Team Physics 312 Name: ____________________________

SuperFunMiniLab 8C

Date: ___________ Table/Team: _________________________

Thin Lenses and Image Formation

Materials/Equipment:

- Optical bench with lens assortment
  - 1 short focal length convex lens (f_{short} of approx. 5 to 10 cm)
  - 1 long focal length convex lens (f_{long} of approx. 10 to 20 cm)
  - 1 negative focal length concave lens (f_{neg} of approx. -15 to -20 cm)
- Lens holders (use rubber bands to hold the lens in place, **not tape, not gum**)
- Light source (goose-neck lamp with 40W clear bulb)
- Meter stick and/or ruler
- 3x5 cardboard cards
- Optional: You may put books under the optical bench if the lamp is too high

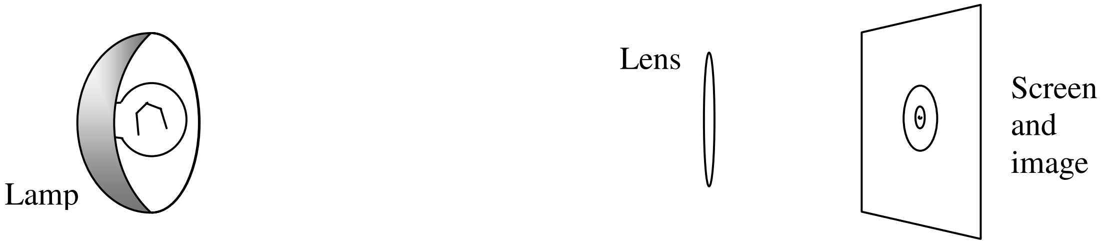
Objectives:

Observe the behavior of lenses and lens combinations, including pinholes. Understand the thin-lens equation, and especially the **sign** choices that arise.

Procedure:

1. The focal length of a convex lens is the distance from the lens to the image of a light source that is infinitely far away. Determine the approximate focal lengths of your convex lenses by measuring this distance with a ruler when forming an image of a distant object (out a hallway window), just to make sure you've got the right ones in the right bags, they may be mislabeled. Write the results here:

2. Arrange the image screen and lamp about one meter apart on your lab table. Hold the long focal length lens between them, nearer to the screen than the lamp, and adjust the **screen's** position until you see a clear, sharp image of the lamp on the screen.



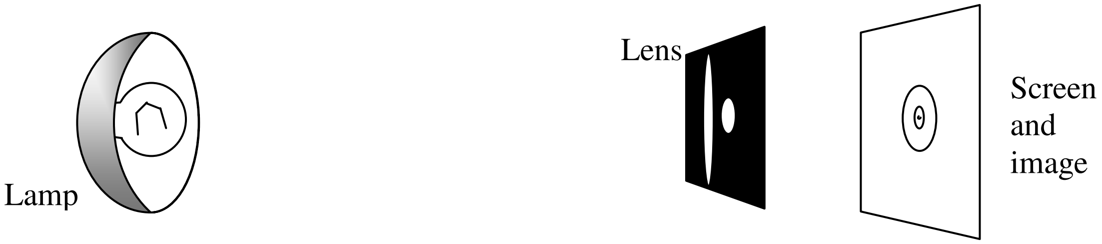
Is the image right-side-up or upside-down? Is it flipped horizontally? How can you tell? [You may want to hold a pencil right in front of the lamp and move it around while watching the image of the pencil.]

3. What do you predict will happen to the image when the top half of the lens is covered so no light gets through that part of the lens? (Answer below before attempting this).

Now try it. Use a 3x5 card to gradually cover the top half of the lens, making sure the card is close enough to touch the lens. What do you observe? Does it agree with your prediction? [Don't change the prediction! It is OK if you predicted wrong, as long as we're learning here.]

What happens if you cover the bottom half or a side half of the lens?

4. What do you predict will happen to the image if you cover the entire lens except for a small hole?



Try it. **Safely** punch a small hole (about one or two mm in diameter) in a card and hold it against the lens. Try moving it around so you see how the image looks when the light goes through different parts of the lens. What do you observe?

5. Draw a conclusion: Does light from one point on the lamp go through only one particular part of the lens, or does light from all points on the lamp go through all parts of the lens? Justify your answer in terms of your observations.

