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Front Page: Participants of the International Physics Olympiad 2013, enjoying a reception at the Town Hall of Copenhagen/Denmark (picture taken by Stefan Petersen / Germany)

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Aims of the Federation

(1) To promote excellence in, and research associated with, physics education through the use of school physics competitions;

(2) To promote meetings and conferences where persons interested in physics contests can exchange and develop ideas of use in their countries;

(3) To provide opportunities for the exchanging of information for physics education through published material, notably through the Journal of the Federation;

(4) To recognize through the WFPhC Awards system persons who have made notable contributions to physics education through physical challenge around the world;

(5) To organize assistance provided by countries with developed system for competitions for countries attempting to develop competitions;

(6) To promote physics and to encourage young physicists.
Editorial

Dear Readers,

This is the third Journal you can read online on our home page. As you can see, it is a double edition. I am very sorry that we have not been in a position to publish two single editions in 2013 and we have to apologise about that. We promise to go back to the normal rhythm of publication in future.

At the beginning you will find a report on the WFPhC-Award-2012, given to Maija Ahtee from Finland, for her outstanding work in physics education in general and her work for the physics competitions in detail. Dear Maija, we will take your work as an example!

Niels Hartling, president of the International Physics Olympiad-2013, wrote an article about this great event, also giving an insight in the occurrences “behind the scene”.

Claudia Resch is the Executive Manager of the Austrian Research and Support Center for the Gifted and Talented. They made an investigation about the efficiency of the training for the Olympiads in physics, chemistry, mathematics and philosophy of Austrian teachers. It might be that some of these results will be representative in general.

“Much physics – little effort” was the topic of an experimental event during the WFPhC-Congress-2012 in the Netherlands. The participants worked out three experiments being very useful for the training of students for Olympiads.

There is an international Olympiad in robotics, too, having to do a lot with physics. You can read a description of this event, written by the trainer. One of the participating students wrote an article about a special aspect of robotics. The students were very successful and we would like to congratulate them!

A good guidance for students to make them interested in different competitions can be done by teaching them the use of research. As good-practice-examples, successfully done in Hungary, you can find an article about the reaction of sunlight on leaves with drops on them, about “green cars”, details about luminescence in nature, something about the climate change and an analysis of students’ misconcepts in mechanics.

I truly hope you can enjoy this Journal and all its interesting points.

Vienna, November 2013

(Helmuth Mayr)
WFPhC-Award-2012

Every two years one of the most honourable duties of our Federation is to hand over an award to a person having done an outstanding activity in physics education and in physics competitions for secondary school students.

Five members of the World Federation of Physics Competitions build an awards committee being responsible to find this distinguished person. In the year 2012 this committee awarded this prize to Maija Ahtee from Finland.

It was in 1982 that I met first Maija Ahtee. At that time former “West-Germany” was host of the International Physics Olympiad and Austria participated in the IPhO for the first time. I was leader of the Austrian team. In those days Maija was leader of the Finnish team, and 17 countries were present at that event on the whole.

During the following years we met every year and got to know each other better and better.

Maija Ahtee studied at the University of Helsinki, was a teacher of physics, mathematics and chemistry in secondary schools in Finland for six years and then she changed into teacher training at that university, becoming a professor in mathematics and science education at the University of Jyväskylä in Finland.

Maija started her activity in the IPhO in 1977. In 1992 Finland was host of the IPhO and Maija Ahtee (together with Jukka Mattila) was very active in bringing this Olympiad to a great success.

Maija Ahtee wrote about 50 research reports in physics in national and international journals and about 100 research reports in science education, also in national and international journals. She was a member of different Physical Societies and an editorial member of the mathematics and science teachers’ magazine “Dimenso” from 1987 to 2000.
Inside Finland Maija published a great number of very useful and well known booklets and text books for teaching physics in different types of schools and for the education of science teachers. 

In 1990 Maija got the honorary credit to become a Lion of Finland Knight (SL R 1)

From 1999 to 2007 Maija Ahtee fulfilled the function of the secretary of the International Physics Olympiad. 

In 2007 she was present when the former IPhO-president, Waldemar Gorzkowski from Poland, totally unexpectedly passed away on the second day of the IPhO in Isfahan/Iran. Hence Maija had to work as acting IPhO-president, and she did so in the current year and in 2008, when the new president, Hans Jordens/Netherlands, was elected. After that election Maija resumed into her role as IPhO-secretary and finished this work with the end of the IPhO-2009/Mexico.

With respect to all her activities Maija Ahtee was honoured by the Award of the World Federation of Physics Competitions in 2012. 

At the beginning of the prize giving ceremony of the IPhO-2012 in Tallinn/Estonia there was a special ceremony to present Maija Ahtee the award of the Federation. 

The president of the Federation, Helmuth Mayr, and the head of the former Award Committee, Matti Rajamäki, honoured the outstanding work and contribution of Maija Ahtee, and the audience gave her a huge applause.

Dear Maija, we have to say “Thank you very much!” for the outstanding job you did for so many years, always warm-hearted and in full command, and we want to congratulate you on the Award 2012 once more.

(Helmuth Mayr)
WFPhC-president
The 44\textsuperscript{th} International Physics Olympiad, IPhO 2013

Niels Hartling  
President of the IPhO-2013

The 44\textsuperscript{th} International Physics Olympiad was held in Denmark this year hosted by Technical University of Denmark (DTU) and Niels Bohr Institute, University of Copenhagen. As reflected in the logo, IPhO 2013 was part of the centennial celebration of the Niels Bohr's quantum model of the hydrogen atom.

Delegations from most of the 81 participating countries arrived on Sunday July 7. Each delegation typically consisted of 5 students and 2-3 leaders and observers. Next day the opening ceremony with entertainment and speeches took place at DTU. Each of the 81 participating teams was presented one by one by standing up to receive applause. The ceremony can be seen on the web site www.ipho2013.dk. After the opening ceremony the leaders and students were separated. The leaders stayed at DTU where they began to negotiate the theoretical problems. The students enjoyed themselves in a nature park nearby.

The theoretical problems comprised: (1) Meteorites, especially the so-called Maribo meteorite, which fell close to the Danish town Maribo in 2009. (2) A so-called plasmonic steam generator, based on local heating of an aqueous suspension of nanoparticles when exposed to a focused light source. (3) Modeling of the Greenland ice sheet, including a newly found and surprising effect of gravitation, namely that the sea level around Denmark will be lowered if the ice sheet melts completely. The experimental problems, presented two days later, dealt with: (4) A determination of the refractive index in water using a laser range finder and (5) an investigation of solar cells. The Danish IPhO committee had aimed at constructing problems inspired by actual physical phenomena and having fairly straightforward introductions that most students could handle, followed by increasingly difficult parts. The proposed problems were met with general acceptance; the only minor gripe was that the problems might be a little too long. The problems turned out to work very well in the test context, in fact some of the students managed to answer nearly all questions.
After the presentation of each problem, the hard part began: The debates among leaders from 81 countries about details. On the one hand, everybody should be allowed to have their say, and on the other hand one has to prevent the negotiations from dragging on indefinitely.

After final adoption of the wording and point-values of the problems, the translation into many different languages began. For some nations it lasted the whole night, so the two nights of the problem presentations were tough for both leaders and organizers.

The final version of all problems and the associated solutions, as well as the presentation slides for each of them, are available for download at www.ipho2013.dk.

For students, the academic part of IPhO 2013 was "just" the two five-hour examinations. The rest of the time there was plenty of opportunity for socializing and shared experiences: Swimming, excursions, among other things visits to Niels Bohr Institute, Tivoli amusement park (including physics experiments on the rides), Copenhagen Experimentarium, historic viking sites, and a harbour cruise. The excursions and a party mid-week, where leaders also attended, were successful.

The visit of the IPhO students to Tivoli amusement park in Copenhagen
The leaders had much more to do than the students. In addition to negotiating and translating problems, they also took part in marking the papers. Moreover they had to attend meetings where decisions about future IPhO work were made. But the leaders had also time for excursions including Niels Bohr Institute, harbour cruise, Carlsberg Museum, Louisiana Museum of Modern Art, Hamlet's castle Kronborg and, together with the students, the City Hall of Copenhagen. On the latter occasion Copenhagen was named "World Capital of Physics 2013", following up on the tradition inaugurated at IPhO 2012 in Estonia.

On Sunday afternoon July 14, all winners were presented on stage at the grand closing ceremony at DTU, followed by dinner and closing party. So, how were the medals distributed? One might say, as usual. Students from the East Asia, led by China and South Korea, from Eastern Europe and from the very large countries won a large part of the gold and silver medals. Students from small western Europeans countries as Denmark typically got one or two bronze medals. Detailed lists of the winners of gold, silver, bronze and honorable mention are presented at the web site www.ipho2013.dk.

All answers from the students at IPhO 2013 under close guard of Professor Henrik Bruus

An arrangement of this type is a very big task - almost three conferences to be organized in parallel. After the intense preparation stretching over 2-3 years, we are very pleased to say that everything went very well. We have received very positive feed-back from students, leaders, and the educational institutions in Denmark, a result of the great effort of many dedicated people. In addition, we were lucky enough to avoid any serious incidents such as illness, assaults or accidents. Finally the Danish summer weather showed itself from an unusually pleasant side: Throughout the Physics Olympiad we enjoyed sunny dry weather and comfortable temperatures.

More details about IPhO 2013 can be found on www.ipho2013.dk including the daily IPhO Newsletter “Hafnium” as well as several photos and videos of the week.
Now we are looking forward to the next International Physics Olympiad, which takes place in Astana, Kazakhstan, in July 2014, where we do not have any organizational responsibilites.

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Olympiads as a means to promote gifted students

Claudia Resch
Executive manager of ÖZBF

Interviews with students and course instructors

On behalf of the Austrian Federal Ministry of Education, Arts and Culture, the Austrian Research and Support Centre for the Gifted and Talented conducted a qualitative survey by interviewing students and course instructors of the four Olympiads in mathematics, physics, chemistry and philosophy to collect information on the following aspects:

- In what way have the students benefitted from the participation in the Olympiads and the respective preparatory courses?
- Were there any negative experiences?
- Did the participation in the prep course or the contest, respectively, have any impact on the regular class as well as on the students’ subsequent choice of study?
- How did students and course instructors assess the level of the contests and the prep courses?
- Were there any methodological and didactic differences between regular class and prep course and, if yes, how were they perceived?
- Were methods of talent promotion such as differentiation and individualisation used in the prep courses?
- What kind of suggestions for improvement did the students and the course instructors have?

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I would like to thank my colleague Andrea Hofer for helping with the translation of these articles into English.
The Austrian Research and Support Center for the Gifted and Talented received the names of the interviewees from the federal coordinators of the above-mentioned subject areas. Among the respondents were relatively young as well as experienced students and course instructors. Altogether fourteen students and ten course instructors were being interviewed between March and June 2011.

**Summary of student interviews**

**Have you benefitted from participating in the Olympiad? If yes, in what way?**

The students unanimously stated that they have benefitted considerably from participating in the Olympiads. For example through

- the additional input,
- the inspiring lectures, in particular those which were being held at the prep course for the national competition,
- the exchange of knowledge with better students,
- the opportunity to socialize and make friends,
- the opportunity to travel to foreign countries (due to the participation in the international contest),
- a gain in competences, e.g. an increased power of concentration (the students had to learn to concentrate for five hours, which they perceived as a good preparation for their school leaving examination) and the skill for solving problems in a systematic way,
- a gain in self-confidence.

Some students stated that the regular class became easier, as some topics had already been discussed in the prep course (in particular, in the prep courses for the national competition and the international competition).

**Were there any negative experiences in connection with the participation?**

All interviewed students denied this question. However, some students stated that there was some “unpleasant” time pressure, as the national competitions were usually carried out at the same time as their school leaving examinations (or tests within the experimental lessons, respectively).
Did the participation in the Olympiad encourage you to further excel in the subject in which the Olympiad took place? Why? Why not?

The students offered varying answers to this question: Some students had already had a great interest in the subject and thus they had decided to participate in the Olympiad in the first place. Others, yet again, intensified their interest in the subject only by participating in the Olympiad.

Some students said that the regular class appeared to them more boring through the participation in the Olympiad.

Did the participation in the Olympiad influence your choice of academic studies?

It is certainly worth noting that all interviewed students affirmed that they wanted to study the same subject at university, i.e., if they had participated in the Chemistry Olympiad, they wanted to study chemistry etc. Almost exclusively they had formed this wish through the participation in the Olympiad because they had noticed that the subject area was very interesting, on the other hand they were actually quite good at it.

How would you assess the difficulty level of the prep course?

