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Modern Engineering Optics Design Project

Introduction

The objective of this project is to be able to create an optical lens (of any kind) for imaging. This project will focus on the creation of a bi-convex lens and the properties of the lens in relation to its ability to magnify and invert an image as well as measure the focal point of the lens.

Design Overview

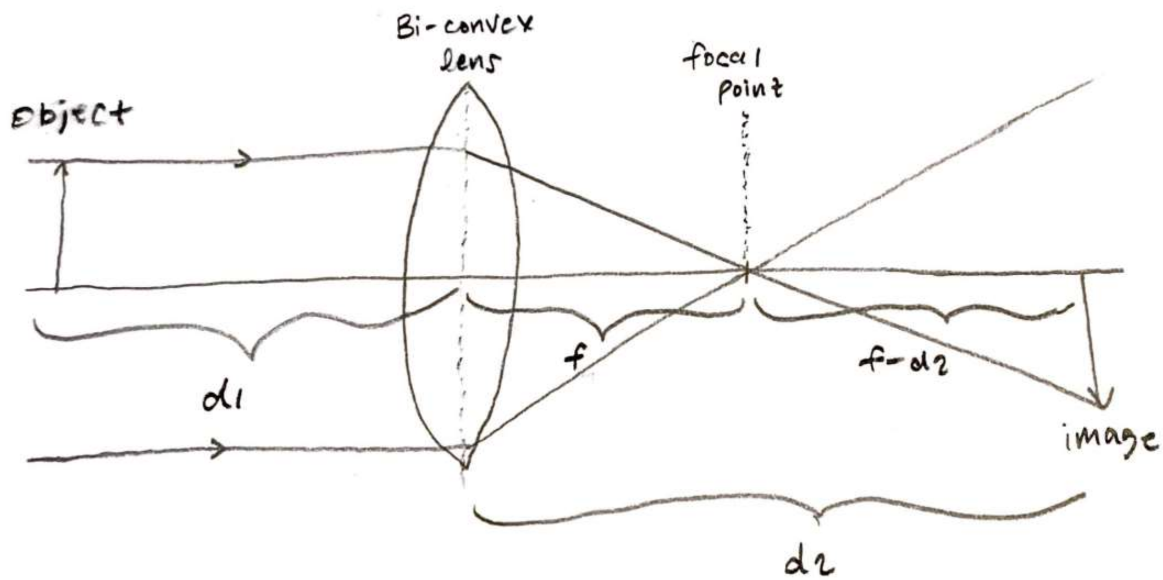
The design of this lens is based on the use of a clear plastic water bottle. The curved part of the plastic bottle is used in order to form two pieces of the lens together to shape that of a convex lens. Water is used to fill the lens up in order for light to pass through a medium which allows the light to be refracted into a single point.

Fig 1: Bottle used (left), finished lens from the front (middle), finished lens from the side (right)

The lens is cut out using scissors to produce two curved circular plastic pieces by cutting the red circles shown in the top left image. These two curved circular pieces are then glued together using a glue gun in order to keep the shape connected but a very small hole is left at the top of the lens for the water to be filled up. This hole does not necessarily need to be connected with more super glue to seal the water inside because there isn't enough surface tension for the water to leak out. The reason this hole is left unglued is because during previous versions of the lens, sealing everything somehow still left water to leak out of a small portion of the lens. This may be due to air pockets that the glue gun may have left that is too small to find or visibly see, therefore this small hole at the top is used to refill the lens in case the water somehow leaks out after a long period of time.

Theory

Below shows a simple diagram of the properties of a convex lens. As studied in class, we know that a convex lens is able to magnify and invert an image, therefore these properties should be expected with the lens being made. We see that a convex lens converges light that is parallel to the principal axis (the axis perpendicular to the lens' front curvature). Our focal length should be the distance between the lens and the focal point which is the point at which the parallel lights converge towards.



Using a basic formula learned in class, we are also able to calculate the focal length by simple knowing d1 (distance from the object to the lens) and d2 (distance from the lens to the screen) and applying the formula:

$$\frac{1}{d_1} + \frac{1}{d_2} = \frac{1}{f},$$

Focal point:

Fig 2: Focal point showing converging of light (left), distance between light, lens, and screen (right)

As shown above, the focal point can be seen as the distance between the lens to the screen where the light seems to converge at one point. Using the above images, we see that the distance between the screen and the lens is at about 2.5 inches whereas the distance from the lens to the flashlight is at about 6.5 inches. Therefore, upon converting these values to centimeters, we see that f = 6.35cm and d1 = 16.51cm. Using these values in the above formula, we can solve for d2 = 10.32cm or about 4.06 inches. The length of d2 should be the length that the lens needs to be from the screen in order to create a real but inverted image.

$d_1 = 16.51\,cm$

$f = 6.35\,cm$

$d_2 = ??$

$$\frac{1}{d_1} + \frac{1}{d_2} = \frac{1}{f}$$

$$\frac{1}{d_2} = \frac{1}{f} - \frac{1}{d_1}$$

$$\frac{1}{d_2} = \frac{1}{6.35} - \frac{1}{16.51}$$

$$\frac{1}{d_2} = \frac{160}{1651} \longrightarrow d_2 \approx 10.32\,cm$$

Results

Inversion:

Fig 3: Inversion of bulbs (left), inversion of screens (middle), inversion of the number 4 (right)

The pictures above show the properties of inversion that this convex lens produces at different lengths. The top left and middle images show the inversion property by producing an image that is visibly inverted on the x-axis shown by the two colors being flipped after the image has passed through it. The right-most image shows that it is flipped on both the x-axis and y-axis as seen by the flipped image of the number “4”. This further proves the properties of the convex lens. Another imaging property of the convex lens would be magnification. As shown in the pictures below, the lens is also capable of magnifying text.

Magnification:

Fig 4: Notebook without magnification (left), magnified text (right)

<u>Conclusion</u>

The lens created during this experiment has shown to successfully confirm the inversion and magnification properties of a convex lens. The only issue encountered during this experiment would be the convergence of light and being able to successfully find a fully circular focal point. As shown above in Fig 2, the focal point can be estimated where it shows all light converging to a certain area, but it’s not quite a “point” exactly due to its shape being somewhat irregular. This issue may be due to the shape of the lens as it may not be fully converging to one point because of its irregular shape. During this experiment, I tried to make the lens as close to a circle as possible with equal curvature on both sides of the lens but failed to do so without having consistent water leakage throughout the molding of the two parts of the lens.

An alternative that I could have done would have probably been to use resin to form a see-through mold of a lens from scratch. This would have allowed more creative freedom over how I would have been able to shape the lens as opposed to having it predetermined by whichever clear plastic bottle I chose to use instead. This also would have eradicated the water leakage issue that seemed to have been persistently occurring during the creation of this lens.