Concave Lenses and Lens Combinations

Goal: To determine the focal length of a concave lens and to better understand how to locate images for lens combinations.

Lab Preparation

We have studied lenses and how they form images. In the previous lab you used different methods to determine the focal length of a lens and how to find real images. The basic relationships that are often used are the thin lens equation and the magnification equation:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \qquad\qquad M = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$$

Convex or converging lenses have positive focal lengths. When rays parallel to the optical (principal) axis hit a convex lens they converge to the focal point of the lens (Figure 1).

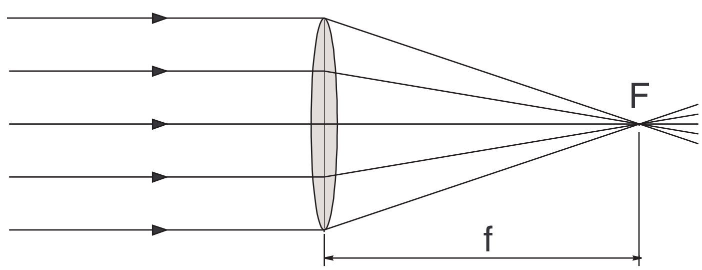


Figure 1

When parallel light rays hit a concave or diverging lens the lights rays diverge away from a focal point which is on the same side as the incoming light, thus it is more complicated to find the focal length of this type of lens because the image that is formed from a single concave lens is not real and cannot be put on a screen (Figure 2). The focal length is negative for this type of lens since the focal point is on the same side as the incoming light.

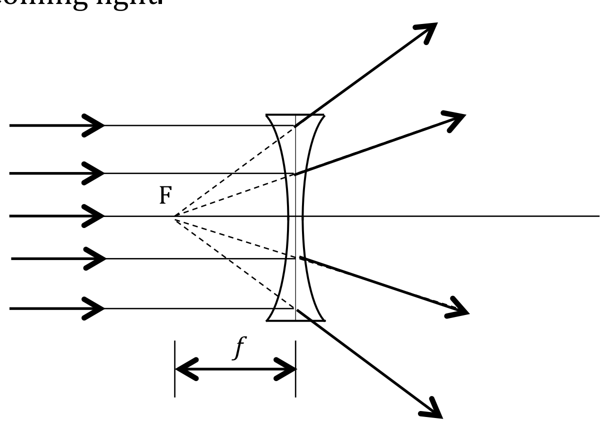


Figure 2

For combinations of lenses, the key is to remember the following: **the image of the first lens is the object for the second lens.**

I. Finding the image from a single concave lens

A. To start with let's review that you remember how to find the image formed by a concave lens. Graphically solve the following problem to scale on a single sheet of paper and measure the image distance. Remember that real light rays (where the light actually goes) should be solid and any other lines (extending rays back, alignment lines) should be dashed.

A flea is 64 cm to the left of a concave lens, which has a focal length of -24 cm. Locate how far the final image is away from the lens.

B. Solve the problem mathematically using the given values (on the bottom of the same page that you solved it graphically is fine) to confirm your answer.

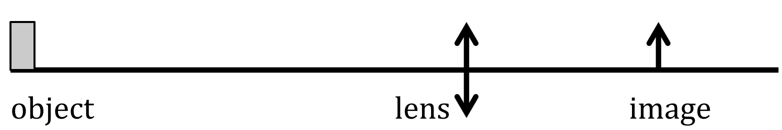
C. Put the lighted object on one end of your optical table and place your concave lens around 60 cm away. To locate the image, look directly through the concave lens at the object and you will see the image of the object. Answer the questions below (use your graphical method from part A to help).
1. Is the image smaller or larger than the object?
2. Is it real or virtual?
3. Is it upright or inverted?
4. Do these answers agree with your graphical method from part A?

II. Finding the focal length of a convex lens

In the previous lab, you used many methods to determine the focal length of a convex lens. Using the convex lens provided and the other equipment on your table, determine the focal length of the convex lens using two of these previous methods. Make sure you record the method used and the value determined for the focal length. You may use the average of these values or whichever you feel is more accurate.

III. Finding the focal length of a concave lens by use of a lens combination

A. Place your object at one end of the optical bench at 0 cm and place your convex lens 70 cm from the object and locate the image formed by the convex lens. Record the position of your object, lens, and image on a diagram similar to the one below. Measure and record your object height (h_{o1}) and your image height (h_{i1}). Record whether the image is inverted or upright and calculate the magnification (M_1). Determine your object distance (d_{o1}) and your image distance (d_{i1}) for the convex lens (lens 1).



B. Answer the following conceptual question and explain:

If a concave lens is now placed between the convex lens and the screen, will the light rays that were forming the image be converged closer together or diverged further apart?

C. Move the screen near the end of the track and place the concave lens in between the convex lens and your screen. Adjust the position of the concave lens until a clear final image is produced on your screen. Record the position of the concave lens and the final position of the screen on a diagram similar to that from part A. Measure and record your final image height (h_{i2}). Record whether the image is inverted or upright. Determine your object distance (d_{o2}) and your final image distance (d_{i2}) for the concave lens (lens 2). Remember, the image of the first lens is the object for the second lens.

D. Calculate the focal length of the concave lens (lens 2) and compare it to the value printed on the lens.

E. Calculate the overall magnification of you two lens system using your measured heights h_{o1} and h_{i2}.

IV. Graphical method: finding the image from a lens combination

We now want to gain an understanding as to what is actually happening to the light rays that go through the two lenses. On a separate sheet of paper (make sure you scale appropriately to use the whole paper) we want to graphically locate where the final image is for the values used in the experiment. Follow the steps below to locate the image and make sure your pencil is sharp.

A. Draw an optical axis and put in the object (object 1 - make it 3 cm tall), the convex lens (lens 1), and the concave lens (lens 2). Use your values from part II and part III. Also put in the focal points of the lenses on both sides of the lenses (mark them F_1 and F_2). Make sure everything is labeled and the distances (not including the object height) are scaled so the images will all fit on your paper.

B. Locate the position of the image from lens 1 (image 1). Do this by drawing two rays that start at the object. Draw one ray that goes parallel from the object to lens 1 and then goes through the focal point F_1 on the other side of the lens. For the second ray draw a ray that starts at the object and then goes through the focal point F_1 that is on the same side of the lens as the object until it hits lens 1. When this ray reaches lens 1 you should be able to determine where the ray goes. Remember that you should only have solid lines up to lens 2, after that they should be dashed because the rays really don't go to the location of image 1 (they get refracted by lens 2). Draw and label image 1 on your diagram.

C. We now have to ask: Where do the rays really go when they hit lens 2? We know parallel rays that hit lens 2 will go away from the focal point of lens 2. We also know rays that hit the center of lens 2 pass right through without bending.

   Take a look at the rays you have drawn to locate image 1. Can you figure out where they really go when they hit lens 2? If you can then draw a solid line where the ray really goes when it hits lens 2.

   At this point you should have one ray of light that goes from the object through the two lenses. If we can find another ray that goes all the way through we will be able to use these two rays to locate the image.

   We know that every light ray that hits lens 1 goes towards the location of image 1. We want to choose a ray such that when it hits lens 2 we will know where it goes. To do this you can work backwards from image 1 (since this is really the object for the second lens - object 2). Draw a line that goes from image 1 through the center of lens 2 back to lens 1. Now draw a line that starts from the point where it hit lens 1and goes back to the object (object 1). Although we drew this backwards, the light ray really started at object 1 and went through lens 1 and then lens 2.

D. You should now have two solid light rays that start at object 1 and pass through the lenses. The image is located where these two light rays cross. Draw and label this image 2.

E. Measure the final image distance from lens 2 and compare it to the result found experimentally from part III (use the experimental value as the correct value).

<u>Homework</u>

#1. (Do in lab if time) If you switch lens 1 and lens 2 will you get the same result for a final image distance? Try it and see (or calculate what it would be).

#2. Is the final image from your two lens system real or virtual? Why?

#3. Calculate the overall magnification of the final image from your two lens system using your object and image distances from part III. Compare with your measured value of magnification from part IIIE.

#4. Measure h_{o1} and h_{i2} on your graphical method for part 4 and use them to find the overall magnification. Compare with your measured value of magnification from part IIIE.