INTRODUCTION
Have you ever really thought about reflection? Sure, you watch yourself brush your teeth every morning, and that rear-view mirror sure is handy when you’re backing out of the driveway, but how about curved mirrors? Why are objects in your side-view mirror closer than they appear? And what shape are all those annoying fitting room mirrors that make everyone look terrible? We also want to think about refraction, which happens when light (instead of bouncing off) passes through from one medium to another (like from air to water). You have probably made casual observations, perhaps noticing that your fingers appear “broken” when you dip them in the pool.

OBJECTIVES
- Observe reflection from flat and curved surfaces
- Establish quantitatively the law of reflection
- Observe the difference between real and virtual reflected images
- Quantify the observed refraction as light passes from one medium to another
- Measure the critical angle for total internal reflection, and compare it to the predicted value for the medium

ACTIVITY 1: PLANE REFLECTION
- Set up the optics bench so that you have a single ray of light striking the plane mirror (details provided in lab).
- Rotate the ray table so that the incoming beam makes a 10° angle to the mirror, and record the angle of reflection.
- Repeat for several more angles, recording both the angle of incidence and angle of reflection.

QUESTIONS
1. Sketch the the incoming and reflected light beams, showing the relationship between the angle of incidence and the angle of reflection. Use a ruler and protractor to make an accurate diagram.
2. Disregarding small discrepancies due to alignment, is there any angle of incidence for which the angle of reflection is not equal?

ACTIVITY 2: CURVED MIRRORS
- Set up the optics bench so that you have multiple parallel beams of light. The beams should be aligned along the normal on the ray table.
- Place the plane mirror on the ray table so that the beam is reflected straight back at the source. This shows that you are properly aligned.
- Replace the plane mirror with the convex mirror, and note the direction of the reflected beams.
- Replace the convex mirror with the concave mirror, and note the direction of the reflected beams.

QUESTIONS
3. Use the ruler and protractor to make an accurate sketch of the incoming and reflected beams for each mirror.
4. Does the rule that angle of incidence = angle of reflection apply to curved mirrors? Explain.
5. Which mirror could also be called a converging mirror? Which mirror could be called diverging?
6. Examine each image above. Identify whether the image is real or virtual, the mirror is concave or convex, and whether the object is located inside or outside the focal length of the mirror.
**Activity 3: UFO Mirror**

Examine the curved dish containing the coins.

**Questions**

7. Where does the image of the pennies appear? Is it inverted? Is this a real or virtual image?

**Activity 4: Snell’s Law**

- Set up the optics bench so that you have a single ray striking the cylindrical lens on the ray table. Initially, the ray should be aligned along the normal and **incident on the flat side** of the lens.
- Rotate the platform for an angle of incidence of 10°. Record the angle of refraction as the beam emerges.
- Repeat for angles of incidence 20°, 30°, and 40°.

**Questions**

8. Sketch the path of the light beam from the source until it exits the cylindrical lens.
9. If the beam strikes the tank perpendicular to the lens (0° on the marker), is the beam refracted? Why not?
10. How does changing the angle of incidence affect the amount of refraction? Include this on your sketch.
11. Use Snell’s Law to determine the index of refraction of the glass lens:

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]

In our example, air is the incident medium (1) and the glass lens is the refracting medium (2). This means that \( n_1 = 1 \), and \( n_2 \) is what you are finding.

**Activity 5: Total Internal Reflection**

- Set up the optics bench so that you have a single ray striking the cylindrical lens on the ray table. Initially, the ray should be aligned along the normal and **incident on the curved side** of the lens.
- Slowly rotate the ray table until there is no emergent beam, and all of the light is reflected back into the glass lens. Record the angle.

**Questions**

12. Describe qualitatively what happens to the emergent beam of light as the angle of incidence approaches the critical angle.
13. What is the critical angle for total internal reflection?
14. Using Snell’s Law, the critical angle can be determined if the indices of refraction are known:

\[ \sin \theta_c = \frac{n_2}{n_1} \]

In our example, the glass lens is the incident medium (1), and air is the refracting medium (2). So \( n_2 \) is the index of refraction for air (\( n_2 = 1 \)). Use the above equation to find the index of refraction for the glass lens (\( n_1 \)).

15. How does the value of the index compare to the value you calculated in Activity 5? Which value do you think is more accurate? Why?

16. If the index of refraction for water is \( n_1 = 1.3 \), will the critical angle for total internal reflection be greater than or smaller than the critical angle you recorded for glass?