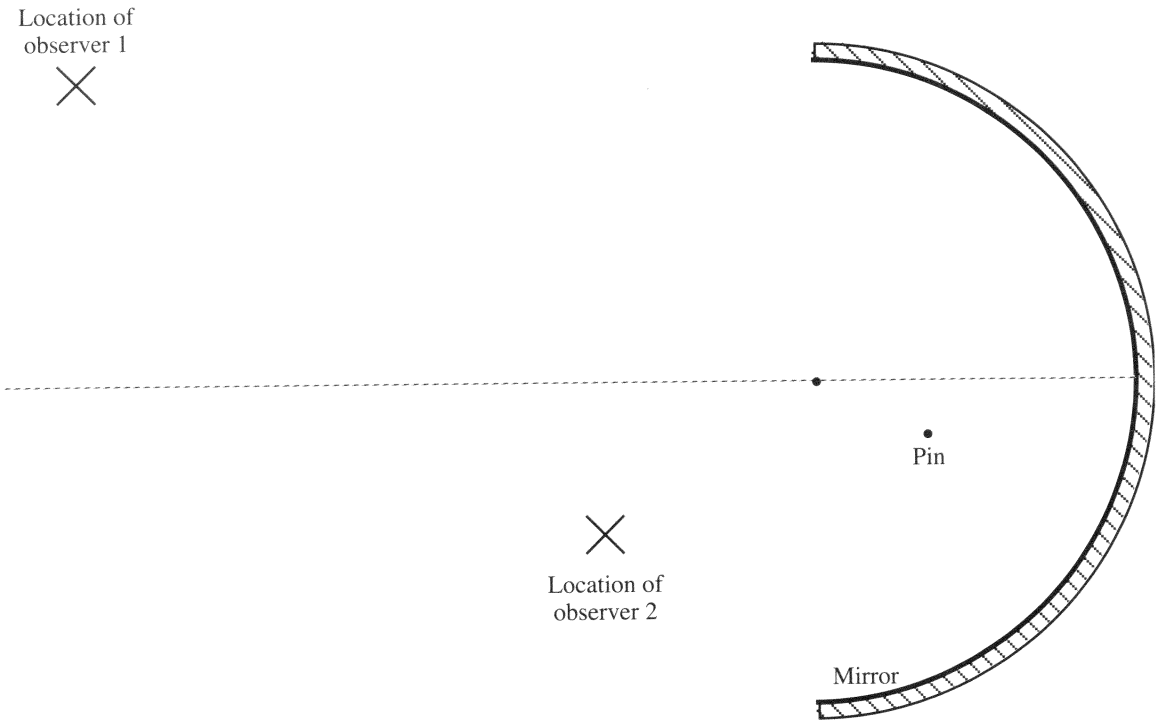
Note: You will need a *straightedge* and a *protractor* for both problems on this homework.

