VL-O3: VERIFICATION OF MALUS' LAW OF POLARIZATION OF LIGHT

Objectives:

- To find the relation between the intensity of transmitted light (I) through analyzer and the angle (θ) between the axes of polarizer and analyzer.
- To verify Malus' law from the *"I"* versus $\cos^2\theta$ graph.

System requirements:

Computer (Desktop/Laptop), Operating systems: Windows, Polarisation_vle (zipped) File.

Advise:

Students are advised to follow the **procedures written in this manual very strictly** while performing the experiment. D**o not try to explore anything else during the experiment.**

Theory:

Light emitted from common sources around us (example: the sun, candles, bulbs, etc.) is known to be un-polarized light. In an un-polarized light, the electric and magnetic field vectors can vibrate in all possible directions perpendicular to each other and also perpendicular to the direction of propagation of light. Light wave can be polarized by the confinement of the vibrations of electric and magnetic field vectors to one plane. When a piece of polarizer is placed in front of normal light it polarizes the light. If the polarizer is ideal, the intensity of the transmitted light is one-half of the incident light. Certain transparent crystalline materials, like Tourmaline, Calcite crystals, etc. are capable of confining vibrations of light waves in only one plane. Such materials are called Polaroids which have high directionality in crystal structure. Light can also be polarized by natural phenomena like reflection, refraction and scattering.

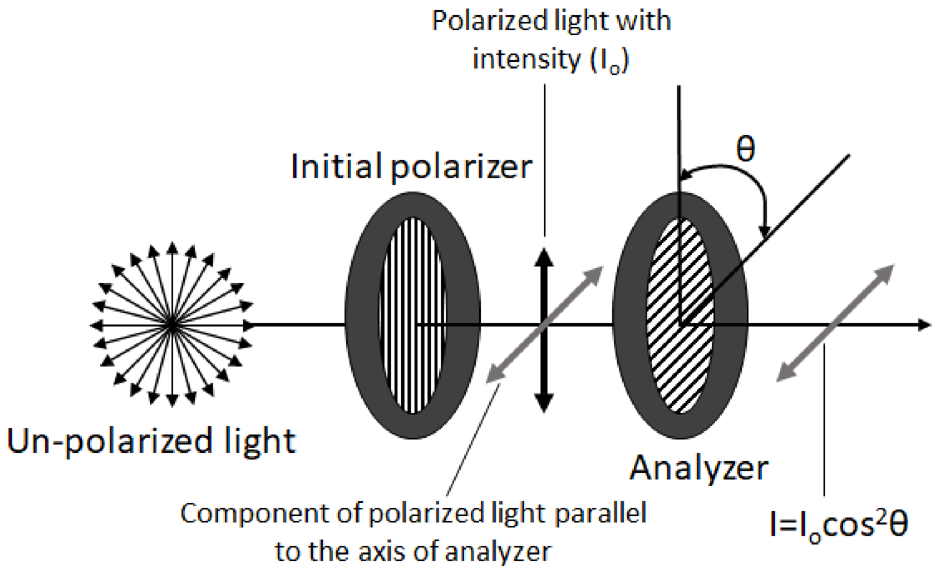


Fig. 1 Schematic representation of Malu's law.

If a piece of Polaroid is rotated in front of a polarized ray of light, it causes a variation in the intensity of the light that gets through. The thing that causes the variation of intensity is the angle between the initial polarization and the axis of second "polarizer". The second polarizer is called "analyzer". The intensity of light transmitted through the analyzer is given by a law named

Malus' law. Malus' law states that the intensity of plane-polarized light that passes through an analyzer varies as the square of the cosine of the angle between the plane of the polarizer and the transmission axes of the analyzer. Fig. 1 shows the schematic illustration of Malus' law.

When the incident polarized light of amplitude A_o strikes the analyzer at an angle θ, it is resolved into two components $A_o cos\theta$ and $A_o sin\theta$ as shown in Fig. 2 The component $A_o sin\theta$ is eliminated in the analyzer. Since, only $A_o cos\theta$ passes through the analyzer the amplitude of the transmitted light is therefore,

$$A = A_o cos\theta \qquad (1)$$

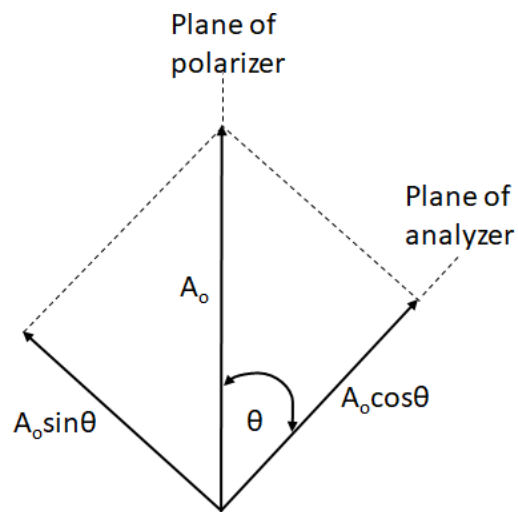


Fig. 2 Resolved components of plane polarized light.

