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MALUS LAW EXPERIMENT - KSCIMLE

1. Key Concepts

- Electromagnetic wave
- Polarisation

2. Introduction

Light, when modelled as a wave phenomenon, can be classified as a transverse electromagnetic wave consisting of oscillating electric and magnetic fields that are oriented perpendicular to each other. Depending on the orientation of the plane of polarization of the electric field with respect to the direction of propagation of the wave, the wave can be classified as polarised or un-polarized. If the plane of polarization of electric field is fixed with respect to the direction of propagation, then the wave is said to be linearly polarized. If the plane of polarisation rotates as the wave propagates, then the wave is said to be elliptically or circularly polarised.

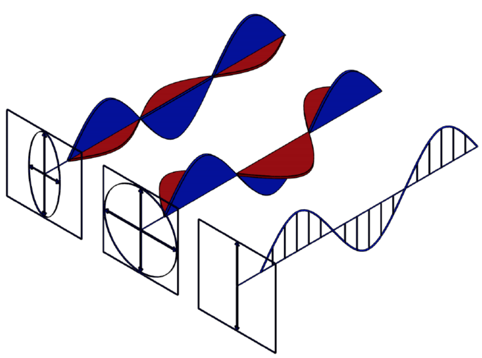

Figure 1: Elliptical, circular and linear polarization states of light.

3. Objective

To experimentally verify the Malus's law. (i.e to measure the variation of transmission of an EM wave through two polarisers as a function of the angle of orientation between them.)

4. Theory

Light from most of the sources is un-polarized. There are different methods of achieving polarized light from un-polarized light.

- Polarization through transmission.
- Polarization through scattering.
- Polarization through reflection.

4.1 Polarization through transmission

A few materials have a property of dichroism, due to which the light of different polarisation states travelling through the material undergoes different degrees of absorption. Using materials that have the property of dichroism, polarisers are made. When an un-polarized beam of light undergoes transmission through a polariser, the transmitted beam of light will be polarzied. A polariser transmits only the component of light polarized along a particular direction and absorbs the component perpendicular to that direction. The intensity of the transmitted light is half of the incident light, because, the incident light is a random mixture of all states of polarisation and the intensity distribution between them on the average is equal.

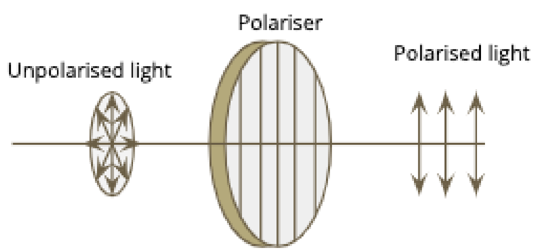

Figure 2: Effect of a polariser on an un-polarized beam of light.

If this plane polarised light is incident on a second polariser whose axis is oriented perpendicular to plane of polarisation of light, no light is transmitted through the secondary polariser. (it is a convention to call polariser 1 as polariser and polariser 2 as analyser.)

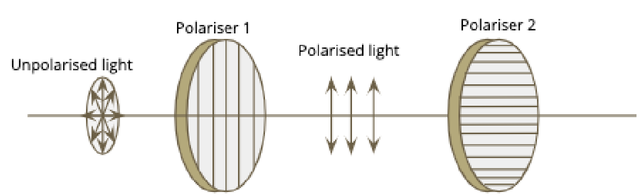

Figure 3: Two polariser with their optical axis oriented perpendicular to each other

In the figure 3, the polariser 2 and 1 have their optical axis oriented perpendicular to each other $\theta = 90^\circ$ were, θ is the angle between the optical axes of the polarizers. If the second polariser is oriented at an angle that is not perpendicular to the first polariser, $\theta \neq 90^\circ$

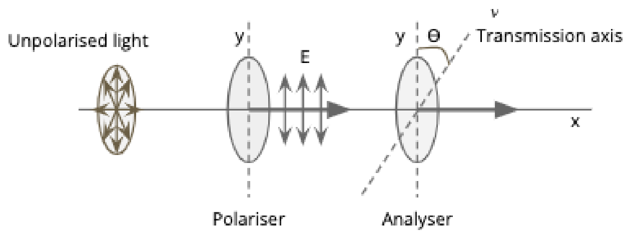

Figure 4: Two polariser with $\theta \neq 90^\circ$.

The light after transmission from polarizer is plane polarised. The electric field vector of the light can be resolved in two components one parallel and one perpendicular to the transmission axis of the analyser (if y' is the direction of transmission of the analyzer.)

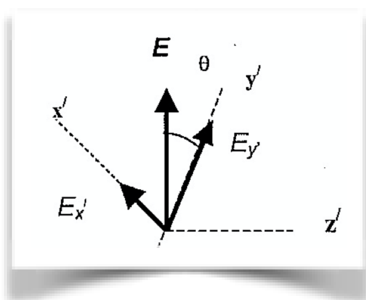

Figure 5: The resolution of E field of the plane polarised light into two

components $E_{x'}$ and $E_{y'}$

Only, $E_{'y}$ component is transmitted by the analyser. We know that, $I = {}^2E$ where, I is the intensity of the EM wave and E is the electric field strength.

If I_0 is the intensity of transmitted light when $\theta = 0°$, the intensity of light transmitted through the polarizer and analyzer system at an angle θ between them is

$$I(\theta) = I_0 cos^2\theta \qquad (1)$$

The above equation is called Malu's law. It was experimentally derived by Étienne-Louis Malus in 1809.

5. Equipment

S. No	Equipment	Item Code	Quantity
1	Optical Bench Set 0.4m	**KSCIOB2**	1
2	Light Source Holder	**KSCIHA001**	1
3	Polarizer Holder	**KSCIHA004**	1
4	Analyzer Holder	**KSCIHA006**	1
5	Light Sensor Holder	**KSCIHA510**	1
6	Power Supply for Light Source	**KSCI-PSLS**	1
7	Data Processor	**KSCIDP1**	1

6. Safety Instructions

- Components like optical bench, and power supply are heavy. Take adequate safety measures while handling them.
- The polarizer and analyzer filters are delicate. Handle them with care.

7. Experimental Setup

- Place the optical bench on a stable horizontal surface such as a sturdy table top and make sure the bench is parallel to the horizontal surface using the adjustable mounts.
- Mount the light source securely on the upright, place the upright on the optical bench and lock the slide screw on the slider.
- Mount the polarizer stage on the upright, place it adjacent to the light source (along the optical path) and lock the slide screw on the slider.
- Mount the analyzer on the upright, place it adjacent to the polarizer and lock the slide screw on the slider.
- Mount the light sensor on the upright and place it adjacent to the analyzer. Connect the light sensor to the data processor.
- Ensure that the light source, polarizer, analyzer and the light sensor are all aligned in the same optical axis.

8.Experiment

- Power up the light source and the data processor.
- Keep the voltage supplied to the light source constant throughout the experiment.

8.1 Checking $\theta = 0^\circ$ reference for polarizer-analyzer combination

- Keep the polarizer at a fixed position.
- Rotate the analyzer slowly and observe the light intensity reading on the data processor. Note the position of the analyzer at which light intensity is maximum. Record the value of light intensity I_0.
- This is the position at which the angle between polarizer and analyzer is 0 degree i.e $\theta = 0^\circ$. Record the value of angle on the analyzer as θ_r.

8.2 Verifying Malu's Law

- Vary θ starting from $\theta = 0^\circ$ to $\theta = 90^\circ$ in steps of 5° and record the values of light intensity for each case. Tabulate the readings.

9. Sample Measurement

θ (deg)	Intensity of the transmitted light (lux)	θ (radian)	$s^{2}(\theta)$
90	0	1.570796327	0
85	14	1.483529864	0.007596123494
80	40	1.396263402	0.03015368961
75	78	1.308996939	0.06698729811
70	133	1.221730476	0.1169777784
65	190	1.134464014	0.1786061952
60	260	1.047197551	0.25
55	334	0.9599310886	0.3289899283
50	414	0.872664626	0.4131759112
45	505	0.7853981634	0.5
40	600	0.6981317008	0.5868240888
35	681	0.6108652382	0.6710100717
30	763	0.5235987756	0.75
25	833	0.436332313	0.8213938048
20	900	0.3490658504	0.8830222216
15	954	0.2617993878	0.9330127019
10	986	0.1745329252	0.9698463104
5	1006	0.0872664626	0.9924038765
0	1010	0	1

