I. Before you come to lab

Read through this handout in its entirety.

II. Learning Objectives

As a result of performing this lab, you will be able to:

1. Use the thin lens equation to determine the focal length of a converging lens;
2. Understand the difference between a real image and a virtual image;
3. Combine two lenses of different focal lengths to form a compound microscope.

III. Materials

Wooden framed lens

This is a double-convex glass lens mounted in a wooden frame. We will use this as the eyepiece for our microscope.

Florence flask filled with water

The spherical part of the flask acts like a converging lens. Although it can be considered a thick lens, for our purposes the thin lens formula will be an adequate model. We will use this as the objective for our microscope.

Tea candle and kitchen matches

The candle flame will be the object that we are interested in imaging.

Lab jacks

We will use the lab jacks to vertically align the candle flame with the lens.

Two-meter stick

This will be used to measure distances as well as provide a tool for horizontal alignment.

Section of white posterboard

This will be used as our screen.

Mounted print and desk lamp

We will look at the mounted print through our microscope. The desk lamp will make the print easier to see.

IV. Procedure

Who are you? (Picture, full names, and emails please)

A:

Part 1: Investigating the thin mounted lens

In this part of the lab, you will use the thin mounted lens to project an image of the candle flame onto the screen.

ALIGNMENT

Position both lab jacks alongside each other. Place the tea candle in the center of one of the lab jack platforms, and place the mounted lens in the center of the other. Adjust their heights so that the top of the candle wick is the same height as the center of the lens. The two should now be vertically aligned.

Place the two-meter stick flat on the bench, with the metric markings facing up. At one of the ends, line up the bases of the lab jacks with the stick. The object and lens should now be horizontally aligned.

REAL AND VIRTUAL IMAGES

Light the candle. Place the lens 15 cm away from our object, the flame.

Can you place the screen anywhere to form a crisp image of the candle flame on it?

A:

With your eyes approximately 2 meters away from the flame, look at it through the lens.

Is the flame upright or inverted?

A:

We will use the applet on this website to understand what's going on:

physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses/Optics-Bench/Optics-Bench-Refraction-Interactive

Like the setup on your lab bench, you have a candle you can move, a lens with a variable focal length, and light rays that converge to show you where you would find a crisp *image* of the candle. If the converging light rays are dotted lines you have a "virtual image" and if the converging light rays are solid lines you "real image."

In the applet, move the focus slider labelled “f” all the way to the right (this increases the focal length of the lens). Now move the candle half way between the lens and the dot indicating the focal length.

Take a screenshot of the applet in this configuration:

[Screenshot of ray diagram in applet]

With the applet in this configuration, is the “image” of the candle (not the candle you moved, the other candle) real or virtual? Is the image larger or smaller than actual candle you moved?

A:

Now back to the setup on your workbench.

Looking through the lens from 2 meters away, is this a real or virtual image, and why?

A:

At this distance, does the flame appear larger or smaller than it does without the lens?

A:

What can you infer from your answers to the previous four questions about the location of the object relative to the focal length of the lens?

A:

Now place the lens 35 cm away from the candle flame.

Can you place the screen anywhere to form a crisp image of the candle flame on it? If so, where is the screen relative to the lens and the object?

A:

Play with the applet to try to get a setup like the one on your workbench. That is, if you see an image on the screen that is very small (or very large) try to get that same magnification, in that same location, in the applet. **Take a screenshot of the applet in this configuration:**

[Screenshot of ray diagram in applet]

With your eyes approximately 2 meters away from the object, look at it through the lens.

Is the flame upright or inverted?

A:

Is this a real or virtual image, and why?

A:

At this distance, does the flame appear larger or smaller than it does without the lens?

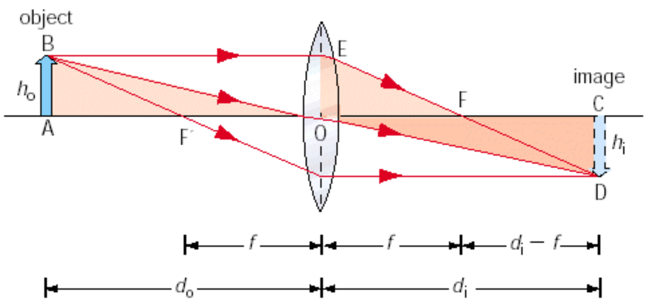
A:

THIN LENS FORMULA

The thin lens formula is

$$\frac{1}{d_0} + \frac{1}{d_i} = \frac{1}{f}$$

where



d_o is the distance from lens to object,
d_i is the distance from lens to image,
f is the focal length of the lens.

With the lens 35 cm away from the object, use the screen to find the location along the optical axis nearest the lens where the image is as sharp as you can get it.

Open Logger Pro (GeometricOptics.cmbl) and enter the image distance for a 35 cm object distance. Repeat for 5 different d_o's.

