Lenses and Ray Tracing

Name:

Group Members:

Date:

TA's Name:

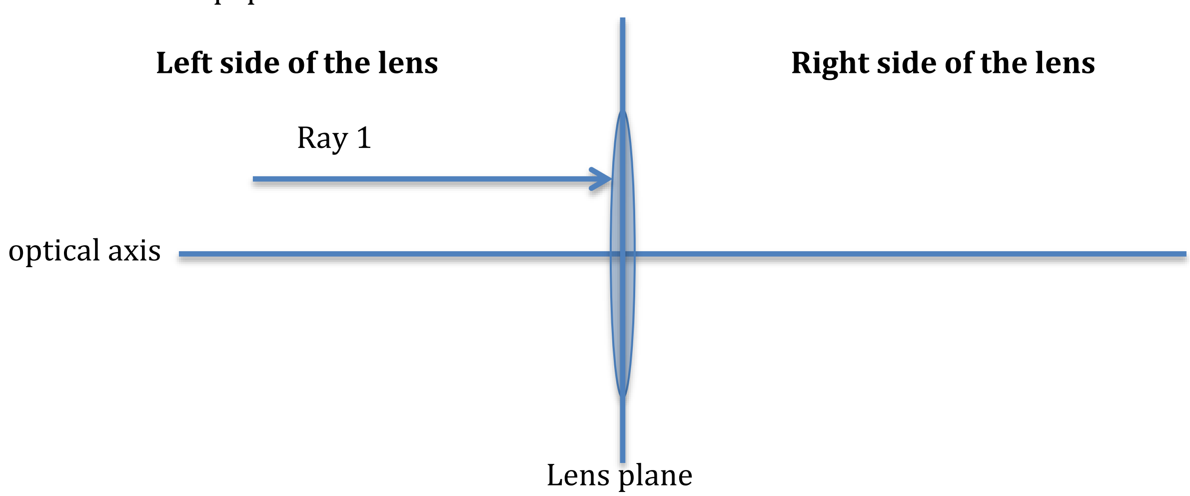
Materials: Ray box, two different converging lenses, one diverging lens, screen, lighted object, three stands, meter stick, two letter size white pages, and pencil.

Objectives:

1. Understanding real image formation from lenses due to refraction.
2. Practicing ray tracing for converging and diverging lenses
3. Understanding magnification and using a lens combination to improve magnification

Part 1: Ray Tracing

1. Draw a long straight line down the middle of a sheet of white paper to be our optical axis. Draw a line perpendicular to the optical axis in the middle of the page to be our lens plane. Take the thinner converging lens out from the box and place it on a white sheet of paper as shown below. (DO NOT use the thickest one.) Now use the ray box to produce a single ray coming from the left side of the lens running parallel to the optical axis. Notice that the ray is refracted by the lens and changes direction. Trace onto the paper the path of the ray before and after going through the lens and label this as Ray 1. Mark the point where the refracted ray crosses the optical axis with an "**F**." This point is the right side focal point of the lens. Be careful not to change the position of the lens on the paper.

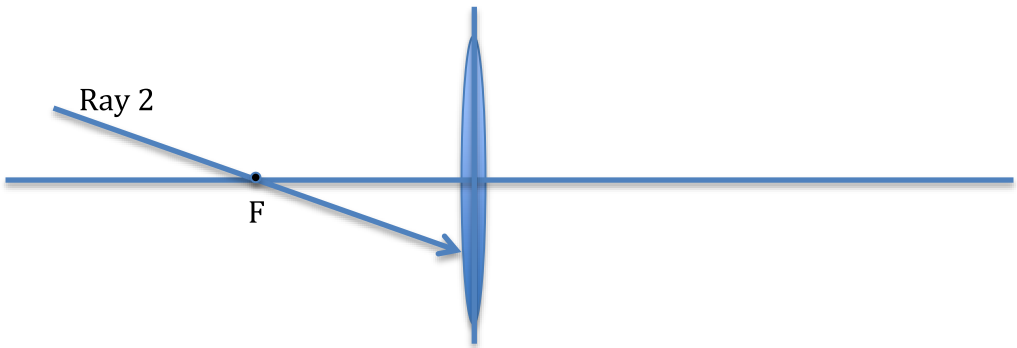


2. The shortest distance from the lens plane to the focal point is called the focal length. From your ray diagram measure the focal length, f, of the converging lens. Remove the lens to do this but put it back in place when done.

