PHY132 Practicals Day 4 Student Guide

Summer 2009

Concepts of today's Module

- Lenses: Magnification and the Thin Lens Equation.

Ray Optics, Activity 8

For this activity you are provided with two lenses which look almost identical. They are both convex, and therefore focusing or "converging" lenses. They both have diameters of 50 mm, but one is labeled "f/4", and the other is labeled "f/2", meaning that their focal ratios are 4 and 2.

For a thin lens:

$$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$$

where f is the focal length, s is the distance between the object and the lens, and s' is the distance between the image and the lens. By measuring s and s' the focal length can be determined.

In this activity, you will estimate the focal length of the lens by making a single measurement of s', with $s \approx \infty$. You will require two convex lenses, a screen or something white to project the image on, and a distant light source, such as a light bulb set up across the room.

A. Hold the lens in one hand and the screen or a white piece of paper in the other. Focus the image of a distant bright object (such as a window or light bulb across the room) on the screen. When the image is in focus, have a partner measure the distance from the lens to the screen. This is the image distance, s'. If you assume $s = \infty$, what is the focal length, f?

B. Make a rough estimate of the actual object distance for your measurement in part A. What percentage error did you introduce to your determination of f by assuming that s was infinity? By using the method of part A, do you think you will slightly overestimate or underestimate f? There are two sources of error here, one is the *random* error introduced when you measure the image distance, and the other is the *systematic* error introduced by assuming that the object was at infinity. In this case, which is larger, the random error or the systematic error?

C. Repeat the procedure of part A for a second convex lens with a different focal length.

Course Concepts Ray Optics, Activity 9

An object and a viewing screen are held at a fixed distance *d*, and a focusing lens with positive focal length f is placed part-way between them. (This is the situation you will be setting up in Activity 10.) In order to form a focused image, the sum of the object and image distances must be equal to *d*: $s + s' = d$.

A. Knowing the distance between the object and image *d*, and the focal length of the lens *f*, solve for the image distance of a focused image, s' in term of *f* and *d*. You will have to eliminate the variable *s*. [You should end up with a quadratic equation.]

B. Identify the discriminant of the quadratic equation for Part A. If the discriminant is negative, then the solution for s' will have an imaginary component. Physically, this means that a focus is impossible and the image will always be blurry. For what condition on *d* will a focused image be impossible?

Magnification, *m*, is the ratio of the image size to the object size. By definition, $|m| = h'/h$. If the image is inverted, *m* is negative. For an image formed by a thin lens:

$$m = -\frac{s'}{s}$$

C. Consider a situation where $d = 1.0$ m, and $f = 0.2$ m. What are the two solutions of s' ? What is the magnification, *m*, for the two solutions?

Expt Ray Optics, Activity 10

This activity uses optical components clipped to the 2.2m aluminum track. It is easy to slide these components along the length of the track, and to measure their position using the ruler on the track.

Set up Viewing Screen at 50 cm. This means the front surface of the white screen should be above the 50 cm mark on the track, and facing down the length of the track where you will be placing other components. Place the f/4 convex lenses in the Adjustable Lens Holder and set up the lens holder at 100 cm and the light source with the illuminated crossed arrows pattern at 150 cm, so the pattern is facing toward the lens. For this set up, the distance between the source and the screen, *d*, is 1 m.

A. Starting with the f/4 lens close to the screen, slide the lens away from the screen to a position where a clear image of the crossed-arrow object is formed on the screen. Measure the image distance s' and the object distance s. Also measure the object size h and the image size h'. The object size is the distance between two pattern features on the crossed-arrow object, and the image size is the corresponding distance between these features in the image.

B. From measurements of s and s' you can predict the magnitude of the magnification, m. For the two different images you focused for Part A, with d = 100 cm, how does the predicted $|m_{pred}| = s / s'$ compare with the measured magnification $|m_{meas}| = h' / h$?

C. Is it possible to find a focus for the f/4 lens when d = 50 cm?

D. For the f/4 lens, repeat measurements of s and s' for d = 90 cm and 110 cm, and fill them in along with their inverse into a table in your lab notebook. Plot $1/s$ versus $1/s'$ and find the best fit line (linear fit). This will give a straight line with the y-intercept (A0) equal to $1/f$. What is the value of f for this lens? [1]

[***STOP!*** Please go back and take a second look at what you have recorded in your notebook for the mandatory activities. Is there anything missing? Can anything be improved? Does your TA have advice on what you might be able to do better? Please do not attempt this "If you have time" activity until you feel confident that the other activities are completed to the best of your ability, and you have obtained permission from one of your TAs.]

If you have time:

E. Replace the f/4 lens with the f/2 lens. Make measurements of s and s' for d = 50 cm, 60 cm and 70 cm, recording the inverses as you go. Plot $1/s$ versus $1/s'$ and find the best fit line (linear fit). This will give a straight line with the y-intercept (A0) equal to $1/f$. What is the value of f for this lens?

Last revision to this write-up: July 8, 2009 by Jason Harlow.

This Ray Optics Module Student Guide was written by Jason B. Harlow, Dept. of Physics, Univ. of Toronto, in the Fall of 2008. Part C of Activity 2 is by David M. Harrison, Dept. of Physics, Univ. of Toronto.

[1] Graphs can be made by hand, or you may use the computers to make and print a graph with a least-squares polynomial fit. The programs are "Create Dataset", "View Dataset" and "Polynomial Fit", and all come with help files if you press F1. You may store your data in your personal directory on Feynman\Classes .