IAPS
IYL School Day Guideline

6. November 2015

Contents

1 Introduction

The Executive committee of IAPS has organised an international IYL School Day on 10. November 2015 in accordance with the International Year of Light. On this day it is anticipated that students/ PhD students all over the world go into schools or invite pupils and teach them physical aspects of light.
One of the goals with this international event is to make more pupils interested in physics. So far more than seven countries which participate in the event are know to the EC With this document we want to raise the number. We hope that you get inspired by the ideas of other members and that the organisation gets easier with its help.

2 Thanks

The IAPS EC wants to thank everyone who either helped in completing this document or participates in the IYL School Day. We hope to encourage even more groups to participate as well. And by allowing us to use your ideas you did a great deal with helping.

3 An example school class

This is taken from the guideline made by NC Germany.

Here we want to present a class with prepared experiments. Of course you are free to adapt the class and the experiments. The class is designed for the following conditions:

- age of the pupils: approx. 15 years old
- duration: 90 min
- number of pupils: approx. 30
- number of experiments: three, each of which is prepared twice so that the pupils can work in smaller groups.

The experiments are planned for five pupils and 15 minutes each. The following schedule gives an overview of how the class could be held:

Time	What
5min	Introduction: Who are you? Introduce yourself and your association. This could be done orally or with a short (!) power point presentation.
5-10min	Introduction of the topic: What is light? Here the aim is to introduce the topic and to motivate the pupils. You could for example create a mind map of "Light" and collect everything the pupils connect with this word. In this way you can also get a feeling what the pupils already know about this subject.
15 min	Demonstration experiment: Interference on CD see the experiment description in section 4.2 for further instructions.
45 min	Group work In total there are three rounds of 15 min each such that everybody can try out each experiment. Here it is important to prepare the experiments beforehand to not lose time for this during class. The pupils have to be divided in groups of five – think about how you want to do this (cards, let the pupils do this themselves etc.). Instructions for the three experiments can be found in the worksheets on 8.
10 min	Finish End the class by summing up the experiments. If you wish you can also advertise upcoming events of your association that might be interesting for the pupils.

4 Experiments

4.1 Contributed by AISF (NC Italy)

4.1.1 Pinhole camera

The students will build a pinhole camera out of a shoe box. One of the short sides of the box will be replaced by a photographic paper sheet, while on the opposite side a hole will be pierced. The students will be encouraged to discuss and think why the image projected through the hole onto the paper is reversed.

4.1.2 Photoelectric effect

The students will build a simple electroscope with a tin can and aluminum foil. The electroscope will be charged with a balloon and UV light will then be shone on it. The students will notice that this will discharge and will be explained the physical phenomenon.

4.1.3 Lenses

Properties of lenses will be studied by means of a laser beam. The focal length will be estimated by means of the lens equations.

4.1.4 Solar oven

A simple solar oven will be built with two boxes. The innermost will be painted in black while the outermost will be covered with aluminum foil. One of the sides will be replaced with transparent foil so that light can be shone through. As a demonstration, a piece of chocolate will melt.

4.1.5 Measure of the width of a hair

This experiment will allow to measure the width of a human hair by exploiting diffraction. A laser beam will be pointed at a hair so that the resulting diffraction pattern can be visible on a free wall. By measuring the distance between the hair and the wall and between the diffraction peaks, the width of the hair can be obtained.

4.1.6 Measure of the speed of light with a microwave oven

A microwave oven will be used to cook a chocolate bar for 10s. Two cooked areas will appear on the bar in correspondence of the maxima of the standing waves produced in the oven. Measuring their distance it is possible to obtain the speed of light. The concept of standing waves will be explained.

4.1.7 Music transmission by light

A radio will be suitably modified to transform the signal into light modulation. Light will be then captured by a distant solar panel and transformed back to sound by loudspeakers.

