Polarization of Light

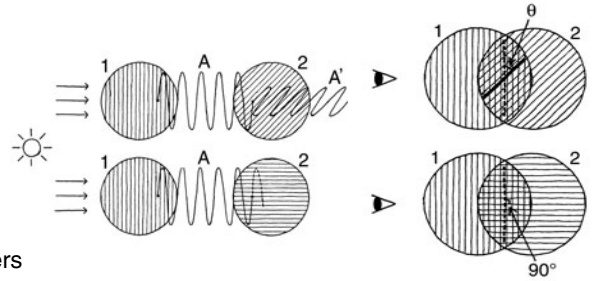
This activity investigates the relationship between reflection, refraction, and polarization of light.

Theory

Light is electromagnetic radiation that has the properties of transverse waves. Sunlight includes transverse waves that oscillate in various directions.
A polarizer allows only light vibrating in a specific direction to pass, which means that sunlight coming out the other side is vibrating in that direction. This is called “polarization of light.” Stacking together two polarizers with their polarization directions oriented perpendicular to each other “extinguishes” the light, which means that no light penetrates the second polarizer.
The expression below represents the change in the amplitude of light passing through the second polarizer. Since light quantity changes in proportion to the square of its amplitude, the light passing through the second polarizer is darker than the original light.

$$A' = A\cos\theta$$

A' : Amplitude of Light Polarized by Polarizer 2
A : Amplitude of Light Polarized by Polarizer 1
$\theta(°)$: Angle of Polarization Direction of Two Polarizers

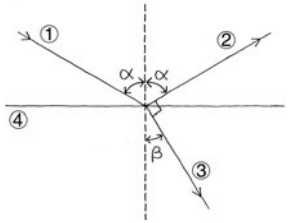


Most light is polarized when it is reflected or refracted by the boundary surface of material where electromagnetic fields meet the required boundary conditions.
Especially at an angle called “Brewster’s angle,” polarization is completely linear, and reflected light and refracted light polarization is orthogonal. The expression shown below defines the conditions that such an angle needs to satisfy.

$$\alpha + \beta = 90°$$

$\alpha(°)$: Angle of Incidence and Angle of Reflection
$\beta(°)$: Angle of Refraction

① Incident Light
② Reflected Light
③ Refracted Light
④ Boundary Surface



Activity: Setup

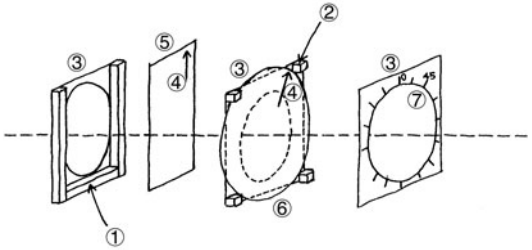
■ Equipment

Polarizers (2) Thick Paper Wood Penlight
Glass Screen Protractor
Optical Measurement Setup (EA-200, graphic scientific calculator, data communication cable, optical probe)

■ Preparing the Polarizers

- Cut holes in three sheets of thick paper, and use the protractor to measure and mark angles on one of them.
- Mark the polarizing direction on the polarizers, and cut out one as a circle.
- Affix the wood frame and blocks to the thick paper, sandwich the polarizer between the two sheets of paper as shown in the illustration.

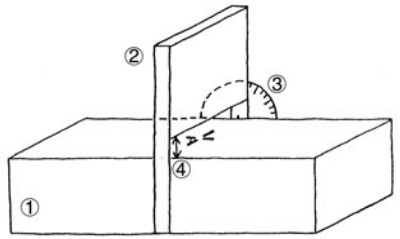
① Wood Frame
② Wood Blocks
③ Thick Paper with Hole Cut Out
④ Arrow Indicating Polarizing Direction
⑤ Removable Polarizer
⑥ Circular Polarizer
⑦ Angle Markings



■ Preparing the Glass Stand

- Fix the screen one centimeter above the glass surface that will be struck by the incident light.
- Affix the protractor in accordance with the screen position.

① Glass
② Screen
③ Protractor
④ Distance Between Screen and Glass Surface: 1cm

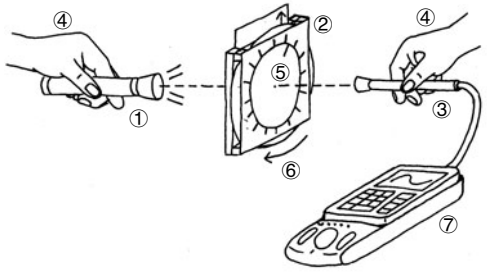


Activity: Operating the Equipment

■ Measuring the Angle of Polarization and the Light Intensity

- Position the optical probe so it is pointing at the penlight and picking up the maximum light intensity.
- Prepare the Optical Measurement Setup and start the measurement. Rotate the polarizer 90 degrees at a constant speed, every 20 seconds.

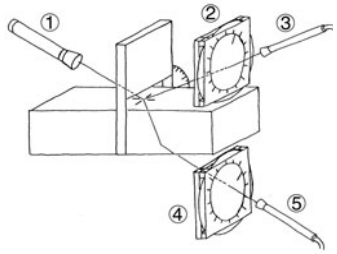
① Penlight
② Polarizers
③ Optical Probe (CH1)
④ Hand
⑤ Polarizing Direction
⑥ Direction of Turn
⑦ EA-200



■ Measuring Brewster's Angle

- The light intensity is displayed on the calculator.
- From an angle determined using the protractor, shine the penlight beam onto the glass.
- Position the optical probe so it is pointing at the light beam and picking up the maximum light intensity.
- Rotate the polarizer until the polarization direction is that where the light intensity is the greatest.
- Measure the polarizing direction of the reflected light.
- Measure the polarizing direction of the refracted light.
- Determine the angle of the penlight beam that satisfies the condition expression of Brewster's angle.

① Penlight
② Polarizer for Reflected Light Measurement
③ Optical Probe for Reflected Light Measurement
④ Polarizer for Refracted Light Measurement
⑤ Optical Probe for Refracted Light Measurement



To obtain an accurate picture of changes in polarizer angle and light intensity, it is a good idea to graph light intensity at various angles.

Measurement

■ Calculator Operation

- Prepare for measurement of light intensity using the optical probe, which will let you determine the angle of polarization.

Using E-CON

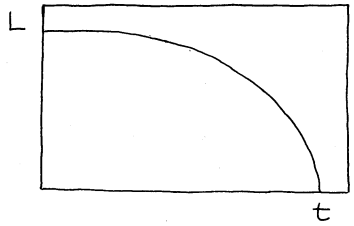
MENU "E-CON" EXE F1 (SETUP) 1 (Wizard) EXE
F1 (CASIO) 3 (Light) 0.1 EXE 200 EXE F1 (YES)

Using a Calculator Program

Find the applicable program in the Program Library (P.2-16-2), input it into your calculator, and then run it.

- This displays a graph that shows changes in light intensity as the polarizer is rotated.

L : Light Intensity
t(s): Time



- Perform the following operation to measure Brewster's angle.
- Find the applicable program (Light Multi Meter) in the Program Library (P.2-16-2), input it into your calculator, and then run it to measure light intensity.

Other Things To Do

- Investigate changes in Brewster's angle using materials other than glass.
- The 3D effect is possible because of the slight difference between how an object is viewed by the left and right eyes. Consider how 3D imaging technology uses the characteristics of light polarization to achieve its effects.