Name: _____   Date: _____

Student Exploration: Ray Tracing (Mirrors)

Vocabulary: concave mirror, convex mirror, focal point, magnification, real image, reflect, virtual image

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
For these questions, it would be helpful to have a metal spoon on hand. If you don't have one, try to imagine looking at yourself in a spoon.

1. Look at yourself in the front of the spoon (the side where the food sits). What do you see?

   _____

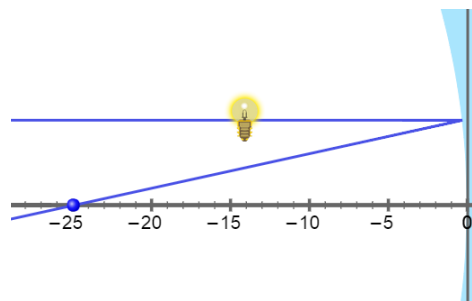   The front of a spoon is an example of a **concave mirror**.

2. What do you see when you look at yourself in the back of a spoon? _____

   _____

   The back of a spoon is an example of a **convex mirror**.

Gizmo Warm-up
The *Ray Tracing (Mirrors)* Gizmo shows a side view of a light bulb positioned to the left of a mirror. Light rays passing from the light bulb to the mirror are shown.

To begin, select the **Concave mirror**. Turn on **Colorize lines**. Under **Show lines**, turn off the **Central line** and the **Line through focal point** so that only the **Parallel line** is showing.
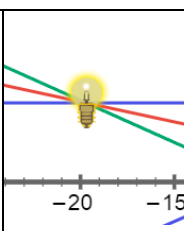

1. The blue dot in front of the mirror is the **focal point** of the mirror. Move the light bulb on the left around. What is always true about the ray that is **reflected** from the parallel ray?

   _____

2. Turn off the **Parallel line** and turn on the **Line through focal point**. Move the light bulb around. What do you notice about the reflected ray in this situation?

   _____

	Get the Gizmo ready:	
Activity A: **Real and virtual images**	• Check that the **Concave mirror** is selected. • Turn on the **Parallel line**, **Central line**, and **Line through focal point**. • Place the light bulb above -24 on the central axis, with the focal point at -12.	

Introduction: A concave mirror is also called a "converging mirror" because it reflects light rays into a point. A **real image** is formed where the reflected light rays converge at a point. Unlike a **virtual image** that forms behind a mirror, a real image can be projected onto a screen.

Question: How do mirrors create real and virtual images?

1. Observe: In its current configuration, the distance from the light bulb to the focal point is slightly more than 12 units. The distance from the focal point to the mirror is exactly 12 units.

    A. What do you notice about the size of the light bulb's image? _____

    _____

    B. What do you notice about the orientation of the light bulb's image? _____

    _____

2. Investigate: Complete each action described in the table below, and state how that action affects the image.

Action	Effect on image
Move the light bulb to the left.	
Move the light bulb to the right.	
Move the focal point to the left.	
Move the focal point to the right.	

3. Analyze: Examine the results recorded in your table.

    A. In general, how do the size and position of the image change when the distance between the light bulb and the focal point increases?

    _____

    B. In general, how do the size and position of the image change when the distance between the light bulb and the focal point decreases?

    _____

(Activity A continued on next page)

Activity A (continued from previous page)

4. <u>Explore</u>: Move the light bulb to -10 and the focal point to -20. What do you notice about the image when the light bulb is between the focal point and the mirror?

_____

The image is virtual because no light rays are focused there. This virtual image is what an observer would see looking into the mirror. The dashed lines represent the direction that an observer would perceive the reflected light was traveling from.

5. <u>Investigate</u>: Select a **Convex mirror**, and turn off the **Original light lines** and the **Apparent light lines**. Move the light bulb back and forth (but keep it close to the central axis).

   A. What do you notice about the three lines reflected from the convex mirror?

   _____

   B. Is the image of the light bulb a real image or a virtual image? Explain. (Hint: Recall that a real image is formed where actual light rays are reflected.)
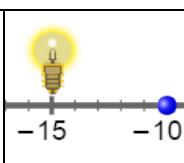
   _____

   C. Move the light bulb back and forth. No matter where the light bulb is located on the central axis, what is always true about size of the image?

   _____

6. <u>Apply</u>: Which type of mirror would you use for the following applications, and why?

   A. Cooking a hot dog: _____

   _____

   _____

   B. Surveillance in a convenience store: _____

   _____

   _____

| Activity B: The mirror equation	Get the Gizmo ready: • Select the **Concave mirror**. • Move the light bulb to -15 and the focal point to -10. • Turn off all lines, and turn on **Show ruler**.	

Question: How is position of the image related to the position of the object and the focal length of the mirror?

