Pre-Lab Preparation Sheet for Lab 2:
Geometric Optics – Reflection and Refraction
(Due at the beginning of lab)

Watch the following videos,
https://www.youtube.com/watch?v=FOwDgpKTqdy

Then read over Lab 2, and answer the following questions.

1. The refractive index of titanium dioxide (aka white pigment) is 2.614, one of the largest of any material. What is the speed of light in TiO₂?

2. What is the critical angle for an TiO₂ to air interface?
WHAT'S THAT TRICK FOR TELLING HOW MANY MILES AWAY LIGHTNING IS?

JUST COUNT THE SECONDS BETWEEN THE VISIBLE FLASH AND THE RADIO WAVE BURST, THEN MULTIPLY BY 5 BILLION.

xkcd.com
All that is now
All that is gone
All that’s to come
and everything under the sun is in tune
but the sun is eclipsed by the moon.

--Pink Floyd, *Dark Side of the Moon*

**Objectives**

To understand Snell’s law, reflection, refraction, and total internal reflection

**Equipment**

- 2 equilateral prisms
- 1 right angle glass prism
- 1 right angle acrylic prim
- Light box
- Clear plastic cup half filled
- Aluminum block
- Protractor and ruler
- Paper towels

**Introduction**

Waves may travel at different speeds in different media. When a wave travels from one medium into another with different wave speeds, two things will occur:

1. Part of the wave will **reflect** off the interface. The reflected angle is equal to the incident angle.
   \[ \theta_i = \theta_r \]  \hspace{1cm} (1)

2. Part of the wave will transmit into the 2nd medium, but its direction of travel will be bent or **refracted**. The angle of the transmitted wave is given by Snell’s Law
   \[ \frac{\sin \theta_i}{\sin \theta_r} = \frac{v_i}{v_t} , \]  \hspace{1cm} (2)

where \( v_i \) and \( v_t \) are the speeds of the incident and transmitted waves.
This is true of all waves: sound waves, light waves, tsunamis, . . . any kind of wave.

When dealing with light waves, we define a value called the index of refraction:

\[ n \equiv \frac{c}{v}, \quad (3) \]

Where \( v \) is the velocity of light in a particular material, and \( c \) is the velocity of light in a vacuum \( \left(2.998 \times 10^8 \, \frac{m}{s}\right)\). Hence, we can write Snell’s Law as

\[ \frac{\sin \theta_i}{\sin \theta_r} = \frac{n_r}{n_i} \quad (4) \]

**Exercise 1: Reflection and Refraction**

1. Place the semi-circle of glass on the printed protractor. Adjust the light box so that a single beam of light is produced. Shine the beam on the center of the flat surface with the incident angle \( \theta_i \) (listed in Table 1A) and measure the corresponding reflected \( \theta_r \) and transmitted \( \theta_t \) angles. (See Figure 2.) Fill in Table 1A below.

2. Next, reverse the semi-circle as illustrated in Figure 2B. Again, Measure the angles and fill in Table 1B below.
3. Using Excel, plot $\sin(\theta_i)$ vs. $\sin(\theta_t)$ for both tables. From this plot, determine the index of refraction of glass.

4. You will notice that light may be bent toward the normal or away from the normal. (See the figure below.) What determines the direction?

![Figure 3](image)

For some of your measurements, there was no transmitted light beyond a particular angle. Instead, all of the light is reflected off the interface. This condition is called *total internal reflection* and occurs because the transmitted angle $\theta_t$ cannot be larger than 90°. The minimum incident angle at which this occurs is called the *critical angle* $\theta_c$.

5. Carefully measure the critical angle of glass.

6. At the critical angle, what is the transmitted angle $\theta_t$?
7. What are the required conditions for total internal reflection?
   a. Explain in English:
   b. Derive an expression for $\theta_c$.

8. Similarly use the water lens to measure the index of refraction for water via multiple refractions and the critical angle.

9. Compare your value for the index of refraction of water to the accepted value.
Snell’s Law still applies if the glass block is placed in water.

10. Submerge the glass block in the water. Measure the critical angle of the glass / water interface.

11. From this, calculate the index of refraction of water. Compare your result with the commonly accepted value.
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Table 1A: Air to glass

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Table 1B: glass to Air
Exercise 2: A glass of water

You should find a clear plastic cup on the table. The bottom of the cup is painted white.

12. Fill half with water, and place it on the black surface of the table.
13. Looking straight down into the cup, observe the reflections on the side.
14. Place a dry finger against the side of the cup and observe the effect on the reflection.
15. Place a wet finger against the side of the cup and observe the effect on the reflection.
16. Describe the phenomenon, then write a complete explanation of the phenomenon.

Figure 4
Exercise 3: Dispersion

17. Using Google, study the cover art for Pink Floyd’s *The Dark Side of the Moon*. Then, attempt to reproduce it with an equilateral prism.* Which color is bent the most? The least?

18. What does this imply about the speed of light and the index of refraction of the different colors in glass? Which color is the fastest? Slowest?

19. Using a 2nd prism, can you recombine the colors? Can you separate them more?

* This is best done while humming *The Great Gig in the Sky*. 
20. Position the aluminum block after the 1\textsuperscript{st} prism so that only red light can pass. Then send the single color through the 2\textsuperscript{nd} prism. Does the 2\textsuperscript{nd} prism have any effect on the color or dispersion of the red beam? How about blue light?