

Art & Science of Light
Fall 2007

Science Lab I – Properties of Light

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Using the Filtergraph (15 minutes)

1. Turn on the filtergraph, place a card on it and look at the output. Draw a picture of the output accurately (what you have is a graph of transmittance versus wavelength). **Draw to scale and be sure to write down the names of the axis of the graph with units.** Next to the graph, write down the color on the card.
2. Repeat the above process with 4 different cards.

Homework:

1. Based on the above lab experience and the wavelengths of the visible light spectrum given below (see table below), write your own definition for “transmittance”.
2. Using the library as a resource, write a definition for “transmittance” (be sure to write down the reference you used in your lab notebook). Are there any differences between your definition and the definition you found in the library?

The following wavelengths for the colors in the visible spectrum are provided for your reference. Please note that these are approximate values.

Color	Wavelength (nm)
Violet	420
Blue	470
Green	530
Yellow	580
Orange	620
Red	700

Using the Singerman Color Apparatus (15 minutes)

In this activity you will be mixing different colors and observing the resulting color using your eyes as the detector.

1. Turn all three lamps in the color apparatus. Insert red, green and blue color cards into the slits of the color apparatus.
2. Observe and record the individual colors with your naked eye. Also record the additive colors where two or three different colors overlap.
3. Change the intensity (there is an intensity knob on the color apparatus) of the lights and see how it affects the colors. Record your observations.
4. Repeat the above process with other color combinations. Record all observations (time limit 15 minutes).

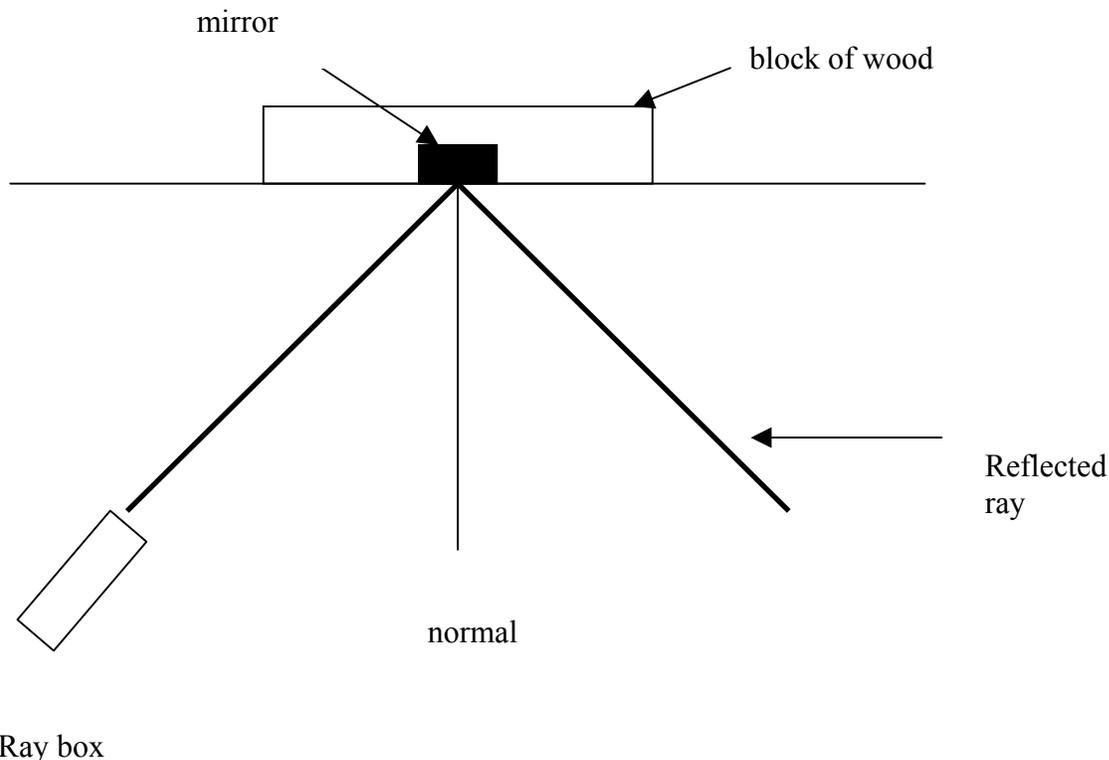
Using the Monochromator with a white light source (10 minutes)

Turn on the white light source. Narrow down the slits (there are two of them) so that you see a narrow, clear beam of light coming out from the monochromator. Change the wavelength dial on the monochromator and see the color of the output beam. Assign a wavelength range to each of the seven colors of the visible spectrum. Record your observations.

Verifying the Law of Reflection (30 minutes)

The law of reflection states that when light is reflected by a surface, the angle of incidence is equal to the angle of reflection. This can be verified by a simple experiment.

1. Using double stick tape, fasten a flat mirror onto a flat surface (a box, a block of wood etc.).
2. Place a ray box on the table, turn it on and get a single ray of light pointing from the box towards the mirror. Make sure you can see the reflected beam of light from the mirror.



