Physics Lab 19: Lenses and Images

Goals: Improve communication, teamwork, and note-taking abilities; Use ray diagrams and the thin lens equation to relate the object distance, image distance, and focal length of a lens; Measure the focal length of a lens; Observe the magnification due to a single lens and deduce the single lens magnification formula; Determine what happens to an image when a part of the object or part of the lens is blocked off; Construct a rudimentary telescope and measure its performance; Find fun with physics phenomena.

Equipment: Optics bench; light source, power supply and mount; CC lens and mount; L lens and mount; screen and mount; ruler.

Groups & Lab Notebook: You will be assigned to lab triples (there may be one or two lab pairs). Draw representative set-ups and other figures as directed. Organize data into tables. Update Table of Contents. Your physics lab notebook should reflect your learning and your engagement, and should serve as a ***stand-alone*** representation of what you did and what you learned.

Part 0: Overview, Theoretical Background, and Experimental/Equipment Orientation

Parts 1 – 4 of the lab deal with using lenses to make images. As a class, we'll discuss terminology and sign conventions, how to draw ray diagrams, and the lens equation, as well as orient you to the equipment. Part W: Watching Waves directs you to watch a video on waves, in preparation for next week's work. If you have time to start these today, do so; otherwise complete on your own as part of next week's reading.

Part 1: Lenses as Light-Bending Devices

a) Start with just the light source and the screen (no lenses). Start with the screen close to the light source object. Can you see the cross shaped pattern on the screen when the screen is close? What about when the screen is far away? Leave the screen far away from the light source object, but still on the optics bench.
b) Place the CC lens between the object and the screen. Set the initial d_o to be 40 cm (recall d_o is the distance from the lens to the object). Keep d_o fixed while moving just the screen closer or farther from the lens. Adjust the position of the screen to get as sharply focused an image as possible (more important to have center of the image focused than edges). Measure d_i (recall d_i is the distance from the lens to the image).
c) Use a ruler to draw a scale diagram of your experimental set-up, along with values. You won't need to do this again in this part.
d) Carefully and clearly record in a table d_o, d_i, (along with units) and some notes about the image (large, small, bright, dim, upright, inverted, etc.).
e) Repeat for d_o of 80 cm, 60 cm, and 25 cm. Add to your table.
f) Repeat for $d_o = 10$ cm. What difficulty do you run into? <u>DISCUSS WITH YOUR INSTRUCTOR</u>. Add to your table.
g) Set the distance between the object and the screen to be 100 cm. You should be able to find TWO locations where you can put the lens to get a sharply focused image on the screen. Record these distances, but in terms of d_o and d_i.
h) For fun, remove the light source, and aim out the window. Move the screen until you get a sharply focused image. What do you see?
i) Remove the CC lens from the optics bench, and hold it like a magnifying glass. Look at something (maybe this handout or a drawing in your lab notebook). Try with the magnifying glass close (less than 10 cm from the object) and far (more than 20 cm from the object. What do you notice about the image you see with your eyes (larger or smaller than the object, upright or inverted, etc.)?
j) For the CC lens $d_o = 40$ cm data, use the thin lens equation to determine the focal length of the lens. Do the same for the $d_o = 60$ cm data. Are the results of these calculations consistent?
k) Using the focal length you calculated for the CC lens, use the lens equation to calculate what d_i would be for $d_o = 80$ cm. How does this match your experimental result?
l) Using the focal length you calculated for the CC lens, use the lens equation to calculate what d_i would be for $d_o = 10$ cm. How does this match your experimental result? Can you use this result to explain the difficulty you ran into?
m) Replace the CC lens with the L lens and replace the light source. Determine the focal length for the L lens.

Part 2: Single Lens Magnification

a) Remove the L lens and return the CC lens to the optics bench. Pick some feature on the light source object, and measure its height h_o (note the marks are 1 mm apart, so that is a convenient feature); note that this can be a vertical or horizontal distance. The height h_i of the same feature on the image on the screen can also be measured. For single lenses, the magnification m is the ratio of the image size to the source object size: $m = h_i/h_o$.
b) Adjust d_o and d_i such that the source object and the (well-focused) image are the same size. In a table, record values for the ratio $m = h_i/h_o$, d_o, and d_i.
c) Adjust d_o and d_i to make a well-focused image which is one half the size of the source object. Update your table.
d) Adjust d_o and d_i to make a well-focused image which is twice the size of the source object. Update your table.
e) Can you determine a relationship between d_o, d_i, and m? <u>DISCUSS WITH YOUR INSTRUCTOR</u>.