4.1.8 Measure of the curvature of light

The curvature of light will be shown in two ways. Firstly, by using a bottle of water and piercing a hole at the bottom. Pointing a laser beam at the suitable angle, light will totally refract in the water and follow the outgoing stream. Secondly, by using a supersaturated mixture of water and sugar, it will be possible to notice that light will bend due to the increasing refraction index.

4.2 Contributed by jDPG (NC Germany)

NC Germany also created some worksheets that can be used in class. Please see section A for the papers.
A demonstration experiment
Required items are:

- 1 common CD
- 1 laser beamer
- 1 light bulb
- 1 circular aperture (pinhole)
- optional: ruler, tape measure

4.2.1 Getting started

Depending on what will have been discussed already during the introduction, you will have more or less time for the demonstration experiment by virtue of explaining additional theory (especially if interference was taught before). If you want, you can smoothly direct the students' discussion to that topic during introduction. To explain interference in a phenomenological way, you can use clips[1] from the Internet, where superposition of waves and the effect of standing waves can be seen. Reflexion.exe[2] is highly recommended, because you can start, stop and speed up/ down the animation by yourself (unfortunately it is in German but there should be an English version, too ;)). With this program constructive and destructive interference can be observed. The first will occur, if the phase difference of two waves is a multiple of 2π wave crests meet wave crests and troughs meet troughs (the resulting amplitude is the sum of the individual amplitudes). Destructive interference is given for a phase difference being an odd multiple of π crests meet troughs and the resulting amplitude is zero. You should explain that with the clips or by drawing sketches on the blackboard.

4.2.2 Laser beamer

Experimental setup: You can use two different setups, depending on the material you got. It is of advantage to prepare the setup (including adjustments) before class to save some time.
Explanation: This experiment is equivalent to experiments showing interference patterns behind a lattice. The only difference is the fact that the light doesn't go through the aperture and gets deflected but gets reflected instead. Thus, a phase difference between adjoining beams due to different path lengths will be given. If the phase difference is an integer multiple of the wavelength, the two waves interfere constructively and you will see a maximum. But pay attention to the second version where you get a phase difference twice! Once on the way to the CD and once on the way back from it. To get the actual phase difference, you have to subtract them from each other. That's why the first version probably is more advisable for students.

4.2.3 Suffix (for higher classes and if you have enough time)

If trigonometry was already discussed you can calculate the distance between the CD gutters. You need to measure the distances between light spots. Establish the trigonometric relation between the phase difference $\Delta\lambda$ and the angle *alpha* to get the following rules:

Version 1	Version 2
$g\Delta sin\alpha = k\Delta\lambda$	$g\Delta(cos\beta_k - cos\beta_D) = k\Delta\lambda$

where $\beta_{k,D}$ are complementary angles to α. It is way easier to measure those.

Measure the distance: By measuring the distances and with the help of the used wave length, you can calculate the gutters' distance (analogously to calculations of a lattices' slit width). It is recommended to measure just the distance between the maxima (maybe a student can do this?). The distance between CD and screen can be obtained beforehand.
Calculation of the gutter distances: Next, use the established formula and the measured values to calculate the gutter distance. Compare the solutions with the specification ($1.6\mu m$) and make size comparisons (e. g. human hair $100\mu m$, regular sheet of paper $80\mu m$).

4.2.4 Continuous spectrum

This is probably more easily understood, because most people have already seen prismatic colors on the back side of a CD. Replace the Laser by a light bulb, which results in different maxima for each wave length and leads to different distances on the screen. This part is only for demonstration, but you should explain that the prismatic colors only get visible due to wavelength dependency for constructive interference.

