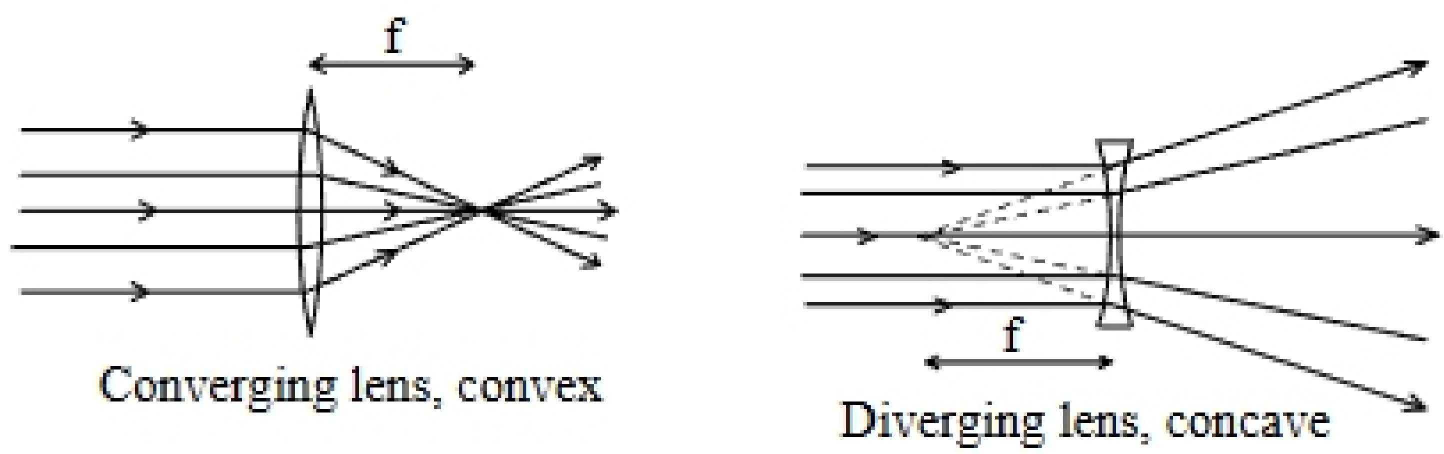
Lab: Lenses & Telescopes

INTRODUCTION AND BACKGROUND:

In this experiment, you will study **converging** lenses and the lens equation. You will make several measurements of the focal length of lenses and you will construct a simple astronomical telescope.

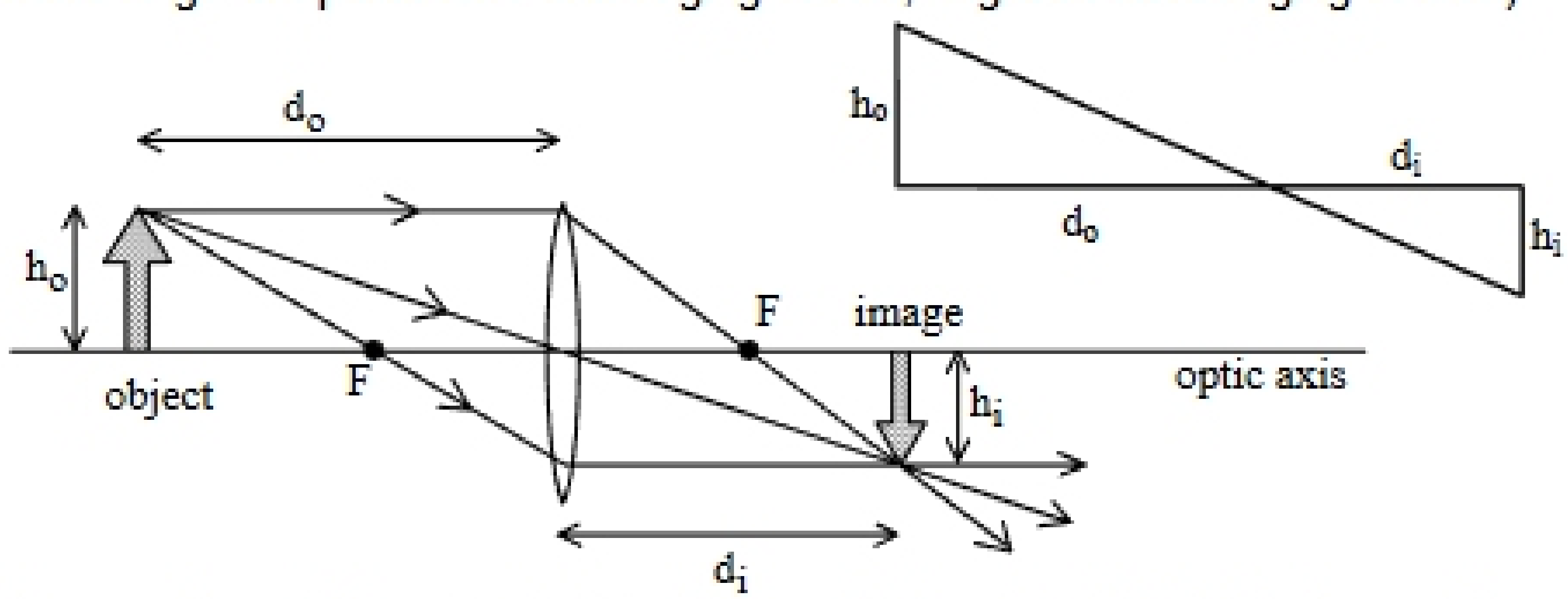
When a bundle of **parallel** light rays enters a converging lens, the rays are focused at a point in space a distance f, the focal length, from the lens. A converging lens is convex in shape, that is, thick in the middle and thin at the edges. A diverging lens is concave in shape, i.e. thin in the middle and thicker near the edges.



