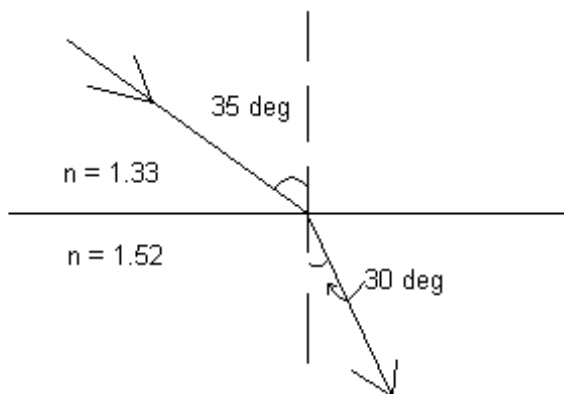# Measuring Refraction: Silicon Worksheet Answer Key

Refraction Review Problems

1. Light travels through a vacuum at a speed of 3×10^8 m/s.
   Determine the speed of light in the following materials:
   a. water (n = 1.333)   **2.25×10^8**
   b. crown glass (n = 1.52)   **1.97×10^8**
   c. cubic zirconia (n = 2.16)   **1.39×10^8**
   d. diamond (n = 2.419)   **1.24×10^8**

2. A ray of light travels through air (n = 1.00) and approaches the boundary with water (n = 1.33). The angle of incidence is 45.0°. Determine the angle of refraction.   **32.12°**

3. During a physics lab, Ray Zuvlight observes a laser line passing through an unknown material towards a boundary with air with an angle of incidence of 24.5°. The light ray emerges into the air with an angle of refraction of 33.8°. Determine the index of refraction of the unknown material.   **n = 1.36**

4. Light in air approaches the boundary of oil at an angle of 36.1 degrees with respect to the normal. The light travels at a speed of 2.27×10^8 m/s through the oil. Determine the angle of refraction.   **26.48°**

5. Suppose light travels from water (n = 1.33) into crown glass (n = 1.52) at an angle of 35° relative to the normal. Draw the path of that the light ray will take in this scenario. Label each substance.

6. Now suppose we mix another substance into the crown glass and change its composition. After doing so, we notice that the angle at which light is refracted in the crown glass has decreased. Did the index of refraction of the glass go up or down? Explain your answer.

   Up. A decrease in the angle of refraction means that the light was bent more than before, so the index of refraction increased.

When Biosensors Talk

1. **Look at the graph that appears when your sample is placed under a spectrometer. What does the graph depict? Hint: What do the x= and y-axes show you?**

   It shows percentage of the total light reflected vs. wavelength.

2. **Why do you see a sinusoidal wave pattern on the graph?**

   Light undergoes total constructive interference only at certain wavelengths that are multiples of the path distance that light takes through the film.

   Alternative explanation: The wavelength(s) of light that are reflected more depend on Snell's law, which is a sinusoidal function.

3. **What would happen to the sinusoidal wave pattern if we tilted our sample so that the light hit it at a different angle?**

   The pattern would shift left or right, to show longer or shorter wavelengths being reflected.

4. **What would happen to the wave pattern if we made our sample thicker?**

   The pattern would shift to the right, indicating longer wavelengths being reflected due to a longer path followed by the light ray.

5. **What would happen to the wave pattern if we put another material in the pores on the sample's surface? Hint: What parameter changes if I put something in the pores?**

   The pattern would shift left or right, showing shorter or longer wavelengths being reflected due to the path of the light ray becoming shorter or longer due to entering the film at a different angle.

Final Problem

Suppose you have biosensor made from a porous thin film engineered to bind with a specific, potentially cancerous gene. You place the film in a sample solution with a patient's DNA (which will bind to the film if the gene is present) then measure the reflectance, and notice that shorter wavelengths of light have a higher percentage reflectance than before exposing it to the patient's DNA.

1. **Does the patient have the potentially cancerous gene? Explain your answer in complete sentences, and draw a labeled picture illustrating your explanation.**

   Yes, the patient has the gene. The reflectance of shorter wavelengths indicates that the light is taking a shorter path through the film. The only way this happens is if the index of refraction increased, causing the light ray to bend more. A change in index of refraction indicates that the composition of the film has changed, that is, the gene bonded to its surface. Expect drawings to be similar to the #5 answer on page 1 of this worksheet.

2. **Suppose light entered the sample from air (n = 1) at an angle of 30°. If the light was refracted in the film at an angle of 20°, what is the index of refraction of the film? n = 1.46**