The students’ responses to this question were very heterogeneous:

- Half of the students said that the course had had a relatively high level, i.e. they felt the requirements could just be met by them.
- Four further students maintained that the level could be placed in the mid-range. For them, the course could have been slightly more difficult.
- Two students stated that the prep course in school had been far too easy for them. Only the prep course for the national competition had had an appropriate difficulty level.

Were there elements in the preparatory course which you missed in regular class? Were there elements of the regular class which you missed in the preparatory course?

The students unanimously negated both questions because they hardly saw any connection between the prep course and the regular class. The respondents simply could not imagine a regular class operating with prep course methods.
Some believed that a methodology change in the regular class was unfeasible, as it would fail due to the lack of interest of most students (while in the prep course all students shared a similarly high interest in the subject area).

According to the students the range of methods in the prep course was more diverse than in the regular class and encouraged the students to work more independently while the regular class was strongly characterized by the teacher’s lecture.

**How did the course instructors deal with varying levels of giftedness and excellence in the preparatory course?**

The students’ responses were quite varied: Some teachers would design an individual lesson plan for each student, while in other courses all students would do the same. In general, however, the teachers differentiated, e.g. by giving some students different tasks for the same subject area.

**Do you have any suggestions for improvement, e.g. concerning organisation, preparatory course or competition?**

Most students were very satisfied with the Olympiad and expressed this accordingly. However some stated the following points of criticism:

- The dissemination of information did not work very well at school because only one teacher at school (re)presented the Olympiad.
- One student suggested carrying out the national competition earlier, so one could better prepare for the international Olympiad (in some countries the qualification already takes place in February).
- After the national competition the students did not have the chance to look into their solution notes. If they, for instance, had not received the points which they believed they should have got, they could not complain.
- The participants of the Physics Olympiad would prefer a better scheduling between the Physics Olympiad and the Austrian Young Physicists’ Tournament (AYPT), as scheduling conflicts often arose.
- In many countries there were many young lecturers, whereas in Austria many teachers at the national competition were at least 45 years of age or older.
- Some students criticised the shortening of prep course lessons.
Summary of course instructor interviews

What are the most positive experiences in connection with the Olympiad and the preparatory courses?

The course instructors found the following aspects to be most positive:

- The students’ great delight in the subject matter.
- The opportunity to work independently and to address the students’ personal interests.
- The friendly interaction with the students.
- Trying out new learning methods.
- The opportunity to deal with individual topics thoroughly.
- Small groups
- No pressure to give grades.
- Realising that the participation in the Olympiad led to the students’ actually studying this subject at university and that they also succeeded there due to the Olympiad.
- The professional and social contact with other course instructors
- Receiving budget for teaching material

Are there any negative experiences?

Overall, the teachers were very satisfied with the Olympiad and the prep courses. Some course instructors, however, mentioned the following negative experiences:

- Many colleagues are not aware of the Olympiad.
- Some teachers complained about the time-intensive preparation that came along with student heterogeneity (up to four different difficulty levels). They would prefer having more prep course lessons so that they could split the groups.

Why did you start teaching preparatory courses?

Most course instructors were actually asked – either by school management, country coordinator, predecessor or students, if they would not like to take over a prep course so that the course would continue at that particular school. Only one teacher answered that he himself had requested to teach a course because he wanted to work with students who were interested in philosophical issues. All of the interviewed teachers stated that they were glad that they took the opportunity and that they very much appreciated working with „interested, motivated and talented“ students.
How are the students being informed about the courses in your school?  
According to the instructors, the students are being informed as follows:

Either the course instructor…

… personally goes from class to class or

… she/he recruits gifted students from her/his own class or

… she/he specifically asks colleagues who then recommend students.

How do you deal with student heterogeneity in the preparatory courses? How are gifted students promoted in the course?

Almost all instructors stated that the differences between the students were sometimes quite considerable and this led to a lot of preparatory work on her or his part. The course instructors mentioned the following possibilities how to deal with student heterogeneity:

• One course instructor prepared three difficulty levels for a topic and recommended one of them to each student. However, the choice was left to the students. Other course instructors responded to student heterogeneity by providing beginners with more information and advanced ones with less.

• According to the instructors, the students’ tackling the tasks independently leads to meaningful differentiation in general. Also open tasks are a very good means to promote gifted students. They are simply „calculating further than the others“. In the philosophy olympiad the essay questions which are relatively open promote students individually.

• One course instructor provides students with more tasks which they can do at home. However, students rarely take up this offer.

• One course instructor talked about a highly gifted student who attended grade 8 but still participated in the prep course of the senior classes. In order to enable him to participate she seperately taught him the necessary subject matter which he had not had in regular class by then.

• Some course instructors divide the prep course into two groups, i.e. one week they teach the beginners and the following week they teach the advanced students.

• One school offers two weekly prep courses which are being planned and conducted by three teachers and attended by all students. Through the team teaching the teachers are able to deal with different groups individually.

• One instructor stated that the student heterogeneity led to students sometimes either joining the course later in the school year or even skipping a whole year.
In what way do you consider the student Olympiad to be a means to teach gifted students for you?

The instructors answered as follows:

- Taking part in the Olympiad provides students with the opportunity to deal with topics which they would not learn about in regular class. Also tasks are usually more difficult, which is a good challenge for them. Students usually have more time to work independently, to deal with real-life problems and to work together with other gifted students.
- Olympiads are a method of enrichment.
- The students attend the course voluntarily and that is why working with them is so different and rewarding.

Do you use a different methodological or didactic approach in the preparatory course in comparison to regular class? If yes, which?

Almost all instructors use a different methodological and didactic approach in their prep courses. In the courses students predominantly work independently by tackling open tasks and questions (which they often check themselves with the help of solution sheets). In the prep course for the Chemistry Olympiad students also experiment a lot more than in regular class. In general, frontal teacher presentation happens considerably less in prep courses.

The teachers mentioned that they appreciated not having to stick to the prescribed curriculum and that they could therefore cater to students’ wishes.

Most teachers doubted whether those so-called “more open” methods, which they used in prep courses, were suitable for regular class. They believed that lower-achieving students would not be able to work out some topics on their own. They also stated that preparing for a prep course needed a lot more time than preparing for regular class – time which they did not always have.

Do you have any suggestions for improvement, e.g. concerning organisation, preparatory course, contest?

Most instructors are quite happy with the organisation of the Olympiad and consider the contest as the school year’s highlight. Nevertheless, the following suggestions were being made:
• **More courses:** Many interviewees wished for more courses, which would enable smaller and slightly more homogeneous groups. They also criticized that each school only received a certain amount of course lessons, which were then divided between *all* the teachers. This, however, would sometimes cause friction with those who wanted to offer courses in sports, music, reading promotion etc.

• **Awareness level:** Instructors generally criticized that the Olympiad was hardly known among their colleagues, let alone students. They would therefore wish for more publicity. They suggested honouring students who were successful at the International Olympiad by officials or politicians in order to make the Olympiad more established. This would also acknowledge the students' efforts.

• **Time issues:** Problems for older students arose because the national contest and the school-leaving exams sometimes overlapped.

• **Physics:** A physics course instructor criticized the bureaucratic way of organizing material for the prep course because this was being handled by a federal authority. Furthermore, he criticized that there was some competition (especially when it came to time schedules) with similar courses such as e.g. the Austrian Young Physicists' Tournament (AYPT). In his opinion, it would be better to teach all students interested in Physics together in one course. After some time, they could then decide which course or contest, respectively, better fitted their competence and interest.

• **Getting credits for academic studies:** The instructors would appreciate it if students who successfully participated at the Olympiad received university credits.

---

**Conclusion**

The comparison between the student and the course instructor interviews leads to the following interesting findings:

Both groups agreed that the teachers used a different methodological and didactic approach in the prep course compared to the regular class. They also agreed on the reasons for this decision. Both groups believed that a didactic approach that encou-
angered students to work out topics independently would overstrain weaker or less interested students. Lower-achieving students would either not be able to work independently or they would not be willing to do so.

Teachers furthermore mentioned that such an approach was more time-consum ing – time which they did not always have.

However, what is striking is that both students and course instructors actually perceived the didactic approach in the prep courses as more meaningful and effective. Accordingly, it remains to be resolved which preconditions have to be met that this way of teaching (e.g. performance differentiation by open tasks or curriculum compacting) will actually become established in the everyday classroom.

Author:
Dr. Claudia Resch
Executive Manager of the Austrian Research and Support Center for the Gifted and Talented

Promoting talent. Shaping the future
The Austrian Research and Support Center for the Gifted and Talented (ÖZBF)

The Austrian Research and Support Centre for the Gifted and Talented is the federal institution for the development of gifted education in Austria and supports persons, institutions and initiatives that promote gifts and talents. It was founded in 1999 and is being financed by the Ministries of Education, Arts and Culture as well as Science and Research.

The ÖZBF stands for a holistic and systematic approach to gifted education which encompasses all fields of action involved in promoting gifts and talents: kindergartens, schools, universities but also communities, economy and working world.

We are working on: strategies and concepts, school development, teacher education, curricula, research, pilot projects, networks and cooperations, conferences, providing information and raising awareness.
Much Physics - Little Effort

Helmuth Mayr
Retired teacher of physics and physics didactics in Vienna/Austria
Federal Coordinator of the Austrian Physics Olympiad

Introduction
During the WFPhC-Congress-2012 there was the workshop "Much Physics – Little Effort". The workshop focused on experiments with rather little effort, but with fruitful insights into important basic concepts of physics.
The participants were asked to work in working groups at several “stations” to carry out these experiments by themselves.
The first experiment was organised in such a way that the participants could take the equipment home.

Experiment 1

This experiment goes back to the former Swedish IPhO-team-leader Hans Uno Bengtsson from the University of Lund. Sadly Hans Uno Bengtsson passed away in May 2007.
I used this experiment to train students for the Physics Olympiads. They also made investigations with different diameters and lengths of the pipe (see fig. 1)
The given parts are optimal.

Material
1 short piece of a plastic pipe with two differently coloured dots on it (see fig. 1)
1 ruler

System
Lay this pipe on the table, so that the two dots are turned upwards. Press one finger on one of the dots. As a reaction the pipe will start to rotate.
To visualize this starting process short video clips are available on the web: Start-A (https://www.dropbox.com/s/75i5855l9teyn1t/Start-A.avi) and Start-B (https://www.dropbox.com/s/sgvbkdmb0wm3lzu/Start-B.avi). In this case the pipe does not have two dots with different colours, but instead there is a red “cross” (X) and a black “ring” (O).

(All clips were produced by Engelbert Stütz/Austria)

What to do?

- Watch carefully what you can see!
- Clarify what’s going on!

Hint

- If you want, you can produce such an object by yourself and take it home.

Solution

One can notice that the pipe rotates around a vertical axis while rolling on its circumference. If you press e.g. the red dot, you can see this red dot four times at the same time.

It is also obvious that one can see just that very dot which has been pressed during the start. The other dot is more or less invisible as long as the speed of the pipe is rather high.

You can watch these movements on the two short videos pipe-green (https://www.dropbox.com/s/gjujmqad3v3pyaf/pipe-green.AVI) and pipe-red (https://www.dropbox.com/s/93pohr6u7h4mtqi/pipe-red.AVI).

These two movies are made in slow motion technique. Hence one can see that the “not-pressed dot” rotates much faster than the other one. That means that it is originally so fast that it is more or less invisible.

Due to the fact that the length of the pipe (length = 64 mm) is four times its diameter (diameter = 16 mm) and our eyes show “inertia” one can see four of the pressed dots at the same time.

Comment

Of course you can produce a pipe being e.g. three times or five times longer than its diameter. In these cases you would notice three or five of the pressed dots at the same time, but it can be that these pipes are harder to start.
Experiment 2

Equipment
1 Erlenmeyer flask
1 stopper with a fixed glass pipe
1 syringe
1 portion of coloured water
1 ruler / tape / calliper
3 plastic jugs
2 thermometers
1 water heater
1 adhesive band
1 vessel with scale
material to fix the equipment
water
cleaning paper

System
The stopper with the glass pipe is to be put in the Erlenmeyer flask. With the syringe one can put a drop of coloured water in the end of the horizontally orientated glass pipe, so that the air in this system is “jailed”. This equipment can be put in warm or not so warm water being in two plastic jugs. Hence one can assume that the “jailed air” has the temperature of the water.

Hints
• In order to put in the drop of coloured water, it is recommended to hold the glass pipe slightly downwards. After putting in the drop, the pipe has to be placed horizontally as quickly as possible.
• There should be only slight variations in the temperature!
• With pieces of the adhesive band one can show the position of the coloured water drop.
• You can assume that the “jailed air” acts as a perfect gas.
• If the Erlenmeyer flask gets wet inside, you have to dry it carefully!