3. Draw a line to mark the position of the mirror and a few carefully placed dots to mark the positions of the incident light ray and the reflected light ray. Remove the mirror and the ray box.
4. Use a ruler to draw lines showing the incident light ray and the reflected light ray. These should be extended to cross the line showing the position of the mirror. At the point where the lines cross, draw a normal to the mirror (this line should be at 90° to the mirror line)

5. Use your diagram and a protractor to measure the angle of incidence and the angle of reflection. Verify if the law of reflection is true. **If you have extra time you can repeat the experiment with a different angle of incidence.**

Snell's Law of Refraction (30 minutes)

Fill a clear glass with water. Put a pencil in the glass of water at an angle and observe the appearance when you look directly along the part of the pencil that is out of the water. Draw the appearance of the pencil. (Important: Look directly along the part of the pencil that sticks out of the water, not from the side.)

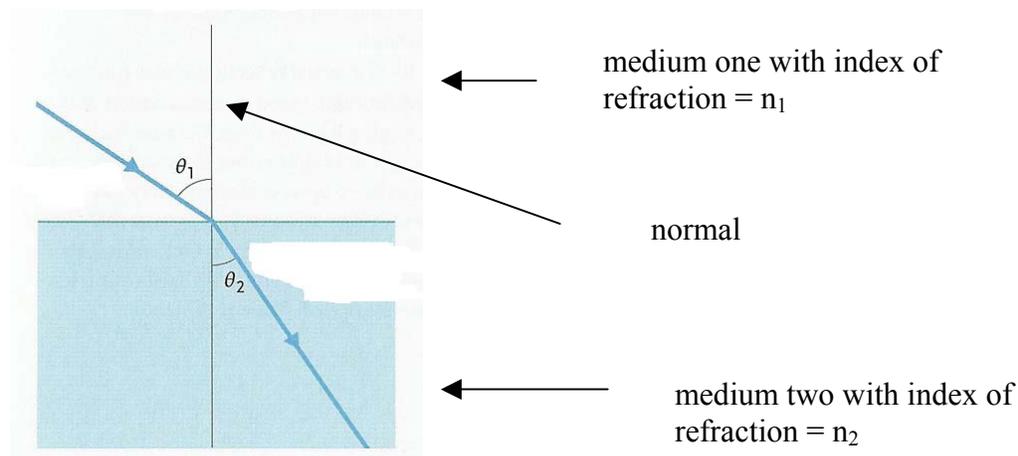
What appears to have happened to the pencil?

Where does the tip of the pencil appear to be relative to its actual position?

When light "rays" pass from one medium to another, as from air to water, they bend (or refract). The rays of light bend toward the line perpendicular to the surface (normal) when they enter a denser medium (water) from a less-dense medium (air). They bend away from this line when they leave the denser medium. This is called Snell's Law.

Snell's Law is written as follows: $n_1 \sin \theta_1 = n_2 \sin \theta_2$

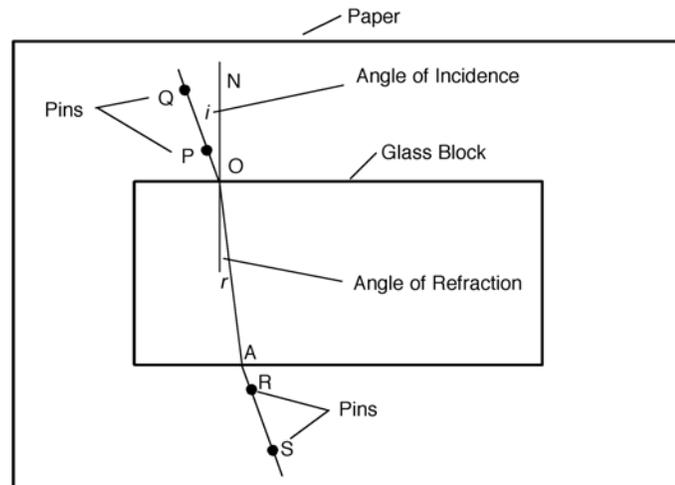
where n_1 is the index of refraction of medium one
 n_2 is the index of refraction of medium two
 θ_1 is the angle of the incident ray
 θ_2 is the angle of the refracted ray



The index of refraction of a medium (n) is the ratio of the speed of light in a vacuum to the speed of light in that medium.

Index of refraction for water = speed of light in vacuum/speed of light in water

Let's determine the index of refraction of glass using Snell's law. Set up the experiment as shown in the following diagram. You need a clean sheet of paper, a block of glass, a laser, a protractor, a ruler and a pencil.



1. Lay the glass block on a sheet of paper. With a sharp pencil trace an outline of the block.
2. Place the laser beam so that it moves along line QP towards the glass block. Carefully place dots along this line so that when you remove the laser you can trace its path along QP.
3. Note that the laser beam emerges from the opposite side. Carefully place dots along the emerging laser beam so that when you remove the laser you can trace its path along RS.
4. Remove the laser beam and the block. Draw in lines QP and RS. Where QP crosses the position of the block mark as point O. Similarly, where RS crosses the position of the block mark as point A. Draw in the line OA.

Do the following as homework.

1. Draw the line ON, which is the normal to the glass block at point O. Use a protractor to measure the angle correctly.
2. Measure the angle of incidence (θ_1) and the angle of refraction (θ_2) carefully with a protractor
3. Now calculate $\sin\theta_1$ and $\sin\theta_2$.
4. Given that the index of refraction of air (n_1) is 1.003, calculate the index of refraction of glass (n_2) using Snell's law.
5. Now that you know the index of refraction of glass, use this value to calculate the speed of light in glass.
6. Use the library to find the established speed of light in glass. Compare with your value and comment on the accuracy of your work.

Kaleidoscope (15 minutes)

Hinge two flat mirrors together with masking tape so that they are at 72° to each other. Use a protractor to make sure you have the right angle. Accuracy is important. Place a small object inside the angled mirrors. Count the number of images you can see and record in the following table. Decreasing the angle by 5° each time, continue to record the number of images you get from this system. Record about 5 data points.

Angle	Number of images
72°	
67°	
62°	
57°	
52°	
47°	
42°	
37°	
32°	
27°	

What effect does the angle between the mirrors have on the number of images?

Using your data, predict what angle would be the best to use if you were to build a Kaleidoscope.

Determining the diameter of the Sun (15 minutes)

Poke a small hole (pin hole works well) in a note card. Hold the card in the sunlight and find the circular image that is cast on the floor by the hole. As you move the card up and down (towards and away from the ground) the size of the image of the hole will change. The image is that of the Sun. The bigger the distance from the pinhole to the ground, the larger the image.

Position the note card so that the image exactly covers a nickel, a dime or a quarter (so you can measure the size of the image accurately). Carefully measure the distance from the pinhole to the image.

$$\frac{\text{diameter of the image}}{\text{distance from the image to pinhole}} = \frac{\text{diameter of the Sun}}{\text{distance to the Sun}}$$

Given that the Sun is approximately 150,000,000 km from the pinhole, calculate the diameter of the Sun. Find the reported diameter of the Sun from a textbook or another resource. Compare your calculated value with this reported value and write a comment.

Observing the Fraunhofer lines of the sun (15 minutes)

(http://en.wikipedia.org/wiki/Fraunhofer_line)

The **Fraunhofer lines** are a set of spectral lines named for the German physicist Joseph von Fraunhofer (1787--1826). The lines were originally observed as dark features in the optical spectrum of the Sun. The English chemist William Hyde Wollaston was in 1802 the first person to note the appearance of a number of dark features in the solar spectrum. In 1814, Fraunhofer independently rediscovered the lines and began a systematic study and careful measurement of the wavelength of these features. In all, he mapped over 570 lines, and designated the principal features with the letters A through K, and weaker lines with other letters. It was later discovered by Kirchoff and Bunsen that each chemical element was associated with a set of spectral lines, and deduced that the dark lines in the solar spectrum were caused by absorption by those elements in the upper layers of the sun. Some of the observed features are also caused by absorption in oxygen molecules in the Earth's atmosphere.

The Fraunhofer C-, F-, G'-, and h- lines correspond to the alpha, beta, gamma and delta lines of the Balmer series of emission lines of the hydrogen atom. The D₁ and D₂ lines form the well-known "sodium doublet", the centre wavelength of which (589.29 nm) is given the designation letter "D". Note that there is disagreement in the literature for some line designations; e.g., the Fraunhofer "d" line may refer to the cyan iron line at 466.814 nm, or alternatively to the yellow helium line (also labelled D₃) at 587.565 nm. Because of their well defined wavelengths, Fraunhofer lines are often used to characterize the refractive index and dispersion properties of optical materials.

The major Fraunhofer lines, and the elements they are associated with, are shown in the following table:

Designation	Element	Wavelength (nm)	Designation	Element	Wavelength (nm)
y	O ₂	898.765	c	Fe	495.761
Z	O ₂	822.696	F	H β	486.134
A	O ₂	759.37	d	Fe	466.814
B	O ₂	686.719	e	Fe	438.355
C	H α	656.281	G'	H γ	434.047
a	O ₂	627.661	G	Fe	430.79
D ₁	Na	589.592	G	Ca	430.774
D ₂	Na	588.995	h	H δ	410.175
D ₃ (or d)	He	587.565	H	Ca ⁺	396.847
E ₂	Fe	527.039	K	Ca ⁺	393.368
b ₁	Mg	518.362	L	Fe	382.044
b ₂	Mg	517.27	N	Fe	358.121
b ₃	Fe	516.891	P	Ti ⁺	336.112
b ₄	Fe	516.751	T	Fe	302.108
b ₄	Mg	516.733	t	Ni	299.444