Large Room Meeting I (Chapter 22.1-22.3)

Major Goals

- □ Determine characteristics of how light travels and what allows us to see objects.
- □ Determine a relationship between the angle of incidence and angle of reflection for light reflecting off a surface.
- □ Determine a relationship between the angle of incidence and angle of refraction for light passing from one medium to another.

Need to Know

What's going on with this pencil?

22.1.1 – Observational Experiment

Go into room that is completely dark (no sources of light) and wait for a few minutes. Record your observations and propose an explanation.

22.1.2 – Observational Experiment

Observe the light that comes out of a laser pointer. What path does the light take to get from the laser pointer to the spot on the wall?

Represent the path the light follows by drawing a long arrow called a ***ray***. A ray is not real, just a representation we can draw to help us understand the direction in which light travels.

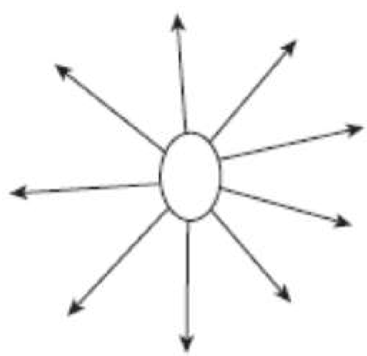
Why can't we see the beam of light itself, but we can see the dot it makes where it hits the wall? Come up with a few possible explanations.

Observe what happens when we spray a miniscule droplets along the path of the light propagation. Record and explain your observations.

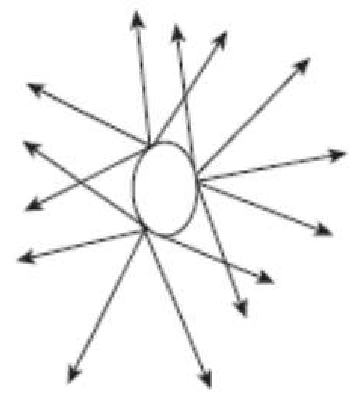
Based on all our observations from 22.1.1 and 22.1.2, what are the conditions necessary for us to see something.

22.1.3 – Testing Experiment
Observe how a frosted lightbulb lights an entire room. Juanita and Carlos drew the two ray diagrams below to explain this observation.

Carlos' Hypothesis:



Juanita's hypothesis:



Describe the difference between these two hypotheses. Consider the rays coming from a single point on the bulb in each hypothesis.

Predict the result of the experiment based on the two hypotheses: We cover the lightbulb with tin foil, leaving only a small spot exposed. What will we see according to each hypothesis?

Carlos' Prediction:	Juanita's Prediction:

Observe and record the outcome of this experiment.

Based on the outcome of this experiment, what can we say about the two hypotheses? Which diagram best represents the light coming from this frosted lightbulb?

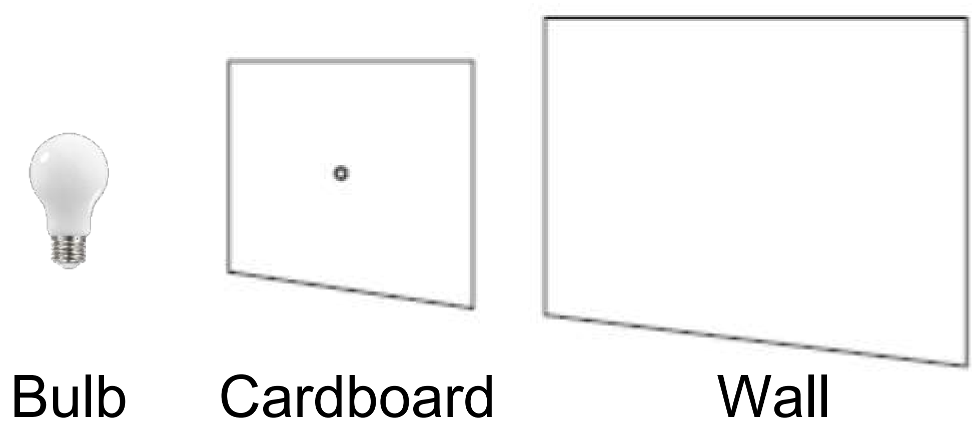
22.1.4 – Observe and Explain
Observe the shadow cast by a pencil illuminated by the same frosted bulb from activity 22.1.3 when it is held *close* to a wall.

Then observe the shadow cast by the pencil when it is moved closer to the bulb.

Explain the difference between these two observations using the diagram from activity 21.1.3.

22.1.6 – Testing Experiment
We will conduct an experiment Where a piece of cardboard with a small hole poked in it will be placed between a frosted bulb and a wall.

Use all the ideas we have discussed so far to draw a ray diagram you can use to predict what the shadow of the cardboard will look like.



