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EE 431 Final Project: The Bi-Convex Lens

Objective:

In this project, our objective is to design, build, and test an optical lens with imaging capabilities.

Design Procedure:

To start off the design process, the first challenge is to create a lens that has not already been previously shaped or carved. With this idea in mind, the main material that I used in order to create the outer medium of the lens is the plastic material out of a soda bottle. By cutting two circular holes of equal length near the top of the plastic bottle, we are able to obtain two pieces that resemble the shape of a convex lens. Then, we use glue to connect these pieces together in order to create the shape of a bi-convex lens. Before completely sealing the convex pieces, we leave a very tiny gap of space in order to fill the inner medium with water. When the inner medium is completely filled up with water, we seal the gap with more glue and observe if the water inside is not leaking out from any part of the lens.

Below are images that show the shape and properties of the biconvex lens:

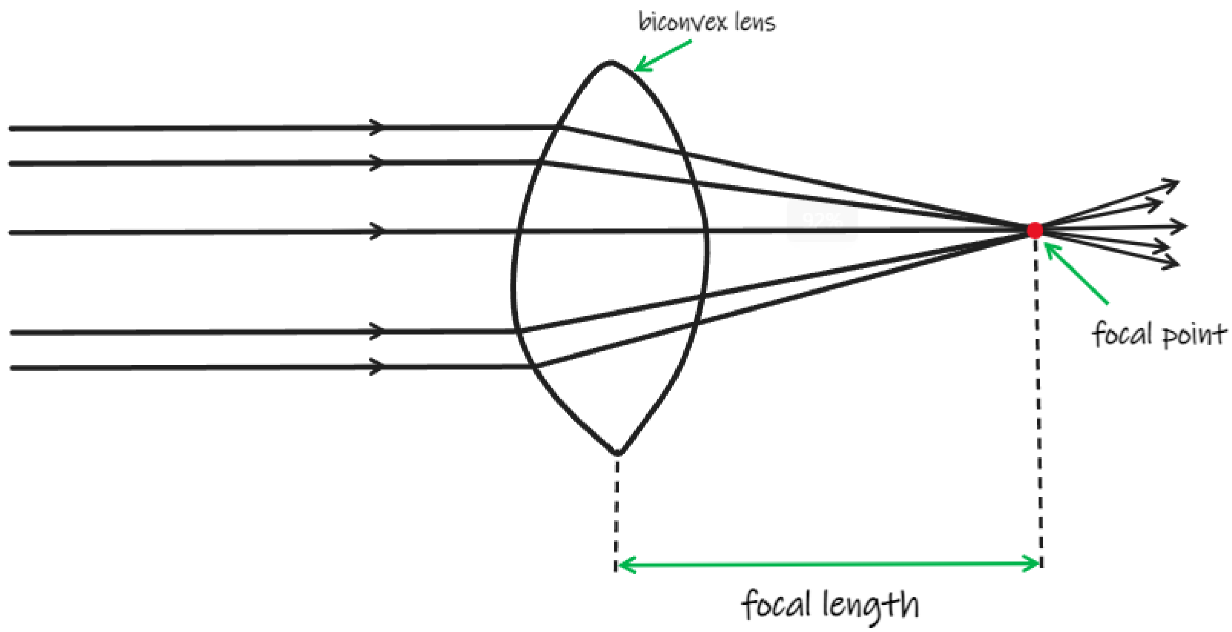
- From the top view, we can see the lens has a circular shape and is filled with water.
- From the side view, we see the convex shape on the upper and lower half of the lens, which creates the bi-convex lens.

Imaging Capabilities and Properties of Lens:
Now that we have identified the lens and its physical properties, we will observe its imaging capabilities. One of the many applications of this particular lens is the use of magnification. The lens takes in the parallel rays of light and refracts it, causing the rays to converge to a single point and create a virtual image. Since our eyes still perceive the rays of light in a parallel fashion, we observe that the object is bigger through the lens than the original object.

We can observe the magnification of the biconvex lens with the images below:

- On the left image, we see the lens on top of the card with no magnification.
- On the right image, we see that the text displayed through the lens is much bigger than the text of the card. Therefore, we see the application of magnification with the biconvex lens.

