Polarization by dispersion

Task and equipment

Information for teachers

Additional Information

A parallel beam of light which passes through an entirely clear medium cannot be seen in the plane perpendicular to the optical axis, but it does become visible if the medium is or becomes cloudy. In this case, parts of the light are dispersed from the small particles. This phenomenon is known as the Tyndall Effect after the Irish physicist, John Tyndall (1820 - 1893), who investigated it first in 1868. The particles which bring about the cloudiness of the medium act as dipoles which are excited and then emit light themselves. This light oscillates in planes which are perpendicular to the oscillation planes of the light passing straight through the cloudy medium.
The students should isolate the Tyndall Effect in the course of this experiment. They should recognize that the dispersed light is polarized and why, and that the light which traverses the medium is not polarized.
They should also understand why with increasing cloudiness the dispersed light becomes visibly bluer and the light passing through the medium takes on a yellow to yellow-red coloration.

Suggestions for Set-up and Performance

For this experiment the laboratory must be as dark as possible. Milk particles are comparatively large. For this reason it is possible that the students will not detect the blue coloration of the dispersed light without a hint from the teachor, as it is not very intensive.
More convincing results can be achieved by dissolving colophonium in methylated spirits (e.g., 1 g colophonium in 20 cm^3 meth. spirit) and adding this solution to the water drop by drop. In this way the blue parts of natural light are more strongly dispersed and the colour difference between passing and dispersed light will be greater. The disadvantage of using colophonium, however, is that it tends to precipitate out and clour the glass beakers used.
It is important that the polarization filters used are notched to mark the direction of polarization.

Remark

The dispersion of the light, and hence the colour difference between dispersed and non-dispersed parts of the light, become clearer, the smaller the particles which bring about dispersion are. Therefore, the sky appears especially blue when the air is very clear. When this is so, the atmosphere contains mainly very small particles which hardly cloud it and so disperse the light particularly well.
We have recommended using the blue filter at the end of the experiment because it demonstrates conclusively the predominant dispersion of the blue parts of the spectrum and the resulting blue coloration of the dispersed light, which were not so clearly visible before.

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Task

Why does a cloudless sky appear blue in daylight, and is this light polarized?

Direct a beam of light through water, adding a substance to make it increasingly cloudier.
At the same time observe the colour of the emergent light and of the visible fraction of the light which is perpendicular to the optical axis, and investigate whether these fractions are polarized.

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	Colour filter set, additive (red, blue, green)	09807-00	1
6	Diaphragm with hole, d=20mm	09816-01	1
7	Lens on slide mount, f=+50mm	09820-01	1
8	Slide mount for optical bench	09822-00	2
9	Mount with scale on slide mount	09823-00	1
10	Screen, white, 150x150mm	09826-00	1
11	Polarising filter, 50 mm x 50mm	08613-00	1
12	Glass beaker DURAN®, short, 250 ml	36013-00	1
13	Diaphragm holder, attachable	11604-09	2
14	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
Additional material			
	pipette		1
	a bit of milk		

Set-up and procedure

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

Fig. 1

Fig. 2

- Assemble the light box according to Figures 3 and 4 and clamp it into the left part of the support base with the lens end pointing away from the optic bench (Fig. 5). Insert the light-tight diaphragm into the well in front of the lens (Fig. 6). Clamp the screen into the right part of the optic bench (Fig. 7).

Fig. 3

Fig. 4

Fig. 5

Fig. 6

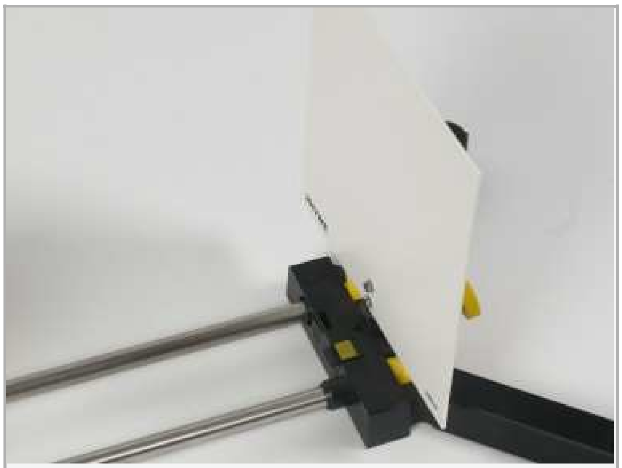

Fig. 7

- Position the lens with *f* = +50 mm directly next to the light on the optic bench and attach the diaphragm holder with the inserted hole diaphragm to the lens mount (Fig. 8).

Fig. 8

- Fill the beaker with approx. 250 ml water and place on two slide mounts about 10 cm away from the lens with the beaker marking pointing to the back (Fig. 9).

Fig. 9

- Connect the light to the power supply (12 V~) and swith on the power supply (Fig. 10).

Fig. 10

- Add milk in stages to make the liquid progressively cloudier: to do this, dip the drinking straw just a few mm into the milk and stir the adherent milk into the water (Fig. 11).

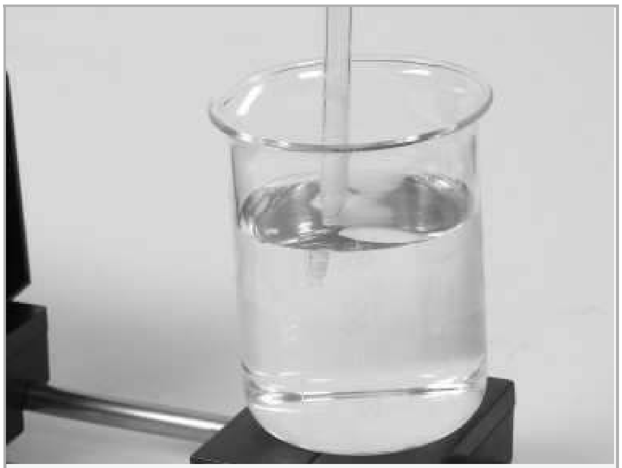

Fig. 11

- After each stage observe the colour of the light spot on the screen and the colour of the light which is visible in a plane perpendicular to the optical axis; then investigate the polarization of the emergent and perpendicular light by briefly removing the screen and looking towards the light through the analyzer (Caution: Avoid dazzle!)
  Remark: To investigate that part of the light emerging at right angles to the optical axis you should look at it through the analyzer not only from the front, but also, for instance, from above.
- Note your observations in the report (Result – Observations 1).
- Now look at the light beam in the cloudy water from above without the polarization filter, paying attention to the coloration of the light beam along its path; note your observations in the report (Result – Observations 2).
- Insert the blue filter into the light well; observe the diffused light and the light spot on the screen (Fig. 12). Note your observations in the report (Result – Observations 3).

Fig. 12

- Switch off the power supply.

Report: Polarization by dispersion

Result – Observations 1

Note down your observations during the first part of the experiment:

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Result – Observations 2

Note down your observations from above without the polarization filter:

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Result – Observations 3

Note down your observations with blue filter:

Evaluation – Question 1

It is possible to observe the beam of light in cloudy water from the side. This is due to the fact that it is partially dispersed. Summarize your observations using the concept of dispersion.

Evaluation – Question 2

Answer the question put at the beginning in the light of the knowledge you have gained from the experiment:
Why does a cloudless sky appear blue in daylight, and is this light polarized?

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Evaluation – Question 3

Weather allowing, verify your answer by looking at the blue sky through a polarization filter set as near as possible at right angles to the incident sunlight and then rotating the filter (analyzer).
What do you observe?

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Evaluation – Question 4

Now attempt to explain how a red sunset comes about.

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