[1] http://www.ibs-akustik.de/Projektbeispiele/ProjektLaerm/LaermBeispiel$_7$/image001. gif, http://www.sengpielaudio.com/ANStehendeWelle.gif
[2] http://www.ebg.tue.bw.schule.de/projekte/p$h_o$bers/programme/Reflexion$_m$fm.exe

4.3 Contribution by Macedonian Society of Physics Students (NC FYR Macedonia)

4.3.1 The law of refraction

Using a laser, some diluted water, a rectangular water tank and dry ice, will show the students the main geometric properties of light, in this case, showcasing the law of refraction. The laser will be shot by and angle on to the water's surface. There will be two angle rulers placed on the tank, one to measure the angles of the incident and the reflected beam, and the other for the refracted beam. This way, the students will see that the formula 1 really is true.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \tag{1}$$

4.3.2 Lensing and curving effects on light

Using several laser-pointers, we will show how spherical mirrors and lenses actually bend and change the direction of a beam of light. Also we will take three lasers to represent the three characteristic beams that are used in high-school level Optics drawings and diagrams. We will use a few rulers to measure the distance from the source, the image and the focal length of the lens/ mirror to confirm the geometric equations of the given object.

4.3.3 Virtual and real images

We will exhibit a fun experiment where we show the difference between a real and a virtual image, produced by convex mirror and a burning candle.

4.3.4 Prism and the spectrum

Now, the plot thickens. Up until now, the students have seen light only as geometrical collection of beams that travel in a straight line. By shining white light (sun light) through a prism, they will see that white light is a collection of many smaller light beams of different colors (wavelength) and this will produce the visible spectrum.

4.3.5 Waves on the water

With this experiment, we will try to explain interference and dispersion using transversal waves on the surface of water. A wave generator (parallel or spherical) will be placed in a shallow water tank. By placing a blockade with one, two and several holes in it, the students will be able to see what happens to the waves.

4.3.6 Young's interference experiment

Now we will correlate the previous experiment of water waves interfering with each other with that of light. With this experiment, the students will see the interference scheme of monochromatic light and its similarity to that of water waves.

4.3.7 Diffraction pattern of a circular aperture

A diffraction pattern of white light will be produced.

4.3.8 Schlieren photography

Schlieren imaging is a method to visualize density variations in transparent media. Schlieren imaging of a focusing ultrasonic transducer In particular, the term "Schlieren imaging" refers to the implementation of Schlieren photography to visualize the pressure field produced by ultrasonic transducer, generally in water or in other tissue-mimicking media] The method provides a two-dimensional (2D) projection image of the acoustic beam in real-time

4.3.9 Diffraction due to helical structure and surface tension waves on water

It is an experiment that was given as an assignment for the students in the 46th International Physics Olympiad in Mumbai, India.

4.4 Contribution by the Student Section of the Croatian Physical Society (NC Croatia)

4.4.1 Polychromatic vs. monochromatic light

Using a prism, kids will first discuss that the light we see is polychromatic and will get to see monochromatic light. With second prism the monochromatic light can again assemble polychromatic light. We will also make Newton's colour wheels.

4.4.2 Lens

Kids will see plain and curved mirrors, convergent and divergent lens, as well as some real-life examples (rear-view mirrors). There will also be a set-up of a mirror in a box so kids can pretend they are flying (excellent photo-op). We will also show Fresnel lens.

4.4.3 Light technologies

Kids will see shade and half-shade, and reflection of light. This will be done with models of Sun and Earth. We will also show how light travels in optical fibers with an experiment (laser and pouring water).

4.4.4 Radiation and absorption

Kids will discuss radiation and absorption through one question "Why should we wear white in summer and black in winter?" We will measure the absorption of light from a lamp on white and black papers.

4.5 Other experiments

In the following additional experiments are listed (without a description) which can be easily realized an explained. They are taken from website of the German Physical Society[3].

- Adaptive color mixing
- Deflection on a single slit
- Deflection rings of a candle
- Camera Obscura
- Chromatography
- Self-made magnifying glass
- A remote control
- Jelly and its features of transmitting light
- Graffiti of light
- A liter of light

The official website of the International Year of Light[4] lists many interesting videos and links to other websites that inform about light.

