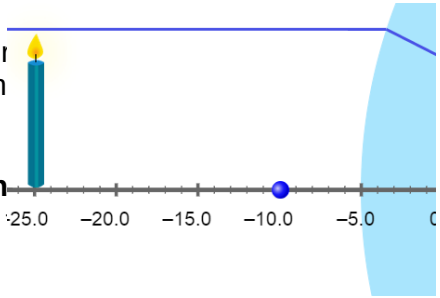
Student Exploration: Ray Tracing (Lenses)

Gizmo Warm-up

The *Ray Tracing (Lenses)* Gizmo™ shows light rays passing thr lens. The light rays are bent by **refraction** as they pass through and form a focused **image** to the right of the lens.



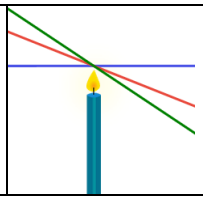
To begin, turn on the **Colorize lines** checkbox. Under **Show lin** the **Central line** and the **Line through focal point** so that only **Parallel line** is showing.

1. The blue dots in front of and behind the lens are the **focal points** of the lens. Move the candle on the left back and forth and up and down.

   What is always true about the light ray that emerges from the right side of the lens?

2. Turn off the **Parallel line** and turn on the **Line through focal point**. Move the candle.

   What do you notice about this line? _____

Activity A: **Real and virtual images**	Get the Gizmo ready: • Turn on the **Parallel line**, **Central line**, and **Line through focal point**. • Move the candle to -24 on the central axis, with the focal point at -12.	

Question: How do lenses create images?

1. Observe: In its current configuration, the distance from the candle to the focal point is 12 units and the distance from the focal point to the lens is also 12 units.

   A. What do you notice about the orientation of the candle's image on the right side of the lens?

   B. What do you notice about the size of the image? _____

2. Investigate: Complete each action listed in the table below, and describe how that action affects the image to the right of the lens. Return the candle and focal point to their original positions (-24 for the candle, -12 for the focal point) after each action.

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

3. Analyze: How is the image size related to the distance between the candle and the focal point?

4. Explore: Move the candle to -12 and the focal point to -24. Shorten the candle to see the whole image. What do you notice when the candle is between the focal point and the lens?

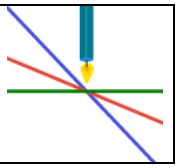
5. Investigate: Return the candle to -24 and the left focal point to -12. Under **Show specific line segments**, turn off **Apparent light lines**. On the menu at lower right, select **Concave lens**. A **concave lens** curves inward on both sides.

   A. What do you notice about the three lines after they pass through the concave lens?

   B. Turn on **Apparent light lines**. Is the image of the candle a real image or a virtual image? Explain. (Hint: Recall that a real image forms where light rays are focused.)

   C. Move the candle back and forth. No matter where the candle is placed, what is true about the image?

   D. What would an observer see if she looked at the candle through the concave lens?

Activity B: **Thin-lens equation**	Get the Gizmo ready: • Select the **Convex lens**. • Move the candle to -15 and the focal point to -10. • Turn off all line segments, and turn on **Show ruler**.	

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

1. Gather data: Use the ruler to measure d_i for each of the following values of d_o and f. For the last row of the table, use your own value of d_o and f.

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

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

3. Practice: A candle is placed 6 cm in front of a convex lens. The image of the candle is focused on a sheet of paper that is exactly 12 cm behind the lens.

   What is the focal length of the lens? _____
   Show your work: