Optical Bench

Finding focal lengths of lenses and mirrors

In this activity you will find focal lengths using the basic lens equation:

\[
\frac{1}{i} + \frac{1}{o} = \frac{1}{f}
\]

**Equipment:**
- Optics bench.
- Light source.
- Crossed arrow target.
- Viewing Screen
- 3 Component Holders
- 75mm Focal Length Convex Lens
- 150 mm Focal Length Convex Lens
- 50 mm Focal Length Spherical Mirror

**Cautions:**
Handle lenses and mirrors by the edges only. *It's a lot easier to keep these clean than it is to clean them!*

First, you’re going to do a basic setup. *Remember, the more careful your setup, the better your data!*

Note: All calculations in this lab will be performed using centimeters.

**Procedure to set up the optics bench** (most of this should be done for you, but it's always good to check):

1. Place the optics bench in the middle of the lab table, with the 0cm mark to your left. *Don't put the bench too close to the edge of the table!*
2. Place the light source on the left end of the bench with the light opening pointing to the right. *Put the right end of the light source at the 8cm mark of the bench.*
3. Mount three of the metal component holders on the bench as shown in the diagram. *Make sure the “feet” point in the indicated directions. Do not use the component holder with the hooked feet.*
4. Mount the crossed arrow target on the metal component holder closest to the light source. Put it on the right side of the holder as shown.
5. Align the right face of the crossed arrow target with the 10cm mark on the scale.
6. Mount the 75mm lens on the right side of the middle component holder. Align the notch on this component holder with the 20cm mark on the bench.
7. Mount the viewing screen on the left side of the remaining component holder
8. Align the face of the viewing screen with the 70cm mark.
**Procedure to determine the focal length of the 75mm lens:**

1. Turn on the light source.
2. Move the 75mm lens and its component holder back and forth on the bench until the image of the arrow is focused on the screen. Look for the best focus possible.
3. Using the notches on the component holders, record the location of each of the three components on the bench in the table below. Also note the size of the image (relative to the size of the crossed arrow target) on the table.

   The crossed arrow target has millimeter markings and the circle is 10mm in diameter. Use the ruler on the screen to measure the image for comparison.
4. Move the lens (only) to the right and look for a second position where the image is in focus.
5. Using the notches on the component holders, record the location of each of the three components on the bench in the table below. Also note the size of the image (relative to the size of the crossed arrow target) on the table.
6. Set the screen at the 39cm position. *You may have to move the lens back to make way for the screen.*
7. Move the lens back and forth to find a good focus.
8. Record the location of each of the components in the table. Also note the size of the image as a ratio object:image, for example 1:3.
9. For each trial in the table, calculate the Object Distance \(o\) by subtracting the location of the crossed arrow target from the location of the lens.
10. For each trial in the table, calculate the Image Distance \(i\) by subtracting the location of the lens from the location of the viewing screen.
11. Using the object distance and image distance values, calculate the experimental focal length \(f_{\text{exp}}\) for each trial in the table.
12. Record the theoretical focal length of the lens (7.5cm) in the table for all trials in the \(f_{\text{theory}}\) column.
13. Calculate the percent error of your experimental results using the following formula. Fill in the appropriate column in the table:

\[
\% \text{ error} = \frac{|f_{\text{exp}} - f_{\text{theory}}|}{f_{\text{theory}}} \times 100
\]

<table>
<thead>
<tr>
<th>Crossed arrow target location</th>
<th>Lens location</th>
<th>Viewing screen location</th>
<th>(o)</th>
<th>(i)</th>
<th>(f_{\text{exp}})</th>
<th>(f_{\text{theory}})</th>
<th>%error</th>
<th>Image size</th>
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**Procedure to determine the focal length of the 150mm lens:**
1. Remove the 75 mm lens and replace it with the 150 mm convex lens.
2. Reset the screen to the 70 cm mark.
3. Find the two positions where the image focuses and record the data below as you did for the previous lens.
4. Complete all calculations as you did for the previous lens.

<table>
<thead>
<tr>
<th>Crossed arrow target location</th>
<th>Lens location</th>
<th>Viewing screen location</th>
<th>o</th>
<th>i</th>
<th>( f_{\text{exp}} )</th>
<th>( f_{\text{theory}} )</th>
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<th>Image size</th>
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**Procedure to determine the focal length of the 50 mm mirror:**

1. Replace the 150 mm lens with the 50 mm mirror. Mount the mirror on the right side of the component holder with the writing facing to the right.
2. Put the mirror at the 22 cm mark.
3. Remove the viewing screen from its component holder.
4. Turn the viewing screen 90° and mount it on the component holder so it only covers the upper third of the hole in the component holder.
5. Put the component holder with the viewing screen between the mirror and the light source, with the screen facing the mirror.
6. Move the viewing screen back and forth until you get a focused image of the crossed arrows on the screen (it may not be a full image).
7. Record the location of each component in the data table below.
8. Repeat the above procedure with the mirror at 25 cm and 30 cm.
9. For each trial in the table, calculate the Object Distance (o) by subtracting the location of the crossed arrow target from the location of the mirror.
10. For each trial in the table, calculate the Image Distance (i) by subtracting the location of the viewing screen from the location of the mirror.
11. Complete all calculations as you did in the lens problems.

<table>
<thead>
<tr>
<th>Crossed arrow target location</th>
<th>Mirror location</th>
<th>Viewing screen location</th>
<th>o</th>
<th>i</th>
<th>( f_{\text{exp}} )</th>
<th>( f_{\text{theory}} )</th>
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Questions:
1. When using the mirror, why did we cover only part of the hole with the viewing screen?

2. Looking at both sets of lens data, is there a relationship between $i$, $o$, and $f$?

   a. If $o$ increases, what happens to $i$ and $f$?

   b. If $o$ decreases, what happens to $i$ and $f$?

3. See if you can complete the chart below:

<table>
<thead>
<tr>
<th></th>
<th>$f &lt; o &lt; 2f$</th>
<th>$o = 2f$</th>
<th>$o &gt; 2f$</th>
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<tbody>
<tr>
<td>$i$ value (relative to $f$)</td>
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