LASER CLASSROOM

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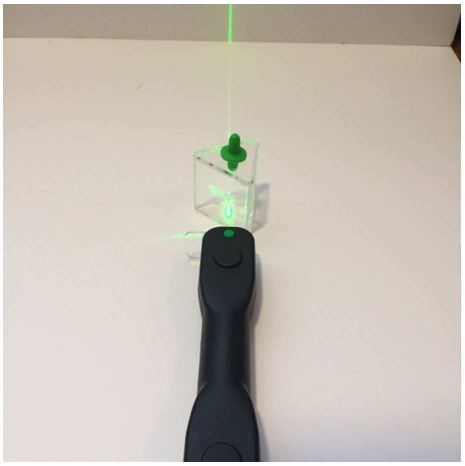


Measure and estimate the sugar content of a liquid with a LASER

Refraction is the property of light that causes it to change speed and bend as it passes from one medium to another. The degree to which a beam of light bends depends on the index of refraction of the two media according to Snell's Law - see below.

In this experiment, students will pass a laser through a prism to measure, calculate and graph the index of refraction of several solutions with known concentrations of sugar. They will then use the data they collected to estimate the sugar content of an unknown solution.

BIG IDEA

Using computational thinking skills and Snell's Law, students collect, calculate, graph and analyze data and draw conclusions to determine the relative sugar content of a mystery solution!

MATERIALS

- Laser Blox or Laser Pointer
- Hollow Acrylic Prism
- Graduated Cylinder
- Stirring Rod
- Sugar
- Water
- Gram scale
- Plain white paper
- Tape
- Tape measure

Index of refraction of material 1 × sin(angle of incidence)

=

Index of refraction of material 2 × sin(angle of refraction)

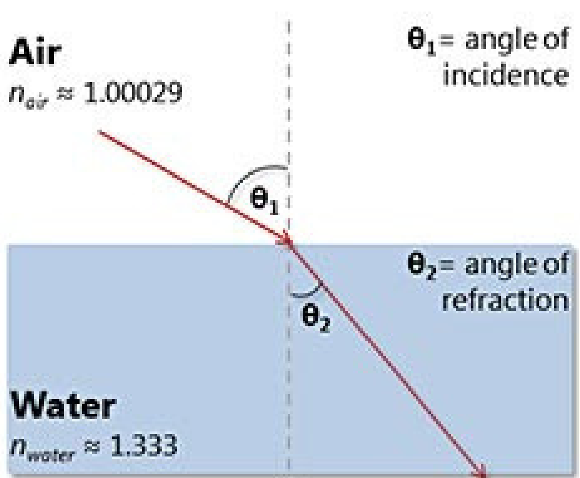
$$n1 \sin \theta 1 = n2 \sin \theta 2$$

n1 = index of refraction of material 1 (no units, since it is a ratio)

θ1 = angle of incidence (degrees or radians)

n2 = index of refraction of material 2 (no units, since it is a ratio)

θ2 = angle of refraction (degrees or radians)



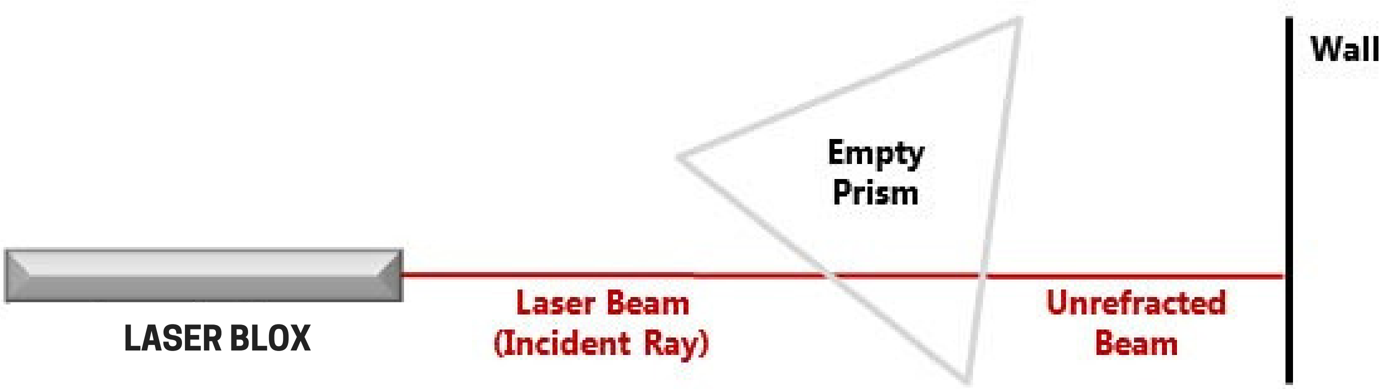
Prep

You can either prepare sugar-water solutions in advance, or incorporate mixing solutions of specific concentrations into the lab. Follow the table below.

