Lab 1—Playing with Light (Mobley)

Purpose: ***Follow your curiosity*** **to get hands-on, qualitative experience with a few properties of light. Several experiments have been set up. Do as many as time permits. If you end up totally confused by some of your observations, so much the better!!**

Experiment 1: Color

What to note or contemplate: What really determines the color of an object?

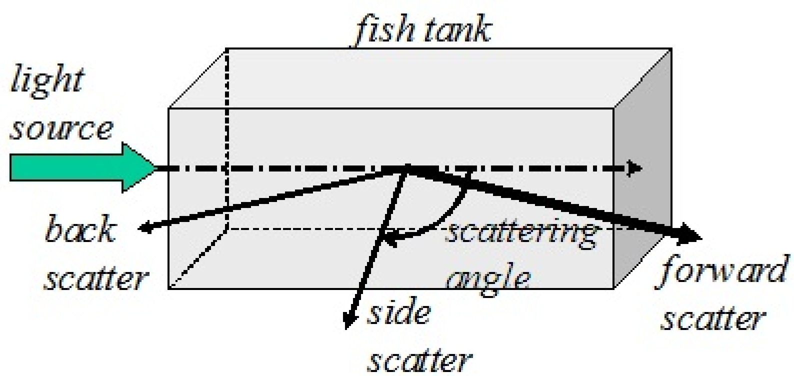
A white wall is called white because it "looks white." What color does a white wall have if you illuminate with a red light? Is viewing a white wall with a red light the same as viewing a red wall with a white light? What color is a blue wall if you illuminate it with a red light instead of a white light?

The computer monitor has panels with various colors displayed. Use the monocular held about 3 inches from the screen so that you can see the individual pixels of the display. What colors are the pixels when you view the white panel? The red, green, and blue panels? What colors do you see when you view the yellow and purple panels? Look at the yellow cardboard with the monocular. What color is the paper? Is there such a thing as yellow light? Is there such a thing as purple light? What does "ocean color" really mean?

Experiment 2: Scattering for an unpolarized incident beam

What to note: How a volume of water scatters light depends on the material (e.g., particle concentration, composition, and size) and the scattering (viewing) direction. Unpolarized incident light can be partially polarized by scattering, but multiple scattering tends to depolarize the light.

Shine a collimated beam from a bright flashlight or slide projector into a fish tank filled with clean water. Look at the beam at near-forward scattering angles (looking back toward the light source), at right angles to the beam, and at backscatter angles (looking away from the source). Does the brightness of the scattered light depend on the scattering angle (the polar angle viewing direction)? For the right-angle (side) view, rotate the flashlight (or look at the beam both from the side and from the top of the tank). Does the brightness of the scattered light depend on the azimuthal viewing direction?



Add a few drops of milk or Maalox to the water (just enough so that you can easily see the scattered light at right angles to the incident beam). At each viewing direction, view the scattered light through a linear polarizer. What happens as you rotate the polarizer?

Add some "large" particles (dirt, chalk dust, microbubbles; here, "large" means large relative to the wavelength of light), which should look like stars twinkling in the beam, viewed against the "glow" of the background scattering. (Tap water may have enough particles in it, without adding more.) Does scattering from the large particles depend on viewing direction? How do the large particles appear through a polarizer?

Add more milk, so that the tank now "glows." How is the glow affected by the polarizer, as opposed to the beam itself?

Experiment 3: Scattering for a polarized incident beam

This is basically Experiment 2 repeated with a laser.

What to note: Scattering of initially polarized light is even more complicated than for unpolarized light. Also, light hitting the air-water surface at any angle can always get into the water, but it can't always get back out.

Shine a laser beam into a fish tank filled with clean water (**Keep in mind the sign often seen in optics labs: "Dang! Do not look into laser with remaining eye!"**). Look at the beam from near-forward angles (looking toward—but not directly into—the laser), at right angles to the beam, and at backscatter angles (looking away from the source). For the right-angle view, look at the beam both from the side and from the top of the tank (or rotate the laser). How does the brightness of the scattered light depend on the viewing direction?

Add a few drops of milk or Maalox to the water (just enough so that you can easily see the scattered light at right angles to the beam). At each viewing direction, view the scattered light through a linear polarizer. What happens as you rotate the polarizer? What happens as you rotate the laser, for a given viewing direction?

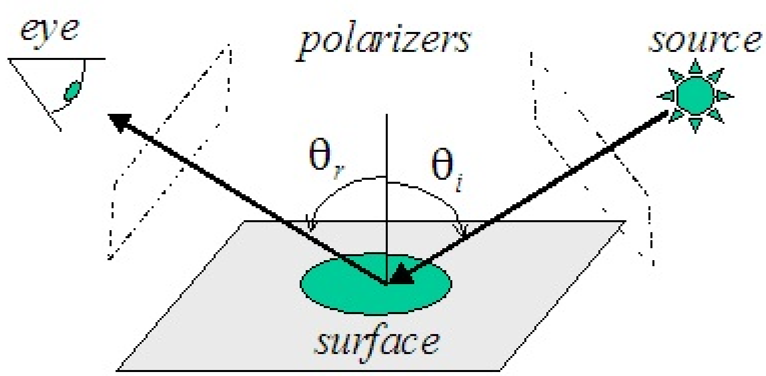
Move the laser so it reflects light off of the top side (air-incident light) or the bottom side (water-incident light) of the air-water surface. Note the angle of total internal reflection for water-incident light.

Add more milk, so that the tank now "glows." How is the glow affected by the viewing direction, the polarizer, and the rotation of the laser?

Experiment 4: Reflection from surfaces

What to note: How a surface reflects light depends on the material, the angles of incidence and reflection, and the polarization state of the incident or reflected light.

Look at the specular reflection (mirror reflection; $\boldsymbol{\theta}_r = \boldsymbol{\theta}_i$ in the figure) from a smooth, non-metallic surface (e.g., plastic, wood, or water). View the surface through a linear polarizer. What happens to the reflection as you rotate the polarizer? What if the polarizer is placed in the incident beam, rather than in the reflected beam? Try polarizers in both beams. Vary the incident angle $\boldsymbol{\theta}_i$ from overhead to near the horizon.



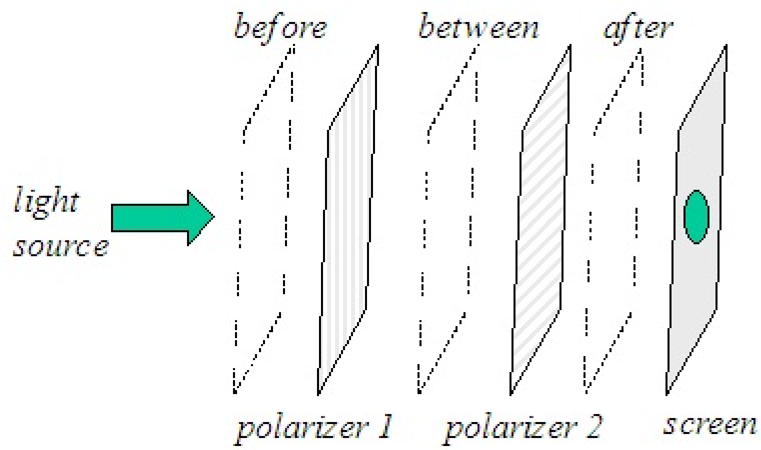
Do the same thing for the specular reflection from a quarter (or some other clean metallic surface). Now what happens to the reflection as you rotate the polarizer, etc?

View various surfaces (writing paper, sandpaper, desktop, water, etc) from various angles for a fixed location of the light source. Also, vary the incident angle from overhead to near the horizon. A *Lambertian* surface (by definition) looks the same from all viewing directions for a fixed incident direction (it is the "opposite" of a specular surface, which reflects light into only one direction). Which surfaces are closest to being Lambertian? Are some surfaces more Lambertian for some incident angles than for others?

Experiment 5: Transmittance through polarizers

What to note: Different materials can affect light in complicated ways. The order in which light passes through a sequence of materials sometimes matters.

Set up the following optical path: a bright, collimated light source (slide projector or flashlight), two linear polarizers, and a screen to detect the transmitted light. Leave room before, between, and after the polarizers to insert other optical elements.



Rotate the polarizes so that the *maximum* light is transmitted. Insert a piece of clear glass between the polarizers. How does this affect the transmitted light (more light transmitted, less light, no change)? Try the glass before or after the polarizers. Does it matter where the glass is inserted in the optical path?

Repeat the above with a piece of waxed paper or parafilm instead of the glass. How does the waxed paper affect the transmitted light? Does it matter whether the waxed paper is placed before, between, or after the polarizers?

Now rotate the polarizers so that the *minimum* light is transmitted. Insert a piece of clear glass before, between, or after the polarizers. How does this affect the transmitted light? Repeat with a piece of waxed paper. Does it matter if the waxed paper is placed before, between, or after the polarizers?

> Think hard about the last result. Putting the waxed paper before or after the polarizers does nothing, but putting it between the polarizers *increases* the amount of light transmitted! But the light is going through the same amount of material in each arrangement. And shouldn't putting *anything* in a beam of light always *decrease* the transmission, due to absorption by the material or reflection from its surface, which are always present? Very strange, indeed!

Experiment 6: Circular Polarization

What to note: The direction in which light passes through a circular polarizer matters, and mirrors do something really strange to circularly polarized light.

Hold the circular polarizer to one eye and look at something (your lab partner or the wall). Rotate the polarizer 180 deg about its diameter so that you look through it from the other side. Does it make any difference which side of the polarizer you look through?

Now look at the reflection of your eye in the mirror when viewed through the circular polarizer. What happens when you look through the polarizer from one side or the other? Can this strange result be explained by the well known fact (Dracula and Stoker, *Transylvanian J. Optics*) that vampires do not reflect in a mirror?

Now look at the mirror through a linear polarizer. Does looking at a mirror through a linear polarizer yield the same type of result as for a circular polarizer?

Now look at something through both circular polarizers. Turn and rotate them all sorts of ways to see what effects you get on transmitted light.

Experiment 7: Polarization of the Sky and Sea Surface

What to note: Sky light is partially polarized, depending on the direction relative to the sun. Light reflected from the sea surface is partially polarized, depending on the viewing direction.

Go outside and view the sky through the linear polarizer (a partly cloudy day is best). Look near the sun (do NOT look directly at the sun!!), at right angles to the sun, and away from the sun as you rotate the polarizer. What happens to the appearance of the blue sky? What happens to the appearance of a white cloud? If there is a convenient rainbow, what happens to it as you rotate the polarizer?

Stand on the dock and look at the sea surface as you rotate the polarizer. Look at the surface at an angle of about 45 deg from the nadir. How does the ocean change in appearance (brightness, color, reflection of sun glint) as you rotate the polarizer, and as you look at different angles from the nadir to the horizon? At what angle does the polarizer remove the most surface reflection? What does the polarizer do to the color of the ocean?