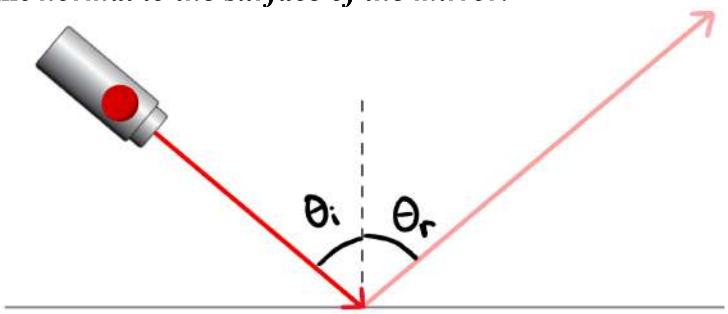
Watch the outcome of the experiment. If necessary, revise your ray diagrams.

Summarizing our Findings

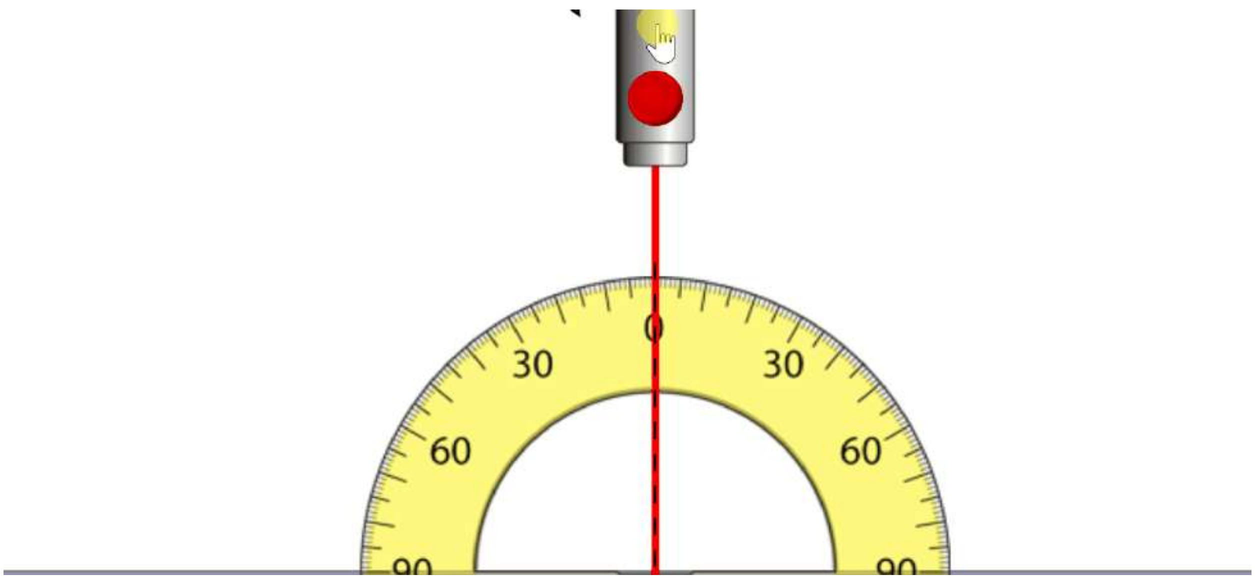
Read and Interrogate Read and interrogate textbook pages 686-689 (stop before Section 22.2).

22.2.1 – Observational Experiment

We call the angle at which light approaches the mirror the ***angle of incidence*** $(\boldsymbol{\theta_i})$**.** The angle at which the light leaves the mirror is called the ***angle of reflection*** $(\boldsymbol{\theta_r})$**.** Both these angles are measured from the line ***normal to the surface of the mirror***.

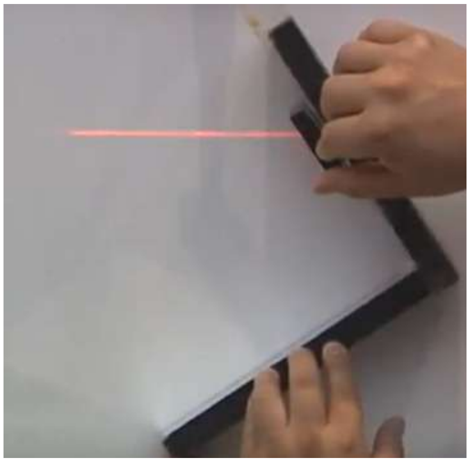


Observe what happens when a laser pointer is pointed at a mirror at various angles. Devise a relationship between θ_i and θ_r.



22.2.2 – Testing Experiment

Use the rule we just invented to predict the path the laser beam will follow once it reflects off the pair of mirrors shown below. Draw a ray diagram to support your prediction.

