PHY 152/252

Thin Lenses – Laboratory 8

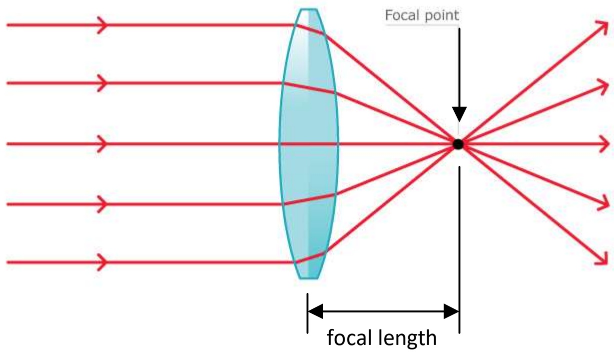
Objective:

The objective is to find the focal lengths of a converging and diverging thin lens.

Theory:

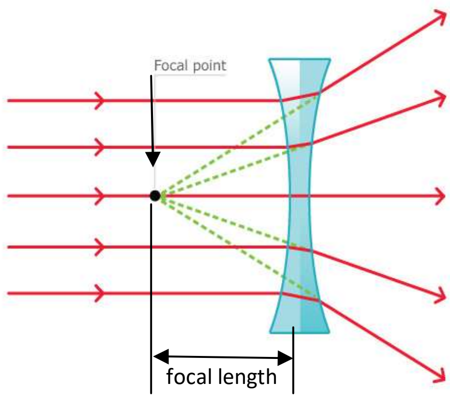
A lens is defined to be “thin” if the thickness is significantly less than the radius of curvature. Lenses may be classified in either of two ways: converging or diverging. A converging lens has the property of taking parallel rays that have refracted through the lens and causing them to converge to a point, called the **focal point**. The distance from the center of the lens to the focal point is the **focal length**. Converging lenses have positive focal lengths; thus they are also called positive lenses.

Refraction of light through a converging lens



A diverging lens has the property of taking parallel rays that have refracted through the lens and make them appear to have diverged from a point. This is the focal point for the diverging lens. Diverging lenses have a negative focal length; thus they are also called negative lenses.

Refraction of light through a diverging lens



Any lens that is thicker at its center than its edges is a converging lens, and any lens that is thicker at its edges than its center is a diverging lens.

These properties of lenses can be used to generate images that are magnified or minified, that are inverted or upright, and that are real or virtual. A real image is created when the rays which have passed through the lens converge to a point as seen in the first diagram. A virtual image is created when the rays which have passed through the lens appear to diverge from a point as seen in the second diagram. A converging lens can produce either a real or a virtual image, while a diverging lens can only produce a virtual image. The image formed by a negative lens cannot be projected, but the focal length of a negative lens can be found if paired with a converging lens. The thin lens equation gives a way to relate object distance, image distance, and focal length.

Thin Lens Equation: $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$
s = object distance
s' = image distance
f = focal length

Magnification: $m = \frac{y'}{y} = -\frac{s'}{s}$
y' = image height
y = object height
This equation, along with the sign convention below, allows for the analysis of thin lens systems.

Sign Conventions
s > 0 when the object is on the incoming side of the light rays; otherwise, s < 0...
s' > 0 when the image is on the outgoing side of the light rays; otherwise, s' < 0..
y > 0 when object is above optic axis or not inverted.
y' > 0 when image is above optic axis or not inverted.
f > 0 for positive (convex) lens. f < 0 for negative (concave) lens.

Equipment List:
Optical Bench(1), Optical Bench Clamps(3), Light Source(1), Lens Holders(2), Screen(1), Lenses (2 – one positive, one negative), Meter Stick(1), Centimeter Ruler(1)

Procedure:
Before the lab begins, create a scratch data sheet having two tables. The 2nd and 4th procedures each require several data points. For Procedure #2 you will need to record 2 image distances, 2 object distances, and 2 measured image heights. You may also want to create table places for the calculated values of magnification and focal lengths. The image distances should be in centimeters, and the image heights should be in millimeters. For Procedure #4, you will have three image/object distances – one from the negative lens to the screen, one between the lenses, and one from the positive lens to the light source. You will also have a calculated object distance for the negative lens.

Procedure #1
When this lab begins, there will be an optical bench on a table located in the doorway of Office 302. One team at a time will take their positive lens to this table, insert the lens in the lens holder, move the lens holder along the bench until a sharp image of the scene outside the office window appears on the bench screen. Each member of each team is to independently find this best focus point, measure the distance from the middle of the lens to the screen, and record it. Then the team is to return to the lab room and to calculate the average of the focal lengths as measured by each team member. This is the first value of the team's focal length of their positive lens.

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Procedure #2

Measure and record the height of the arrow on your light source in millimeters. This will be your object height for the observed magnification calculations. Using your team's optical bench, position the screen (with paper side facing lens) and the light source 100 cm apart. Put your positive lens in one of the two lens holders and move it back and forth along the bench until you get a sharp image of the light source on the screen. There will be <u>two position of the lens for which a sharp image will occur</u>. Measure and record both object and image distances for both sharp-focus positions. One position will produce a magnified image and the other will produce a de-magnified image. Calculate a focal length using the thin lens equation for both of these positions. Record and report observations about the image (magnified, upright, etc…) for each position. Use your centimeter ruler to measure and record the object height (length of the arrow on the light source) and image height for both sharp-focus positions to calculate the observed or experimental magnifications. The two magnifications at the two sharp-focus positions will be very different.

Procedure #3

Use the thin lens equation to calculate a focal length of the positive lens for both positions in Procedure #2. You should now have 3 values for the focal length of the positive lens. Take their average, record this value, and consider that to be the focal length for this lens. Use this value of f for Procedure #4.

Procedure #4

Using the optical bench with the light source and screen 100 cm apart, put the negative lens in your other lens holder and place it somewhere between the positive lens and the screen. Move both lenses along the optical bench until a focused image is formed on the screen. This may require some searching. There will be several positions where a sharp image of the light source occurs. Choose the one that appears to give the best image. Note: If you get a shadow in the middle of the screen image, it's not an image formed by the two lenses; instead, the shadow is that of the negative lens. Choose another position.

With a focused image on the screen at your chosen position, measure and record the distance between the positive and negative lenses, the distance from the negative lens to the screen, and the distance from the positive lens to the light source (should add to 100 cm).

The image of the positive lens serves as the object for the negative lens. (1) Determine the image position produced by the positive lens using the thin lens equation. You do this pretending that the negative lens is absent. Then (2) calculate the object position for the negative lens, relative to the positive lens, by subtracting the positive lens image distance (that you calculated above) from the distance between the two lenses. From these values, you are to (3) calculate and record the focal length of the negative lens.

Calculations

1. Show your focal length calculations for the positive lens and record your average value.

2. Calculate the two <u>theoretical</u> magnifications from Procedure 2, using: $m = -s'/s$. Also, calculate the two experimental magnifications using $m = y'/y$. Do your theoretical magnifications match your experimental magnifications? Calculate the percent difference between experimental and theoretical magnifications for both positions on the optical bench.

3. Show your focal length calculations of your negative lens and state its focal length.