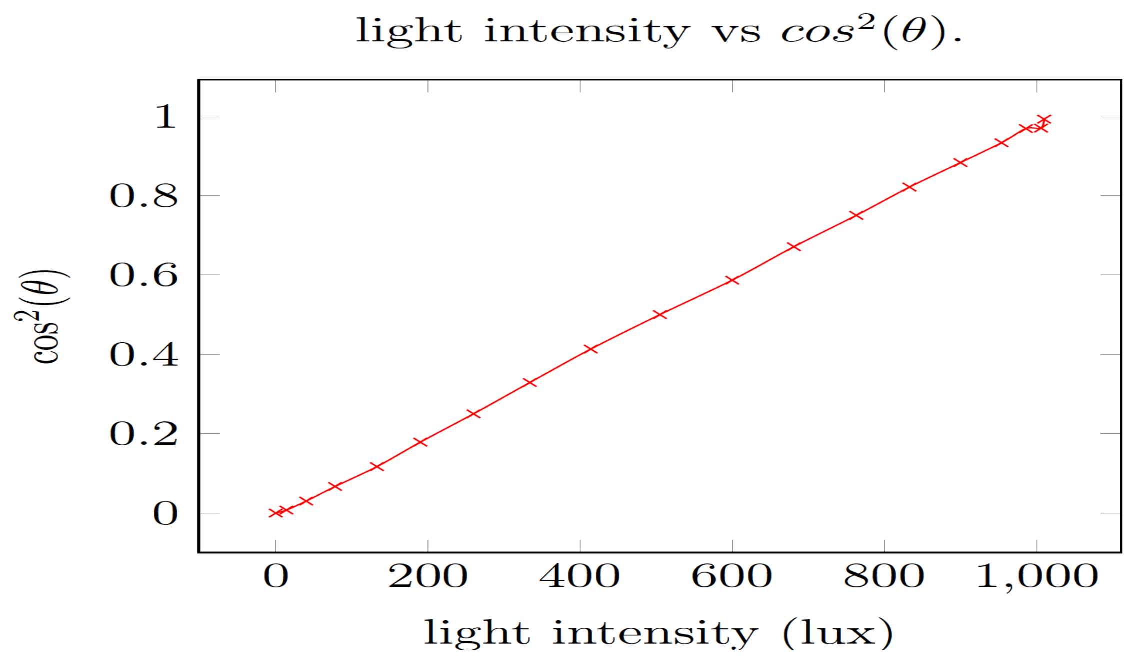

Figure 7: cosine square of angle as a function of light intensity.

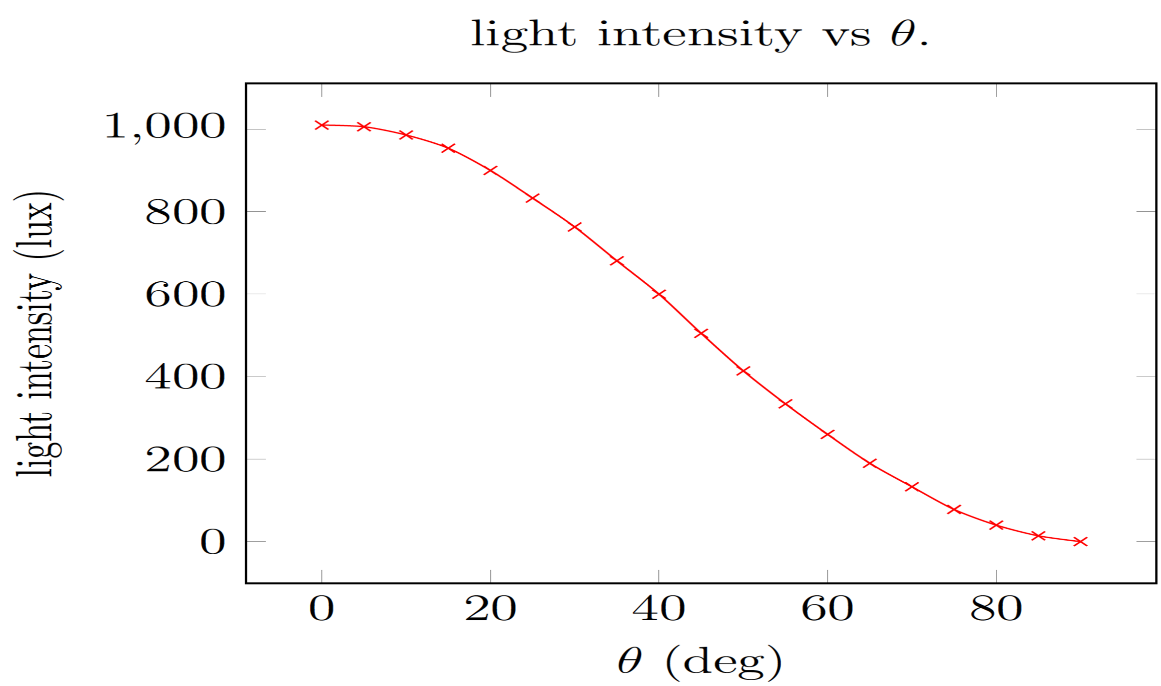

Figure 8: Variation of light intensity as a function of angle between axis of the polarizer and analyzer .

10. Reference

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