1. A pin is placed in front of a semi-cylindrical mirror as shown in the top view diagram below.



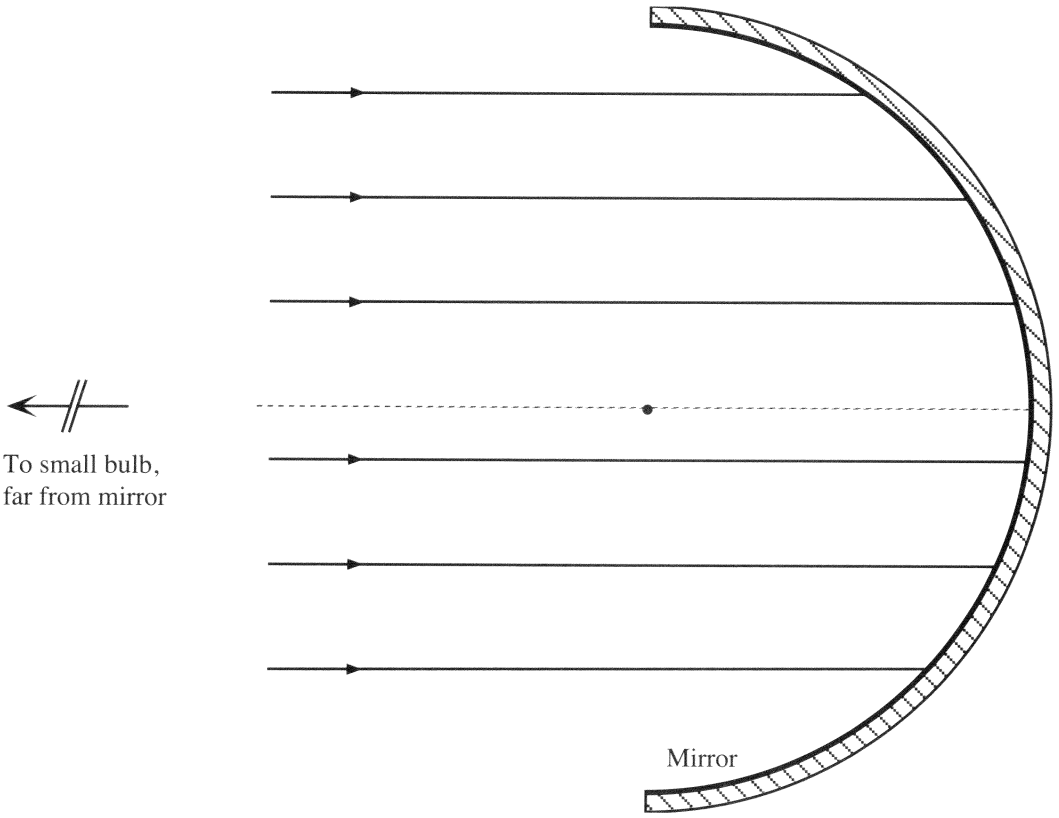
a. Use the law of reflection to draw a ray diagram that shows the location of the image seen by observer 1. Use a protractor and a straightedge to make your diagram as accurate as you can. (*Note:* The center of curvature and the axis of the mirror are marked.)

Clearly label the location of the image on your ray diagram.

b. Is this image *real* or *virtual?* Explain your reasoning.

c. Will observers 1 and 2 agree on the location of the image of the pin? Support your answer with a ray diagram and explain how you used the diagram to determine your answer.

2. A very small, very bright bulb is placed far from a semi-cylindrical mirror. The bulb is located on the axis of the mirror. Some light rays from the distant bulb are shown in the diagram below.



a. Use the law of reflection to continue the rays shown in the diagram. Use a protractor and a straightedge to make your diagram as accurate as you can. (*Note:* The center of curvature and the axis of the mirror are marked.)

b. Is there a well-defined focal point for the (entire) mirror?

If so: Identify and label the focal point on the diagram. Explain how you used your ray diagram to determine your answer.

If not: Identify and label the approximate portion of the mirror for which a focal point is well defined. Identify and label the focal point for this portion of the mirror. Explain how you used your ray diagram to determine your answers.

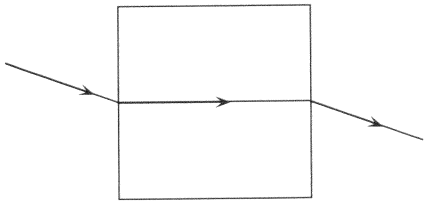
INTERPRETATION OF RAY DIAGRAMS

Name _____

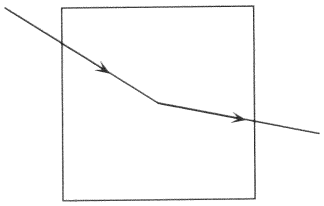
1. The following are top view diagrams of solid cylinders and cubes. Assume that light travels more slowly through the objects than through the surrounding medium.

   Each diagram shows a path for light that is *not* qualitatively correct; there is at least one flaw, perhaps more, in each diagram. Identify *all* flaws. Explain your reasoning.