What to do?
Determine the absolute zero of temperature!
Solution
It is obvious that the pressure of the “jailed” air is constant. Hence the volume of the “jailed” air will be higher at a higher temperature, and visa versa. If the jailed air were a perfect gas, its volume would be zero at 0 K.

From \( p \cdot V = N \cdot k \cdot T \) we get

\[
\frac{V}{T} = \frac{N \cdot k}{p}
\]

Hence

\[
\frac{V_1}{T_1} = \frac{V_2}{T_2}
\]

that means:

\[
\frac{V_1}{T_1} \approx \frac{V_2}{T_2} \approx \frac{V_{\text{total}}}{T_0}
\]

Put the Erlenmeyer flask into the warmer water (its temperature is measured by a thermometer) and wait some minutes so that the air inside has about the same temperature as the warmer water. Then – following the hints – put the drop of coloured water into the end of the pipe by use of the syringe. Use a short bit of the adhesive band to show the position of the coloured drop. After that take the whole apparatus out of the warmer water and put it in the not so warm water, whose temperature is also measured by use of a thermometer: (The difference of the temperatures should be about 5°C to 10°C in maximum; otherwise the drop will go into the flask). Hence the coloured drop will move in another position, which can also be shown by another bit of the adhesive band.

The easiest way to measure the necessary volumes is to fill the system completely with water and to fill it into the vessel with the scale.

Having done this it is easy to calculate the temperature \( T_0 \).

Comment
The goal of this experiment is definitely not an exact value of 0 K, furthermore students should understand that there is a deepest temperature which can be estimated with rather simple equipment.

Carefully done, one can get results in the range of about -250°C to about -300°C.
Experiment 3

This experiment is a part of the experimental problem of the IPhO-1982/Germany. One can find the whole optical experiment including the solution of the IPhO-1982 in Germany at the IPHO-home-page


Equipment

1 convergent lens
1 plan mirror
1 pencil
1 ruler / tape / calliper
material to fix the components

What to do?

Determine the focal length of this lens as accurately as it can be!

Solution

This solution is part of the official solution of the whole problem, one can find at the IPHO-home-page given above.

For the determination of the focal length \( f_L \), place the lens on the mirror and with the clamp fix the pencil on the supporting base. Lens and mirror are then moved around until the vertically downward looking eye sees the pencil and its image side by side.

In order to have object and image in focus at the same time, they must be placed at an equal distance to the eye. In this case object distance and image distance are the same and the magnification factor is 1.

It may be proved quite accurately, whether magnification 1 has in fact been obtained, if one concentrates on parallatical shifts between object and image when moving the eye: only when the distances are equal do the pencil-tips point at each other all the time.
The light rays pass the lens twice because they are reflected by the mirror. Therefore the optical mapping under consideration corresponds to a mapping with two lenses placed directly one after another:

\[ \frac{1}{g} + \frac{1}{b} = \frac{1}{f} \]

where

\[ \frac{1}{f} = \frac{1}{f_L} + \frac{1}{f_L} \]

i.e. the effective focal length is just half the focal length of the lens. Thus we find for magnification 1:

\[ g = b \quad \text{and} \quad \frac{2}{g} = \frac{2}{f_L} \quad \text{i.e.} \quad f_L = g \]

A different derivation for \( f_L = g = b \):

For a mapping of magnification 1 the light rays emerging from a point on the optical axis are reflected into themselves. Therefore these rays have to hit the mirror at right angle and so the distance \( g \) equals the focal length \( f_L \) of the lens in this case.

The distance between pencil point and mirror has to be determined with an accuracy, which enables one to state \( f_L \) with a maximum error of \( \pm 1\% \). This is accomplished either by averaging several measurements or by stating an uncertainty interval, which is found through the appearance of parallaxe.

Half the thickness of the lens has to be subtracted from the distance between pencil point and mirror:

\[ f_L = f'_L - \frac{d}{2} \]

The given lens had a thickness \( d = 4 \pm 0.2 \text{ mm} \)

The nominal value of the focal length of the given lens is \( f_L = 100 \text{ mm} \).

**Comment**

*I used this part of the problem successfully very often in order to train optics.*
Team Puzzles –
A Meteoric Rise of Austrian Students
Participating in the Robotic World Championship of Botball

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Abstract
This publication describes the participation of an Austrian student team in the World championship in robotics. It provides insights of the competition procedure and its requirements. The student group shown in Figure 1 consisted of three female students and three male ones aged between 16 and 19. They won the European championship in robotics in Vienna in 2012. Hence, they were entitled to participate in the World Cup in the United States.

Introduction
Team Puzzles, a robotic student group of the Federal Secondary College of Information Technology located in Wiener Neustadt, Austria, participated in the Global Conference on Educational Robotics during July 18 to July 22 2012 (GCER12) in Honolulu/Hawaii [1]. The annual competition is part of the American educational program under the auspices of the National Aeronautics and Space Administration (NASA).

Figure 1: The members of team Puzzles at the Global Conference on Educational Robotics in Honolulu. Standing from left to right: F. Krause, M. Wallner, A. Stockinger, and D. Weber. Squatting from left to right: S. Stoppacher, and V. Schrenk.
The aim of the Botball program is “to stimulate and engage students in exploring their potential in engineering, science and math” [2]. For this purpose, a predefined set of robot parts (motors, sensors, structural parts, 2 controllers, camera, etc.) is required to fulfill certain tasks of the competition. The set is available at the KISS Institute for Practical Robotics [3].

Among the world’s top 60 teams [4], Puzzles got to the finals and was honoured with the following exceptional awards:

- **Finalist**
- **Outstanding Onsite Presentation and Documentation**
- **Judges’ Choice – Outstanding Programming**
- **Judges’ Choice – Spirit Team Award**

The outstanding programming award was granted due to an implemented C++ software architecture exclusively developed for this specific robotic contest.

**What is the competition all about?**

![Figure 2: Scheme of the challenge course for the tournament. The theme is based on the ocean reef and is called Reef Renewal/GCER12 [5].](image)
Every year a new theme for the competition is announced. There are about 30 tasks that can be carried out by the team robots on the game board in Figure 2. During the competition, the robots have to act autonomously, i.e., without the intervention of the teams. They should do as many tasks as possible within two minutes. Each team has two robots, built up with exactly the same components, but individually designed. The choice of the design is made due to the different strategies of the robotic teams.

The overall standing consists of the achieved score regarding the documentation and presentation of the robot project, the placement of the seeding rounds and the result of the double elimination, altogether in equal parts [6]. The documentation is separated into three periods. All of them have to be completed before the Global Conference starts. Each period consists of different tasks to document. Finally the documentation has to be concluded und presented during the competition. In the seeding rounds the robot has to solve as many tasks as possible. This can be e.g., object detection or object collection associated with its transportation. The objects have different shapes, textures and colors. They have to be placed in specified areas or must be stacked due to their shape or color. Finally, in the double elimination rounds the challenge becomes very competitive because two robots have to fulfill the tasks of the seeding rounds, but additionally they have to fight against each other. The different applied strategies can either be passive or active, and simultaneously constructive or destructive. Whether the latter conforms to the rules is a matter of interpretation by the referees.

Perspective of the Participants

The Global Conference lasted for five days. On the first day the teams had the chance to adapt their robots to the environment, e.g. to the specific light conditions on the game table. Periodically, the teams were called up to test their robots for exactly three minutes on the game table.

On the second day the seeding rounds started. The task of the day for the autonomous robots was to gather as many points as possible within a time period of two minutes. There were three runs, only the best two runs were counted. The seeding rounds were part of the overall standings. Due to the place of the seeding rounds, it turned out which team would compete in the double–elimination against each other.

On the third day, all teams had the opportunity to prepare their robots for the double–elimination. Most of the teams changed their strategies. Hence, knock out rules determined the remaining contest. Additionally, very dedicated participants optionally held presentations on one of the following four categories:
• Robotics and Movement
• Best Practices Lightning Talks
• Practical Programming
• Autonomous Projects

On the fourth day the double–elimination started. The double–elimination is a very competitive round, where the robotic teams fight against each other in a knock out system. Those who can respond best to the strategy of their opponent will win and proceed to the next round until they reach the finals. Again, the results of the double–elimination rounds are part of the overall standings.

In addition to the seeding and the double–elimination rounds, the documentation plays an important role, for example, describing the strategy and the design of the robot in detail. The on–site presentation is also part of the overall standings. Two team members have to present the progress of the project in English in front of a jury. The focus should be placed on the hardware design and the software implementation. Afterwards, the presenters are interviewed by the jury for half an hour regarding the contents of their presentation. The overall rating results from the points of the seeding, the double–elimination rounds, the documentation and the on–site presentation. Furthermore, emphasis is laid on the cooperative attitude and enthusiasm of each team.

On the fifth and last day the final double–elimination rounds are performed. The impressive competition is concluded with speeches of scientists who have been invited and the award ceremony. Beside the participation during the five–day competition a conference is performed. Scientists, students and pupils have the chance to submit publications regarding educational robotics. After a positive review process they can publish their latest scientific results and give a talk about the topic of the papers.

The contribution of team Puzzles was published in the proceedings of the conference with the title "Sparkling Coding – a Paradigm Shift in Teaching Programming Robots" [7].

Conclusion
During the GCER12 the participants were able to listen to very interesting talks from other teams, but the highlights were the talks of three international robotics specialists. These three keynote speakers were Dr. Vijay Kumar (Quadrotors Perform), Dr. Maurizio Porfiri (Robotic Fish) and Dr. Hiroshi Ishiguro (Robotician Explores Nature of Humanity). They presented interesting future aspects of robotics, where we could
expand our horizon enormously. During the competition we came in contact with a lot of nice and interesting like-minded people and we made a lot of friends. We look forward to further competitions and conferences and we think that this experience has changed the perspective of our future!

Acknowledgement
We would like to thank our principal, Mrs. Mag. U. Hammel, for the continuous support, such as providing a robotic laboratory. Furthermore we would like to thank all our sponsors [8].

Comments
S. Stoppacher was a student of the Federal Secondary College of Information Technology located in Wiener Neustadt and head of team Puzzles. The team participated at the Global Conference on Educational Robotics during July 18 to July 22 2012 (GCER12) in Honolulu/Hawaii under the supervision of Dr. M. Stifter. Team Puzzles reached the finals of the double elimination at their first participation at GCER, which is a rare event.

References
http://www.kipr.org/gcer/2012/international-botball-results, September 2013
http://my.hsj.org/Schools/Newspaper/, September 2013
http://www.robo4you.at/, September 2013.
Programming Low End Robots

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Abstract
This paper discusses the problem of programming low end robots like an Arduino platform from the perspective of two students at the age of 18 [1]. B. Tiefengraber and C. Jung are currently students of the Federal Secondary College of Information Technology located in Wiener Neustadt and members of an amazing team. This publication is aimed at supporting those secondary school students who would like to enter a robot tournament. Hopefully, they will benefit from the experience of the authors who have successfully participated in the Global Conference on Educational Robotics 2013 in Norman/Oklahoma [2]. Optimization of low end robots is important due to their limited resources in respect of the programming capabilities. Other constraints of low end robots are usually the limited sensor sensitivities, resulting in a sophisticated data processing.

Introduction
Platforms like Arduino are rapidly claiming the commercial aspect of Robotics. But most of the commonly used platforms sacrifice high performance in order to maintain accessibility. These low performance robots are available to a broad audience, but programming complex algorithms on these platforms is a greater challenge than that for high end robots or PC’s. Nevertheless, the low performance of these robots does not limit its application, as long as the implemented code is efficiently written by the programmer [3].

The proposed projects on the HackADay – website provide an insight into how comprehensive the applications of the Arduino platform can be [4]. Young engineers deal e.g. with trivial things like a mailbox robot notifying you if there is a new mail to more advanced implementations like an Arduino-controlled QuadroCopter [5, 6].
A server-client technology is often applied to centralize the logic platform behind the robot. Robots simply act as a client, transmitting sensor values and executing commands from the server. The bottleneck of this approach is the limited capability regarding the response time in this command structure. Programs that run directly on the autonomous robot react faster to any problem that occurs during the operation of the robot.

This publication will provide a guideline on programming low end robots and on the way how to optimize the program code for these demanding platforms.

**Methods in Programming on Low Cost Robots**

The most important method that needs to be established when working on low end Robots is using the Preprocessor [7].

The Preprocessor helps writing a source code by defining constants that get replaced by literals before being compiled. It makes the code more readable, ensuring that you cannot edit the values during runtime and taking up less memory during runtime when using standard variables.

**Knowledge of your Firmware**

When programming on desktops you really appreciate high level application programming interfaces (API’s). They won’t require excessive testing and generally help you programming. There are often a lot of API-layers.