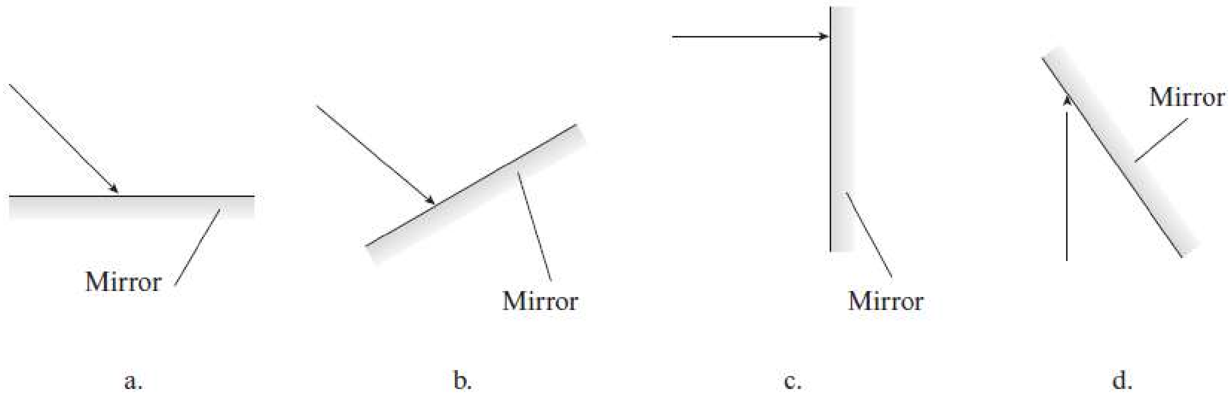


Observe the outcome of the experiment and compare it to your prediction:
https://youtu.be/DfkVcwA_bgs?t=10

Summarizing our Findings

Read and Interrogate Read and interrogate textbook pages 689 (start with Section 22.2) till 692 (stop before Section 22.3). Describe the difference between specular and diffuse reflection. What type of reflection allows us to see objects in the room? Explain.

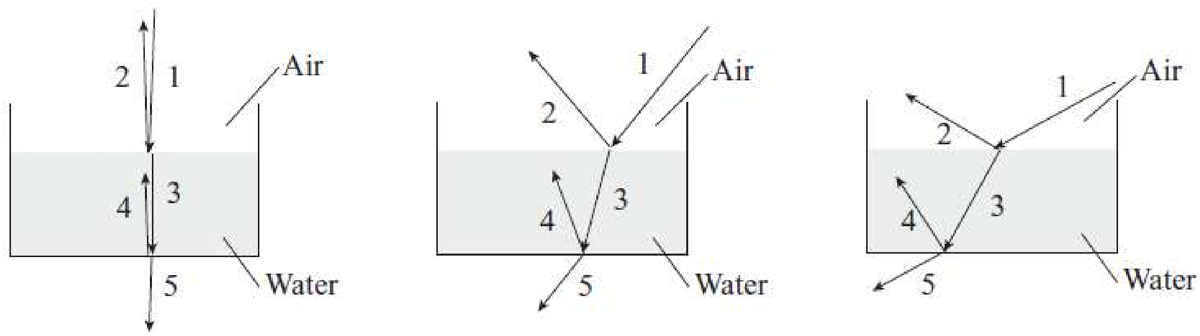
22.2.3 – Represent and Reason
Practice using the law of reflection to draw the reflected ray in each of the arrangements below.



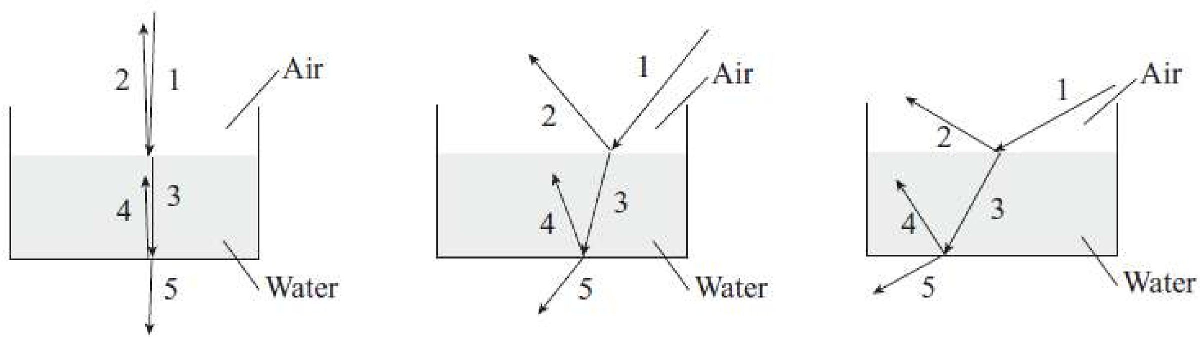
22.3.1 – Observational Experiment
Observe what happens when we shine a laser pointer onto the surface of water in a clear plastic container (some corn starch was added to the water to make the beam more visible).

Based on your observations, what happens to the direction the light is traveling when it crosses the boundary from air into water?

