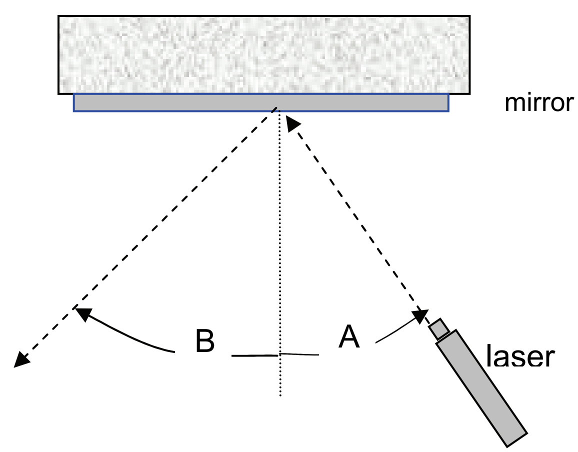
Experiment 11: Reflection and Refraction of Light

CAUTION: **In this exploration you will use a laser beam. Even the weakest laser can harm your eyes. DON'T LOOK INTO THE LASER WHEN IT'S ON. Think about where the beam might go, and avoid having the beam at eye level.**

1. Obtain a beaker, and add warm-hot water until it is 1/2 to 2/3 full. Place the beaker on a white piece of paper. Shine the laser beam into the water, from the top. Repeat this after mixing in a pinch of coffee creamer to the water. Compare your observations of each case. Set the beaker and water aside for later.

2. Obtain a blank piece of paper, a plastic bag, a mirror, and a laser.

   a. Design an experiment to find how the laser reflects off the mirror. Specifically, you are to predict and determine how the angles A (angle of incidence) and B (angle of reflection) are related. You need not use all the materials. Describe your experiment in enough detail that another person could reproduce it. How many different incident angles would be needed to be confident in the relationship between A and B?



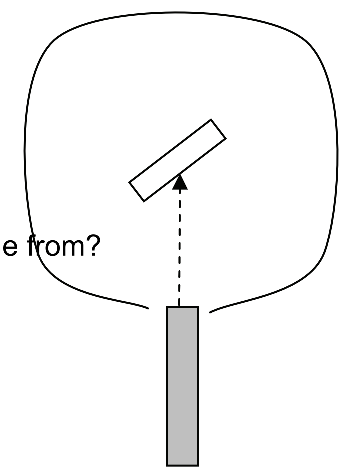
   b. Describe your results.

3. Obtain a Lucite (a plastic used for optics) triangle and another piece of paper. Cut the paper lengthwise into 2 pieces and tape it to create a circular screen of about 20cm diameter. Leave a gap for the laser to shine through (see picture, below). Place the triangle in the center of the circle.

a. Predict what would happen to the laser beam if it were shined through the side of the Lucite triangle, as in the sketch below:

Test your prediction and describe the results:

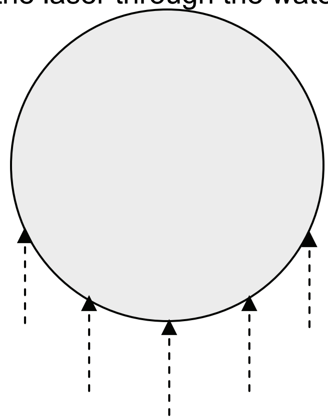
b. Now try rotating the triangle about a vertical axis. Avoid the cases where the laser shines through an edge—these are more complex. You should see three laser "images" on the screen. How do these images move as the triangle is rotated? Hint: examine the one that goes "straight through" very closely.



c. How can you explain these movements and where the three images come from?

d. In #2, above, you found a relationship between the angles of incidence and reflection. Examine the paths of the laser for the Lucite triangle, and draw a picture to show how this law applies.

4. Shine the laser through the side of the beaker and cloudy water, below the water line. Look at the path of the laser from above.
   As you change the direction of the laser pointer from the center of the beaker to the edge, examine how the resulting laser beam changes direction in the water. On the diagram, sketch the path of the laser through the water for each case.



5. Now put the beaker inside the “surround screen.” To simulate step 4, you can either aim the laser at different parts of the beaker, or slide the beaker left-right.

   a. What laser projections do you see now? Hint: one of the paths/projections is much fainter than the others, especially through the water.

   b. How can you explain these movements and where the three images come from? Draw a picture (as seen from above) to show how the reflection is occurring.

   c. Now point the laser through the beaker *above the water line*. Is the light bent more or less without the water?

Discussion: Reflection and Refraction

A *reflection* occurs whenever light encounters a surface. The reflection is called *specular* if the surface is smooth (like a mirror) and *diffuse* if it is rough (like a movie screen). Specular reflection isn't all that complicated, as you showed in part 2, except that it can happen at multiple surfaces, leading to more reflections than you might expect.