Robot API’s do exist, but most of the time they are hardly optimized and therefore not suited for low performance robots. There is a way out — most of the low end robots have an Open Source firmware, enabling an open access of the source. Downloading, reading and modifying the firmware can improve the performance a lot. It also helps you understand how the firmware operates.

Robots start to support more and more programming languages. Until recent years you were limited to C and maybe some C dialects. Nowadays you get a wide variety of languages ranging from C++ to Java or even Python. With the support of wide spread desktop languages like Java a huge step to improve the applicability is done. In the case of low performance robots you must carefully select the considered programming language.

Java, for example, is really widely spread, which makes the chance very high that the young programmer is already familiar with it. But you have to consider the additional performance the Java virtual machine (JVM) needs [8]. Additionally, Java doesn’t run without the JVM. The JVM is another abstraction layer which is not controllable by the programmer. Hence, robot programming requires a thorough knowledge of the
programming techniques and the programming language chosen for the software development.

Code Efficiency
Writing an efficient code is strongly recommended on low end robots. Correctly implemented software even at low end hardware can run the most complex algorithms. Control algorithms require quite a lot of experience regarding optimization, but there are also a few smart tricks you can use for better performance in general.

```c
while(analog_read(0)>10) {
    int distance = analog_read(0); //save distance into a variable
    //do something with it
}
```

This is an example of a widely applied code snippet. The program reads the distance of the front sensor from sensor-port 0. If the distance is larger than 10, it loops over the operation. In the loop the distance is read-out continuously and saved into a variable. Then the distance determines the next steps of the robots actions.

At first glance this code looks quite simple and you wouldn’t even think about optimizing it, but there are two major flaws in this bit of code.

First Flaw: Lots of Garbage
Every iteration cycle of the loop the integer distance will be allocated. This results in a lot of allocated memory space without any pointers [9]. Some languages like Java use a garbage collector that interrupts your program temporarily and clears allocations to variables. Garbage collectors interrupt the program at scheduled times and are often the reason of randomly appearing mysterious error messages in Java based robot programming.

Other languages like C++ don’t have a garbage collector in the background. This results in a lot of memory space which is allocated and therefore unfeasible for program operations. The programmer could now de-allocate the allocations but that is cumbersome.

The central problem in robotics is that you want the most current values you can get. So if the robot is driving straight ahead to a wall and you want to stop it in front of it minimizing the distance between the wall, every additionally millisecond of controlling the robot results in a lot of iterations through this loop.

With the following code snippet you can fix this problem:
Now the integer distance is allocated once again and every iteration cycle is overwritten.

Second Flaw: Multiple Reads
While the programs always want to have the most current values, the procedure of reading twice in two consecutive lines is not very helpful. Sometimes it even happens that one of the read-out data is a noisy value. It depends a lot on the firmware and how the data can be discriminated.

There are events where the firmware buffers values for all sensors at all times and updates them every, e.g., 100 milliseconds. This is often a problem since the value which the program receives could be up to 100 milliseconds old.

Very often sensor values fluctuate a lot, which makes accurate calculations nearly impossible. When a firmware does not store the values, this might result in large differences between the two values in the sample code. An efficient way to reduce fluctuation of sensor values are filtering techniques described in section 5/sensor values.

To eliminate the differences between consecutive values you can apply the following code:

```c
int distance;
while(analog_read(0)>10){  //check distance of front sensor
distance = analog_read(0);  //save distance into a variable
... //do something with it}
```

By initializing the variable distance with a sensor value and updating it at the end of the loop the code doesn’t need to be read in the while-condition. Now the code should be running a lot more smoothly.

Sometimes, a loop is used as a method to wait for a certain event when programming robots. In that case the following code snippet is more convenient:

```c
driveForward();  //start motors
while(analog_read(0)>10);  //checks distance of front sensor
stop();  //stops the motors
```
After the motors are started, the loop will be repeated until the sensor value is lower or equals 10, but this program will discharge the robots battery continuously.

During execution this loop will use up all the performance of the robot because there is no pause in the loop. This causes problems when operating on robots with just a single core and multiple threads.

With this code snippet the robot will wait 10 milliseconds after every check. When optimizing an algorithm, you normally start with an inefficient version. The optimization process is limited by the running time or the allocated memory. In robotics you also have to consider applicability of the battery and its lifespan. An optimized algorithm often has much more code lines than the raw code. But the code length should not be a criterion. Paul Masuarel wrote on his blog about intersecting linked lists in Python [2]. In the optimized code version he went from a five line code to 50 lines.

Sensor Values
Sensor values tend to fluctuate around a given value. These fluctuations have various reasons and should be handled properly by the program of the robot. For that purpose programs often use smoothing algorithms. These filter techniques can be done by hardware or software actions. In this publication this problem is solved by a code.

driveForward(); //start motors
while(analog_read(0)>10){ Sleep(10); } //checks distance of front sensor
stop(); //stops the motors

Figure 3 shows the difference a smoothing algorithm can make. The raw data come from an infrared distance-sensor. From the overall 1400 values this particular smoothing algorithm leaves all values that are out of tolerance of the previous ones. This results in an abstract view of the data without losing too much of the reasonable values.
The averaging from four to ten regular values is sufficient.

```c
int analogSmooth(int sensor){
    int total = 0;
    int i;
    for(i = 0; i < 5; i++){
        total += analog_read(sensor);
    }
    return total/5;
}
```

Sometimes pauses are added in order to get a better distribution of the values. An extended value range can be helpful when the firmware is caching sensor values. This can cause some confusion from time to time.

```c
int analogSmooth(int sensor){
    int total = 0;
    int i;
    for(i = 0; i < 5; i++){
        total += analog_read(sensor);
        sleep(10);
    }
    return total/5;
}
```

The next algorithm is a custom-made algorithm which tries to cut out values that have a high fluctuation while having a backup strategy and running out of time. The algorithm should not exceed 50 milliseconds, where the smallest quantity of values in the calculations is 12.

The choice of a certain smoothing algorithm depends on the context in which you use the following: (see next page)
If values need to be up to date as possible, consider simple algorithms like the moving average. On the other hand, if you want a value that represents a time period rather than a particular moment, some more complex algorithms must be implemented.

**Conclusion**

This publication has shown how complex optimizing programs for low performance robots can be. Optimizing is necessary to run more complex programs on low end robots. There are many applications from analysis of sensor values to optimizing robot algorithms.

Additionally, in this publication value smoothing approaches are compared and discussed quantitatively. These approaches differ from those that are commonly applied in robots.
Acknowledgement
We would like to thank our principal, Mrs. Mag. U. Hammel, for the continuous support, such as providing a robotic laboratory. Furthermore we would like to thank all our sponsors.

Comments
Amazing Team participated in the Global Conference on Educational Robotics in Norman/Oklahoma during July 6 to July 10 2012 (GCER13) under the supervision of Dr. M. Stifter.

The team members won the World championship in the Alliance Challenge. All team members in alphabetical order: Hovorka Markus, Jung Clemens, Langenau Thomas, Lütge Philipp, Podest Patrick, and Tiefengraber Bruno [10].

References
(1) V. Georgitzikis, O. Akribopoulos, I. Chatzigiannakis; “Controlling Physical Objects via the
a. Internet using the Arduino Platform over 802.15.4 Networks,“ Latin America Transactions,
(2) http://www.botball.org/2013/events/international-botball, September 2013.
(5) http://hackaday.com/2013/03/13/mailbox-notifier-texts-when-the-letter-carrier-arrives/,
a. September 2013.
(6) http://hackaday.com/2013/03/19/diy-arduino-pro-mini-quadcopter/, September 2013.
(7) D. Compton; “Application of an Olfactory Data-Preprocessing Algorithm to Chemotactic
(10) http://www.robo4you.at/, September 2013.
Can Sunlit Leaves With Liquid Drops On Their Surface Be Burnt?

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Abstract
My students learn elementary optics in their 11th school year, including the use of light rays in understanding the effect of focusing. In a problem of one of their physics books the task is to search for the causes why leaves can be burnt in hot summer after being watered. As a solution, the book indicates the convex-lens-like behaviour of water drops focusing sunlight on the leaf surface and thus burning them this way. After reading some publications [1-4] of Gábor Horváth and his colleagues on this topic, listening to his lecture and watching a short film about this subject broadcast by the Hungarian Television [5], I recognised how exciting this issue could be for secondary grammar school students, who could make an experiment with sunlit plant leaves covered by liquid drops. I had a few more ideas with which the problem could be approached and examined from a different physical point of view [6].

Antecedents

Figure 1. Glycerine balls (A-C) and oil drops (D) were used in the experiments
I have read a bipartite article [1, 2] in Fizikai Szemle (Physical Review), the journal of the Hungarian Physical Association, and the relating literature [3, 4], furthermore listened to a short film on this theme broadcast by the Hungarian Television [5]. Then I recognised how exciting it could be to inspire secondary grammar school students to make an experiment with leaves covered with liquid drops and to study whether these leaves are or are not burnt by the focused sunlight. I had a few more ideas with which the problem could be approached and examined from a different point of view [6].

The basic experiment

“It is a widely accepted view in gardening and plant protection that plants mustn’t be watered in the blazing sun at noon as the waterdrops sticking to the leaves can burn them by focusing the sunlight on its surface. A similar opinion in dermatology and cosmetics states that the waterdrops sticking to the skin can also mean danger during sunbath as they focus the sunlight on the skin. In forestry literature one can also come along a belief saying that the sunshine focused on the dried plants by the waterdrops can cause forestfire” – you can read it in the article mentioned above.

The details about the waterdrops sitting on the surface of the plants and focusing the sunlight were examined by Gábor Horváth and his colleagues in 2010. The authors made computer models and experiments with the waterdrops sticking to the sunlit leaves. They took photos of waterdrops sitting on the horizontal leaves of different species of plants and they determined their shape. After that they calculated the dispersion of the light-intensity made by the rotation-symmetric waterdrops on the horizontal leaf surface. The result depended on the shape of the drop and the angle of incidence of the sunlight.

![Figure 2. One example from the many simulations. (A) Side-view photograph of a spheroid water drop on a horizontal rowan (Sorbus aucuparia) leaf. (B) Ray tracing through the vertical main cross-section of the water drop (the contour of which is shown by the red curve) versus solar elevation angle θ. (C) Two-dimensional distribution of the light-collecting efficiency Q of the water drop on the leaf. The area where the water drop contacts the leaf is shown by the inner circle, while the contour of the drop as seen from above is indicated by the outer circle. (Figure 4 on page 984 of Egri et al., 2010 [4])](image-url)
The lesson taught at school

My students learned the basic terms of optics in their 11th form including the image-making and noteworthy beamstream of convex lenses.

![Image: Book cover](image)

**Figure 3.** Students often use the book titled ‘Unified collection of tasks for the school-leaving exam’ in the lessons and for their homework, too.

The task: 2152: In summer it is not advisable to water the plants at midday because the leaves of the plants get ‘burnt’. From the following explanations only one can be accepted. Which is that?

A) The damage to the plants is caused by the steam evaporating from the water.

B) The waterdrops behave as convex lenses and they focus the sunlight on the surface of the leaves.

C) The warmed parts of the plant get cool after the sudden effect of the cold water, which causes the plant to get burnt.

The key of the book chose B) as the correct answer. Together with my students we decided to examine with physical experiments whether the raindrops can really focus the sunlight in such a way that they cause sunburn on the surface of the leaves.
Our ideas and experiments

Figure 4. The authors put glassballs on the leaves: instead of the glassballs we used glycerine balls that can be bought at florists’ as the refraction index of the glycerine ball soaked in water is closer to that of the water.

Figure 5. The authors put waterdrops on the leaves but due to the quick evaporation it had to be repeated several times during the experiment. We replaced the waterdrops with oildrops as it can evaporate more slowly than the water.

Fattening the glycerine balls

Figure 6. The changes in the size of the glycerine balls put into water in the function of time
The starting volume of the glycerine ball was:

\[ V_1 = \frac{4r^3 \pi}{3} = \frac{4 \cdot (1.205mm)^3 \pi}{3} = 7.33mm^3 \]

And its final volume was:

\[ V_2 = \frac{4R^3 \pi}{3} = \frac{4 \cdot (5.15mm)^3 \pi}{3} = 572.15mm^3 \]

It can be stated that at the end of soaking 98.72% of the glycerine ball there was water. Such a ball put in water becomes almost invisible because its refractive index is very close to that of the water. So with the glycerine balls the waterdrops can be modelled well. The volume reduction of the glycerine ball in the air is not significant within 6 hours, whereas the same size waterdrop - depending on the temperature and the strength of the sunshine - evaporates in 25 minutes.