6. Predict what will happen to the image if you remove the lens and leave the card with the small hole in it.

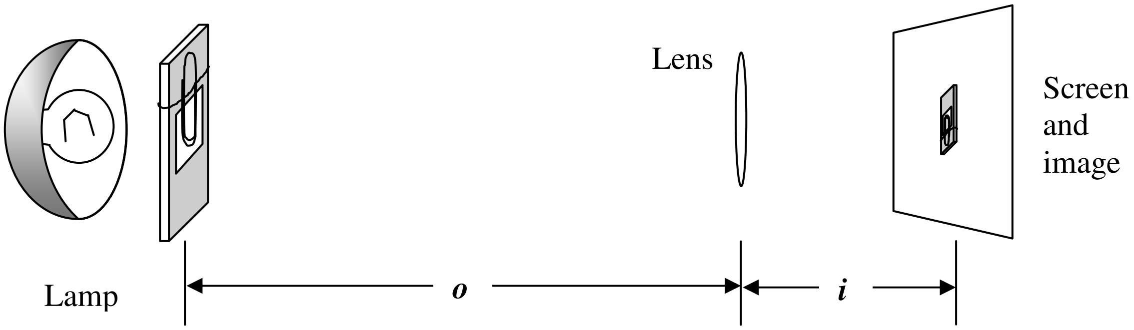
7. Try it. Instead of removing the lens from its holder, just replace the lens and holder with a different holder that has a card with a small hole in it. What do you observe?

You may have heard of a "pinhole camera." This is just a camera that has a tiny hole, like the one you are using, instead of a lens. For better results, you may want to try a smaller hole, but there is always a trade-off as this reduces the brightness of the image.

Brain-buster: Does a focal length for your pinhole make sense? What do you find when you try to measure it?

Thin-lens equation and magnification

Attach a paperclip in a lens holder (it's magnetic) as shown below and use this as your object for the remainder of the lab. You can bend them if needed; they're not special physics paperclips.



The thin-lens equation relates the focal length ***f*** of a lens to the object distance ***o*** and the image distance ***i***:

$$\frac{1}{f}=\frac{1}{o}+\frac{1}{i}$$

When a lens forms an image of an object, the size of the image is generally different from the size of the object. We define the lateral magnification m to be the ratio of image height h_i to object height h_o (where "height" means the distance from the bottom of the image to the top of the image, for example, not the distance from the table top). If an image or object is inverted, we take its height to be negative.

$$m = \frac{h_i}{h_o}$$

Measurements

8. Set up the long focal length lens so it forms an image of a distant object on the screen. (This step was done earlier, so only repeat it if you think your measurements might be more accurate now that you've fiddled with things a little). Now **accurately** measure the distance from the screen to the **center** of the lens. Since the object is far away, record this result as the focal length of the lens:

$f =$

9. Set up the paperclip and lens as in the diagram. Can you see the chromatic aberration around the edges of the image? **Accurately** measure the object and image distances:

$o =$ $i =$

10. Use the thin lens equation to compute the focal length from your measurements in step 9, and record the result here. How closely does this agree with your measurement from step 8?

11. Measure the width of the paperclip (some convenient reference distance on it) and measure the width of its corresponding image. Compute the magnification:

$h_o =$ $h_i =$ $m =$

12. Compare the magnification from step 11 to the negative of the ratio of the image and object distances. (Remember that an inverted image has a negative height.)

$$-\frac{i}{o} =$$

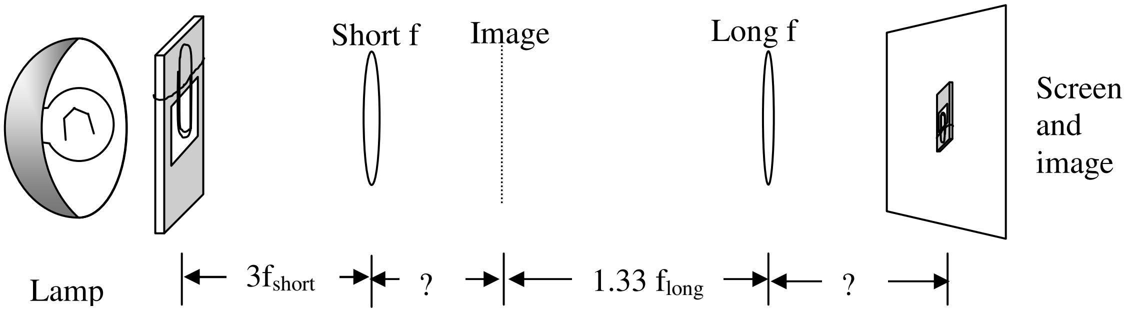
13. Repeat steps 8 through 12 using the short focal length lens, and record the results here:

14. The textbook shows that the magnification is related to the ratio of image and object distances: $m = - i/o$. How well did that hold for your measurements?

