Total reflection and the critical angle

Physics > Light & Optics > Reflection & refraction of light

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/631b11d0bce9830003710df4

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Teacher information

Application

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Refraction at the transition from glass to air

In optics, the phenomenon of total internal reflection is when a light beam is completely reflected at the interface of two media and there is no transmission. This type of reflection only occurs at a certain angle, the so-called critical angle.

Total internal reflection can be observed particularly well in the transition between a transparent medium such as water or glass and air.

One application of this is, for example, optical fibres in the form of glass fibre cables. These can transport information almost loss-free up to 20,000 metres.

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Other teacher information (1/4)

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Prior knowledge

Students should have previously learned the basics of straight-line propagation and reflection of light. The concept of a perpendicular should be known.

Principle

The light is refracted at the transition from an optically thinner to an optically denser medium (a reverse transition is also possible). Total reflection occurs when the light from an optically denser medium hits the interface to an optically thinner medium.

Incidence and the angle of incidence is greater than the critical angle.

Other teacher information (2/4)

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Learning objective

With total internal reflection, the student learns about an important special case of the law of refraction in the transition of light from the optically denser to the optically thinner medium, which is of great importance for technology (fibre optic cables).

Tasks

In this experiment, the students should first observe the well-known phenomenon of refraction when light passes from glass into air, but also turn their attention to the area inside the model body and thus to the increasing reflection of the light. In the further procedure, they observe and examine the case more closely when the light hits the glass-to-air interface at the critical angle of total reflection.

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Other teacher information (3/4)

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Note

The student's attention can be drawn to the dispersion of refracted light observable at angles of incidence close to the critical angle.

Other teacher information (4/4)

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Notes on set-up and procedure

The success of the experiment and, in particular, the exact determination of the critical angle depend decisively on a careful adjustment of the experimental setup (0° method) and an exact incidence of the light in the direction of the plumb bob. The model body should lie on the optical disc with the roughened side facing downwards so that the light path inside the body is visible.

If necessary, the teacher should provide assistance in finding the critical angle, as experience has shown that students are very quick to let the light fall beyond the critical angle.

Another possible aid is the use of a small, white piece of paper which is held perpendicular to the optical disc in the beam path of the refracted light beam and on which this creates a light spot.

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Safety instructions

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

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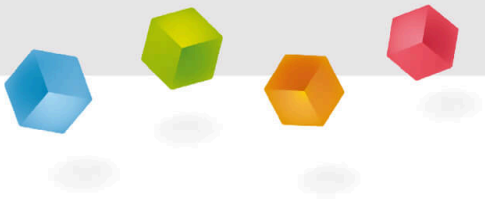

Student information

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Motivation

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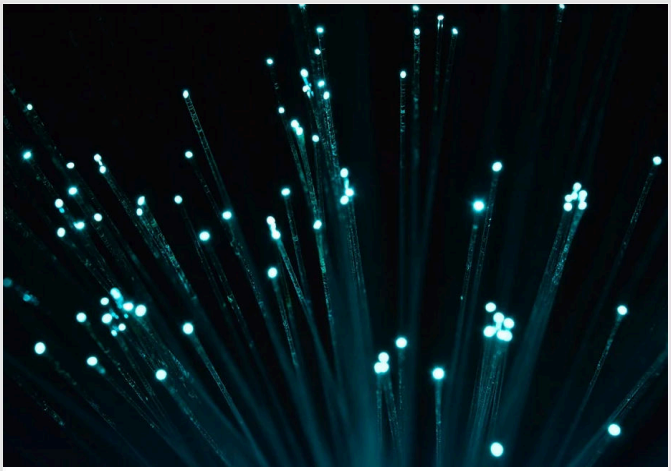
A special form of reflection is the so-called total reflection. It occurs when light hits a boundary surface at a certain angle, the critical angle. Almost all of the light is reflected and no light enters the medium.

This phenomenon takes place in optical fibres or fibre optic cables, for example. With the help of this, information can be transported up to 20,000 m almost loss-free.



Total reflection in light guides

Task

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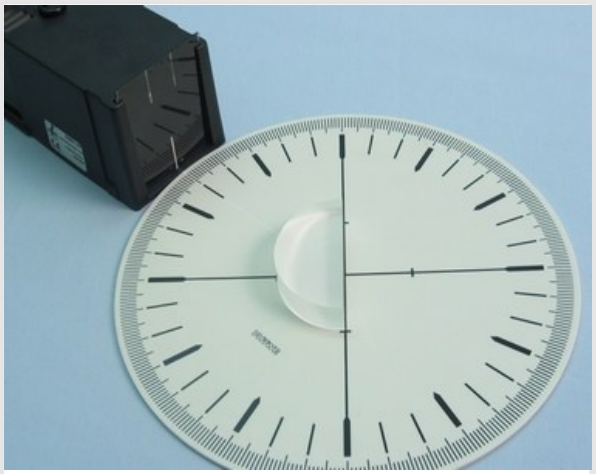

Experimental setup

What is meant by total internal reflection?