<table>
<thead>
<tr>
<th>Average evaporation time (min)</th>
<th>in shade</th>
<th>in sunlight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acer platanoides</td>
<td>192</td>
<td>24</td>
</tr>
<tr>
<td>Ginkgo biloba</td>
<td>172</td>
<td>23</td>
</tr>
</tbody>
</table>

**Table 1. Evaporation time of waterdrops on leaves in shade and in sunlight**

In our experiments the evaporation time of the waterdrops put on leaves in the shade and in sunlight were compared.

**Figure 7.** With the help of a computer software the size-changes of the waterdrops could be followed.
In general on the basis of the experiments it can be stated that the waterdrops evaporate from the surface of the leaf in half an hour while their shape changes. The parameters of the width to a smaller extent, while the height of the waterdrops decreases to a greater extent, as a result of which the drops become flatter. It means the waterdrops have half an hour to burn the sunrays into the surface of the leaves and in addition the flatter drops are less and less able to do so as it turns out from the basic experiment.

**Methods of experimenting**

Figure 9. 1-st Experiment: The leaves from the same maple tree were placed in two glass-plates: in plate a) the leaves were put with the right side upwards whereas on plate b) they were put with their back upwards. In plates a) and b) the leaves were covered with balls soaked in water (20mm and 2mm).
In the 2nd experiment we tried to provide natural conditions: from above, the leaves got natural light, from beneath diffused green light was provided with the help of the green felt material. One of them received the light on its back side, whereas the other one received it on the right side. Because of the movement of the sun it was important to fix the points of the compasses. Two different types of oil were dropped on the leaves from a pipette: on the maple tree leaves 174-182 drops, on the fernpine tree leaves 15-20 drops.

Control experiments

Figure 11. In the pictures on the left the leaves were put in the shade, while in the pictures on the right they were exposed to direct sunlight. In the upper line oil drops were put on the leaves, in the middle one 20mm glycerine balls and in the bottom one 2mm balls were placed.
The results of the author’s experiment

Figure 12. (A-F) Sunburnt maple (Acer platanoides) leaves exposed to direct sunlight for long (left column), medium (middle column), and short (right column) periods covered by glass spheres with 2 and 10 mm diameter in the 1st experiment. The grid pattern of sunburnt brown patches caused by intense focused sunlight is clearly visible on the green leaves. (Figure 1 on page 981 of Egri et al., 2010 [4])

Figure 13. log₁₀Q versus solar elevation angle θ computed for a water drop on a horizontal maple (A), plane tree (B) and rowan (C) leaf with decreasing wettability from A to C. Q(n_w=1.33,θ) is the maximum light-collecting efficiency of water drops in the focal region. Insets show the side-view photograph of water drops. Data corresponding to rows 1, 2, ... 7, 8 in Figs. 4-6 are marked by filled squares. (Figure 7 on page 985 of Egri et al., 2010 [4])
The final conclusion
The waterdrops from the pipette did not cause traces of burn (except for the Salvinia Natans). Only after about half an hour exposure to sunlight were the glassballs able to burn the leaves (the raindrops would evaporate in 25 minutes). The final conclusion of the authors is that the sunlit waterdrops never cause sunburn either on hydrophobic or hairless, plain leaves. On the other hand, if the leaves are covered with hydrophobic waxhair, which are able to hold the waterdrops above the surface of the leaves, the tissue of the leaf may be burned in the blazing sun.

The results of our experiment

Figure 14. In picture 1) the maple leave covered with the soaked 20 mm glycerine balls can be seen, whereas in picture 2) the maple leave covered with 2 mm soaked glycerine balls is shown after being exposed to the sunlight for 6 hours. The traces of burn can be recognized and their stretching is due to the relative movement of the sun. In pictures 4) and 5) the maple leaves covered with oildrops can be seen. They spent 6 hours being exposed to the sunlight. No traces of burn can be seen. In pictures 3) and 6) traces of burn can be recognized on the fernpine leaves covered with oil drops.

Figure 15. The results of an experiment from 3 pm till 5 pm. Figure a) shows the traces of burn on the maple leave covered with 20 mm soaked glycerine balls after being in the sun. In figure b) one of the traces of burn can be seen in a magnified view. In figure c) the tiny traces of burn on the fernpine leaf covered with 2 mm soaked glycerine balls is shown.
As the control-experiment was made late in the afternoon, the angle of incidence of the sunlight was smaller measured from the horizontal plane, so the mappings of the sunlight passing through the glycerine balls also modified. During the control there was a much more intensive burning effect, in some places there were completely dark stains. According to these results it can be stated that the burning effect of the sun is much stronger late in the afternoon - which also follows from the theoretical prediction - than at midday (as it was claimed in the text of the book). Late in the afternoon the burning effects of the sunshine focused by the soaked glycerine balls is stronger.

Our conclusions
The oildrops did not cause traces of burn on the maple leaves although they focused the sunlight on the leaves for several hours. The traces of burn on the leaves of ginkgo biloba did not show the dispersion of the computer-model. As the oils used in the experiment were not transparent, they got warm due to the absorption of the light. The chemical reaction was not possible as no traces appeared on the leaves covered with oildrops in the shade. For further examination the experiment is going to be made with transparent paraffin oil this year and also hot oil is going to be dropped on the ginkgo leaves in the shade.

To summarize our results, the waterdrops as flat convex lenses are not able to burn the smooth-surfaced leaves in the blazing sun. One consequence of this is that indicating the possible causes of forest fires with such an explanation in forestry literature and saying the strong focusing effect of the waterdrops can cause fire proves to be a false thought. As for task 2152, in the solution book (Unified collection of tasks for the School-leaving exam) the correct answer is not given, i.e. the possible alternatives do not include this explanation, so the publisher of the book is kindly requested to correct the mistake.

I wish to express my thanks to my tutors dr. Horváth Gábor and dr. Juhász András, my students, Murguly Alexandra, Pátyay Richárd and Czéna László, the “Webcam-laboratory” for the free software use, and also to Kürti Anetta.
References


[3] Egri Ádám (2009) Bioptics of waterdrops sticked to plants with a special attention to leaves being sunburnt. Thesis, Eötvös University, Department of Biological Physics, Environmental Optics Laboratory, Budapest, p. 57 (supervisor: Gábor Horváth) (in Hungarian)


Towards green cars

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Abstract
From the beginning of the 20th century many people and factories have been trying to introduce better and better environment-friendly cars. In our days there are several different types of vehicles, which can get the „Green Car” award.

Which was the first car like that? Why is it good to use that kind of car? Just because its operation is cheaper? What are the benefits of using a green car? People know that they are environment-friendly vehicles, powered by alternative fuels and more expensive than other conventional internal combustion engine vehicles.

I am going to give the reasons why we should speak about this topic in a secondary school, how we can bring hybrid technology into education.

Then, I am going to present some parts of the development of alternative cars and to analyse the structure of the most remarkable models.

Introduction
Undoubtedly, the energy crisis, the air pollution and the increasing emission of greenhouse gases are among the biggest problems of the contemporary world. The primary cause of these problems is the excessive use of fossil fuels in energy production. Not only physicists, chemists and engineers have the responsibility to save the environment, and by trying to reduce the energy crisis through their new inventions, but also teachers, by making children interested in these problems. The remedy is complex, here we discuss only some issues related to the substitutes to combustion engine driven vehicles. The large scale introduction of alternative vehicles would have a positive impact on global climate change, too.

Outline the problem
Population and income growth are the two most powerful driving forces behind the demand for energy. According to the United Nations, the world population reached 7 billion on October 31, 2011. Nowadays, more than 250 children are born and 100 people die every minute, so in every 60 seconds the world’s population increases by 150 people! Since 1900 world population has more than quadrupled, real income has
grown by a factor of 25, and primary energy consumption by a factor of 22.5. The next 30 years are likely to see continued global integration and rapid growth of low and medium income economies. Maybe, the population growth is trending down, but we know from the statistics that the income growth is trending up.

Over the last 20 years the world population has increased by 1.6 billion people, and it is projected to rise by 1.4 billion over the next 20 years. The world’s real income has risen by 87% over the past 20 years and it is likely to rise by 100% over the next 20 years. At the global level, the most fundamental relationship in energy economics remains robust – more people with more income means that the production and consumption of energy will rise. The transportation sector is second in terms of world energy use. The transportation share of total liquids consumption increases from 51% in 2006 to 56%.\(^{[1,2]}\)

But do we have enough coal, gas, oil on our planet? Is it possible to increase the production continuously? Or should we change the energy sources?

There are more than 600 million motor vehicles on the streets. The biggest manufacturer is Japan, having produced 8,056,000 cars in 1998. Then the US, with 5,554,000, and Germany with 5,348,000. In course of time, these numbers experience a rapid growth. In 1960 Japan produced "just" 185,000 cars, but by the end of the 1990s it was producing nearly 10 million a year. It is believed that at this growth rate, the number of cars on Earth will double within the next 30 years.

Human life demands mobility, so we can’t organize our everyday lives without changing places. In several countries in Europe people are used to travelling 100 kilometres a day, so they can’t imagine life without transportation.

Carbon dioxide is a greenhouse gas. Greenhouse gases (GHG) are those gaseous constituents of the atmosphere, both natural and anthropogenic which absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth’s surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H₂O), carbon dioxide (CO₂), nitrous oxide (N₂O), methane (CH₄) and ozone (O₃) are the primary greenhouse gases in the Earth’s atmosphere.\(^{[3,4]}\)

I only chose carbon dioxide (CO₂) to analyse, but the other emitted gases show the same change in the same length of time. The analysed data and the diagram come from the official website „Carbon dioxide Information Analysis Centre“ and present the major global sources of carbon dioxide (CO₂) emissions from different countries, from the beginning of the Industrial Revolution to the present.\(^{[5]}\)
Figure 1. Diagram left shows the change in the number of cars, on diagram right the global carbon dioxide emission from fossil-fuel burning is presented.

I have to add that the emitted carbon dioxide gas comes from transportation (20%), cement manufacture and gas flaring.

When on a smoggy day we cannot see the Sun because of the air pollution, maybe everybody will feel his responsibility, and everybody will be able to grasp, we have to do something at the moment, for the future! That is not a yes or no question, there is no choice!

Do we have to change our habits? - Do we need to change our cars?

But better late than never!

Solution (?) for the problem

How can we find the good solution to reduce the air pollution and the greenhouse gas emission coming from transportation? Maybe by developing new kinds of cars, which emit less gas, or run without gas emission! But is the idea of hybrid cars a new one?

The world's first hybrid car was “The Semper Vivus”, by Prof. Ferdinand Porsche, who was busy designing and developing this car as early as 1896. Four years later, when his second car the Lohner-Porsche with electrical motors first appeared in the “World Exhibition of Paris, in April 14, 1900, - it was 112 years ago - it astonished the automobile world and was an authentic novelty for the automobile fans of that time. The innovating success of this design catapulted Dr. Ferdinand Porsche to the fame as engineer. 300 Lohner Porsches were produced.” [6]

Up to the 1920s a lot of manufacturers made "hybrid cars" in a very similar pattern.

After this date in the transport history we cannot find any other hybrid trials until the 1960s and 1970s. What was the reason? The advances in ICE- Internal Combustion
Engine, the cheap oil and automobile production in general killed off the hybrid cars. Then, the „first” reviving hybrids appeared owing to the Arab Oil embargo.

What does a green car and a hybrid car mean? We can frequently meet these expressions. But which one is correct? It seems difficult to give the answer. It is certain that all green vehicles must be environmentally friendly, so they must not produce so many harmful impacts on the environment, they reduce air pollution and greenhouse gas emission. A green vehicle can be a hybrid electric vehicle, a plug-in hybrid electric vehicle... sometimes they include just a conventional motor with high fuel economy.

The real hybrid vehicle can be described as a curious mixture of an electrical vehicle and a car with an internal combustion engine. There are two different drive systems in it, where the first is the normal internal combustion engine, and the second one is the electric motor.

There are more possibilities in hybrid car classification, we can make this for example according to the driving system. Nowadays the serial-hybrid and the parallel-hybrid constructions are the two most current technical solutions. Serial-hybrid vehicles are driven only by electric traction only. Due to the lack of direct drive between wheels and internal combustion engine a permanent revolution per minute can be obtained in the ICE. The internal combustion engine drives a generator, which is responsible for simultaneously supplying electricity to electric motors and batteries. In the parallel-hybrid an internal combustion engine works in conjunction with a small electric motor, 5kW to 25kW, which has to provide extra torque to the power train system in the car. When the power driving cycle is less intense, the vehicle can also utilize the engine to charge the battery pack.

If our car is a parallel-hybrid, we have the possibility to turn off the internal combustion engine and use the vehicle like a completely emission free full electric vehicle. In this case the electric motor runs on the battery pack. But please note that we have electric energy only for a shorter in-town drive.