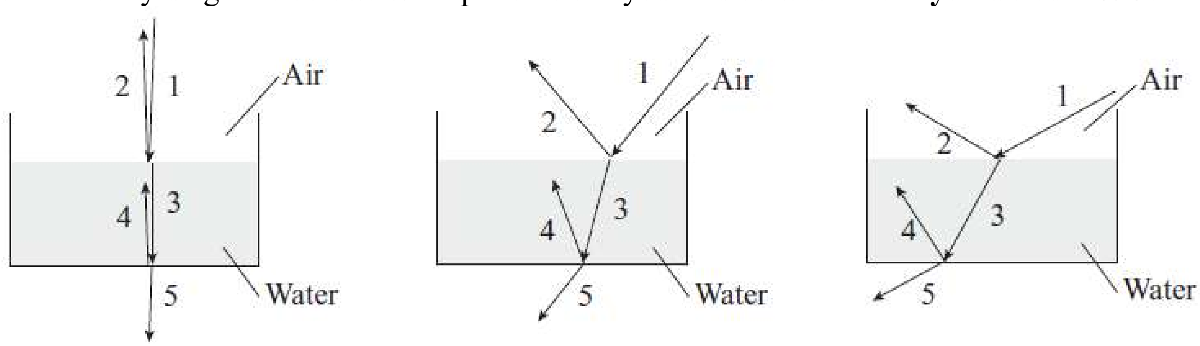
Look at the ray diagrams below. What patterns can you find between the **rays labeled 1 & 2 (and the rays labeled 3 & 4)** in each diagram?



Look at the ray diagrams below. What patterns can you find between the **rays labeled 1 & 3 (and the rays labeled 3 & 5)** in each diagram?

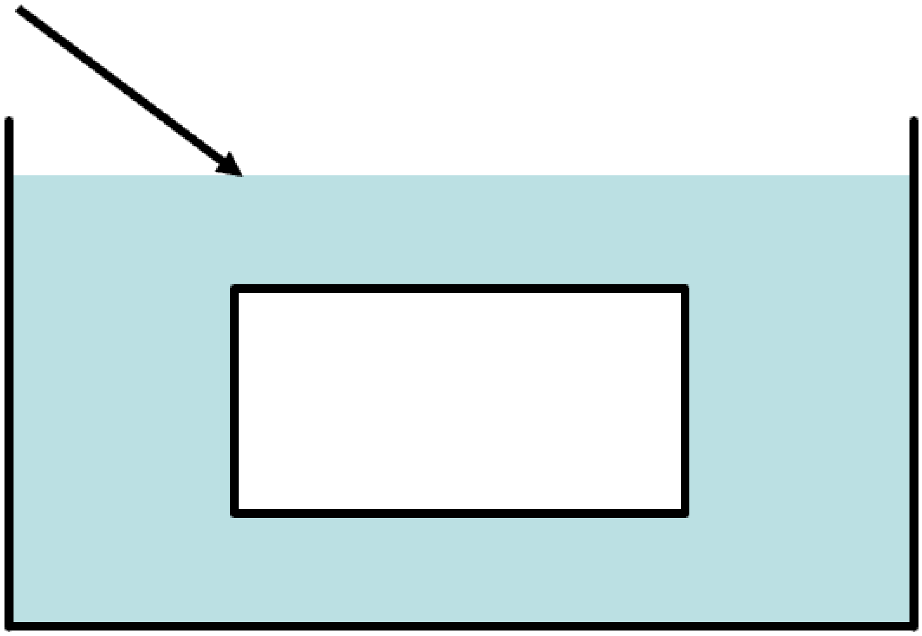


Look at the ray diagrams below. What patterns can you find between the **rays labeled 1 & 5**?



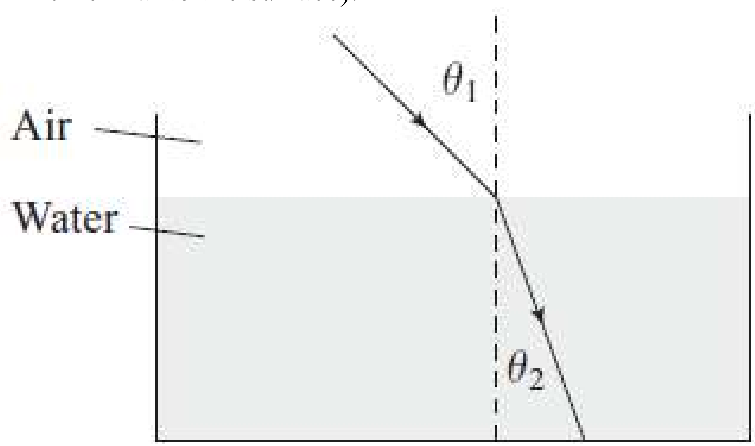
22.3.3 – Represent and Reason

Imagine that you place a closed, empty glass box (with thin glass walls) filled with air underwater and hold it there. A beam of light shines on the top surface of the water, as represented by the ray in the figure. Draw arrows representing the path the light takes as it reflects off and passes through each surface.



