at an equal distance 2f. Place the screen at a distance 2f from the lens. If you see a clear image on the screen, your calculated f is correct.

Analysis Questions:

1. What relationship do you observe between the image distances and the object distances measured in steps 3 and 7 above? Explain.

2. Draw a ray diagram to scale to verify that if the object distance is 2f the image is equal to the object and formed at an equal distance 2f

3. For the data above, verify the magnification equation by calculating h_i/h_o, $-d_i/d_o$ and the % Error.

Table 2			
Trial	**h_i/h_o**	**$-d_i/d_o$**	**% Error**
1			
2			
3			
4			

B. Combination of Lenses

1. Using 2 identical lenses, position them along the optical bench to obtain a focused the image of the object on the screen.

2. Measure the distance between the object and the first lens (d_{o1}), the distance between the two lenses (L), and the distance between the second lens and the screen, d_{i2}. Record these measurements in table 3.

Table 3		
d_{o1}	**L**	d_{i2}

3. Draw a diagram of for your 2 lens arrangement in step 1.

4. Calculate the final image position (relative to the second lens) using the value of "f" determined above in part A and record in table 4. *Show your calculations.*

Table 4			
Lens 1		***Lens 2***	
d_{o1}		d_{o2}	
f_1		f_2	
d_{i1}		d_{i2}	
		% Error	

5. Calculate the % Error between the calculated and measured final image distance (d_{i2}).

% Error = ________