INTRODUCTION

By now you should know that light consists of rapidly oscillating and traveling waves of electric and magnetic fields. The fields are always perpendicular to the direction of propagation, but the fields can have different orientations and timings relative to the propagation direction. The electric fields and magnetic fields are always perpendicular to each other, so you only need to describe the direction of one of the fields to describe the *polarization* of light. The electric field is always the one that is described.

The simplest polarization is *linear polarization* (abbreviated LP.) Linearly polarized light has the electric field oscillating in one direction. In Pedrotti's textbook, the x-axis is horizontal, the y-axis is upward vertical, and the angle α is the angle counter-clockwise from the x-axis. Unfortunately our polarization mounts are marked from the vertical, so our angles are shifted 90º from the textbook.

Before you start measuring polarization, you will learn how to set up a laser beam.

I) SET UP LASER BEAM

You are going to have to spend some time setting up your laser beam. This will probably take you a while. Here are some requirements:

- The beam must be 10 cm above the breadboard.
- The beam must be parallel to the breadboard.
- The beam must be centered on (and parallel) to a row of screw holes.
- The beam must be horizontally polarized.
- A *rail* must be bolted to the table such that a 2" base is centered on the beam. Once the rail is set up it is easy to add additional optical elements centered on the beam. Here are some steps to help you.

A) Make the Beam Horizontal and 10 cm High

1) Adjust the laser so the center of its lens is 10 cm high.
2) Check the beam height as close as you can to the laser. Adjust the ***height*** of the laser to get it to 10 cm.
3) Check the beam height at the end of the table. Adjust the ***tilt*** of the laser to get it to 10 cm.
4) Repeat 2) & 3) until the beam is horizontal and 10 cm above the breadboard.

B) Make the Beam Parallel to a Row of Holes

Try not to change the height or angle of the laser while doing these steps! If you do recheck part A).

1) Move the laser so the center of its lens is above a row of holes.
2) Place the screen as close as you can to the laser and so the slots in the base holding the screen are lined up with a line of holes.
3) Adjust the horizontal position of the laser so the beam it centered on the center of the screen.
4) Move the screen to the end of the breadboard, line up its slots with holes, and adjust the *angle* of the laser so the beam is centered on the screen.
5) Repeat 2) – 5) until the beam is parallel to the holes.
6) Finally, screw the laser mount to the table, and put the screen at the end of the breadboard and screw it down also. Gently slide the rail against the two bases and attach it to the table using table clamps.
7) Check the horizontal alignment of Part B.

Alignment is an iterative process. You usually have to go back and forth until you have everything lined up correctly.

Have the instructor check your alignment before proceeding.

II) MEASURE POLARIZATION OF THE LASER BEAM

1) Place a linear polarizer (marked *LP*) on a rotation mount in beam. Face the numbers *away* from the source.
2) Read the laser intensity using LoggerPro on the laptop.
3) Just observe as you slowly rotate the sensor and watch the intensity as a function of angle. The pattern should repeat every 180º.

GETTING STARTED WITH SAGEMATH CLOUD

Now we are going to spend time getting familiar with a very nice data analysis and plotting system.

Stop and work through the handout *Optics Lab08 Jupyter-IPython Plotting*.

BACK TO MEASURING POLARIZATION

4) Take data every 15º from 0 to 180º. Record your data in a data file on SageMath Cloud.
5) Fit the data to a $\cos^2$ function like you did in the example in the handout.
6) In the space below, write the function and record the best-fit (optimal) values for your parameters. Interpret the meaning of each parameter. Check with the instructor before proceeding.

III) ALIGN LASER BEAM POLARIZATION HORIZONTALLY

C) Rotate the Laser until the Beam is Horizontally Polarized

1) Put a polarizer in the laser beam.
2) Rotate the polarizer to 0º.
3) Rotate the laser in its mount until the beam is the dimmest. (The reason you look for the dimmest is because it is easier to judge the dimmest than the brightest angle.) Note that now the electric field is perpendicular to the polarizer, so it is in the horizontal, or x direction.
4) Tighten the laser in its mount. Try not to rotate or move the laser after you do this.

