DEPARTMENT OF PHYSICS
AND ASTRONOMY
*Faculty of Science
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MACQUARIE
University

The Polarisation of Light

Figure 1: Linear Polarisation Glasses

Introduction

As shown in the figure to the right, an electromagnetic wave, such as light, is produced by both an electric (E) and magnetic field (B) component, which oscillates perpendicular to the direction of propagation (c). The direction of the electric field component is called the polarisation of light.

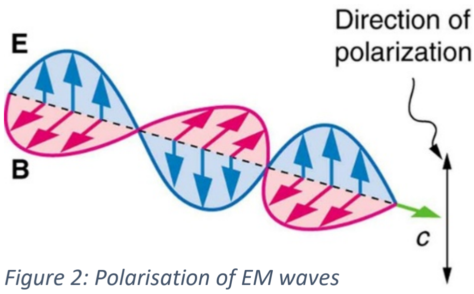


Figure 2: Polarisation of EM waves (Image credit: https://opentextbc.ca/)

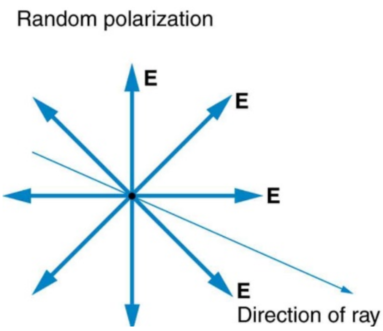


Figure 3: Random polarisation (Image credit: https://physics.stackexchange.com)

Natural light and most other common sources of visible light are unpolarized because they're composed of many waves with all possible directions of polarisation. The figure to the left illustrates unpolarised light, with arrows representing the many directions of polarisation of the many individual waves composing the light ray.

A special material, known as a polarising filter, can limit the direction of polarisation in light. You may have heard of or even own a pair of Polaroid sunglasses, which can cut the glare out of light reflected from water or glass. This special ability is possible because of their polarising filters.

