(GO1-2) Focal Length of a Convex Lens Using General Law

$M = \frac{100}{f\,(cm)}$ diopeter

Aim of experiment

1. Determination of the focal length and magnification of a convex lens using general law method .
2. Comparison between focal length determined by a far distance object and the general law method referred to the lens makers value.

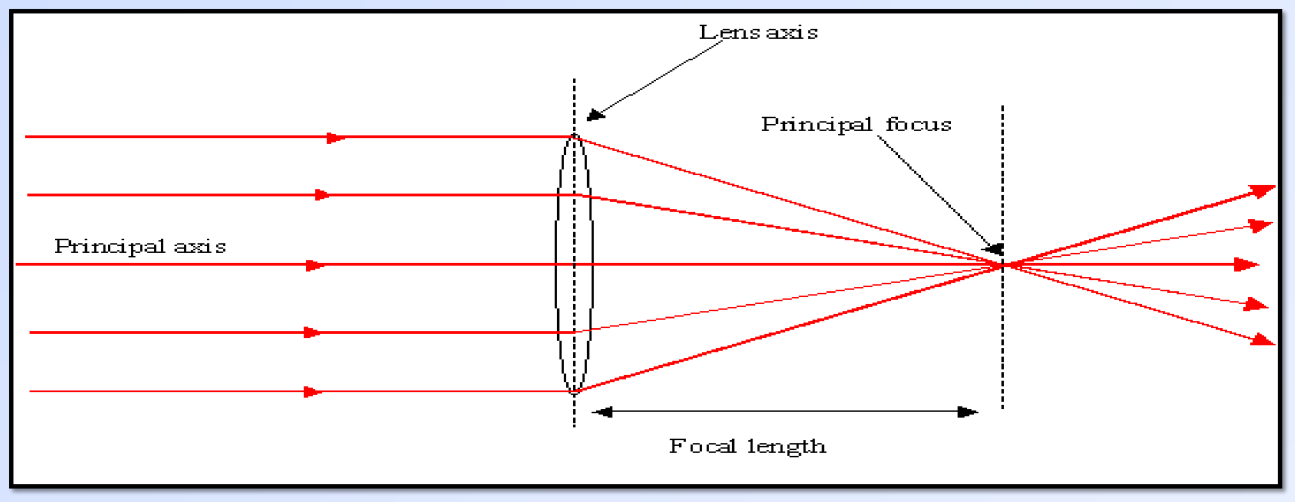
Apparatus

Optical Bench with Lens and Screen Holders, Illuminated Object with a Fine Cross-Wire Hole, Convex Lenses, Optical Screen.