You may notice that a plot of d_o vs d_i is not a straight line; this does not tell us much about the focal length. Instead, we will use the following trick: We will cast the thin-lens formula into the canonical straight-line form (y = m*x + b) so that it reads

$$\frac{1}{d_0} = -1\frac{1}{d_i} + \frac{1}{f}$$

y m x b

From this we see that a plot of $1/d_o$ versus $1/d_i$ should yield a straight line of slope −1, and 1/f will be the y-intercept.

Use the graph of $1/d_o$ vs $1/d_i$ to estimate the focal length of the mounted thin lens.

A:

Position the lens so that the object is at the focal length.

Take a screenshot of the applet in this configuration:

[Screenshot of ray diagram in applet]

Can you place the screen anywhere to form a crisp image of the candle flame on it? Does this agree with your ray diagram?

A:

With your eyes approximately 2 meters away from the object, look through the lens at the object. **Describe what you see.**

A:

If instead of a candle flame on your bench, you had a bright light source very far away ("at infinity"). **How could you determine the focal length of your lens with just one measurement?**

A:

Part 2: Investigating the thick spherical lens

We will now approximate a Florence flask filled with water as a thin lens, and will use the thin-lens formula to find the focal length.

ALIGNMENT

Replace the mounted thin lens with the Florence flask. Adjust the heights of the lab jacks so that the center of the spherical part of the flask is at the same height as the flame. Adjust the flask and the candle so that they are horizontally aligned.

FOCAL LENGTH

We will now repeat the procedure we used for the mounted thin lens to find the focal length of the flask. Measure d_i for d_o = 16 cm, 18 cm, 20 cm, … 34 cm and enter these data into LoggerPro. Plot $1/d_o$ vs $1/d_i$ and find the y-intercept. If you have trouble getting a crisp image of the flame, then try holding the piece of cardboard with a hole in the middle between the flame and flask, and nearly touching the flask (this doesn't allow light rays from the candle to reach to edges of the flask, making it act more like a thin lens)

Use the graph of $1/d_o$ vs $1/d_i$ to estimate the focal length of the flask as we did before for the other lens.

A:

Place the candle flame and the flask at opposite ends of the 2-meter stick.
Is the focal length you observe close to what you calculated from the graph?

A:

Use the ruler to measure the radius of the spherical flask. How does its radius compare to its focal length?

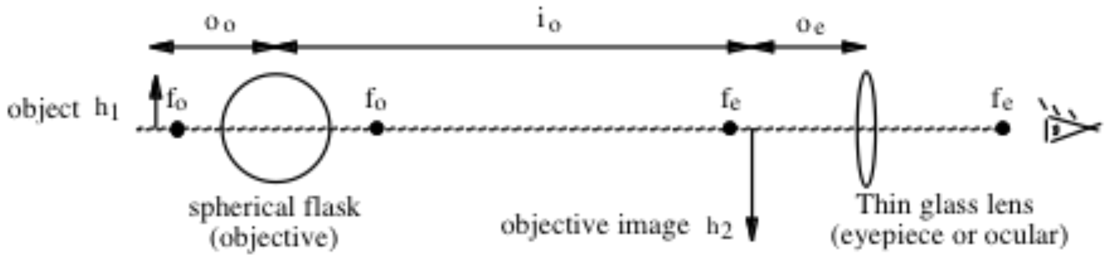
A:

Do your measurements agree with the "ball" lens equation, $f_{ball} = \frac{nR}{2(n-1)}$, where R is the radius and n the index of refraction of water?

A:

Part 3: Compound microscope

Now we will combine our two lenses to make a microscope. The short focal-length *objective* lens will be the flask, and the longer focal-length *eyepiece* lens will be the mounted lens.



The object to be examined should be placed just slightly outside the focal length of the objective. This “intermediate image” is formed a distance i_o from the objective and a distance o_e from the eyepiece. If the eyepiece is positioned so that the intermediate image is just within the focal length, then we should be able to see a magnified virtual image very far away.

SET UP THE MICROSCOPE

Place the mounted print at the end of the 2-meter stick. Illuminate the print by bringing the desk lamp as close as you can to it. Align the objective at a distance of 16 cm from the object.

Based on your previous measurements, where do you expect the intermediate image to be formed?

Align the eyepiece with the objective so that the intermediate image is just within the focal length of the eyepiece.

Start with your eye close to the eyepiece; you should see the printed material in the central portion of the objective and greatly distorted images in the rest of the objective (you may want to have your lab partner make small adjustments to the alignment of the object and objective). Move your eye away slowly, keeping the central portion of the objective lined up with the center of the eyepiece. At one position, the field of view of the central area seems to just fill the eyepiece lens. This is the optimum position for the eye, called the “exit pupil.”

Describe what you see.

A:

The magnifying power of a microscope can be defined as the ratio of the angular size of the object when viewed with the microscope to the angular size of the object when viewed at 25 cm from the naked eye.

Use a ruler to estimate the magnification of your microscope.

A:

Bonus (not required): Magnify the center of the tails side of a penny. What is there

hidden?

A:

VI. Conclusion

What is the most important thing you learned in lab today?

A: