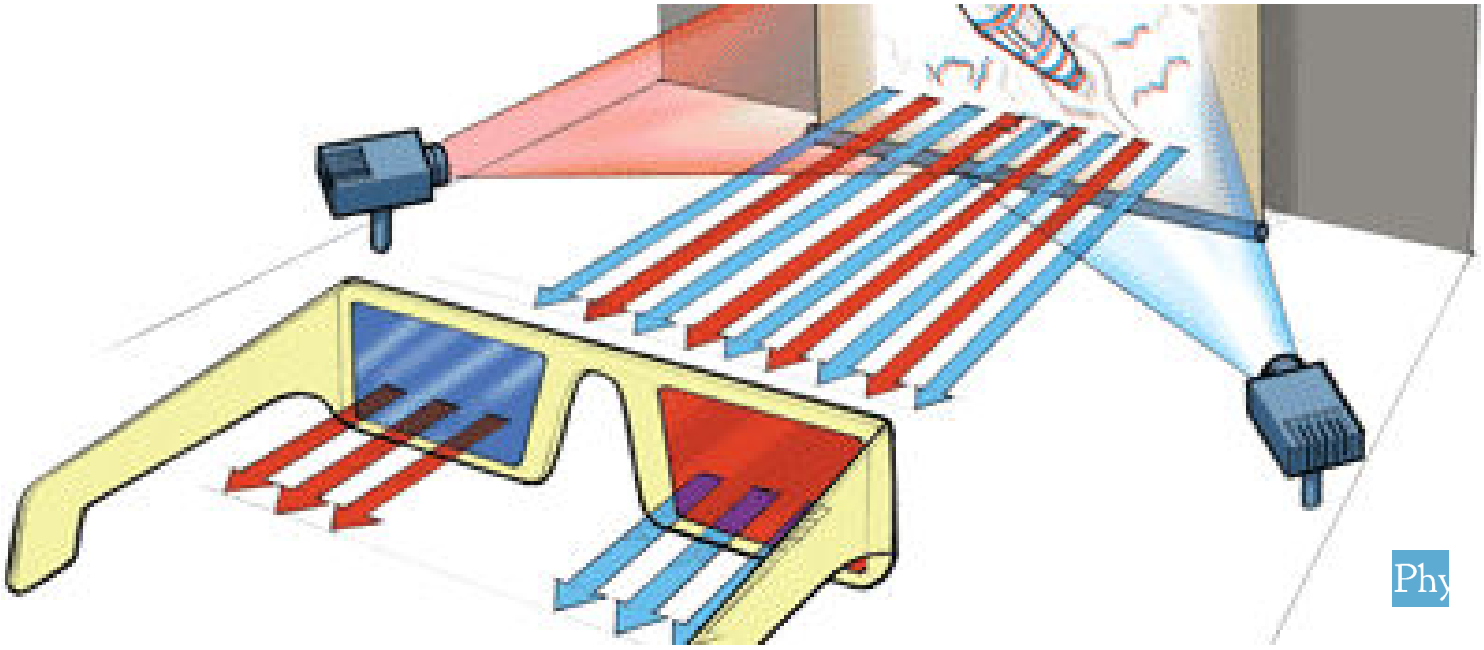
Malus' law



Physics | Light & Optics | Polarisation

Difficulty level	Group size	Preparation time	Execution time
-	-	-	-

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General information

Application

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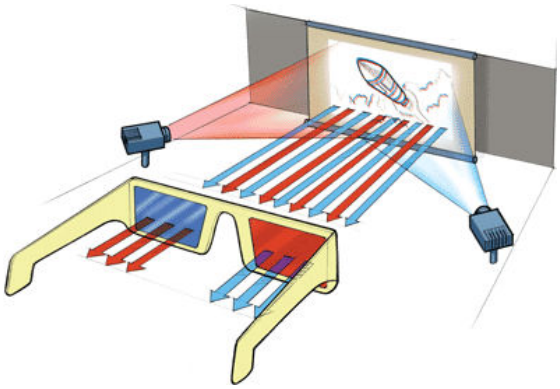

The projection of two images in 3D movies

Since the light from the sun and most of any other light sources are unpolarized, implementing polarization control can be useful in a variety of imaging applications, for examples LCD screens and 3D movies. In the cinema, the two reels of film are projected through different polarised filters, and the glasses cause one of the images to enter one eye and the other to enter the other eye. Audiences' glasses use the same polarising filters to separate out the two images again, giving each eye sees a slightly different perspective.

Polarizers are applied to eliminate glare from light scattering, increase contrast, and eliminate hot spots from reflective objects. This either brings out more intense color or contrast or helps to better identify surface defects or other otherwise hidden structures.

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Other information (1/2)

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Prior knowledge

Light is an electromagnetic wave, in which the electric field of this wave oscillates perpendicularly to the direction of propagation (magnetic field). By convention, the polarization of electromagnetic waves refers to the direction of the electric field.

Scientific principle

1. An important property of reflected polarized light is that the degree of polarization is dependent upon the incident angle of the light. It transmits the desired polarization while reflecting the rest.
2. If the unpolarized light passes through the polarizer, the intensity is reduced by a factor of 2. If the light is polarized before passing through the polarizer, Malus' Law is applied.

Other information (2/2)

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Learning objective

Linear polarized light passes through a polarization filter. Transmitted light intensity is determined as a function of the angular position of the polarization filter.