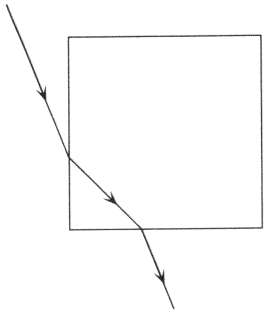
a.



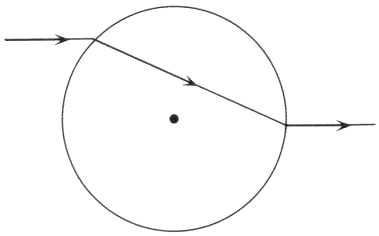
b.



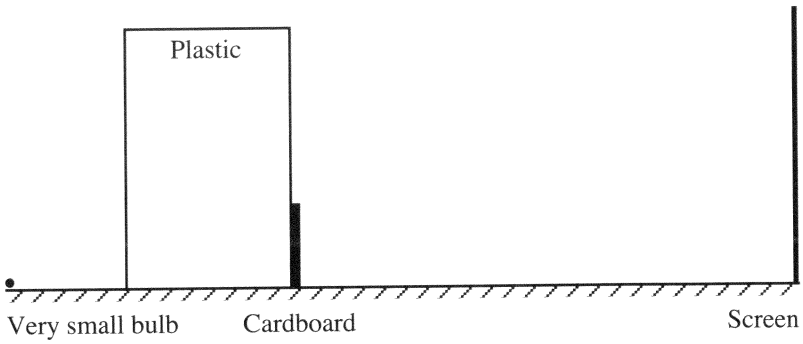
c.



d.



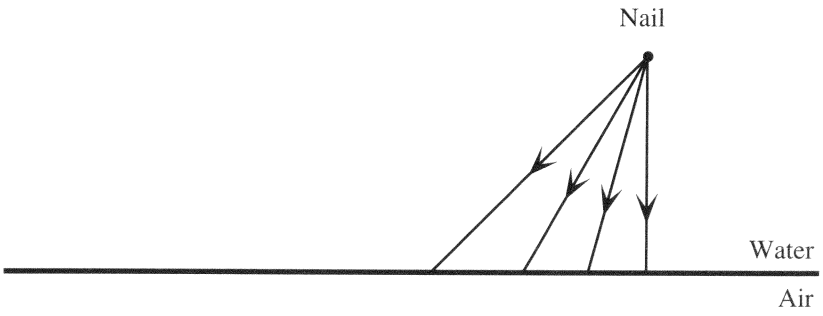
2. A very small bulb, a rectangular block of plastic, a piece of cardboard, and a screen are placed as shown at right. Imagine that the room is darkened and the bulb is turned on.



   If the plastic were removed, would the height of the shadow on the screen *increase, decrease,* or *stay the same?* Explain your reasoning, and support your answer with a clear ray diagram.

3. A nail is placed in a tank of water as shown in the top view diagram below. (Only a portion of the tank is shown.) Assume that light passes directly from water to air.

   a. Use a protractor and straightedge to draw each of the four refracted rays on the diagram *accurately*. (The index of refraction for water is 1.33.) Record the angles of incidence and refraction in the table below.



θ_{inc} (in water)	θ_{refr} (in air)

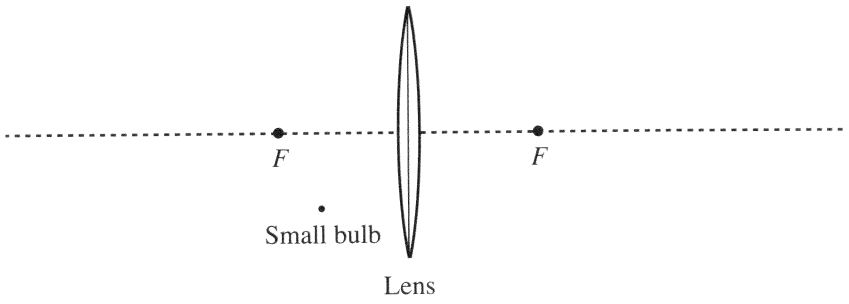
   b. If several different observers were standing in front of the tank, would they agree upon the location of the image of the nail (as viewed through the water)? Explain how you can tell from your ray diagram.

