Student Guide

Name:________________________________Date:_______________Class:___________

Sand and Multiple Light Scattering

Safety

1. Silica sand: avoid prolonged breathing of any fine sand particles that may become airborne.
2. Toluene, acetone, and other organic solvents: use in a fume hood. Chemical resistant gloves should be worn when pouring or transferring solvents.
3. Dispose of toluene in an approved solvent waste container which will be disposed of in accordance with school regulations.

Introduction: Nanoparticles are very small bits of matter, typically less than 100 nanometers across. This is 1/1000 the thickness of a human hair! A nanometer is $1x10^{-9}$ meters or one billionth of a meter. Nanoparticles are increasingly being used in many consumer products, such as sunscreens, skin creams, and food additives. When they work with nanoparticles, scientists and engineers must measure several key properties, especially the size distribution of the particles. Since these particles are so small, they cannot be seen even with a good light microscope. Instead, such tiny particles are often analyzed through the specialized use of light scattering.

This lab introduces concepts of particle light scattering, using somewhat larger particles that you can more easily see. In this lab you will study the optical properties of various materials: sand, air, water, and toluene. You will then use your observations to predict the optical properties of a Mystery Liquid. Do you notice that when things get wet, they change color - for example, when you spill water on your jeans? Today we will work to discover why this happens, and to further explore this phenomena of light scatter.

Light scattering occurs when a given material interacts with light rays. The figure below shows a ray of light striking the boundary between two different materials, for example, air and water. You can easily observe that light appears to bend at the interface between the two materials. If we measure the angles that the ray makes with a line drawn perpendicularly to the interface (called the “normal”), we find that the angle in air $Ø_1$ and the angle in water $Ø_2$ are related by Snell’s Law:

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$

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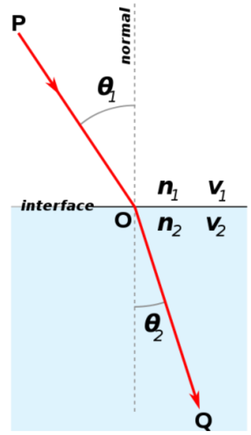

Figure 1: Light striking an interface between air and water. The light bends as it passes from one material to the other.

Snell's law states that the ratio of the sines of the angles of incidence and refraction is equivalent to the ratio of phase velocities in the two media, or equivalent to the reciprocal of the ratio of the indices of refraction. Snell's Law says that this bending of light is related to the *index of refraction* of each material, labeled n_1 and n_2 in the figure. The property of refractive index acts as a fingerprint of individual materials. It may be used to provide precise and repeatable data on the identity of a given material. It is also a key predictor of how light will scatter from a material, as you will see.

Question: How is light scattering involved with our ability to see objects illuminated by a light source?

Make a prediction of what the sand will look like

1. **as we add water to the sand**
2. **as we add toluene to the sand**

Materials:

- Safety goggles
- Petri dishes (3)
- 10ml graduated cylinders (3)
- Sand – enough to fill Petri dishes
- Ruler to level sand in dish
- Distilled or deionized water (3ml)
- Toluene (3 ml)
- Mystery Liquid (3ml)
- Black paper or cardstock
- 3x5 cards
- marker

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Procedure:

1. Using the Internet, research the refractive index of air, sand, water, and toluene. Complete the Research column in the Observation Table below.
2. Complete the Prediction Column in the Observation Table below.
3. Gather your materials. Add sand to each of the Petri dishes, tamp it down, and smooth the surface across the top with the side of a ruler.
4. Place the dishes on a black paper background. Using a piece of paper or 3x5 card, label the dishes as “1-water”, “ 2-toluene”, “3-mystery”.
5. For the first dish, use a graduated cylinder to add 3 ml of water to the sand in one half of dish #1. (Use just enough water to wet the sand—do not add so much that the water pools in the sand.)
6. Describe and record the different appearance between the dry and water-wetted sides. An example is shown in Figure 2.

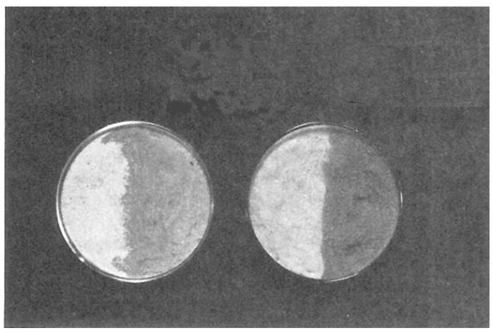

Figure 2. Left: Comparison of sand in air to sand in the mystery liquid. Right: Comparison of sand in water to sand in toluene

7. For dish #2, use a different graduated cylinder to add 3 ml of toluene to the sand in one half of the dish. Describe the different appearance between the dry and toluene-wetted sides.
8. Compare the appearance of the dry, water-wetted, and toluene-wetted sand samples. Which one is darker or lighter?
9. Compare the observation results with the index of refraction information you researched. Explain the different appearances of the sand samples in terms of the index of refraction of sand versus the surrounding material.
10. Your instructor will give you a “mystery liquid”. Add 3 ml of this liquid to the sand in one half of dish #3. Describe the different appearance between the dry and liquid-wetted sides.
11. Based on your analysis in step 9, estimate the value of the index of refraction of the mystery liquid. Is it greater or lower than air, toluene, or water?

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Observation Table

	Observation	Amount of Liquid Added	Research: Refractive Index	Prediction: Lighter or Darker?
Sand with Air		Not applicable		
Sand with Water				The sand with the water compared to the sand with air with will be ___________________.
Sand with Toluene				The sand with the toluene compared to the sand with air with will be ___________________.
Sand with Mystery Liquid				The sand with the mystery liquid compared to the sand with air with will be ___________________.

Using your lab notebook

Analyze Results:

What did you observe and why?

Draw Conclusions:

1. Is a chemical reaction taking place that would explain the observation? Support your reasoning.
2. Sketch a possible photon path through the sand for each of the trials using a cut away side view that would explain your observations.
3. Why did the water in the sand create the smallest color difference as compared to the dry sand?
4. Which liquid has a refractive index that is closest to that of sand?
5. Based on your observations, comment on the refractive index of sand and the Mystery Liquid. Include in your discussion the accuracy of your predictions of comparing the

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mystery Liquid to the other liquids. Once the identity of the mystery liquid is revealed by your instructor, look up its refractive index. Does this explain what you observed?

6. Was it critical to add a precise and consistent amount of liquid to each sample in this lab
7. If you were given a liquid with the same refractive index as the sand, would you be able to see the sand?
8. At what scale are the optical properties of this lab occurring at? At what scale are you making your observations?

Clean up: Sand wetted with water or the solvents can be dried and re-used. Allow the solvent-wetted sand to dry in a fume hood. Extra organic solvents should be collected as solvent waste and disposed of in compliance with your school's hazardous waste procedures.

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