WOW Lab
Science Education R&D

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Light-Bending JELL-O

Additional Information

Optics - A Quick Introduction

Light travels at different speeds in different materials. The denser a material is, the more slowly light will travel through that material. One of the most important concepts in the study of optics is the phenomenon of refraction. Everyone has observed refraction. Think of a pencil placed in a glass of water. The pencil seems to bend or break at the surface of the water. See **figure 1** for a picture of this phenomenon. In this case, refraction occurs because the light slows down as it passes through the interface between air and water, which is denser.

The best way to understand this concept is to imagine shooting a laser beam into a piece of JELL-O as in **figure 2**. For a very short period of time, as the beam passes from the air into the JELL-O, the very front of the beam will be in two different materials. During this small amount of time, the portion of the beam inside the JELL-O will be travelling slower than the portion of the beam in the air.

Figure 1

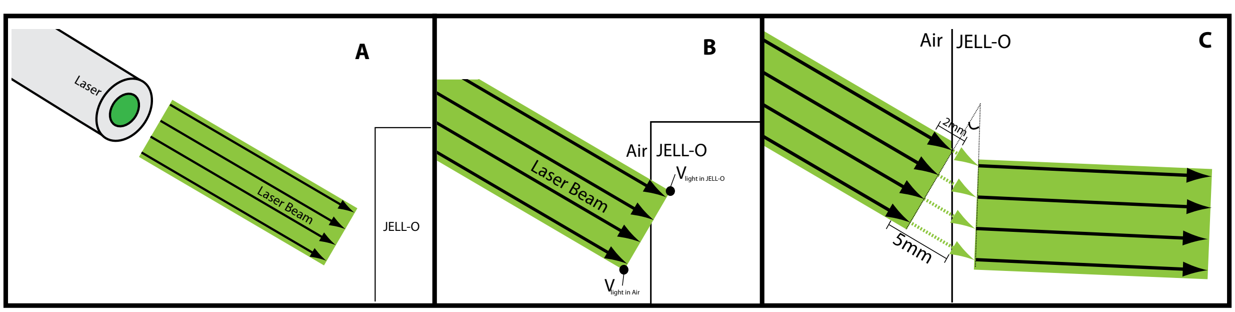

Figure 2. Refraction Explained

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To understand how these two different speeds result in refraction, imagine an axle between two wheels (**Figure 3**). What happens if one wheel turns faster than the other? The axle will begin to rotate. This happens to the laser beam, as illustrated in part C of **figure 2**. In the same amount of time, the bottom portion of the beam travels a greater distance than the top portion of the beam. The beam effectively rotates until the entire beam has passed through the interface and the entire beam is travelling at the same speed. At this point, the beam travels once again in a straight line. Now, however, its path is at a different angle than before.

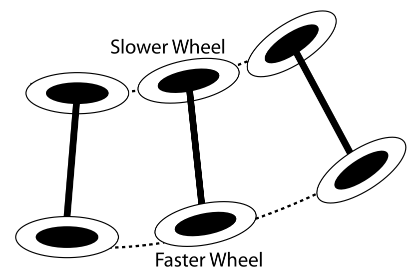

Figure 3

The angle at which the beam hits the interface (the angle of incidence) determines the amount the light refracted. The angle of refraction is the angle at which the beam leaves the interface. The larger the angle of incidence, the more the light will rotate, as the different portions of the beam will be travelling at different speeds for a larger period of time. Therefore, the greater the angle of incidence, the more refraction the light will experience. Snell's law is an equation which describes this behaviour:

$$n_1 \sin\theta_i = n_2 \sin\theta_r$$

Snell's law governs the relationship between four variables: how fast light travels in material 1 (n_1), how fast light travels in material 2 (n_2), the angle of incidence θ_i and the angle of refraction θ_r (**Figure 4**).

The angle of incidence and the angle of refraction are measured from a line perpendicular to the interface called the normal line.