Tasks

1. The plane of polarization of a linear polarized laser beam is to be determined.
2. The intensity of the light transmitted by the polarization filter is to be determined as a function of the angular position of the filter.
3. Malus' law must be verified.

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Safety instructions

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For this experiment the general instructions for safe experimentation in science lessons apply.

The generally applicable rules for handling lasers according to the ANSI and IEC Laser Classification must be considered.

Do not look directly into the laser beam and reflected beam. Always wear the appropriate laser safety eyewear (goggles) when the exit aperture of the laser is uncovered.

Use suitable screening to isolate the area around the laser and avoid unwanted reflections.

Theory

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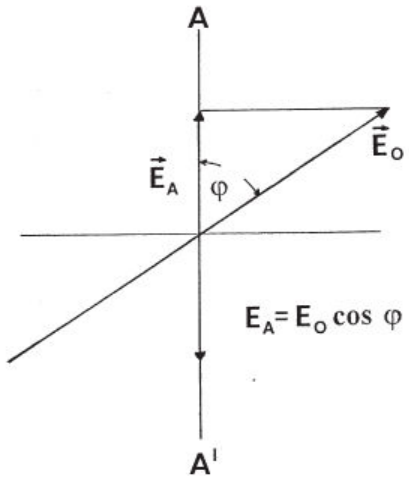
Let *AA'* be the polarization planes of the analyzer in the Figure. If linearly polarized light, the vibrating plane of which forms an angle ϕ with the polarization plane of the filter, impinges on the analyzer, only the part

$$E_A = E_0 \cos \phi$$

will be transmitted.

As the intensity I of the light wave is proportional to the square of electric field intensity vector $\vec{E}$, the following relation (Malus' law) is obtained:

$$I_A = I_0 \cos^2 \phi$$



Geometry for the determination of transmitted light intensity

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Equipment

Position	Material	Item No.	Quantity
1	Diodelaser, green, 1 mW, 532 nm	08765-99	1
2	Optical bench expert l = 600 mm	08283-00	1
3	Base for optical bench expert, adjustable	08284-00	2
4	Slide mount for optical bench expert, h = 30 mm	08286-01	3
5	Polarisation filter	08610-02	1
6	Digital array camera	35612-99	1

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Setup and procedure

Setup

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Experimental set-up: Malus' law

It must be made sure that the photocell is totally illuminated when the polarization filter is set up.

If the experiment is carried out in a non darkened room, the disturbing background current i_0 must be determined with the laser switched off and this must be taken into account during evaluation.

The laser should be allowed to warm up for about 30 minutes to prevent disturbing intensity fluctuations.

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Procedure

Using the polarisation filter.

The polarization filter is rotated in steps of 5° between the filter positions +/− 90° and the corresponding photo cell current (most sensitive direct current range of the digital multimeter) is determined.

Evaluation (1/4)

- Note the measured values for the angles and the currents in the table.
- Then determine the dtransmitted current and the normalized photo cell current.

$\phi/\circ$	$I/\mu A$	$I - I_0/\mu A$	$\frac{I-I_0}{I_{max}-I_0}$	$\cos^2\phi$
-90				
-85				
.				
.				
.				
90				

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Evaluation (2/4)

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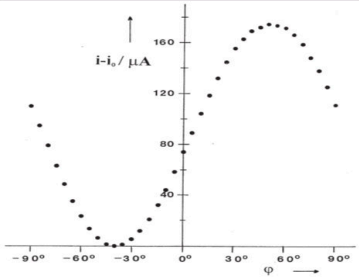

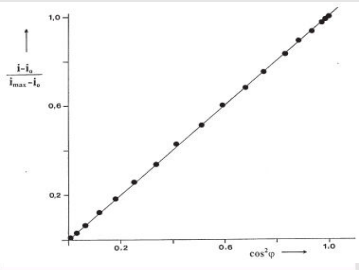

Plot a graph of the photo cell current after background correction (this is a measure for the transmitted light intensity) as a function of the angular position of the polarization plane of the analyzer.

The intensity peak for $\phi = 50^\circ$ shows that the polarization plane of the emitted laser beam has already been rotated by this angle against the vertical.

Plot a graph of the normalized and corrected photo cell currents as a function of the angular position of the analyzer. Malus's law is verified by the initial line's 45° slope.

(Note: to determine Malus' line, an angular setting of 50° of the analyzer must be considered for $\phi = 0^\circ$)

Evaluation (3/4)

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Describe the principles of Malus' Law:

According to Malus' Law, when completely plane polarized light is incident on a _____, the intensity I of the light transmitted by the polarizer is directly _____ to the square of the cosine of angle between the light's initial polarization _____ and the axis of the polarizer. By rotating the polarizer, the changes of light _____ in term of brightness that passing through the polarizer can be observed. If the polarizer is rotated at the _____, the transmitted light intensity is the highest.

intensity
direction
proportional
Brewster's angle
polarizer

Check

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Evaluation (4/4)

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Choose the true statements if the unpolarized light passes trough two polarizers:

- [ ] The intensity of transmitted light after the second polarizer decreases by a factor of $\cos^2\theta$ from the intensity of light source.
- [ ] When the two polarizers are crossed ($\theta = 90$ degrees), the transmitted intensity is zero.
- [ ] When the two polarizers are parallel, 100% transmission is achieved.

Check

Slide	Score / Total
Slide 13: Principles of Malus' law	0/5
Slide 14: Passing polarizors	0/2

Total Score 0/7

Show solutions Retry

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