Brewster's Law

Task and equipment

Information for teachers

Additional information

When light is reflected at the boundary surface of two non-absorbing media (e.g., at an air-glass boundary), at a certain angle of incidence α the reflected light is completely plane-polarized. This angle is known as the polarization angle (α_p). The sum of α_p and the complementary angle of refraction β_p is equal to 90°, i.e. if $\alpha = \alpha_p$, the reflected and the refracted ray are at right angles to one another (Brewster's law).
In the course of the experiment the students should verify this law.

Suggestions for set-up and performance

The experimental set-up does not pose any particular problems. The experiment must be performed in a darkened room. However, some students may find it difficult to adjust the optical disc each time so that the light beam falls precisely on the common circle centre of the optical disc and the block. This is a very important condition for finding true values of α_p and β_p.

Always make sure that the polarization filters used have a notch to mark the polarization path.

Remarks

Polarization by reflection can be explained with the aid of Figs. L1 and L2. The molecules in the glass block are excited by the incident light into oscillation direction. Therefore, light which is polarized parallel to the angle of incidence, and which occurs at the angle of polarization α_p, cannot be reflected.

This experiment shows that it is also possible to determine the oscillation plane of plane-polarized light on the basis of reflection from a glass plate.
The values 56° for the polarization angle α_p and 34° for the refraction angle β_p must be considered as examples. It is to be expected that, even when working accurately, the students' results will deviate by a degree or so.

To help the students recognize that the reflected and refracred parts of the light undergo maximum and mutually perpendicular polarization when $\alpha = \alpha_p$ the following supplementary experiment can be carried out:

12 carefully wiped glass plates (microscopic slides, order no. 64691-00) are inserted into a plane mount (order no. 09830-00). These are to be positioned on the slide mount instead of the glass block at $\alpha = \alpha_p$. With the aid of the analyzer it is quite obvious that even those fractions of the light which have undergone 12-fold refraction are highly polarized, and this polarization is in a plane perpendicular to that of the reflected fractions of the light.

When the light is refracted once only from the semicircular glass block, the (partial) polarization of the refracted fraction is hardly noticeable.

The following mathematical problem could help the students towards a better understanding of polarization by refracrion:

When natural light strikes a glass plate in the angle of polarization, under ideal conditions approx. 16% will be reflected, and this is fully polarized. Accordingly, an identical proportion if the light will be transmitted through the glass plate, and this part will be polarized at right angles to the reflected part. Thus 68% of the incident light will emerge from the glass plate in a non-polarized state.

If this 68% in turn strikes a second glass plate which is parallel to the first one, again 16% of that light will be reflected and polarized, and so on.

Calculate what percentage of the light incident at the angle of polarization will be polarized after is has travelled through 10 glass plates.

Solution:

1 glas plate: 32% polarized
2 glas plates: $32\% + 0{,}68 \cdot 32\%$
3 glas plates: $32\% + 0{,}68 \cdot 32\% + 0{,}68^2 \cdot 32\%$
n glas plates: $32\% + 0{,}68 \cdot 32\% + ... + 0{,}68^n \cdot 32\%$

$s_n = 0{,}32 \cdot (1-0{,}68^n)/(1-0{,}68)$
For n = 10:
$s_{10} = 0{,}32 \cdot (1-0{,}68^{10})/(1-0{,}68) = 0{,}32 \cdot (1-0{,}021)/(1-0{,}68)$ ≈0,98

Answer: Approx. 98% of the incident light is polarized when 10 glass plates are used.

