LAB 2 LENSES(TPL2)

Goals:

- Measure the focal lengths of converging lenses
- Investigate the general lens formula (object distance, image distance and focal lengths)
- Investigate the creation of an image by the lens

Preliminary activities

1. Prepare equipment. It would be very helpful to look at the online help page for this lab.

2. Load the Excel lens graph template. On the lab schedule webpage, there is an Excel sheet, **`T2Lab02_Lenses.XLS`**, load it into Excel. You might want to save it under a new name, as a working copy.

INTRODUCTION:

We will investigate the images formed by thin lenses according to the thin lens formula :

$$\frac{1}{f}=\frac{1}{s}+\frac{1}{s'} \qquad s = \text{object distance} \quad s' = \text{image distance} \quad f = \text{focal length}$$

There are convenient rules for the plus/minus conventions in object and image distances and the focal lengths:

- When the system is *converging* (lens or mirror), the focal length is *positive*.
- When the object is *real* (light exists at that point), the object distance is *positive*.
- When the image is *real* (light exists at that point), the image distance is *positive*.
- When the system is *diverging* (lens or mirror), the focal length is *negative*.
- When the object is *virtual* (you have to look into the system to see the object), the object distance is *negative*.
- When the image is *virtual* (you have to look into the system to see the image), the image distance is *negative*.

The graphical diagram for a converging thin lens system is shown below :

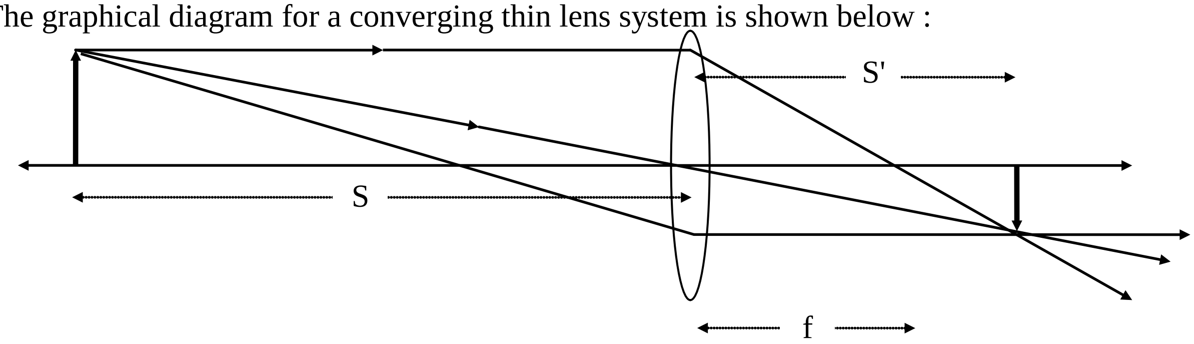

Figure 1 - Single converging lens system

Part 1 Single converging lens system - measuring limits of the bench

1. Identifying the limits of the bench. Put the light object at the 0cm position of the optical bench, and the image card at the 110cm position of the bench. There should be two positions on the bench for the lens for which there will be a clear image on the card. These are the limits of the positions we could use for the lens. The lens (f=200mm) should be put very near the light object. Move the lens closer to the image card until the first real image appears (until you see a figure on the screen) limit position 1. Then start with the lens near the image card, and move the lens back toward the object to find the other limit position, limit position 2.

Questions Answer on the Data/Question sheet
What differences do you notice in the images formed from each of the two limit positions? In your answer discuss the object and image distances as well as the relative heights between object and image for each location.

2. Record image/object distances and heights. At both positions, we will want to record the distances involved and measure the height of the image. Record the information about the positions and relative heights of the images on the Data/Question sheet. From this information you can calculate a value for the focal length of the lens.

3. Magnification. The magnification of the image is given by the following equations:

$$M_{\text{height}} = \frac{image\ height}{object\ height} = \frac{h_i}{h_o} \qquad M_{\text{distance}} = -\frac{s'}{s} \quad \text{(note negative sign)}$$

The magnification is the ratio of the size of the image to the object. The sign of the magnification indicates whether the image is inverted or upright relative to the object. So, a magnification of -2 would mean the image is inverted and twice the size. A magnification of +0.25 would be an image that is upright and one quarter of the size relative to the object.

4. Calculating the magnification. Calculate the magnification and the %diff using both of the equations above and the %diff formula on the Data/Question sheet. **Remember that since the image is upside down, the height of the image should be negative!** Show your calculations on the Data/Question sheet.

Question Answer on the Data/Question sheet.
How do the two magnification values compare to each other?

Part 2 Converging lens - Image and object distances - Lens equation

1. Excel. We are going to graph the lens/image positions in Excel. The template is arranged so that you can input the "positions" of the optical elements (lens, image screen), and the "distances" will be calculated and graphed.

2. Setting up to measure image and object distance locations. With the light object at 0cm of the optical bench - this will stay in that location. Start with the lens at the limit position 1 (found in Part 1.1 above) which is closest to the light object. The image should show up at the far end of the bench (as before).

3. Reason for collecting information. We want to be able to graph the lens equation relationship by making image/object distance measurements. An example of the graph is shown to the right. Notice the marks on the horizontal axis ... those represent roughly where you will want to make measurements. (Notice that the "far" object distances can move in relatively large jumps, but "near" object distances must change in smaller jumps to smooth out the curve (since the image distance changes more rapidly for smaller object distances).

