Experiment 20: Thin Lenses

Figure 20.1: Optical Bench Arrangement

EQUIPMENT

Optical Bench
(2) Lens Holders
(4) Optical Bench Clamps
Object Box (Light Source)
Small Screen
Large Screen (clipboard, paper)
Bi-Convex Lens (Converging Lens)
Bi-Concave Lens (Diverging Lens)
30-cm Ruler
Flashlight (1 per person)
Lens Cleaning Towelettes (TA's Table)

Advance Reading

Text: Thin lenses, converging lens, diverging lens, lens equation, object distance, image distance, refraction, focal length, magnification, index of refraction, real image, virtual image.

Objective

The objective of this experiment is to measure the focal lengths of a converging lens and a diverging lens and investigate magnification.

Theory

Light refracts (bends) when passing through media with difference indices of refraction. This property can be very useful, especially when a *thin lens* is used. A thin lens' thickness is much less than its diameter.

A converging (convex, positive) lens is thicker in the center than at the edges. It 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 formed by light actually passing through the image. A real image can be projected on a screen. The image exists regardless of whether or not a screen is in position to show it.

A diverging (concave, negative) lens normally forms a *virtual image*. Light rays do not actually pass through a virtual image. It cannot be projected on a screen. When you look at yourself in a mirror, you are looking at a virtual image. If the object is real, the image is virtual. However, when a diverging lens is used in combination with a converging lens, for instance, the object can be virtual, the image real. Parameters must be met for a real image to be formed; read the *Part 2* procedure carefully.

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

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \tag{20.1}$$

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

Consider Eq. 21.1. For an object that is infinitely far away ($d_o \to \infty$).

Rays of light from an object very far away from a thin lens will be approximately parallel when they reach the lens. The light rays will then refract as they pass through the lens. For a converging lens, rays parallel to the optical axis refract towards the normal and focus at a point (small area) called the *focal point*, F. The distance between the center line of the lens and the focal point is the *focal length*, f. Refer to Fig. 21.2. Fig. 21.2 through Fig. 21.6 are courtesy of Giancoli's *Physics*[1].

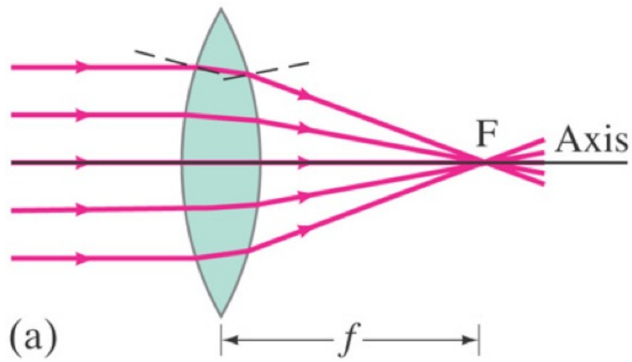

Figure 20.2: Ray Tracing: $d_o \to \infty$, $d_i \equiv f$

For a converging lens, rays of light that are parallel to each other but not parallel to the optical axis will still refract towards the normal, but will focus at the *focal plane.*

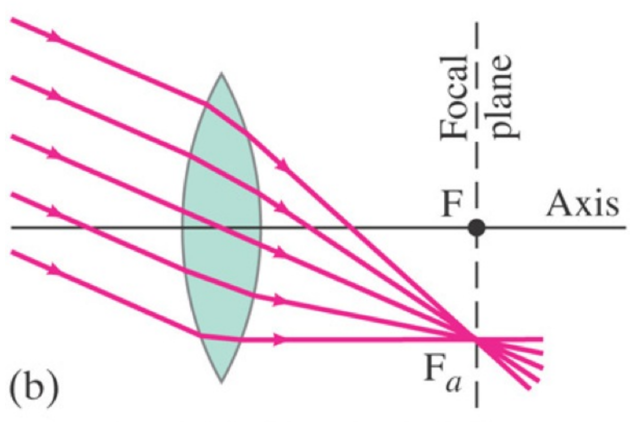

Figure 20.3: Ray Tracing: Focal Plane

[1]Giancoli, Douglas C., 2005. *Physics*, 6$^{\text{th}}$ Edition. Pearson Education, Inc., Upper Saddle River, NJ.

Rays of light from a nearby object will arrive at the lens at various angles. The light rays will then refract as they pass through the lens and, for a converging lens, form an image at a distance d_i (refer to Fig. 21.4).

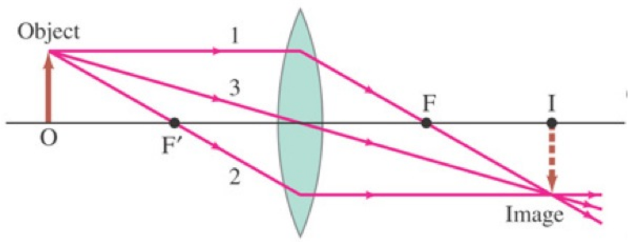

Figure 20.4: Ray Tracing: Nearby Object

As mentioned, a diverging lens will usually form a virtual image. The image can be seen but cannot be projected onto a screen.

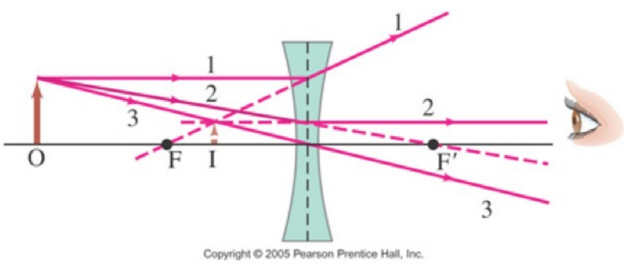

Figure 20.5: Ray Tracing: Diverging Lens

To determine the focal length of a diverging lens in lab, we will need to use two lenses. The *real image* from the converging lens will become the *virtual object* for the diverging lens. Refer to Fig. 21.6; although our arrangement must be somewhat different than shown below, the figure has the same concept we require.

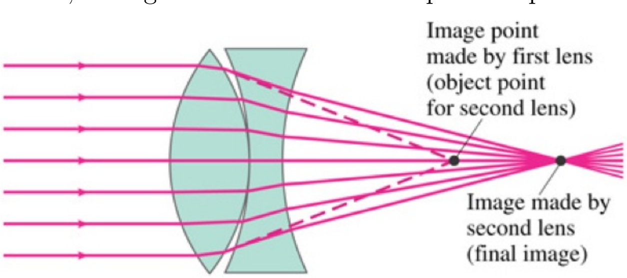

Figure 20.6: Ray Tracing: Combination Lenses

Lateral magnification, M, is defined as the ratio of the image height, h_i, to object height, h_o. The object height is assumed to be positive; the image height is positive if the image is upright and negative if the image is inverted.

$$M = \frac{h_i}{h_o} \tag{20.2}$$

Magnification is also proportional to the relative distances of object and image from the lens:

$$M = -\frac{d_i}{d_o} \tag{20.3}$$

The sign conventions for object distance and image distance remain the same. These are calculated as in Eq. 21.4 and Eq. 21.5.

The lab will be dark (lights off) for the remaining experiments this semester. It is important that your flashlight be pointed *below horizontal* at all times. This limits the bleaching of visual purple, which permits night vision. Please turn off the flashlight when it is not in use and before you leave lab.