Summary of the *Len Optics* Experiment

This document is a companion to a web-based document on the *Lens Optics* experiment in the Physics laboratories at the University of toronto. The web-document may be accessed at:

http://www.upscale.utoronto.ca/IYearLab/Intros/LensOptics/LensOptics.html

Since this document is a *summary*, we do not duplicate the more complete discussion contained in that web-document.

Thin Lenses

- Thickness is small compared to the radii of curvature of the surfaces.
- The radii of curvature of the surfaces are equal.
- The relation between the focal length **f**, the distance from the center of the lens to the object, **o**, and the distance from the center of the lens to the image, **i**, is:

$$1 / \mathbf{f} = 1 / \mathbf{o} + 1 / \mathbf{i} \qquad (1)$$

- When **o** is greater than **f**, a *real* image is formed on the other side of the lens from the object. This image may be seen by placing a white screen at the position of the image.

Initial Exploration

Suppose the upper half of the lens is blocked out by a *mask* constructed of a piece of cardboard held in place with masking tape. What do you predict will happen to the image?

Check your prediction with the actual apparatus.

Is your prediction correct? If not, can you explain why?

Keep the mask in place; this is to keep the intensity low and be more gentle to your eyes. Set the equipment up so that you get a good sized image on the screen; Remove the screen and try to locate the image in your eye; you will find that you have to move your head back and forth a bit to find a clear image. Is the position of the image on the screen at the same place as your eye when the image is focused? Can you explain?

Preliminaries

You will need to determine a correction factor for the object-lens and for the lens-image distance to account for the thickness of the lens and for the fact that the offsets from the mounts is probably different for the object, the lens, and the image screen

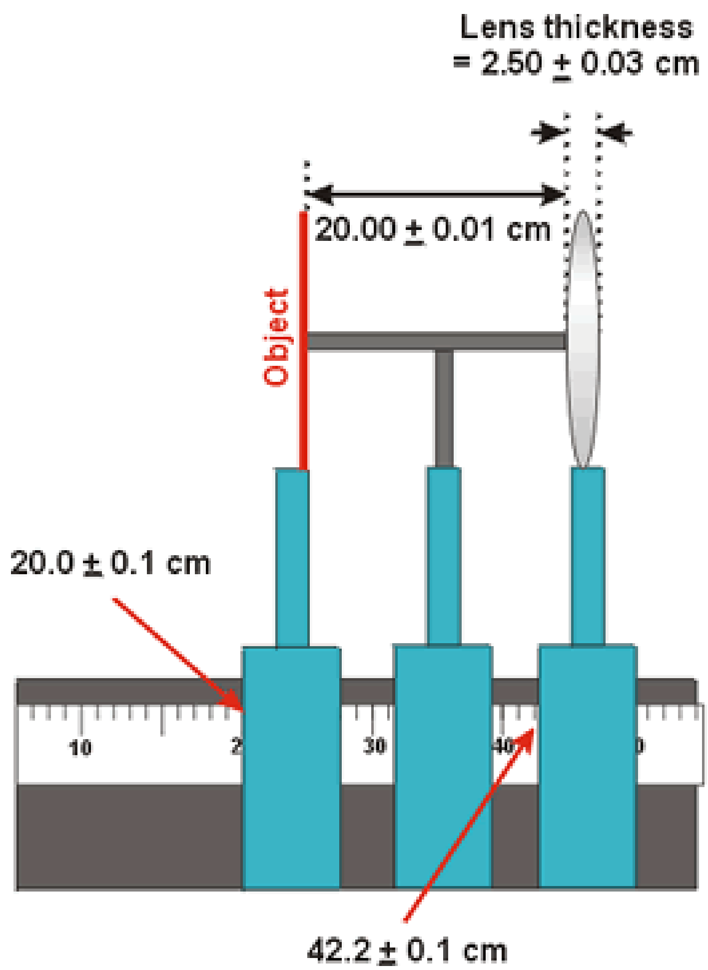
Here we give a sample calculation.

In the figure to the right we show part of the optical bench, with the Object, Aluminum rod, and a thin lens mounted on holders. We decide to read distances on the optical bench from the left-hand side of the holders. Thus, in this case the distance between the Object holder and the lens holder is read to be:

$$\mathbf{d}_{\text{read}} = (42.2 \pm 0.1) - (20.0 \pm 0.1)$$
$$= 22.2 \pm 0.1 \text{ cm}$$

However, the distance between the Object and center of the lens, **o**, is the length of the Aluminum rod plus one-half the thickness of the lens::

$$\mathbf{o} = (20.00 \pm 0.01) + (1.25 \pm 0.02)$$
$$= 21.25 \pm 0.02 \text{ cm}$$



Thus, all readings of the Object-lens distance need to have **0.95 ± 0.10** cm *subtracted* from them.

Note that all the above numbers, including estimated errors, are fictitious except that the length of the Aluminum rod that you will use really is 20.00 ± 0.02 cm long.

First Project

Devise a procedure, for use by a technician, to rapidly measure the focal length of a lens. In the procedure:

- The positions of the object and the lens holder are fixed.
- The technician mounts the lens to be measured in the lens holder.
- The image screen is moved back and forth for the sharpest image

Assume that all lenses to be measured have roughly the same focal length as the one that you are using.

The dominant error in the determination will probably be how much the image screen can be moved back and forth without seeing an appreciable difference in the quality of the image.

There are three possible ways to set up the apparatus:

1. Large object-lens distance and small lens-image distance
2. Small object-lens distance and large lens-image distance.
3. Medium values for both.

You will determine which of these gives the best value of the focal length.

You will need to decide if the thickness of the lens needs to be measured by the technician and included in the determination.

Present the final formula, suitable for putting into a simple computer program, in which the inputs are the reading of the position of the image screen and perhaps the thickness of the lens; the output is the value of the focal length of the lens. Assume that the technician's vision is about as good as yours, so the uncertainty in **i** for the technician's measurements is about the same as yours. What is going to be the final uncertainty in the technician's measurement of the focal length?

Second Project

Often the focal length **f** of a lens depends on the wavelength λ of the light. Thus, if white light is incident on the lens, the different colors will be focused at different positions. This is called *chromatic aberration*.

Now your supervisor at *XYX Organisation* wants you to see whether this phenomenon is measurable with your apparatus and lens. You are supplied with color filters which mount on the light source behind the object. The effective maximum transmission of the filters are at:

- Red: 690nm.
- Green: 530 nm.
- Blue: 420 nm.

What is your report to your supervisor?

Preparatory Questions

1. The relation between focal length **f**, object distance **o**, and image distance **i** is:
   1 / **f** = 1 / **o** + 1 / **i**
   - Rearrange the equation so that it gives **f** instead of one over **f** as a function of **o** and **i**.
   - For determining the error in **f** as a function of the errors in **o** and **i**, this equation is harder to use than the original one. Why?
2. In the discussion of the properties of thin lenses above, we stated that "The ray from the source that goes through the center of the lens is not refracted." We noted at the time that this was only approximately true. Why is this only approximately true, and how does the approximation relate to the word *thin*?