So, the amplitude of polarization of the transmitted wave is proportional to the cosine of the relative angle (θ). Since intensity (I) is the square of the amplitude (A), it can be expressed as

$$I = A_o^2 cos^2\theta$$

$$I = I_o cos^2\theta \qquad (2)$$

Here, I_o is the intensity of the incident polarized light.

There are two extreme conditions of θ followed by Eq. (2) given as

(i) If $\theta = 0$, then $cos\theta = 1$ and $cos^2\theta = 1$; hence $I = I_o$. That means the intensity transmitted through the analyzer is equal to the initial light intensity that passes through the polarizer. Thus, light having the maximum intensity is allowed to pass through analyzer.

(ii) If $\theta = 90^o$, $cos\theta = 0$ and $cos^2\theta = 0$; hence $I = 0$. That means the light is extinguish completely, i.e. no light is allowed to pass through analyzer.

Procedures:

1. At first unzip the "**Polarisation_vle (zipped)"** File. Click on the executable file "**Polarisation_vle**" and then a window will be open as shown in Fig. 3.

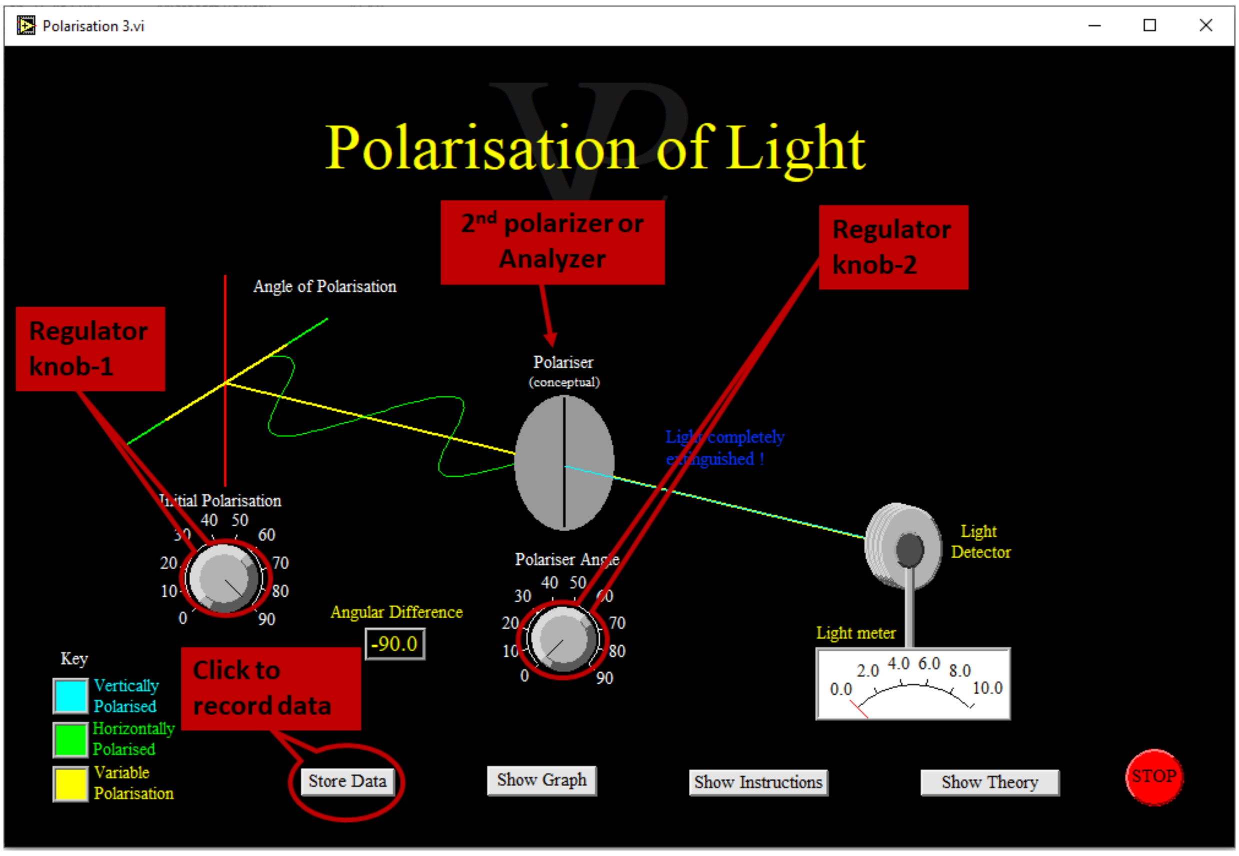


Fig. 3

2. Set the angle of initial polarization at 90° using the "**regulator knob-1**" and the second polarizer angle (analyzer angle) at 0° using "**regulator knob-2**" as indicated in Fig. 3.
3. Change the second polarizer angle (analyzer angle) using "**regulator knob-2**" as specified in the Fig. 1.3. Click on "**Store data**" for each polarizer angle and take at least 10 data for the angular difference θ between -90° and 0°.
4. Again set the angle of initial polarization at 0° using the "**regulator knob-1**" and and the second polarizer angle (analyzer angle) at 0° using "**regulator knob-2**". Follow step 3 and continue "store data" for changing the analyzer angle using "**regulator knob-2**" for the angular difference θ between 0° and 90°.

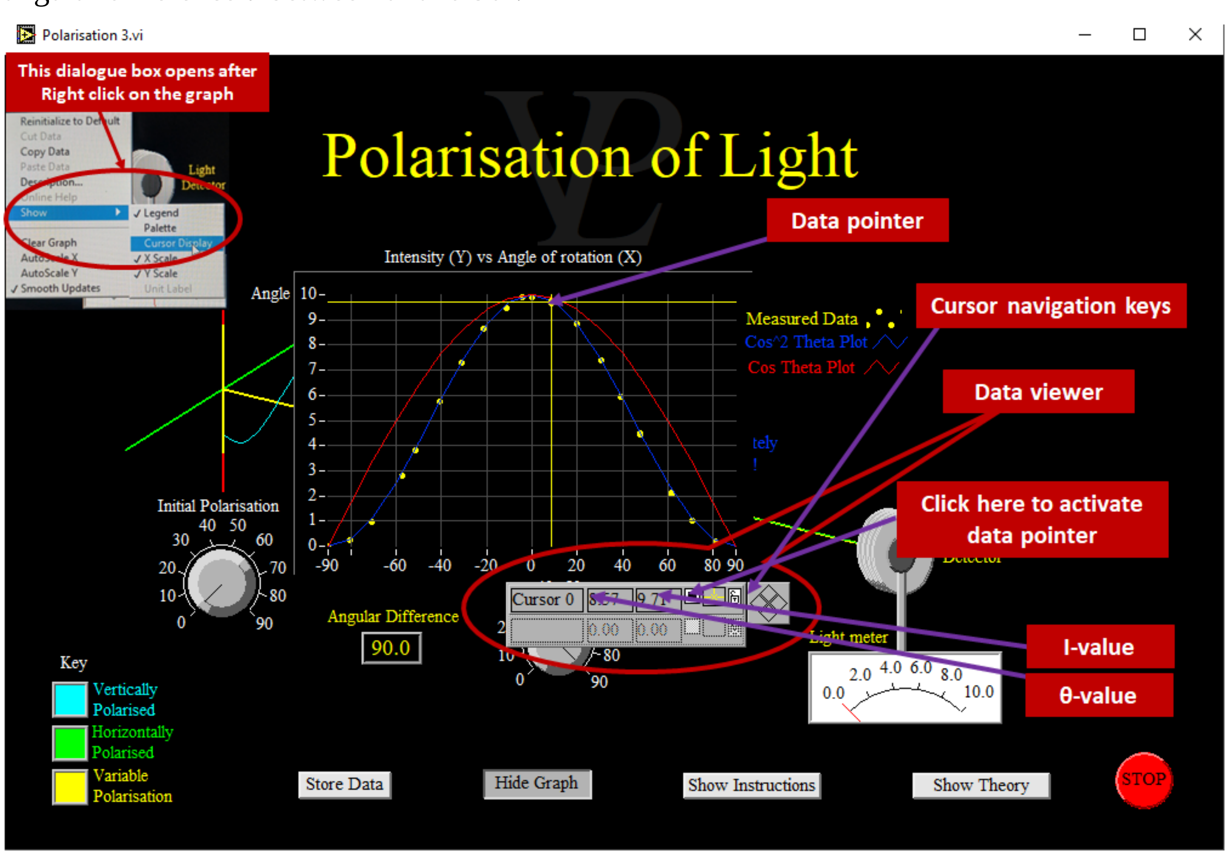
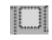


