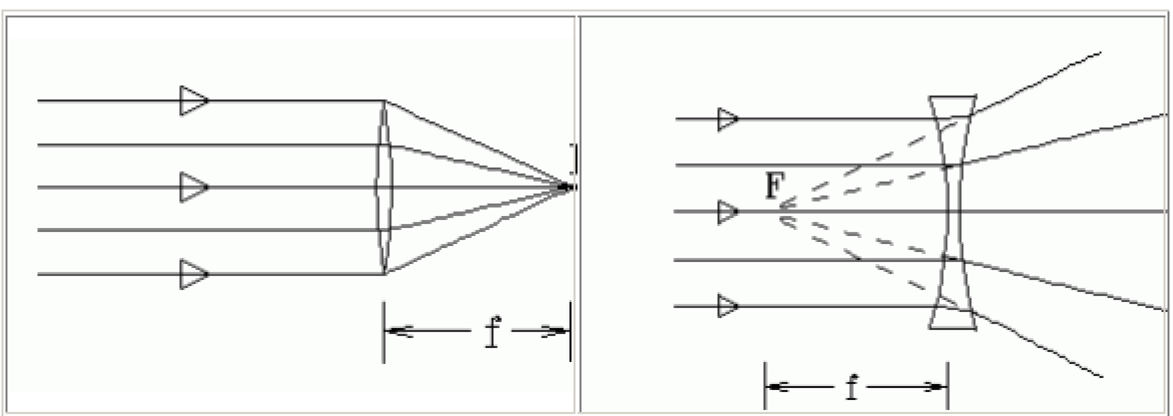
EXPERIMENT 5
Optics: Focal Length of a Lens

Introduction:

(a) For convenience of discussion we assume that the light passes through the lens from left to right. Ray diagrams will follow this convention.

(b) The ***focal point*** of a lens is found by allowing a bundle of mutually parallel rays to enter the lens (i.e., from an object infinitely far from the lens). The lens alters the direction of these rays, making them emerge as a convergent or divergent bundle. The point to which they converge (or from which they diverge) is called the ***focal point***. The diagrams below show the focal points **F**.

Diagram #1 **Diagram #2**



(c) A lens which ***converges*** a bundle of parallel rays is called a ***converging lens***, or ***positive lens*** (its focal length is taken as positive). The converging lens is thicker at its center than at its edge.

(d) A lens which ***diverges*** a bundle of parallel rays is called a ***diverging lens***, or a ***negative lens*** (its focal length is taken as negative). The diverging lens is thicker at its edge than at its center.

(e) Light rays from a point source (object) passing through a lens emerge convergent to a point or divergent from a point. In either case, that point is called the ***image*** of the source.

(f) When the emergent rays ***converge*** to a point, the image is called ***real***.

(g) When the emergent rays ***diverge*** from a point, the image is called ***virtual***. Such images can be seen only by looking through the lens, toward the light source. By our convention, with the rays passing through the lens from left to right, you must have your eye to the right of the lens and look through the lens to see the image which is to the left of the lens.

Equipment:

Optics Bench (OS-8518)
Light source (object) (OS-8517)
Convex lens
Screen

Purpose:

To determine the focal length of a thin lens and to explore the difference between convex and concave lenses and to determine their focal lengths.

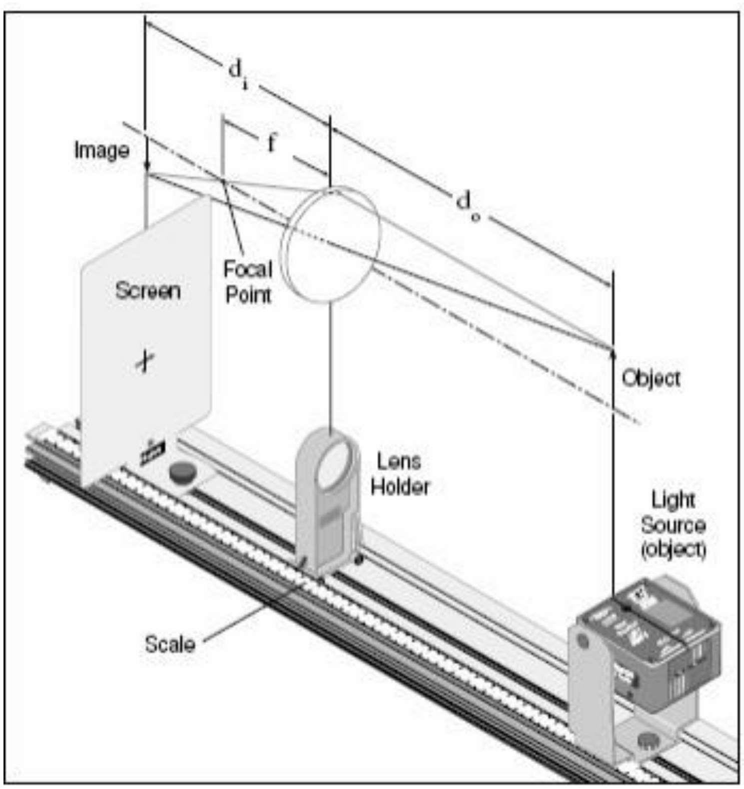
Theory:

For a thin lens in air:

$$\frac{1}{f} = \frac{1}{do} + \frac{1}{di}$$

f is the focal length, ***do*** is the distance between the object and the lens, and ***di*** is the distance between the image and the lens.

See Diagram #3 (Below)



<u>Procedure:</u>

PART I FOCAL LENGTH USING AN OBJECT AT INFINITY

In this part, you will determine the focal length **(*f*)** of the lens by making a single measurement of the image distance **(*di*)** while keeping the object distance **(*do*)** at infinity **(∞)**. Students will use a distant light source as an object at infinity.

(1) Using the supplied lens to form an image of a distant light source on a paper. Move the lens until a clear image is formed on the paper.

(2) Measure the distance from the lens to the paper. This is the Image Distance ***(*di)***

image distance ***(*di)*** =____________*cm*

(3) As an object approaches to infinity, $\frac{1}{do}$ approaches to ________. So, when a distant light source uses as an object at infinity, the focal length (***f***) of the supplied lens =______________*cm*.

*Question: Can image distance also be infinity? If so, when image is formed at infinity, what does it mean?

PART II FOCAL LENGTH BY PLOTTING $\frac{1}{do}$ vs. $\frac{1}{di}$

(1) On the optical bench, position the lens between a light source (the object) and the screen. The screen should be 115 centimeters away from the object.

(2) Move the lens to a position where an image of the object is formed on the screen. Measure the image distance and the object distance. Record all measurements in Table #1.

(3) Measure the object size and the image size for this position of the lens.

(4) Move the lens to a second position where the image is in focus (Do not move the screen or Light Source). Measure the image distance and the object distance.

(5) Measure the image size for this position also.

(6) Move the screen 5 centimeters closer (110 cm) to the object. Repeat steps 2 and 4 for this position of the screen and for 4 other positions (105 cm, 100 cm, 95cm, and 90 cm) of the screen. This will give you 6 sets of two data points each which will give you 12 data points.

(7) Plot $\frac{1}{do}$ vs. $\frac{1}{di}$ using the 12 data points. This will give a straight line and the x- and y-intercepts are each equal to $\frac{1}{f}$. Determine the focal length (***f***).

(8) Calculate the ***f*** average and find the percent difference between this average and the focal length found in Part I.

(9) **For the first set of data points ONLY**, use the image and object distances to find the magnification at each position of the lens.

Magnification: $M_1 = \frac{di}{do}$

Then, using your measurements of the image size and object size, find the magnification by measuring the image size and the object size.

Magnification: M_2 = image size / object size

Find the percent different.

Table #1

Run	Distance from Light Source to Screen	Object Distance	Image Distance	Image Size	$\frac{1}{do}$	$\frac{1}{di}$
1	115 cm					
2	110 cm					
3	105 cm					
4	100 cm					
5	95 cm					
6	90 cm					

Object Size: _______________

Data Analysis:

x – intercept ($\frac{\mathbf{1}}{\boldsymbol{f_1}}$) = _________________ y – intercept ($\frac{\mathbf{1}}{\boldsymbol{f_2}}$) = _________________

Solve for: $\boldsymbol{f_1}$ = _________________ $\boldsymbol{f_2}$ = _________________

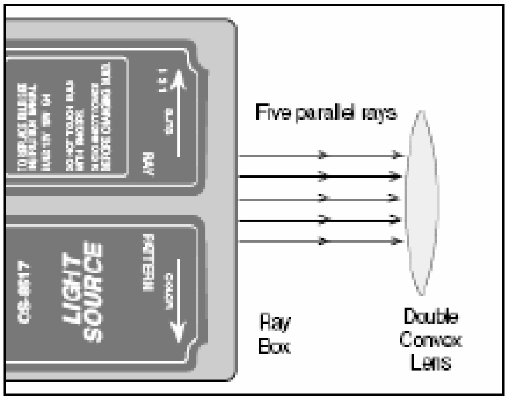
$\boldsymbol{f}$ average: ($\frac{\boldsymbol{f_1 + f_2}}{\mathbf{2}}$) = _________________

Percent difference = $\frac{|*\boldsymbol{di} - \boldsymbol{f}\ \textbf{average}|}{*\boldsymbol{di}}$ **× 100%** = _________________

Magnification for the first set of data points:

Part III

(1) Remove the ray box from the optical bench and place the ray box on a white piece of paper. Using five white rays from the ray box, shine the rays straight into the convex lens. See figure below.



Note: Concave and Convex lenses have only one flat edge. Place flat edge on surface. Trace around the surface of the lens and trace the incident and transmitted rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions.

(2) The place where the five refracted rays cross each other is the focal point of the lens. Measure the focal length from the center of the convex lens to the focal point. Record the result below:

	Convex Lens	Concave Lens
Focal Length		

(3) Repeat the procedure for the concave lens. Note that in Step 2, the rays leaving the lens are diverging and they will not cross. Use a ruler to extend the outgoing rays straight back through the lens which is called a **virtual** focus. The focal point is where these extended rays cross.

(4) Place the convex and concave lenses together and place them in the path of the parallel rays. Trace the rays. What does this tell you about the relationship between the focal lengths of these two lenses?

(5) Slide the convex and concave lenses apart to observe the effect of a combination of two lenses. Then reverse the order of the lenses. Trace at least one pattern of this type.