Below shows a ray diagram of the biconvex lens when parallel rays of light pass through the lens; we can see that the rays of light converge at what is called the focal point. The distance from the center of the biconvex lens to the focal point is known as the focal length.

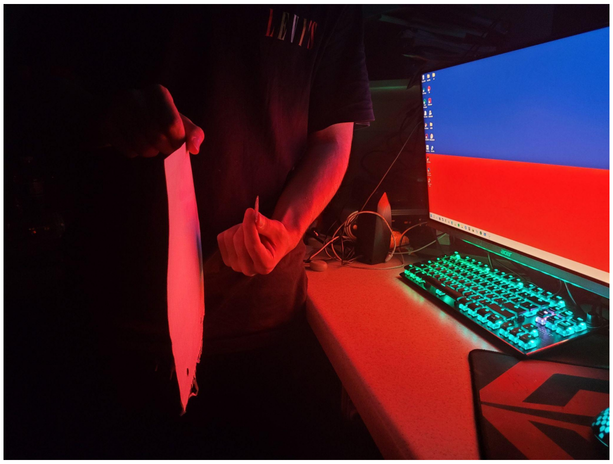


Although a ray diagram is helpful in visually understanding the location of the image and where the focal point exists, it does not provide the actual numerical values of the image distance and focal length. This is where the lens equation becomes significant in this scenario; this equation expresses the relationship between the image distance, object distance, and the focal length. The formula of the lens equation can be seen below:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

In this equation, “f” represents the focal length, “d_o” represents the distance of the object from the lens, and “d_i” represents the distance of the image from the lens. With this information, we can implement the lens equation in a practical sense. We start off by choosing any distant object as our input image, and then we choose a screen where the inverted image can be seen. The distant object I used was my monitor screen, and my “screen” to view the inverted image was on a piece of paper. In order for the lens equation to be valid, I had to place the lens in the middle of the monitor screen and the piece of paper, and slowly shift the paper back and forth until the inverted image became very sharp. Once the location has been found, we can measure both the object distance and the image distance to find the focal length of our biconvex lens.

A picture can be seen below of me attempting to obtain a sharp inverted image with the monitor as a distant object, and the piece of paper as the screen:



Once I found the sharp inverted image on the screen, I measured the distance between the lens and the screen and obtained a value of 3.5 inches. Then, I measured the distance between the lens and the monitor and obtained a value of 43.5 inches. Now, we can implement these values into the lens equation and solve for the focal length.

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$f = \frac{3.24\text{ in}}{} \left| \frac{2.54\text{ cm}}{1\text{ in}} \right.$$

$$f = \frac{1}{\frac{1}{d_o} + \frac{1}{d_i}}$$

$$f = 8.23\text{ cm}$$

$$f = \frac{1}{\frac{1}{43.50} + \frac{1}{3.50}}$$

$$f = 3.24\text{ inches}$$

From the picture above, we found that the focal length is 3.24 inches, or 8.23 centimeters.

In order to verify the value of the focal length, we can simply measure the distance between the lens and the screen when the light rays converge into a point known as the focal point. This can also be implemented in a practical sense as well. To start off, I used a flashlight as my input source, and a wall as my screen. Then, the rest of the procedure involves shifting the lens back and forth until all the rays of light converge to a single point on the wall.

The picture below shows my demonstration of finding the focal length of the lens as the light rays converge into a focal point on the wall:

When I measured the distance between the lens and the wall in the picture above, I obtained a value of approximately 3.3 inches, or 8.382 centimeters. Consequently, we see that the focal length from both methods are very accurate and similar to each other. Therefore, we can verify that the focal length of the biconvex lens is somewhere between 8.23-8.38 centimeters.

Another property that this lens has the capability of doing is inverting real images on the screen. The inversion essentially occurs when the light rays continue beyond the focal point as the initial light rays become inverted. This was a property that I saw frequently whenever I shifted the lens beyond the focal length. Overall, the biconvex lens has the properties of magnification, inversion, and has the capability of imaging. We were able to calculate the focal length with two practical methods and compared the similarity of the values to verify its validity.