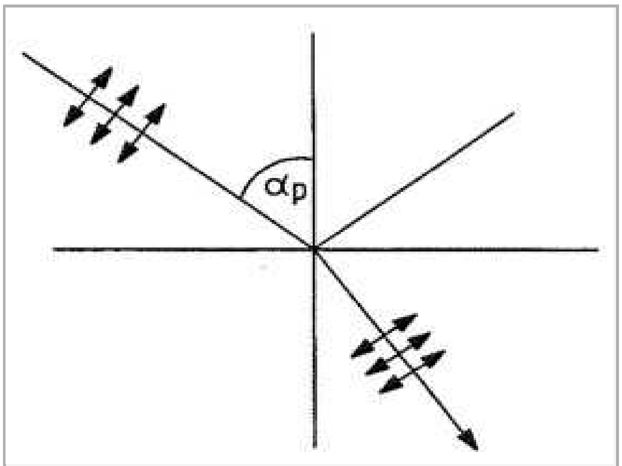


Fig. L1

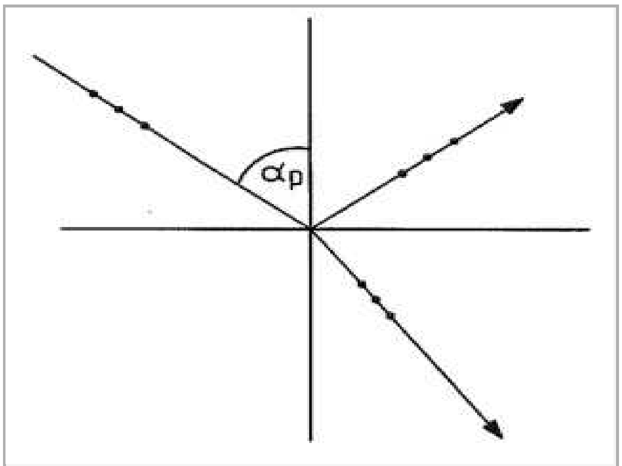


Fig. L2

Fig. L1: Light polarized parallel to the incident plane is not reflected when the angle of incidence is equal to the polarization angle α_p.
Fig. L2: Light polarized at right angles to the incident plane (represented by dots on the ray) is reflected at all angles of incidence.

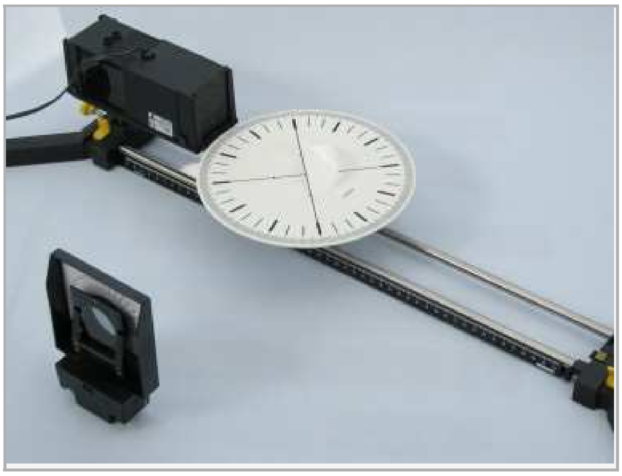
Brewster's Law

Task and equipment

Task

What correlation exists between the angle of incidence and the angle of refraction when the reflected light is completely polarized?

A parallel light beam falls aslant onto a transparent object with a smooth surface. The angle of incidence at which the reflected fraction of the light has undergone maximum polarization is to be ascertained.
This angle of incidence, known as polarization angle (α_p), and the corresponding refraction angle β_p are measured. Afterwards, it is to be investigated which correlations between α_p and β_p exist.



Equipment

Position No.	Material	Order No.	Quantity
1	Light box, halogen 12V/20 W	09801-00	1
2	Bottom with stem for light box	09802-10	1
3	Support base, variable	02001-00	1
4	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
5	Meter scale for optical bench	09800-00	1
6	Block, semicircular	09810-01	1
7	Optical disk	09811-00	1
8	Slide mount for optical bench	09822-00	1
9	Table with stem	09824-00	1
10	Mount with scale on slide mount	09823-00	1
11	Diaphragm holder, attachable	11604-09	1
12	Polarising filter, 50 mm x 50mm	08613-00	1
-	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1

Set-up and procedure

Set-up

- Set up the optic bench with the two support rods and the support base and place the scale in position (Fig. 1 and Fig. 2).


Fig. 1


Fig. 2

- Assemble the light box as shown in Figures 3 and 4 and clamp it into the left part of the support base with the lens end pointing towards the optic bench (Fig. 5).

Fig. 3

Fig. 4

Fig. 5

- Insert the one-slit / two-slit diaphragm into the well in front of the condenser lens of the light box so that only one light beam can pass through it (cf. Fig. 8).
- Position the table on slide mount at 22.5 cm on the optic bench (Fig. 6); do not clamp the table in position.