Sugar Concentration	Amount (g) of Sugar	Amount (mL) of water
10% Sugar	10g Sugar	90mL water
20% Sugar	20g Sugar	80mL water
30% Sugar	30g Sugar	70mL water

Experimental Set Up

To set up to measure the index of refraction of a liquid with a Laser Blox, **begin by inserting the line generating lens and be sure you can see the beam as it passes through the empty prism** when you set up according to the following diagram.



- Lay a piece of paper in front of the LASER Blox. Tape it securely to the table. The paper will be used to mark where the laser beam enters and exits the prism.
- Tape a piece of paper to the wall in front of the laser pointer. You will use this paper to mark where the laser beam hits the wall.
- Place the prism on top of the paper, a few centimeters in front of the LASER Blox. One of the prism's triangular faces should be resting on the paper.
- **Using a pencil, trace around the prism's base. If you move the prism, always return it to this location before rotating it.**
- Turn on your LASER Blox and check to be sure that the beam passes through the EMPTY prism with out refracting/bending/deviating.

Procedure

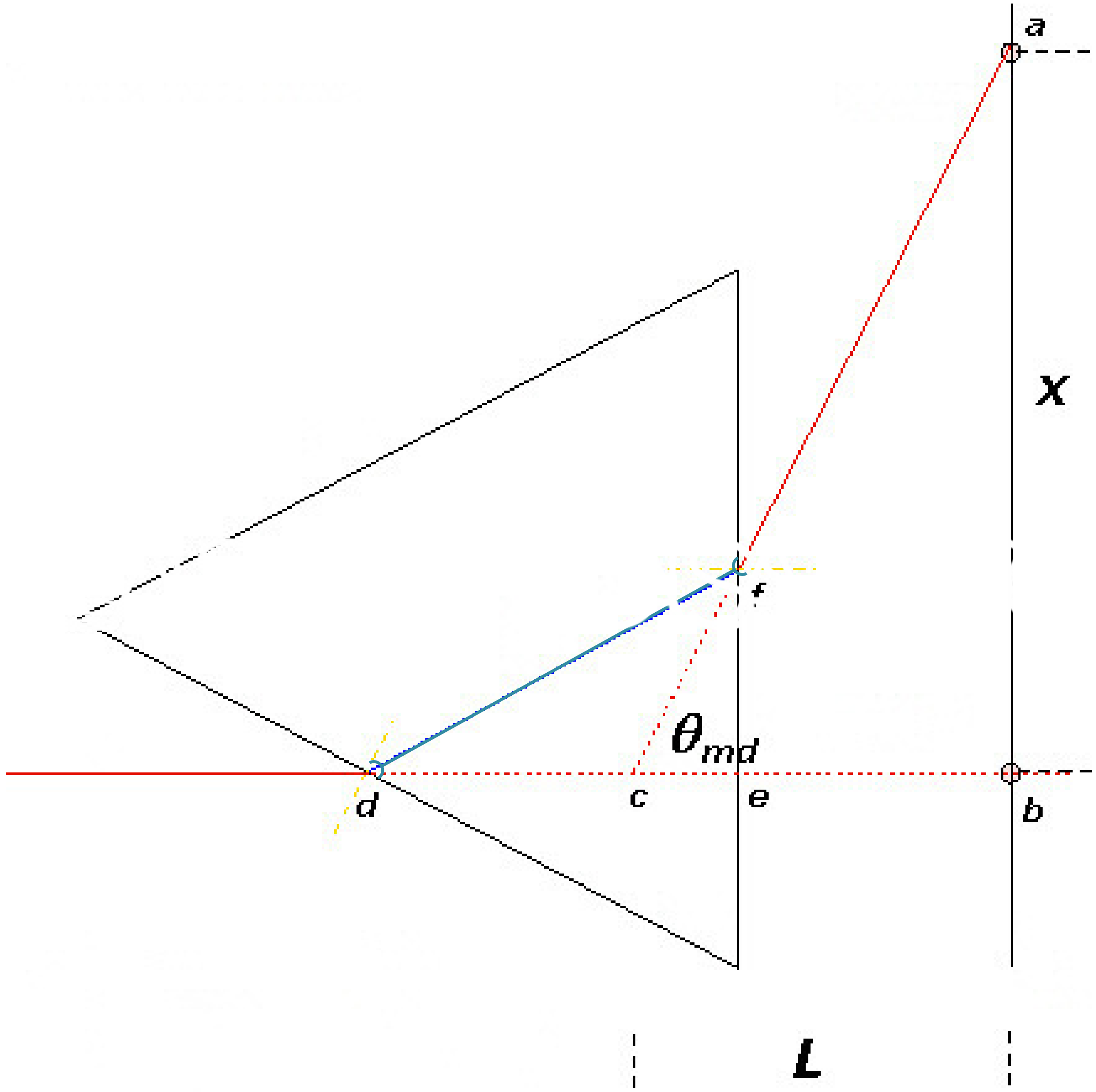
1. Measure the angle of minimum deviation (θmd)

