Physics 215 - Experiment 14
Thin Lenses

Advance Reading
Urone, Chapter 24, Section 24-6

Objective: The objective of this experiment is to measure the focal length of a converging lens and a diverging lens.

Theory: Light refracts when passing through media with different indices of refraction. This property can be utilized to bend light in useful ways.

A converging (convex, positive) lens can be used to focus parallel light rays and form a real image as the light travels from air to glass and back to air ($n_{air} \approx 1.0$, $n_{glass} \approx 1.5$). A real image is one that can be projected on a screen.

A diverging (concave, negative) lens normally forms a virtual image that can not be projected on a screen.

An important property of a lens is its focal length, f. The focal length of a thin lens is given by:

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad \text{(Eq. 14-1)}$$

where d_o is the object distance and d_i is the image distance. These distances are measured from the lens.

For an object that is infinitely far away ($d_o \to \infty$), the image distance and the focal length are equal. For lenses used in this lab an object distance ≥ 20m is considered infinitely far away.

Procedure

Converging Lens

We will use two methods to determine f, then compare those values.

(I) Use a distant object ($d_o \to \infty$).

(II) Use the lens equation (Eq. 14-1).

Method I:

1. Hold the lens by the edges between your fingers and project the image of a distant object on a screen. One way to achieve this is to take the lens and a ruler to the hallway just outside the lab. Hold the lens such that light reflecting off the exterior doors at the other end of the hallway will pass through the lens. Adjust the distance between the lens and the wall until a clear, distinct image of the exterior doors is projected onto the screen (wall).
2. Measure the distance from the lens to the screen. If we assume that d_o

in Eq. 14-1 is very large compared to d_i, then $d_i = f$. Is the image inverted? Magnified? Reversed?

Method II:

3. Mount the lens, the screen, and the light source on the optical bench (Fig. 14-1). Adjust the position of each device until a clear image of the object is projected onto the screen. Consider Eq. 14-1. How many combinations of d_i and d_o are possible? Record the position of each device. Calculate d_i, d_o, and f.
4. Each student will perform Step 3 at least twice to obtain different values of d_i and d_o.
5. Compare the focal lengths from the two methods.

Diverging Lens

We will use a real image (formed by a converging lens, I_C) as a virtual object for the diverging lens, O_D. (I_C=O_D.)

6. Form an image from the converging lens, I_C, on the screen (Fig. 14-3). Record the position. This image is the virtual object for the diverging lens, O_D.
7. Leave the converging lens in place. Place the diverging lens between the converging lens and O_D. Form a

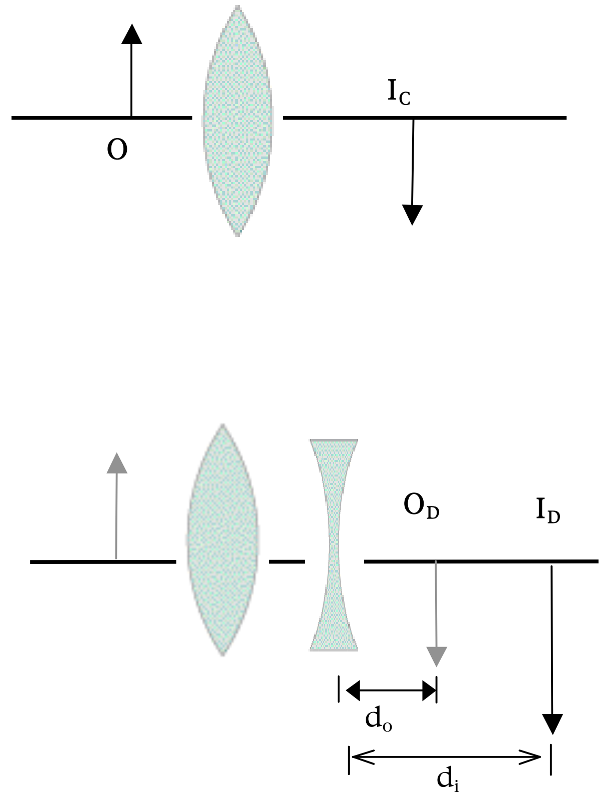

Fig. 14-3 Diverging Lens Arrangement

8. clear image on the screen by adjusting the position of the screen.
9. Record the position of the diverging lens and the screen, I_D.
10. Calculate d_o and d_i. Note that d_i is the distance from the diverging lens to the screen (*image distance*), and d_o is the distance from the diverging lens to O_C (I_C, *object distance*). d_o will be negative when using Eq. 14-1.
11. Calculate f for the diverging lens.
12. Your partner will repeat this procedure from a different starting

position for the converging lens (results in a different I_C).

13. Average the values of f.

Compare

14. Define $|d_o| = V$ and $|d_i| = W$.

Calculate f using:

$$f = \frac{VW}{V - W} \qquad \text{(Eq. 14-2)}$$

15. Calculate the percent difference for f for this lens. If the percent difference is greater than 0.00 %, ask your TA for help.

Part 3: Lateral Magnification, m

For Steps 15 - Step 17:

- Sketch each set up (Fig. 14-4).
- Record the position of:
  - O (object)
  - L (lens)
  - S (screen)
- Measure, when possible:
  - h_i (image height)
  - h_o (object height).
- Determine and record d_o and d_i,

To calculate lateral magnification, use:

$$m = \frac{h_i}{h_o} \qquad \text{(Eq. 14-3)}$$

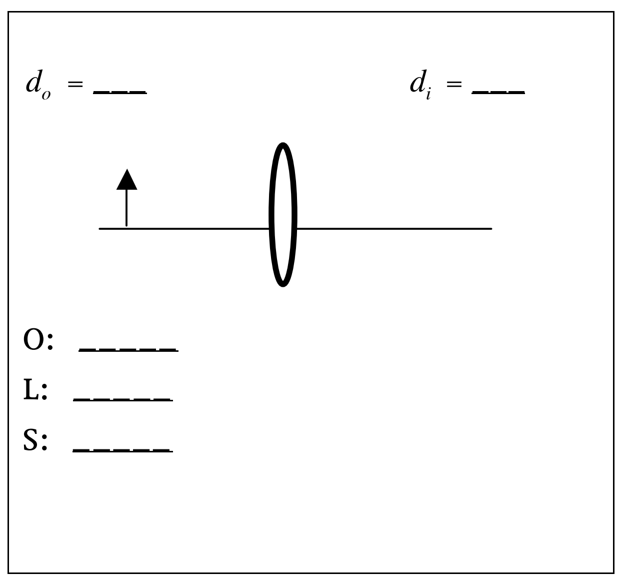

Fig. 14-4

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16. Set d_o = f. Try to find d_i (consider Method I and Eq. 14-1).

17. Set $d_o > 2f$. Find d_i; calculate m.

18. Set $f < d_o < 2f$. Find d_i and calculate m.

19. Set $d_o < f$. Look through the lens at the object. Note your observations.

20. Calculate $m = \frac{-d_i}{d_o}$ for Step 16 and Step 17. Compare these values to Eq. 14-3 values.

Questions:

1. Draw ray diagrams for both methods used for converging lens.

2. A *concave* lens made out of air is immersed in water (perhaps two watch glasses glued to each end of a piece of pipe, with air inside). Will it form a real image that can be focused on a screen? Why or why not?

3. If a convex lens with n = 1.50 and f = 20 cm is immersed in a fluid whose index of refraction is also 1.50, what is the new focal length of the lens? (Hint: trick question!)

4. What are the major sources of uncertainty in this experiment?