   f = ______________________________ Remember Units

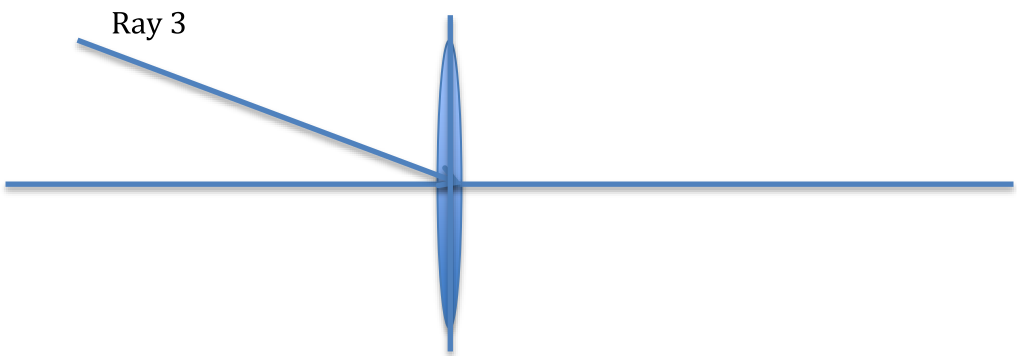
3. Now use a parallel ray coming from the right side of the lens to locate the focal point of the lens on the left side. Also mark this point with an "**F.**" Is the focal length the same as you found in Question 2?

4. Send a ray from the left side of the lens through the left side focal point and into the lens as shown below. Trace the ray onto the paper before and after it is refracted by the lens and label it on your paper as Ray 2.



5. After going through the lens, is the refracted Ray 2 parallel to the optical axis?

6. Send a ray directly through the center of the lens and trace the ray. Label it as Ray 3 on your paper.



7. Summarize the behavior of each of these three rays (called principal rays) after they pass through the converging lens.

Ray 1 – a ray parallel to the optical axis ____

____

Ray 2 – a ray passing through the front-side focal point ________________________________

____

Ray 3 – a ray passing through the center of the lens ___________________________________

____

8. Now we will use these three rays to construct a ray diagram in order to locate an image. For that on a separate sheet of paper draw the optical axis and the lens plane. Use your measured value of the focal length to mark the left and right side focal points and label them each "F." Now draw an arrow with its base at the optical axis which has a height, h, of 1.0 cm and is located 10.0 cm from the center of the lens (10.0 cm will be the object distance, s). This arrow represents the object.

9. We will use the ray tracing method to find the image. We do this by locating the image point for the tip of the object. This tells us where the tip of the image must be. Use the ray box to create Ray 1 which passes through the tip of the arrow and continues parallel to the optical axis until striking the lens. Trace Ray 1 onto your paper both before and after passing through the lens. Use the ray box to create and trace Ray 2 passing through the tip of the arrow and through the left side focal point before striking the lens. Create and trace Ray 3 passing through the tip of the arrow and then through the center of the lens.

10. Do the three refracted rays cross at a single point? Yes or No.
    If not, do they cross nearly at the same point? Yes or No.
    This crossing point is the location of the tip of the image. Draw an arrow with its tip at the crossing point and its tail at the optical axis to represent the image.

11. Is this image real or virtual? ________________________
    Explain your reasoning using the features of your ray diagram to support you answer.

12. Is the image upright or inverted? _______________________________
    Explain how you know.

13. Measure the height of the image, h'. If the image is inverted then make your image height negative to indicate that image is inverted. Remember units.

    h' = ____

14. The ratio $\frac{h'}{h}$ is called the magnification. What is the magnification?

    $m = \frac{h'}{h} =$ ___________________________________ Be careful with the units here!

