Multiple Polarization Effects of Light & Quantum Mechanics

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This research project investigates two facets of the multiple polarization of light: the rotational affect of polarizing filters on light beams, and the polarization of light reflected from globular particles suspended in a light beam’s path.

The rotational affect of polarizing filters on a light beam was shown in an experiment measuring the intensity of light traveling through a series of three polarizing filters. The first and third filters in the series were relatively perpendicular. The affect was measured as a function of the angle of the middle filter as measured in degrees deviation from the angle of the first filter. This experiment found light intensity (I) as a function of the angle ($\emptyset$) of the middle filter to be of the form $I=\sin(2\emptyset)+c$, therefore proving that light is rotated during polarization.

The affects of suspended globular particles on the polarization of the reflected light were discussed first in terms of the atmosphere on sunlight, and then demonstrated using a laser beam and milky water.

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Light, a member of the electromagnetic spectrum, is composed of two transverse waves--a magnetic one which, as it moves, creates an electric one which, as it moves, creates a magnetic one, and so on and so forth. Waves of light are clustered in quanta known as photons, and as such can be described both as a wave and as a particle. This is know as wave-particle duality.

Due to its wave-particle duality, and confusion over exactly what happens to light as it's polarized, the polarization of light can be described in several ways. It can be described as a photon that does or does not rotate as it goes through a polarizing filter, or as a wave that is or is not rotated as it passes through a polarizing filter. In this order I shall describe these phenomena.

Imagine a spherical magnet like the Earth is a photon of light. Now, imagine playing a game of soccer with that sphere. Allow the goal posts to also be magnetized. If a shot is made, and the ball is not properly aligned, the ball will probably be repelled. There is a chance that it might go through, however if you kick it hard enough right down the middle. One certainty does exist however, if it goes through it will align itself in one orientation, namely that opposite to the orientation of the posts.

Visualizing the polarization of light this way is shows what would happen if a photon of light were rotated during polarization.

Another way to describe polarized light is as a bag of pipe cleaners, which splits open above a storm grate. Each pipe cleaner has a specific orientation as it falls. Because the two waves of light are both transverse, and therefore the photon's orientation must be perpendicular to the direction of travel assume that the pipe cleaners can revolve 360°, but cannot be oriented up or down. Allow the storm grating gaps to be skinnier than the pipe cleaners. Some pipe cleaners would fall through the cracks, while others would hit the grating and bounce off. Visualizing the polarization of light this way is shows what would happen if a photon of light were not rotated during polarization.

In waves new ideas sweep over humanity. They are either new ideas or old ideas or a combination of the two. New ideas occasionally keep going if they are good, especially if they are based on old ideas, but usually fail because the inventor was "ahead of his [or her] time" or the idea is just too "new-fangled" to use. Old ideas usually are accepted as the tried and true method. If they do work they are all oriented toward progress and then become old ideas. If the waves of ideas are light and time is a polarizing filter, then rotation is taking place because any ideas that make it through all become oriented as old ideas. This describes rotating waves of light as they pass through a polarizing filter.

Waves of rumors of scandal wash through our government. The more oriented toward truth a rumor of scandal is, the more likely it will pass through the media into congress. Passing through does not force the rumor to be true. It is so with light waves passing through polarizing filters if no rotation takes place.

Now, there appears to be some confusion over where or not light is rotated during polarization and so the purpose of my experiment was to determine whether or not light is indeed rotated during polarization.

I sent a light beam through three polarizing filters, the first and third of which a relatively perpendicular, to find the relationship between the intensity of the resultant beam and the central polarizing filter. As I saw it, there were three possible results, indicating three possible things. If light is not polarized by the polarizing filters then the light intensity (I) as a function of the angle (Ø) of the central filter will be of the form $I=c$. If the polarizing filters do indeed polarize the light then one of two things should happen. If light is rotated the function will be of the form $I=a*\sin(2Ø)+c$. If light is not rotated during polarization, the function will be of the form $I=a*\cos(2Ø)+c$.

