Physics Department
Kuwait University

EXP. TWO
Course 127

February, 2001

Thin Lenses

Objective

- To study images formed by a converging lens.
- To verifying the ray diagram method.
- To verify the thin lens equation.
- To study the conjugate points, and the magnification factor of a lens.

Theory

The image of an extended object such as an illuminated arrow, being put in front of a converging thin lens, can be located using the ray diagram (Fig.1) which is drawn using the following facts:

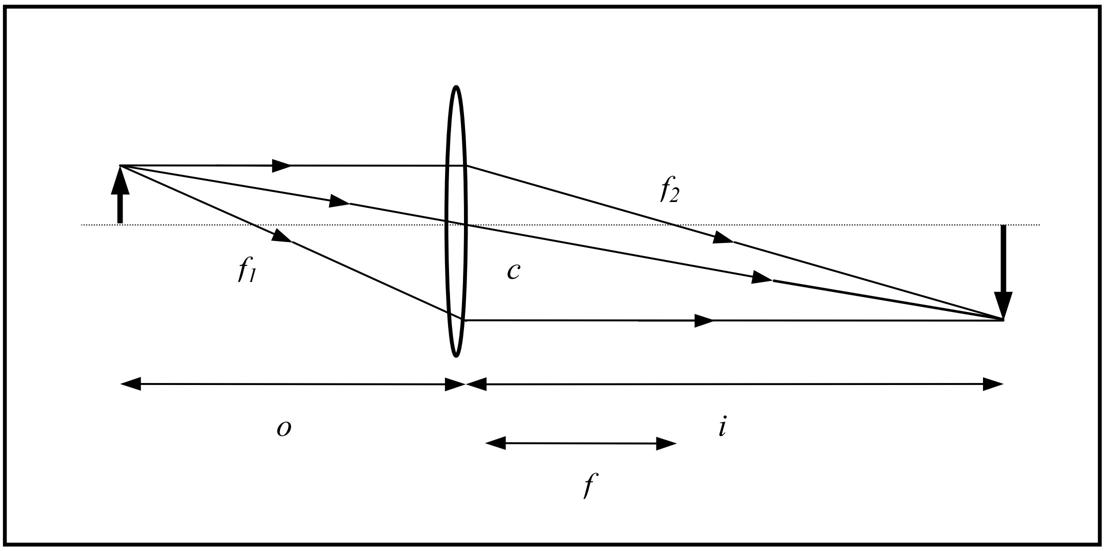

Figure 1: Ray diagram

1. A ray parallel to the principle axis, on emerging from the lens, is refracted and passes through the second focal point, f_2.

2. A ray falling on the lens after passing through the first focal point, emerges from the lens parallel to the principle axis.
3. A ray falling on the lens through its center (*c)* will pass through undeflected.

The equation that governs the relation between the focal length (*f*), the lens object (*o*) and lens image (*i*) distances (refer to Fig. 1) is given by

$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f}, \tag{1}$$

which can be rearranged as

$$\frac{1}{i}=\frac{1}{f}-\frac{1}{o}. \tag{2}$$

Therefore, by plotting $1/i$ versus $1/o$, a straight line is obtained, for which the y-intercept represents $1/f$.

Multiplying all terms in Eq.(1) by i yields

$$\frac{i}{o}+1=\frac{i}{f}. \tag{3}$$

The term i/o is defined as the magnification factor M, therefore, Eq.(3) can be rewritten as

$$M=(\frac{1}{f})\, i-1. \tag{4}$$

Thus, a plot of M versus i results in a straight line from which f can be determined.

In Eq.(1), the values of o and i are interchangeable. Such a pair of interchangeable symmetry property is called conjugate pair. It is more convenient to change the position of the lens to achieve this change of o or i as shown in Fig. 2.

The values for o and i in Fig. 2 can be written as

$$o = ½\,(D - d) \qquad , \qquad i = ½\,(D + d) \tag{5}$$

where

D = distance from screen to object position,

d = displacement distance between the two symmetrical positions of the lens.

