Optical Materials

Background: Read Mike Nofziger's Optical Materials and Dispersion I and II for the description of the techniques mathematics required for the index calculations. Also, search the web and find the index of refraction of distilled water, propyl alcohol, and vegetable oil.

Introduction: The Abbe refractometer is a classic optical instrument used to measure the refractive index of liquids or solids. The instrument is based on the principle of total internal reflection (TIR). Experimentally, a 'shadow boundary' created at the sample's critical angle is used to determine the index. The handheld refractometer is useful for measuring index of refraction of some liquids. It uses a prism and LED illumination to measure the refractive index. Unfortunately, the refractometers upper limit is about n_d = 1.44. For higher index liquids, we need some alternative methods of measuring refractive index. Directly measuring the angle of refraction is one possible technique for measuring these higher index liquids. Finally, unknown glass types can be narrowed with knowledge of the material's density. We will measure the density of a glass sample.

Abbe Refractometer Experiement:

1. Locate the power switch on the left side of the Abbe refractometer. It has these positions:

   UP: off
   CENTER: illuminates the prism/sample
   DOWN: illuminates the scale

2. Locate the source and note how it moves on its arm. Also note how the inside of the plastic diffuser is constructed.

   WARNING: The next step involves the use of 1-Bromonaphthalene as an index matching fluid. This fluid acts as a skin and eye irritant, and is POISONOUS if ingested. Avoid inhalation of the vapors. Be extremely careful not to spill the bottle and keep it tightly closed when not in use. Wash your hands after this part of the lab if you've handled the fluid or samples.

3. Open the top (illuminating) prism. Apply one or two drops of distilled water to the bottom (measuring) prism. Use care not to scratch the prism surface with the dropper.

4. Gently close the top prism, until it snaps shut. This forms a thin, uniform layer of water between the two prisms.

5. Refer to Fig. 10.4 in Nofziger's notes to learn how to read the Refractive Index Scale. The index is read where the vertical cross hair intersects the top (n_d) scale.

6. Hold the power switch in the down position. Use the hand wheel on the right side of the case to set the index scale (visible through the eyepiece) to read 1.3333, the refractive index of water.

7. Release the switch to the center position. Look through the eyepiece and note the shadow boundary. Adjust the source arm and rotate the shield for best contrast and definition of the boundary. Refer to Fig. 10.5 in Nofziger's notes to confirm what you should be seeing.

8. The compensator (rotating prism) corrects for the dispersion inherent in the refractometer optics and the sample when using white light. The compensator is adjusted using the large dial on the front of the instrument. When properly set, the shadow boundary seen through the eyepiece will be achromatic (without color) in the center (at the cross hair), with a faint red color at one end, and a faint blue color at the other end. Remove the plastic cover and rotate the compensator dial until the center of the boundary becomes achromatic.

9. Use the handwheel and center the shadow boundary exactly on the reticle "X" cross hairs.

10. Hold the switch in the down position and note the index reading. It may (or may not read 1.3333). To adjust the scale so that the reading is exactly 1.3333, use the allen wrench to rotate the setscrew (located in the middle of the right-hand side of the housing). Rotate the screw and adjust the scale reading to be exactly 1.3333. The instrument is now calibrated!

11. Open the top prism. Use lens tissue to dry off the water from both prisms.

12. Put on a pair of gloves, and place one drop of index matching fluid (**1-Bromonaphthalene)** on the bottom prism. Place one of the two glass-disk samples on top. **<u>DO NOT</u>** close the top prism!!! Measure the refractive index of this sample. Repeat for the other glass disk.

13. Use a clean piece of lens tissue and acetone to wipe the fluid off of the bottom prism. The prism may be gently wiped with the tissue. Dragging the tissue is not necessary.

14. Throw away the lens tissue, take off the gloves, and go wash your hands to make sure that you have not contacted any of the 1-Bromonaphthalene.

Handheld Refractometer Experiement:

1. Place several drops of distilled water on the handheld refractometer. Hold down the calibrate button for 5 seconds. Press the read key and record the index of refraction. How does this compare to the theoretical value?
2. Remove the water and dry the well. Place several drops of propyl alcohol in the well and press the read button. How does this compare to the theoretical value?

Snell's Law Calculation

3. Pour distilled water and vegetable oil separately into the two semi-circular dishes. Place the semi-circular dish on the refractive index sheet so that the flat side of the dish is flush with the horizontal line. Take the laser pointer and shine the beam along the 30 degree line marked on the bottom portion of the sheet. Mark the direction of the emerging beam. Measure the angle formed by the emerging beam with the protractor. Use Snell's law to calculate the index of refraction of the various liquids. ***Please return the liquids to their various containers when complete and wash the dishes thoroughly.*** How does the measured indices compare to the theoretical values?

Density Calculation

4. Set up the balance and make sure it is zeroed by adjusting the knob under the platter. Take the small BK7 lens and measure its weight. Place about 40 mL of distilled water in the Pyrex cup. Place the cup on the scale and measure its weight. Tie a thread around the edge of the lens. Holding the thread, lower the lens into the cup of water. With the lens fully immersed, but not touching the sides or bottom of the cup, re-measure the weight. The volume of the lens is equivalent to the volume of the water that was displaced when the lens is immersed. Water has the property that 1g of water is equivalent to 1 mL, so the measured difference in weight is equal to the lens volume in mL. Also, 1 cm^3 = 1mL. Calculate the density of the BK7 lens in g/cm^3. How does this measured value compare to published values for BK7? This scale is somewhat limited. You will need to estimate the weights to sub-gram values to get close to the true value. Ideally, we would have larger samples or a scale with a more sensitive range.