Characterization of a Dichroic Sheet Polarizer
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Introduction
The Department of Physics and Astronomy of Eastern Michigan University offers biannually an upper-level elective course, PHY 442 Optics and Optics Lab, that counts for four semester credit hours and meets each week for three hours in a classroom setting (two 75-minute meetings) and for three hours in a laboratory setting (one 170-minute meeting on Friday). The course covers electromagnetic waves, geometric optics, and physical optics (polarization, interference, and diffraction).

During the 2012 Winter Semester, 16 students enrolled in (and finished) the course. Their course grades were constructed as follows: homework and in-class assignments, 14%; two preliminary exams, 24%; final exam, 14%; research project, 15%; and laboratory, 33%. A completely overhauled set of laboratory experiments was adapted from existing materials [1, 2] or developed as needed [3]. The laboratory experiments are listed below:

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<th>Week</th>
<th>Experiment</th>
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Context
The Polarized Light lab occurred at the end of the ninth full week of instruction. Three classes covering polarization preceded this lab. During those classes, the mathematical description of polarized light, polarization-changing processes (e.g., dichroism) and devices (e.g., ideal sheet polarizer), Malus’ Law, and optical effects were described.

Goals
The goals for the Pre-Lab and Lab included:
• Demonstrating the construction of a model to describe the effect of a real sheet polarizer on an incident wave.
• Developing skills in using computational software for modeling.
• Observing and characterizing the effect of a sheet polarizer on incident laser light.
• Developing skills in safely and effectively using a diode laser source, a light sensor, and data acquisition software.
• Practicing skills of data analysis, including interpretation of contour plots.

Pre-Lab
A Pre-Lab was distributed two days in advance of the lab; its purpose was to introduce a simple way of thinking about and modeling the transmission process in a polaroid sheet for normally incident light.

![Diagram of light passing through a sheet polarizer](image)

Students were asked to run a MATLAB code that implemented the transmission model to determine whether a set of parameters exists that reproduces the specifications of a commercial sheet polarizer [4].

For light polarized parallel to or perpendicular to the polarizer axis, the predicted transmission is

\[
T_{||} = \frac{1 - R_{||}}{1 - 1 - A_{||}} \quad \text{and} \quad T_{\perp} = \frac{1}{R_{\perp}}
\]

If the incident light is unpolarized, then the predicted fraction of the incident power transmitted through a single sheet is

\[
\frac{P}{P_0} = 0.5(T_{||} + T_{\perp})
\]

Results
The dependence of the fraction of the incident power transmitted through a PASCO single sheet polarizer on the angular position of the polarizer, \(P(\theta)/P_0\), is shown at right below. The size of the data points represent the uncertainties derived from the measurements. The solid line is a fit of a scaled, offset cosine squared to the data. The offset was found to originate from an orientation offset of the diode laser polarization. Using the measured values, the single pass absorptions may be estimated.

\[
P_{\perp} = 0.747 \pm 0.007, \quad P_{\parallel} = 0.002 \pm 0.002
\]

Summary
Sheet polarizers are relatively inexpensive, useful devices to explore polarization phenomena in upper-level optics courses. Because students may retain an idealized concept of such polarizers from the introductory course, this laboratory can help students to understand how the actual sheet polarizer modifies incident light and how one would measure its performance, as would be necessary if one worked in the area of optical quality control.

Future Improvements
• Attend much more to issues of contour plot generation and interpretation through a class-time or video tutorial.
• Be much more explicit about the goals (e.g., content and skill development) and relevance (e.g., to commercial products) of the laboratory experiment.
• Improve the written analysis procedures.
• Guide students to annotate and verbally demonstrate an understanding of the written analysis procedures before they leave the laboratory.

References
[3] Developed at EMU by the author; copies available upon request.
[4] Edmund Optics TECHSPEC® Visible Linear Polarizing Laminated Film, with 38% single pass transmission for unpolarized light.