15. Notice that the thin lens equation is symmetric in the variables o and i. Try setting up the paperclip and long focal length lens with the distances reversed. That is, set it up so that the lens is now as far from the *paperclip* as it was from the screen in step 9. It will now be as far from the *screen* as it was from the paperclip in step 9. What do you see on the screen?

16. Measure the magnification and record the result here. Does it agree with $m = - i/o$? The image may be very large now and difficult to measure, but give it your best try. If it's really screwed up, try starting with different numbers in step 9.

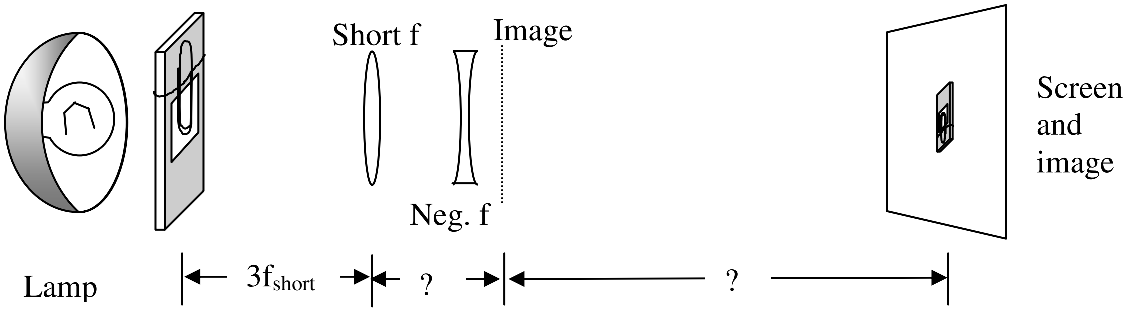
17. Put the short focal length lens in a holder and place it approximately a distance of 3 f_{short} from the paperclip. Using the screen, locate the image of the paperclip. Measure the image distance and compare it to what you calculate with the thin-lens equation.



Put the long focal length lens in a holder and place it approximately a distance of 1.3 f_{long} from the image. (These are very rough estimates of the distances, and they'll vary for the different lenses, so you may have to alter this configuration significantly to get it to work). Using the screen, locate the image created by the long focal length lens (see diagram above). You might have to fiddle with the distances a little to get this to work, as the lenses are of various focal lengths. Measure this image distance and compare it to what you calculate with the thin-lens equation. Is the resulting image due to the two-lens system inverted or erect? Why?

<u>Show work here</u>:

18. Leave the short focal length lens where it is and remove the long focal length lens from the setup. Place the negative lens in a holder and arrange it *in between* the short focal length lens and the image position you found earlier for the short focal length lens. Using the screen, locate the image formed by this two-lens system.



Is the resulting image due to this two-lens system inverted or erect? Why? Measure the image and object distances for the negative lens (Note that its object and image are both on the *same side of the lens* in the drawing above, so the Image goes in with a minus sign and the screen is positive in the last stage). Be careful with the signs! Use the thin-lens equation to calculate the focal length of the negative lens. (Note: You couldn't otherwise do this trying to project a real image with just the concave lens by itself. This is one way to determine a focal length if f < 0).

<u>Show work here</u>:

19. If you have extra time: Experiment with one short and one long focal length convex lens used together to see if you can make a simple telescope. Draw the ray diagram to explain what is going on here. (hint: you'll want to look through the short focal length lens with your eye fairly close to it.)

Circle one: (comments from previous quarters)

(a) This lab was both exciting and challenging. My head is spinning with the possible industrial applications of the thin lens equation. I'll have problems sleeping tonight.
(b) This lab sucks; I could have been sleeping now. (Please attach revised lab script).
(c) I know all this already. (Please attach full derivation of the thin-lens equation).
(d) What happened to burning ants?
(e) These lenses taste like rubber bands.

Other: ____