Phys1112: Lenses and Ray Tracing

Name:

Group Members:

Date:

TA's Name:

Materials: Ray box, converging lenses, 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.

\[ f = \text{_______________} \]

Remember Units

\[ \text{Remember Units} \]
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.

![Ray 2](image)

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.

![Ray 3](image)

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. 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 15.0 cm from the center of the lens (15.0 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.

10. Use the same technique to find Ray 2 (passing through the tip of the arrow and through the left side focal point before striking the lens) and Ray 3 (passing through the tip of the arrow and then through the center of the lens). Trace Ray 2 and Ray 3 onto your paper both before and after passing through the lens.

11. 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.

12. This crossing point is the location of the tip of the image. We know that the base of the object must lie on the optical axis. Draw an arrow with its tip at the crossing point and its tail at the optical axis to represent the image.
13. Is this image real or virtual? ___________________________
   Explain your reasoning using the features of your ray diagram to support you answer.

14. Is the image upright or inverted? ___________________________
   Explain how you know.

15. 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’ = ____________________________

16. The ratio $\frac{h'}{h}$ is called the magnification. What is the magnification?
   $m = \frac{h'}{h} = ____________________________$ Be careful with the units here!

17. 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’ = ____________________________

18. 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.
   $m = -\frac{s'}{s} = ____________________________$

19. 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 shown in the figure below.

![Optical bench arrangement](image)

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.)

20. What is the focal length of the lens?

\[ f = \underline{\text{_________}} \quad \text{Remember Units} \]

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

21. 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.
22. How do you know when the screen is at the location of the image?

23. Is the image the same orientation as the object (called upright) or is it inverted?

Move the object (light source) a little farther away from the lens. This makes the object distance (distance between the object and the lens) a little larger. Now move the screen to get a sharp image again.

24. Did you need to move the screen farther from or closer to the lens?

25. State your conclusion to this:

    When the object distance is increased the image distance ____________________________

26. Did the image get larger or smaller?

27. State your conclusion to this:

    When the image distance __________________ then the magnification ____________________.

Please remember to write your names and attach ray tracing papers to one person’s lab report for grading.