LASER CLASSROOM
Bringing STEM to light®

BIG IDEA

- It doesn't take expensive or sophisticated equipment for measuring the speed of light! Measuring the speed of light with nothing but a laser, a protractor and a slab of gelatin, is inexpensive and surprisingly accurate!

MATERIALS

- Classroom Safe Laser
- Protractor
- Prepared plain gelatin

RELATED PRODUCTS


Laser Blox


Protractor

THE SPEED OF LIGHT

BACKGROUND

We know how fast light travels in a vacuum… but what about in other materials? When a light wave hits a boundary between materials, it changes speed. The change in speed depends on the index of refraction of the material the light travels through.

In this experiment, we'll be measuring the speed of light (a laser beam) as it travels from room air through one or more samples of gelatin.

REFACTION AND MEASURING LIGHT

When a light wave hits a boundary between materials, it changes speed. As a result of this change in speed, it also changes direction or "bends". This phenomenon is known as refraction.

The law of refraction, also known as Snell's law, is a formula that precisely describes how the direction of light changes when it hits a boundary (like from air to gelatin).

Snell's law can help us with measuring the speed of light by solving the following equation:

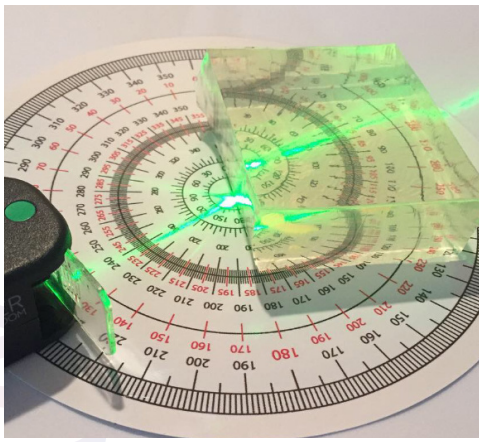
Snell's Law says: $\text{Sin } \theta_1/\text{Sin } \theta_2 = v_1/v_2 = n_1/n_2$

- **$\text{Sin } \theta_1/\text{Sin } \theta_2$** describes the change in the angle between the incident light beam (laser moving through air in our case) and the surface normal (in our case, the edge of the gelatin)

- **v_1/v_2** describes the speed of light as it travels from the first material (air) into the second material (gelatin)
- **n_1/n_2** describes the change in the index of refraction as light travels from one medium (air) into a second medium (gelatin)

Therefore:

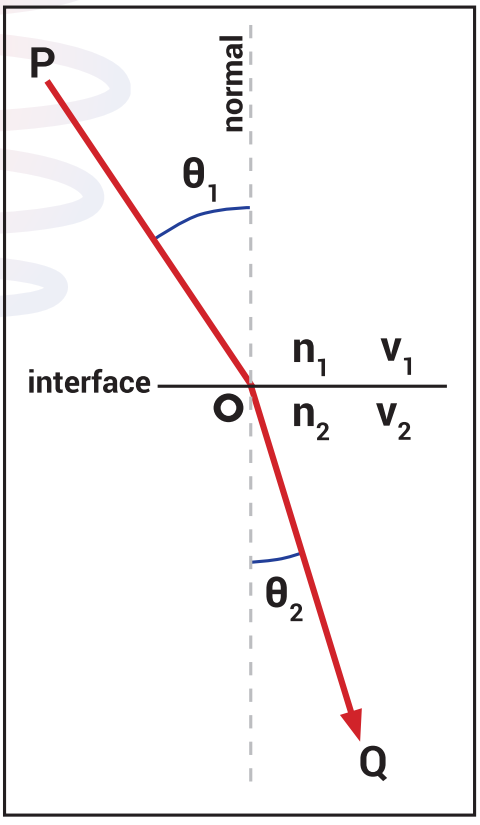
- θ_1 is the angle between the incident light beam and the surface normal
- θ_2 is the angle between the departing light beam and the surface normal
- v_1 is the speed of light in the first material **(v_{air})**
- v_2 is the speed of light in the second material **($v_{gelatin}$)**
- n_1 is the index of refraction of the first material **(n_{air})**
- n_2 is the index of refraction of the second material **($n_{gelatin}$)**



PROCEDURE

In order to measure the speed of light, we'll need to solve the equation in two steps.

1. Prepare gelatin – we use Knox plain gelatin. You can prepare as directed on the package – or double the gelatin for a firmer sample. You can also add sugar. The index of refraction will depend on the concentration of gelatin and/or sugar. You may want to prepare two separate samples to compare .
2. Once gelatin has set, cut out a square/rectangle and place it on a firm, white surface.
3. Use the protractor to measure, and record, the angles of refraction (θ_1, θ_2)
4. Set up the Laser Blox , gelatin and protractor so that the incident beam lands on the boundary between gelatin and air at an angle. Measure the angle between the incident beam and normal. This is θ_1.
5. Measure the angle between normal and the refracted beam in the gelatin. This is θ_2.



Consider (Refer to Diagram on Right): Measuring the speed of light depends on accurately measuring the angle from the normal, and this can be tricky. Just remember that if you look directly

into a refracting medium, i.e. perpendicular to the surface, the angles are accurate, but if you look off the normal, the angles are distorted. For example, a straight stick thrust into water looks broken at the surface. Therefore, it is important to set up the Laser Blox and protractor properly so accurate readings can be obtained.

6. Use your measured values for θ1 and θ2 and the known quantity index of refraction in air = 1.00029, n_1 to solve for the index of refraction in YOUR gelatin sample(s), $n_{gelatin}$

   $\text{Sin } \theta_1 / \text{Sin } \theta_2 = n_{air} / n_{gelatin}$

   The calculated index of refraction for the gelatin will vary depending on how concentrated it is and how much sugar (if any) you add.

7. Now you can use the measured angles of refraction ($\text{Sin } \theta_1$ and $\text{Sin } \theta_2$) and calculated (and known) values for indexes of refraction (n_1 and n_2) as well as the known value for the speed of light in a vacuum C=299,792,458 m/s for measuring the speed of light in the medium (gelatin) .

   $V_{gelatin} = c/n_{gelatin} = (2.99792458 \text{ X108 m/s}) / n_{gelatin}$