Physics 216 Lab 5, Spring 2018
Reflection, refraction, and image formation

Some of these experiments were adapted from McDermott *et al., Physics by Inquiry.*

Investigation I: Reflection and image formation in a plane mirror

Activity 1-1: Using parallax to find image location

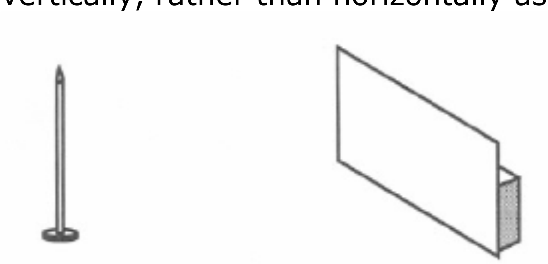
Have your partner hold two pencils about one meter in front of you, one vertically above the other so that their points are almost touching. Then have your partner move one pencil about 15 cm closer to you. Close one eye, then place your head so that one pencil appears to be directly above the other. Now move your head from side to side. Describe what you observe. If you move your head to the right, which pencil appears to be on the right: the one closer to you or farther from you? If instead you move your head to the left, which pencil appears to be on the left: the one closer to you or farther from you?

Have your partner move the closer pencil back so it's the same distance from you as the other pencil is. How does this change affect what you observe when you move your head from side to side?

You observe that two objects at different distances from your eye appear to move relative to each other when you move your head from side to side. This effect is called parallax, and while it can be a problem when reading instruments, it is useful for determining the location of an image.

How must two objects be located relative to one another if you observe no effect of parallax when you move your head from side to side?

Obtain two identical large nails and a mirror. Place one nail upright on a large sheet of paper about 10 cm in front of the mirror (you may find it easier with the mirror oriented vertically, rather than horizontally as shown below). We will call this nail the "object nail."



Place your head so that you can see the image of the object nail. Apply the strategy for using parallax to place a second nail at the location of the image. Mark this location on the paper.

Move your head to a new location and repeat the procedure. Is there a unique location where all observers would agree that the image is located (provided they can see an image)? Check your answer experimentally. Is the image where you expect it to be?

√Checkpoint 1

Activity 1-2: Lines of sight
In the following activity, we'll determine the location of an image by another technique. This technique is based on the ray model for light in which we envision light as being emitted in all directions by luminous objects, such as light bulbs, or as being reflected in all directions by non-luminous objects, such as nails.

Place a mirror and a large nail on top of the paper as you did in the previous activity. Mark the location of the object nail on the paper, and draw a line on the paper to mark the location of the mirror.

Place your head near the surface of the table and look at the <u>image</u> of the nail. Position a ruler on the paper so that, from your location, the edge of the ruler appears to be in line with the image of the nail. Use the edge of the ruler to draw your line of sight to the image. Can you tell the location of the image from the single line of sight that you have drawn? Explain.

Repeat the procedure above from two different eye locations. Remove the nails and mirror from the paper and use the lines of sight that you drew to determine the location of the image of the nail. Is the image where you expect it to be?

Activity 1-3: Ray tracing
Use your sheet of paper from the previous activity (with the lines of sight drawn on it). For each of the lines of sight, draw a ray that shows the <u>entire</u> path of light from the object nail, reflecting off the mirror, to your eye. Show how such a ray diagram can be used to locate the image of the nail.

√Checkpoint 2

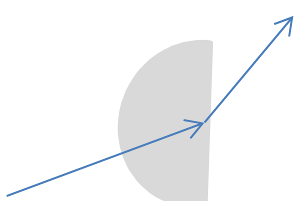
Activity 1-4: Image size
Place one large nail (the "object nail") in front of the mirror. Use the method of parallax to place the second large nail at the location of the image of the object nail. How does the size of the image compare to the size of the object nail? Explain your reasoning.

Move the object nail farther away from the mirror and repeat the experiment. Is the size of the image still the same as it was before? Explain how you can tell.

What do we mean when we say that the image in a plane mirror is the same size as the object?

√Checkpoint 3

Investigation II: Refraction
Activity 2-1: Measuring the index of refraction
The goal of this experiment is to use Snell's Law to determine the index of refraction of a plastic material. We will use a semi-cylinder of plastic (see top view below), with the beam of light aimed at the center of the cylinder so that it enters the plastic along the normal (and therefore doesn't bend when entering the plastic), and then refracts back out into the air at the flat surface. You may need to remove laser from its stand to get height right.