   - If different observers would *agree* upon the image location, indicate this image location on the diagram.
   - If different observers would *not agree* upon the image location, indicate on the diagram the approximate image location for each of *three* different observer locations. Clearly indicate which image location corresponds to which observer location.

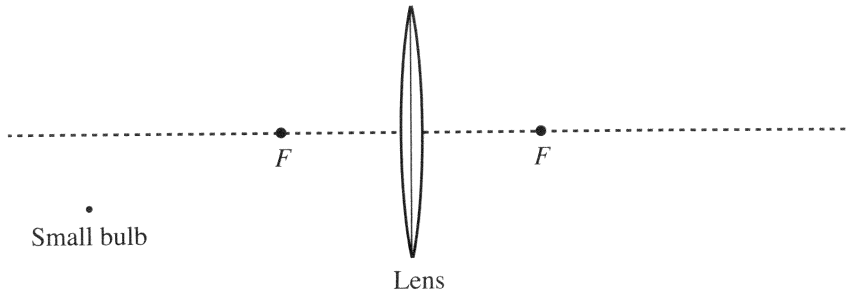
   c. Is the image(s) of the nail *real* or *virtual?* Explain your reasoning.

1. A small bulb is placed in front of a convex lens.

   a. Suppose that the bulb is placed as shown. Using all three principal rays, draw an accurate ray diagram to determine the location of the image. Label the image location.

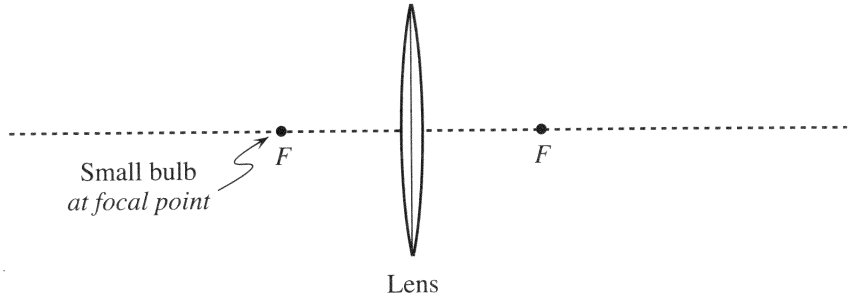


   b. Repeat part a for the case shown at right, in which the bulb is farther from the lens.



   c. Suppose that in each case above you were to place a small paper screen at the image location. What you would see on the screen in each case? Imagine that the room is dark except for the small bulb.

   d. The light bulb is placed at one focal point of the lens as shown at right.

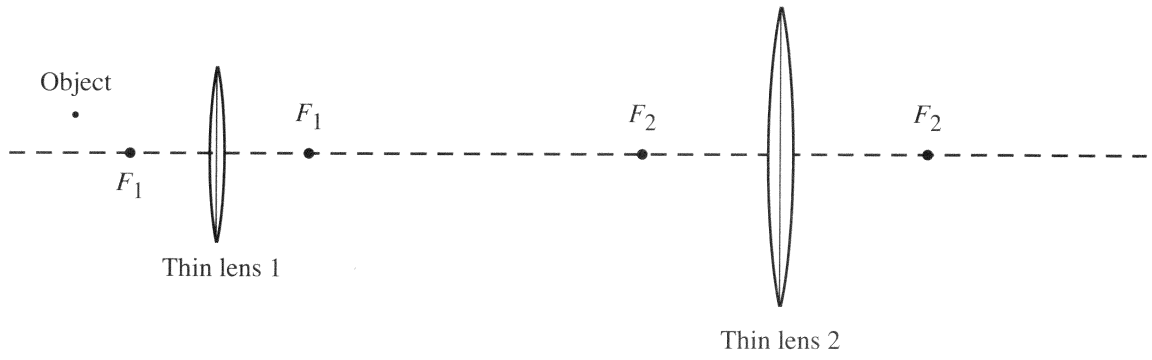


   Draw at least five rays from the bulb that pass through the lens.