Investigate the behaviour of narrow beams of light when light passes from glass into air when the angle of incidence is greater than 40°.

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Equipment

Position	Material	Item No.	Quantity
1	Light box, halogen 12V/20 W	09801-00	1
2	Block, semicircular	09810-01	1
3	Optical disk	09811-00	1
4	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1

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Set-up

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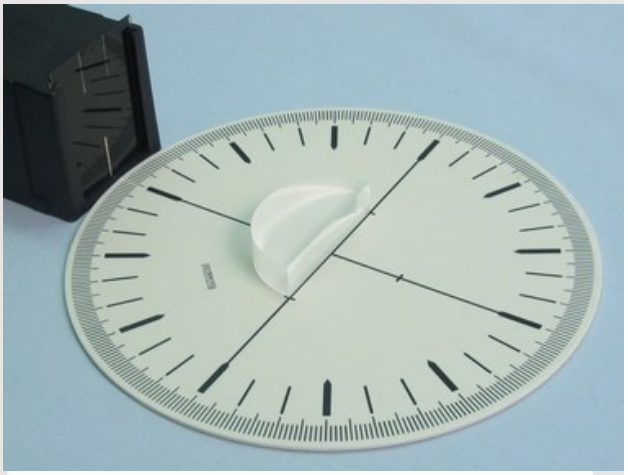
Attention!

Make sure that the narrow beam of light coming from the light box always runs exactly in the direction of the centre of the optical disc (to the plumb bob point) and that the model body does not change its position when the light box is moved.

- Place the optical disc in front of you on the table and place the semi-circular model body (with the roughened surface facing downwards) within the marks on the vertical line.



Experimental setup

Procedure (1/5)

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- Place the light box with the slit diaphragm on the lens side opposite the model body. The semicircular side of the model body and the light box face each other.

- Connect the light box to the power supply unit (12 V ~).

Commissioning the power supply unit

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Procedure (2/5)

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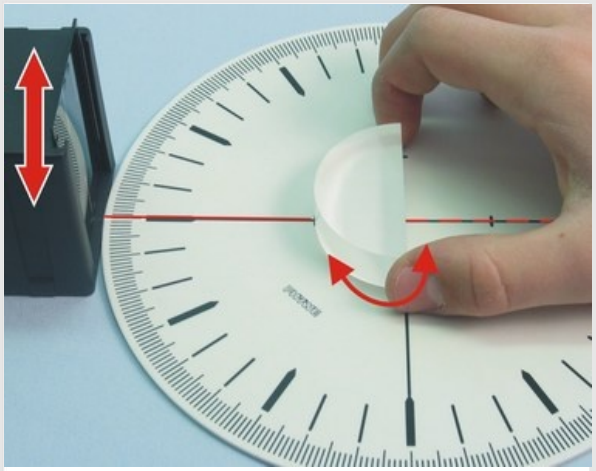

Adjusting the beam path

- Adjust your experimental set-up so that a narrow beam of light incident along the optical axis continues along the optical axis after passing through the glass.
- Now move the light box until the light falls on the model body at an angle of 35°.
- Observe the behaviour of the narrow beam of light after it has passed through the model body when it hits the glass-air interface. Write down your observations.
- Measure the angle of refraction β and note the measured value as well.

Procedure (3/5)

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Turning the light box

- Now move the light box until the incident light beam encloses the angle of 40° with the incidence slot.
- Observe the behaviour of the narrow beam of light when it hits the interface between glass and air (especially the area inside the model body). Write down your observations.
- Measure the corresponding angle of refraction β and note the measured value.

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Procedure (4/5)

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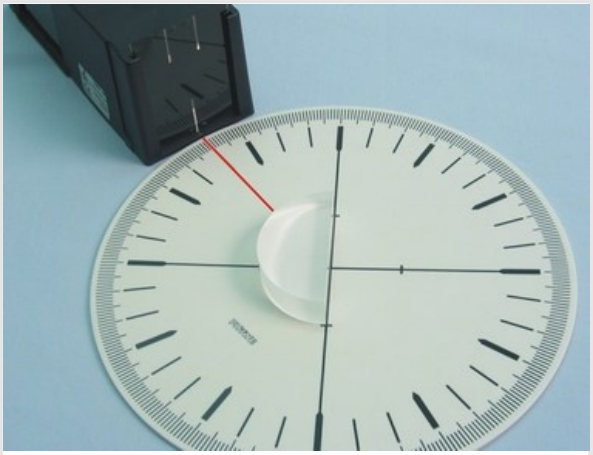

Moving the light box

- Increase the angle of incidence by carefully moving the light box and observe the course of the refracted light beam and the area inside the model body. Make a note of your observations.
- Measure the angle of incidence α and the angle of reflection exactly when the angle of refraction is just β = 90°. Write down your observations and your measurements.

