

Bell Ringer: Thin Converging Lenses – ID:

13697

Based on an activity by Irina Lyublinskaya

Time required
90 minutes

Topic: Light

- Determine the positions and magnifications of images produced by converging lenses using ray diagrams.

Activity Overview

In this activity, students use simulated experiments to explore ray diagrams for converging thin lenses. They explore the situations in which real and virtual images form, and they derive the lens equation from their observations.

Materials

To complete this activity, each student or student group will require the following:

- TI-Nspire™ technology
- blank sheet of paper
- pen or pencil

TI-Nspire Applications

Graphs & Geometry, Lists & Spreadsheet, Data & Statistics, Notes

Teacher Preparation

Before carrying out this activity, you should review with students the concepts of light refraction through curved surfaces, convex lenses, the focal distance of a lens, and real and virtual images.

- The screenshots on pages 2–4 demonstrate expected student results. Refer to the screenshots on page 5 for a preview of the student TI-Nspire document (.tns file). The solution .tns file contains sample responses to the questions posed in the student .tns file.
- **To download the student .tns file and solution .tns file, go to education.ti.com/exchange and enter “13697” in the search box.**
- This activity is related to activity 12379: Looking Through the Lens. If you wish, you may extend this bell-ringer activity with the longer activity. You can download the files for activity 12379 at education.ti.com/exchange.

Classroom Management

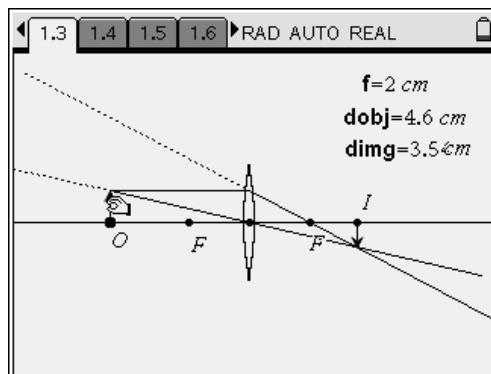
- This activity is designed to be **teacher-led** with students following along on their handhelds. You may use the following pages to present the material to the class and encourage discussion.
- The ideas contained in the following pages are intended to provide a framework as to how the activity will progress. Suggestions are also provided to help ensure that the objectives for this activity are met.
- Students may answer the questions posed in the .tns file using the Notes application or on blank paper.
- In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.

The following question will guide student exploration during this activity:

- How does the position of an object relative to the focal point affect the position and properties of an image for converging lenses?

The purpose of this activity is to allow students to explore ray diagrams for converging lenses. Students explore image formation for various positions of an object for a converging lens. They use these observations to derive the lens equation.

Step 1: Students should open the file **PhysBR_week25_conv_lenses.tns**, read the first two pages, and then move to page 1.3, where they can explore a ray diagram for a converging lens. (To maintain the accuracy of the simulation, the object should remain to the left of the lens at all times.) The focus of the lens is kept constant.



Step 2: Students should drag point *O* to change the position of the object. (To drag point *O*, students should use the NavPad to move the cursor until it is above point *O*. The cursor will turn into an open hand. Students should press and hold Ⓢ until the cursor changes to a closed hand. They can then use the NavPad to drag the point left and right. To release the point, they can press Ⓢ again.) They should study the position of the image, *I*, and the distance from the lens to the object, **dobj**, and to the image, **dimg**.

Note: The positive direction for the object is to the left of the lens, and the positive direction for the image is to the right of the lens. Thus, when the image is located on the same side as the object, the image is virtual, and **dimg** < 0.

Step 3: Next, students should move to page 1.4. The distances (**dobj** and **dimg**) from page 1.3 are automatically captured in columns A and B in the *Lists & Spreadsheet* application on this page.

Columns C and D contain the reciprocals of those distances (*obj_r* and *img_r*, respectively). Students

should study the collected data and values of $\frac{1}{\text{dobj}}$

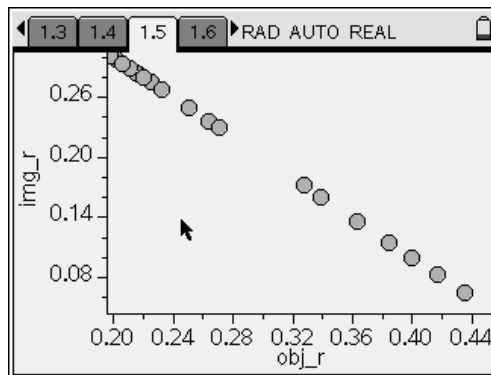
and $\frac{1}{\text{dimg}}$ and begin to infer characteristics of their

relationship (for example, they may observe that the sum of these values stays constant).

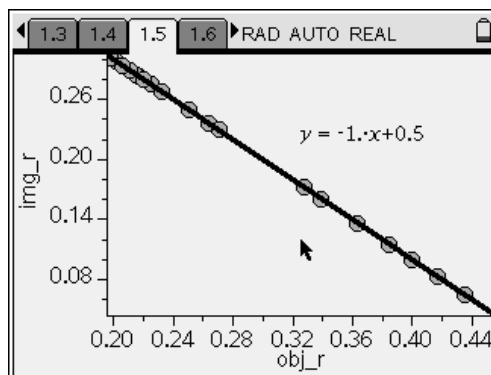
A	B	C	D
object	image	obj_r	img_r
3.05	5.80952	0.327869	0.172
2.95	6.21053	0.338983	0.161
2.75	7.33333	0.363636	0.136
2.6	8.66667	0.384615	0.115
2.4	12.	0.416667	0.083

A1 = 3.05

Step 4: Next, students should move to page 1.4, which contains a *Data & Statistics* application. Students should use the application to make a plot of img_r vs. obj_r . To make the plot, students should click (press $\text{\textcircled{D}}$) on the area just below each axis. A list of available variables will pop up. They should choose obj_r for the x-variable and img_r for the y-variable. Alternatively, they can add the x- and y-variables using the **Plot Properties** menu (**Menu > Plot Properties > Add X Variable** or **Add Y Variable**).