[3] http://www.dpg-physik.de/dpg/gliederung/junge/rg/freiburg/year$_o f_l$ight/alle-nup.pdf
[4] http://www.light2015.org/Home/HandsOnInvolvement/Kids-and-Optics.html

5 Other ideas

Apart from going into schools and teaching a class about light and light based technologies you can organise many different types of events as well.
Some groups invite school classes to their universities. There a lecture is held, experiments shown and maybe even alb tours are organised. Other psooibilities are seminars or trips. But this document does not by far list all potential events.

5.1 Contributed by METU Physics Society (LC Ankara)

Laser Maze Tournament: Laser Maze is a board game which is very familiar with chess. Lights and mirrors may make it feel like magic, but it's really science and a good dose of brain power that's needed to direct the laser beam through this series of mind challenging mazes.

A Worksheets

The following pages are taken from the guideline by NC Germany.

B. Worksheet Visible Spectrum

B.1. Experiment 1: Decomposition of light using a prism

Material:

- light bulb with power supply
- single slit aperture
- glass prism
- screen (you can use a white sheet of paper, folded to stand upright)

Setup:

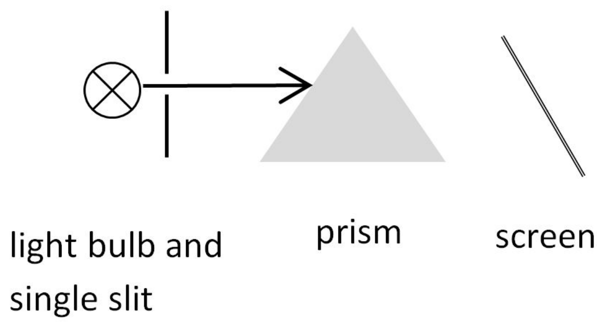


Figure B.1: Setup.

Observations: Switch on the light bulb. What do you see on the screen? Draw a picture of your observation!

Evaluation: As you have seen, light is refracted to a different extend depending on its colour. In simple terms: If there is light of every colour, we consider this to be "white" light.

But why are different coloured light rays refracted differently? And what kind of physical phenomenon causes this?

It is not possible to say what light "is". In physics, models are used to explain and predict phenomena. Models are simplified descriptions of reality. A typical result of this – as can be seen in our experiment – is, that one model is not able to explain every observed phenomenon. The ray model is not suitable to explain our observations. But there are further models describing light, e. g. the wave model. The wave model describes light as a wave. The direction of propagation corresponds to the direction of the "light ray".

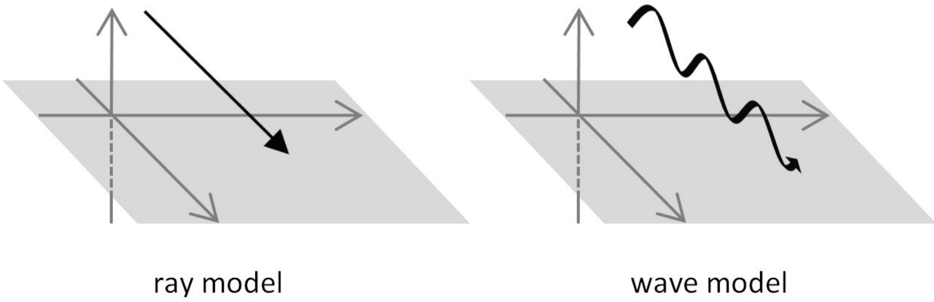
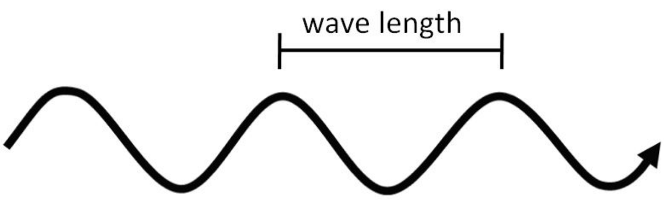


Figure B.2: Light described as a ray and as a wave.

