Polarization and Brewster's Angle Experiment

Purpose

Understand the polarization feature and phenomenon of light. Distinguish the difference between daylight and linear-polarized light.

Theory

Light is an electromagnetic wave. When daylight propagates, the electromagnetic wave oscillates randomly in the air. If the oscillation direction occurs in one plane, the oscillation direction of the electric field and the magnetic field of light are fixed. This type of light is polarized light and the direction of electric field is the polarized direction of light. Polarized lights can also be classified into linearly polarized, circularly polarized and elliptically polarized. In this experiment, we mainly focus at the linear-polarized light. Since human eyes cannot distinguish polarized light and non-polarized light, we need the help of polarizers to make distinguish. From **Figure 2**, we can discover that

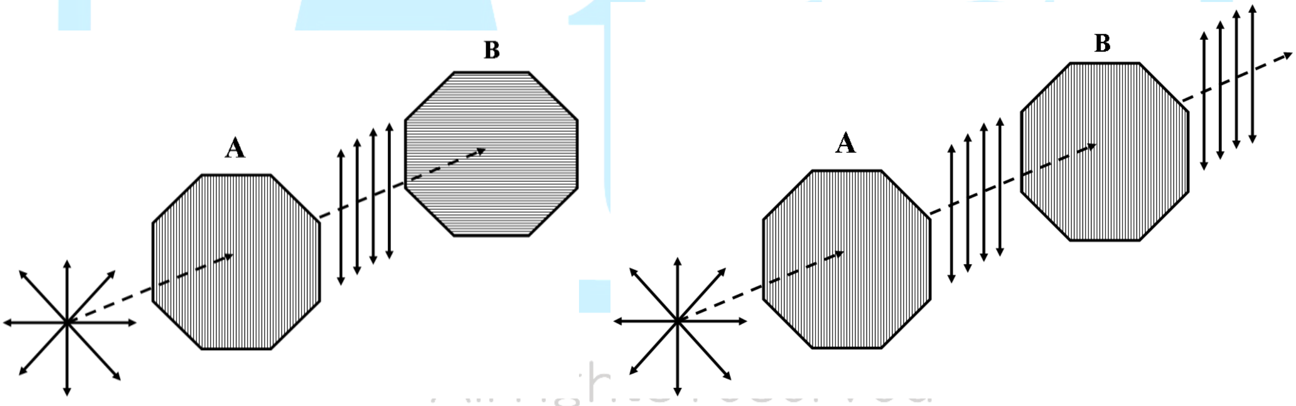

Figure 2

When daylight passes through polarizer A, the light vibration turns into polarized light with direction. Polarizer A converts non-polarized light into polarized light. A polarizer has two asymmetrical axes. The axis that light can easily transmit is axis of easy transmission which is commonly referred to. When the vibration direction of light is vertical to axis of easy transmission, the light will be completely blocked by the polarizer. When polarized light passes through polarizer B which is the analyzer, it will be influenced by its polarized direction and the axis of polarizer B

A. Law of Malus

Non-polarized light oscillates evenly in every direction. However, when it passes through a polarizer, the vibration direction will only consist with the axis direction of polarizer and its intensity will reduced to 1/2. When the polarized light passes through an analyzer and the angle between the vibration direction of light and the axis of easy transmission is θ, the amplitude of polarized light (amplitude A) will become Acosθ. Since the intensity of light is directly proportional to the square of amplitude, the relationship before and after the light passes through the polarizer can be expressed as

$$I_0 \text{ (Intensity of incident polarized light)} \propto A^2$$

$$I \text{ (Intensity after the light passes through analyzer)} \propto A^2 \cos\theta^2$$

$$I = I_0 \cos^2\theta \quad \text{Law of Malus}$$

From the Law of Malus, when the angle θ is zero (θ= 0), all polarized light can pass through the analyzer and their intensities remain unchanged ($I = I_0$). When the angle is 90 degrees (θ= 90), the intensity is zero (I = 0). Thus, when the axis of polarizer is perpendicular to the axis of analyzer, the light cannot pass the analyzer. The angle θ between the polarizer and the analyzer is also the angel between two axes of polarizers. Hence, when non-polarized light passes through the polarizer and the analyzer, the intensity can be expressed as

$$I = 1/2\ I_0 \cos^2\theta$$

B. Polarization of reflective light

In 1808, Malus discovered the method to polarize light. He noticed after light reflected by non-metal surface, reflected light would convert to partial polarized light. By increasing the incident angle to certain degree, all reflected light can be polarized entirely. This angle is Brewster's angle θ_B, as shown in **Figure 3**.

