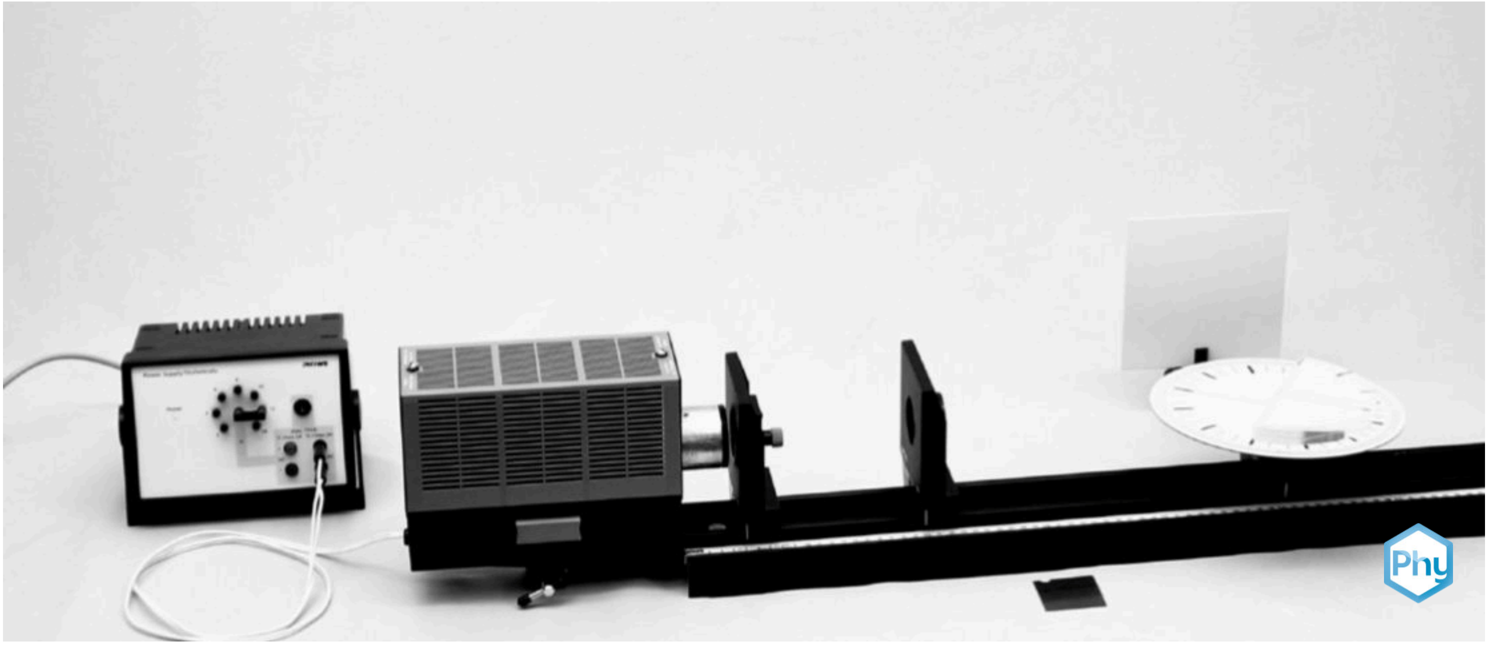
Polarisation by reflection - polarisation angle (Brewster's angle)



The task of this experiment is to determine the polarisation angle (Brewster's angle).

Physics > Light & Optics > Polarisation

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

This content can also be found online at:

http://localhost:1337/c/6492bf2581696d0002732a12

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General information

Application

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The Brewster angle discussed in this experiment has numerous applications in technology. For example, it is used in so-called Brewster windows in gas lasers to minimise losses.