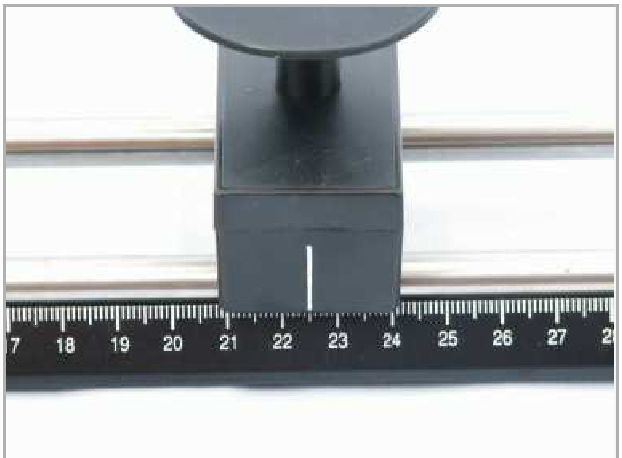


Fig. 6

- Connect the light box to the power supply (12 V~) (Fig. 7) and switch on the power supply.

Fig. 7

Procedure

- Adjust the position of the light box so that the light beam travels across the centre point of the table (Fig. 8).

Fig. 8

- Place the optical disk onto the table with the light beam traversing its centre point (Fig. 9).

Fig. 9

- Place the block on a diameter of the optical disk precisely between two markings so that the circle centres correspond and the light beam strikes the rectangular surface of the block (Fig. 10).

Fig. 10

- Set the angle of incidence to approx. 45° (Fig. 11).

Fig. 11

- Insert a polarization filter into the diaphragm holder (Fig. 12) and attach this to the scale mount (Fig. 13).

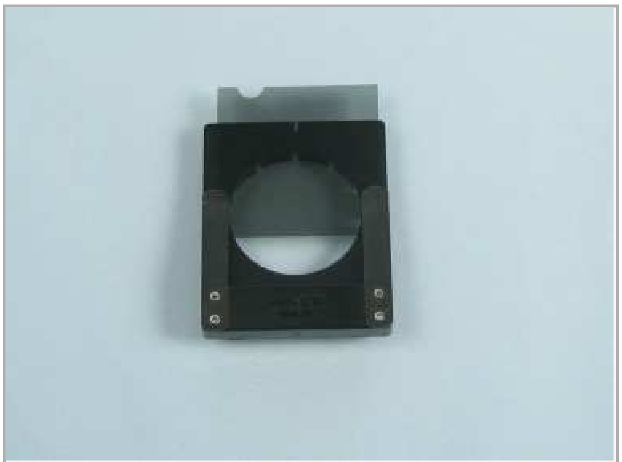


Fig. 12

Fig. 13

- Look through the polarization filter (analyzer) towards the reflected light, i.e. observe the slit.
- Rotate the analyzer until the intensity of the light emerging from it is at a minimum; retain this setting of the analyzer for the rest of the experiment.
- Turn the optical disc to increase the angle of incidence (Fig. 14) and observe the brightness of the slit through the analyzer. (*Hint*: After turning the optical disc, make sure that the incident light still strikes the block in the centre of the disc.)

Fig. 14

- Find the angle of incidence α_p at which the reflected light is polarized to the largest extent; measure and note α_p in the report (Result – Observations 1).
- Note the angle of refraction β_p for this case in the report, too (Result – Observations 1).
- Insert the polarization filter without changing its orientation into the well of the light box (in front of the slit diaphragm to prevent overheating) (Fig. 15). Note your observations of the reflected light and the position of the notch in the polarization filter in the report (Result – Observations 2).

Fig. 15

- Now, rotate the polarization filter by 90° and reinsert it into the well; note your observations in the report (Result – Observations 3).
- Switch off the power supply.

Report: Brewster's Law

Result – Observations 1

Enter the values:

Polarization angle: α_p = ...°
Corresponding refraction angle: β_p = ...°

Result – Observations 2

Note down your observations with polarization filter, without changing its orientation:

....

....

....

....

Result – Observations 3

Note down your observations with polarization filter, with its rotation by 90°:

....

....

....

....

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com

Evaluation – Question 1

Find the sum of α_p and β_p! What do you notice?

Evaluation – Question 2

According to Snell's Law the following formula is valid for refraction:

$$\sin(\alpha) / \sin(\beta) = c_1 / c_2 = n$$

(where: $c_{1,2}$ = velocity of light in adjacent light-transmitting media; n = refractive index).

What does this law say about the case when $\alpha = \alpha_p$?

(*Hint:* Eliminate β_p on the basis of the correlation found above between α_p and β_p.)

Evaluation – Question 3

The speed of light in air is about 300.000 km · s^{-1}. Using the equation derived under Question 2, calculate the speed of light in the block used in this experiment.

....

....

....

....

Evaluation – Question 4

The notch in the polarization filter indicates the oscillation direction. In the light of this information describe the observations under 2 and 3:

....

....

....

....