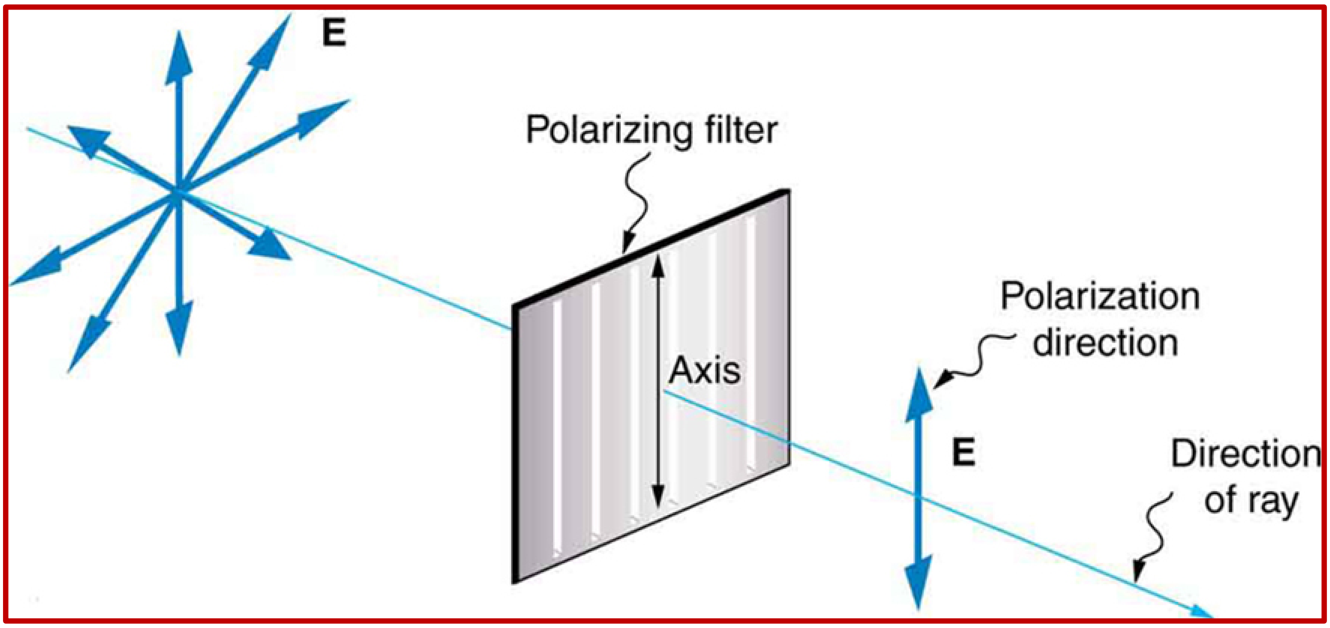


Figure 4: Example of a polarising filter (Image credit: https://physics.stackexchange.com)

Let's now consider a beam of polarised light, which strikes a piece of polarising material, like in the figure above. Only the component of the wave parallel to the axis of a filter is passed through. If we let θ equal the angle between the axis of the polarising material and the polarisation of the incident light. The intensity of light that passes through the polarising material will diminish by an amount equal to:

$$\boxed{I = I_0 \cos^2 \theta}$$

In this case, I_0 is the initial intensity of the light before it passes through the polarising material. This equation is known as Malus's Law, named after the French physicist and mathematician, Étienne-Louis Malus, who discovered the polarisation of light in the early 1800s.

In this experiment, a source of polarised light, a polariser, and a smartphone are used to investigate Malus' Law. The source of linear polarised light is a flat computer monitor displaying plain white light, while the polariser is a small piece of polarising material. Sensors in the smartphone, namely the light sensor and gyroscope, are used to measure the intensity (i.e. illuminance) of light and the orientation angle, respectively.

Instructions

1. Locate a plain white background for the flat computer monitor and turning the brightness to maximum (Tip: try using Google to find a white background image).
2. On an Android or iOS smartphone, download and install "Physics Toolbox Sensor Suite":
   a. Google Play Link: https://goo.gl/9QH6dV
   b. Apple App Store Link: https://goo.gl/41T9AT
3. In the "Physics Toolbox Sensor Suite", select the *Inclinometer* option and try testing by rotating your phone from upright to sideways. As illustrated in the figure, the "pitch" angle should be close to -90 degrees when held upright, and 0 degrees when held sideways.

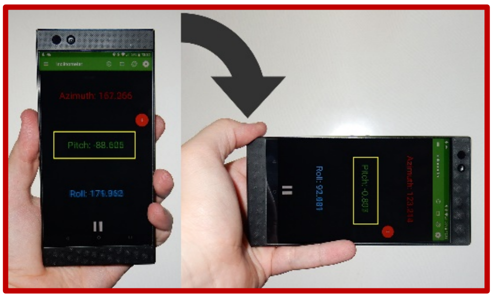


Figure 5: Example of Inclinometer rotation

4. In the "Physics Toolbox Sensor Suite", select the *Light Meter* option and try testing it by holding your smartphone up to a light and then covering it with your hand.
5. Hold a piece of the polarising material up to the monitor and try rotating it in your hands. As shown in the figure to the right, you should see the light from the monitor vary as you rotate the material. Note the orientation of the material at the point when the most light is blocked.

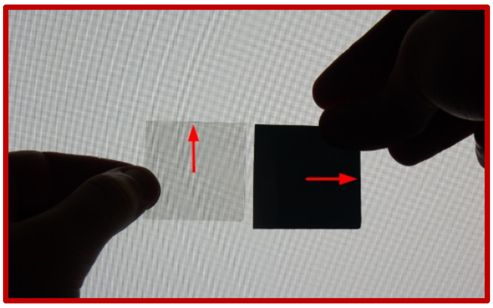


Figure 6: Example of polarisation material

6. Using clear sticky tape, tape the polarising material over the light sensor on the front of your smartphone. It's important to align the polarising material over the light sensor, so when the smartphone is held upright, the light from the monitor is blocked. Try repeating step 5 to ensure you complete this step correctly.

