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Didactics of Physics, with elements of General Didactics and Didactics of Astronomy

Subsidiary for lectures and laboratories

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Table of Contents

I. Introduction - social determinants of didactics

1.1. Didactics in a modern democratic society

How physics should be taught? Of course well, that is to say, firstly, keeping all conceptual, mathematical and interpretative rigors that are demanded by physics - probably the only scientific field with so precise requirements. This condition would be called the methodological requirement. Secondly, good teaching provides that during the exams students met the requirements firstly demanded by teacher from himself. This requirement stems from the contemporary conditions of a modern democratic society. And finally, thirdly, students should get interested in physics, nay, even to get fascinated by it during the educational process. The latter requirement aims to ensure a professional success for a graduate.

This approach comes with the tacit assumption that the university is a kind of repository of knowledge and a professor is a custodian of this knowledge. Each student, without exception, should have a chance (and should follow it) to become such a custodian in the future. Someone compared the physicists working in large laboratories closed for external world to medieval monks who carefully prescribe wise books in the silence of the monasteries. Universities, starting from the Middle Ages, are culture-centre; a profession of scientist is always a vocation. The role of the researcher / lecturer / teacher as creator and custodian of culture should be also translated into didactics and pedagogy.

Universities and schools produce the most delicate product - a young man, and they bear the full responsibility for this product. If this product is clearly "defective" at the end of the educational line, this is the production process to be blamed, not a faulty prime matter. Many good tools for various purposes can be produced from steel of poor quality.

Therefore it is necessary to reverse an opinion about the didactics: it is not an auxiliary science but *sine qua non* condition for existing of a modern, economically efficient society. The education system should produce the members of this society who will succeed individually (and collectively) in the future. In this book we apply this argument in a discussion about the macroeconomic conditions of educational systems. National social systems, such as French, American and German, set the priorities of education depending on the complementary functions which this education has to fullfil with respect to the rest of the society. In other words: all societies need the consumers, a labour power and a state-creative elite. Each of the mentioned countries solves these problems in their own way. The education system is only complementary.

So maybe the teacher should first trigger a positive attitude and an interest of students and only later, in the second plan he should transmit knowledge? Yes, he should, but only if the interest of students is to serve further purposes which have to be realized. So if the goal is to educate engineers, the teaching process must be practical. If the goal is an economic progress, the teaching must develop a sense of the proper role of science with respect to economics. All of this must be carried out with the rigor of mathematical correctness of physics.

There is still a second condition in didactics, in addition to the macroeconomic one mentioned here above, that has to be fulfilled in order to have a prosperous society. It is the requirement imposed by the modern societies characterized by a high degree of respect for the individual ontological identity and a respect for the existing legal system. Namely, an individual student must become the centre of the education system! We can speak about the change of heliocentric system to homocentric one. The respect for the individual and unique role that each student can possibly play in the society must be the guiding principle of didactics in all democratic societies.

1.2. The tasks of didactics in the era of hyperinflation of information[1]

According to an anecdote, Thomas Edison, when he was a child, he promised himself to read all the books in the world. As an adult he invented the telegraph, the light bulb, the phonograph but he did not manage to read all books. One of the empirical laws of computer science predicts that computing power doubles every 5 years. This means that the storage capacity and the information processing are increased in the same way.

Before World War II, the Belgian producer of soda "Solvay" organized many physics congresses. Year after year, the pictures from these conferences show the same faces - Albert Einstein, Marie Curie, Max Planck. Today, only in Poland there are more than 500 scientists with the title of professor of physical sciences. Inevitably, not only the existing body of knowledge has become enormous but also its growth rate.

New technologies come with help. In the electronic citations database there are over 16,000 journals in the field of science[2]. Web browsers can accesses data containing millions of items in a fraction of seconds. Unfortunately, the number of responses of the web search systems contains also millions of items. Information becomes, indeed, widely available, but combining various elements into one comprehensive knowledge, is becoming more and more difficult.

The modern world characterized by a dizzying pace of economic and social changes- by sequences of completely new technologies and geopolitical transformations – force an individual person to self-adapt to various tasks within his life. We are observing the disappearance of a professional class of politicians and more frequently people possessing the education from various sectors of economic and social life occupy the governmental positions in many developed European countries. At the other end of the social pyramid, individual citizens have access to a wider class of consumer goods including travelling and knowledge from Internet. They should have the skills allowing for consumption of these goods.

The modern world imposes on educational processes the multiple tasks. The final product of the education system, that is the formed citizen, should possess the following skills:
- to be able to operate all-available information resources (to sift and sort information, to make generalizations and to find operative tips from the possessed knowledge)
- to understand more and more the specialized knowledge
- to possess the general knowledge
- to develop self-education, to self-adapt to changing professional requirements and technological opportunities of everyday life.

