Lab 9: Converging and Diverging Lenses Pandemic Edition

In today's lab, you will experiment with the thin lens equation and determine the focal length of converging and diverging lenses.

Important note: your light source should be located close to zero on the meter stick.

Part I: Converging Lenses

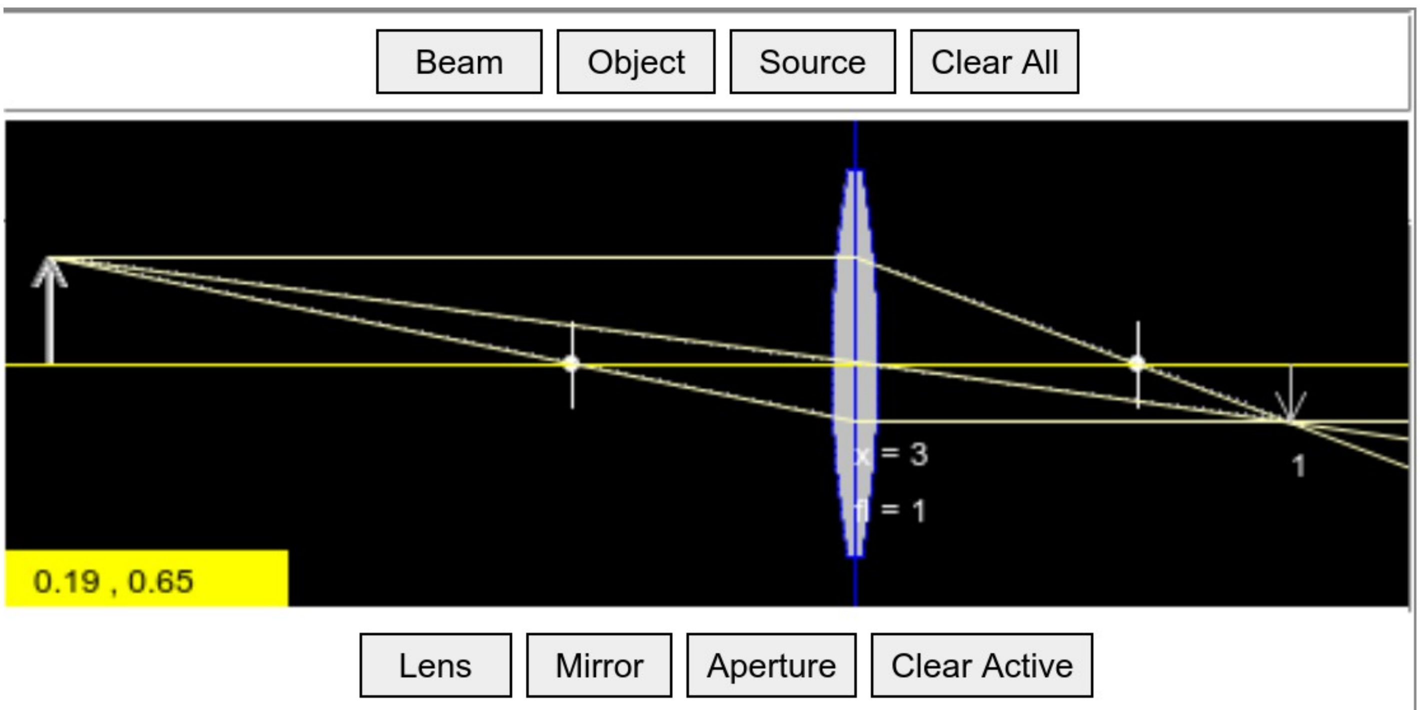
I want you to run the OpticsBenchApplet (I should have already started it for you).
Set up the following situation:

Lens:

a converging lens at 2.00
adjust the focal length so one point is at 3 while the other is at 1.
Look in the yellow box for these coordinates. This will give a focal length of 1.

Object:

Place a relatively small object at 0.15
Now move the lens to **3.0** . Notice where the image is located. You will see that the image is outside the focal length, it is inverted and reduced.



Next I want you to SLOWLY move the lens back towards the object and notice how the motion of the image occurs. Also notice that while the image remains inverted, at one point the motion changes direction ... instead of moving to the right it starts moving to the left. Notice the lens location and the image location where this happens. You can move your mouse over the image to see the result which, if you have done it correctly is about **4.19.** This means that the distance from the image to the object is **4.04** units. The lens is located at **about 2** units meaning it is about **2.19** units from the object. Now continue to move the lens towards the object and you should continue to observe the image characteristics. Instead of being reduced, it will be enlarged.