1. Measure: In this activity, you will measure the relationships between several values:

   d_o: Distance between object and mirror

   f: Distance between focal point and mirror

   d_i: Distance between image and mirror
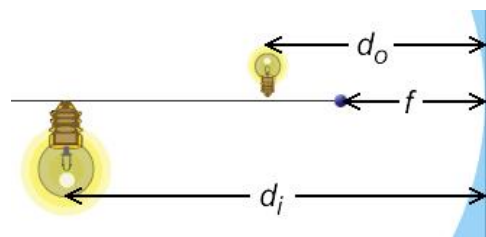
   What are the current values of each of these variables? (Note: You can use the ruler to measure d_o and d_i.)

   d_o = _____ f = _____ d_i = _____

2. Gather data: Measure d_i for each of the following values of d_o and f. For the last two rows of the table, use your own values of d_o and f. (Note: If the light bulb is to the right of the focal point ($d_o < f$), the image is virtual and d_i is negative.)

d_o	f	d_i	$\dfrac{1}{d_o}$	$\dfrac{1}{d_i}$	$\dfrac{1}{f}$
15	10				
25	10				

3. Calculate: Find the reciprocal of each value and fill in the last three columns of the table.

4. Analyze: For each row of the table, find the sum of $\dfrac{1}{d_o}$ and $\dfrac{1}{d_i}$. Record these values here:

   _____   _____   _____   _____

   What do you notice? _____

   _____

   (Activity B continued on next page)

Activity B (continued from previous page)

5. <u>Make a rule</u>: Express the relationship between $\dfrac{1}{d_o}$, $\dfrac{1}{d_i}$, and $\dfrac{1}{f}$ as an equation.

    $$=$$

    This equation is called the *mirror equation*. For the spherical mirror shown in this Gizmo, the equation works well so long as the object is close to the central axis.

6. <u>Practice</u>: You place a light bulb 8 cm in front of a concave mirror. You then move a sheet of paper back and forth in front of the mirror. The image of the light bulb focuses on the paper when the paper is 12 cm in front of the mirror.

    What is the focal length of the mirror? _____

    Show your work:

7. <u>Practice</u>: A light bulb is placed 20 cm in front of a concave mirror with a focal length of 8 cm.

    How far from the mirror will the image of the light bulb be focused? _____

    Show your work:

8. <u>On your own</u>: Does the mirror equation work for a convex mirror? Use the Gizmo to find out and describe your findings below. (Hint: In this situation, d_i and f are negative.)

    _____
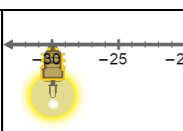
    _____

    _____

    _____

    _____

| Activity C: Magnification | Get the Gizmo ready:

• Check that the **Concave mirror** is selected.
• Move the light bulb to -15 and the focal point to -10. | |

Introduction: Mirrors are often used to change the size of an image. The **magnification** of an image is equal to the ratio of the image height to the object height. Some mirrors, such as the mirrors in reflecting telescopes, produce images that are greatly magnified. Other mirrors, such as the mirrors in side-view mirrors on cars, produce images that are reduced in size.

Question: What determines the magnification of an image?

1. <u>Measure</u>: What are the current values of these variables?

   d_o = _____ f = _____ d_i = _____

2. <u>Measure</u>: In addition to the variables you explored in the previous activity, you will investigate several others. Measure each of these variables and list their values below. Pay close attention to the sign conventions as you do this.

   h_o: Object height (always positive)

   h_i: Image height (negative if image is inverted)

   s_o: Focal point to object distance: $s_o = f - d_o$

   s_i: Focal point to image distance: $s_i = f - d_i$
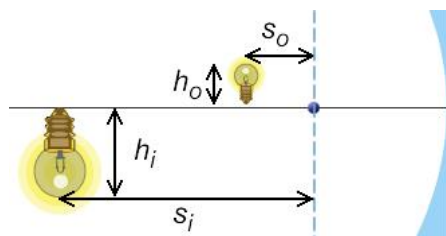
   h_o = _____ h_i = _____ s_o = _____ s_i = _____

3. <u>Gather data</u>: Use the values above to fill in the first row of the table. Then run your own experiments to fill in the last two rows.

d_o	f	d_i	h_o	h_i	s_o	s_i	$-\dfrac{d_i}{d_o}$	$\dfrac{h_i}{h_o}$	$\dfrac{f}{s_o}$	$\dfrac{s_i}{f}$
15	10	30								

4. <u>Calculate</u>: Calculate the given ratios to fill in the last four columns of the table. (Hint: As long as the image is a real, upside-down image, all four ratios will be negative.)

5. <u>Analyze</u>: What do you notice about the four ratios? _____

(Activity C continued on next page)

Activity C (continued from previous page)

6. <u>Make a rule</u>: The magnification of an image is equal to the ratio of the image height to the object height. If the image is inverted, the magnification is negative. Using the ratios from the table on the previous page, write three equations to calculate magnification:

$$\frac{h_i}{h_o} = \qquad\qquad \frac{h_i}{h_o} = \qquad\qquad \frac{h_i}{h_o} =$$

7. <u>Manipulate</u>: If $\dfrac{f}{s_o} = \dfrac{s_i}{f}$, what is true about the product of s_o and s_i? _____

   Use the data you collected on the previous page to confirm that this relationship holds.

8. <u>Practice</u>: A candle is placed 14 cm in front of a concave mirror. The image of the candle is focused on a sheet of paper that is exactly 21 cm in front of the mirror.

   A. What is the magnification of the image? _____

   B. What is the focal length of this mirror? (Hint: Use the mirror equation.) _____

   Show your work:

9. <u>Practice</u>: A candle is placed 9 cm in front of a concave mirror with a focal length of 6 cm.

   A. How far from the mirror will the image be located? _____

   B. What is the magnification of this image? _____

   Show your work:

10. <u>Challenge</u>: When an object is between the focal point and a concave mirror an upright virtual image is created behind the mirror. Because the image is upright, the value of h_i is positive. In this case, what must be true about the values of d_i, s_o, and s_i?

_____

_____