All these requirements ought to be realized in the same biological structure of human like it was 110,000 years ago and in the cultural frame not much different from life in ancient Rome.

Hence, the changes in teaching paradigms become an indispensable necessity. Otherwise, the limited perception of the human will become a barrier for a further development of civilization and / or constitute a serious threat to humanity.

[1] English version: collaboration dr K. Fedus
[2] Reasons to make distinction between *Science* and *Research* will be given later on.

II. Subject and methodology of Didactics

2.1. Didactics deals with teaching and learning

Traditionally, didactic is defined as matter dealing with teaching and learning. The two actors of the didactical process – trainee and trainer are linked together, although in the present internet era their common complementary role can significantly evolve. In the traditional school, the physical co-presence between teacher and the pupil exists and the majority of the teaching process is executed, in principle, in school. In the didactics of XXI century the two roles, of the teacher and the pupil, can be completely separated – anonymous pupils uses the didactical material deposited in the internet by authors, who rarely exercise the profession of the educator (teacher, trainer, university lecturer, teachers' advisor or educational expert).

The subject of the Didactics in not the context (i.e. the knowledge) itself, but the Didactics teaches how this knowledge is to be transmitted. The subject of Didactics is widely understood *methods* of effective teaching. The scope of Didactics is to make the teaching and learning at the highest possible level of efficiency, with the predetermined educational goals. As far as the term "efficiency" does not create ambiguities, the defining goals require some explanations.

Historically, different ways of teaching were determined by:
- operators delivering teaching (confessional schools, local churches, regional authorities, religious orders, schools for nobility, state institutions, private enterprises)
- extent of taught context
- ways and symbols of teaching (verses Tora brought in boxes on the head or mnemo-technics on the sign of trigonometric functions) [3]

and the most important - *goals* of teaching.
Goals of teaching are, to some extent, determined by the above mentioned relations, but on the other hand determine the relations, themselves. Other ways of teaching are used in muslim religious schools and other elite state universities like Ecole Normale in France..

Criteria for the goals should understood quite widely. The goals come result from the macro-economics (for example in VIIth EU Framework in Poland "specialist in science and engineering are needed, or like in the USA in 60'ies of last century – "by the end of this decade we will land on the Moon"[4]; "the number of scientists in USA should be doubled", ideological "Education for Peace"[5]) or even psychological ("we educate pupils without stress").
Criteria for choosing goals to a great extent can influence *recipes* of educational activities that are proposed by Didactics. It would influence negatively the *objectivity* of the Didactics as science. .

Didactics, therefore, should recon on the linkage between *contexts* taught with the abilities to learn of the addressee, respecting the existing economical and social environment. Both contexts do change (i.e. do develop) in continuous both the perception abilities of pupils. The

[3] In the first [quarter of Cartesian plane] all are positive,
In the second only sinus,
In the third tangent i cotangent
And in the forth only cosinus.
[4] The famous speech by J. Kennedy at Rice University, Houston, Texas, 12.09.1962 r.
[5] The resolution on Education for Peace by the United Nations was Poland in the 80ties of XXth century.

permanent change of context do not involve only history, literature and sociology, but also so called exact sciences, traditional ones as physics and new ones as informatics. The perception of the addressee changes – his attitude to gaining the information and the possibilities of understanding it. The change in the perception are forced both by new technical means (internet, TV) as well as by evolution of the cultural environment, dominating motivation etc.

The process of teaching, from ever, is in a irresolvable manner linked to *pedagogy*, understood as transmitting examples to be followed, ethical constraints, modes of behaviour. This link is active both at early stages of education, when a teacher is an example of an adult, as well as in formation of adults, where the teacher becomes an expert on the basis of a free choice. In the Polish educational system, the function of teaching and education are frequently separated – methodic advisors and school psychologists are two different persons. Similarly, in the higher education, the pedagogy is understood mainly as general education (i.e. formation) and didactics is allocated to specific sciences (physics, geography and so on).

This separation between didactics and pedagogy does not reflect tendencies in the international research and practice. At the end of XXth century, a serie of works showed that in the process of teaching *pedagogical functions* an essential role must be played by the transfer of specific knowledge. This school was called „pedagogical contents knowledge" (PCK). Stressing an operational knowledge apart from the knowledge specific to every particular subject was introduced to school curricula. "PCK" is also to be understood in a broader manner – the transfer of the specific knowledge should be governed by the *pedagogical* abilities of comprehension at a given level of mental development.

The subject of didactic is, therefore, teaching of a specific subject, but in a broad relation to:

i) human sciences, that define cultural goals,
ii) social sciences, that define operative goals of the education system
iii) specific sciences (languages, mathematics and so on) that define the contents of the knowledge to be taught.

