Physics 197 Lab 6: Thin Lenses and Optics

Equipment:

Item	Part #	Qty per Team	# of Teams	Total Qty Needed	Storage Location	Qty Set Out	Qty Put Back
Basic Optics Light Source	PASCO OS-8517	1	8	8			
Power Cord for Light Source		1	8	8			
Screen	PASCO	1	8	8			
Optics Bench	PASCO OS-85518	1	8	8			
100 mm Convex Lens in holder	PASCO	1	8	8			
200 mm Convex Lens in holder	PASCO	1	8	8			
50 mm Convex Lens in holder	PASCO	1	8	8			
25 mm Convex Lens in holder	PASCO	1	8	8			

Layouts:

Figure 1, Experiment A
Focal Length of a Thin Lens

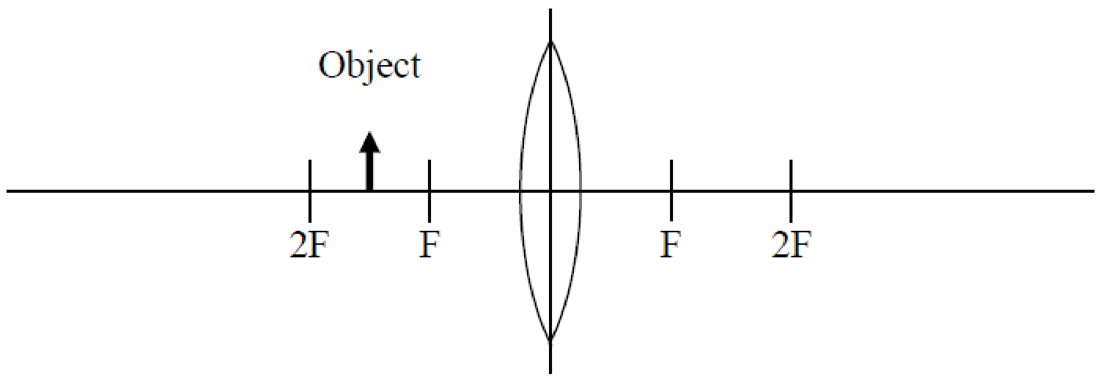
Figure 2, Experiment B
Telescope

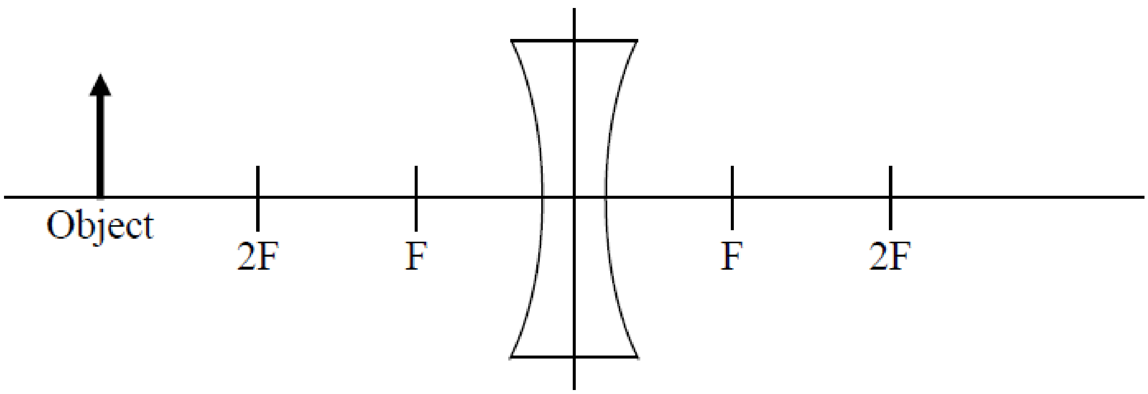
Summary:

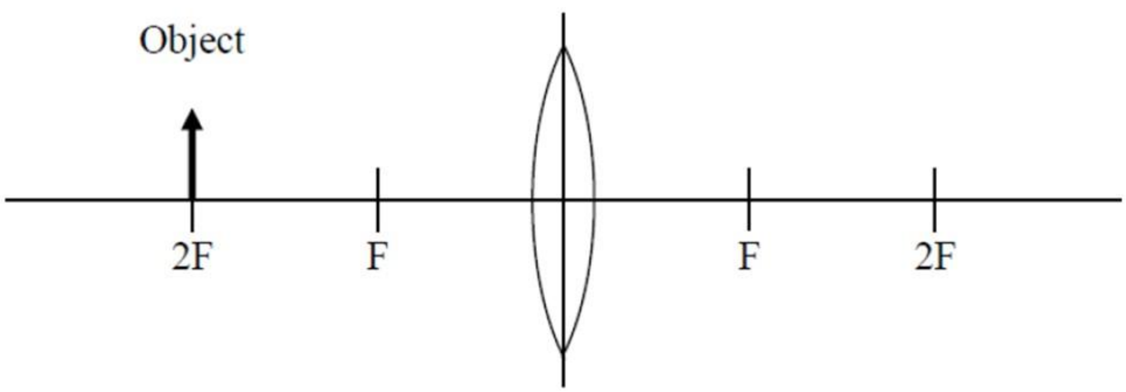
In this lab, students will investigate some properties of thin lenses. In Experiment A (figure 1), students will vary the distance between a source (illuminated pattern), a convex lens, and a screen to study the equation relating these quantities when the system is in focus. In Experiment B (figure 2), students will measure the magnification of a telescope consisting of two convex lenses by looking through the telescope at a faraway object. The lens further from the eye is called the objective lens, and the lens next to the eye is called the eyepiece lens. By substituting eyepiece lenses with different focal lengths into the telescope, the magnification will be changed. Students will estimate the magnification by looking at the faraway object through the telescope with one eye while simultaneously looking at the object along the outside of the telescope with the other eye.

