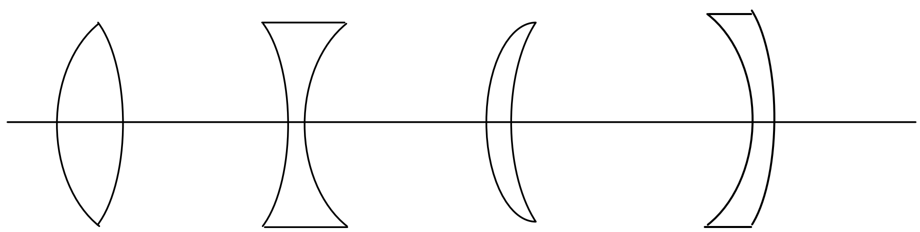
Lenses and Mirrors

Lenses and mirrors can be used to form images of objects. A lens redirects light rays because of refraction (bending) at each surface of the lens. The amount of bending depends on the curvature of the lens and its index of refraction. A mirror redirects light rays by reflection and this depends on the curvature of the surface.

Preliminary problems:

1. Which of the following lenses are converging and which are diverging.



2. An object is placed in front of a converging lens so that an image is formed on the opposite side of the lens. What happens to the image position if you bring the object closer to the lens?

   (a) moves further from the lens (b) moves closer to lens (c) doesn't change position

3. What happens to the image position if you make the lens thinner?

   (b) moves further from the lens (b) moves closer to lens (c) doesn't change position

4. Is the image upright or inverted?

Check your answers:

Now use the following simulation to check your answers.

http://phet.colorado.edu/en/simulation/geometric-optics

Note what happens when the object is placed closer to the lens than the focal length.

Lenses

Pasco apparatus:

Let's first measure the focal lengths of some lenses. Start by using the PASCO light boxes and the plastic cylindrical lenses. (The lens surfaces have a cylindrical shape.) Adjust the light box to get 5 parallel rays of light.

Place the converging lens (thicker in the middle) in front of the light box. Note that the rays of light converge at a point on the side of the lens opposite from the light source. This is the focal point and the distance from this point to the lens is the focal length, f. Trace the rays and measure *f*. In this case, we have a 'real' image (the light passes through the image) and the focal length is positive.

Now repeat using the diverging lens (thinner in the middle). Note that the rays of light diverge after they pass through the lens. To obtain the focal point, we need to trace these diverging rays and extrapolate the rays to their point of convergence in front of the lens (on the same side as the light source). Measure *f*. In this case, we have a 'virtual' image since the light rays don't actually emanate from the image, and the focal length is considered to be negative.

Lens assortment:

You have an assortment of various lenses. Select a *converging* lens. Use it to image a distant light source (e.g., a bright window on the opposite side of the room). View the image on a piece of paper and vary the distance from the lens in order to bring the image into focus. Determine the focal length (distance from paper to lens).

Now use the lens to image a much closer source. Let's first make a suitable object to image with the lens. Make a cutout of a shape (e.g., an upright arrow) in a sheet of cardboard. Tape a sheet of translucent material over the cutout and place this in front of an incandescent lamp. Place the lens a few tens of centimeters from the object (a distance greater than the focal length), and view the image on a sheet of paper. Determine the distance of the object from the lens (*p*) and the distance of the image from the lens (*q*). *p* and *q* should be related to the focal length, *f*, by the equation

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \quad .$$

Use this equation to calculate *f* from your measured values of *p* and *q*. How does this compare with your previous calculation of *f* using a distant light source?

Note the orientation and size of the image relative to the object. Measure the magnification (ratio of image size to object size). How does this compare to the ratio *q/p*? (They should be the same.)

Now select a *diverging* lens. What kind of image do you see when you look at an object through the lens? Is it real or virtual? You may be able to roughly estimate the focal length of the lens by estimating the image distance when viewing a distant source.

<u>Mirrors</u>

Examine the two large demonstration mirrors. Look at yourself in the concave mirror. Describe your image when you are close to the mirror. Is it real or virtual? Upright or inverted? Magnified or reduced? Repeat when you are far from the mirror.

Now look at yourself in the convex mirror. Describe your image. Is it real or virtual? Upright or inverted? Magnified or reduced?

For Further Study

1. Use the following applet to further investigate lenses and mirrors:

   http://bama.ua.edu/~jharrell/PH106-S06/activities/classes/optics/optics_bench.html

2. Make a pinhole camera. Cut an opening in one end of a small, enclosed box. Tape a piece of aluminum foil over the opening and use a pen to make a small hole in the foil. Cut out the other end and tape over the cutout a piece of translucent paper. When light from a bright object is admitted into the pinhole, the image projected onto the translucent paper can be viewed from outside the box.