

**Model: Ray Optics****Act 8.6.4 Applying Refraction (FNTs 0-3) (~45 min)****Learning Goals:**

(see DLM08 for learning goals)

**Model: Thin Lenses****Act 8.7.1 The Properties of Thin Lenses (~55 min)****Learning Goals:**

- Many rays pass through the lenses. The principal rays are rays that are easiest to draw, using the focusing/defocusing properties of converging/diverging lenses
- Thin lenses are lenses that are thin enough to neglect the double refraction of light rays at their front and back surfaces; thus, we will assume that light rays are bent only once by a thin lens
- The images produced by lenses can be equivalently analyzed by either analytical (thin lens equation) or graphical (ray tracing) approaches
- Understanding real images as the result of an actual intersection of light rays refracted by the lens, and the implications with regards to image location.
- Understanding virtual images as the result of light rays diverging from a common point at which there is no actual intersection of light rays, and the implications with regards to image location.
- Ability to use the thin lens equation, including proper sign use for  $i$  and  $f$ .

**Act 8.7.2 Seeing Images (~30 min)****Learning Goals:**

- Understanding real images as the result of an actual intersection of light rays refracted by the lens, and the implications with regards to image location
- Understanding virtual images as the result of light rays diverging from a common point at which there is no actual intersection of light rays, and the implications with regards to image location

**Act 8.7.3 Image Formation in a Multiple Lens System (~10 min)****Learning Goals:**

- A lens effectively treats the light from an image (whether real or virtual) produced by another lens as an object
- In a two-lens system, the thin lens equation can be applied consecutively and independently to each lens

- 1) (Application) More practice with real lenses. You have been given three lenses to take home and keep.
- Look through each lens at a variety of objects at different distances. For each lens, note properties of the image such as size and orientation.
  - Use what you found in (a) to determine if the lens is converging or diverging based on the type of images you see.
  - As best as possible, determine the focal length of each lens. At a minimum you should be able to say, “very long” or “lens X has a greater focal length than lens Y.”
2. (Application) Finish reading Activity 8.7.3 and repeat the design of a multiple lens system for the systems listed below. Again, the lenses you have available to you are:
- converging ( $f=7.5$  cm)
  - converging ( $f=15.0$  cm)
  - diverging ( $f=-15.0$  cm)

Think about the following scenarios:

- Lens 1 makes a real image  $i_1$ , of which lens 2 makes a real image  $i_2$ .
- Lens 1 makes a real image  $i_1$ , of which diverging lens 2 makes a virtual image  $i_2$ .
- Converging lens 1 makes a virtual image  $i_1$ , of which converging lens 2 makes a virtual image  $i_2$ .
- Converging lens 1 makes a virtual image  $i_1$ , of which lens 2 makes a real image  $i_2$ .

For each scenario, decide:

- What type of lens is lens 1? Lens 2? Why? (Note the type is given for some lenses).
- Where should the object be placed with respect to the focal point to make the indicated type of image?
- Make a schematic drawing for **Scenario D** only. If you want extra practice, try to make schematic drawings of the other three scenarios. You can check your work in office hours or show your TA after class.

For help in understanding ray optics, view the lens animations on the web.

3. (Solidification) The eye has a lens that places the image at the retina (in the rear of the eye). For this exercise, assume that the retina is 2.5 cm behind the lens of the eye.
- What kind of image is this? What kind of lens is this?
  - The lens is adjustable by tensing and relaxing muscles. When a person focuses on an object at 25 cm from the eye, what is the focal length  $f$  of the eye at this time? (Note: 25 cm is the shortest distance that a “normal” eye can see an object clearly so it is called the “near point”.)
  - When a person focuses on an object at  $\infty$  from the eye, what is the focal length  $f$  of the eye at this time? (Note:  $\infty$  is the farthest distance that a “normal” eye can see an object clearly so it is called the “far point”.)