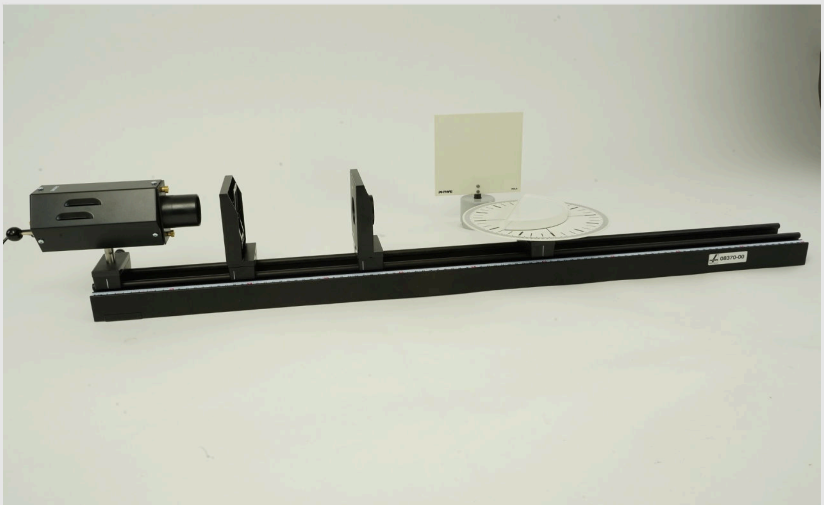

Figure 1: Experimental setup

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Other information (1/2)

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Prior knowledge

Students should have knowledge about the reflection and refraction of light.

Principle

If electromagnetic radiation is reflected from the surface of a dielectric body, the reflected radiation is partially linearly polarised. Complete polarisation of the reflected beam occurs when the refracted beam is perpendicular to the reflected beam. The corresponding angle of incidence is called the polarisation angle or Brewster's angle.

Other information (2/2)

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Learning objective

Students will learn the specifics of the Brewester angle and be able to calculate it.

Tasks

The task of this experiment is to determine the polarisation angle (Brewster's angle).

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Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

Theory (1/2)

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An unpolarized light beam hits the surface of a Plexiglas body at the angle of incidence α and is partly reflected there and partly refracted into the glass body at the angle of refraction b. The angle of the refracted ray and that of the reflected ray are determined as a function of the angle of incidence. In addition, the polarization state of the reflected beam is examined.

According to Snell's law of refraction, the sine of the angle of incidence α to the sine of the angle of refraction β is in a fixed ratio, which corresponds to the refractive index n of the refracting medium.

Snell's law of refraction: $\frac{\sin\alpha}{\sin\beta} = n$.

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Theory (2/2)

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For the special case that the reflected beam is perpendicular to the refracted one, the following applies (see Fig. 2):

$$\beta_p = 180^\circ - 90^\circ - \alpha_p = 90^\circ - \alpha_p \rightarrow \sin\beta_p = \cos\alpha_p$$

From the law of refraction it follows with the previous relationship:

$$\frac{\sin\alpha_p}{\sin\beta_p} = \tan\alpha_p = n\,.$$

The index p indicates that under these conditions the reflected light beam is now fully polarized. α_p is the angle of incidence at which the reflected beam is perpendicular to the refracted beam, the polarization angle or the Brewster angle.

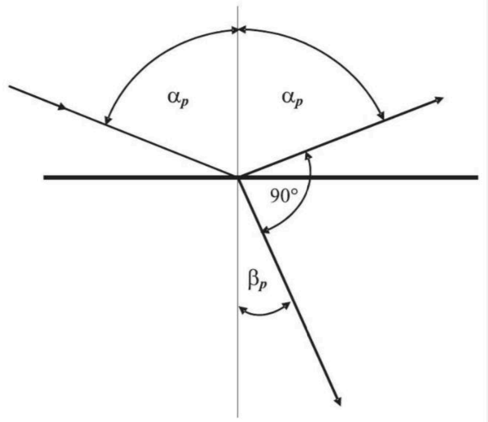

Figure 2

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Equipment

Position	Material	Item No.	Quantity
1	Optical profile-bench, l = 1000 mm	08370-00	1
2	Experimental lamp LED HEX 1	08130-99	1
3	Slide mount for optical bench	09822-00	2
4	Mount with scale on slide mount	09823-00	2
5	Diaphragm holder, attachable	11604-09	1
6	Polarising filter, 50 mm x 50mm	08613-00	1
7	Lens on slide mount, f=+100mm	09820-02	1
8	Diaphragm with slit	09816-02	1
9	Model, semicircular	08374-00	1
10	Optical disk with joint	11604-03	1
11	Screen, white, 150x150 mm	09826-00	1
12	Barrel base expert	02004-00	1

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Set-up and Procedure

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Set-up

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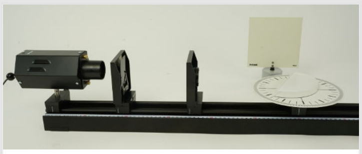

Final experimental set-up with all the necessary components for implementation

The experimental lamp with attached single condenser is inserted and fastened with a horizontal support rod in the front hole of the holder at the head end of the optical bench.

