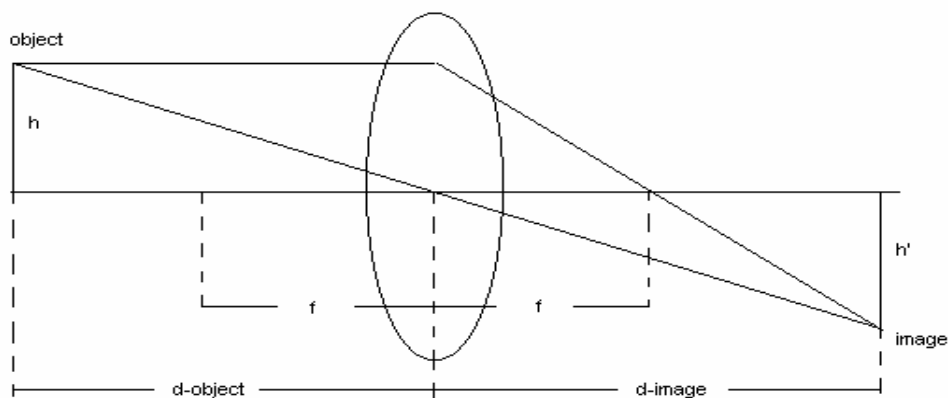


LENSES AND IMAGE FORMATION

It is shown in the text that, for a thin lens, the focal length f , which is by definition the image distance when the object observed is a very great distance away, is related to the object distance, d_o , and the image distance, d_i , corresponding to a relatively close object by the relationship

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



The expression, the thin lens equation, as written is an approximation. In deriving it we have neglected the thickness of the lens in comparison to distances comparable to the focal length. However for relatively long focal length lenses it provides a simple, remarkably accurate way of calculating properties of images. In using the above expression one must always be careful to observe the sign conventions used in deriving it. These sign conventions are indicated in the figure above.

Here if the object lies to the left of the lens d_o is taken as positive; if it lies to the right d_o is taken as negative. If the image lies to the right of the lens d_i is taken as positive; if it lies to the left d_i is taken as negative hence it is a virtual image. Note that if an image is virtual, the light does not pass through it. Every object is assumed erect and its height h is taken positive. The height h' of the image is taken as positive if the image is erect; h' is taken as negative if the image is inverted. The focal length f is taken as positive if the lens will actually focus light from a very distant source. A lens of this type is called a converging lens and is thicker at the center than at the edges. If the lens will not focus light from a very distant source it is called a diverging lens.

PROCEDURE:

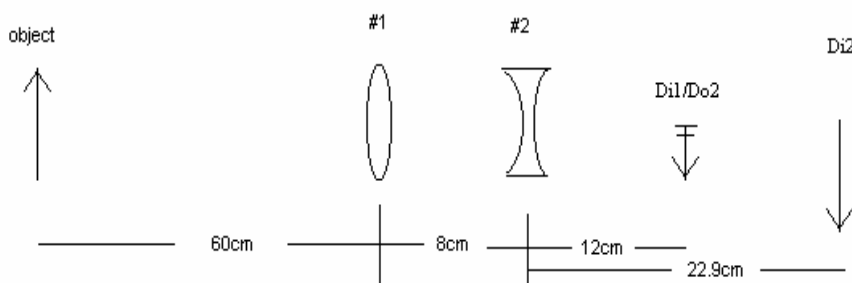
PART I:

We will begin this experiment by checking the thin lens equation. Select a converging lens and set it up in such a way as to form an image on a white screen of a very distant object, i.e., an object well outside the window of the laboratory. Now measure the image distance. This will be essentially equal to the focal length since d_o can be taken at infinity. Enter your results in the table below. Now set up an illuminated arrow as an object at an object distance of about four times the focal length. Move the white screen until an image is formed. Record the object and image distances and calculate the focal length from the thin lens equation. Also record the lengths h and h' of the arrow and its image. Calculate the magnification $m = h'/h$ and compare this to the ratio $-d_i/d_o$. Repeat this experiment with an object distance of about $2\frac{1}{2}$ times the focal length and $\frac{3}{4}$ the focal length. **Note, if a real image cannot be formed be sure to explain why one could not see the image.**

PART II:

Next we will find the focal length of a diverging lens. We will do this by two methods. In the first method we will use a converging lens ahead of a diverging lens to converge the rays before they reach the diverging lens thus using the image of the converging lens as the object for the diverging lens. Place the arrow at one end of the bench and position the converging lens a distance of $4f$ from the object (as you've done earlier). Calculate the image location (d_{i1}) using the thin lens equation. Now place the diverging lens 8 cm away from the converging lens. Calculate the object distance of lens 2 (d_{o2}) by subtracting the separation distance of the lenses from d_{i1} . Next move the white screen until the image is in focus and record the distance between the screen and lens 2 (d_{i2}). Calculate the focal length of the diverging lens (F_2) using the thin lens equation. Follow the example outlined below and record all relevant data in the table provided.

Let $f_1=15\text{cm}$, then $d_{o1} = 60\text{cm}$, and d_{o2} is calculated from d_{i1}



$$\frac{1}{f_1} = \frac{1}{d_{o1}} + \frac{1}{d_{i1}}$$

$$d_{i1} = \left(\frac{1}{f_1} - \frac{1}{d_{o1}} \right)^{-1}$$

$$d_{i1} = 20\text{cm}$$

$$\frac{1}{f_2} = \frac{1}{d_{i2}} + \frac{1}{d_{o2}}$$

$$d_{o2} = -12\text{cm} = (8\text{cm} - d_{i1})$$

$$d_{i2} = 22.9\text{cm}(\text{measured})$$

$$f_2 = -25.2\text{cm}$$

Repeat this experiment by using separation distances of 4.5cm and 0cm between the lenses. Be sure to use + and - signs correctly. Determine the focal length in each case and calculate the average focal length.

PART III:

We can also calculate the focal length of the diverging lens by placing the converging lens next to the diverging lens and measuring the combined focal length by focusing on a distant object. If two thin lenses are placed close together the effective focal length f_c of the combination is given by the expression

$$\frac{1}{f_c} = \frac{1}{f_1} + \frac{1}{f_2}$$

The student may easily derive this result from the thin lens equation by noting that the object distance for the second lens is, to the degree of approximation of the thin lens equation, numerically equal to the image distance of the first lens.

Lenses and Image Formation

Name _____

Partner _____

Lab Section _____

Lecture Section _____

PART I: Converging Lens

	Object Distance d_o	Image Distance d_i	Focal Length f	Object Size h	Image Size h'	h'/h	$-d_i/d_o$
Distant Object	∞			_____	_____	_____	_____
$d_o \cong 4f$							
$d_o \cong 2 \frac{1}{2} f$							
$d_o \cong \frac{3}{4} f$							

PART II: Diverging Lens

separation distance	f_1	d_{o1}	d_{i1}	d_{o2}	d_{i2}	f_2
8cm						
4.5cm						
0cm						

average focal length of the diverging lens _____

PART III: Combination of Lenses

focal length of diverging lens by combination of lenses _____

% difference between Part II and Part III _____

QUESTIONS:

Do your measurements for the converging lens agree with the mathematical relationship between h'/h and $-d_i/d_o$?

Why must the converging lens have a shorter focal length than the diverging lens if the latter's focal length is to be determined by combining them?