The Lens Equation Lab

Teacher's Guide

Topic:

Refraction and Lenses

The following information is provided to the student:

Question:
How can carefully-collected data and a graphical analysis of the data be used to derive the lens equation?

Purpose:
To experimentally derive the lens equation using collected data and methods of graphical analysis and linear regression.

A complete lab write-up includes a Title, a Purpose, a Data section, a Conclusion and a Discussion of Results. The Data section should include a table of object distance and image distance data; column headings and units should be included. Values of $1/d_{object}$ and $1/d_{image}$ should be calculated and a plot of $1/d_{image}$ vs. $1/d_{object}$ should be constructed. Linear regression should be performed for the graph and the slope, y-intercept, regression constant and equation should be reported. The Conclusion should respond to the question raised in the Purpose of the lab (as always). The Discussion of Results section should include an error analysis in which you evaluate the reliability of your equation, relate the equation to the theoretically expected equation and determine the focal length from your y-intercept. The logic associated with the focal length calculations should be fully explained.

Materials Required:

Small converging lens (focal length of 10 cm-20 cm; diameter of 4 to 6 cm); lens holder; 7-Watt night light bulb; bulb base; large note card; meter stick.

Description of Procedure:

The meter stick is placed upon the lab table. The lens and lens holder are positioned at the 50.0-cm mark on the meter stick. The light bulb (affectionately known as "Smiley") is placed at the 100.0-cm mark on the meter stick. The light refracted through the lens is projected onto a note card. The note card is slowly moved away from the lens along the meter stick until a focused image of Smiley is observed on the card. The d_{object} and d_{image} values are recorded in a Data table. The light bulb is moved forward by about 5.0 cm and the new image is located. The d_{object} and d_{image} values are once more recorded in a Data table. The procedure continues for smaller and smaller object distances. Once the image distance begins to make considerable movement from one trial to the next, the object distances are altered less and less from trial to trial. Data collection ceases when the object is so close to the lens that the image is virtual (and not projectable). Reciprocal values are calculated and plotted in an effort to answer the question raised in the Purpose of the lab.

Alternative Materials and Procedure:

Safety Concern:

The Laboratory

There is always a higher than usual level of risk associated with working in a science lab. Teachers should be aware of this and take the necessary precautions to insure that the working environment is as safe as possible. Student *horseplay* and off-task behaviors should not be tolerated.

Suggestions, Precautions, Notes:

1. Night light bulbs can be purchased at home stores and department stores. A permanent marker can be used to draw a picture of a smiley face on the part of the bulb facing the lens.
2. Introduce the lab by rearranging the lens equation to take a slope-intercept form of

$$\frac{1}{di} = -\frac{1}{do} + \frac{1}{f}$$

   This equation has the form of $y = m \bullet x + b$ where $1/d_i$ is the y, $1/d_o$ is the x, -1 is the value of m and $1/f$ is b. If graphed as $1/d_i$ vs. $1/d_i$, then a line with a slope of -1 and a y-intercept of $1/f$ would be expected.
3. If possible, use the same mirror used in the Finding Smiley Lab. The focal length was already determined in that lab.
4. Students often confuse the meter stick reading with the object distance or the image distance. The object distance is the distance between the light bulb and the lens; the image distance is the distance between the image and the lens. If the procedure is done as described, then the difference between 50.0 cm and the meter stick reading must be taken to determine the object distance and the image distance.
5. If students sight in the lens at the image of Smiley and observe it to be upright, then Smiley is positioned inside the focal point and the image is virtual.
6. Label the lens using a marker, giving each a unique number or letter. Have students record the number or letter of the lens which they used. The same lens can be used in subsequent labs of if measurements need to be redone for this lab.

Auxiliary Materials:

None

Scoring Rubric:

RL10.	**The Lens Equation Lab**	**Score**
____	Included, labeled and organized all parts of the lab report.	
____	Data section includes a table of relevant measurements with column headings and units. Data appear accurate. Reciprocal values are calculated and recorded to the proper number of significant digits. Sketched a plot of $1/d_{image}$ vs. $1/d_{object}$ and included the results of the linear regression analysis. Wrote equation in slope-intercept form; did not include y's and x's in the equation; used symbols of actual quantities.	____/____
____	Conclusion states the experimentally-derived equation relating object and image distance.	
____	Discussion of Results provides and error analysis discussing the reliability of the experimentally-derived equation. Equation is compared to theoretical expectation. Focal length is determined from the y-intercept; calculation is shown and explained in writing.	

Connections to The Physics Classroom Tutorial:

The following reading is a suitable accompaniment to this lab:

http://www.physicsclassroom.com/Class/refrn/u14l5f.cfm

Connections to Minds on Physics Internet Modules:

There are currently no sublevels of Minds on Physics on the topic of the lens equation.