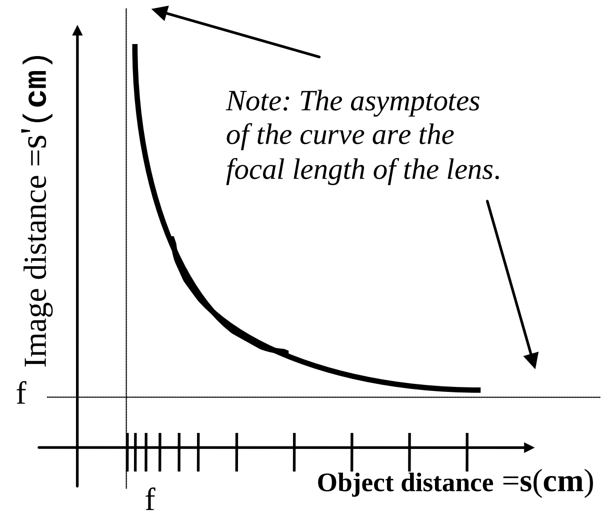

Figure 2 - Focal Graph

4. Image/object distances. As you move the lens farther from the light object, the image location will first move closer to the lens and then farther out (until the lens is at the second limit position, and the image is at the end of the bench). Move the lens in roughly 1-2 cm increments away from the light object, until you get about halfway to the far limit point, then go in steps of 5 cm. Each time you move the lens, you will have to move the screen to find the new image location. Using the chart on the Data/Question sheet, record the lens and image positions. At the same time you record the measurements, you can add the data points to the Excel spreadsheet - the graph will automatically start to fill in. If you decide you want to "smooth out" the graph a little more, go back and take another data point!

Note: The Excel template draws the curve as long as you take the data points in order. If you add data points out of order, you will have to re-sort the data (once you are not adding points). You could then change the options of the graph data series to draw the graph (see the online help page). You will still need to sketch the asymptotes on the final printout based on your calculation of the focal length.

5. Chart and graph. Put the lens and image positions into the chart in Excel. There are equations in the other columns to calculate the object distance and the image distance (such as the ones you used before). The focal length for each of those measurements is also calculated.

6. Finishing the graph after printing. You should be able to produce a graph similar to the one above. **Each member of the group should have a printed graph for the lab report.** On the graph printout, using the vertical and horizontal scale, **hand-sketch asymptote lines (vertical and horizontal) based on your calculations of the focal length from Part 1.2.**

Question Answer on the Data/Question sheet.
Do the lines you drew for the focal lengths seem reasonable in relation to the curve represented by the data points?

Part 3 Investigating Images formed by Converging Lens

In this section we will investigate the image formed by a single converging lens.

1. Generating an image larger than the object. Arrange the light object, the converging lens, and the image screen at the positions for limit position 1. (We want an enlarged image.)

Prediction Answer on the Data/Question sheet
What would happen to the image if you covered up part of the lens with an opaque object? Explain what effect you think that would have on the image size, the clarity of the image, the image position, and the amount of the image seen.

2. Covering lens. Make sure the elements are aligned to give a clear image of the light object. Cover up about a quarter of the lens with an opaque object. Note your observations (based on the question above). Cover up half of the lens. Now cover three quarters of the lens. Cover most of the lens.

Question Answer on the Data/Question sheet.
What did you observe about the size, clarity, position, and extent of the image as the opaque object covers more and more of the lens? Was the entire image intact with most of the lens covered (how do you think that is possible)? Can you think of an explanation of these results?

DATA/QUESTION SHEET FOR LAB 2 LENSES

Part 1 Single converging lens system - measuring limits of the bench

1. Identifying limits.

Questions What difference do you notice in the image formed from each of the two limit positions? In your answer discuss the object and image distances as well as the relative heights between object and image for each location.

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2. Record image/object distances and heights.

Position of the light object = _________ cm
Position of the image screen = _________ cm

a) First limit position of the lens = _________ cm (Lens nearer the light object)

Object height = ________ cm Image height = ________ cm (inverted image is negative)

Object distance = lens position - object position = **s** = ________ cm

Image distance = image position - lens position = **s'** = ________ cm

focal length = $f = \dfrac{s's}{s+s'}$ = _________cm (This is the thin lens formula solved for the focal length, *f*.)

b) Second limit position of the lens = _________ cm (Lens nearer the screen)

Object height = ________ cm Image height = ________ cm (inverted image is negative)

Object distance = lens position - object position = **s** = ________ cm

Image distance = image position - lens position = **s'** = ________ cm

focal length = $f = \dfrac{s's}{s+s'}$ = ___________cm

4. Calculating the magnification.

Using either **2a) OR 2b)** above, calculate the magnifications using

$M_{height} = \dfrac{h_i}{h_o}$ = ______ and $M_{distance} = -\dfrac{s'}{s}$ = ______ (note the negative sign)

In general: $\%diff = \dfrac{|x_1 - x_2|}{\left({(x_1 + x_2)}/{2} \right)} x100$

In general, the x_1 and the x_2 refer to the quantities we are comparing. Usually, one we have measured by one method to one we have measured by a second method (or one that has been provided). In particular, in this case, $x_1 = M_{height}$ and $x_2 = M_{distance}$ or vice versa.

(Note, use the absolute values of the magnifications to find the % diff)

%difference = _______________%

Question How do the two magnification values compare to each other?

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Part 2 Converging lens - Image and object distances - Lens equation

4. Image/object distances.

Lens Pos (cm)	Screen (cm)

Question Do the lines you drew for the focal lengths seem reasonable in relation to the curve represented by the data points?

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Part 3 Investigating Images formed by Converging Lens

Prediction What would happen to the image if you covered up part of the lens with an opaque object? Explain what effect you think that would have on the image size, the clarity of the image, the image position, and the amount of the image seen.

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2. Covering lens.

Question What did you observe about the size, clarity, position, and extent of the image as the opaque object covered more and more of the lens? Was the entire image intact with most of the lens covered (how do you think that is possible)? Can you think of an explanation of these results?

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