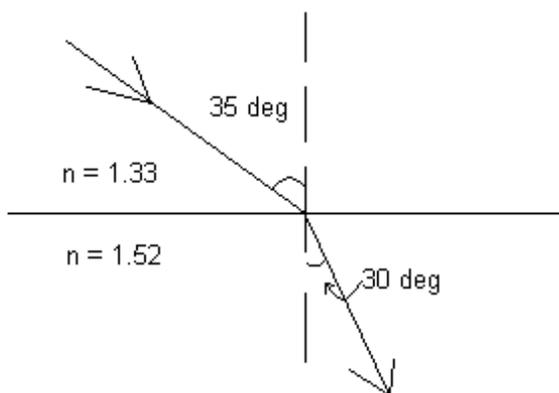


Measuring Refraction: Thin Films Worksheet **Answer Key**

Refraction Review Problems

- Light travels through a vacuum at a speed of 3×10^8 m/s. Determine the speed of light in the following materials:
 - water ($n = 1.333$) **2.25×10^8**
 - crown glass ($n = 1.52$) **1.97×10^8**
 - cubic zirconia ($n = 2.16$) **1.39×10^8**
 - diamond ($n = 2.419$) **1.24×10^8**
- 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°**
- 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. **$n = 1.36$**
- 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°**
- 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.



- 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 your nail polish film from various angles. What do you see? In other words, what changes do you observe when you look at the film from different angles?

Example answer: I see different colors begin to dominate at different angles.

2. What causes the film to look different when viewed from different angles?

Different wavelengths of light are being reflected constructively back to our eyes. This happens because the light is taking different paths (with different path lengths) so different wavelengths of light “fit” in this space/path.

3. What would you expect to see if light was refracted inside our film at a different angle?

The color would change even though our viewing angle remained the same. How it would change would depend on the angle of refraction. A larger index of refraction would mean a smaller angle of refraction, and therefore a shorter path length and shorter wavelength reflected. A smaller index of refraction would cause a larger angle of refraction, and therefore a longer path length and a longer reflected wavelength.

4. What would happen to the colors we see if we made our sample thicker?

We would see colors corresponding to longer wavelengths of light due to the longer path light would have to take through the film.

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 index of refraction would increase, causing the angle of refraction to decrease, which would mean a shorter path, and a shorter wavelength of light reflected back to our eyes.

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? $n = 1.46$