Physics Lab Experiments with Simulated Data for Remote Delivery

Department of Chemistry and Physics

3-2022

Experiment 2.10: Lenses

Diego Castano

Victor Castro

I. EXPERIMENT 2.10: THIN LENSES

A. Abstract

The thin lens equation is used to determine the focal length of a lens.

B. Formulas

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

$$\frac{1}{f_{\mathrm{doublet}}} = \frac{1}{p_1} + \frac{1}{q_2} + d\left(\frac{1}{p_1 q_2} - \frac{1}{q_2 f_1} - \frac{1}{p_1 f_2}\right) \tag{2}$$

$$P = \frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \tag{3}$$

where p is the object location, q is the image location in the single lens case, and p_1 is the object location from the first lens, q_2 is the image location from the second lens, and d is the distance between the lenses in a doublet case. Equation (3) is the lens-maker's formula with $R_{1,2}$ the radii of the two surfaces of the lens and n the lens' index of refraction.

C. Description and Background

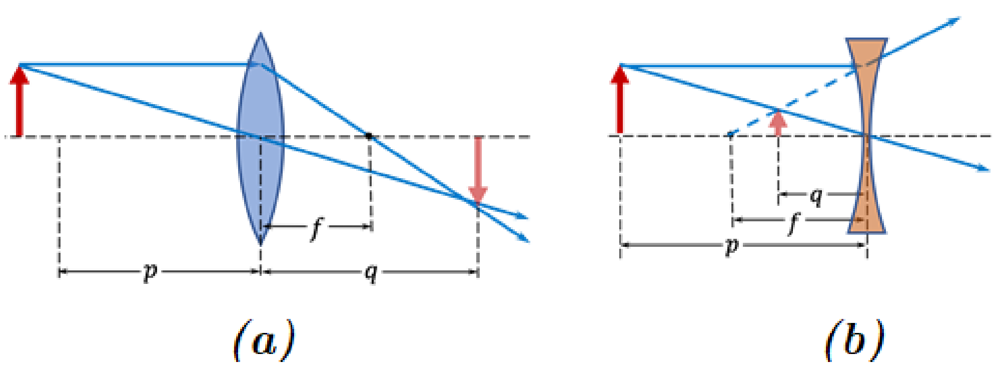

FIG. 1. (a) Converging and (b) diverging lenses.

Thin lenses have a thickness that is small compared to their radius of curvature. They may be either converging or diverging. A converging lens (Fig. 1a) makes parallel rays of light (to the optical axis) converge to a focus (a point on the axis). They have a positive focal length ($f > 0$). A diverging lens (Fig. 1b) makes parallel light diverge from the optical axis; the focal point is now located where the diverging rays originate on the axis if extended behind the lens. They have a negative focal length ($f < 0$). The images of these lenses are always virtual.

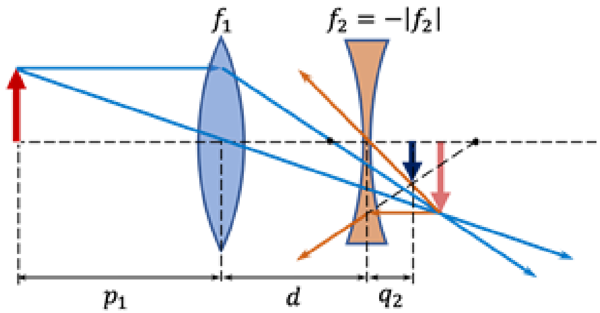

FIG. 2. Separated doublet.

The Lens equation can be derived geometrically. This equation relates the object location, p, image location, q, and focal length of a the lens, f, according to Eq. (1). For a (separated) doublet of lenses (Fig. 2), the relation is given by Eq. (2) in which where p_1 is the object location from the first lens, q_2 is the image location from the second lens, and d is the distance between the lenses.

D. Procedure

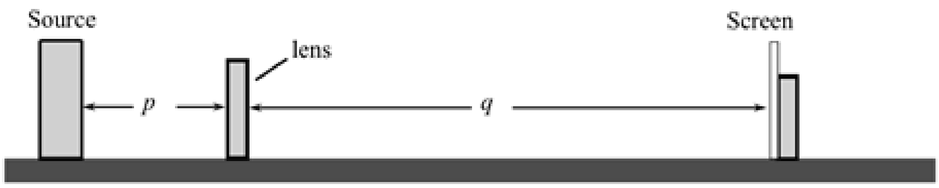

FIG. 3. Optical bench used in the experiment.

1. Place lens A (whose rated focal length, $f_A^* = 20\ cm$) on the optical bench. By adjusting its location and the location of the screen, arrive at a focused image on the screen.
2. Record the location of the object (p) and of the image (q).
3. Place lens B (whose rated focal length, $f_B^* = 10\ cm$) on the optical bench. By adjusting its location and the location of the screen, arrive at a focused image on the screen.
4. Record the location of the object (p) and of the image (q).
5. Place lens B and C (whose rated focal length, $f_C^* = -15\ cm$) on the optical bench as close together as possible. By adjusting its location and the location of the screen, arrive at a focused image on the screen.
6. Record the location of the object (p_1), from the first lens, and the location of the image (q_2), from the second lens.

E. Measurements

lens A: f_A^* [cm] =		
trial	p [cm]	q [cm]
1		
2		
3		
4		
5		
6		

lens B: f_B^* [cm] =		
trial	p [cm]	q [cm]
1		
2		
3		
4		
5		
6		

lens C: f_C^* [cm] =			BC distance: d [cm] =	
trial	f * lens 1 [cm]	p_1 [cm] from lens 1	f * lens 2 [cm]	q_2 [cm] from lens 2
1				
2				
3				
4				
5				
6				

F. Instructions

1. Use (1) to calculate the focal length in the A and B cases and (2) in BC case for all trials.

2. Calculate the average focal length and the associated standard error in each of the three cases.

3. The focal length of a separated doublet of lenses is given by

$$\frac{1}{f_{\text{doublet}}} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2} \tag{4}$$

   Assume $f_{\text{doublet}} = f_{BC}$, the focal length in the BC case in any given trial and $f_1 = \bar{f}_B$, the average focal length found for lens B, then use this equation to determine $f_2 = f_C$, the focal length of lens C:

$$f_C = \left(\frac{\bar{f}_B - d}{\bar{f}_B - f_{BC}} \right) f_{BC}$$

4. Calculate the percent error assuming the accepted values are $f_A^* = +20\ cm$, $f_B^* = +10\ cm$, and $f_C^* = -15\ cm$, and take the accepted value for the BC case to be the result of using (4) with $f_1 = f_B^*$ and $f_2 = f_C^*$.

G. Calculations

lens	A	B	BC	C
focal length (trial 1) [cm]				
focal length (trial 2) [cm]				
focal length (trial 3) [cm]				
focal length (trial 4) [cm]				
focal length (trial 5) [cm]				
focal length (trial 6) [cm]				
$\bar{f}$ [cm]				
$\delta\bar{f}$ [cm]				
f^* [cm]				
%-Err				