**Personal Engagement**

One of my first existential questions I remember having is what if how the color red looks to me is not how it appears to other people? We call it the same thing, we describe it the same way, we all know that it is red, but do we really see the same thing? Maybe how another person’s mind interoperates that particular wavelength of light is how my mine interoperates the wavelength for, say, green. Ever since then I have had an interest in how light works and as I have learned more about the physics of light, the more curious I became. One quite interesting aspect of light is how it interacts with polarization filters. Most everything about light’s interactions with polarization filters isn’t perfectly intuitive. For example, I learned that polarization filters are composed of long, chain like organic molecules all orientated in the same direction, not unlike the bars of a prison window. Following intuition, you’d imagine that light orientated parallel to the organic molecules would slip through like paper slipping through a jail window. But it’s the opposite. Light orientated the same direction as the polarization filter is absorbed by the organic molecules and light perpendicular to them is let through. Except even that isn’t quite right. And to see why and retrain my intuition, I experimented with light and polarization filters.

**Research Question**

How is the *quantity* of light passing through two polarization filters affected by changing the relative orientation of the filters?

This question will be tested by having a focused light source pointing at a digital light sensor. Between the light emitter and sensor will be two polarization filters mounted in a way that they can be rotated to set degrees. These filters will block some of the light and that difference will be measured by the digital light sensor.

