Thin Lenses

Equipment List

Qty	Items	Part Numbers
1	Light Source	OS-8470
1	Optics Bench	OS-8518
1	Viewing Screen	OS-8460
1	100 mm Convex Lens	OS-8519
1	50 mm Convex Lens	OS-8519
1	Vernier Caliper	

Introduction

The purpose of this activity is to determine the relationship between object distance and image distance for a thin convex lens. A thin lens is one whose thickness is negligible in comparison to the image and object distance. A convex lens is thicker in the center than at the edges and can also be called a positive lens or converging lens. A concave lens is thinner at the center than at the edges and can also be called a negative lens or a diverging lens. Use a light source, optics bench, lens, and viewing screen to measure object distance, image distance and size. The technological pieces of equipment pictured here make use of lenses.

Background

When a light source, like a light bulb shine, it radiates light in all directions. A lens will alter the direction of those rays of light which strike it, resulting in either a real or virtual image to be formed. If the rays of light go from the source through the lens to form a single point in space, it will form a real image. However, a virtual image is formed if the projections from the rays of light form on the same side as the source. These can be seen in Figure 1 and Figure 2.

Fig. 1: Real Image Formation

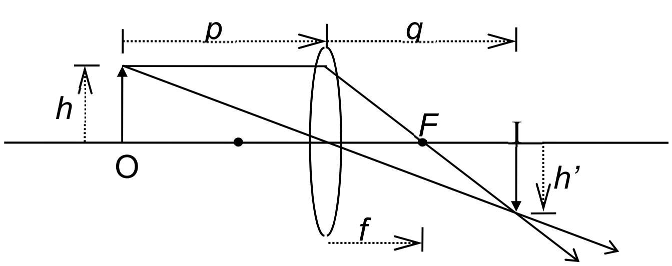


Fig. 2: Virtual Image Formation

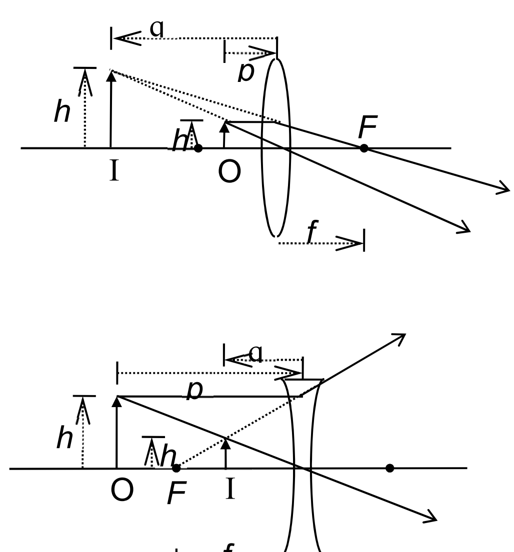
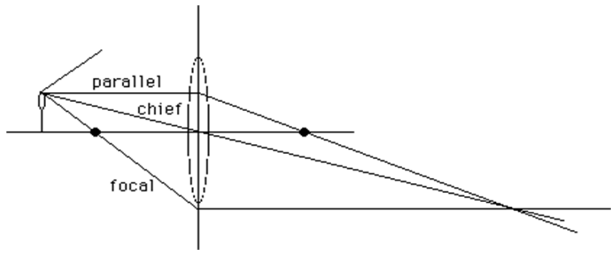


Fig. 3: Ray Naming



These distances and focal lengths are related by **The Thin Lens Equation**:

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

Object distances, image distances and focal lengths can be positive or negative. There is also a **Magnification Equation** to help predict how large or small the image will be compared to the size of the original object. This equation is:

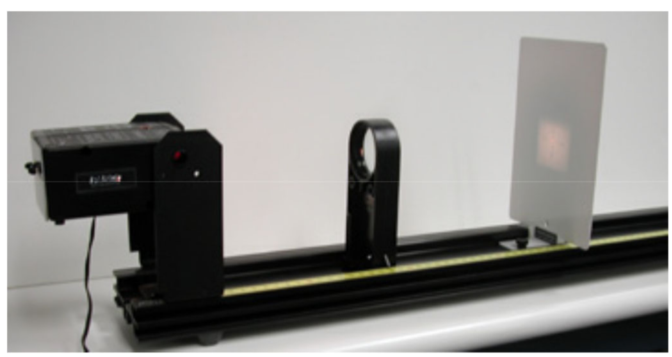
$$\mathbf{M_{exp}} = \frac{h'}{h} = -\frac{q}{p}$$

For multiple lenses, the magnification multiply; that is to say,

$$M_T = \prod_i^n M_i = M_1 \cdot M_2 \cdot \ldots = \frac{(-q_1)\cdot(-q_2)\cdot \ldots}{p_1 \cdot p_2 \cdot \ldots}$$

This is the ratio of the image size h’ to the object size, h. Note that if the image is inverted relative to the object, then h’ is negative, making M negative.

Setup



1. Mount Object Source at the 0.0 cm mark of the Optics Bench. Connect the power supply.
2. Mount the Viewing Screen at the other end of the bench.
3. Make sure the crossed-arrow ‘object’ is illuminated and pointing toward the viewing screen.
4. Place the 100-mm Convex Lens on the Optics Bench at the 50.0 cm mark.