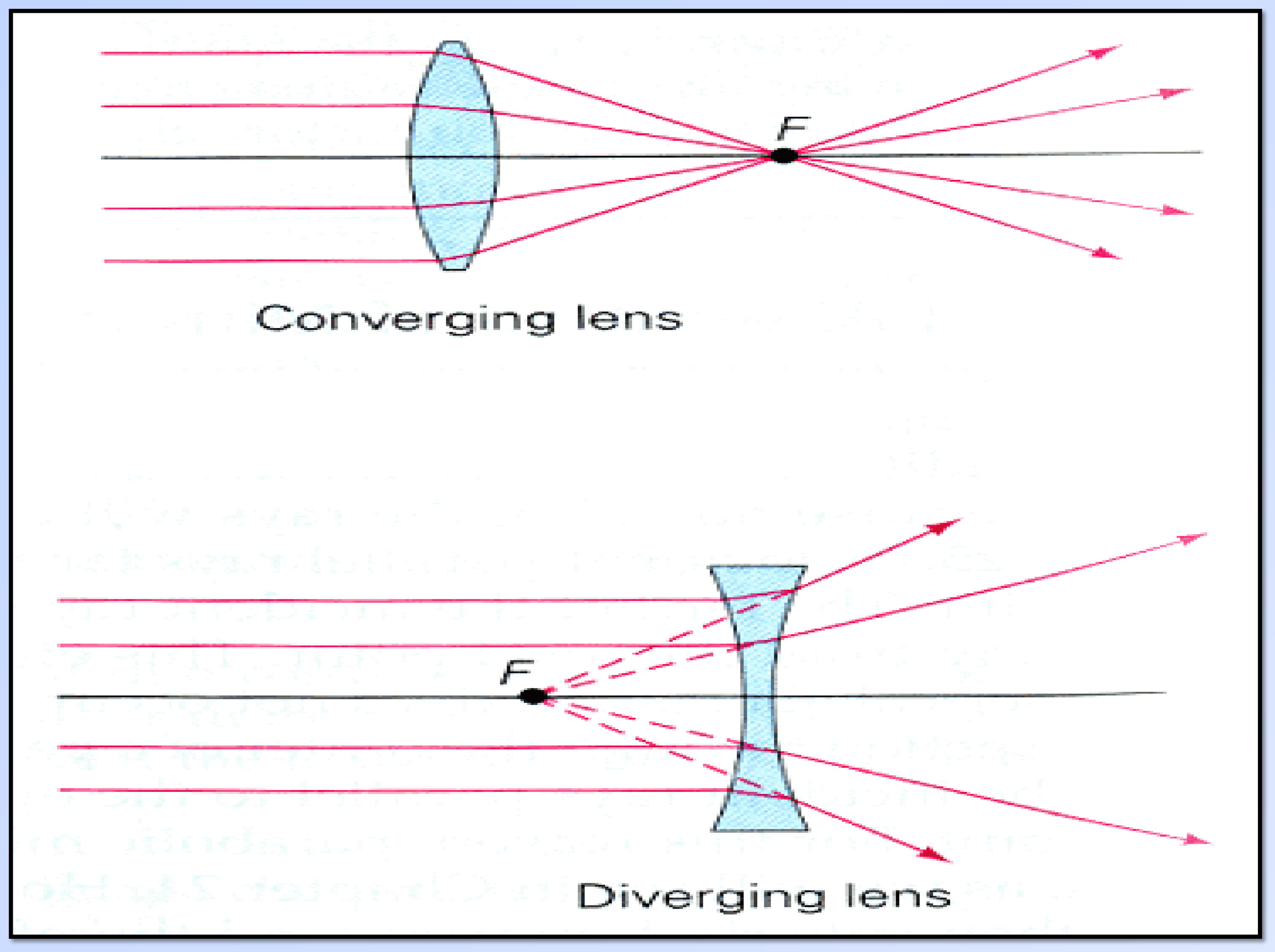
Theory of experiment

Lenses are commonly used to form images by refraction in optical instruments, such as cameras, telescopes, and microscopes. If the lens thickness is small compared to the radius of curvature of both lens sides, this lens is classified as thin.

An optical lens is a piece of transparent material, such as glass or plastic, which is shaped so that a light ray pass-ing through it undergoes refraction at both surfaces. The ray perpendicular to the lens and going through its center is called the *principal axis* of the lens, figure 1(a) Refracted rays will either converge or diverge to the *principal axis*. Therefore, lenses are classified as being either converging lenses or diverging lenses, figure 1(b).



(a)



(b)

Figure 1. (a) Principal axis, focal length, and focal points of a thin lens, **(b)** converging and diverging lenses.

Ray Diagrams for Thin Lenses

Ray diagrams are convenient for locating the images formed by thin lenses or systems of lenses. They also help clarify our sign conventions. To locate the image of a converging lens, figure 2, the following three rays are drawn from the top of the object:

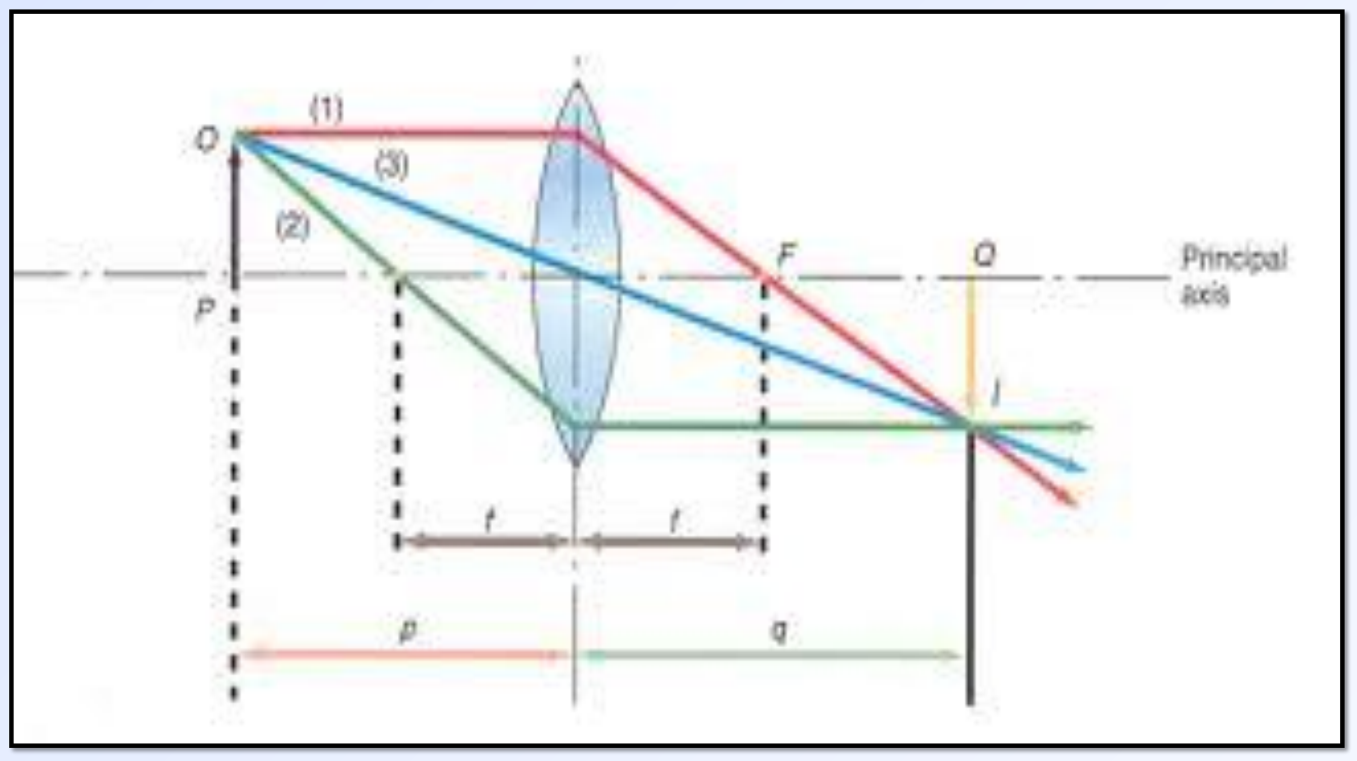


Figure 2. Ray diagrams for locating the image formed by a thin lens.

•*Ray1* is drawn parallel to the principal axis. After being refracted by the lens, this ray passes through the focal point on the back side of the lens.

• *Ray 2* is drawn through the focal point on the front side of the lens (or as if coming from the focal point if $p < f$) and emerges from the lens parallel to the principal axis.

• *Ray 3* is drawn through the center of the lens and continues in a straight line.

Thin Lens Equation

There are different methods to calculate the focal length of lenses such as far distant object and general law method.

General Law Method

The relation between the object distance *p*, the image distance *q*, and the focal length *f* is given by the thin lens formula as

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

The lens power , *M,* is defined as

$$M = \frac{100}{f\ cm}\,Diopeter$$

The magnification M of a lens is defined as

$$\mathrm{M} = \frac{h'}{h} = -\frac{p}{q}$$

Where *h* and *h`* are the object and image heights respectively. A sign convention must be applied in these equations to determine the specification of the formed image; such as its position, upright or inverted, real or imaginary, enlarged or smaller than the object. A diagram for obtaining the signs of *p* and *q* is shown in figure 3.