If we look at the palette of hybrid cars, we will see that a lot of them are actually parallel-hybrid vehicles.

The other way to classify the hybrids is by their power, sometimes we say the cars are on different degrees of hybridization. The microhybrids have less electric power, they are utilized only in parallel hybrids. A special electrical engine with a belt drive is in charge of the electric supply, and it is useful in the start-stop mechanism.

The mildhybrid has more power than the microhybrid, but it is not enough to make the car move. The electric motor helps the ICE during acceleration, therefore the normal engine is calmer and needs less gasoline.
Only the full hybrid- strong hybrid- vehicles are able to move by electric power without running the internal combustion engine. When the power driving cycle is less intense- we run downhill- the potential energy will be stored in the battery. When we need more energy, during acceleration, the electric and the internal combustion engine are working together. It is always an on-board computer that adjusts the electric motor permanent depending on the thrust level. This computer has to check the battery charge status too, as the battery must not be charged less than 40%, or more than 60%. In this way the battery can actually last longer than the car itself!

Conclusions- experience during the research –
How can we introduce this subject to the students?
You might think that nowadays it is not difficult to see hybrid vehicles, even if you do not own them. In my country you would be surprised. During the work on this topic – the hybrid car- I tried to speak to hybrid car owners, but they were unfriendly and suspicious, I was turned down many times. To get information about the car was a mission impossible! I was at the point of giving up, when fortunately I was helped by a really good colleague, who turned out to have such a car herself. We had a test drive, I was lucky enough to look under the hood, I found the high voltage units, and the warning cautions. Sitting in the car I felt I was in a SCI-FI.

It is useful to read the user’s manual of a hybrid car, it is really informative. We must learn how to drive hybrids. Without a manual the owner can have some serious problems, too, the owner can even cause damage to the car. [7,8]
In the car salons the sellers could not give any additional information about the technology, they were able to read the papers behind the windscreen. They told me I should buy a car with normal combustion engine... (I was in 12 car salons- and I found just one where they suggested buying a hybrid car.)

In the abstract I wrote “Not only physicists, chemists and engineers have the responsibility to save the environment, and by trying to reduce the energy crisis through their new inventions, but also teachers, by making children interested in these problems.” Teachers have an important role not only in teaching, but in the environmental education. In school we must speak about the energy consumption, about the greenhouse gases, and about the climate change. Students do not gather enough information at home. Even if they receive information from the media about air pollution or the greenhouse effect, maybe they do not realize their relevance. If we don’t show them a way to environment friendly life, they will never have a green attitude. They will simply live like the other thousands of millions of people in a consumer society, who start and stop their ICE cars several times day by day. The striking facts and interesting details of technology collected in the present paper may serve as a good starting point for elaborating on this aspect of environmental education.
Acknowledgements

Very special thanks go to Eszter Viszlai-Nagy for English translation, and special thanks go to Dr. Mátyás Koniorczyk, Dr. Tamás Tasnádi for their professional help.

References


[7] Toyota group. *Owner’s manual*

Luminescence in Nature and in the Education

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Abstract

Luminescence is an attractive phenomenon that is present in our artificial environment as well as in nature. This interdisciplinary topic involves physical, chemical, and biological aspects. Luminescence can be easily demonstrated in classrooms, which is an efficient way to motivate students and to turn their interest toward science. Students develop a specific knowledge by learning about luminescence that helps them to see nature as a complete and complex system. Luminescence has numerous occurrences in nature offering spectacular images to demonstrate this phenomenon.

Introduction

Multiple reasons prove the usefulness of teaching luminescence in high schools. We are going to list some of them here.

Luminescence is a phenomenon that is more common than one would think. It is present in our everyday life, such as on the face of watches and clocks, light switches, security marks on bank notes, in tonic water, light sticks, and glow-in-the-dark ornaments. Besides these, it occurs at more exotic places, such as in deep-sea animals.

Unfortunately students know very little or even nothing about luminescence although they learn about atomic physics that builds up the fundamentals. Teaching atomic energy-levels, absorption, and emission becomes more interesting for students by connecting them with luminescence.

Luminescence is an interdisciplinary topic. Areas of physics, chemistry, and biology have to be covered to answer a question like “How do fireflies emit light?”. Physics and chemistry are necessary to understand the process of light emission. Biology helps to discover the importance of this skill in animals during the evolution. By learning about luminescence, students develop a specific knowledge in this topic that helps them to see nature as a whole and complex system. This topic also provides a good opportunity to assign projects for students.
Students find themselves easily excited about this topic by searching for the presence of luminescence and by recognizing it where they would not expect it. Students gain motivation and start to develop a strong interest in science by learning about luminescence.

Luminescence is still a hot topic for researchers and provides new discoveries even today, e.g., in 2008, the Nobel-prize in chemistry was given to a scientist doing research on cancer treatment based on luminescence research results.

The phenomenon of luminescence

Luminescence is a light emission caused by an excitation effect. It is important to note that this emission is not the result of heating, i.e., the emitted light is not from a thermal radiation.

According to the source of excitation, the main types of luminescence are the photoluminescence (the excitation source is an incident light), the chemiluminescence (chemical reaction causes the excitation), the bioluminescence (photoluminescence or chemiluminescence in a living organism), the electroluminescence (electrical interaction is the root cause) and the triboluminescence (luminescence of a crystal after mechanical stress).

This article focuses on photoluminescence, chemiluminescence, and bioluminescence because these types are the most motivating and easy to understand for students.

Photoluminescence

Photoluminescence is a light emission caused by light excitation, i.e., the incident UV light excites electrons from ground state to a high energy-level. The energy difference is emitted as a visible light, as the electrons return to the ground state. According to Stokes-law, the wavelength of the emitted light is longer than the incident light, so some energy deficit is observed. Fluorescence and phosphorescence are distinguished by the light emission process that is discussed below.

In fluorescence, the emission is short. It lasts as long as the excitation. The emitted energy of the light is lower and the wavelength is longer than the incident light. Fluorescence can be easily demonstrated in classrooms. Only a UV-lamp, and either a banknote, or washing powder (or a white cloth washed by this washing powder), a fluorescent lamp bulb or tonic water are necessary. The fluorescence appears immediately as any of these are illuminated.
In phosphorescence, the emission is present even after the end of the excitation. It can last as long as several hours. Phosphorescence can be demonstrated in classrooms by UV illumination of clock faces, light switches, toys, or glow-in-the-dark ornaments.

The difference between the phenomena of phosphorescence and fluorescence is shown in Fig. 1 by the Jablonski-diagrams. Figure 1(a) shows the energy level-changes of an electron in the case of fluorescence. The excited molecules exert an impact on each other. Their electrons, losing some energy, fall down to a low vibration energy level and to the ground state in one step. Figure 1(b) explains the energy change of an electron in the case of phosphorescence. The electrons also step down to a low vibration energy level like in fluorescence, but in two steps. First, the electrons step to an intermediate energy level in a fast process, and then they fall down to the ground state in a slow process. The second transition of the electron is slow because it is limited by the quantum mechanical selection rules. These rules state that only those transitions are allowed in which the quantum numbers are changed with the stated values. Therefore, electron transition occurs rarely and stretched in time, but light emission lasts even after the illumination is removed.

![Jablonski-diagram](image1)

**Figure 1.** The Jablonski-diagram of fluorescence (a) and phosphorescence (b).

**Chemiluminescence**

Chemiluminescence is based on a chemical reaction, in which one of the products in excited state emits light while relaxing to the ground state. This reaction is followed by a minimal heat emission as most of the energy is emitted as light. Enzymes can raise the efficiency of the reaction. Party light sticks, fishing lures and the luminol-test in criminal investigation are a few examples of chemiluminescence.

Light sticks and fishing lures are commercially available; therefore experiments in classrooms can be easily performed. These sticks are constructed from two cylinders, the inner one has a fragile wall and contains hydrogen-peroxide, whereas the outer one is flexible made from plastic and contains phenyl-oxalate-ester (DNPO or TCPO, Fig 2.) and fluorescent dye.

To demonstrate chemiluminescence, the stick needs to be bent so that the inner cylinder is broken, allowing the chemicals to mix. During the reaction, DNPO/TCPO is
oxidized by the hydrogen-peroxide, and the resulting energy excites the fluorescent dye, which emits visible light.

![Chemical structures of DNPO and TCPO](image.png)

*Figure 2. The skeletal formula of DNPO (left) and TCPO (right).*

Chemiluminescence is used in criminal investigation that definitely increases the interest of the students. The so-called ‘luminol-test’ detects old, dried blood stains. During the investigation, luminol (Fig. 3) and hydrogen-peroxide are sprayed to the fabric, and the iron of hemoglobin catalyzes the chemical reaction of these two compounds. As the chemical reaction of chemiluminescence starts and the light is emitted, the available 30 seconds can be used to photograph the blood stain. This experiment is possible to work in classrooms with luminol, hydrogen-peroxide, sodium-hydroxide and potassium-carbonate. By mixing these materials in a dark room blue light is emitted.

![Chemical structure of luminol](image.png)

*Figure 3. The skeletal formula of luminol.*

**Bioluminescence**

Bioluminescence is a light emission by fluorescence or chemiluminescence in a living organism. Since incident light is required for fluorescence, it is rare in nature. Therefore, chemiluminescence is more common and mostly used by deep-sea animals due to the lack of light.

Although the occurrences of bioluminescence in species are numerous, the same type of chemical reaction provides the light. In this chemical reaction, the so-called luciferin reacts with oxygen in presence of luciferase enzyme, magnesium-ions and adenosine-triphosphate (ATP). Light is emitted as the excited luciferin resumes to the ground state. The efficiency of this reaction is 100 %, meaning that the whole relaxation energy is emitted as light without any heat dissipation. Therefore, the emitted light is often called “cold light”.
The only difference between the various species is the specific compound that is used as luciferin and as luciferase. Figure 4 shows a specific luciferin of the firefly.

![Figure 4. The skeletal formula of the luciferin of the firefly.](image)

Animals known for their ability to emit light are the mushrooms, unicellular, bacteria, worms, sponges, jellyfishes, squids, crabs, shells, snails, and insects. Luminescence does not exist in vertebrates as it is missing from the list above as well. Among several explanations, one is mentioned here below. At the beginning of the life on earth, the atmosphere had a different gas content than today, it had a reducing effect. The oxygen was present in a small amount, being toxic for anaerobe animals. These animals had to eliminate oxygen; therefore they developed a chemical reaction that could not include any heat release although every oxidation reaction is exothermic. As a solution, luminescence was used that allows energy release as light emission. As the atmosphere became oxygenated by time, the skill of emitting light remained, although, the function changed. The glow is used in these animals for reproduction, for prey inveiglement, for deterring, and for escape. The vertebrates appeared on Earth after the atmosphere became rich in oxygen, therefore having no need to develop such a skill.

In the following paragraph, some light emitting species are listed. Amazing pictures are available on the internet that can be shown in classrooms or used as homework assignments.

**Mushrooms**

Among mushrooms, there are more than sixty species that use luminescence. The Jack-o’-lantern mushroom (*Omphalotus olearius*) is one example. The ‘ghost fungus’ (*Omphalotus nidiformis*), which lives in southern-Australia, was used by soldiers as a torch on their guns.

**Bacteria**

Bacteria often live in symbiosis with other animals e.g. the flashlight fish (*Photoblepharon*). It has bacteria under the eyes helping the fish to navigate under the sea. Another example of symbiosis is the humpback anglerfish (*Melanocetus johnsonii*) that has bacteria in its hook to attract prey close to its mouth.
Some luminescent bacteria are present on specific meat surfaces that were common at markets before the age of refrigerators. A French scientist, Raphael Dubois was the first who examined luminescence in the 19th century and showed that bacterial cultures filled in a 25-liter bottle can illuminate a room on the World Expo, Paris, 1900.

Worms

The female fireworm (*Odontosyllis enopla*) hovers on the surface of the seabed and emits green light that attracts males. The railroadworm (*Phrixothrix hirtus*) shows an interesting behavior by emitting two different light colors. Only two red dots illuminate its head when the animal is calm. In stress, eleven pairs of spots start to emit green light and the worm seems like a train in the darkness.

Jellyfishes

Crystal jelly (*Aequorea victoria*) uses fluorescence with a special protein, the green fluorescent protein (GFP). For the discovery of this protein and its application in cancer therapy, a Nobel-prize was given in 2008. GFP binds to cancerous cells and emits green light at UV illumination. During the surgery, this allows the doctor to see the real tumor size along with the boundary between cancerous and healthy tissues.

Shells

The first animal which was studied in terms of luminescence was a shell, *Pholas dactylus*, that uses luminescence for escaping.

Crabs

As an example among the crabs, krill can emit light. The reason of light emitting might be hiding. During the World War II, Japanese soldiers used krill to illuminate their maps in the darkness.