Fig. 4

5. Click on “**Show graph**” for the resultant graph to be appeared as shown in Fig. 4. The data points (**yellow**) will be found on the **blue** sinusoidal graph (Fig. 4).
6. Right click on the graph, place the mouse pointer on “**Show**” and a list will appear (Fig 4). Click on the “**Cursor display**” from the list and a “**Data viewer**” will appear (Fig. 4).
7. To activate the “**Data pointer**” click on the button  and the button will appear like  as indicated the Fig. 4 Drag the “**Data pointer**” on the measured data points **OR** use the “**Cursor navigation keys**” to see the θ and I-values. Record the θ and I-values in table 1.
8. Plot an intensity (I) versus (θ) graph for the angular differences θ between -90^o and +90^o as indicated in Fig. 1.5.
9. Calculate $cos\theta$ and $cos^2\theta$ values and record in the table 1. Plot I-values against $cos^2\theta$ (e.g. Fig.1.6) for the angular difference θ between 0^o and +90^o (or, -90^o and 0^o). If the graph is a straight line, Malus’ law is verified. Determine the slope of the $cos^2\theta$ versus I graph, which will give the I_o-value.

Data collections:

Table 1: Measurement of the intensity of light transmitted through the analyzer (*I*) corresponding to various angles between the axes of polarizer and analyzer (*θ*).

Sl. No.	θ (Degree)	$cos\theta$	$cos^2\theta$	I (arb. unit)
1				
2				
3				
4				
5				
6				
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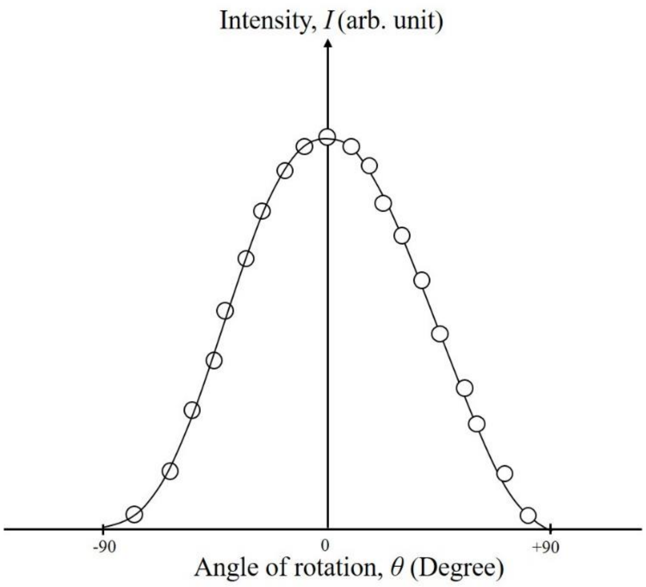

Fig. 5 A plot of light intensity (I) versus θ.

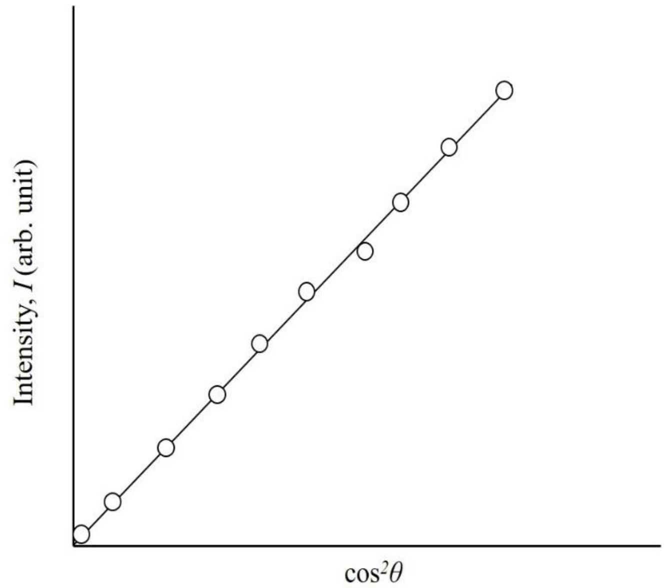

Fig. 6 A plot of light intensity (I) versus $cos^2\theta$.

Calculations:

Slope of the $cos^2\theta$ vs I graph =……………………………………………………….

Results:

1. The nature of the I vs θ graph is oscillatory (cosine square curve).
2. The nature of the I vs $cos^2\theta$ graph is linear. Therefore, Malus' law is verified.
3. Initial intensity of the polarized light determined from $cos^2\theta$ vs I graph is I_o = …… arb. unit.

Error analysis:

Compare I_o value with the maximum transmitted intensity (I).

Discussion:

Based on your understanding from this experiment, answer the following questions:

1) Why analyzer is used to identify polarized light? What happens when a polarized light strikes an analyzer?
2) Under what condition, the intensity of light transmitted through the analyzer will be the same as that of the incident light?
3) Can the intensity of light transmitted through the analyzer be higher than that of the incident light intensity?
4) Under what condition, the intensity of light transmitted through the analyzer will be half of the incident light intensity?
5) If θ is changed in the range 0 to 360°, what will be the nature of the θ versus I graph?