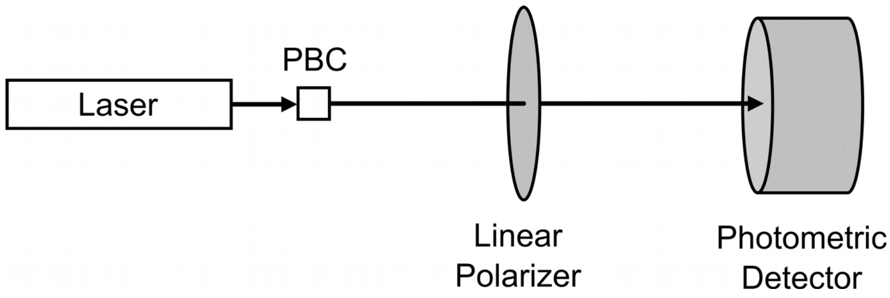
D) Put the Polarizing Beamsplitter Cube (PBC) in the Beam

1) The PBC is a very good polarizer. All of the horizontally polarized light travels straight through and no vertically polarized light. Mount the PCB in the center of the beam.
2) Note that a secondary beam with the opposite polarization comes out at right angles. Tape a piece of black construction paper on the breadboard to block the secondary beam.

Congratulations, you finally have a properly aligned and highly polarized laser beam!

Check with your instructor before proceeding.

IV) EFFECT OF A LINEAR POLARIZER



Put a linear polarizer in a hand-turned mount between the PCB and the sensor as shown. Make sure the numbers are facing *away* from the laser.

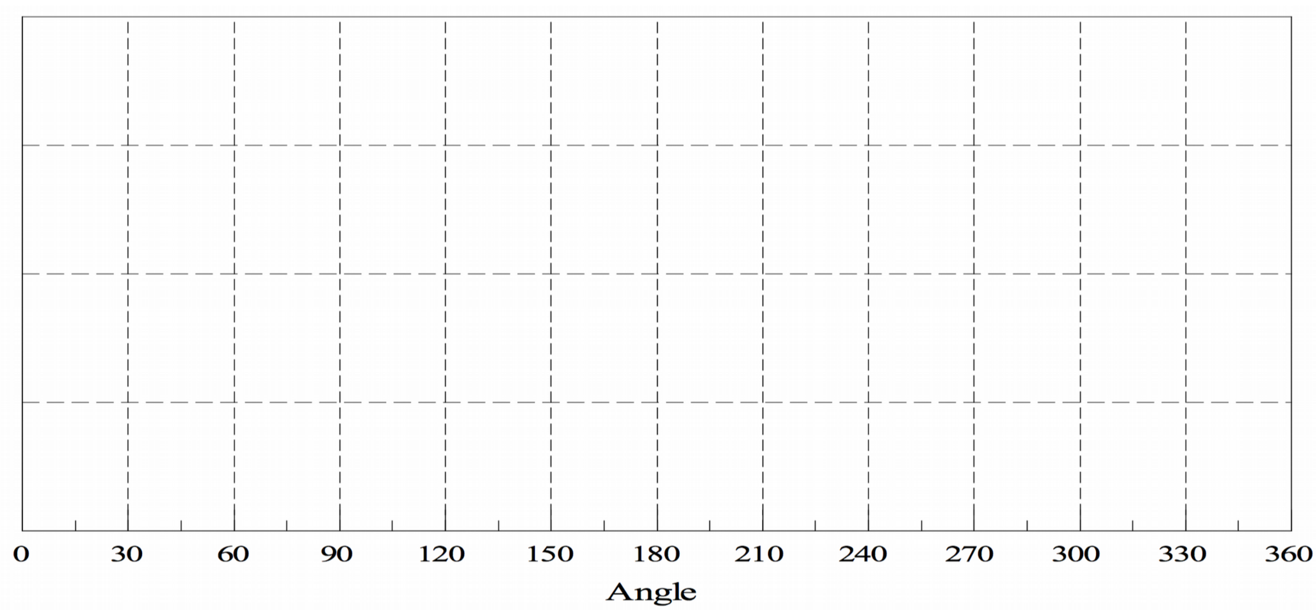
Rotate the linear polarizer to minimize the transmitted laser beam power. We will call this 90° since the polarizer is now perpendicular to the electric field of the light. We will keep this definition throughout the rest of the investigation. Record the value below. ***NOTE***: This designation should be around the 0° mark on the rotation mount.