Part 3: Blocking Some Rays

a) Using the CC lens on the optics bench, get a large, bright, and well-focused image. Consider the following scenarios with your lab partners. WRITE DOWN your predictions. DISCUSS YOUR PREDICTIONS WITH YOUR INSTRUCTOR BEFORE MOVING ON.

Scenario I: Your instructor will use an index card to cover up half the source. What will happen to the image?

Scenario II: Your instructor will use an index card to cover up half the lens. What will happen to the image?

b) After discussing your predictions for the two scenarios, test your predictions with your instructor present.

c) Record your observations.

Part 4: Multi-lens Imagers: Microscopes and Telescopes

An example of a two element optical device is the microscope, which is designed to increase the magnification of an object more than a single lens. The first lens (the objective lens) forms a real image of the object you are examining. This real image (which is inverted) serves as the object for the second lens (the eyepiece). You can set up a simple microscope using your two lenses and your optical bench. Use the small focal length lens as your objective lens, and the large focal length lens as your eyepiece lens. Use the light source as your object.

a) Set up your optics bench with just your light source and your objective lens. Remember that the objective lens for a microscope is the one with the shorter focal length, which in this case is the L lens. Set the distance between the object and the objective lens to be as close as possible (push them as close as you can get them given the mounts). This distance will be close to the focal length of the objective lens. Look through the objective lens at the object. What do you observe (specifically: upright/inverted, magnified/de-magnified, clear/distorted, etc.)? Move your eye closer and further from the objective lens. What do you observe?

b) Now, set the distance between the object and the objective lens to be 10 cm (this is a bit more than the focal length of the objective lens). Look directly through just the objective lens at the object. Move your eye closer and further from the objective lens. What do you observe?

c) Now, add in the eyepiece lens. Remember that the eyepiece lens has the longer focal length, which in this case is the CC lens. Start with the eyepiece lens 30 cm away from the objective lens (this distance between eyepiece and objective is called the barrel length); you may need to adjust this. Look through the eyepiece lens directly through the objective lens at the object. Move your eye closer and further from the eyepiece lens. Adjust the eyepiece lens position until you see a sharply focused and magnified image. Record the barrel length.

d) Draw a scale diagram of your experimental set-up, along with values.

e) While looking through the eyepiece, move the objective lens closer to the object. What happens to the magnification? Does anything happen to the sharpness of the image viewed through the eyepiece?

f) Return to the distances in part c). Now, keeping the objective and eyepiece fixed, move just the object a bit closer to the objective lens (maybe to 8 cm separation distance). What, if anything, happened to the image viewed through the eyepiece? If out of focus, can you adjust the eyepiece position to bring back in to focus?

g) Review your distance data and scale diagram from part d) above. Use the lens equation to determine where the real image formed by the objective lens would be.

h) Calculate the magnification from the objective lens.

i) Use that real image as the object for the eyepiece lens, and determine where the image formed by the eyepiece lens would be (also: is this a real or virtual image?).

j) Calculate the magnification from the eyepiece lens. Also, calculate the overall magnification.

k) Draw an accurate scaled ray diagram.

CLEAN-UP: Return all equipment to the location where you obtained it.

Part W: **Watching Waves.** Do the following if there is time during lab. Otherwise, complete as part of your reading preparation for next week.

a) Watch the following video. Actively engage with the video: pause, re-wind, and re-watch as needed. Write down vocabulary, draw sketches, note questions, discuss with your partners, etc. There is narration, so make sure you have the volume turned on. https://www.youtube.com/watch?v=jUQkG1A0_Sk.

b) Play with the simulation Waves on Strings at https://phet.colorado.edu/en/simulation/wave-on-a-string. Set the Damping to None. Start with Pulse. Investigate the various end conditions. Play with other parameters.