In analogy to telecommunication, the Didactics consists both of teaching (the transfer of knowledge) and *adopting* the knowledge transferred (receiving and registration – active or passive). In analogy to *economics*, the Didactics deals with *maximizing* the effects of teaching while minimizing costs, where by costs we understand both macro-economic financial allowances and organization structures as well as the individual amount of works spent bye the teacher and the pupil. In analogy with natural sciences, the Didactics searches for general principles of effective teaching and draws conclusions important for present and future educational systems and contents of knowledge to be taught/ learned. Didactics, as a science on non-material objects (i.e. "knowledge") uses a general wisdom on the information in social means of communication and in individual transfer of knowledge. In particular, strong are the links with pedagogy and psychology, mainly pedagogy and psychology of *development* and inter-disciplinary science on learning – cognitivistics, that uses achievements of neuro-psychology, informatics, theory of information and novel diagnostic technics based on physics and medicine.

Resuming, the didactics works-out solution on *contents, methods and means*, but also on *goals* of teaching and *organization* of teaching. Didactics collaborates in this extent both with pedagogy and specific sciences; in the question of organizing educational systems it takes into account also the actual social-economic constraints.

In this broad aspect it is difficult to underestimate the role of didactics: that is didactics that decides on a *future* success (or failure) of societies and nations. As Polish chancellor Zamoyski (1600) wrote and reformer St. Staszic repeated at the beginning of XIXth century: the Republic will be that, like decided by the education".

2.2. The subject of teaching and didactics of the subject

So called general didactics deals with problem of teaching efficiency that are common for different subjects of knowledge. The general didactics gives rules, that are properly developed in specific knowledge subjects. The general didactics defines:

- didactical *principles*, i.e. general rules of acting in the process of teaching; such a principle is, for example, the principle of graduate increasing the subject difficulty

- didactical *methods*. i.e. general scenarios of acting to transfer a particular quanta of knowledge or capacities; a method is, for example, self-reading of a text by pupils;

- *forms* of organizing the didactical activities, for example a lecture, exercises, laboratories.

The aims of general didactics, together with pedagogy and other social sciences is also to determine *goals* of teaching and formation in a broader sense, as it was discussed already in par. 1.1 i 1.2. Generally, the didactical goals and principles should be modified according the subject of teaching, the target group and the extent of the material to be taught. The teacher/ lecturer should handle with elasticity all these rules, not only for teaching his own subject at different levels, at different specialities, but principally in possible future, variable social conditions and in changing individual perception of the student.

Didactics of particular scientific disciplines, in common inter-discussions, after having specified goals and maintaining all general didactical principles and using *selected* methods and forms, have the aim to define *contents* for every level of teaching. Such contents can be, for example, thee principles of dynamics by Newton on the basic level of knowledge, the principles of conservation in mechanics as the generalization of Newton's dynamics on the level intermediate or the principles of Hamilton for mechanics, on the university level of teaching.

Didactics of particular scientific disciplines define also *didactical means* and didactical *subsidiares.* Such a subsidiary is borh blackboard and chald in the traditional university lecture, as well as multimedia physical models in the internet way of teaching. A subsidiary is, for example, a single physical experiment performed in the classroom, a collection of minerals or dried flowers in a copybook.

As far as principles of general didactics are strictly linked to the methodology of pedagogy, didactic of particular scientific disciplines must also respect the commonly adopted paradigm of this specific discipline. Different are the methodologies of validating scientific theories in cosmology and different in microscope studies of metal alloys. As compered to cosmology, the metallurgy is more direct – the sample is placed inside the microscope on the desk of the researcher. In cosmology, the verifying of the theory is much more based on models, assumptions, extrapolations in space and time: the Big Bang happened once and was very remote in time.

Particularly important in didactics of physics is the necessity of using many different methods, forms and didactical subsidiaries. As compared to mathematics, in teaching physics the experiments are necessary (the laboratory method, the forms based on simple, small experiments or shown by the teacher), as compared to biology – mathematical calculations are needed, maintaining all formal procedures. Physics, as compared to teaching foreign languages, uses also various didactical subsidiaries. For theses reasons, an efficient teaching of physics at school level requires detailed and various preparation, a broad general culture, good methodological abilities, mathematical skills and knowledge of other sciences, also in context of applications of physical techniques and methods in medicine, technology etc.

2.3. Didactics as pro-positive science

The didactics, and especially the didactics of particular sciences, can be treated in a double way. In a standard approach the scientific subject of didactics is to *evaluate* the efficiency of teaching; this evaluation is to b performed by well defined procedures and methods. The researcher proposes to different groups of pupils alternative ways to explain the same term/ phenomena and in aftermaths compares results from different groups, using some standard tests. The evaluation should give the leveled of: *apprehension*, *understanding*, *durability* of knowledge*, flexibility* of the use of this knowledge, ability to find *practical* applications, possible *creativity* based on this knowledge and so on.