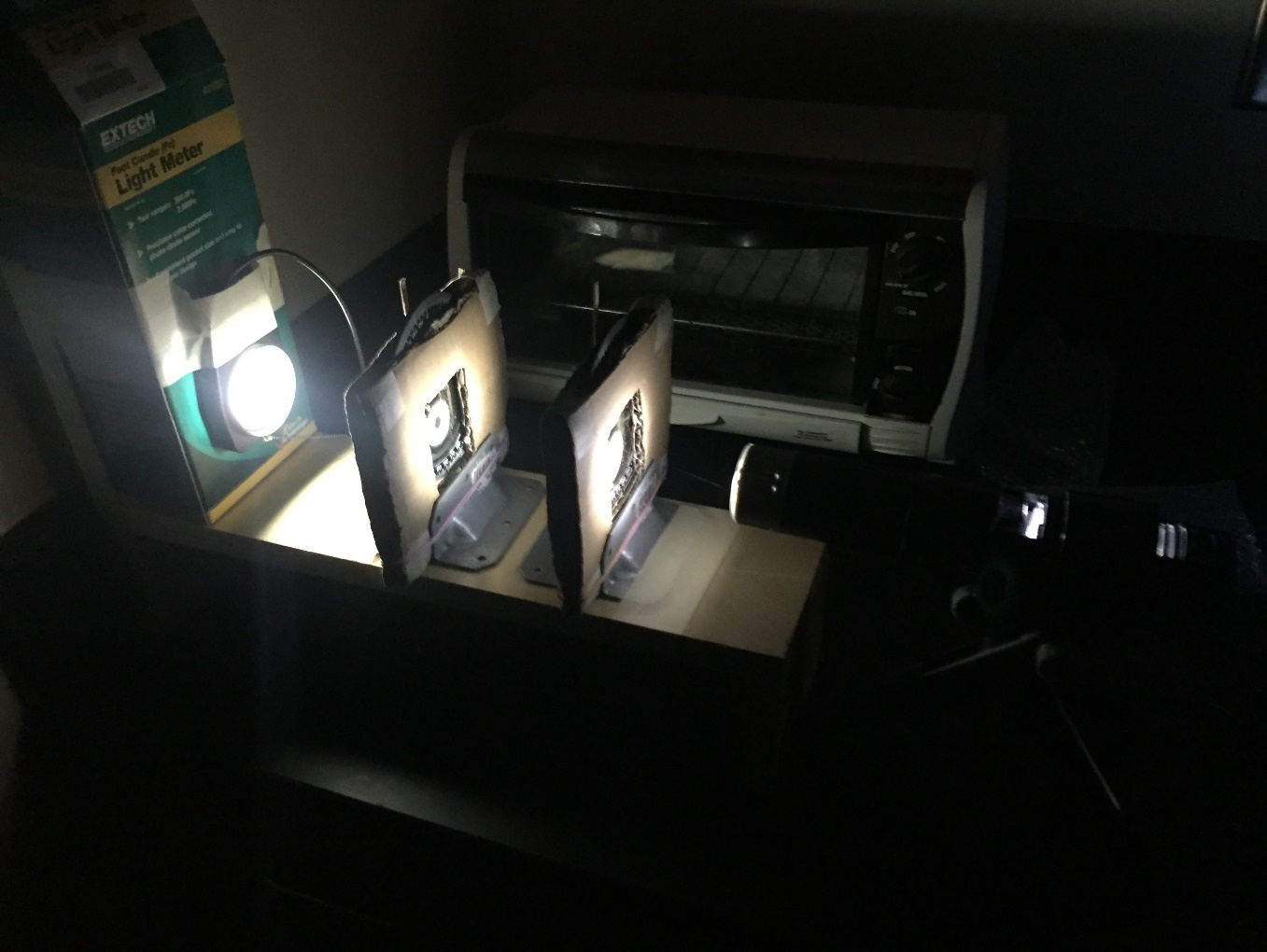
**Background**

**Variables**

|  |  |  |
| --- | --- | --- |
| **Variable** |  | ***How is it measured?*** |
| **Manipulated** | **Difference in orientation of polarization filters** | Both polarization filters were circular and marked every degree. The degree on each polarization filter was measured by aligning the wanted angle with the edge of a vertical indicator consisting of a thin coffee stirrer. The coffee stirrers were aligned vertically using a plumb line and held in place by tape for the duration of the experiment without and interferences. |
| **Responding** | ***Quantity* of light passed through both filters** | The *quantity* of light that passed through both filters was measured by a digital light sensor that was fixed in place on the back of the apparatus by tape and held without interference for the entire duration of the experiment. The light sensor I used, an Extech Light Meter, has two modes. One has a range of 200 foot candles and measured down to 0.1 foot candles and the other mode has a range of 2000 foot candles and measures down to 1 foot candle. I used the later mode as at it’s very peak the measured light was greater than 200 foot candles. |
| **Controlled**  **Controlled**  **(continued)** | **Initial light intensity**  **Distance between all instruments**  **Distance between all instruments**  **(continued)**  **Outside Light** | The spotlight used to emit the initial light was powered by a controllable power source that was not adjusted for the entirety of the experiment. The spotlight itself was not touched or moved or otherwise interfered with during the experiment  The distance between the spotlight, the two polarization filters, and the digital light sensor were fixed through the use of a custom made mounting structure. This structure looks like the lowercase letter “h” but greatly stretched horizontally.  The digital light sensor was first taped to its box and then taped against the back wall, the tall part of the “h”. The box was included to move the light sensor closer to the spotlight to decrease the spread of the light and increase the accuracy of the data.  The polarization filters were mounted inside custom made holders that secured them while allowing them to rotate. Each filter was placed in a card board rectangle that had a circle cut out to fit the filter and these were each placed between two more cardboard rectangles which had a smaller square cut out that allowed the light to pass through while holding the filters in placed. Both three layer holders were taped shut to form two tasty polarizing cardboard sandwiches. Two right angle brackets were then attached to the bottom of the holders and were taped down onto the bed of the mounting structure, the elongated horizontal part of the “h”.  The spotlight was placed up against the front wall of the mounting structure, the right leg of the “h”, and pointed at the center of the digital light sensor. It was kept in place and not moved during the experiment.  Outside light interference was controlled by performing the experiment in a nearly dark room. The only other light besides the spotlight was from a second, much dimmer, spotlight not pointed at the experiment that was used to read the output of the light sensor and record the data. The output of the light sensor did not change when this second spotlight was turned off and on even when the polarization filters were orientated so that the light sensor was reporting -1 foot candles. Furthermore, even when the door to the room was opened the sensor did not change. Even so the experiment was only performed when the door was closed and with the second spotlight being at a constant intensity. |

**Apparatus and Materials**

* Extech Light Meter (range of 2,000 foot candles with precision down to ±1 foot candle)
* Light Meter box.
* Spotlight with a diameter of 3.3 cm at a 20 cm range capable of producing over 200 foot candles of light.
* Controllable power supply.
* Two circular polarization filters with marked angles in degrees.
* Carboard to hold polarization filters.
* 4 wide right-angle brackets and 4 rubber bands to hold car board mounts up.
* 3.5 cm thick Scotch 3M tape.
* 3 pieces of 10 cm wide wood, one 8cm long, one 25 cm long, and one 38 cm long.
* Two long right-angle brackets and 8 short nails to connect the wood.
* Two short coffee stirrer sticks to measure the angle on the polarization filters.
* A plumb line to orientate the coffee stirrers to vertical.



Mounting Structure

Coffee stirrer sticks

Polarization Filter

Spotlight

Carboard Filter Holders

Wide Right-Angle Brackets And Rubber Bands

Wooden Mounting Structure

Light Meter

**Safety**

Do not look directly into the light.

**Procedure**

1. Assemble the mounting structure by attaching the 8cm long plank of wood under one end of the 38 cm plank using the long right-angle brackets and short nails and then attaching the resulting structure a vertical 25cm long plank to form an elongated “h” structure.
2. Assemble the filter holders by placing the polarization filters inside a carboard rectangle cut out to fit the filters with the top of the filter showing to read the angle markers. Place that between two identical cardboard rectangles that have a square cut out of the middle to let light through.
3. Place a wide right-angle bracket one either side of both carboard-filter sandwiches and place two rubber bands around each filter holder and brackets to hold the brackets onto the filter holders.
4. Using a plumb line to ensure they are orientated vertically, attach a coffee stirrer stick to the top center of both filter holders and align the filters so that their zero-degree mark lines up with the vertical coffee stirrer sticks.
5. Place the filter holders onto the bed of the mounting structure and tape the bottom part of the right-angle brackets to the mounting structure to hold the filter holders in place.
6. Position the spotlight against the front of the mounting structure and orientate it so that it emits light straight through both filters.
7. Plug in the power supply to a wall outlet and the spotlight to the power supply. Turn on the power to the spotlight.
8. Tape the box of the light sensor to the back wall of the mounting structure and to that tape the light sensor so that the light from the spotlight hits the center of the sensor.
9. Turn off the lights and make sure any ambient light sources are not affecting the sensor.
10. Rotate the first filter from 0 degrees all the way around stopping every 10 degrees to record the output of the light sensor. Use the vertical coffee stirrer sticks to read the angle of the filter. Make sure to press down the filter holder so that it does not move when you rotate the filter. If it is constructed correctly the filter should be able to rotate freely inside the holder.
11. After rotating the filter all the way around collecting data every 10 degrees, start again and repeat the process for each trial. Record as many trials as possible.