Substituting the values of o and i in Eq.(1), f can be written as

$$f=\frac{D^2-d^2}{4D}. \tag{6}$$

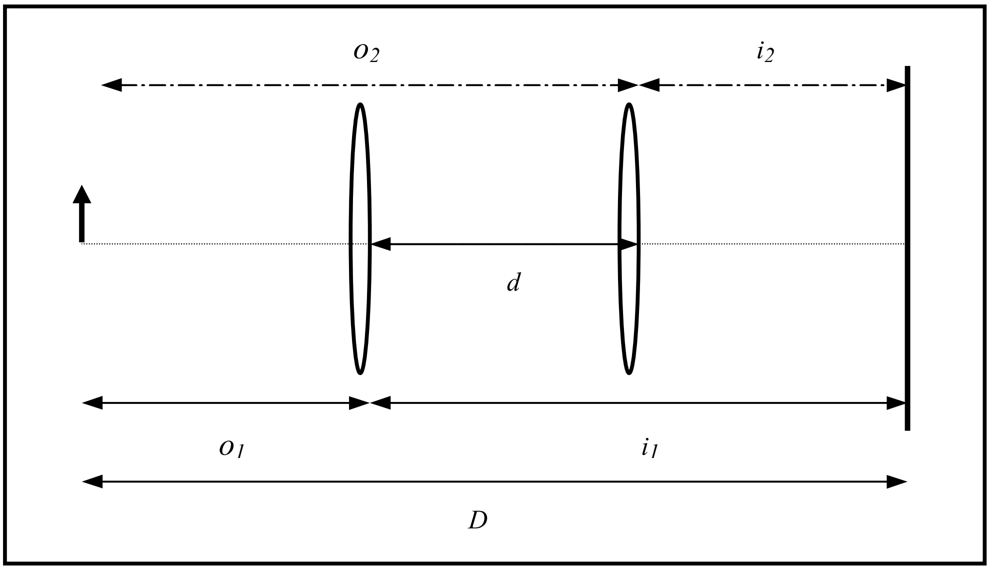

Figure 2: Double-position method for measuring focal length

Equipment

- Optical bench
- Light source
- Object with holder
- Converging lens (100 mm)
- Screen.

Procedure

1. Arrange the setup as shown in Fig. 3, set the distance between the object and the screen to 75 cm.
2. Let the lens be close to the object then start to move it towards the screen until the brightest and sharpest image is obtained.
3. Measure o, and *i*, then determine *M*. Record your results in Table I.
4. Move the lens further towards the screen to get a second clear image. Determine *d*, which equals the difference between the two lens positions. Record in the table.
5. Using Eq.(6), calculate the focal length, *f*.
6. Repeat steps 2-5 for a range of *D* from 70-50 cm in 5 cm intervals.
7. Plot a graph of 1/*i* versus 1/*o* then determine *f*.
8. Plot a second graph of *M* versus *i* from which determine *f*.

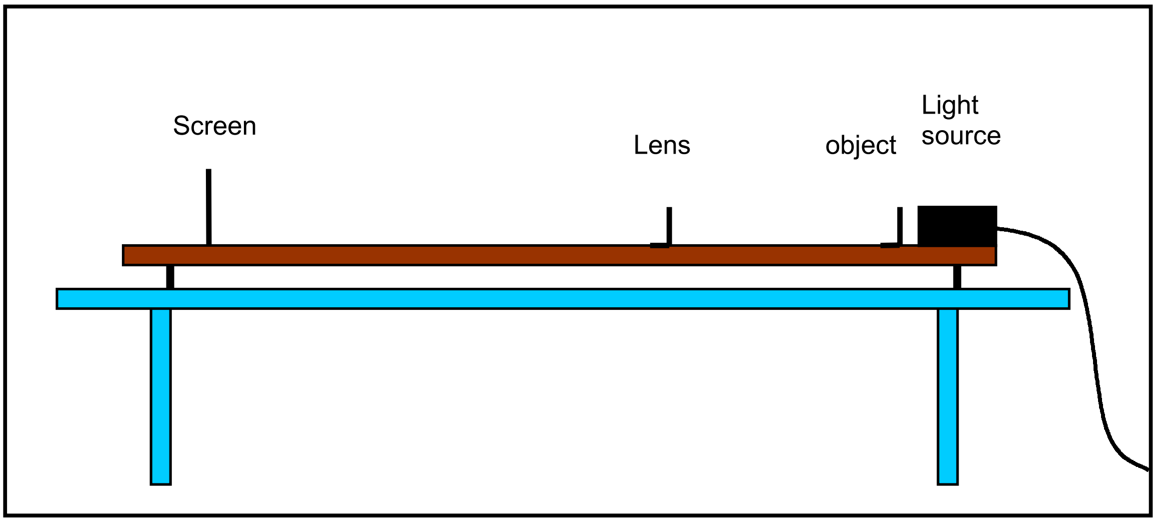

Figure 3: Optical bench setup

Table I

D (cm)	o (cm)	i (cm)	M	d (cm)	D^2(cm)^2	d^2(cm)^2	$4D$ (cm)	$f_{eq(6)}$ (cm)
75								
70								
65								
60								
55								
50								

Questions

1. Define: principal focus, refraction, reflection, real and virtual images, and magnification.
2. How does the lens-image distance vary as you change the lens-object distance?
3. Using Eq.(6), determine the value of D which leads to a single lens position for the lens used in this experiment.
4. Why is it impossible to use the same setup to determine the focal length for a concave lens?