The Second Day

22 January 2019

Contents

1. Session One

1.1. Can MalusÃ¢â‚¬â„¢s law be verified experimentally?

1.1.1. Procedure (Practical Method)

1. Set up the equipment with the white LED and two filters.
2. Turn on the microcontroller, and set the filters to a 0 degrees offset.
3. Record the initial intensity sensor value.
4. Change the angle between the two filters in steps of 5 degrees, and record the intensity sensor value at each offset interval, being careful not to misalign the sensor or LED.
5. Repeat steps 3 and 4 until a sufficient number of repeats has been obtained to reduce the impact of anomalous results.

1.1.2. Evaluation of Procedure

This first method was easy to carry out once all the equipment was aligned correctly, and the sensor placed over the center of the LED beam. Initially, two clamp stands were used for each of the polarising filters, and the primary filter was rotated in place. This, however, caused a cramped working space, causing the sensor to shift position.

To combat this, I placed both the filters, sandwiched together, in the same clamp stand. For each offset interval, both filters were removed, rotated, and put back into place, carefully making sure that the filter covered all the beam.

Angle	Raw sensor output				
	Repeat one	Repeat two	Repeat three	Average	Std Dev
0	1240	1121	1255	1205	73.4
5	1270	1105	1225	1200	85.3
10	1265	1077	1187	1176	94.4
15	1245	1022	1115	1127	112.0
20	1204	961	1036	1067	124.4
25	1151	887	949	996	138.0
30	1099	839	875	937	140.9
35	1030	751	773	851	155.1
40	971	636	655	754	188.1
45	841	561	514	639	176.8
50	697	448	465	539	139.1
55	571	398	366	445	110.3
60	451	278	303	344	93.5
65	321	203	195	240	70.6
70	222	141	120	161	53.9
75	130	83	62	92	34.8
80	64	38	34	45	16.3
85	17	16	9	14	4.4
90	1	1	1	1	0

Table 1. Experiment 1 results

The LED beam also spread further than expected, reducing the intensity at the sensor. This was reduced by moving the components as close together as possible, but could have been entirely eliminated with the use of a laser.

1.1.3. Table of Results.

Table 1 shows the results of session one.

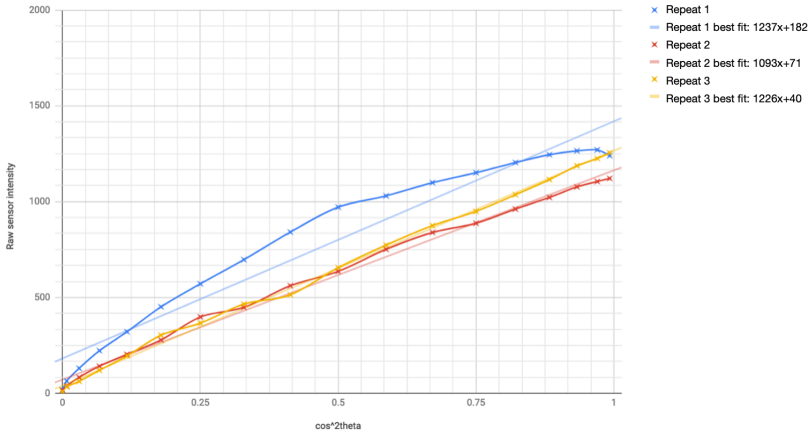
1.1.4. Evaluation of Readings

These results follow exactly with the expected outcomes. The variation in initial values is due to changes in the distance between LED and sensor, and the different polarising filters used. The standard variation of the results is within acceptable ranges, but it is interesting to note that the standard deviation clearly increases towards the middle of the range of angles, and decreases again towards the end of the range. This is due to the change in starting intensity having little effect towards the extremes of intensity

1.1.5. Analysis of Readings

To verify that these readings follow Malus's law, we need to use the following substitutions:

$I \propto \cos^2\theta$
$I = I_0 \cos^2\theta$
$\Rightarrow y = mx + c$
$\therefore y = I, m = I_0, x = \cos^2\theta, c = 0$
We can plot these values on a line graph:



From these graphs, we can see that each repeat produces roughly the same result - the line of best fit produces gradients which are roughly equal to the initial intensity I_0. From this, combined with the accurate prediction of a linear function, shows with considerable confidence that these results experimentally verify Malus's law.

For each repeat, the calculated I_0 is not exactly as observed, as seen in table 2

Repeat	Observed	Calculated	Difference
1	1240	1237	3
2	1121	1093	28
3	1255	1226	29

Table 2. Difference in observed and calculated I_0

This shows differences between observed and calculated initial intensities within acceptable error ranges. The difference can mostly be explained by the neutral density effect of the polarising filters - even at zero degrees there is a significant reduction in intensity with and without the filter.

These results also seem to indicate that the original method (with two separate clamp stands for each filter) seemed to produce more accurate results than the secondary method (with one clamp stand for both filters sandwiched together). However, repeats two and three clearly show a better line of best fit, with much larger deviation from best fit in repeat one. This means that the accuracy is purely a coincidentally better gradient.