Without negation of this type of activity it is to be stressed that such operations have mainly the function of *diagnosis*: several different ways of teaching are being prepared, knowing also just before the investigation that some of them must be less effective than others. Paraphrasing, this is like saying to the patient by the doctor: "In my opinion you are sick". Such examples of ill-posed didactical trials at the school level are illustrated in pictures below, taken from on PhD thesis in didactics of physics.

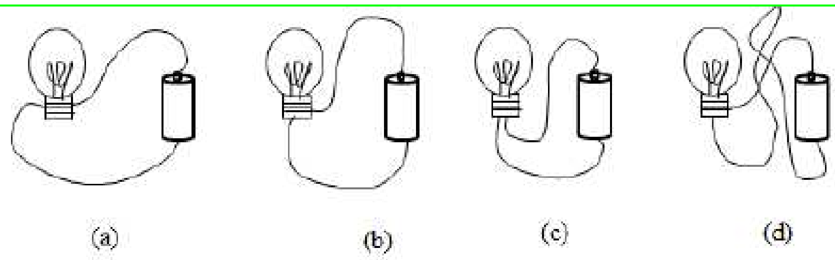


Figure 5.7.: Which of the bulbs will light up?

These pictures are so unclear also to a professional physicists (no correct connection on the bulb is evident), that in all these cases the pupil is induced to make an error, so first, the efficiency of teaching will be low, and second, even worse – the scientific outcome of these studies will be t a great extent random. This low efficiency is not the result of the difficulty of the problem or inadequacy of the didactical method, but comes from wrongly posed sketches (a photo would be much better). This low efficiency for sure does come from the wrong reasoning by the pupil. In other words, extremely important in teaching in general, not only in didactical tests, is to *pose correctly* questions: the question should *induce* the pupil to a right reasoning and as a result to a correct answer. Again paraphrasing, there are no wrong answers by the pupil but only wrongly posed questions – inadequate to his level of knowledge and reasoning. In a traditional didactics, this difficulty would correspond, even if only partially, to the principle of step-by-step increasing difficulty.

Coming back to the principle of democratic and individual treating the pupils, ill-posed questions – unclear or too much difficult, even if correct from the scientific point of view (according to biology, physics and so on) are incorrect *pedagogically*: they lower the level of auto-estimation by the pupils. In a modern (Western-like) society it is more important to form in a pupil the (subjective) security that he will manage (almost always) with (and almost) every problem that to prove that the teacher is "wiser" than the pupil and can exercise a kind of psychological pressure.

We can give much more examples of wrongly posed questions in didactics of physics. In one of the didactical tests performed in Singapur, pupils were asked how they imagine the electrical current inside a conductor. Obviously, the pupils in that age does not use the term of voltage nor the current intensity. They either do not know the signs of the electrical charges that were discovered in a very simple “experiment” by Symmer who noticed the attraction or the repulsion of the tow socks (in silk or in wool), see pictures below. Pupils also do not operate any modern knowledge on electrical carriers in metal or semiconductors. Therefore, their responses were in majority cases simply wrong.

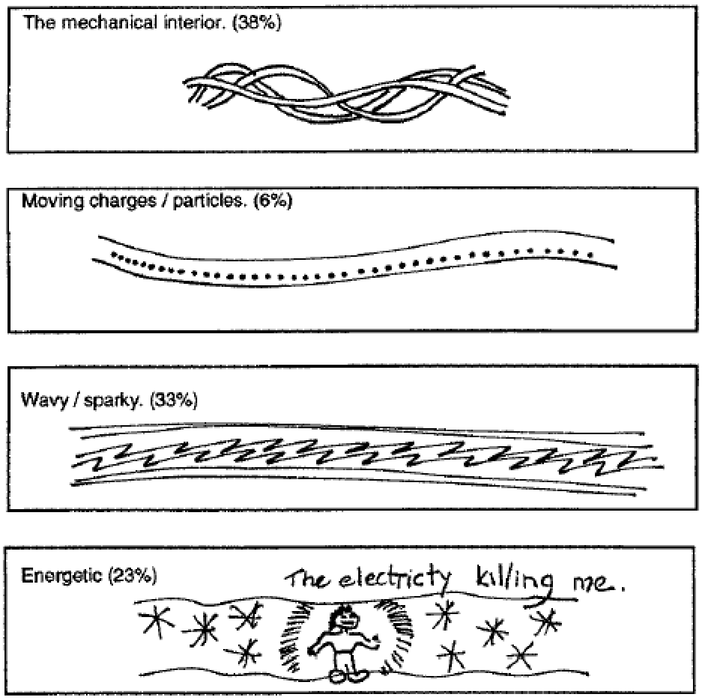
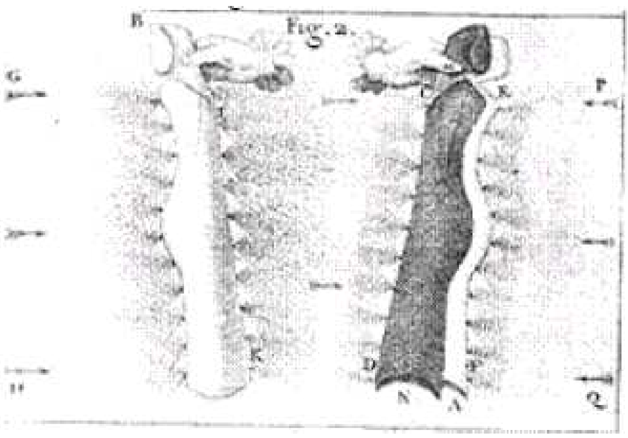