The "colour" of light corresponds the wavelength. The wave length is the distance between two wave crests or two wave troughs:



In conclusion, the difference between light colours is their wavelength. Blue light has a short wave length, followed by green, yellow and red light, which has the largest wave length we can see with our eyes. The shorter the wave length is, the more the light is refracted. (This effect is called dispersion, and unfortunately it is beyond the scope of this first experiment. But do not worry, you will learn about this soon enough in your physics classes ;))

Due to different magnitudes of refraction every position on the screen can be assigned to a certain wavelength. Measuring the distances of the refracted rays from the center (case of non-refraction) their wavelengths and therefore the components of the light source can be determined. If a wavelength is not included in the light the screen is dark at this position. The picture at the screen is also called "spectrum".

B.2. Experiment 2: Spectra of different light sources

Material:

- light bulb with power supply
- fluorescent lamp (often hangs from the ceiling)
- electronic LED torch
- white sheet of paper
- spectrometer

Setup and observations: The spectrum of a light source can easily be analysed using a spectrometer. Point it towards one light source at a time and let everyone of your group have a look at the spectrum. Sketch the spectra!

a) if you have time left: the light bulb again

b) fluorescent lamp

c) electronic LED torch

d) a white sheet of paper that is illuminated by the sun

CAUTION: Never look directly into the sun!

Remark: If you look at a white sheet of paper which is illuminated by a light source, you can see the same spectrum as when looking directly in the light source. You can proof this by comparing the spectrum of the fluorescent lamp with one of a paper illuminated by the lamp.

Evaluation: Describe the differences between the spectra! Are all colours present in the light, or are there gaps? Are there light sources which emit a spectrum where most wavelengths are missing and which contains only a few single wavelengths? Is the brightness of the colours different depending on the light source?

If you have time left: anomaly of LEDs. It is remarkable that the spectra of the sun and the light bulb are continuous, that is, that there are hardly missing wavelengths. Only their intensities are different. However, the light of the LEDs is different. Depending on the type of LED, the spectrum contains only two or three single wavelengths. Why do we see “white” light, even if it contains only a few colours?

The reason is the way our eyes perceive light. It is not precise to say that we see white light if it contains “every” colour. To explain why we rate the light of a LED which encloses only two or three colours as white, it is necessary to have a closer look at the phenomenon in a biological sense:

Inside our eyes there are sensors (cone cells) that are sensitive for green, red and blue light. If light illuminates them, an electrical signal is sent to the brain. Although the cone cells also react to light having a different wavelength, the signal is the weaker the more the wavelength differs from the one these cone cells are most sensitive for (e. g. the wavelength of green light). We do not recognise the wavelength of light shining on our eyes – we only recognise that the cone cells get stimulated to a certain amount. This means, we consider light to be “white” if our three types of color sensitive cone cells are stimulated as much as from light containing every color. The blue light of the LED stimulates (mainly) the blue cone cells. The yellow light of the LED stimulates both the green and red cone cells because the wavelength of yellow light is in between the wavelengths of green and red light. If the ratio of blue and yellow light is correct, all three types of the color sensitive cone cells are stimulated to an amount making it impossible for our eye to differentiate the light from white light.

C. Worksheet Polarisation

There are different ways to describe light. One that you already know is the ray picture. But to explain the characteristics of polarisation another model, the wave picture, is necessary.

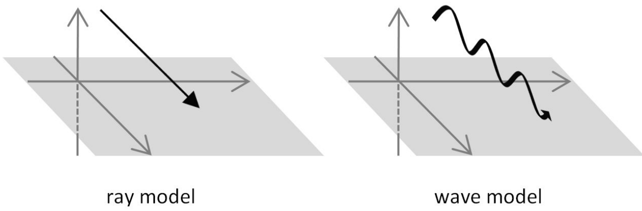


Figure C.1: Model of light as a ray and light as a wave.