Reading on the plate rotator at minimum intensity:

Now turn the polarizer ***exactly*** 90° counter-clockwise toward 90°. This is your "zero" for the rest of the experiments today. The beam intensity should be at its maximum value. Record the value below,

Your defined 0°:

Predict how the power of the transmitted light will change as a function of the linear polarizer's angle. That is, make a plot of the transmitted laser beam power vs. polarizer's angle.



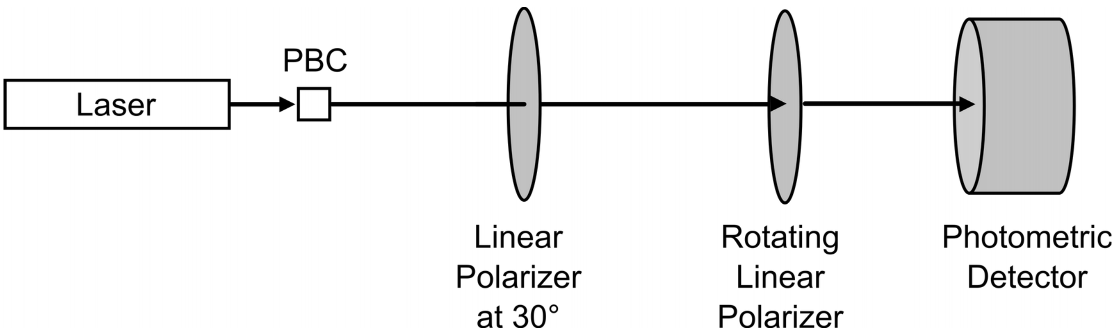
Explain the reasoning for your graph.

Now take data every 15º from 0º to 360º. Record your results in a data file in SMC, plot your data, save the figure on SMC, and sketch your data on the graph above.

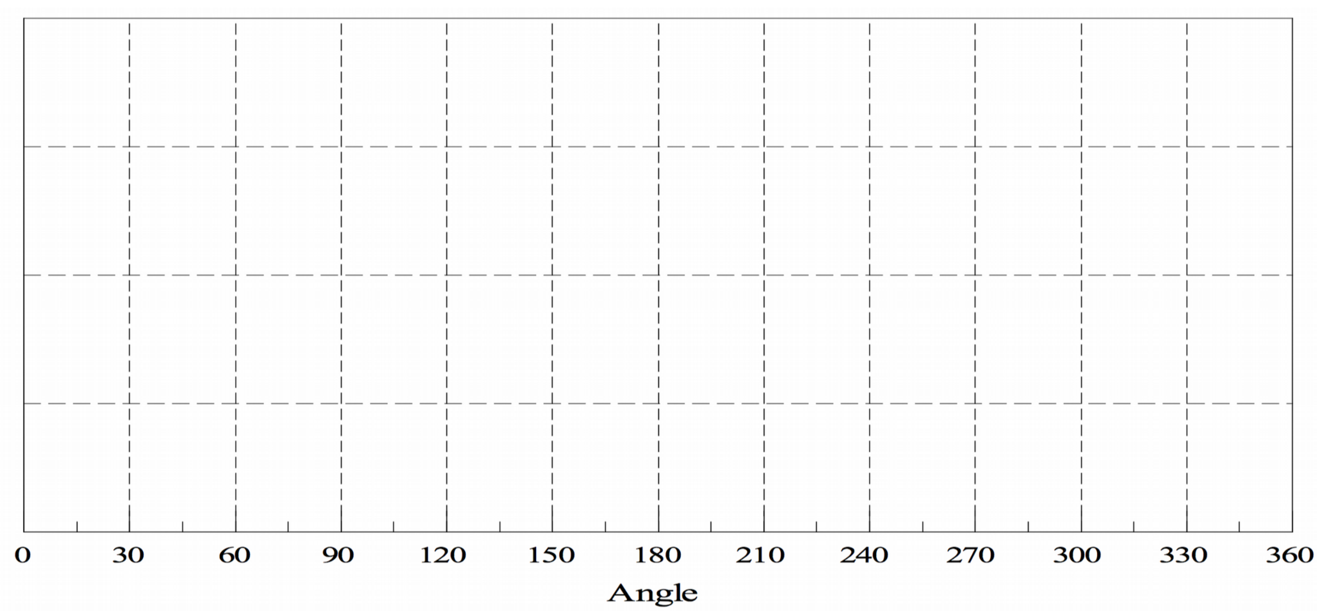
Compare to your results to your predictions. Resolve any differences.

