PHYSICS 1040L LAB
LAB:7 LENSES AND IMAGES

Object: To measure and compare the focal lengths of some lenses using different methods, and to determine the magnification of a simple telescope.

Apparatus: Optical bench, light box, lenses, lens holders, illuminated target object, white screen with scale, mirror.

Theory: Lenses are classified into two general categories, converging and diverging, according their action on parallel rays of light striking the lens. For a converging lens, the parallel rays of light entering from one side pass through a point on the opposite side (Figure 1). For a diverging lens, the parallel rays entering from one side appear, to the eye, to come from a point on the same side (Figure 2). The points at which the rays of light pass through, or appear to come from, are called the focal points and the distance from the lens to those points are called the focal distances.

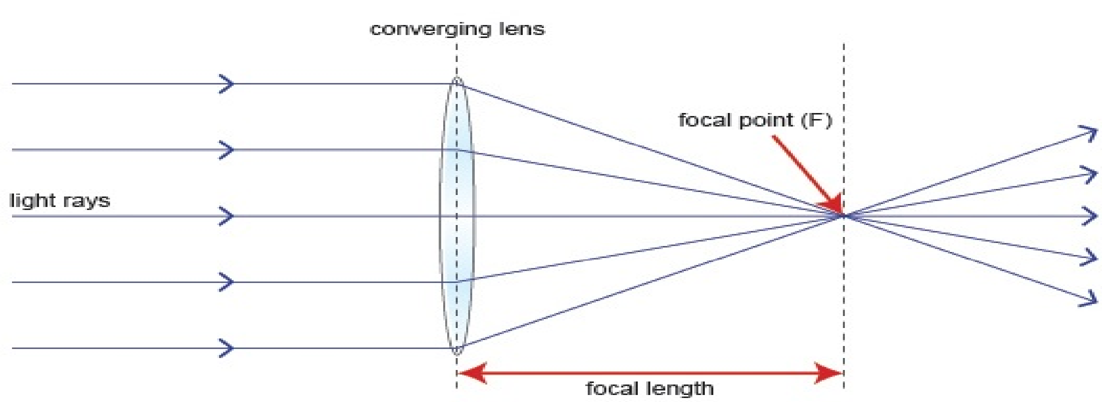


Figure1: Converging (Convex) Lens

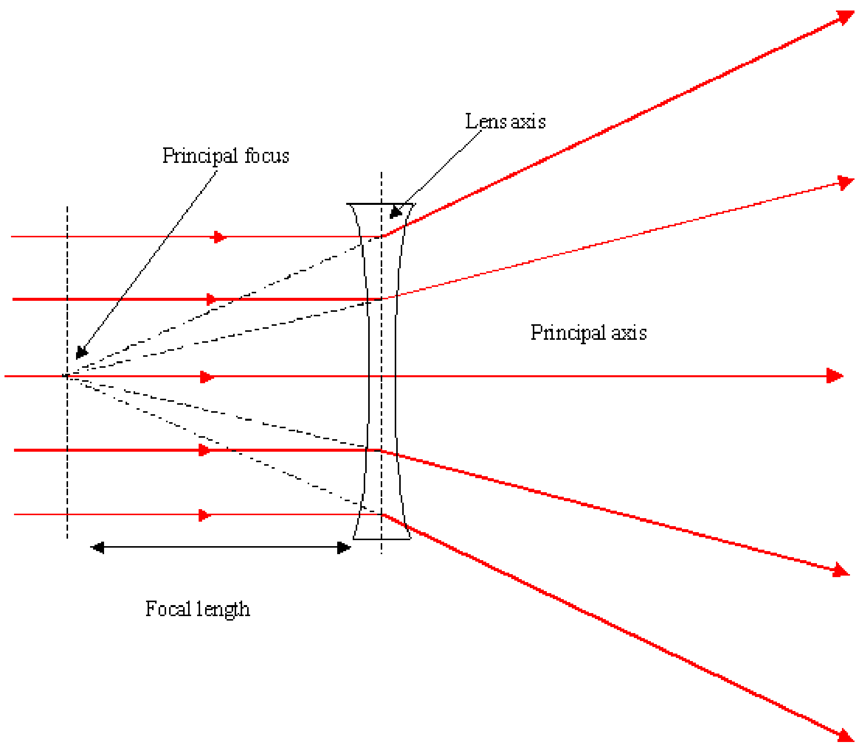


Figure2: Diverging (Concave) Lens

The object, image, and focal distances are measured from the center of the lens. The object distance is considered positive when it is on the same side that light enters the lens, while the image distance is positive if it is on the side that light leaves the lens. Lenses may also be classified according to the curvature of their two sides, plane, convex, or concave. The focal length is positive for convex lenses and negative for concave lenses. Furthermore, lenses may either "thick" or "thin" according to whether or not they operate as two plano-convex (or concave) lenses separated by a thickness of lens material. In this experiment, we will be working with thin lenses for which both sides have the same curvature or for which one side is plane.

The purpose of a lens is to form the image of an object. For a thin lens, there is a simple relationship between the focal length, f, the distance an object is located from the lens, d_o, and the distance from the lens, d_i, at which the image is formed: This equation is called the thin lens or the lens maker's formula.

$$\frac{1}{f} = \left(\frac{1}{d_o}\right) + \left(\frac{1}{d_i}\right) \qquad \textbf{(1)}$$

In this experiment, the focal length of each lens will be determined using the following three methods.