It is important to note that for Snell's law, the speed of light in a material is computed as a ratio of the speed of light in a vacuum. In general, n is defined as:

$$n_0 = \frac{c}{v_0}$$

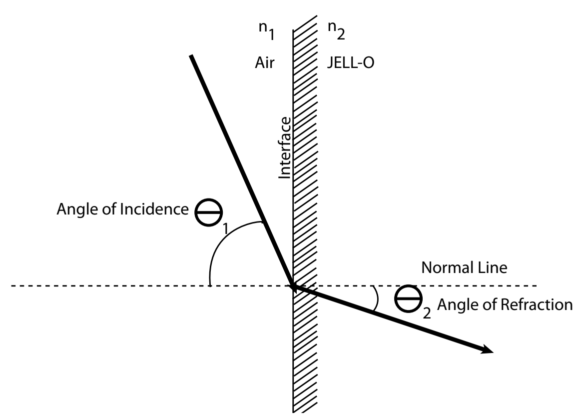

Figure 4

Where n_0 is the index of refraction in a material, c is the speed of light in a vacuum and v_0 is the speed of light in the material. The index of refraction of air is about 1.0003. This means that in air, light travels at

$$\frac{c}{n_{air}} = \frac{c}{1.0003} = \frac{3.0\times 10^8 \text{ m/s}}{1.0003} = 2.981\times 10^8 \text{ m/s}$$

Students will calculate the speed of light in JELL-O as part of the activity.

Further Application

When light enters a material at an angle perpendicular to the interface it will not refract. All parts of the wave will change speed at the same time. Think back to the wheels and axle. If both wheels spin at the same time, the axle will simply continue in a straight line. Snell's law shows this to be true as well. If the angle of reflection is zero, then sin(0)=0.

$$\sin(0) \rightarrow n_1 \cdot 0 = 0 = n_2 \sin(\theta_2) \rightarrow \sin(\theta_2) = 0 \rightarrow \underline{\theta_2 = 0}$$

When light passes from a material with a high index of refraction into a material with a lower index of refraction, will the light bend towards or away from the normal line?

Instead of memorizing a rule, one can easily figure out the answer to this question by applying an understanding of why refraction occurs.

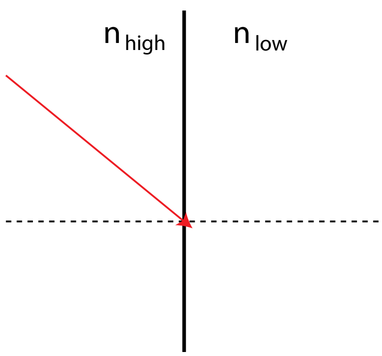

Figure 5

As the beam first strikes the interface, the portion of the beam closest to the normal line will pass through the interface first, as shown in **figure 5**, and will therefore be travelling faster than the portion of the beam farther away from the normal line. **Figure 6** illustrates that the portion of the beam travelling faster will travel farther than the other part of the beam. It is clear that the beam will bend downwards and therefore away from the normal line (**Figure 7**).

Variations of this question could include a scenario where light passes from a material with a low index of refraction to one with a high index of refraction, having the light beam enter the interface from below the normal line or moving from right to left instead of left to right. Try each of these scenarios and determine whether the refracted light bends towards or away from the normal line.