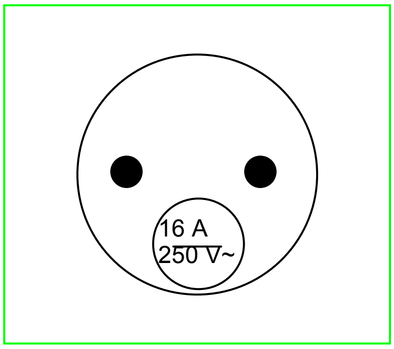
Fig. 3 Risposte da ragazzini di scuola primaria di 9-11 anni al questionario proposto da Kibble [Kibble, 1999]

An ill-posed question – in the case on the nature of the electrical current flow, without earlier elementary explanations, gets majority of wrong answers. Such a type of research activity should not constitute the main subject of didactics as a science.



The experiment by Symmer (1759) with attraction or repulsion of two socks showed the presence of two types of electrical charges. The reducing of the idea of the current flow to the transport of only electrons is a simplification and is also scientifically incorrect. In liquids (like water), in plasmas (like in the so-called neon lamps) and in semiconductors the electrical charges flowing (in opposite directions) are of two types: electrons and positive ions (in plasmas), electrons and so-called holes (in semiconductors, independently on the type of the semiconductors, *p* either *n*), negative and positive ions (in liquids like water or in atmosphere).

The introduction to the subject of electricity, even for small children, in times of the day-per-day presence of electrical appliances everywhere (in home, at the street, in pupils’ pockets) can not ignore the terms of volt and ampere: the cell phones use (nowadays) mainly lithium batteries (with 3,7 V "voltage") while the home electricity (in Europe) is 220 V. Applying the didactical principle of *visualization* these symbols are present on every plug (respecting the EU technical normative), see the sketch below.



Teaching social competences, with the excuse of electricity subject: the ability of reading the signs on the plug of the washing machine; an autonomous measurement of the voltage (10 V max!) ©GK

The introduction to the subject of electricity, even at the elementary level, should operate the two concepts:
- of the voltage, that determines t what extent the source of electricity in dangerous
- of the current, determining the "amount" of the electricity flowing, so indirectly also the energetic result of the current flow over time.

Let it explain shortly. The indications by the EU, adopted in recent years also by universities and in the "Programme base" of the Polish Ministry of Education include:
- knowledge
- skills
- social competences.

The distinction between these three functions creates in Poland serious difficulties; we find a trace in the ME "Programme base" in wordings like "The student knows the Newton's law" – as the knowledge, "The student understand the N law" (as the ability), "The student is able ti apply the N's law" (as the social competence". Paraphrasing, these are not competences or skills but "God's wishes". The didactic is formally correct, but does not propose much.

How can we distinguish the knowledge, skills and social competences at the lesson on electricity, for example? In spite of apparent difficulties, it is quite easy:
- **knowledge,** are the notions, and their meaning of voltage and current, of volts and ampere, and what are reasonable values f these units,
- **skills** are for example, the ability to perform a measurement of the voltage of the pocket appliance battery – new or old, like we show in the photo above taken by authors lesson
- **social competence** is, for example, the consciousness which voltages are dangerous, which charges can damage the computer, what power should be delivered fro the net to run the inductive oven, how the security switch at home works.

The three didactical goals change in this way from formal statements into the variety of activity proposed by the teacher to pupils, they enlarge the target group (into the housewives, for example) and, what is the most important, they teach the teacher the new, more effective and diversified ways of the knowledge transfer. First of all, they create a *net* for the knowledge of physics in the contemporary world and make the knowledge "friendly-use".