**Data**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Difference in filter orientation** | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** | **Trial 6** | **Trial 7** | **Average** | **Deviation** |
| Degrees |  |  |  | Intensiry of Light That Passed Through Both Filters (Foot Candles) |  |  |  | Foot Candle | Foot Candle |
| ±0.5 Degrees |  |  |  | ±1 Foot Candle |  |  |  |  |  |
| 0.0 | 0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1 |
| 10.0 | 2 | 3 | 1 | 2 | 2 | 2 | 2 | 2 | 1 |
| 20.0 | 16 | 17 | 17 | 16 | 17 | 16 | 18 | 17 | 1 |
| 30.0 | 39 | 41 | 37 | 41 | 39 | 38 | 42 | 40 | 3 |
| 40.0 | 69 | 70 | 69 | 70 | 70 | 71 | 71 | 70 | 1 |
| 50.0 | 103 | 104 | 102 | 100 | 103 | 106 | 108 | 104 | 4 |
| 60.0 | 133 | 135 | 137 | 135 | 133 | 134 | 143 | 136 | 7 |
| 70.0 | 160 | 161 | 158 | 159 | 158 | 159 | 168 | 160 | 8 |
| 80.0 | 177 | 177 | 177 | 176 | 176 | 176 | 188 | 178 | 10 |
| 90.0 | 184 | 185 | 184 | 185 | 183 | 184 | 198 | 186 | 12 |
| 100.0 | 181 | 182 | 181 | 181 | 180 | 180 | 194 | 183 | 11 |
| 110.0 | 168 | 167 | 169 | 168 | 165 | 167 | 181 | 169 | 12 |
| 120.0 | 145 | 145 | 145 | 144 | 145 | 142 | 157 | 146 | 11 |
| 130.0 | 117 | 114 | 115 | 114 | 113 | 112 | 123 | 115 | 8 |
| 140.0 | 86 | 82 | 85 | 83 | 84 | 83 | 89 | 85 | 4 |
| 150.0 | 55 | 52 | 53 | 54 | 52 | 52 | 53 | 53 | 2 |
| 160.0 | 25 | 24 | 26 | 25 | 24 | 27 | 26 | 25 | 2 |
| 170.0 | 7 | 7 | 6 | 7 | 8 | 7 | 8 | 7 | 1 |
| 180.0 | -1 | 0 | -1 | -1 | -1 | -1 | -1 | -1 | 1 |
| 190.0 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| 200.0 | 15 | 15 | 15 | 16 | 15 | 14 | 16 | 15 | 1 |
| 210.0 | 36 | 40 | 38 | 41 | 38 | 41 | 41 | 39 | 3 |
| 220.0 | 67 | 71 | 69 | 71 | 70 | 68 | 74 | 70 | 4 |
| 230.0 | 102 | 103 | 101 | 101 | 99 | 106 | 105 | 102 | 4 |
| 240.0 | 137 | 137 | 138 | 136 | 138 | 136 | 142 | 138 | 4 |
| 250.0 | 165 | 164 | 169 | 161 | 163 | 164 | 172 | 165 | 7 |
| 260.0 | 184 | 187 | 186 | 187 | 186 | 197 | 198 | 189 | 9 |
| 270.0 | 198 | 198 | 198 | 198 | 198 | 217 | 211 | 203 | 14 |
| 280.0 | 197 | 197 | 198 | 196 | 197 | 209 | 210 | 201 | 9 |
| 290.0 | 184 | 183 | 183 | 181 | 180 | 195 | 197 | 186 | 11 |
| 300.0 | 158 | 157 | 158 | 155 | 157 | 168 | 170 | 160 | 10 |
| 310.0 | 124 | 122 | 121 | 122 | 121 | 130 | 130 | 124 | 6 |
| 320.0 | 88 | 88 | 88 | 87 | 88 | 92 | 96 | 90 | 6 |
| 330.0 | 54 | 54 | 52 | 55 | 55 | 56 | 57 | 55 | 3 |
| 340.0 | 25 | 26 | 25 | 27 | 25 | 26 | 25 | 26 | 1 |
| 350.0 | 8 | 7 | 7 | 7 | 6 | 7 | 8 | 7 | 1 |
| 360.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 0 |