Insects

Several insects are able to emit light with luminescence. Only the fireflies have two thousand species. Fireflies like the *Pteroptyx tener* can control the time and the duration of light emission. Therefore, they can perform synchronized light emission giving the impression of a Christmas tree in the dark.
Summary

Teaching of the phenomenon of luminescence involves several disciplines, which makes it challenging. The physical, chemical, and biological background is hard to understand for high school students, but the relatively easy experiments and interesting pictures from nature provide a strong motivation. This topic helps students to gain an interdisciplinary picture of nature.

Acknowledgements

I would like to thank my PhD supervisor, Zsuzsanna Rajkovits, for bringing the luminescence to my attention and for initiating a detailed study of high school teaching methods.

References

Energy, Power and Climate Change in Physics Lessons

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Abstract

Energy crisis and climate change are both among the vital and yet unsolved problems that mankind must face in the 21st century. Though from the media we can learn about many catastrophes – floods, droughts, hurricanes – devastating different regions of the world, and continuously experience the increase of the price of electricity and gasoline, in Hungarian schools not much is taught about the different energy sources and global warming.

Although the extent of global warming is still a question of debate, even at secondary school level simple climate models can be introduced. Power generation involves a wide range of physics, – depending on the type of power station – from mechanics to nuclear physics; however, the present paper is restricted to wind energy only.

Motivation

Nowadays, in Hungary, physics is quite an unpopular and difficult subject, which is learned unwillingly, though in many cases it would be very important for people to be more familiar with the laws of physics, in order not to be misled. Also it would be essential to have greater knowledge of our environment; since it may happen that we have to vote for or against some type of power station, radar station, or simply have to decide what type of material to use when a house is built, or renovated.

The importance of educating people who become more environmental minded was realized by the International Baccalaureate\(^2\) many years ago, and since 2007 energy, power and climate change have become part of the compulsory material. This gave

\(^2\) International Baccalaureate (IB) is an international educational foundation, which has schools in more than a hundred countries, and provides a two-year diploma programme, recognized by many universities in the world.

My school is a dual language school, where the students learn most of their subjects, including physics, in English, and each year there are some students who take the International Baccalaureate exams.
me the idea to teach some parts of these topics to my students in the Hungarian classes.

First approximately half of last year’s students were given a questionnaire, in order to find out how much they knew about the topic. Most of them could differentiate between the renewable and non-renewable energy sources, could list some greenhouse gases, and believed that the climate is changing, but did not know how exactly the atmosphere warms up the surface of the Earth, what exactly greenhouse gas means, did not have much knowledge of power generation, the difference, for example, between the solar panel and the solar cell. The topics were discussed in several lessons, and although most of them did not like the calculations, they found the results interesting and said that it was exciting and useful.

Simple models

In order to show the role of the atmosphere, and the greenhouse gases, two simple models can be introduced. As a background, the students should have been introduced to the blackbody radiation, the Stefan—Boltzmann law, and Wien’s displacement law; also the solar constant and the term albedo must be explained. Although it might not need to be mentioned at secondary school level, in these simple models Kirchhoff’s law – the efficiency of the absorbed and emitted power is the same – is also supposed to be true.

a) The temperature of the Earth surface without the atmosphere

In this estimation the Earth is considered a black body which absorbs some part of the incoming radiation from the Sun, while the rest is reflected – in case of the Earth the average albedo \(a\) is considered as 30 % – and also emits radiation. Because the Earth is in thermal equilibrium the absorbed and the reflected energies are equal. At secondary school level the trickiest step of the derivation is to make the students understand that in case of the incoming radiation the solar flux can be calculated by multiplying the Solar constant \((S=1370 \text{ W/m}^2)\) by the cross section of the Earth, whilst in case of the emitted radiation the surface area of the globe must be used. Thus the equation is:

\[
r^2 \pi S (1-a)=4 r^2 \pi \sigma T_0^4
\]

where \(r\) is the radius of the earth.

From this the temperature of the earth without the atmosphere \(T_0\) can be calculated:

\[
T_0=\sqrt[4]{\frac{S(1-a)}{4\sigma}} = 255 \ K = -18^o \ C
\]

The gained temperature is surprisingly small, so it is pretty obvious that the model is not good enough. So let us consider the atmosphere as well.
b) The temperature of the Earth with an opaque atmosphere

Before any calculation, the role of the atmosphere must be explained. Both the Sun and the Earth are considered as black bodies, so they emit radiation at all frequencies, but according to the Wien’s displacement law the intensity of the emitted radiation at the different frequencies is different. The surface temperature of the Sun is approximately 6000 K, so the most intense emitted radiation is in the visible light region; whilst in case of the Earth the surface temperature is much lower so the wave of maximum intensity emitted by the Earth is in the infrared region. (Applying Wien’s law and using 15°C as the average surface temperature of the Earth we gain: \(\lambda_m=0.0029/288=10^{-5}m\).)

Observing figure 1, it can clearly be seen that the atmosphere is almost completely transparent in the visible spectrum, which is the peak of the solar spectrum. It is very opaque in the UV spectrum (mostly because of the ozone molecules), and it has variable opacity across the IR spectrum. Obviously there are other gases in the air as well, but except for Oxygen, which absorbs UV, the others shown in the figure are the so called greenhouse gases, since they cause the warming of the surface, because they absorb the infrared radiation emitted by the Earth. (The surface of the Earth warms up because these greenhouse gases re-radiate the absorbed power into all direction, so some part of the infrared radiation cannot escape to space.)
In the second model a totally opaque atmosphere is assumed, which means that all the IR radiation is absorbed by the air. The arrows in figure 2. show the radiations:

If i.) the earth and ii.) the earth and the atmosphere system are considered, the energy balances can be written in both cases (as both the earth, and the earth atmosphere system are in thermal equilibrium):

i.) at the earth:  
\[(1 - a)S\pi r^2 + \sigma T_a^4 \cdot 4\pi r^2 = \sigma T_e^4 \cdot 4\pi r^2\]

ii.) at the top of the atmosphere:  
\[(1 - a)S\pi r^2 = \sigma T_a^4 \cdot 4\pi r^2\]

\(T_a\) is the temperature of the atmosphere, and \(T_e\) is the temperature of the earth.

Dividing the equations by the surface area of the earth \(4\pi r^2\) the following equations are gained:

i.)  
\[\left(1 - a\right)^\frac{S}{\pi} + \sigma T_a^4 = \sigma T_e^4\]

ii.)  
\[\left(1 - a\right)^\frac{S}{\pi} = \sigma T_a^4 ;\]

Thus we get:

\[T_a = T_0 = 255K = -18^\circ C\text{, and } T_e = \sqrt[4]{2}T_0 = 303K = 30^\circ C.\]

The first is quite understandable; the temperature of the atmosphere must be the same as the temperature of the Earth without the air, since the Earth and atmosphere system must behave similarly as the bare Earth in the previous model. However, the temperature of the surface of the Earth in this latter model (30°C) is higher than the average surface temperature in reality (15°C). So the model shows that the atmosphere makes the temperature of the surface higher, but it is still too simple to
give the true value. This can be experienced, too, in summer walking bare foot in the sand feels really hotter than the air.

Another interesting fact that is worth pointing out to the students is that although there is thermal equilibrium, the temperatures are not equal. This is because the earth and atmosphere system is not a closed system; there is a constant incoming flow of energy from the sun.

(Some students may have the idea to consider the earth as one system and the atmosphere as another one. In this case the energy balance for the earth is the same as i.) \( (1-a)S\pi r^2 + \sigma T_e^4 4\pi r^2 = \sigma T_e^4 4\pi r^2 \). However, in case of the atmosphere the incoming radiation is only the radiation from the earth, since the radiation from the sun goes through it, and the atmosphere re-radiates both towards the ground and towards the space, its surface must be doubled. Thus the energy balance for the atmosphere is: \( \sigma T_e^4 4\pi r^2 = 2\sigma T_a^4 4\pi r^2 \). These equations give the same result as the previous ones.)

Further problems

The following two problems might not be as important as the previous two models, and might only be mentioned to more able and inquiring students.

a.) A more opaque atmosphere: [2]

In this model let us assume that the atmosphere consists of two layers, each of which totally absorbs IR radiation. Figure 3. shows the radiations. Now the earth and the two layers together; the earth and the air layer next to it and the bare earth are considered as three systems, and the energy balances can be written. The equations below are the energy balances divided by the surface area of the earth, or with other words the intensity equations. \( (T_e, T_1, T_2) \) are the temperature values of the ground, the layer next to the ground and the upper layer, respectively, \( S \) is the solar constant, and \( a \) is the albedo.)

\[
(1-a)^4 = \sigma T_e^4 \\
\sigma T_1^4 = \sigma T_2^4 + (1-a)^4 S \\
(1-a)^4 + \sigma T_1^4 = \sigma T_e^4
\]

Figure 3. The arrows show the radiations in case of a double layer atmosphere
From the equations the following temperature values are gained:

\[ T_1 = \sqrt[4]{2} T_0 = 303K = 30 \, ^\circ C \]

\[ T_2 = T_0 = 255K = -18 \, ^\circ C \]

\[ T_e = \sqrt[4]{3} T_0 = 336K = 63 \, ^\circ C \]

Clearly this model gives an even warmer temperature value for the ground, but it might be a good practice for the students to set up the energy balances, and at least the result is supported by our experience that two or more layers produce better heat insulation, so in cold weather layered clothing is preferred.

\[ a) \text{ Leaky greenhouse} \ [3] \]

According to the measurements the average surface temperature of the earth is 15\(^\circ\)C. If we use our second model (the earth and one layer of air) we have to assume that some part of the emitted IR radiation can escape to space, so the atmosphere is leaky. The following question may be raised: what fraction of the radiation emitted by the earth is absorbed by the dry atmosphere if we assume that the surface temperature of the earth is 15\(^\circ\)C? Let us introduce the letter \( \varepsilon \) for this fraction, and let \( A \) be the intensity of the emitted radiation by the atmosphere.

Intensity equations:

At the ground (written for the earth):

\[
(1 - a) \frac{S}{4} + A = \sigma T^4_e,
\]

At the top of the atmosphere (written for the earth-atmosphere system):

\[
(1 - a) \frac{S}{4} = A + (1 - \varepsilon) \sigma T^4_e
\]

Adding on the two equations \( A \) can be cancelled and substituting the data, the solution is:
\[ \varepsilon = 0.77 \]

thus 23\% of the emitted radiation by the ground escapes to space.

The Earth’s annual and global mean energy balance

In reality the atmosphere is much more complex; figure 5. below shows the intensity of the different radiations. Furthermore the heat transfer is not only radiation, but convection and evaporation as well.

From figure 5. it can be read that the emitted intensity by the ground is 396 W/m\(^2\), and the intensity of the escaping radiation is 239 W/m\(^2\), which means that 239/396 = 60\% of the emitted radiation is leaking, which is more than the 23 \% that was gained in problem b.). The reason is that the atmosphere is warmed up not just by the radiation of the ground, but by the thermals and by the evapotranspiration, thus more heat must pass the atmosphere to space.

Figure 5. The earth’s annual and global mean energy balance for the Mar 2000 to May 2004 period (W/m\(^2\)) [4]
Another important property of the radiations is that they are not uniformly absorbed and emitted by the surface of the earth. It is quite obvious that the absorbed power is greater at the equator than at the poles. However, the earth radiates more power than it absorbs at the poles, and radiates less than the absorbed power in the tropics. (Figure 6.) (Interestingly it radiates most at the Tropic of Cancer and at the Tropic of Capricorn, and not above the equator, because above the equator there are more clouds, which impedes the emitted radiation to pass the atmosphere.)

The inequality of the incoming and released powers means that there must be a global energy transport, which is partly by means of the wind.

![Figure 6. The graph shows the intensity of the absorbed (blue curve) and emitted (red curve) radiations as a function of the latitude. (Zero is the equator.) [5]](image)
Harnessing the wind

Now we can see that the energy of the wind is generated by the sun. Wind energy has many advantages: it is renewable, clean, there is no CO₂ emission, land can be cultivated around wind turbines, but also it has disadvantages as well: it is unreliable, changes the landscape, has low energy density, building a wind farm is expensive.

Hungary is not very luckily situated from the point of view of wind energy, since in the middle of the continent the wind speed is much smaller than near the ocean. The best area is the North-west region of Hungary. During the lessons a particular wind turbine Enercon 40 was discussed (figure 7.). Its characteristic data are the following: peak power: 600 kW, diameter of rotor: 44 m, height: 65 m, starting wind speed: 2.5 m/s, optimal wind speed: 12 m/s. [6]

(It may be worth mentioning that the maximum power per unit area generated by the wind is proportional to the third power of the velocity of the air, but for a hypothetical ideal wind-extraction machine no more than the 16/27 of the kinetic energy of the wind can be captured.)

