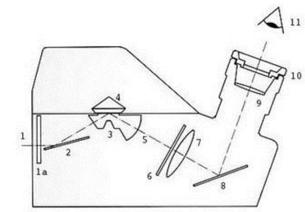
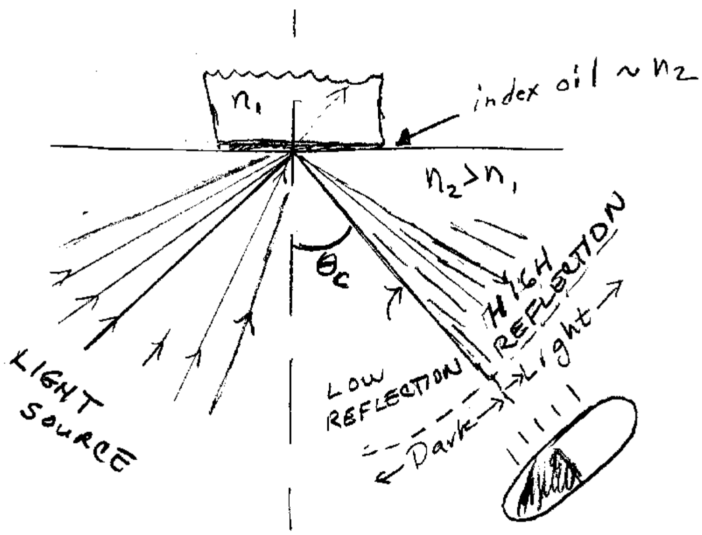
Measuring Refractive Index of Glass Using Gem Refractometer



Summary of Activity: In this activity we will use the Gem Refractometer to measure the refractive index of common glassy materials. To use the method the sample must have one flat surface. In this lab we provide a collection of glassy materials of different refractive index for the experimenter to measure and compare with known values. The Gem Refractometer can be purchased for approximately $100 and provides a very easy and convenient apparatus for measuring the refractive index of a wide range of materials with at least one flat surface, which includes prisms, plano lenses, panes and flats.

Overview of Method:
The method is based on the direct application of Snell's law and the critical angle, above which total internal reflection occurs. For θ above θ_c we will observe essentially 100% back reflection from the higher index medium side. Thus if a divergent light source impinges on the interface through the higher density material from the left as shown in the figure, then there will be an abrupt increase in the brightness of light reflected back at the critical angle. Below the critical angle most of the light will be transmitted and not reflected; thus the region below the critical angle will appear darker in reflection.



Recall $\sin \theta_c = n_1/n_2$

This effect is easiest to observe through a high index hemisphere where it is easy to observe the back reflected light. The Gem Refractometer utilizes such a high index, "hemispherical" lens with an attached or built in light source to facilitate the measurement. A special high index oil is used to preclude a glass/air interface which would disrupt the phenomena. Additional details on the actual gem refractometer are provides in an appendix.

How to Use the Gem Refractometer:

Photo from http://www.prettyrock.com/refractometer-instructions.htm

Note: Always wash your hands after you make physical contact with the refractive index (RI) liquids. The MSDS list no health hazard at Condition of Intended Use but the oil should not be inhaled and avoid contact with skin for good measure. See MSDS and note 6 for details.

Directions for Use:
1. Make sure the lamp is attached (if not internally lighted), batteries fresh and switch on.

2. Put a tiny drop of RI liquid on the metal plate near the hemicylinder. You only need to place a really small drop of the solution -- just enough to cover a small portion of the metal base near the hemicylinder.

3. Place the glass sample right on top of the RI liquid and slide it onto the cylinder without breaking the seal between the surfaces. Center the sample and RI on the hemicylinder.

4. View the reading scale through the eyepiece at about 6" away so you can see the scale inside the refractometer. With practice, you will find the right spot to use for your eyes. Note the point on the scale where the dark to light transition line rests; this will be the measure for your refractive index.

For more detailed procedures or to learn about a You Tube video on the method see a discussion in the end notes[3].

Gem Refractometer Experimental Activity:

Using the method on the previous page determine the refractive index of the samples provided by you instructor and listed in the table below. Make 2 measurements to check repeatability.