   Where is the image located in this case? Explain. (*Hint:* How are the rays that have passed through the lens oriented? From where do these rays *appear* to have come?)

2. Two thin convex lenses (1 and 2) and a small object are arranged as shown.

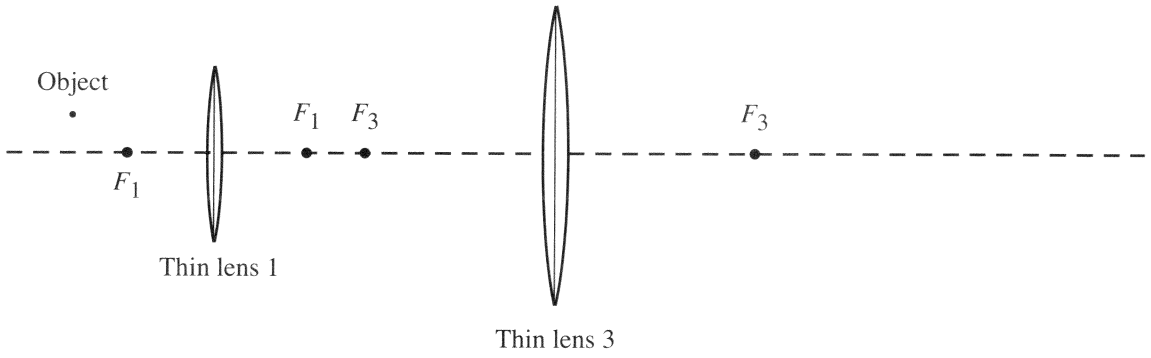
   a. Use the three principal rays to determine the location of the image of the object produced by lens 1.



   b. Treat the image produced by lens 1 as an object for lens 2. Use the three principal rays to determine the location of the image of this object produced by lens 2.

   Is this image produced by the pair of lenses *real* or *virtual?* Explain your reasoning.

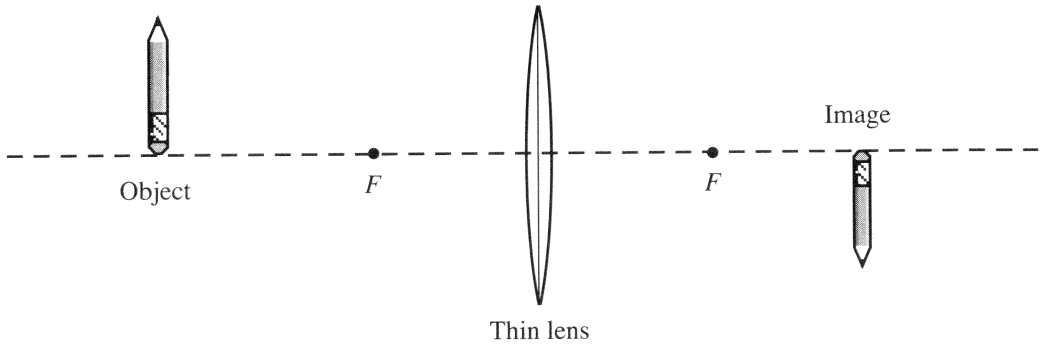
   c. Repeat parts a and b for the case in which lens 2 is replaced with a different lens (lens 3), as shown below.



   Is the image produced by the pair of lenses *real* or *virtual?* Explain your reasoning.