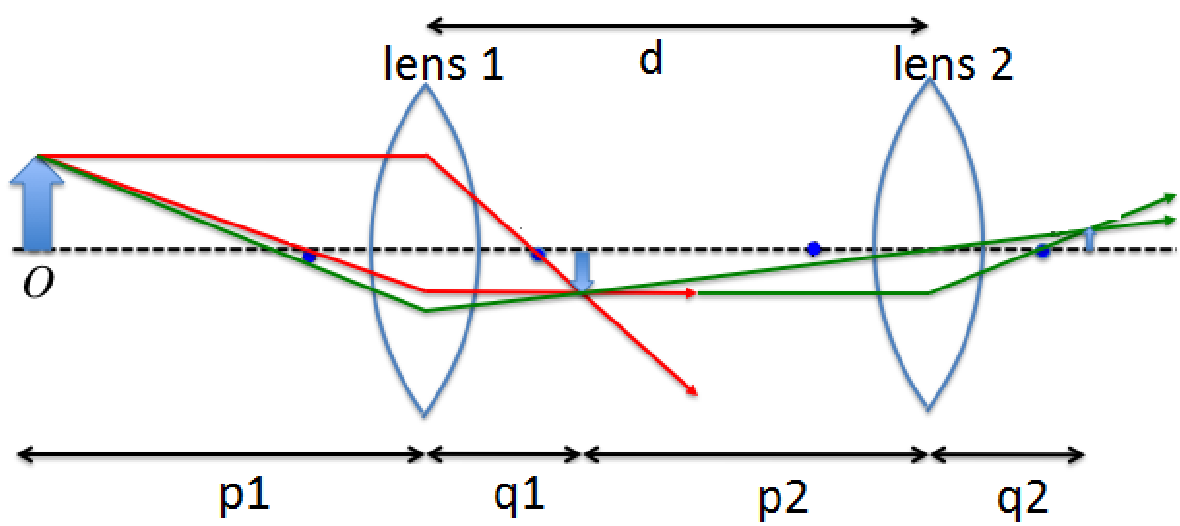
Procedure for part 1: One Lens System

1. With the lens positioned at the 50.0 cm position move the viewing screen so that a clear and focused image of the crossed arrow appears on the viewing screen.
2. Record, in Table 1, the distance from the *lens to the viewing screen* as the image distance for given object distance.
3. Using the Vernier Caliper, measure the *height of the image* on the viewing screen, and then record that as the *image height* for the given object distance.

4. Repeat steps 1 – 3 for the rest of the listed object distances in Table 1.

Procedure for Part 2: Two Lens System (f_1=10.0 cm, f_2=5.0 cm)

1. Place the object source on one side of the track so that its front is at location 0.0 cm. Place lens 1 at 30.0 cm then place the lens 2 at 70.0 cm.
2. In the first row of Table 2 record the *distance from the object to the first lens* as $\boldsymbol{p_1}$.
3. In the first row of Table 2 record the *distance between the two lenses as d.*
4. Place the screen behind the lens 2 and slide the screen back and forth as needed until a clear image forms on the screen. In the first row of Table 2 record the *distance from the second lens to the screen as* $\boldsymbol{q_2}$.
5. For the second row of Table 2 repeat steps 1 – 4, but with lens 1 at 5.0 cm, and lens 2 at 30.0 cm
6. For the third row of Table 2 repeat steps 1 - 4, but with lens 1 at 30 cm, and lens 2 at 35.0 cm.
7. These are your experimental values for q_2. Now for each configuration, using the thin lens equation, calculate the theoretical value of q_2, which we will label as q_{cal}. Show the calculations in the space provided beneath Table 2.
8. Determine the percent error for each case. Show the calculations in the space provided beneath the Table 2.



Note: the above diagram is drawn with the image from lens 1 forming in front of lens 2. That is not always the case. It is possible that the image from the first lens will form behind the second lens.

Analysis of Thin Lenses Lab

Name____ Group#________
Course/Section_______________________________________
Instructor____

Table 1: One Lens (20 points)

Object Distance p(cm)	Image Distance q(cm)	Image Height h'(cm)		Object Distance p(cm)	Image Distance q(cm)	Image Height h'(cm)
50.0				25.0		
47.5				20.0		
45.0				15.0		
40.0				12.5		
35.0				12.0		
30.0				11.0		

1. Using Excel, or some other graphing program, make a graph of Image Distance vs. Object Distance (q vs. p), then answer the following questions about this graph. (10 points)

2. What value does the *image distance* approach as the *object distance* becomes larger? (5 points)

3. What value does the *object distance* approach as the *image distance* becomes larger? (5 points)

4. How does the value of the answers to questions 1 and 2 relate to the lens used in part 1? (5 points)

5. What is the relationship between *image distance* and *object distance*? (directly related or inversely related?) Give evidence supporting your answer. (5 points)

6. What is the relationship between *object distance* and *image height*? (Directly related or inversely related?) Give evidence supporting your answer. (5 points)

7. Where would you place the object to obtain an image as far away from the lens as possible? (5 points)

8. Where would you place the object to obtain an image located at the focal length of the lens (100 mm)? (5 points)

Table 2: Two Lenses (15 Points)

f_1(cm)	p_1(cm)	q_1(cm)	d(cm)	f_2(cm)	p_2(cm)	q_2(cm)	q_{cal}(cm)
10	30			5.0			
10	5.0			5.0			
10	30			5.0			

Show calculations. (q_2 is to be measured, while q_1, d, p_2 & q_{cal} must be calculated)

9. Calculate the % error between the calculated second image position q_{cal}, and the measured second image position q_2 for each of the three lenses configurations. (5 points)

10. State at least <u>two</u> possible 'physics' sources of our percent error (*do not include rounding errors, calculation errors, human errors or equipment malfunction*). (5 points)

11. Did our experiments confirm the theory? Explain your answer. (10 points)