The characterizations of the image are:
(first case): Real: Inverted: Reduced
(second case): Real: Inverted: Enlarged

You will notice (see details below) that the minimum distance between the image and the object is 4 focal lengths. This would be in general true for the thin lens equation and converging lenses since the units here are rather arbitrary. You are going to observe exactly this behavior in reality in the lab today. In another firefox window, download the spreadsheet helper for today's lab. You'll want to open up the spreadsheet helper for today's lab and look at the converging lens data that I took first (then, delete it).

Since f>0 and s_0 is greater than zero, we are assured that a real image will result here.

Suppose that the image and the object are separated by a distance d. The object distance is then given by:

$$s_0 = d - s_i$$

We want to find out what the minimum distance between the image and object is.

Use this in the thin lens equation:

$$\frac{1}{f} = \frac{1}{s_i} + \frac{1}{d - s_i} \Rightarrow \frac{d - s_i + s_i}{s_i(d - s_i)} = \frac{d}{s_i(d - s_i)} \Rightarrow s_i(d - s_i) = fd \Rightarrow -s_i^2 + s_i d - fd = 0$$

So the equation that needs to be solved is this:

$$s_i^2 - s_i d + fd = 0$$

$$s_i = \frac{d \pm \sqrt{d^2 - 4fd}}{2}$$

The roots of this have to be real for a physical solution which means

$$d^2 \geq 4fd \Rightarrow d \text{ or } d \geq 4f$$

The minimum distance between the image and object is then given when

$$d = 4f$$

Warning: The light bulb covers can become hot. Don't touch them!

You should set up your system in the following way:

Object: at 1.5 cm

The most common mistake is to not do this.

Converging lens: close to the object

Screen: at 95 cm

You'll want to cut your lamp on but don't apply more than about 40% of the full scale voltage since this will destroy the lamps.

Now move your converging lens until you obtain an image. Record the location in the spreadsheet under Lens p1. Then move the lens until you obtain the second image. Record your lens location under Lens p2 on the spreadsheet. Both of these locations are recorded beside the "95" screen position. Now continue making measurements for each of the locations that I've indicated on the spreadsheet. You should see the graph of object position vs image position start to fill out. You should particularly notice if any of your measurements have not followed the curve since it is very easy to make an incorrect reading from the meter stick in partial darkness. If you see an incorrect measurement, repeat the measurement rather than discarding it. **Do two measurements of lens position for each of the screen locations shown on the spreadsheet. Note that the helper has 2 tabs, one for each part of today's lab.**

Now enter your data into the spreadsheet. Note that p1 refers to the position when the screen when the lens is closer to the screen and p2 refers to the position when the screen if far away from the lens. Then using the control bar, solve for the converging focal length by minimizing the error criteria given in cell k9. In principle, the focal length of the converging lens ought to be about 10 cm. The solver will be fitting directly to the thin lens equation which is

$$\frac{1}{s_i}+\frac{1}{s_o}=\frac{1}{f}$$

in order to determine the focal length.

Part II: Measurement of the focal length of a diverging lens

Now that you have measured the focal length of the converging lens, I want to show you how to do this with a diverging lens. Open your optics bench. Move your converging lens until the image appears at **about** 4.5.

You have two positions that you could choose here. Choose the converging lens position which is closer to the light source (although good results can happen for the other choice) for this portion of the lab.

I'm going to call this image I1. Now you will not move the converging lens again and you know that the image from the converging lens is exactly located at 4.5 units.

Next, insert a diverging lens and adjust the focal length of it until it is -1. You can do this by pulling one of the focal points through the lens. The bottom number should say 1 although seeing the negative sign is not too easy.
Now place the diverging lens between the converging lens and I1 and close to I1. This image will serve as the object for the diverging lens. Since it is behind the lens, it is a virtual object so we can have a real image resulting from this combination. You will observe the image I2 which is inverted from the original object but not inverted from the virtual object. Let me show you how to define the distances:

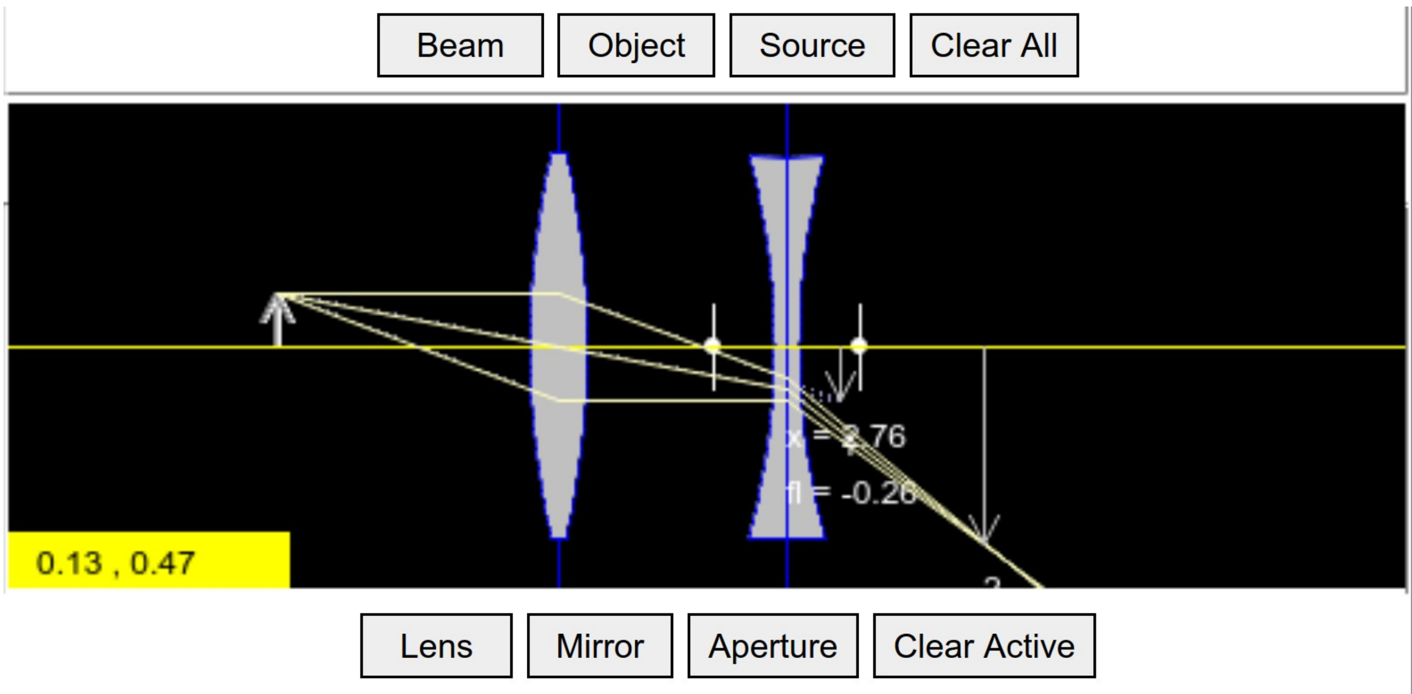
Diverging Lens position: DL (try maybe 2.75 here)

Virtual object position: 3.0

$d_{o,2}$ =object distance=DL-3.0 (which is negative).

$d_{i,2}$ =second image distance=I2-DL (which is positive).

You can choose other distances here as you like. I think you will see the effect.



So long as you do not move the lens so far from the virtual object so that it is outside the focal length of the diverging lens, an image will form. In practice we won't have a problem with that in lab since our meter stick is only 1 m long.

I would characterize the overall image as {inverted: real: enlarged}.
One further note: although we won't use this in today's lab, the final magnification is the image is the product of the individual magnifications:

$$M=M_1M_2$$

Now I want you to set up a similar situation on the meter stick: place the screen at: **(Important note here: with the new lenses, you will need to set the screen at S=50 because the image at S=45 is not clear)** S=50 cm. Move the convex lens away from the screen towards the light source so that the first (closest) image appears on the screen. The image ought to be reduced, that is how you can know you have the correct image here. You will not adjust the convex lens again in the lab. You must keep the first image exactly at the present location!

Now place the diverging lens between the converging lens and the screen, with it being closer to the screen. Move the screen to: **(Important note here: with the new lenses, you may need to choose S=51 if the image from above was formed at S=50) S=50 (Cell C2)**. **In your spreadsheet for the diverging lens, if you used sometyhing other than 50 , you will need to change that cell. This is cell C2 in the diverging lens tab.** Move the diverging lens until a sharp image forms and record the lens position in the spreadsheet. Repeat these measurements for each of the positions specified in the spreadsheet. You will want to delete my data before you start entering your own data in the spreadsheet. If you can't do positions close to the screen, do them as close as you can to start with.

Now I want you to run the solver to fit the thin lens equation for the focal length of the diverging lens. After you run your solver, you should obtain a focal length which is around -10 (the lenses are supposed to have this focal length but, as you can see from my data, I had about 10 % error in this measurement). One thing about which you can be sure is that if your focal length is not negative, there was an error somewhere.