PreLab:

Trace rays for the following three optical configurations, and include them in your notebook. Draw at least two sets of rays to locate the image. State whether the image is upright or inverted, virtual or real, and enlarged or reduced. Also calculate the magnification of the image. (For ray tracing method, see Chapter 34, Figure 34.36, Graphical Methods for Lenses. Start at top of object arrow. Lines through center of lens go straight. Lines through focus on one side of lens go parallel to axis on other side of lens. Lines intersect at Image)







Experiment A: Focal Length of a Thin Lens (PASCO Experiment manual Basic Optics Kit, Part 012-05628C)

Purpose

To determine the focal length of a thin lens.

Theory

For a thin lens: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

where f is focal length, d_o is the distance between the object and the lens, and d_i is the distance between the image and the lens. See Figure 9.1.

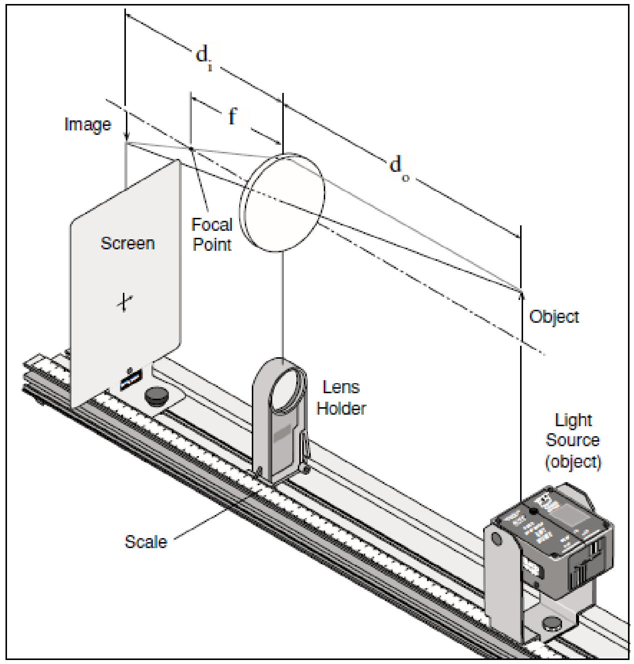


Figure 9.1

Procedure

I. FOCAL LENGTH USING AN OBJECT AT INFINITY

① Using one of the positive lenses focus a distant light source on a paper.

② Measure the distance from the lens to the paper. This is the image distance.

③ Take the limit as the object distance goes to infinity in the Thin Lens Formula:

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

Solve for the focal length. $f =$ _______________

II. FOCAL LENGTH BY PLOTTING $1/d_0$ vs. $1/d_i$

a. On the optical bench, position the light source (reticle pattern with cross and circles) one meter from the screen. Place the 100 mm focal length lens on the bench between the light source and screen, and find a position for the lens where the light source pattern comes to a focus on the screen.

b. Measure the image distance and the object distance and record. Measure the image size and object size and record. Using your measurements of the image size and object size, find the magnification

$$|M| = \textit{image size/object size}$$

Compare the measured magnification to the expected magnification based on the object distance and image distance

$$\textit{Magnification} = M = -d_i / d_o$$

Calculate the percent difference between these two values for the magnification.

c. Move the lens only (leaving the light source and screen fixed) to the other position where the light source pattern comes to a focus on the screen. Measure the image distance, object distance, image size, and object size. Calculate the magnification using the two methods from part b, and compare, calculating the percent difference.

d. Make a table in your lab notebook having 12 rows and five columns. The columns should be labelled Screen-Object distance, Object distance d_0, Image distance d_i, $1/d_0$, and $1/d_i$.

e. In the first two rows, record 1 meter as the Screen-Object distance, and your two sets of measurements for object distance and image distance (at the two locations where you found a focus in part a and c)

f. For the next two rows in the table, change the screen-object distance to 0.9m, and record the object and image distance for the lens positions where the image is in focus.

g. Repeat step f for screen-object distances of 0.8m, 0.7m, 0.6m, and 0.5m.

h. What happens if the screen-object distance is reduced to 0.4m? Less than 0.4m?

i. Calculate and fill in the table for the values of $1/d_o$ and $1/d_i$ in each row. Plot $1/d_o$ vs. $1/d_i$ using the 12 data points. Make the plot carefully in your notebook, taking up most of the width of the paper. Each axis should go from 0 to 12.0/m. The data should lie along a fairly straight line and the x- and y- intercepts should each equal 1/f.

h. Find the percent difference between the two values of the focal length found from the intercepts.

Then average these two values and find the percent difference between this average and the stated lens focal length of 100mm (which should also agree with what you found using the method of Part I.)

QUESTIONS

① Is the image formed by the lens erect or inverted?

② Is the image real or virtual? How do you know?

③ Explain why, for a given screen–object distance, there are two positions where the image is in focus.

④ Why is the magnification negative?

Experiment B: Telescope

We can make a simple telescope, used for viewing far away objects or for reducing or magnifying the diameter of a laser beam, by using two lenses. In the following, we will use two convex lenses, each with a positive focal length, which will form a Keplerian telescope (see figure B1). If the object is located very far away, the incoming rays from each point in the object will be approximately parallel to each other, and come to a focus at a distance f (equal to the focal length of the lens) on the other side of the lens from the object. (At this focal point there will be a real, inverted image of the object).

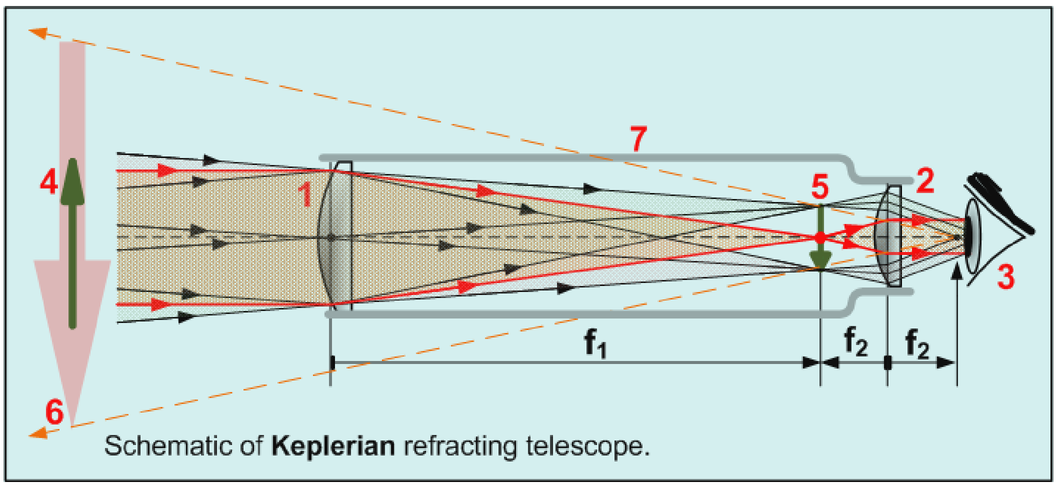


Figure B1. Keplerian refracting telescope (from Wikipedia article on Refracting Telescope, 9/27/18). The arrow at (4) is a notional representation of the original object (located at distance infinity). The arrow at (5) is the inverted image at the focal plane, and the arrow at (6) is the virtual image that forms in the viewer's visual sphere. The red rays produce the midpoint of the arrow. Two other sets of rays, each black, produce its head and tail.

The first lens (lens 1 in the diagram) is called the objective lens (the one which is nearer to the object). The second lens (lens 2 in the diagram) is called the eyepiece lens (the one which is nearer to the eye). For our experiment, we will use a 200 mm lens as the objective lens and combine this in turn with a 100 mm lens, 50 mm lens and 25 mm lens as the eyepiece lens to get three different telescope magnifications. Start with the 200 mm lens and 100 mm lens. Place these two lenses on the optical rail such that the eyepiece lens is near one end (so you can look through it easily with your eye). Place the objective lens a distance of 300 mm in front of the eyepiece lens. In that configuration, a parallel beam of light entering the objective lens would come to a focus 200 mm from the objective lens, and the eyepiece lens would re-collimate the light from that focal point. The recollimated light would have exactly half the diameter of the original beam (the ratio of the lens focal lengths, 100mm/200mm).

Now look through your two lens assembly at a far away object (for instance the exit sign in the room) and compare the image you see through the telescope and the image you see by looking directly at the object. Is the telescope image inverted or upright compared to the direct image? Is it magnified? Estimate the magnification and compare it to what you would expect from the ratio of the lens focal lengths ($f_{\text{objective lens}}/f_{\text{eyepiece lens}}$).

Replace the 100 mm eyepiece lens with the 50 mm eyepiece lens. Refocus the telescope by placing the objective lens 250 mm from the eyepiece lens. Look through the telescope at a far away object, estimate the magnification, and compare to what you would expect with this new set of telescope lenses. Then finally repeat the experiment using a 25 mm lens for the eyepiece lens (with the objective lens placed 225 mm away).