EXPERIMENT 5

Jai Prasadh

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INTRODUCTION

In this experiment I sought to learn about electromagnetic waves and their properties when polarized. I first explored the intensity decrease from polarizing unpolarized light. I then focused on verifying Malus’s Law, both in the case of two polarizers at some relative angle and in the case of two crossed polarizers with a third polarizer at some angle between them allowing light to pass. I additionally examined the behavior of light when passing a half waveplate. I also aimed to experimentally determine Brewster’s angle and explore behavior of reflected light at this special angle. Please note that in this experiment, the optical activity section was omitted.

RESULTS

Light Polarization and Malus’s Law:

First, I observed the drop in the intensity signal going from the unpolarized LED to a plane-polarized light wave after one polarizer was placed. I also rotated the polarizer’s transmission axis through a full rotation to observe fluctuations in the transmitted intensity. I found that the light intensity dropped by about 66% (from 65.8% saturation to 21.6% saturation of the sensor) in the process of polarization, which is greater than the theoretically predicted 50% intensity drop for an ideal polarizer. A fraction of of the light aligned with the transmission axis was absorbed by the polarizer, which is a significant deviation from the ideal polarizer. Furthermore, in rotating the polarizer’s transmission axis, I found that the transmitted intensity varied from 18.8% sensor saturation to 21.6% saturation, which indicated either that the LED light was initially partially polarized, or more likely that the irregularities in the polarizer (scratches, scuffs) resulted in an imperfect performance. In the case of unpolarized light, a single ideal polarizer’s transmission axis angle shouldn’t affect transmitted intensity.

Next, to test Malus’s Law, I measured the transmitted intensity at various relative angles between the original polarizer and a second polarizer I placed after it. I fitted the observations to the familiar squared cosine function predicted by Malus, and the results are as follows.



Figure

The closeness of the fitted values to the observations in figure 1 confirms Malus’s law and is exactly as expected.

I then tested a particular case of Malus’s law in which I placed two polarizers crossed such that they blocked nearly all (only 0.1% sensor saturation) of the light. I then placed a third polarizer in between the crossed ones, and of course at certain angles, the middle polarizer permits light to pass since no two adjacent polarizers have axes perpendicular to each other, and thus by Malus’s law, the light intensity never goes to zero. I rotated the middle polarizer through a full rotation and recorded its relative angle to the first at each local maximum of intensity. Those results are as follows, with uncertainties specified.

|  |  |  |  |
| --- | --- | --- | --- |
| Relative angle to 1st polarizer (rad) | | Local maximum value of intensity (%) | |
| 0.79 | 0.01 | 4.4 | 0.1 |
| 2.36 | 0.01 | 4.7 | 0.1 |
| 3.93 | 0.01 | 3.5 | 0.1 |
| 5.55 | 0.01 | 4.5 | 0.1 |

These angles are very close to those predicted by Malus’s law to maximize transmitted intensity across the three-polarizer system, namely , which provides further validation of the theory.

A ratio of interest is that of the intensity transmitted with all 3 polarizers lined up to the maximum intensity transmitted in the crossed scenario (with each polarizer at angle to the last). In the ideal polarizer case, this ratio would be equal to , which is obtained by using Malus’s law twice in succession, once at each polarizer after the first, but the ratio I observed was . A reason for this discrepancy is the unideal nature of the polarizers, since each one absorbs some of the intensity even if they are all lined up with their transmission axes parallel.

Light Rotation with Half Waveplate

In this section, I sought to determine the rotation caused by passing light through a half waveplate. To accomplish this, I first polarized the light source with one polarizer, then lined up a second polarizer with the waveplate such that the transmitted light was at a maximum, essentially using the second polarizer to determine the direction of the plane of the wave after the waveplate. To measure the effect of the waveplate angle, I changed the fast axis on the waveplate by a certain angle, and then adjusted the second polarizer to rediscover the maximum transmission intensity. I measured the change in angle of the light at many changes in waveplate fast axis angle and fitted the results to what the theoretical model is, namely for any waveplate relative angle , the light wave deflects by some constant b times . Theoretically, I knew that , but for the sake of confirming the theory, I let the fit determine the constant . The results are as follows and the fitted function alongside the data points is shown in figure 2 below.



The result was spot on for the expected value , so this confirms the theory behind waveplate effects on transmitted light.

Brewster’s Angle

In this section, I aimed to experimentally observe Brewster’s angle and behavior and properties of light at that angle. To determine the angle, I applied a polarizer to the LED beam and then adjusted a glass slab and focusing lens to reflect part of the beam onto a backdrop. I then angled the glass until the reflection vanished entirely and took that relative angle of the slab to the light beam to be Brewster’s angle, . My result was . I determined that if the incident light is unpolarized, the reflected light is horizontally polarized by moving the polarizer between the slab and the backdrop. If the incident light is unpolarized, the refracted light becomes partially polarized while if the incident light is polarized, the refracted light is also polarized, just in a different direction. Based on these findings, polarized sunglasses should have a vertical transmission axis so that they block horizontally polarized glare from reflections.

SUMMARY

I successfully validated Malus’s law in my observations in this experiment, although with some departures coming from the unideal nature of the polarizers. I observed the expected drop of 50% intensity of an unpolarized light beam passing a polarizer, but in the experiment, I saw the intensity drop even further due to absorption of light parallel to the transmission axis, which would of course be transmitted by an ideal polarizer. This confirms much of the theoretical expectations regarding polarization of light but raised questions regarding how I could accurately predict the unideal behavior of the polarizer given its physical irregularities. In changing the relative angles of a second polarizer to the first, I observed that Malus’s law held true and transmitted intensity was reduced by a factor of the square of the cosine of the relative angle. I further demonstrated the phenomena of permitting light to pass crossed polarizers by placing a third at an intermediate angle between them, essentially a specific case of Malus’s law. In trying to validate the predicted deflection of light through a half waveplate, I was again able to show that the theoretical prediction, that light is deflected at twice the relative angle of the fast axis to the incident light, indeed was true with a great degree of confidence. Finally, I experimentally observed Brewster angle and the way it horizontally polarized reflected light. In doing so, I was able to accomplish the outlined objectives in the introduction. A further question to explore could be the effect of chirality on angle of plane-polarized light and how racemization of a solution manages to negate this effect.