I had a multiplicity of problems getting clean data, not all of which I cleared up before the end of the experiment. The most aggravating source of error was from the AC current. Figure 1 shows the amount of variance caused by the current. I solved this problem by taking the maximum or minimum light intensity of 25 different readings for each data point. Unfortunately this meant calibration of the sensors was impossible Other problems included debugging the program for Lab Works to get the data, setting up the apparatus so that a minimum amount of outside light struck the photometer, and getting a constant amount of light from the sodium lamp struck the photometer. This last source of error was really two problems. The first was that the lamp couldn't be held in place because the amount of variance in the light if it was moved just a little was simply too great. In the final analysis, however, it is hard to tell if that was really what was going on or if it was caused by the AC current. The second problem associated with the sodium lamp was heat. When the light was on, the bulb heated up, generating more light. The directions for the sodium bulb specified not to leave it on any longer than necessary, so I couldn't allow it to rise to equilibrium. I tried using other light sources, but if they were bright enough, I just couldn't contain their light.

In trial 4.05, the first trial that showed a clear correlation between light intensity and the angle of the central polarizing filter, I had the following experimental design. I placed a polarimeter on its side and duct-taped it to an optical bench. I taped a polarizing lens to the optical bench in such a manner that when the polarimeter showed 90°, a minimal amount of light showed through the final lens. I taped a photometer to the lens in a position that allowed it to register a maximum amount of light. To your right is a photograph of this set-up. I sent the outputs of the photometer into Lab Works as shown by the following circuit diagram. I did not use the Data Analog Converter (DAC), but included it in the circuit diagram as it was a potential source of error. The photometer's resistance varies inversely proportionately with light intensity, and therefore the current is directly proportional to the light intensity. Because I could neither accurately calibrate the photometer nor convert my data into any standard measure of light intensity, my data cannot be construed as accurate.

In this trial, I measured the lowest of 25 readings 10 times every 10 degrees. This gave me a rough graph, however when I fit a fourth degree curve to my data in figure 2, I found a very high correlation coefficient.

In trial 5.05, I took 100 readings for each data point--as opposed to the 10 readings per data point for trial 4.05--and many more data points than my earlier trials--I found that not only was my data very inaccurate due to the lack of any meaningful conversion, it was also imprecise. I believe this was due to the sodium bulb. As the bulb began to warm up, it gave off more light. As you can see in figure 3, each trial showed a general trend, however none showed the same data curve. I was afraid that if I let the bulb heat up to equilibrium, it would burn out.

Even though the experiments were inaccurate and imprecise, they ALL showed a general trend. The light intensity (I) as a function of the angle of the central lens (Ø) is definitely of the form I=a*sin(2Ø)+c and NOT I=a*cos(2Ø)+c that indicates that the first alternate hypothesis is correct: light definitely rotates when it passes through polarizing filters.

The other part of my project was a demonstration involving light's reaction with globular particles. When light from the sun passes through the atmosphere, an observer on the surface of the Earth does not see the light directly from the sun--unless the observer wishes to become blind by staring directly at the sun--but rather, after it has been reflected from particles in the atmosphere to the observer's eyes. The position of the particle from which the sunlight has been reflected into the eyes of the observer, and that of the observer determines the angle of reflection as well as the orientation of the photon that is necessary for the photon to enter the observer's eye. For this reason, light observed from the sun appears to be polarized. Please see figures 4 and 5.[1]

[1]Craig Bohren, "Polarization of Skylight," Weatherwise **37**, 261-265 (October 1984).

This can be seen by observing a laser beam in a solution of milky water as well as by using polarizing filters on the atmosphere.[2] Figure 6 shows such a light beam, though with incandescent rather than laser light, without a polarizing filter. Figure 8 is a graph of the light intensity of the beam as a function of the angle of a polarizing filter on the side of the jar. If dust is added to a solution of milky water, the result is that the dust particles can be observed reflecting the light beam while the rest of the beam vanishes. Figure 7 shows this phenomenon. This appears to be due to the non spherical shape of the dust particles.[3]

I conducted a demonstration of the polarizing effects of the atmosphere. A fish tank filled with a solution of milky water will house a beam of laser light. Polarizing lenses were given to observers to demonstrate how the beam disappears when the lenses are turned.

I believe the most surprising result was that when I tested a solution of milky water in a polarimeter, and found that milk is NOT optically active!

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[2] Craig Bohren, "Polarization of Skylight," Weatherwise **37**, 261-265 (October 1984).

[3] Craig Bohren, "Polarization of Skylight," Weatherwise **37**, 261-265 (October 1984)

Bibliography

Bohren, Craig. "Polarization of Skylight." Weatherwise, vol. **37**, (October 1984), pp. 261-265.