The path direction therefore corresponds to the direction of the ray of light. If two light waves travel in the same direction, they still can differ in their direction of oscillation. The first wave for example could oscillate vertically ("up and down"), while the second one does it horizontally ("left and right"). Those waves you can see in the following figure:

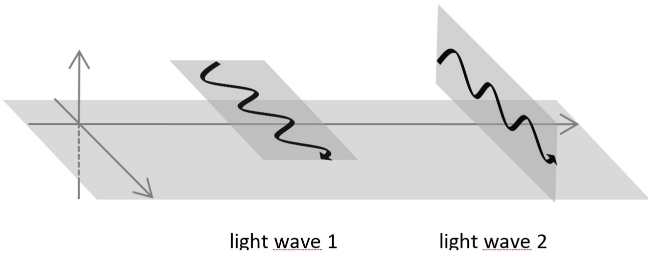


Figure C.2: Planes of oscillation of light waves.

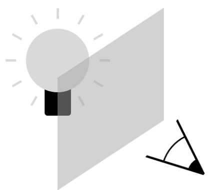
Instead of showing the plane of oscillation you often can find an arrow indicating its direction. Together with the direction of propagation this arrow spans the plane of oscillation. One beam of light consists of many light waves. For neutral light sources like the sun, candles or bulbs these waves can have random planes of oscillation. We speak of unpolarised light. If all of a beams' light waves have the same plane of oscillation the light is polarised. How do we create polarised light? For example by guiding unpolarised light through a polarisation filter. Here only waves with a certain polarisation can pass. Try it yourself:

C.1. Part 1: Polarisation of light

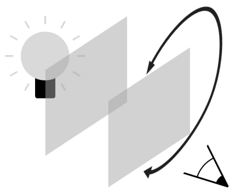
Required material:

- bulb with power connection
- two polarising filters

Experiment: Place the filter in front of the bulb. Now look at the bulb through the filter. What can you see?



Now place a second polarisation filter between the first and your eye and turn the filter slowly by 180°. What can you see now?



Observations:

a) ______________________________

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b) ______________________________

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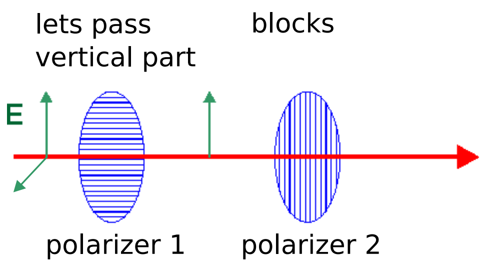
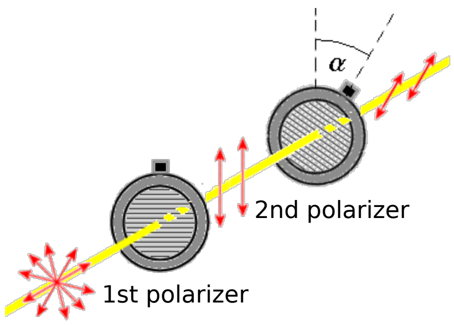
Evaluation: The bulb emits unpolarised light, which means that all planes of oscillation are present. Only light waves oscillating perpendicular to the lattice can pass the polarisation filter. As a result linear polarised light is created. If unpolarised light is hitting the filter, the orientation of the filter does not matter. Always there is a wave fulfilling the above condition. But if adding a second filter, its orientation with respect to the first is of importance. If the second filter is perpendicular to the first, no light will pass through it (see figure) and an intensity minimum is created. All of the light is transmitted if both filters are parallel to each other. For any other angle a small fraction of light can pass the second filter, as the linear polarised light created by the first can be divided in two components: one that is parallel to the second filter and therefore blocked, while the other is perpendicular to the second filter and thus can pass it (see figure).



(a) Light is completely blocked [3].



(b) Light is partially let through [1].

Figure C.3: Transmissibiltiy of polarizers is dependent on the plane of oscillation.

C.2. Versuch 2: How do 3D goggles work?

