Physics IV: Light and Optics **Name** ______________
Summerfield Waldorf School and Farm **Date** ______________

Lab: Snell's Law

Introduction

When we look into a pool or lake, the position of the bottom is changed. This shifting is called refraction, and occurs in all sorts of media and many different types of waves–light, sound, radio, and even mechanical vibrations (earthquake waves).

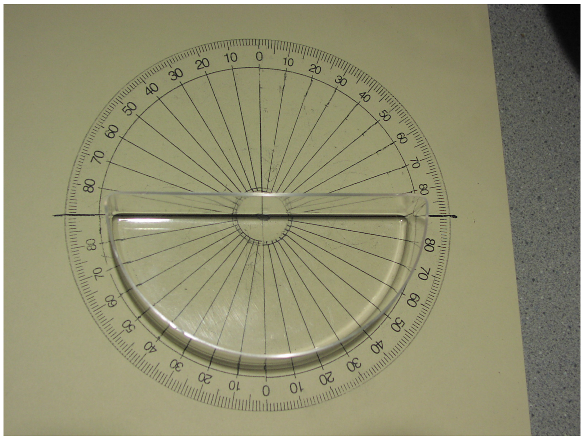
The principles of refraction are applied in a wide variety of optical devices: eyeglasses, microscopes, cameras and binoculars.

Purpose

Measure the refraction of a light in water and recreate the analysis that led to what is called Snell's Law.

Materials and Equipment

- Darkened room
- Plastic D-Tank
- Water
- Custom 360° protractor
- Foam core board
- Quilting pins
- Pencil and notepaper



Procedures

1. Set up D-tank
    1. Place the protractor on the foam core board.
    2. Place the D-tank on the protractor.
    3. Adjust the D-tank so its long straight edge lays over the base line of the protractor and the curved edge is concentric to and equally distant from the protractor angle measurements.
    4. Check: The 0 (zero) line of the protractor should bisect the D-tank when you have it set up correctly.
    5. Fill the D-tank about half full with water. (You should not need to move the D-tank again once the water is added.)
2. Set up light box
    1. Position the light box with the single slit card such that it can shine toward the straight edge side of the D-tank at various angles, as measured from the normal (0 degree angle line on the flat side), but always meets and "enters" the D-tank at the center of the protractor.
    2. Depending on the angle that the incident light enters the flat side of the D-tank, the refracted light will exit the curved side of the D-tank at a different refracted angle, as measured from the 0 angle reference line on the curved side of the D-tank. There is one

incident angle where the incident and refracted angles are equal. Can you tell which angle that is?

3. Measure various angles
    1. Be prepared to mark each pair of incident and corresponding refracted angle using pins of the same color.
    2. Move the light box and repeat for several different angles, using pins of the same color for each set of angles. Take pairs of readings for:
        1. 1 incident angle less than 20 degrees,
        2. 2 incident angles between 20 and 50 degrees, and
        3. 1 incident angle greater than 50 degrees.
    3. With each test, verify the refraction effect for yourself by looking from the incident angle marking pin, through the water and toward the center of the flat side of the D-tank to the corresponding refracted angle pin. Then raise your viewpoint slightly to view from above the waterline.
    4. Calculate the sin value for each angle.
    5. Compute each ratio of $\frac{sin\ i}{sin\ r}$.

Data

Position	Pin Color	θ_i	θ_r	$sin\ i$	$sin\ r$	$\frac{sin\ i}{sin\ r}$
1	Red	22	16.5	0.3746	0.2840	1.32
2	Blue	32	23.5	0.5299	0.3987	1.33
3						
4						
5						
6						
7						
8						
9						
10						

Observations

Lab: Snell's Law Conclusions

1. After computing the sines and ratios, for each experiment, compare the ratios. How consistent are they? If Snell was correct, all the ratios should come out nearly the same (within experimental error).
2. What were your sources of error?

Observing Refraction

When we looked into the creek and tried to touch a stone with a relatively straight stick we experienced the bottom as 'lifted'. We can study the ratio of the apparent depth of the visible (refracted) bottom, and the depth of the tangible bottom. As seen in the side view of the tank (right), these are the depths OA ('visible'), and OB ('tangible'). However, the relationship of the two depths is not a simple arithmetic difference; the difference grows as the point of view approaches horizontal.

Snell's Discovery

The actual relationship or law of refraction was first worked out in 1621 by Dutch mathematician Willebrord van Roijen Snell (1591-1626). Snell noticed that the ratio of depths seemed constant for a given pair of media. (Strictly, this is true only for vertical view.) He finally realized that if we use their 'visible length', then that ratio was a constant (equivalent to the index of refraction). Using a water tank, we could also measure the length SB to the lower (tangible) point B, compared to the 'sight-line' length SA, seen from the entrance point S to the upper ('lifted') point A.

Snell's Law in Modern Form

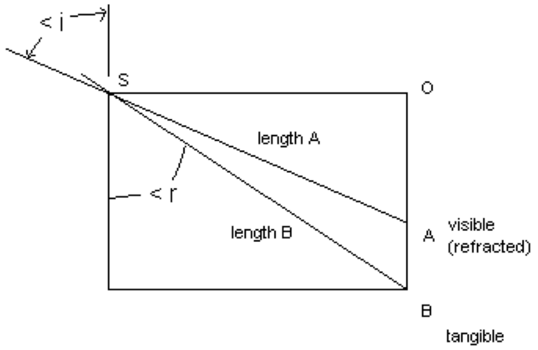
Since these "path length" are difficult to measure in practice, simply measure the angle, and use trigonometry to compare this ratio. If i is the incident angle to the *surface normal* in the upper media of light entering the lower media, and r is the *refracted angle* of the light in the lower media relative to the normal, then the refractive index n is the ratio of:

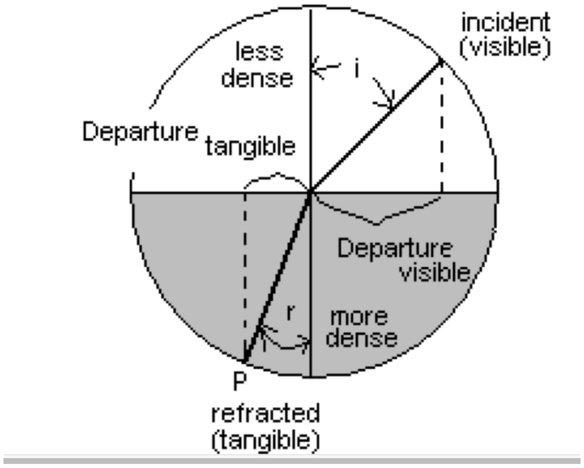
$$\text{(index of refraction of the medium with incident beam)} : \text{(index of refraction of the medium with refracted beam)}$$

Thus, our tangible position B in the tank diagram corresponds to P on the r beam, since our direction of view is shifted or refracted downwards within the water; while the direction to the visible lifted position is called the i beam, since this is the direction we look initially to see the apparently lifted object.

So, in general, Snell's law implies that when tracing the pathway into a denser medium (air into water for example), the direction of light is bent toward the *surface normal*, while tracing it the other way, entering a less dense medium (from water into air), the beam is bent away from the *normal*.

Note: We disregard as negligible any additional refraction that occurs as a result of light passing through the plastic of the D-tank between water and the air.


< i
S
O
length A
< r
length B
A
visible
(refracted)
B
tangible


incident
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