**Worksheet 2.6 How do sunglasses work?**

In the 1800’s Malus proposed a law to predict the light transmission through two polarizing filters. The relationship is

I = I*0* *cos2(*θ*)*

where *I*0 is the maximum intensity when the angle *θ* between the polarizer axes is zero. You will see if this law is useful in describing your polarizing filters.



Figure 1. Set-up for polarization of light.

This activity is described using a Texas Instruments TI-83 Graphing calculator.

1. Turn on the calculator. If your calculator is in radian mode change it to degree mode.

* Press  to access the settings screen.
* Use the cursor keys to highlight DEGREE.   
  Press .
* Press  [QUIT].

2. Align the light source, polarizing filters, and Light Sensor so light passes through the filters and then into the sensor. You will rotate only one filter to change the transmission; the other filter, the light source, and the sensor must not move. Turn on the light source.

3. Attach the Light Sensor to Channel 1 on the CBL2 interface. If your sensor has a range switch, set it to 600 lux. Use the black link cable to connect the CBL2 unit to the calculator. Firmly press in the cable ends.

4. Start the DATAMATE program from the APPS menu.

5. If CH 1 displays a Light Sensor and its current reading, skip the remainder of this step. If it does not, set up DATAMATE for the sensor manually. To do this,

1. Select SETUP from the main screen.
2. Press  to select CH 1.
3. Choose LIGHT from the SELECT SENSOR list.
4. Choose LIGHT 600 (LX) from the LIGHT list.
5. Select OK to return to the main screen.

6. Set up the calculator and the interface for the appropriate data collection mode.

1. Select SETUP from the main screen.
2. Press  to select MODE and press .
3. Select EVENTS WITH ENTRY from the SELECT MODE menu to collect light data as a function of distance. In this mode you will trigger the interface to record the light intensity for each position you choose.
4. Select OK to return to the main screen.

7. The main screen will display a new light intensity every second. Rotate the analyse until the reading on the calculator is maximized. This is your zero angle. The axis marks on the two filters should be parallel, or 0°.

8. In the *event with entry mode* light intensity will only be measured when the  button is pressed. You will then type the analyzer angle in degrees and press  to complete the data point.

1. Select START from the main screen to prepare for data collection.
2. Rotate the analyzer to the 0º position.
3. Press  to take the first point and enter “0” for the angle. Remember to press  to complete your numerical entry.

9. Rotate the analyzer by 15º, press  and enter “15” for the angle. Repeat this process, entering “30” for the next angle, and so forth, until you have rotated the analyzer through one revolution, or 360º. After the last point, press  to end data collection.

**Now answer questions A1 on the answer sheet**

##### **Analysis**

1. Display the graph of light intensity *vs*. angle on the screen.
2. Trace across your graph with the  and  keys. Note the maximum value of the intensity and record it in the data table A4. The maximum value does not quite correspond to the constant *I*0 in the Law of Malus since it includes the background light.
3. Note the minimum value of the intensity (at 90º) and enter this in your data table A4 as the back ground intensity.

4. To plot the Law of Malus *I* = *I*0 cos2(*θ*)with your data, you need to enter the equation “A\*(cos(X))2 + B” in your calculator. The variable A will correspond to the maximum intensity *I*0.The + B term is present to represent the effect of background light. To enter the equation in your calculator, you need to temporarily leave the DATAMATE program. Press  and select QUIT.

1. From the calculator home screen, press .
2. Press  to clear the Y1 equation.
3. Enter “A\*(cos(X))2 + B” in the Y1 line.

[Hint: To enter letters A, B and X press the green Alpha button and the corresponding letter key.]

d. Press  and select QUIT.

5. To plot your data and the Law of Malus model on the graph at the same time

1. Start the DATAMATE program.
2. Select ANALYZE from the main screen.
3. Select ADD MODEL from the ANALYZE OPTIONS.
4. Select CH1 from the SELECT GRAPH screen.
5. Select ADJUST B.
6. Enter the background intensity you observed.
7. The graph you see may not yet show the model, since you have not set the constant A. Press  to prepare to set A.
8. Select ADJUST A.
9. Enter the difference between the maximum intensity from Step 2 and the background intensity from Step 3.

**Now answer questions A2 through A6 on the answer sheet**

**ANSWER SHEET**

**A1.** Place one polarizing filter on top of a second so you have to look through both of them. Rotate the top filter. What do you notice?

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**A2.** Record the values of the analyser angle and the intensity.

|  |  |
| --- | --- |
| **Angle (°)** | **Intensity (lux)** |
|  |  |

**A3.** Prepare a sketch of the variation of intensity with angle. Label your axes.

**A4.** From your graph record the maximum and minimum intensity values.

|  |  |  |
| --- | --- | --- |
| **Maximum Intensity** | **Io + B** | **lux** |
| **Background Intensity** | **B** | **lux** |
| **Difference in Intensity** | **A** | **lux** |

**A5.** How well does your results agree with Malus’s Law, *I* = *I*0 cos2(*θ*)

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**A6.**  What happens when you pass laser light through the two polarizers?

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