1 . *Focal length by imaging a distant object.* If a bright, high contrast object is placed at a very large distance from a converging lens, the light from this object is, for practical - purposes, parallel and will form an image at the focal length of the lens. From the lens equation above, one can see that the reciprocal of the object distance approaches zero as the distance increases, and the image distance approaches the focal distance of the lens.

2. *Focal length by auto collimation.* When a mirror is placed directly behind a lens, light from a brightly illuminated object on the opposite side will be reflect back through the lens. When the object is at the focal length of the lens, the mirror, light from the object enters the lens and emerges as parallel light. It is reflected back through the lens as parallel light and will, therefore, produce an image in the focal plane of the lens. The image will be inverted and will appear in the same plane as the object. This can be verified by viewing the image from different angles. If the image does not move relative to the object (parallax) then the image and object lie in the same plane.

3) *Focal length by conjugate foci.* When a converging lens is placed between an illuminated object and a screen, there are two positions of the lens for which a sharp image will be formed on the screen. The image in one position will be larger than the other. The relationship between the focal length of the lens and these positions is given by:

$$\mathbf{f = b^2 - a^2 / 4b}, \qquad \textbf{(2)}$$

where b is the distance between the object and the screen, a is the distance between the two positions of the lens, and f is the focal length of the lens. A careful examination of this equation will show that this method cannot be used unless $b > 4f$.

The student should study a relative chapter of "College Physics" textbook before performing this experiment.

Procedure and Data analysis

Part A: Focal Length Measurements

In this part, you will measure the focal length of a converging lens by three methods and compare the results. Refer to the Theory section for explanation of these methods.

1 . Focus the image of a distant object on the screen using a converging lens. Record the image distance. If the object distance is very large with respect to the image distance, this will also be the focal length of the lens.

2. Place a mirror next to the lens and on the opposite side from the object. Adjust the position of the object until the image and object are in the same plane. Record the object/image distance which is also the focal length of the lens.

3. Place an object at a distance, b, from the screen and adjust the position of the lens until a sharp image is formed. Record this position. Adjust the lens position to find the point at which a second (and different size) image is formed. The distance between these two lens positions, a, is used with the screen to object distance, b, in determining the focal length by the conjugate foci method.

4. Tabulate the values for the focal length of the lens using the above three methods and discuss sources of error and differences.

Figure3. Optical Bench with Light Box, Lens, Screen.

Figure 4: Light with Target Slide on the front.

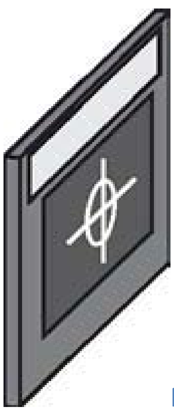


Figure 5A: Crossed-Arrow Target.

In the picture above, in the front of the light box is the Crossed-Arrow target that will be the object in the auto collimation and the conjugate foci section in the experiment. The horizontal arrow has mm markings to help see when the image is at its sharpest focus. Compare the direction of the arrows to their image on the screen.

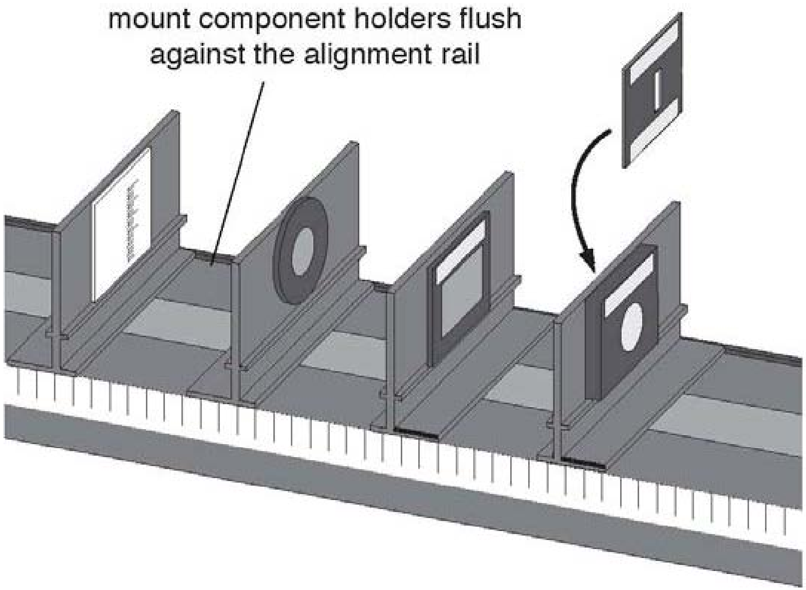
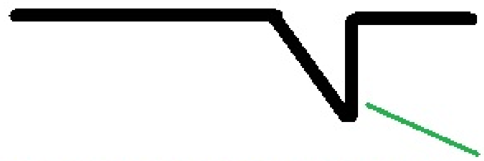


Figure 5 Using Component Holders

Figure 6: Lens attached to Lens mount. Note: the lens must be mounted on the lens mount on the side of the mount where the metal foot has been cut. See figure 7.



This is the side(Foot) of the lens mount that rests on the optical bench. The cut out piece that is perpendicular to the foot marks the location of the center of the lens