Required material:

- 3D goggles (http://genau-bb.de/wp-content/uploads/DLR_next_Anleitungen-Stereoskopie-fuer-Zuhause.pdf)
- red / green picture

Experiment: Look at the picture through the 3D goggle. What can you see?

Observations: ____

____

____

Evaluation: For our eyes to see a 3D world, each one has to receive a picture of slightly different angles of our surrounding (close each of your eyes separately and you will see that we see the world from two different perspectives). In the cinema this effect is made by showing two different slightly spatially shifted movies at the same time. There are various techniques to archive each eye to receive different pictures. In this experiment two pictures – a red and a green one taken from different perspectives – are overlaid. The colour filters of the goggles allow a separation of the pictures for each eye. Another technique uses polarisation filters. Two projectors project a picture on the screen, whereby the planes of oscillation of those are perpendicular to each other. Using polarisation filters in 3D goggles the pictures are separated. This is a way to produce different perspectives and therefore to create 3D movies on a 2D screen. Can you think of advantages and disadvantages of those two techniques?

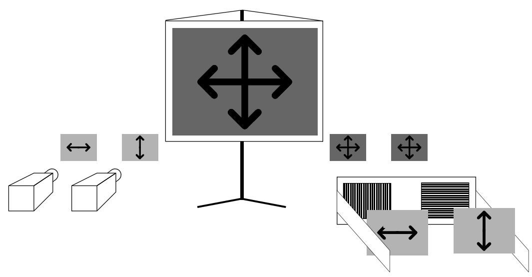


Figure C.4: Working principle of 3D-goggles.

D. Worksheet Fermat's Principle

Required items.

- 1 cuvette
- water, sugar
- 1 laser

Preparation. *This part should only be included in the guideline, not in the worksheets.*

About 15 min before the lesson starts, one should begin the preparations for this experiment. Fill less than half of the cuvette with a saturated sugar solution. Now stack carefully a layer of distilled water on top. The cuvette shouldn't be moved too much in order not two mix the two layers. After some time there'll be a vertical concentration gradient due to the process of diffusion. (That corresponds to a vertical concentration gradient; this increases from top to bottom.)

Observations. Shine with the laser lateral through the cuvette. What do you observe?

Now change the angle of incidence of the laser. What do you observe now?

Explanation. As you have seen: the laser beam gets curved while travelling through the cuvette, as shown in figure D.1.

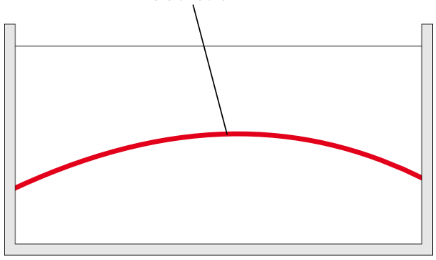


Figure D.1: curved laser beam [4].

As you changed the angle of incidence you could observe that even after reflection of the laser beam on the water surface or ground the curvature of the laser beam still is maintained.

To explain this phenomenon, we first need to understand *Fermat's principle*. This principle implies, that the path taken between two points by a ray of light is the path that can be traversed in the least time.

For example, think of the following: which way does a lifesaver have to take if he wants to rescue someone from the water?

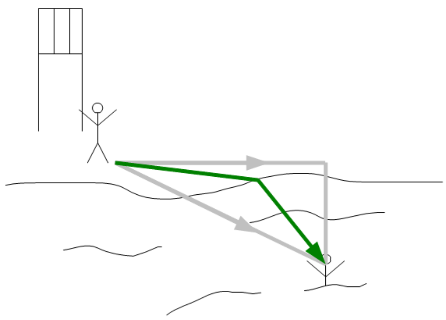


Figure D.2: Example of a livesaver [7].

The livesaver runs on the beach to a specific point, from which the way through the water is short, because in water he only can move slower. If he runs to far, the way in the water is even shorter, but the distance on land is a lot further. You can see the optimal way in figure D.2.