Liquids with different concentrations of sugar in them have different indices of refraction. The index of refraction can be found by solving for n in the following equation.

$$n = 2.00056 \times \sin[0.5(\theta md + 60°)]$$

In order to use this equation - you need first to define the angel minimum deviation for your particular set up. To do this, follow the steps below and refer to the figure on the next page.

- While the prism is EMPTY, mark on the paper the spot where the beam hits the paper against the wall - label it b as in the diagram below.
- While the prism is EMPTY, mark the spot where the beam enters the prism and label it d
- While the prism is EMPTY, mark the spot where the beam exits the prism and label it e
- Now turn off the LASER Blox and fill the prism with water
- Return the FULL of WATER prism to its prior location (using your outline)
- Rotate the prism so that the path of the refracted beam within the prism (solid blue line from d to f in the figure below) is parallel with the base of the prism, the side of the prism that has no laser beam hitting it.
- When the prism is rotated correctly, mark the position where the emerging beam hits the paper taped to the wall (point a in Figure 9). Label it point a.
- On the paper on the table, mark the point where the beam emerges from the prism Label it point f.
- Now you can move the prism aside. Leave the papers taped in place.
- Use a ruler to draw a line from point d to point e. This marks the path of the un-diverted beam.
- Next, extend a line from point a (on the wall) through point f (on the table). To do this, stretch a string from point a so that it passes over point f. Mark the point where the string crosses the line between d and e. This is point c.
- Measure the distance between points a and b, and record it in your lab notebook. This is distance x
- Measure the distance between points b and c, and record it in your lab notebook. This is distance L
- The distances you have measured define the angle of minimum deviation, θmd. The ratio x/L is the tangent of the angle of minimum deviation, θmd. To calculate the angle, use your calculator to find the arctangent of x/L. (The arctangent of x/L means "the angle whose tangent is equal to x/L.") Record the angle θmd and its units (radians or degrees) in your lab notebook.
- RECORD ON YOUR DATA SHEET



a
X
f
θ_{md}
d
c
e
b
L

2. Record your θmd

3. Solve for n for plain water with no sugar using the following formula. Your answer should be very close to 1.334. If it's not, either your set up or your calculations are incorrect.

$$n = 2.00056 \times \sin[0.5(\theta md + 60°)]$$

n = index of refraction of solution (unitless, since it is a ratio)

θmd = angle of minimum deviation (degrees)

4. Calculate the index of refraction of three solutions with known concentrations of sugar.

Calculate and record the index of refraction of three solutions with known concentrations of sugar.

Measure the index of refraction of the 10% sugar solution (following the steps in the "Measuring the Index of Refraction of a Liquid" section of the procedure, above). Repeat your measurements 4 more times for the 10% sugar solution, for a total of 5 replicates. Average your results.

Empty the prism and rinse it with plain water. Then repeat step 3 using 20% and then 30% sugar solutions.

Sugar Concentration	Amount (g) of Sugar	Amount (mL) of water
10% Sugar	10g Sugar	90mL water
20% Sugar	20g Sugar	80mL water
30% Sugar	30g Sugar	70mL water

n for 10% sugar solution:

n for 20% sugar solution:

n for 30% sugar solution:

5. Calculate the index of refraction of a liquid of unknown sugar content

A clear soda or Karo syrup is a good choice - since you can see the beam. If you use soda, be sure to let it go flat first.A clear soda or Karo syrup is a good choice - since you can see the beam. If you use soda, be sure to let it go flat first.

5. Estimate the concentration of sugar in the liquid of unknown sugar content

With the index of refraction of the unknown solution, combined with the data you have from your known sugar solutions, you should be able to estimate the sugar concentration of the unknown solution.