Step 5: The scatter plot should show a linear relationship. Students should use the **Linear Regression** tool (**Menu > Analyze > Regression > Show Linear (mx + b)**) to identify the best-fit equation for the data. (The best-fit equation should be $y = 0.5 - x$.) Next, students should answer questions 1 and 2.



Q1. Describe all situations in which the image is real. Derive an equation describing the relationship between f , $dobj$, and $dimg$ in these situations.

A. The image is real when $dimg > 0$ —that is, when the image is to the right of the lens. This happens when the object is at a distance larger than the focal distance from the lens. From the

regression equation,
$$\frac{1}{dimg} = \frac{1}{2} - \frac{1}{dobj}.$$

Because $f = 2$, the equation relating f , $dobj$,

and $dimg$ is
$$\frac{1}{dobj} + \frac{1}{dimg} = \frac{1}{f}.$$

Q2. Describe all situations in which the image is virtual. Derive an equation describing the relationship between f , d_{obj} , and d_{img} in these situations.

- A.** The image is virtual when $d_{img} < 0$ —that is, when image is to the left of the lens. This happens when the object is at a distance smaller than the focal distance from the lens.

The equation $\frac{1}{d_{obj}} + \frac{1}{d_{img}} = \frac{1}{f}$ holds true for

this situation as well.

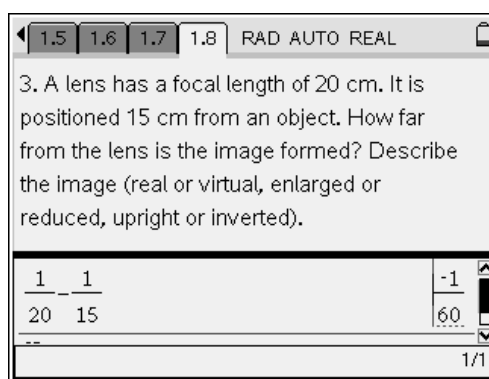
Step 6: Next, students should move to page 1.8 and solve question 3 using the lens equation they derived.

Q3. A lens has a focal length of 20 cm. It is positioned 15 cm from an object. How far from the lens is the image formed? Describe the image (real or virtual, enlarged or reduced, upright or inverted).

- A.** Students should use the Calculator application on the bottom of the page to calculate the

distance: $\frac{1}{15} + \frac{1}{d_{img}} = \frac{1}{20}$, so $d_{img} = -60$ cm.

(Students should press $\text{ctrl} + \text{tab}$ to move between windows on the screen.) Since distance is negative, the image is virtual. It is farther away from the lens than the object is, so it is enlarged and upright.



Ideas for Extension Activities: If you wish, you may have students solve additional problems involving image location, size, and orientation. You may wish to extend this activity by having students experiment with real converging lenses and confirm their observations of the simulation.

Bell Ringer: Thin Converging Lenses – ID: 13697

(Student)TI-Nspire File: *PhysBR_week25_conv_lenses.tns*

<p>1.1 1.2 1.3 1.4 ▶RAD AUTO REAL</p> <hr/> <p style="text-align: center;">THIN CONVERGING LENSES</p> <hr/> <p style="text-align: center;">Physics</p> <p style="text-align: center;">Optics</p>	<p>1.1 1.2 1.3 1.4 ▶RAD AUTO REAL</p> <p>Lenses bend light rays such that they diverge or converge. In this activity, you will explore the properties of an image formed by a thin converging lens. The focal length of the lens on the next page is fixed. As you vary the distance to the object, dobj, observe changes in the distance from the lens to the image, dimg, and in the relative position of the image.</p>	<p>1.1 1.2 1.3 1.4 ▶RAD AUTO REAL</p> <div style="text-align: right;"> <p>$f=2\text{ cm}$</p> <p>$dobj=3.05\text{ cm}$</p> <p>$dimg=5.82\text{ cm}$</p> </div>
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<p>1.1 1.2 1.3 1.4 ▶RAD AUTO REAL</p> <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> <tr> <th>object</th> <th>image</th> <th>obj_r</th> <th>img_r</th> </tr> </thead> <tbody> <tr> <td>$=\text{capture}(dobj)$</td> <td>$=\text{capture}(dimg)$</td> <td>$=1/\text{object}$</td> <td>$=1/\text{img}$</td> </tr> <tr> <td>1</td> <td>3.05</td> <td>5.80952</td> <td>0.327869</td> </tr> <tr> <td>2</td> <td></td> <td></td> <td></td> </tr> <tr> <td>3</td> <td></td> <td></td> <td></td> </tr> <tr> <td>4</td> <td></td> <td></td> <td></td> </tr> <tr> <td>5</td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p>A7 =3.05</p>	A	B	C	D	object	image	obj_r	img_r	$=\text{capture}(dobj)$	$=\text{capture}(dimg)$	$=1/\text{object}$	$=1/\text{img}$	1	3.05	5.80952	0.327869	2				3				4				5				<p>1.2 1.3 1.4 1.5 ▶RAD AUTO REAL</p> <p>Caption: <none></p> <p>Click to add variable</p>	<p>1.3 1.4 1.5 1.6 ▶RAD AUTO REAL</p> <p>1. Describe all situations in which the image is real. Derive an equation describing the relationship between f, dobj, and dimg in these situations.</p>
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