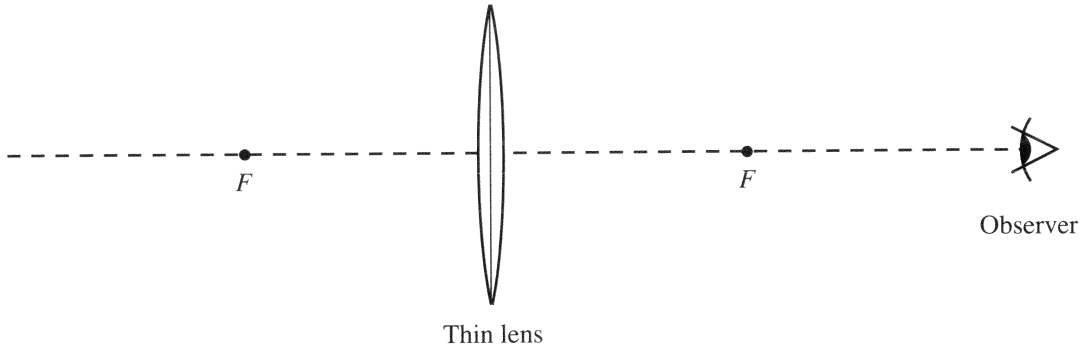
1. Reproduced below is a side view diagram of the situation described in section II of the tutorial.

   Determine an expression for the lateral magnification, $m_l = h'/h$, in terms of the object distance, x_o, and the image distance, x_i. (*Hint:* Draw the principal rays for the tip of the pencil and look for similar triangles. Clearly indicate the similar triangles that you use to determine your answer.)

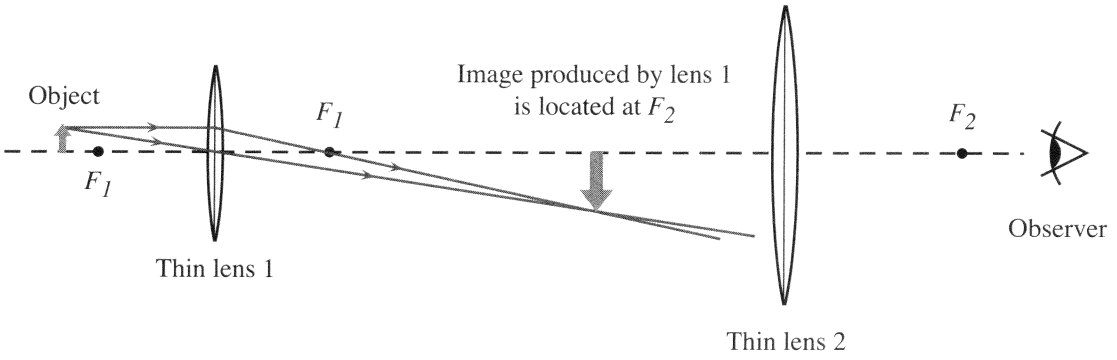


2. In section III of the tutorial *Magnification,* you used a convex lens as a magnifying glass.

   Is the expression that you derived in problem 1 above for the lateral magnification, m, also valid in this case? If not, what expression holds in this case? Draw a diagram below to support your answer.



3. Two thin convex lenses and an object are arranged as shown below. Two rays from the tip of the object are drawn in order to determine the location of the image produced by lens 1. Lens 2 is placed so that one of its focal points coincides with the location of the image produced by lens 1.



a. Treating the image produced by lens 1 as an object for lens 2, draw *two* principal rays from the tip of this image that pass through lens 2. (Note that one of the principal rays cannot be drawn in this case.)

   Using either geometry or trigonometry, show that these two principal rays are *parallel* on the right side of lens 2. (*Hint:* Look for congruent right triangles in your ray diagram.)

b. Where is the tip of the image seen by the observer located? Explain. (*Hint:* From where do the rays on the right side of lens 2 *appear* to have come?)

c. On the diagram above, clearly indicate:

   - the direction in which the observer must look to see the *tip* of the image,
   - the direction in which the observer must look to see the *tail* of the image, and
   - an angle that represents the angular size of the *entire* image seen by the observer.