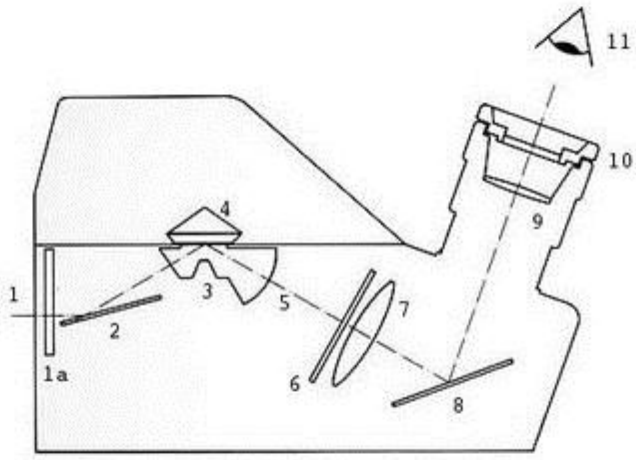
Sample	material type	Expected Index	Measured Index		
			1st	2nd	Avg.
F2 - Prism (L1885D)	flint (lead) glass high dispersion	1.62			
BK7 prism (L1851D)	crown glass, alkalai, Ca silica	1.517			
window glass	soda lime silica	1.520			
LEBG sq. blank (PM1250)	low expansion borosilicate glass	1.47			
Fused silica window (PM1078)	silica glass	1.46			
acrylic sheet	pmma	1.49			
poly styrene sheet		1.59			
unknowns					
microscope slide					
hard candy					

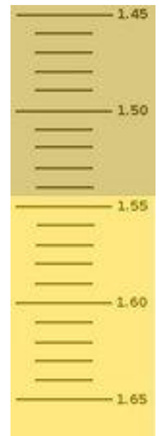
For source of data used in the above table see note 3. Indices listed are for 587 nm. See note 4

Make a graph of measured value vs. expected and comment on how well they compare.

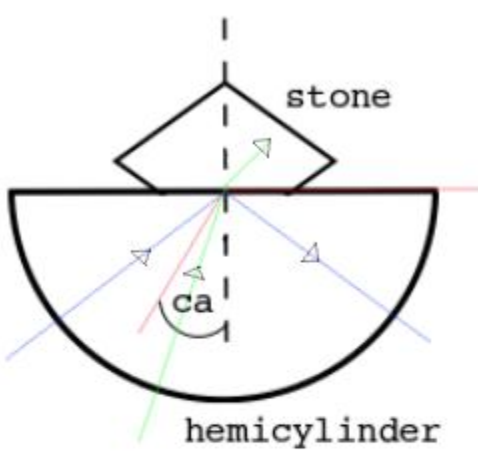
Instructor could have the students look up the refractive index of the materials if they want to add a data search dimension to the lab.

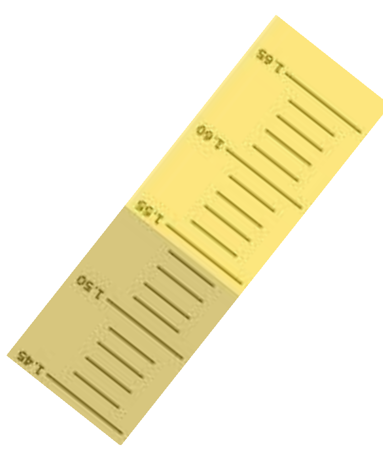
Appendix A: Under the Hood – How the Gem Refractometer Works
(from http://gemologyproject.com/wiki/index.php?title=Refractometer)





Light (1) enters through the rear of the refractometer through an opening (1a) in (or before) which a yellow sodium filter can be placed. It then hits a mirror (2) which transmits the light to the center of the hemicylinder (3). This hemicylinder is made of high refractive glass (usually N-LaSF by Schott with a refractive index of ~ 1.88 at nD and a hardness of about 6.5 on Moh's scale). At the boundary between the hemicylinder and the gemstone (4), the light will be partially refracted inside the stone and partially reflected in the hemicylinder (see below on Total Internal reflection). The reflected rays (5) will pass through a reading scale (6) and a lens (7) or a series of lenses, depending on the type of refractometer.
The reflected rays hit a mirror (8) which directs the light to the ocular (9) and then outside the refractometer to your eye (11). The ocular (9) can slide in and out for better focus and is usually accompanied with a detachable polarizing filter (10).





Appendix B: Sources for Gem Refractometer and Samples

Gem Refractometers:

The Gem Refractometer used to be a fairly expensive item (above $500) but more recently a variety of clones have been coming out of China, and you should not have to pay more than $100 for a descent model. But you may have to shop around; use "gem refractometer" in your search. Both Amazon and Ebay are good places to find competitively priced products. There are several different versions out there. Some have internal light sources (single color, usually a yellow LED) while others use a detachable light source. Either seem fine. Most come with a small bottle of the high index (RI) oil. A bottle of RI oil sold separately will cost about $20 so make sure your kit includes a bottle.

I will list below the two recent purchases that I made, but you should have no problem finding something from a US supplier on Amazon.