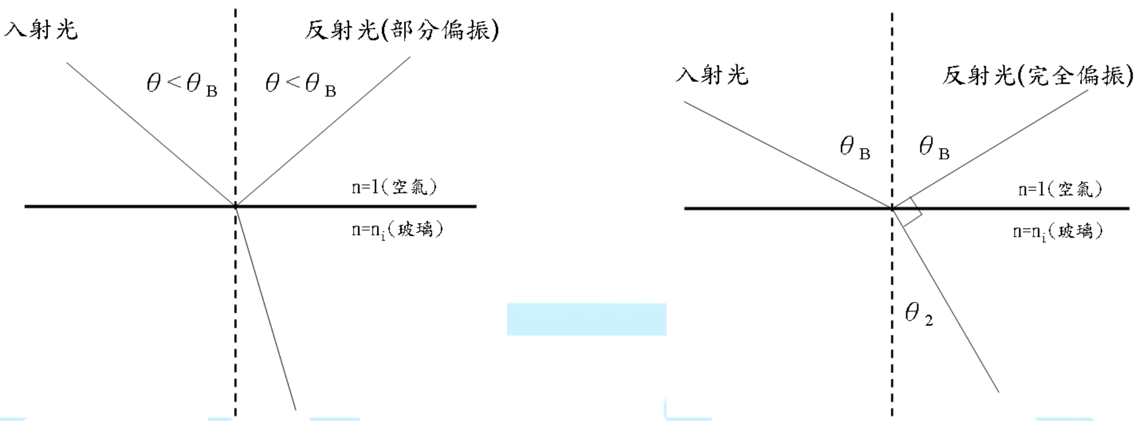

Figure 3

From **Figure 2**, when the reflected light polarizes completely, the reflected light and the refracted light will be perpendicular to each other so we can deduce that

$$\theta_B + \theta_2 = \pi/2$$

$$\sin\theta_B = \sin(\pi/2 - \theta_B) = \cos\theta_B$$

From above equation and Snell's law, we know that

$$n\sin\theta_B = n_i\sin\theta_2 = n_i \cos\theta_B$$

$$\tan\theta_B = n_i/n \quad \text{(Brewster's law,)}$$

Thus, we can use the index of refraction of two mediums to calculate Brewster's angle. For example, in **Figure 3**, the index of refraction of glass is 1.54 and the index of refraction of air is about 1 so the Brewster's angle is $\theta_B = \tan^{-1}(1.54/1) = 57°$.

Instrument

No.	Accessory	Qty	No	Accessory	Qty
1.	Optical slide platform	1	2.	Fixable connector	1
3.	LED light source (with handle) (including power supply 3 DCV)	1	4.	Dimmable gate (with handle)	1
5.	Fixable connector	1	6.	Polarizer (with handle)	2
7.	Movable rotational angle platform (including fixable slide implement *3 holes and glass slide fixer)	1	8.	Glass slide (with binder clip*2)	1
9.	Laser light source (including a laser light source, a light regulator, power supply 4.5DCV, leveling seat and fixed slot) Note: Additional selection		10.	Light sensor (with fixable slot) Note: Additional selection	
11.	Photogate electronic timer (Including power supply 12DCV*1, ISB A-A*1) Note: Additional selection				

		
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	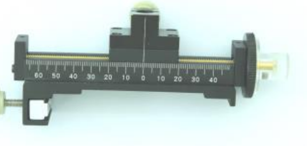	
4.	5.	6.
		
7.	8.	
		
9.		
		
10.	11.	

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