We will paraphrase the words by A. Einstein, who said that "everything should be explained as simple as possible, but not simpler". In order to raise the ability of the future adult (and now a child) to move in a future world a good didactical practice is "to explain things as easy as possible, and even easier".

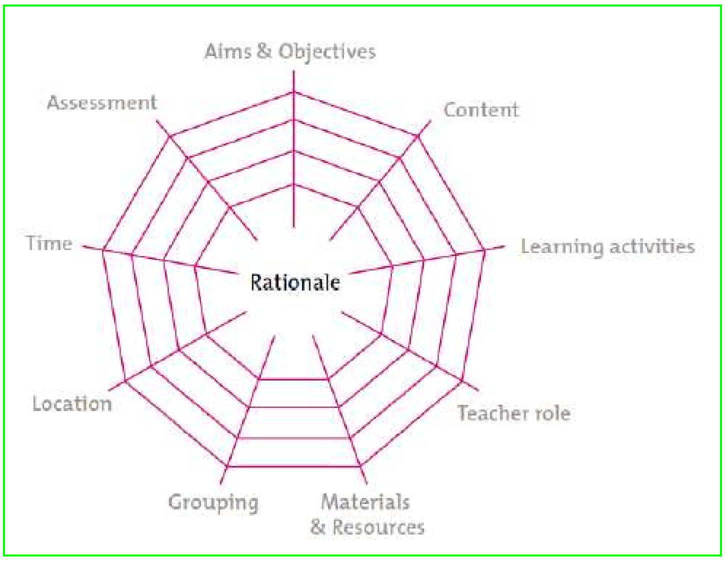
In this way the didactics evolves from pure diagnostics to a real therapy.

2.4. Networks of didactical acting

The system "didactics" contains the pupil, teacher, methods, goals, actions and so on. Different authors expose differently the specific elements, underlining for example *teaching* and *learning*, *methods* and *means*, *goals* and *ethics* etc. Wincenty Okoń writes on didactical research that "this is a system of mutually linked actions and tools, that allow to discover interdependencies between particular elements of the didactical process as a whole and general rules in teaching and education"[6].

Van der Akker[7] resumes this networking in a following scheme: in the center of the net there is *rationale*, i.e. the **reason** for the whole process of education. According to this understanding, the reason, the goal is the *whole*, organized process of teaching. This *rationale* comes first, before all other elements. In other words, before the morning leaving to the school the teacher should ask him/ herself: "What do I want to teach pupils today?" From this central point the specific lines of the net do leave:

- time – today, the next hour, in a one months time when the lesson will be run by the staff of the university?
- location – in the school lab, in classroom, in science museum?
- grouping – which class, how to divide them, should the group be supplementary or cometing, which roles are to be assigned to single pupils?
- materials & resources – what do I have in the classroom, what should pupils bring from home, which resources can be found on web?
- teacher role – a classwork? a test? Presentations by pupils or my own lecture?
- learning activities – independent experiments run by pupils, educational games?
- content – only main definitions? Discussing practical applications? Some examples of calculations?
- aims & objectives – the final test of the gimnazjum exam? The security while wrking with the electrical current?
- assessment – verifying the results and the costs



Resuming, the level of complexity of the didactics, both the general and even more of the specific subjects is high. It is difficult to deliver ready recepies for all possible contexts, contents, and educational goals. The didactics may help, but at the end this is the single teacher who should resolve independently the didactical problems, in varying conditions.

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[6] W. Okoń, *Wprowadzenie do dydaktyki ogólnej*, Warszawa, 1987, str. 12.

[7] J. van der Akker, *Curriculum perspectives: An introduction*. W: J. van den Akker, W. Kuiper & U. Hameyer (Eds.), Curriculum landscapes and trends (pp. 1-10). Dordrecht: Kluwer Academic Publishers, 2003.

2.5. Definition of didactics

As we already mentioned, the didactics is defined as a science on teaching and learning, from the Greek word *didaktós* = teaching, advising[8]. Further, according to the Dictionary PWN: „didactics is a part o pedagogy, dealing with methods of teaching and learning". This way of defining, deriving the meaning just from the Greek word could be considered as a mere *tautology*. Wincenty Okoń adds „didactics is a science on education and self-education, on goals and contents, methods, means and organization"[9].

Numerous authors define the didactic as a part of *pedagogy*, dealing with regularities of teaching and learning: Franciszek Bereźnicki defines the didactic in a following way: „Dydactics is a science o teaching and learning, finds and explains specific relations between determined actions, contents, methods, forms and means, conditions of work of teachers and pupils, and the results of teaching and on this basis formulates general dependencies regarding the process of education, i.e. the process of teaching and learning."[10]

On the other hand, didactics of specific sciences are considered a kind of "projecting" (using the term from the technical design) of rules and principles of the general didactics on teaching those specific sciences. "In order to perform efficiently the didactical process it is not enough to know the general rules of teaching and learning. The implementation of didactics in the practical activity requires both the general understanding of the didactical processes as well as the knowledge of the concrete and particular features of teaching the given subject"[11]

Note that the above definition abstracts from the meritocratic knowledge of the subject by the teacher, assuming intrinsically that the teacher is able to adopt in every condition the ways of transmitting the notions of the subject, using merely a projection of general directives, based frequently on quite theoretical considerations. This leads directly to treating particular didactics as disciplines subsidiary both in respect to the general didactics as well in respect to the very scientific subject of teaching.

On the other hand, didactics of subjects, including the didactics of physics are (in particular in Poland) treated in a marginal way as compared to other branches of physics. This comes rather from ignorance of local "deciders": knowing physics does not mean the ability of transmitting it. This supposition comes from (somewhat illusory) own experience ("I remember from my own lyceum…"), which was placed years ago, in different conditions and in a passive manner. Paraphrasing, all of us go to a dentists but this does not assure to be able to heal the tooth by myself…

In countries leading in scientific research, including physics, like USA, Germany, Italy, Great Britain, didactics of physics constitutes a separate branch of physics. IN Great Britain practically every university keeps own research in didactics of physics and additionally general observations are performed in London by Institute of Education. In USA special journal in physics education are issued, like *American Journal of Physics.* In the classification of physical sciences (PACS) in the first category, 00 of the General Physics, the didactics of physics is placed under the number 0.11. In Italy the professorship in didactics of phsycis is jointed to the history of physics.

So it is only in the narrow understanding of some authors that particular didactics can be deduced from general didactics. In this meaning the didactics would be a science based in

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[8] *Słownik wyrazów obcych PWN*, Warszawa 1972, str. 163
[9] W. Okoń, *Wprowadzenie do dydaktyki ogólnej*, Warszawa, 1987, str. 55
[10] F. Bereźnicki, *Dydaktyka kształcenia ogólnego*, Oficyna Wydawnicza „Impuls", Kraków, 2007, str. 15
[11] F. Bereźnicki, tamże, str. 16

deduction, i.e. would resemble mathematics. As indicated, for example, by reading the classics of didactics, like Jan Comenius, his didactics is different: no particular recipes can be drawn for teaching particular subjects merely from the general didactics. In other words, the didactics, similarly to other science like physics, biology, history is an inductive science: general conclusions are to be drawn from numerous observations in different scientific disciplines. In properly understood disciplinary didactics, given contents presented by specific methods specific to the determined science, but to any target group, after being examined by standard methods of the general didactics become the "experimental" evidence to the latter and allow to construct generalizations. Assuming that particular applications just of the indications for general didactics in teaching different scientific disciplines will bring *generally* expected results is an improper supposition. And again recalling the second, "disciplinary" danger: "in some way all notions can be transmitted and if this transmission fails, the fault is of the student who does not work/ want/ study etc."

Here we come to the very understanding both the disciplinary didactics as the general didactics. That is the particular method and a particular content of a given scientific discipline which is the very *subject* of research of the didactics. Let us make an example: "Is it possible to use the concept of the vector potential for teaching the subject of superconductivity at the secondary school level?[12] Or easier: "How can we explain the rule of summing forces on the level of gymnasium, without using the concept of vectors?"; or "How can we teach modern physics in the first class of the professional school?"

After all these remarks we can formulate an operative definition of didactics:
Didactics acts in revealing, diagnosis and solving problems in the process of assimilating the knowledge and skills by the pupil.

In other words, the merely studying the process of apprehension, without proposing concrete solutions for problems in learning would be for similar for a talk on electricity, but without showing its applications and giving the rules for using it. Didactics is not a science to make solely diagnosis, but first of all, a science devoted to *intervene* into the process of teaching. Didactics is to find knots on the process of acquiring knowledge and to undo these knots.

In relation to this, into the subject of *didactics* comes proposing new solution in matter of:
1) contents of teaching
2) methods of school and extra-school teaching, including the self-work by pupils,
3) means of teaching, facilities, tools and subsidiaries.

These notes are particularly important for didactics of physics, where a high level of mathematical formulations, technical implications, a fast progress in great world laboratories, forces a fast evolution of contents, requires compressing previously taught notions, rising the efficiency while keeping the attractivity of the discipline for the pupil and contemporary maintaining the scientific rigorosity.