Figure 7: Example of polarisation material on smartphone

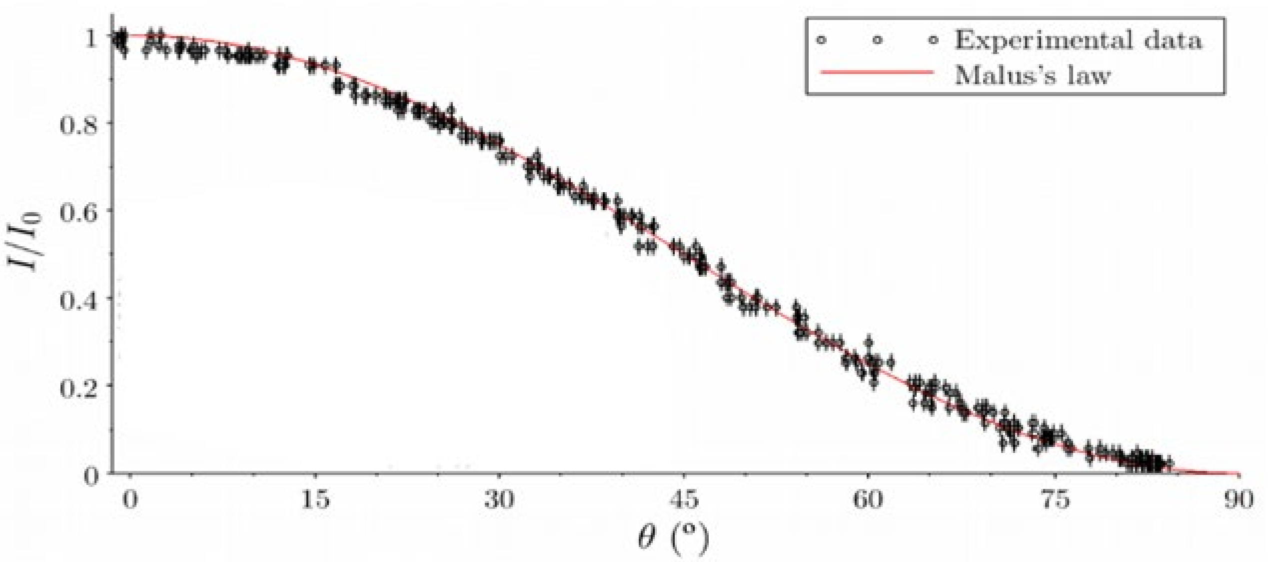
7. In the "Physics Toolbox Sensor Suite", select *Multi Record* and then the *Light Meter* and the *Inclinometer* options. Then press the plus icon to start recording data.
8. Gently hold the front of your smartphone up to the monitor in an upright fashion. Then rotate the smartphone against the computer monitor, completing a quarter revolution.
9. Open the resulting *CSV* file on your smartphone or a computer to view your data.

Analysis

1) Using the data collected in your *CSV* file,

   a) plot the normalised intensity $\left(\frac{I}{I_0}\right)$ versus the angle (θ between 0 and 90°). Recall that the maximum lux reading corresponds to I_0.

   b) over plot a line representing Malus' Law ($I = I_0 \cos^2 \theta$)



How did your data compare to Malus' Law?
The experimental data (circles) of the normalised intensity of light as a function
of angle was going to agree well with the theoretical expression of Malus' law
(red line)

List some uses for polarising material.
Cameras and sunglasses – polarising material reduces the scattered light
LCDs – polarising material control the light that is transmitted through liquid
crystal molecules
3D movies – these are possible thanks to polarising glasses

What could you use the smartphone polarised light measurer for outside of the lab?
Polarisation detectors can be used to pick out human-made materials against
natural surfaces, which has defence and security applications. They could also be
used for atmospheric monitoring, measuring polarisation to track the size and
distribution of particles in the atmosphere, which is useful for both air quality
and atmospheric research applications.

Acknowledgements

The experiment is based on the work by Monteiro et al. 2016.