6.4.1: Lens Simulation

You may have noticed in the last simulation, a wave that passes all the way through a piece of material with parallel sides (for instance light through a flat slab of glass) leaves the material at the same angle that it entered. The wave un-bends when it exits the material by the same amount that it bent when entering. This is only true if the sides of the material are parallel, however. In the simulation below we have convex and concave lenses where the sides of the glass are *not* parallel (except near the center). In this case parallel rays of light end up exiting in different directions. This is the basis for any optical device that uses lenses, for example cameras, binoculars, microscopes, glasses, eyes of various animals, etc.

At each surface the waves obey the law of refraction (Snell's law) but the result is that parallel rays that enter are not parallel when they exit. Although our example is for light it should be kept in mind that the same behavior occurs for other types of waves when they enter a medium where their speed is different (as in the previous refraction of sound in a balloon filled with Carbon Dioxide).

For this simulation we use the thin lens approximation which assumes the lens thickness is small compared to the curvature of the lens. This allows us to approximate the bending as if it occurs all at once at the middle line of the lens (instead of some bending at each surface which in fact is what happens).

The object (a candle) in the simulation can be moved using the mouse. White arrows show where the light rays actually travel. The purple lines are imaginary extensions of the real light rays. Our brain/vision system assumes light always travels in a straight line and does not bend. For light that does bend due to refraction, our brain interprets the light as following the purple paths and constructs and image based on this information. The units of height, h, and distance, d, are arbitrary (cm, inches, etc.)

Simulation Questions:

1. The definition of the focal length of a converging lens is the distance to the point where rays initially parallel to the axis meet after passing through the lens. The point is marked by a red circle called the focal point. Why is there a focal point on each side of the lens? Does it make any difference which way light travels through a thin lens?
2. Drag the object back and forth. Describe what you see. What two things are different about the image if the object is closer than the focal length, as compared to when it is further away from the focal length?
3. Use the slider to change the height of the object. How does the height of the image compare to the object height? Does the height of the object change any of your conclusions from the previous question? Explain.
4. For all cases a one ray goes straight through the center of the lens. Why is that? (Hint: Read the introduction.)
5. Carefully describe the other two rays. What happens to a ray that enters the lens parallel to the horizontal axis? What happens to a ray that goes through the focus (if the object is further away from the focus)? What happens to a ray that appears to come from the focus (if the object is closer than the focus)?
6. The previous two questions are about the rules for drawing light rays for a converging lens: 1. Rays parallel to the axis bend and go through the focus on the other side of the lens; 2. Rays going through the focus (or coming from the focus if the object is closer to the focus) bend to exit the lens parallel to the axis; and 3. Rays through the center go straight through without bending. Using these three rules, it is possible to determine where the image will be and how big it will be for any converging lens. Go back and verify these rules. Are they true?
7. Now choose the diverging lens case and experiment. How is it different from the converging case? How does the image size compare with the object size? Is there any case where the image is bigger than the object?
8. One of the rules for drawing rays for a diverging lens is the same as for a converging lens. Which one?
9. Carefully state what happens to a ray that is parallel to the axis when it exits a diverging lens. Also describe what happens to a ray that starts from the object and heads towards the focus on the opposite side. How are these rules different from the converging lens case?
10. As in the case of mirrors, some images from lenses are real (can be projected onto a screen) while others are virtual (are only seen by looking through the lens). For lenses, real images appear inverted and on the other side of the lens. Which cases above had real images and which had virtual images?
11. Your eye has a single lens which projects a real image onto your retina. The retina turns the image into nerve impulses which go to the brain to be interpreted. What is the orientation of this image? Is this surprising?