For light we have to describe the transition from the beach to the water (from the livesaver-example) from a different point of view.

The refreactive index n is a dimensionless quantity, that specifies the ratio between the velocity of light in vacuum c_0 to the velocity of light in the medium c_M:

$$n = \frac{c_0}{c_M}.$$

The light is the fastest in vacuum (or in a good approximation even in air). The larger the refractive index of a medium is, the smaller is the propagation speed of light in this medium.

When the light travels from a medium with a refraction index n_1 into a medium with a refraction index n_2, a part of the light is reflected on the interface while the other part goes into the other medium. When the refraction indices are different, the light gets

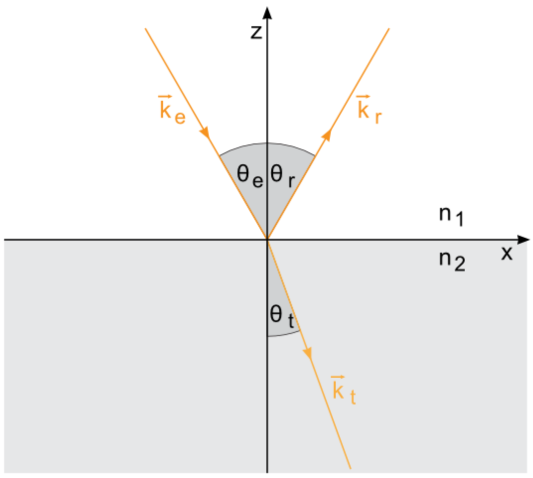


Figure D.3: Refraction at the boundary of two materials [5].

refracted in this transition. This can be expressed by the following formula, which is named "Snells' law":

$$n_1 \sin(\theta_e) = n_2 \sin(\theta_t),$$

with the angle θ_e between the incident light and the plane perpendicular to the interface.

In the cuvette we have a sugar solution, which shows a concentration gradient. Therefore we have a vertical gradient in the refractive index: The refractive index increases from top to bottom.

The light ray, which enters the cuvette from the side, is bent in the water at the interface of two layers of the sugar solution with different saturations. Afterwards the ray is going smoother trough the water. At a certain angle of incidence the light ray is totally reflected at the interface of two sugar layers. On other interfaces the light ray ist bent further. So we get the observed effect.

E. References

[1] Chemgapedia: *Polarisation.* – URL http://www.chemgapedia.de/vsengine/vlu/vsc/de/ph/14/ep/einfuehrung/wellenoptik/polarisation.vlu/Page/vsc/de/ph/14/ep/einfuehrung/wellenoptik/polarisation12.vscml.html. – Zugriff: 07.04.2015.

[2] Chemgapedia: *Wellenoptik.* – URL http://www.chemgapedia.de/vsengine/media/vsc/de/ph/14/ep/einfuehrung/wellenoptik/bilder/sk7_8.png. – Zugriff: 07.04.2015.

[3] Leifiphysik: *Polarisation.* – URL http://www.leifiphysik.de/themenbereiche/polarisation. – Zugriff: 07.04.2015.

[4] Pohl, Robert O.: *Krummer Lichtstrahl.* – URL lp.uni-goettingen.de/get/text/1219. – Zugriff: 27.03.2015.

[5] Prior, Mira: *Das Snelliussche Brechungsgesetz.* – URL lp.uni-goettingen.de/get/text/5650. – Zugriff: 27.03.2015.

[6] Uni Bayreuth: *Beugung und Interferenz.* – URL http://btmdx1.mat.uni-bayreuth.de/smart/physik/3_optik/beugunginterferenz/beugunginterferenz.pdf. – Zugriff: 07.04.2015.

[7] Wikipedia: *Fermatsches Prinzip.* – URL de.wikipedia.org/w/index.php?title=Fermatsches_Prinzip&oldid=135027064. – Zugriff: 27.03.2015.

[8] Wolf, Fritz: *Impulse Physik – Praktikum Optik.* Klett Verlag, 1997.