V) WHEN A POLARIZED BEAM GOES THROUGH A POLARIZER …

Set up the situation below where the polarized light of a laser goes through a polarizer set at +30º to its polarization. (Make sure you take your "zero" into account.)



Once again, sketch what you think the result will look like when you take data every 15º.

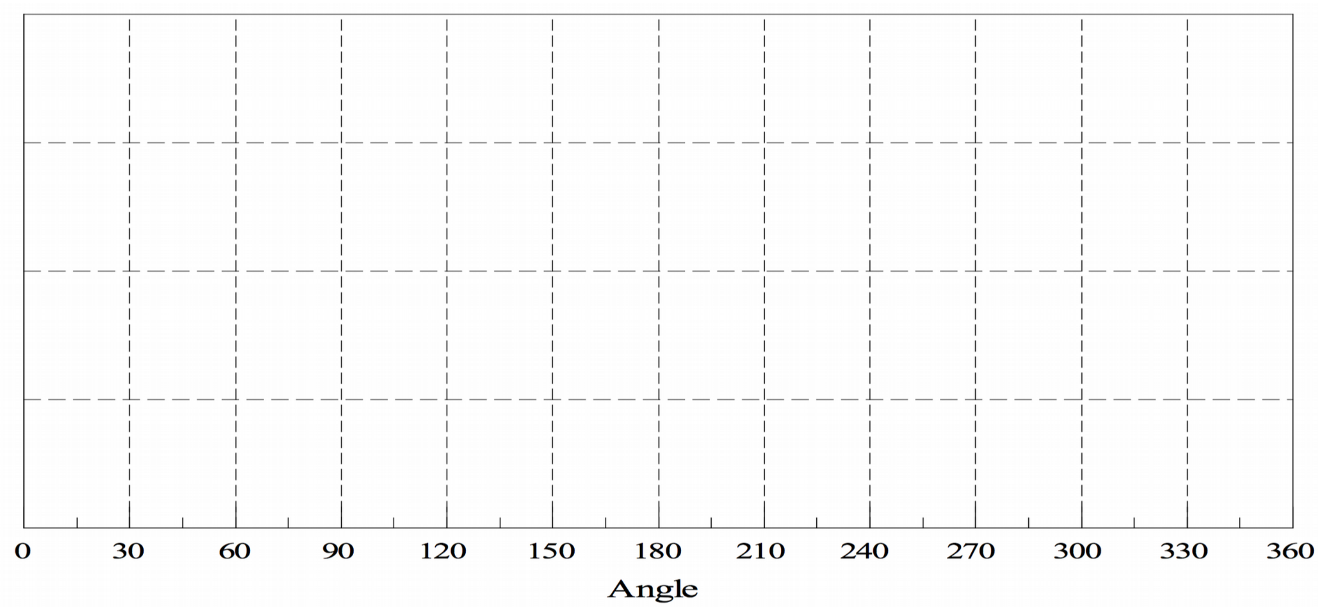


Now take data every 15º from 0º to 360º. Record your results in a data file in SMC, plot your data, save the figure on SMC, and sketch your data on the graph above.

Compare to your results to your predictions. Resolve any differences.

VI) BETWEEN CROSSED POLARIZERS

Now remove the middle polarizer and set the second polarizer so that ***no*** (or a minimum amount of) light gets to the photodetector. You are now going to think about putting the rotating polarizer before the crossed polarizer. Sketch your prediction on the graph below.



Like before, take data every 15º from 0º to 360º. Record your results in a data file in SMC, plot your data, save the figure on SMC, and sketch your data on the graph above.

Compare to your results to your predictions. Resolve any differences.