Procedure (5/5)

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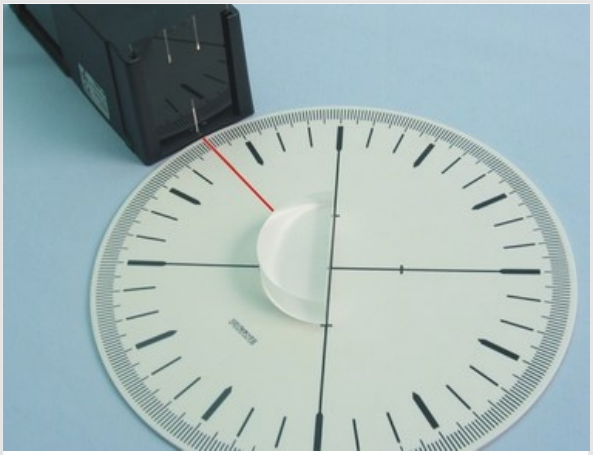

Moving the light box

- Now move the light box until the incident light beam makes an angle of 50° with the incident slot. Observe and note your results.
- In this case, measure the angle between the reflected light beam and the incidence slot and note the measured value again.
- Switch off the power supply unit.

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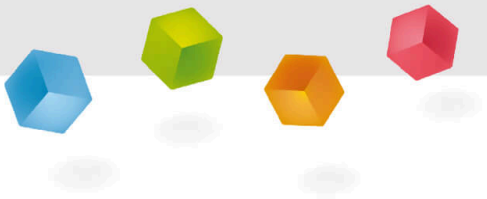

Report

Task 1

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Using your observations and measurements, describe how narrow beams of light behave when they strike a glass/air interface when the angle of incidence is $\alpha < 42°$.

The incident light beam is completely reflected at the interface between glass and air and continues in the model body. Total reflection occurs.

The incident light beam completely penetrates the glass-to-air interface and is refracted away from the perpendicular.

The incident light beam is split at the interface between glass and air. Part of the light passes through the interface and is refracted away from the perpendicular. The other part is reflected at the interface and continues in the model body.

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Task 2

PHYWE

Using your observations and measurements, describe how narrow beams of light behave when they strike a glass/air interface when the angle of incidence is α = 42°.

The incident light beam is split at the interface between glass and air. Part of the light travels exactly along the interface (refraction angle β = 90°). The other part is reflected at the interface and continues in the model body.

The incident light beam completely penetrates the glass-to-air interface and is refracted away from the perpendicular.

The incident light beam is split at the interface between glass and air. Part of the light passes through the interface and is refracted away from the perpendicular. The other part is reflected at the interface and continues in the model body.

Task 3

PHYWE

Using your observations and measurements, describe how narrow beams of light behave when they strike a glass/air interface when the angle of incidence is α > 42°.

The incident light beam is split at the interface between glass and air. Part of the light travels exactly along the interface (refraction angle β = 90°). The other part is reflected at the interface and continues in the model body.

The incident light beam is split at the interface between glass and air. Part of the light passes through the interface and is refracted away from the perpendicular. The other part is reflected at the interface and continues in the model body.

The incident light beam is completely reflected at the interface between glass and air and continues in the model body. No more refraction occurs.

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Task 4

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The phenomenon you observed is called total internal reflection. Under what conditions does it occur? Judge whether the following statement is true or false.

Total internal reflection occurs when light from an optically thinner material (air) is incident on the interface with an optically denser material (glass) and the angle of incidence is less than a certain angle (critical angle).

○ True ○ False

Check

Task 5

PHYWE

Why does an asphalt road seem to be wet in the distance on warm summer days when looking at the road from a car? Fill in the blank.

The air in the immediate vicinity of the asphalt road is strongly _____ and is thus _____ than the _____ layer of air above it. With a very _____ incidence of light, the condition for _____ is thus fulfilled. The sunlight is reflected at the _____ and reaches the eye of the observer, who thus gains the impression of having a reflecting water surface in front of him in the distance.

heated
total reflection
slanting
optically thinner
boundary layer
colder

Check

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Task 6

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What are applications of total internal reflection?

- [ ] Headlights
- [ ] Fibre optic cable
- [ ] Light guide cable
- [ ] Mirage
- [ ] Prism binoculars

Check

Additional task

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With the help of the law of refraction and the reversibility of the light path, try to give a reason for the occurrence of total internal reflection. Fill in the blanks.

If the light hits the _____ air to glass, the _____ cannot take on larger values than 90°.
This also means that _____ larger than 90° cannot occur if the light path runs in the opposite direction. The _____ from which a total reflection of the light occurs is therefore the one at which the refracted light beam just touches the interface between glass and _____.

border angle
air
refraction angles
interface
angle of incidence

Check

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Slide	Score / Total
Slide 19: Behaviour at angles of incidence <42°.	0/1
Slide 20: Behaviour at an angle of incidence of 42	0/1
Slide 21: Behaviour at an angle of incidence >42	0/1
Slide 22: Conditions for total internal reflection	0/1
Slide 23: Causes for an "apparently" wet road	0/6
Slide 24: Applications of total internal reflection	0/4
Slide 25: Cause of total internal reflection	0/5

Total 0 / 19

Solutions Repeat

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