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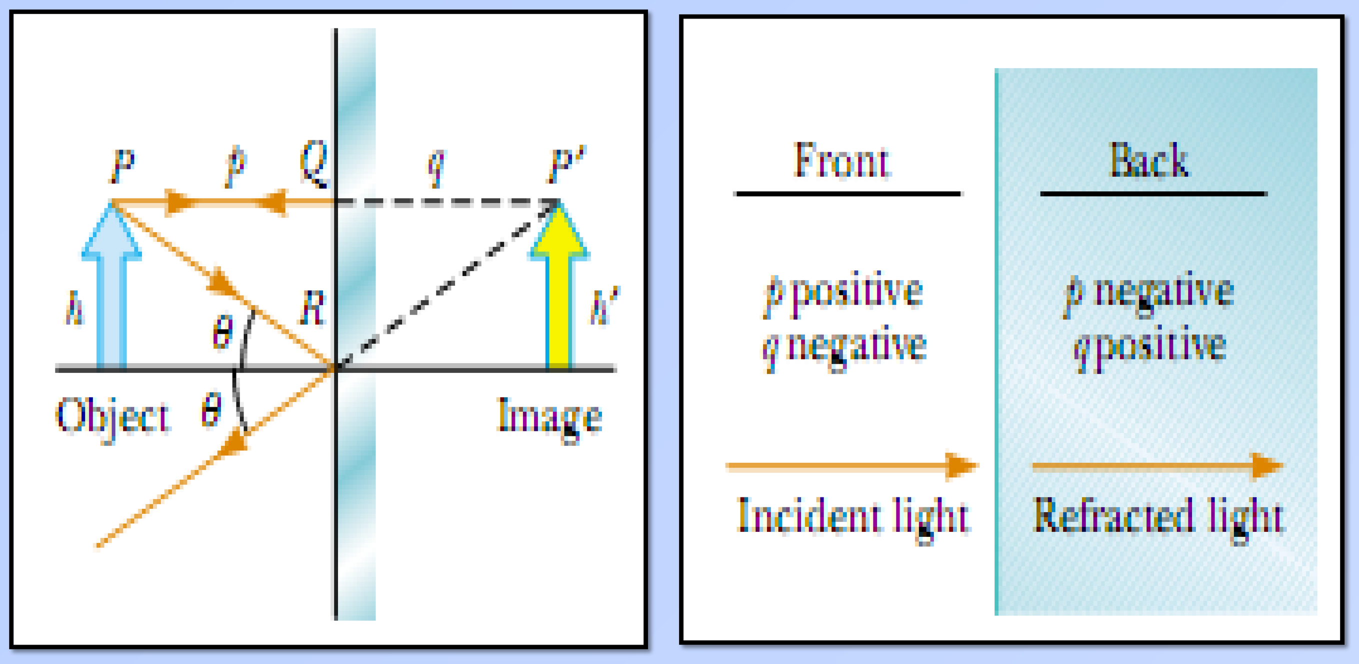

Figure 3. A diagram for obtaining the signs of p and q for a thin lens.

From this expression, it follows that when q is negative, the image is virtual and when M is positive, the image is upright and on the same side of the lens as the object. When M is negative, the image is inverted and on the side of the lens opposite the object.

Procedure

A. The Focal Length of a Converging Lens Using a Far Distant Object Method

1. Turn the optical bench so that it is pointing out the window at some far distant object or the room window itself if it is far.
2. Place the screen at the zero end of the optical bench
3. Place the convex lens in the lens holder and set the lens holder on the optical bench.
4. Move the lens toward or away from the screen until a sharp image of the distance object is focused on the screen. The distance between the lens and the screen is the experimental focal length of the convex lens f_{expA}. Record this value on your data sheet.
5. Repeat steps 3 and 4 for three times

Trial No.	$f_{exp\ A}$
1	
2	
3	
$f_{av\ exp\ A}$	

Far distance objet Percentage error $= \dfrac{f - f_{avexp\,A}}{f} x100\% =$

Where f is the standard value.

Procedure

B. The Focal Length of a Converging Lens Using General Law Method

1. Place the lighted object at the 0 position on the optical bench.
2. Place the convex lens of focal length f in a lens holder and set it at a distance of more than $2f_{avexp\ A}$ from the light object
3. Read the distance from the object to the lens as object distance p and record this value on your data sheet.
4. While looking from behind, move the screen toward the lens until a sharp image appears upon it. The distance from the lens to the screen is the experimental image distance q. Record this value on your data sheet.
5. Move the lighted object closer to the lens in steps of 2cm, up to $f_{av\ exp\ A}$*+2 cm,* and move the screen toward or away from the lens until a sharp image appears upon it. Record the values p and q on your data sheet.
6. Repeat previous steps at least two more times.
7. Plot the relation between $\frac{1}{p}$ *and* $\frac{1}{q_{av}}$ and determine the intersections on both axes, that is equal to *1/ f*.
8. Calculate the average $f_{av\ exp\ B}$ and the percentage error

Results

Object distance	*Trial 1*	*Trial 2*	*Trial 3*			
P cm	q_1 *cm*	q_2 *cm*	q_3 *cm*	q_{av} *cm*	*1/p*	$1/q_{av}$

Percentage error $= \dfrac{f - f_{avexp\,B}}{f} x100\% =$

9. Compare the results of percentage errors to demonstrate the more accurate method.