The lamp is to be operated with an AC voltage of $12 volts$. The other components are positioned with their markings on the optical bench as follows:

- Mount with scale with aperture holder and slit aperture at $5cm$
- Mount with scale with converging lens $f = 100mm$ at $20cm$
- Slider for tripod bench with optical disc at $50cm$

The screen is fixed in the barrel base and initially set up approx. $20cm$ from the center of the table at a right angle to the optical bench.

Procedure (1/3)

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With the help of the slider on the lamp housing, the halogen bulb is brought into the focal point of the single condenser. Place the semi-circular Plexiglas body on the table, whose diameter should correspond to the optical axis, so that its flat surface lies exactly over the diameter of the table. The auxiliary line of the body must point exactly to the centre of the table (Fig. 3).

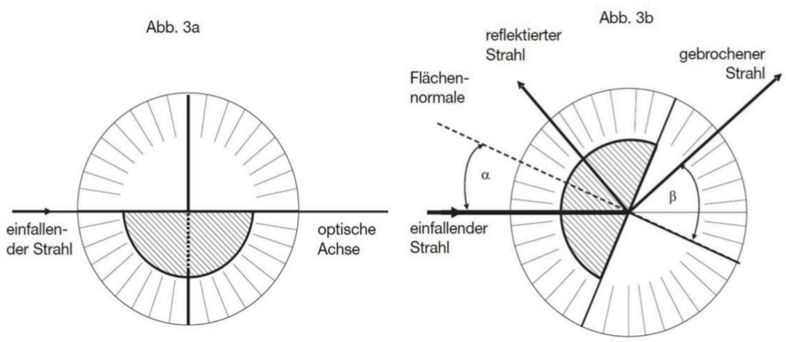

Figure 3a and 3b: Correct position of the Plexiglas body

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Procedure (2/3)

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If you now turn the table a little, the incident, reflected and refracted beam should be clearly visible. By shifting the lens in the direction of the optical axis, you can achieve a sharp image of all three rays. If the incident beam does not hit the center of the arrangement exactly, this can be corrected by slightly horizontally shifting the slit diaphragm in its holder.

Starting at an angle of incidence of $30^\circ < \alpha < 40^\circ$, the polarization filter (analyzer) is brought into the reflected beam by hand and minimum brightness is set on the receiver screen by rotating it perpendicularly around the beam direction. The position of the hole mark, which is used to indicate the direction of polarization of the analyzer, should be noted.

Procedure (3/3)

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By rotating the table, the angle of incidence is now continuously increased. To check the reflected beam, the analyser must be carried along continuously. Its position for the forward direction remains unchanged. If complete darkness appears on the screen, the associated angles of incidence, reflection and refraction should be noted.

Finally, the analyser is brought into the incident beam by hand and also rotated vertically in its direction. The analyser pinhole locations are noted for which the reflected beam shows maximum brightness or maximum darkness.

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Evaluation (1/2)

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As the angle of incidence increases, the intensity of the reflected beam decreases if the analyzer's pinhole mark is horizontal, i.e. if its polarization direction is in the plane of incidence of the light.

With the following angle constellation, the reflected beam is completely extinguished:

Angle of incidence/exit $\alpha_p = 56^\circ$; Angle of refraction $\beta_p = 34^\circ$, i.e. reflected and refracted rays are perpendicular to each other. In this case, the reflected beam is fully polarized with its vibration direction perpendicular to the plane of incidence.

The following then applies to the refractive index of the Plexiglas body: $\tan 56^\circ = n = 1.48$.

The refractive index also reflects the ratio of the speeds of light of the media involved in refraction. $n = c_L / c_{Gl}$ if c_{Gl} is the speed of light in Plexiglas and c_L is the corresponding one in air. Thus the speed of light in Plexiglas is: $c_{Gl} \approx 202000 km/s$.

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