GEMOLOGICAL REFRACTOMETER, GEMSTONE TESTING INSTRUMENT
Ordered on Amazon from sportswarehouse (Dec. 2011) for $97 with shipping but did not come with the RI oil. Had to purchase that separately from them for $20 plus $5 shipping.
The unit is nice and has an internal yellow LED as the light source.
I also saw essentially the same item with oil from Ecrater (listed as a US seller) at $98+13.50
Gem Refractometer w/ Built-in Light Source + RI liquid
http://www.ecrater.com/p/9757510/gem-refractometer-w-built-in-light-source

My most recent purchase was found on Ebay from Gemology Gemstone listed as
Gem Refractometer LED 1.81 RI Oil
It ships from Australia but only paid $80 + $17 for S&H and it came within 10 days.
It has an external yellow LED light source, which I prefer since I can now try different color light sources. So for me this is the best model at the best price.

Sources for Sample Materials:

The acrylate and PS samples are from window panes available at the local hardware store (e.g., Home Depot) where these window materials are identified as follows:
Plaskolite 8 in. x 10 in. Polystyrene Sheet, Model # 1S08104A, Store SKU # 628837, $1.97 ea.
OPTIX 11 in. x 14 in. x .093 Acrylic Sheet, Model # MC-27, Store SKU # 241302, $3.98 ea.
(Using the thicker 0.093" thick acrylate will help avoid confusion with the thinner PS pane)
A very good, lower cost source for optics and optical glass is the Surplus Shed at http://www.surplusshed.com/ All of the optical glass samples in this experiment came from Surplus Shed and the items are listed below with current prices.

- F2 EQUILATERAL DISPERSION PRISM (L1885D) at $22.50 n=1.62
  High index, high dispersion flint glass sample (prism) – the most expensive sample
- BK7 EQUILATERAL PRISM (L1851D) at $7.50
  BK7 is a more standard crown glass with n=1.717
- 25MM DIA FUSED SILICA WINDOW (PM1078), $5 (closeout price)
- 30MM DIAMETER LOW EXPANSION NOT ALUMINIZED MIRROR (PM1246), $3 closeout price (LEBG is very similar to pyrex with an index close to fused silica)
- PM1221 3.5 mm th, opt window, BK7, D=20 mm $1.50 n=1.517

Notes and References:

1. Wikipedia provides a good orientation on the topic of refractive index, Snell's law and the wavelength dependence or dispersion of common glasses at:
http://en.wikipedia.org/wiki/Refractive_index

2. For an excellent description of the gem refractometer and how it works see:
http://gemologyproject.com/wiki/index.php?title=Refractometer
For more detailed comparison info on various refractometers see:
http://www.nordskip.com/refractometer.html

3. For information on how to use a gem refractometer see one seller's recommendation at
http://www.prettyrock.com/refractometer-instructions.htm
or a slightly different version at How to Use a Gemological Refractometer | eHow.com
http://www.ehow.com/how_5002478_use-gemological-refractometer.html#ixzz1k4a1NOrY
There is also a You-tube demo on how to use gem refractometer titled: How to Use a Refractometer for Gem Testing Model FGR-003 at http://www.youtube.com/watch?v=zi3PaHTKJ6U

4. Edmonds Scientific has a very great summary table of the properties of optical glasses at
http://www.edmundoptics.com/technical-support/optics/optical-glass/?&viewall
The values in our table are obtained from this source. The data for plastics like acrylate and PS are available from the Wiki article on refractive index in reference 1 above, and also with more detail and dispersion plots see http://refractiveindex.info/?group=PLASTICS&material=PS

5. Wavelength reference for refractive index values used:
For the Edmonds table the refractive index for optical glasses, n_d, is specified at a wavelength of 587.6nm (yellow, He d-line). Wikipedia suggests that "n_D is the refractive index at the Fraunhofer "D" line, the center of the yellow sodium double emission at 589.29 nm wavelength."(Wiki). Of course, the difference in these two wavelengths is too small for us to argue about here.

6. The chemical composition of the RI liquids commonly used are:
   1.79 - Saturated solution of sulphur and di-idiomethane
   1.81 - Saturated solution of sulphur, di-idiomethane and tetraidioethylene
(from Gemology Project site mentioned in note 2 above)
The Material Safety Data Sheet (msdi) for the 181 oil is available from the manufacturer at:
http://www.cargille.com/pdf2/MSDS-Gem_Refract.pdf

7. For estimating the refractive index of sugar glass see the reference to the Feyman lecture covering refractive index of sucrose already mentioned in notes from the Pfund Method experiment.

Extra stuff – probably won't use:

A very nice but much more technical review of refractive index measuring methods can be found in the 2002 review paper:
Shyam Singh, Refractive Index Measurement and its Applications, Physics Scripta., Vol. 65, 167-180, 2002. Currently available online from MIT at:
http://web.mit.edu/mtim/www/asef/techniques/Spectroscopy/Refractive_Index/physscr_65_2_008.pdf

Another cool set of experiments related to index of refraction is available at:
http://www.pl.euhou.net/docupload/files/Excersises/WorldAroundUs/IndexOfRefraction/IndexOfRefraction.pdf