In binoculars and camera lenses, special coatings are applied to the surfaces of the lenses to minimize reflections, since these reflections reduce light transmission and degrade the image. The usual single coating absorbs the middle of the spectrum of reflected light and only allows red and violet to be reflected; this is why the coatings appear to be purple.

Refraction is the bending of light when it passes between different materials. Fundamentally, light bends because the speed of light varies in different materials: it is fast in air but slower in water, plastic, or glass. The amount of bending (and slowing) of light is described by the *index of refraction*. The higher the index, the more the bending (and slowing):

Medium	**Index of Refraction**
Air	1.00
Water	1.33
Lucite	1.51
Glass (regular)	1.52
Glass (optical)	1.66
"High Index" eyeglass plastic	1.66
Diamond	2.42

When light goes from air to glass it must slow down, and it so happens that it bends towards the perpendicular of the surface when it does so. Conversely, when light goes from glass to air, it speeds up and bends away from the perpendicular.

Question:

In parts 3 and 5 above, explain how refraction affected the path of the laser beam.

Lenses

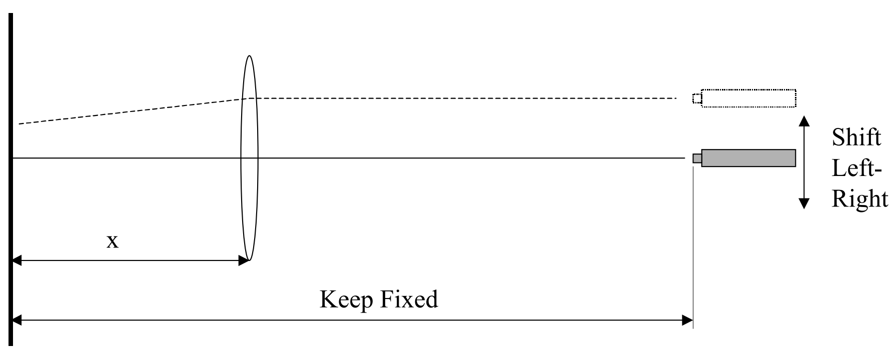
Obtain 3 lenses (marked #1, #2, #3), a laser, a meter stick, and a white screen.

1. a. Look at the surfaces of the three lenses. Two are convex (like the beaker) and one is concave (like a “cave”). You can use the meter stick to see the concave surface better. Look at lenses #1 and #2 from the side. How do the curvatures of the surfaces compare? If you have eyeglasses, check out what kind of lenses they are, too.

b. Experiment with the three lenses to get a feel for their magnification individually and in combination (e.g., #1 and #2 together, etc.). Holding the lenses a few inches off this paper works well. Make predictions and test (e.g., "1 and 2 together will be stronger than lens ___ but weaker than ___")

Combination	Prediction	Result
1 and 2		
1 and 3		
2 and 3		

2. a. Start with the convex lens #1. Holding the laser horizontally on the table, point the beam through the lens held vertically (see diagram below). Shine the beam on a piece of paper/cardboard about 20 centimeters on the other side of the lens (x=20cm). Keep the laser horizontal and describe what happens to the spot on the paper as you raise the beam; as you lower the beam; as you shift it left or right. Also, keep the distance from the laser to the paper fixed.



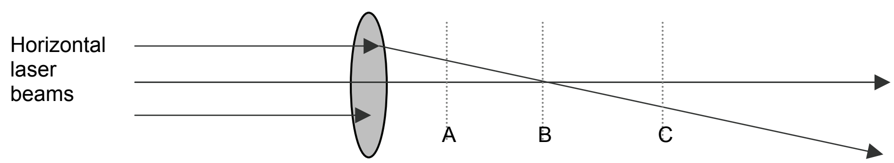
b. Change x to 5cm, and describe what happens.

c. Find the distance, x, where nothing happens as you shift the horizontal beam left and right (try to keep the laser beams parallel to each other). Record this special distance x_f.

d. Now turn the room lights off, and move away from the windows. Allow the window light to shine through the lens and onto a piece of paper/cardboard. Vary the dimension, x, and describe what you see. Record the x_f that produces a clear image. Compare it to that in part c, above.

3. a. Switch to the thinner lens, marked "2", and repeat step d, above. How is the image different?

4. A SCIENTIFIC MODEL:



When the paper is held at C, explain why the dot on the paper moves up and down as the laser moves down and up (opposite).

When the paper is held at B, explain why the dot on the paper doesn't move when the laser moves.

When the paper is held at A, explain why the dot on the paper moves up and down as the laser moves up and down.

5. How is x_f related to:

a. The strength of magnification?

b. The curvature of the lens?

c. The amount the lens bends the laser light?