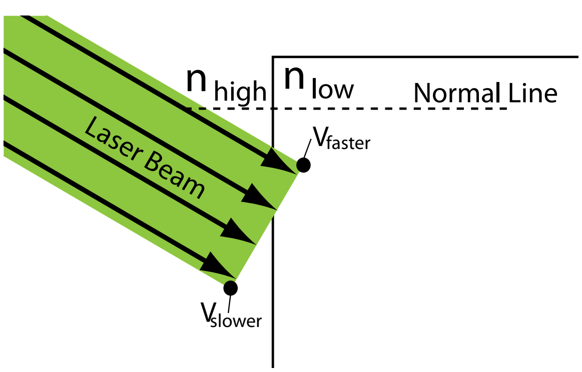

Figure 6

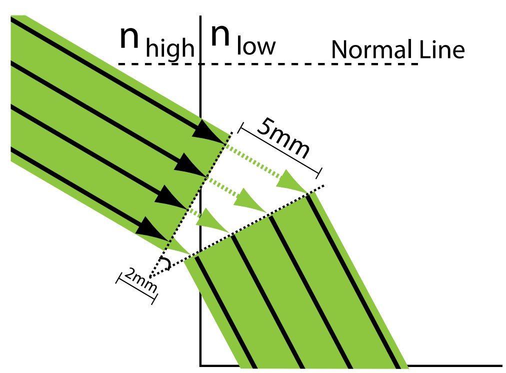

Figure 7

Colour Absorption

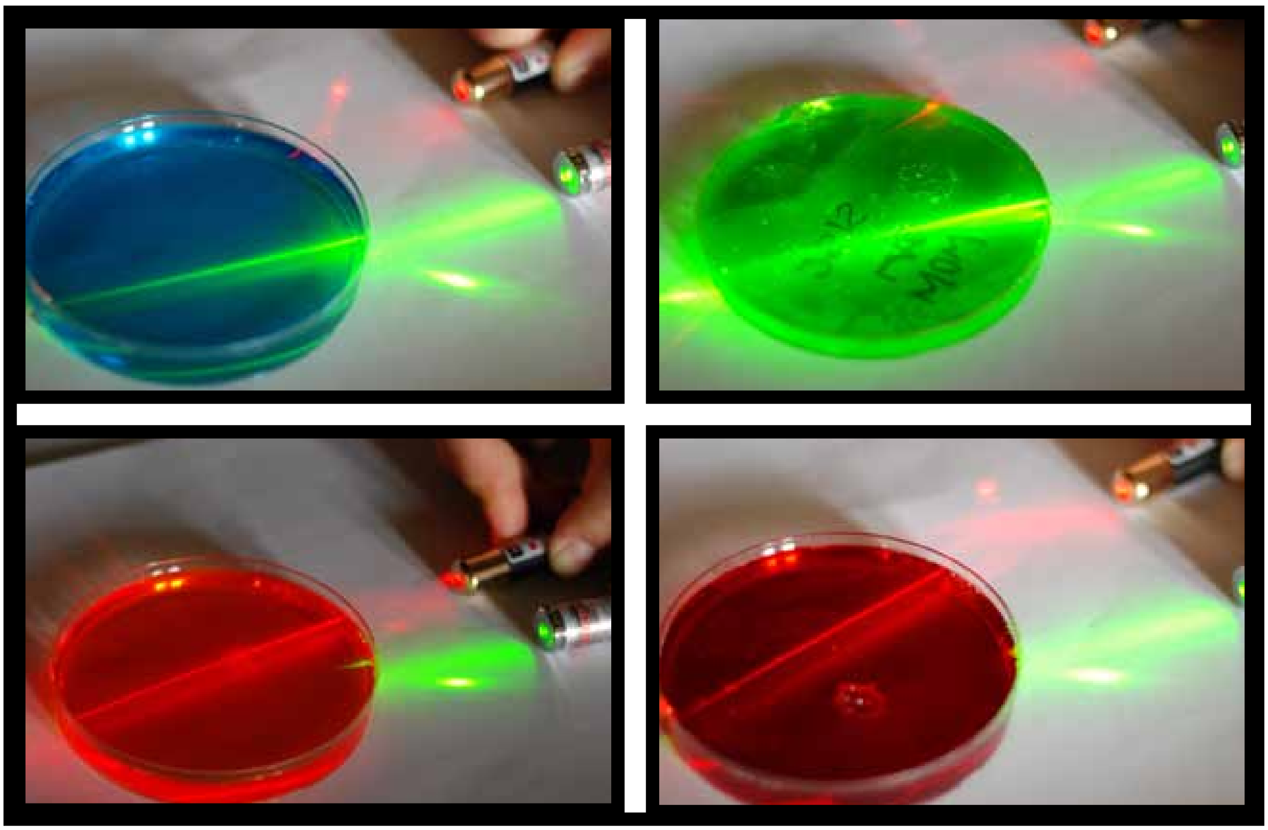

Figure 8

(Top) The green laser will go through the blue JELL-O (left) and the green JELL-O (right), while the red laser is absorbed by these colours.
(Bottom) The red laser will go through the orange JELL-O (left) and the red JELL-O (right), while the green laser is absorbed by these colours.

Different colours of JELL-O reflect different wavelengths of light: the wavelength of light that an object reflects and absorbs is what gives the object colour. Green objects reflect green light and absorb all other colours, red objects reflect red light and absorb all other colours, and so on, as can be demonstrated with JELL-O (**Figure 8**).

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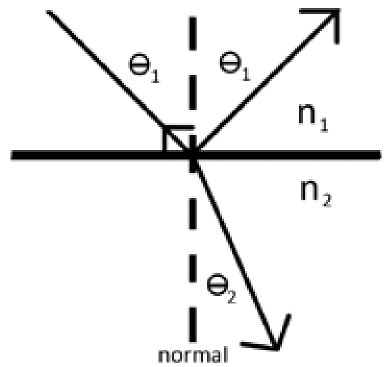
Equations

1) $$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_1}{n_2} = \frac{v_1}{v_2}$$



2) $$n_1 = \frac{c}{v_1}$$