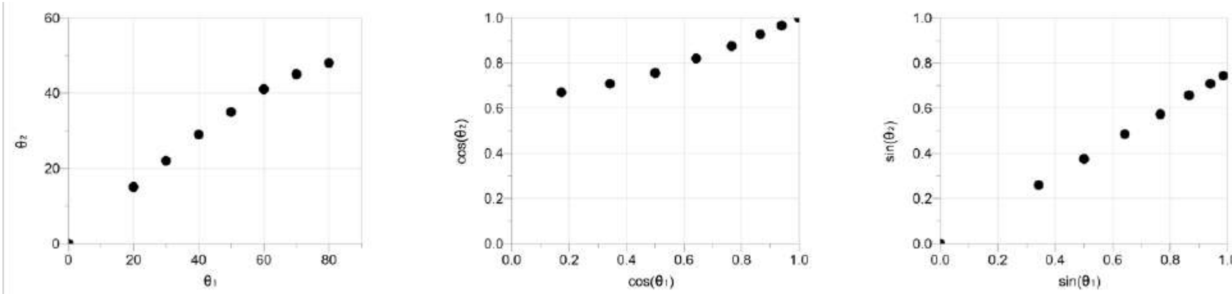
Read and Interrogate Read and interrogate pages 692-693.

22.3.4 – Observational Experiment
A clear container was filled with water and a laser was shone at the surface at different ***angles of incidence*** (θ_1). The ***angle of refraction*** (θ_2) was measured with a protractor (both angles are measured from the line normal to the surface).



Incident angle θ_1	$\cos(\theta_1)$	$\sin(\theta_1)$	Refracted angle θ_2	$\cos(\theta_2)$	$\sin(\theta_2)$
20°	0.94	0.34	15°	0.97	0.26
30°	0.87	0.5	22°	0.93	0.37
40°	0.77	0.64	29°	0.87	0.48
50°	0.64	0.77	35°	0.82	0.57
60°	0.50	0.87	41°	0.76	0.65

What pattern best describes the relationship between θ_1 and θ_2?



22.3.5 – Observational Experiment
The experiment in activity 22.3.4 is repeated using a glass block rather than water. Compare the air-water refraction to the air-glass refraction.

Incident angle	Refracted angle in water	Refracted angle in glass
20^o	15^o	13^o
30^o	22^o	19^o
40^o	29^o	25^o
50^o	35^o	30^o
60^o	41^o	35^o

Summarizing our Findings

Read and Interrogate Read and interrogate pages 694-694.

Small Room Meeting (Chapter 22.3)

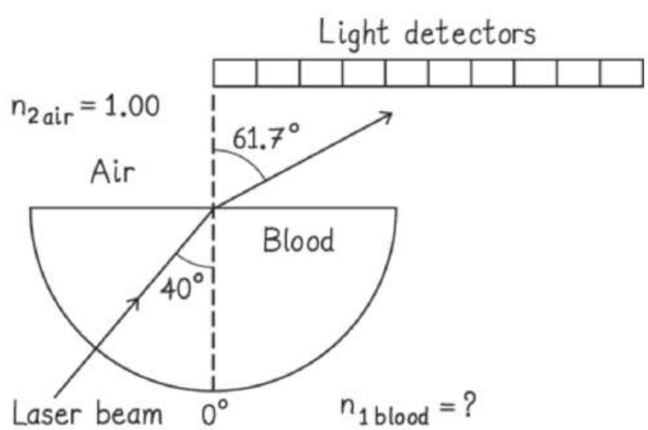
Major Goals

- □ Use Snell's Law to determine the angle of incidence, angle of refraction, and index of refraction for light passing from one medium to another.

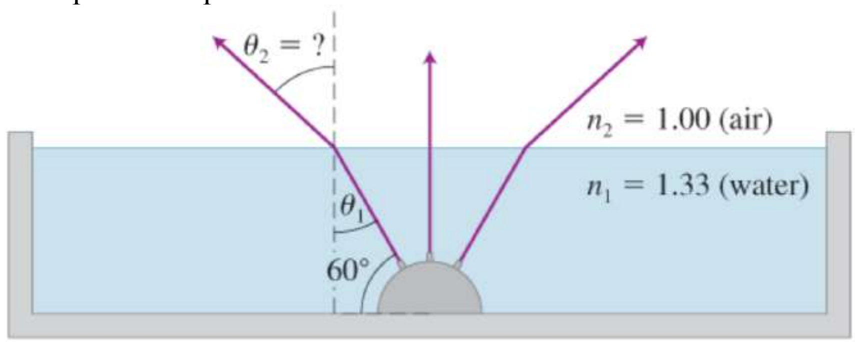
Question #1 (Example 22.3) (Clarity and Evaluation)

The refractive index of blood increases as the blood's glucose concentration increases (for normal glucose content it ranges from 1.34 to 1.36; it is higher than the 1.33 for water because of all the additional organic components in the blood). Therefore, measuring the index of refraction of blood can help determine its glucose concentration.

