Concepts in Physics
Lab 7: Lenses

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Activity 1: Preliminaries

You are going to find the relationship between the distance of an object from a lens O, the distance of the image of that object from the lens I, and the focal length of the lens f.

If you put an object on one side of a convex lens, then there will be an image on the other side of the lens. If the object is glowing, then the image can be projected onto a screen, but for a given object-to-lens distance O there is only one screen position at which the image will be sharp. I is the image-to-lens distance when the image is sharp.

The focal length f of a lens is the image-to-lens distance, when the image is sharp, for an object which is infinitely far away.

To prepare you for figuring out the relationship between O, I and f in this lab, here are some mathematical relationships which you will graph. Suppose you had two experimental quantities x and y, where neither x nor y could take on negative values. Now suppose x and y were related so that

$$xy = 1 \tag{1}$$

Make a clear, accurate graph of y versus x for equation (1). Now make a graph of y versus x for the relationship

$$(x-5)(y-5) = 5^2 \tag{2}$$

and note the similarities and differences between your graph of equation (1) and your graph of equation (2).

You will attempt to discover the relationship between O, I and f by measuring values of O and I for many different positions of the object and the lens. f is constant for a particular lens. By graphing your results, and by trial-and-error guessing based on your graphs, you will decide on one equation which you think expresses the relationship of each of these quantities to the others. You will then check your equation by substituting in measured values and seeing if the equation is true (within the precision of your experiment) for those values. If not, you will have to revise your equation.

Finally, you will test your equation by using it to predict what I would be for an O that you have not tried yet. Then you will do the experiment (for that value of O), and see if the resulting value of I agrees, within the uncertainty of your experiment, with the value you predicted. If not, then you may have to revise your equation yet again.

To hand in for activity 1

Your graphs.

Activity 2: The Image of an Obscured Object

Set the lens at the center of the optical bench. Set the light (the object) at one end of the optical bench, and set the screen, onto which will be projected the image, at the other.

Now move the screen up and down the bench, and note that, for a particular position of the object, there is only one position of the screen for which the image is in focus. As you move the object closer and closer to the lens, you will have to keep moving the screen further and further from the lens.

Set up the lens to project an upside-down image of your object (a lit-up arrow) onto your screen. Focus it well.

Now ask yourself what the projected image would look like if you were to take a piece of paper and obscure *the top half* of the lens by placing the paper on the side of the lens closer to the object. Would anything different happen if you placed the obscuring paper on the other side of the lens, the side closer to the image? Write down your predictions of what you would expect to see. As usual, I don't care if your predictions end up correct or not.

Now do the experiment and write down what happens. Does it match

your predictions? What is your explanation for what is happening?

To hand in for activity 2

Your predictions, results, and explanation.

Activity 3: The Experiment

Now start varying the position of the image and object. Take data by finding I for a given value of O. Using as wide a possible range of values of O, take at least 10 data points. At each point measure O and I. Make sure that you get a wide range of values of both quantities. Record the data in a table.

Now you are ready to study the relationship between O, I and f—the "focal length" of the lens. f for the lenses you are using is between 10 and 25 cm. Plot a graph of I versus O. What mathematical relationship between I and O does the shape of your graph suggest? Test this relationship by seeing if your data points obey it.

What limiting value does I approach as O increases, that is, how close to the lens would you expect to find the image if the object distance were very great? What limit does O seem to approach as I increases? Do these limiting values appear to be related to any other quantity in the experiment?

Using the above two suggestions as a start, eventually, you are to come up with an equation that relates O, I and f. You may want to make other graphs of quantities you calculate from O and I. You will know if your formula is reasonable by substituting actual data points (more than one!), and seeing if the formula is correct for those data points within the precision of this experiment.

As a final test of your formula, express I as some function of O and f and insert a new (untested) value of O into it, calculate the I that it predicts, and check the prediction with your apparatus. See if your measured value of I agrees with your predicted value, within the precision of this experiment. Be sure to leave your apparatus set up until you have checked your prediction. Again, if necessary, go back and modify your formula.

To hand in for Activity 3

- Graphs of equations (1) and (2), for $x > 0$ and $y > 0$,

- All data gathered,

- Any additional graphs made,

- All guesses at the relationship between O, I and f, including guesses that turned out to be incorrect (clearly say which relationship is the one you think is the correct one),

- Equation for I as some function of O and f,

- Results of your attempt to experimentally verify your prediction.