15. The distance from the center of lens to the tail of the image is called the image distance, s'. Measure it for your ray diagram.

    s' = ____

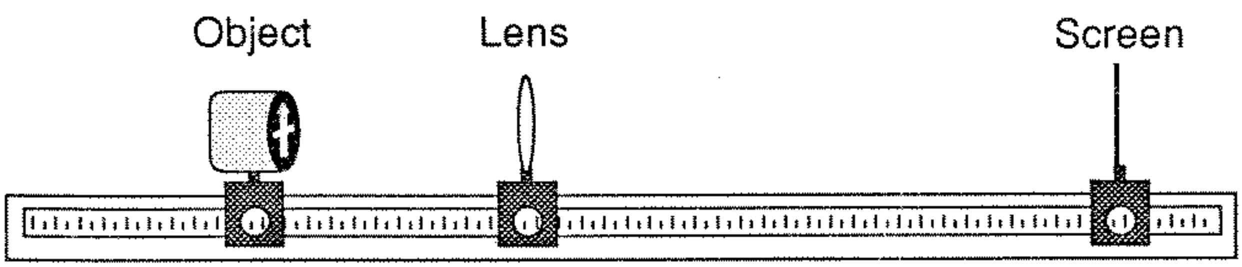
16. Using geometry we can predict that the magnification will also be equal to $m = -\frac{s'}{s}$. Use the object and image distances to calculate M.

$m = -\frac{s'}{s} =$ ________________________________

17. Is the value of magnification calculated from distances nearly the same as what you found using the heights?

Part 2: Creating an Image with a Converging Lens

For this part of the experiment we investigate the creation of an image by a converging lens. You will be changing the distance to the object from the center of the lens and measuring the image distance and height. Set up the apparatus as show in the figure below.



Optical bench arrangement

You need to determine the focal length for your lens. To determine the focal length you can do one of the following. (Ask for help from your TA if you cannot determine the focal length)

a) Using the lens as a magnifying glass to find the where a distant light is focused to a point.
b) Locating the image of an object which is very far from the lens (rays from that object will be traveling parallel to the optical axis when they strike the lens). For that, you can keep the lighted object at one end of the meter stick and the screen at the other end. Then bring the lens very close to the screen and then move toward the object while observing the image. (Hint: You know that parallel rays entering the converging lens go through the focal point.)

18. What is the focal length of the lens?

f = ________________________________ Remember Units

Which of the above methods did you use? Explain how you identified the focal length.

19. Position the object a distance away from the lens that is larger than the focal length you measured above. Start with the screen at the far end of the bench and slowly move the screen closer to the lens. Describe what you see on the screen as you do this.

20. How do you know when the screen is at the location of the image?

21. Find the image distance for 4 different object distances, each longer than the focal length of the lens, as shown below. Move the screen as required and get the sharpest image on the screen that you can to make sure you get the correct image distance. Also measure the height of the object and image for each case. Remember that h' is negative for inverted images. You should keep the lens position fixed all time during the experiment. Also calculate the magnification from the distances and from the heights.

s	s' (cm)	m=-s'/s	h (cm)	h' (cm)	m=h'/h
f + 15.0 cm = ____________					
f + 20.0 cm = ____________					
f + 30.0 cm = ____________					
f + 50.0 cm = ____________					

22. What happens to the image position as the object distance is increased?

23. What happens to the size of the image as the object distance is increased?

24. Is the magnification calculated from the distances above equal to the magnification calculated from the heights in each case?

25. Move the object so that it is closer to the lens than the focal distance. Now move the screen to locate the image. What do you find?

Part 3: Lens Combinations

26. From the experiment above you realized that the image gets smaller as the object distance increases. You may wonder if it is possible to place another lens and improve the magnification of the image. See if you can increase the magnification by placing a diverging lens either in between the converging lens and the screen or between the object and the converging lens. Make a drawing of the arrangement that gives you the largest magnification. Label the distances on the drawing. Also determine the magnification you achieved and report it below.