In a hypothetical process, a hemispheric container holds a small sample of blood. A narrow laser beam enters from the bottom of the container perpendicular to the curved surface and into the sample. The light reaches the blood-air interface at a 40.0° angle relative to the normal line. The light leaves the blood and passes through the air toward a row of light detectors indicating that the light beam left the blood at a 61.7° angle. Determine the refractive index of the blood.



Question #2 (Example 22.4) (Clarity and Evaluation)
A waterproof laser device produces three laser beams in the same vertical plane, one pointing directly upward and two at 60.0° above the horizontal. You put the device on the bottom of your swimming pool. The directions of the beams emerging from the water change as shown in the figure. At what angles relative to the horizontal do the laser beams emerge from the pool? Does the depth of the pool affect the answer?



Question #3 (Problem #16) (Clarity, Consistency and Evaluation)
A laser beam passes from air into a 25% glucose solution (n = 1.372) at an incident angle of 35°. In what direction does light travel in the glucose solution? Draw a picture showing the interface between the media, the normal line, the incident rays, the reflected rays, the refracted rays, and the angles of these rays relative to the normal line.

Criterion	**Perfect (2)**	**Needs some work (1)**	**Needs a lot of work (0)**
Clarity	The solution is clear, expressed in words and symbols, takes no effort to comprehend.	The words are lacking but the symbolic part is clear. Takes some effort to comprehend.	Takes a lot of effort to comprehend. There is only math, mostly numbers, not general equations and there are no words explaining the thought process.
Consistency	Two or more different representations are present, they are correct and consistent with each other.	Two or more different representations are present and they are consistent but there are mistakes in representations.	Mistakes in representations or different representations are inconsistent with each other.
Evaluation	The answer is evaluated using at least two of the methods listed below: unit analysis, extreme case analysis, reasonability of the answer, consistency of representations.	The answer is evaluated using only one of the methods listed in "Perfect".	There is no evaluation or there are serious mistakes in the evaluation (wrong units, misunderstanding of how reasonable numbers are).

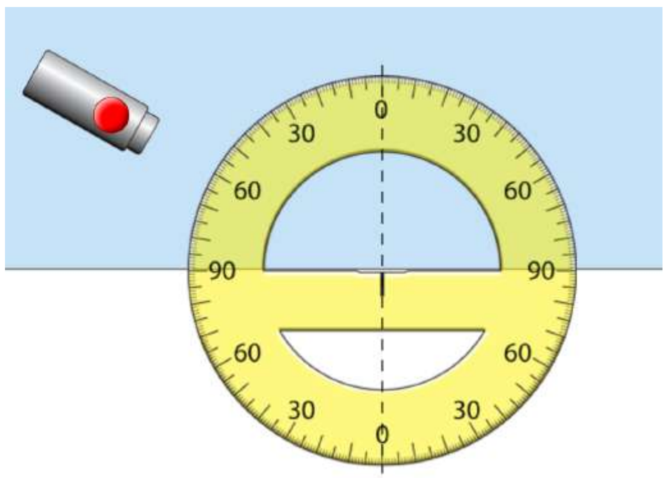
Large Room Meeting II (Chapter 22.4-22.6)

Major Goals

- ☐ Determine an angle at which a light beam is completely reflected (when $n_1 > n_2$).
- ☐ Explain how rainbows form given that different colors of light have different indexes of refraction.
- ☐ Apply Snell's Law to solve and evaluate problems.

Need to Know
How do rainbows form?

22.4.1 – Testing Experiment
Use your knowledge of refraction to predict qualitatively and quantitatively what will happen when a beam of light passes from water (n = 1.33) into air (n = 1.00) at angles of incidence of 30° and 60°.



Is there some angle at which you would predict that you would stop seeing any refraction?

Watch what happens when we use this simulation to test our predictions:
https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html
Did you correctly predict this special ***critical angle?*** What happens to the beam past that angle?

What Have we Learned?

Read and Interrogate Read and Interrogate Section 22.4 in the textbook.

22.5.4 – Equation Jeopardy

A mathematical representation of a situation is shown below:

$$1.00 \sin\left(53^{o}\right) = n_2 \sin\left(41^{o}\right)$$

a) Solve for the unknown quantity.
b) Sketch the situation described by the equation.
c) Write a description of the situation in words.

A mathematical representation of a situation is shown below:

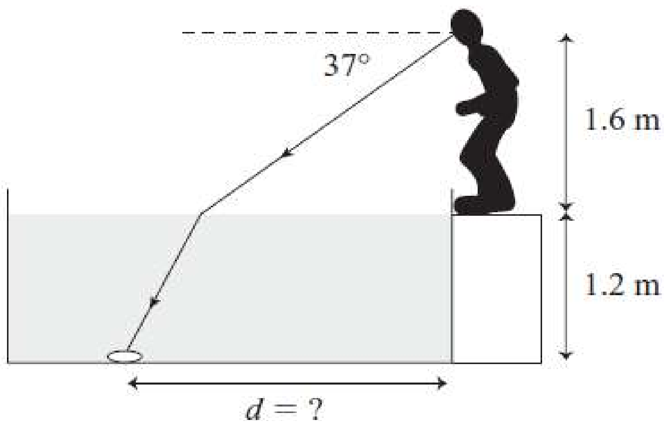
$$1.00 \sin\left(53^{o}\right) = 1.56 \sin\left(\theta_2\right) = 1.33 \sin\left(\theta_3\right)$$

a) Solve for the unknown quantities.
b) Sketch the situation described by the equation.
c) Write a description of the situation in words.