Design an experiment to determine the index of refraction of the plastic using this method. You will have a laser, protractors, and rulers. Your experimental design should take into account the fact that using multiple measurements yields more accurate results. You should also be able to estimate the uncertainty in your measurement. One possible approach is to make measurements for a number of incident angles and use those measurements to find a mean and standard error of the mean. Another possibility is to exploit the fact that $\sin\theta_2$is proportional to $\sin\theta_1$, and the proportionality constant is related to the index of refraction—so the index of refraction can be obtained by plotting measured values of $\sin\theta_2$vs. $\sin\theta_1$ and fitting with a straight line.

Talk with me about your proposed experimental procedure before beginning any measurements.

In the space below, describe your experimental procedure and record your measurements appropriately. If you do any graphing/fitting indicate that and attach printouts.

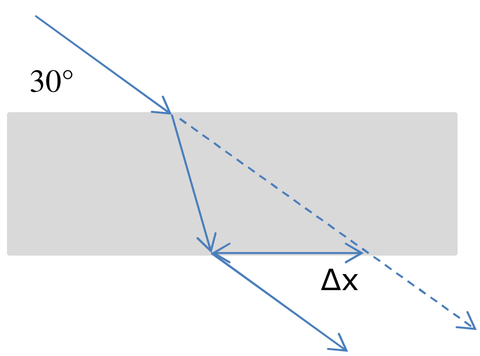
From your data, determine the index of refraction of the plastic, with uncertainty.

√Checkpoint 4

Activity 2-2: Total internal reflection
Use the same equipment to measure the critical angle for total internal reflection for light going from plastic to air. Include uncertainty. Use your results to determine the index of refraction for the plastic. Compare the result of this determination with that from Activity 2-1 and comment on the agreement.

√Checkpoint 5

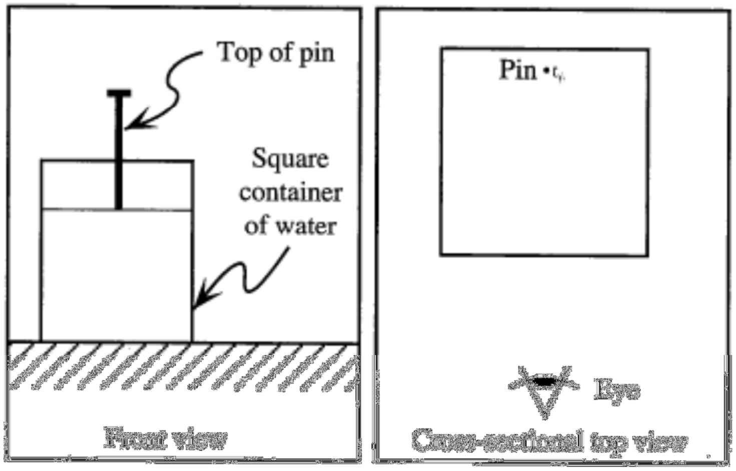
Activity 2-3: Application: Deflecting a laser beam
Use your measured index of refraction to predict by how much the laser beam will shift from its original path if it shines on a rectangular piece of the same type of plastic at an angle of 30° to the surface as shown below (Δx). Carry out the experiment and comment on how well your results agreed with your prediction.



√Checkpoint 6

Activity 2-4: Application: Images formed by refraction at a single surface

Prediction 2-1: A nail is held vertically at the back of a clear square container of water as shown below. The portion of the nail below the surface of the water is not shown. Do you expect the part of the nail that's below the surface to look closer to you, farther from you, or the same distance from you as the part of the nail that's above the surface? Explain briefly.



On the top view diagram, sketch several rays from the nail that pass through the water and out the front of the container, near the observer's eye. (Use the approximation that light passes directly from water to air—that is, ignore any refraction by the thin walls of the container. Why is this justified?)

On the basis of the rays you have drawn, predict where the image of the part of the nail that's underwater appears to be. Would it appear to be located closer to, farther from, or the same distance from the observer as the portion of the nail that's out of the water? Explain your reasoning.

Obtain the necessary equipment and use the method of parallax, or the method of line of sight, to check your prediction. If your ray diagram is not consistent with your observations, modify your ray diagram.

Application: a swim mask has a pocket of air between your eyes and the flat glass front. If you're swimming underwater and wearing the swim mask and you look at a fish a few feet in front of you, does the fish appear closer or farther than it really is? Why? Does the fish see your face closer or farther than it really is? Why?

√Checkpoint 7