Figure 8. shows the average wind speeds in Hungary at a height of 75 m, even in the North-west region it is only 5-6 m/s, which is half of the optimal wind speed of the wind turbine E40. One more characteristic which might be good to define is the capacity factor: a factor that describes the fraction of the time that wind conditions are near optimal. This capacity factor in the North-west region of Hungary is approximately 20%. Though the following problem is mainly math, the result was interesting to the students.

Assuming that the capacity factor is 20%, how many wind turbines similar to E40 should be used if we were to replace the nuclear power station at Paks with a wind farm? The power generated at Paks is 2000MW. (Hungary has only one nuclear power station at Paks.) The result is 16000, which stunned the students.
Figure 7. Enercon 40

Figure 8. Wind speeds in Hungary
Conclusion

Nowadays the energy crisis, power generation and climate change are hot topics. Students are usually interested in them since a lot of information is provided by the media or the internet: it is interesting, surprising, astounding, unbelievable, worrying, but not always true or unbiased.

The explanation of the greenhouse effect involves a lot of physics, from model creation through thermodynamics to the black-body radiation, and maybe a popular topic makes it easier and more enjoyable for the students to learn and practice the laws of physics as well. In order to educate students to be more environmental-minded and energy-conscious, the discussion of the different possibilities for power generation is very urgent and important.

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References

Students' Misconceptions in Mechanics and their Manifestation in a Survey

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Abstract
Regardless that students have been taught physics or not, they have their own visions, which influence their physical thinking. These visions can facilitate the teacher’s work, but they can also make it difficult. There is a well-defined, specific form of reflective thinking when students seem to have the right visions and do not easily accept the scientific knowledge to replace them. This is the case of students’ misconceptions.

Our goal is to characterize misconceptions in mechanics, present some misconceptions, and construct a questionnaire to test them. We also deal with classification of misconceptions and appropriate strategies to fight against them.

What are the misconceptions?
Student’s misconception is that kind of school belief that contradicts the scientific evidence. Probably it is an inevitable part of the teaching process. It cannot be handled as a simple mistake because it seems to be based on real facts. Therefore it is resistant to any efforts of correction [1].

Misconceptions often contradict the key knowledge of physics; therefore they basically obstruct the process of gaining meaningful knowledge.

We should be aware of the fact that misconceptions are related to actual and qualitative understanding of physical situations. The students’ misconceptions play a remarkable role in teaching physics. We can fight them only if we are aware of their features. Galilei knew about that when writing the Dialogues, and he purposefully aimed at resolving misconceptions.
Some specific misconceptions at any age

Our research of misconceptions has been restricted to problems of mechanics. Therefore, the list of some specific examples is limited only to this area. Some of the following examples are frequently presented in tests and during the teaching process:

- Vehicles overtaking each-other are at the same speed when next to each other.
- When the acceleration of two vehicles is equal, their velocities are equal, too.
- The heavier the objects the higher its speed, when it falls to the ground.
- The velocity is directly proportional to the active power of the body. If the body is not forced, the speed is zero.
- Passive objects, for example a table, cannot be the source of a force.
- Forces in the action-reaction law act on the same body. The equality of forces in the action-reaction law is condition of the balance of the body.

In addition to those listed, there are sometimes quite surprising misconceptions in men´s thinking, such as the external driving force can be exerted only by living creatures.

The ways of mapping misconceptions

The primary source of knowledge of misconceptions is the teacher´s experience. Experienced teachers may have complex knowledge of it, while some of the new teachers do not even assume that students can have misconceptions [1]. Teachers should consciously map misconceptions in advance, especially before teaching some of the topics individually. This can be done through questionnaires, tests, interviews, or a combination of all. The audio recordings of the interviews may be analyzed in detail. The advantage of the tests is their easy statistical interpretability, their disadvantage is that they can hide, in fact, the degree of how well students understand the lecture.

By preliminary testing the misconceptions we arranged a list of 15 questions from the tests of Hesteness´ previous studies [2]. Results by preliminary test have been made so far in cooperation with 15 students from grade 9 and 16 students from grade 11 (15 and 17 years old) [3]. The entire test was planned to be used in other groups, too. In the complete test (29 questions) we tested 62 students from grade 9, 30 stu-
Some questions from the test of Hestenes

- In this figure, which trajectory shows the cannon ball’s path (see Fig. 1.) most accurately?

![Figure 1. The cannon ball’s path](image)

- A box is being pulled at a 4 m/s constant speed on the floor. What conclusion can be drawn from the forces on the box?
  
  (a) If the force is doubled, the speed of the box grows to 8 m/s.
  
  (b) In order to pull the box at a constant speed, a bigger force has to be exerted than it weighs itself.
  
  (c) The driving force and the friction force operating on the box have to be equal.
  
  (d) To ensure that the box moves at a constant speed, a greater force must be exerted on it than the friction force itself.
  
  (e) A single force acting on the box is the driving force, external forces such as friction are not "real" forces, they are able only to obstruct the movement.
The students are sitting in the same type of swirl-chair (see Fig. 2.). Which statement is true?

(a) None of the students exerts force on the other.  
(b) Student A exerts force on student B, but B does not affect A.  
(c) Both of them exert force on each other, but B exerts a greater force.  
(d) Both students exert force on each other, but A exerts a greater force.  
(e) Both students exert exactly the same force on each other.

Main results of the complete Hestenes test from our 9 grade students:

- 50% of students agree that a truck exerts a greater force on the car by collision.
- 85% of students agree that a decreasing upward force exerts force on the vertically thrown ball.
- 79% of students agree that by neglecting friction the attraction force of the rope is greater than the gravitational, when the velocity of the elevator is constant.
- 87% of the students agree that the force of the kick is exerted on the golf ball during the entire flight time (8% correct).
- 55% of the students think that the ball falls from the airplane to the ground according to Fig. 3. (24% correct).
Main results of the complete test from our 11 grade students

- 80% of students agree that a decreasing upward force exerts on the vertically thrown ball (13% correct).
- 43% of students agree that the puck, which is pulled at point B at right angles, is moving to point C as in Fig. 4. (40% correct).
- 66% of the students don’t see in a collision of truck and car the law of action-reaction.
- 57% of students agree that by neglecting friction the pulling force of the rope is greater than the gravitational force, when the velocity of elevator is constant.
- 73% of students agree that the force of the kick is exerted on the golf ball during the entire flight time (20% correct).
- students think that the ball falls from the airplane to the ground as follows: 11 times (a), 5 times (b), 3 times (c) and 10 times (d) - see Fig. 3.
The main results from the complete test from Bsc students

- 77% of students agree that the force of the kick is exerted on the golf ball during the entire flight time (18% correct).
- 86% of students agree that the same applies to a puck.
- 82% of students agree that (neglecting air resistance) a decreasing upward force exerts force on the vertically thrown ball.
- 45% of students agree that in case of students in the swirl-chair the active person exerts a greater force on the other one.

The classification of misconceptions

The misconceptions can be classified according to different criteria. They could belong to the sphere of kinematics and dynamics. They can be also grouped according to their origin, according to the action that made them develop, or according to their source of information. The source of such information can be television, friends, adults, readings, or their own observations and experiences. Literature can also offer misconceptions related to the laboratory, or the classroom [4].

There is an opportunity of useful grouping if we try to find the wrong principle hidden in the background. Such an idea as, e.g. a body is at a standstill in its natural state and a certain force is needed to maintain its motion is the sign of Aristotle’s thinking. It does not contain the law of inertia. This is related to the idea that the abandoned bodies move due to the inner driving force (impetus), and the movement goes on until the internal power is exhausted.

The listed cases could be further classified according to whether the formation of the misconceptions had external reasons or these were internal reasons related to students’ thinking or activities [1].
The origins of the formation of misconceptions

The students' misconceptions can have a variety of sources and trace back to both external and internal causes. [1] Besides the external factors, the students’ own activity and experience play the most important role. In many cases, students may notice that motion ceases if force causing the movement is lost. Taking into account this experience makes the refutation of misconceptions much more difficult.

The majority of teachers assume that these misconceptions can be explained especially by external reasons rather than by cognitive deficits of the students. Indeed, not only less gifted students may have misconceptions. Do not forget that there are difficult internal basic concepts of physics, too, such as mass or electric charge. We must take into consideration that a physical concept such as the conservation of energy and the momentum conservation laws, is often complex and preliminary knowledge is needed [5]. The teacher usually takes into account the existence of previous knowledge, but it sometimes happens that there is a lack of this knowledge [6]. In this case, we can use any method of teaching, students will not understand the subject of instruction.

Misconceptions occur in the thinking of people of all ages although their number decreases with higher grade students. In the higher grades, students are able to learn more and more complex models. This is certainly due to their mental development. However, the survey made among engineering students has shown that students achieved a result of only 20 percent in the misconception occurrence test. Furthermore, they could not reach more than 50 percent even after they had already attended a special course about misconceptions [7].

Correction methods

The study of misconceptions in classical mechanics is largely related to everyday experience. Misconceptions, which were developed through many years and are seemingly logically supported, have to be often transformed. Existing knowledge is more difficult to be changed than to teach new ones. But it can be successfully done if we compare the bias with experimental facts. Experimenting is a key issue for the development and credibility of physics as a science. Students have to be taken to the laboratory, where they can have qualitative experience. We have to help them to explain their prejudices and their preconceptions may be confronted with the laboratory experience. The best thing is, if this process takes place before the teaching process is starting [7], [8]. It is always useful to clarify all the qualitative questions before the first numerical analysis [5].
We have to raise awareness that the basic concepts and principles of physics are often difficult or complex. It is important to pay great attention to their explanation and understanding. It requires such teaching methods that promote the correct understanding. Students’ thinking and their own pace should be taken into account. The fine details will be lost in a frontal lecture; it allows a perception of only a little individual feedback. The tailor-made teaching is more effective, but rarely implemented in school settings. Individual speed of learning can be provided relatively well by computer programs [6].

Suitable software can support students to gain experience. They can imitate, for example, that the students are driving while they can draw speed and distance graphs of the way. But there is also software that can compare students’ answers to a database of misconceptions, and on the basis of it, it organizes the further work of students [9].

Parallel advances in science
In students' learning process similar stages can be observed to those of the development of science [10]. Parallels can be observed in the durability of students’ misconceptions and the durability of misconceptions in the physics as a science. In case of little knowledge, such ideas can be formed in both fields, which are under certain circumstances seemingly valid, but do not reflect the true face of phenomena. We can find such examples in the history of physics, that is why the history of physics is worth studying. For example, Galileo and Newton played an important role so that Aristotle’s approach of thinking has been superseded by the physical one. But there are many still-debated questions in modern physics as well.

Misconceptions arising during the study of quantum mechanics, of course, are very far from everyday experience, their existence could rather be explained by incomplete knowledge of the experimental results or by the wrong interpretation. For instance, the problem of measurements referring to the polarized states of splitting photon pairs, when the results of the experiments are explained by momentary signal transmission or covert parameters. It is also possible that the used analogy is only apparent, but in fact, it is not permitted. Such misconceptions are even more difficult to be explained [11]. The well-designed and executed experiments play a decisive role in their refutation.
Incentives for attention

Only a few teachers deal with the reason of the raising of misconceptions and the ways of handling them, only a few of them devote enough attention to these during the planning phase of the teaching process. Teachers suppose they can easily cope with misconceptions. Unfortunately, it is frequent that only the subsequent surveys show that the teachers’ efforts are useless, and it can develop a tension between the teacher’s expectations and the students’ results. University students of physics may have misconceptions, too, and thus they are mostly unaware of them. The fact that the misconceptions occur even among practising teachers, are also shown in multi-country surveys [7]. In these cases, the teacher can contribute to the creation of misconceptions in children's minds. An on-line forum can help in an effective exchange of experiences where teachers are anonymous and can discuss their problems more openly [12].

There is a very extensive literature on misconceptions, but the results are not sufficiently implemented into the teaching process [1], [12]. However, it is important to teach the scientific view in a broader context.

It is worth connecting the misconceptions research with the theory of cognition and other spheres of education [13]. Misconceptions occur not only in physics, but in other disciplines as well [14].

Summary

By testing the mechanical misconceptions we can observe that the students start up from seemingly true but actually wrong ideas in many cases instead of having the laws of dynamics as a starting point. We can state that students are often not aware if some force attracts or not and do not respect the law of inertia and the law of action-reaction. From the nature of misconceptions and the students’ typical answers results in the most important method of correcting misconceptions, in making experiments. This is an important method of effective, deep and convincing teaching of the basic concepts of physics.

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References