22.5.5 – Evaluate a Solution

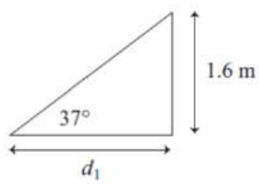
A student was asked to solve the following problem. Evaluate each step of the student's work, and if there are any errors correct them.

The eyes of a person standing at the edge of a 1.2-m-deep swimming pool are 1.6 m above the surface of the water. The person sees a silver dollar at the bottom of the pool at a 37º angle below the horizontal. Determine the horizontal distance *d* from the person to the dollar.



Their solution:

1) Using trigonometry to find the distance from the edge of pool to where the light ray contacts the surface:

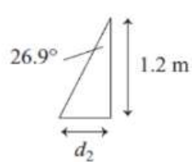


$$\sin(37^\circ) = \frac{1.6\text{m}}{d_1}$$
$$d_1 = 2.67\text{m}$$

2) Apply Snell's Law to find the angle of refraction into the water:

$$1.00 \sin\left(37^\circ\right) = 1.33 \sin\left(\theta_2\right)$$
$$\theta_2 = 26.9^\circ$$

3) Using trigonometry to find the distance from where the light ray contacts the surface to the dollar coin:



$$\sin(26.9^\circ) = \frac{1.2\text{m}}{d_2}$$
$$d_1 = 0.54\text{m}$$

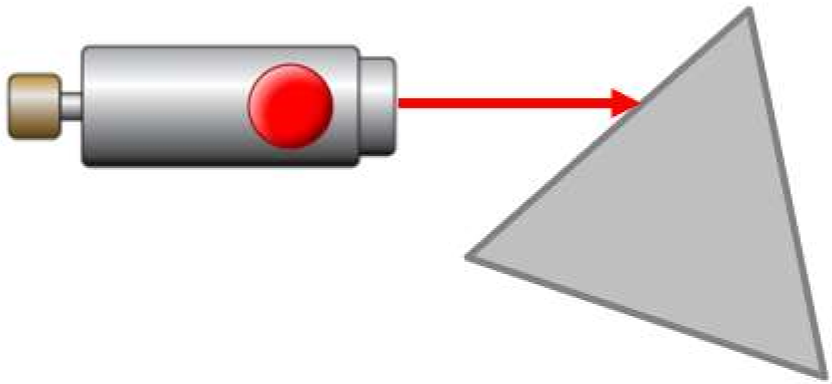
4) Add d_1 and d_2 to get the total distance from the edge of the pool to the dollar:

$$d = d_1 + d_2 = 2.67\text{m} + 0.54\text{m} = 3.2\text{m}$$

22.6.2 – Testing Experiment

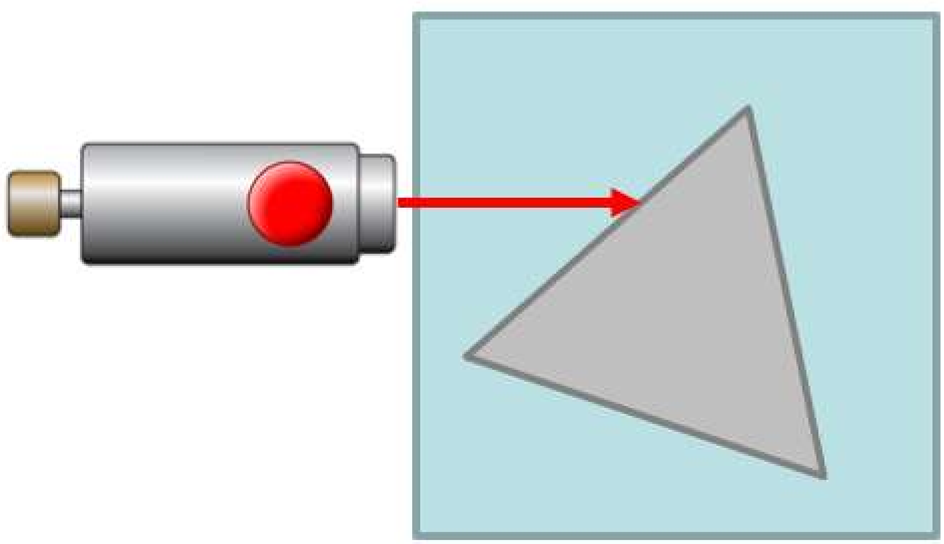
Use the ideas we have developed this week to make qualitative predictions about the path the beam will take when it passes through the glass prism shown below.