A converging lens can be used to form an **image** of an object on a screen. The **lens equation** relates the focal length **f** of a lens, the object distance $\mathbf{d_o}$ and the image distance $\mathbf{d_i}$:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}. \qquad (1)$$

(This equation can used for both converging and diverging lens; the only difference is that the focal length f is positive for converging lenses, negative for diverging lenses.)



In the diagram above, the points labeled F are the focal points of the lens – the distance from the lens to either of the points F is the lens **focal length**.

The *magnification* m of the image is defined as $m = \left|\frac{h_i}{h_o}\right|$. From the diagram above, one can use similar triangles to show that m can also be written as $m = \left|\frac{d_i}{d_o}\right|$.

In the preceding figure, there are two important points to note: First, notice that the distance from the lens to the image is **not** the focal length of the lens, but is related to it through equation 1. Secondly, note that light is being reflected off of the object in *many* directions. The amazing thing about lenses is that all of the light rays that **originate at some specific point on the object** (radiating outward in all different directions) and then **go through the lens** are redirected to **arrive at a single point on the image**.

Re-draw a simplified version of the preceding drawing, but without the lens. Namely, draw the arrow-shaped **object**, and draw rays of light coming from the tip of the object going out in many directions. Now draw rays of light coming from the middle of the object going out in many directions. If you were to expose a piece of photographic film to this mess of rays at some distance away (with **no** lens present), what would it look like? Would it form an image?

Re-sketch the same drawing, but now with the lens in place. Duplicate the drawing with the object, the lens, and 5 different rays coming from the tip of the object through the lens, and converging at the image location. Draw 3 rays coming from the middle of the object and converging at the image location. (Draw carefully and precisely, or your drawing will be a mess…)

If you were to expose a piece of film to the rays that arrive at the image location, what would it look like? Would it form a picture?

In this lab, you will use three different techniques to measure focal lengths.

Method I: How can you use equation (1) to determine the focal length (**f**) of a lens, if you can measure $\mathbf{d_i}$ and $\mathbf{d_o}$?

Method II: If $\mathbf{d_i}$ were set to ∞ in equation (1), and we could measure $\mathbf{d_o}$, how could we determine the focal length **f**? What would the rays of light look like near the lens if the rays converged to an image "at infinity"? Make a diagram, indicating the lens, the rays which emerge from a point at a distance $\mathbf{d_o}$ on the left side and then form an image "at infinity" on the other. Indicate the focal length **f** on the figure.

Method III: If a point source and a lens have been set up to produce a collimated beam (i.e. parallel rays), then the focal length of another lens can be easily measured. The second lens (lens B) is placed in the collimated beam, and the place where the rays are brought to focus is measured. The distance from lens B to the focal point is f_B, the focal length of lens B. How is equation (1) used in this situation to determine f_B ?