Hint: Do not forget to draw a normal line at which the light beam hits the border of the two materials.

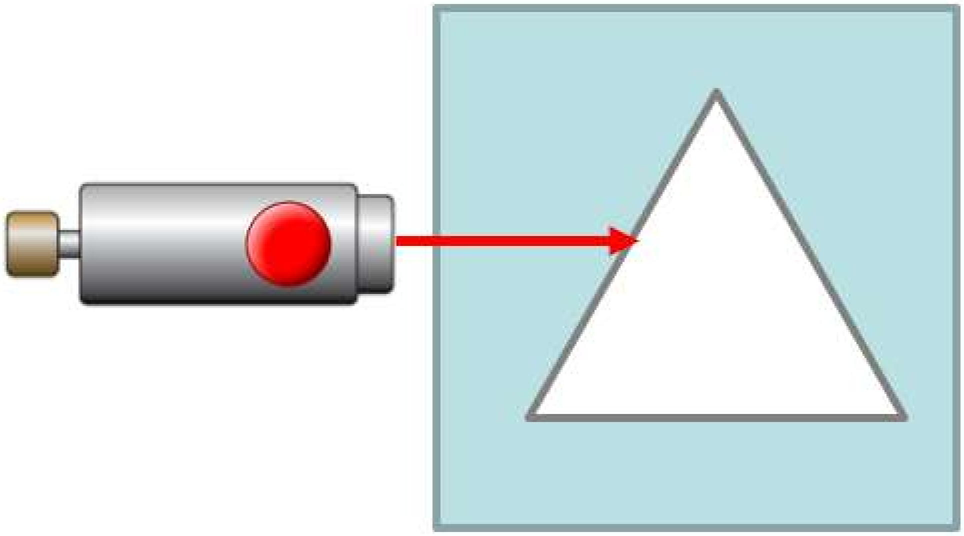


How would the path of the beam change if the prism were submerged in water as shown below?

Hint: Think about how the indices of refraction on each side of the boundary compare to what they were before.



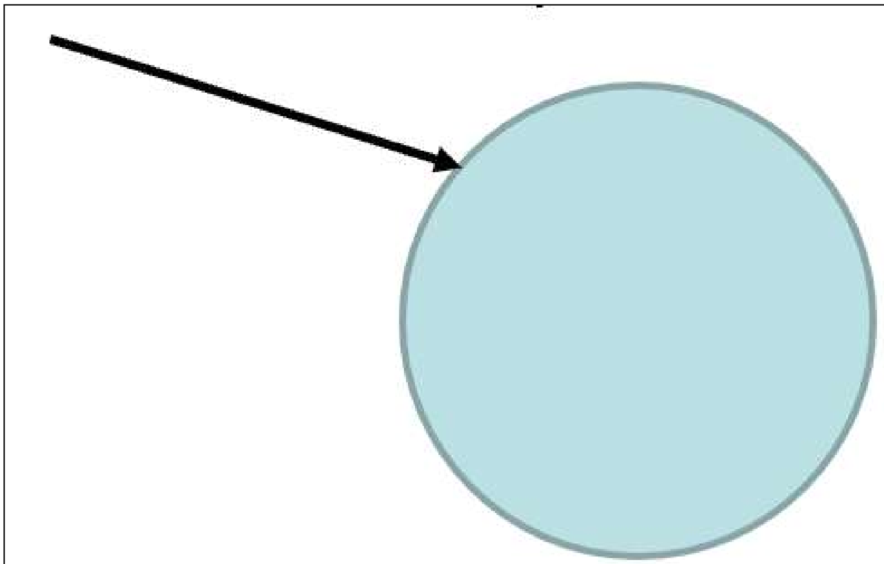
Now draw the path you think a beam would travel through an empty (air filled) prism submerged in water.



Read and Interrogate Read and Interrogate Section 22.5 in the textbook.

22.6.5 – Reason and Explain
Different colors of light have different indexes of refraction when passing though water droplets (see the table below).

Based on this, what would happen to white light (which contains all colors) when it is incident on a spherical rain droplet at some angle and reflects off the back of the droplet?



Color	Index of Refraction
Red	1.613
Yellow	1.621
Green	1.628
Blue	1.636
Violet	1.661

Based on what we just saw, answer the following questions:

1. Why do the colors always appear in the same order in a rainbow?
2. Why do we only see rainbows when the sun is behind us?

Problem 22.21 – Try it Yourself

* A light beam hits the interface between air and an unknown material at an angle of 43° relative to the normal. The reflected ray and the refracted ray make an angle of 108° with respect to each other. What is the index of refraction of the material?

Solve this problem using the 4-step method:

1. Sketch and Translate
2. Simplify and Diagram
3. Represent mathematically
4. Solve and evaluate

Problem 22.33 – Try it Yourself

* **Prism total reflection** What must be the minimum value of the refractive index of the prism shown in Figure P22.33 in order that light is totally reflected where indicated? Will some of the light make it out of the top surface? Explain.

Figure P22.33