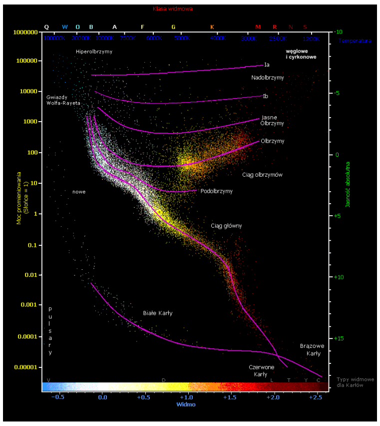
The universality of the secondary educations (notions on modern physics – atomic, nuclear, cosmology are in all types of the secondary schools) requires an elastic adoption methods and tools to different target groups. At the same time a specialization in higher classes of the secondary schools causes that majority of the adult society in the nearest future will be ignorant in basics laws of mechanics, which is taught only in the first class of the lower secondary school. As far as these notions are essential, for example in driving cars, higher becomes the responsibility of different institutions preparing teachers, and the responsibility of universities, in particular.

[12] S. Barbieri, *Superconductivity explained with the tools of the classical electromagnetism. Educational path for the secondary school and its experimentation.* Tesi di dottorato, Universita' di Palermo, 2014

III. European scientific and didactic tradition

3.1. Aristotle - the father of modern science

In his numerous works (*Physics, On the Heavens, Zoology, Ethics, Poetics, Metaphysics*) Aristotle (384 – 322 B.C.) presented the considerable scholarly achievements of several ages of Greek philosophy development; his works constitute the encyclopedia of ancient academic standing, one and only of its kind. Modern critique of his works focuses on the assumption of the negative impact, which the centuries-old attachment of generations of philosophers to the works of Stagirite exerted on further development of science. *Ipse dixit* [He said.] became proverbial as it cut short any scientific debate. However, while reading numerous excerpts from Aristotelian papers, his great scientific intuition is clear. In *De ceoelis* he wrote: "Although they are distributed orderly units, we perceive the stars as simple celestial bodies, not living things, whereas one needs to know that they are developing their activity and enjoying their life." It is only for a century, following the application of the optical spectroscopy methods and following thousands of nights women-astronomers spent looking through telescopes, that we have known, that stars evolve: they are born, they burn or die out or explode. It goes without saying, Aristotle's conclusions were drawn upon speculative reasoning, the results from further 2000-years of scientific research within the fields of observational astronomy and astrophysics were not available at his time.



According to Aristotle the stars are living things – the fact of which we have known only since 1912, i.e. since the so called Diagram of Hertzsprung – Russell was compiled. The Diagram shows the relationship between the star's power of radiation and its temperature. It is the historic Harward telescope and the exceptional perseverance in gathering information of Henrietta Swan Leavit and other women astronomers, that made work on H – R Diagram possible. The telescope is now in the UMK Observatory.

Similarly, with respect to physics, although Aristotle did not define mathematically the notions of momentum, energy and potential, he applied these terms in order to explain some processes and phenomena. In the narrow interpretation his *energeion* stands for *potential* energy, understood in a wider aspect it represents hidden, future, potential variability of the state of the object: 'the act of action'. It is worth noting here that identifying *energy* as the *potential* to perform work, as we understand it today, was only put forward in mid XIXth. Not only did Aristotle collect the results from academic studies available at the time, but he also carefully observed nature. His conclusions concerning the curvature of the flight path of objects thrown into the air (a ballistic curve), although departing from mathematically described relationships, were otherwise quite accurate. Aristotle maintained that after reaching the highest point of a trajectory path such objects suddenly fall down. Described by means of mathematics (in a vacuum) a trajectory path is a parabola, still trajectories observed in reality, e.g. a trajectory path of a football, might considerably depart from the mathematical model. Why is that? Due to so called Magnus' effect a football follows the path whose shape resembles more Aristotelian curve than the shape of a parabola. Not without reason football, golf and tennis balls do not have smooth surface, the resistance of the air, especially when the ball is rotating, makes its trajectory more difficult to predict. The comparison between Aristotelian ideas and contemporary physics leads an attentive teacher to the following conclusion: any rational search for scientific truth deserves credit.

3.2. The medieval scientific achievements

The Middle Ages are considered the period of decline in science. As a matter of fact it was the time when new advances in scientific studies spread from a few academic centres all over European continent of today. Similarly misleading is a conviction of an essential contribution of Arab scientists; during the Middle Ages. Actually they absorbed the scholarly achievements of their European ancient predecessors and at the time of turmoil of war in the Mediterranean Basin the legacy of Greek philosophers survived with them. The Middle Ages brought some practical inventions such as the watermill or buttons on clothes. Two famous physicists should be mentioned here: Witelo (1237-1300?), presumably born in Legnica and Jean Buridian (1300-1358?), the Rector of the University of Paris. Both of them were monks.

Contrary to Aristotle, who claimed that constant pushing force is essential to keep material objects in motion, Buridian introduced the motion of *inertia*, 'impetus'. It is him who first formulated Newtonian First law of physics: i.e. unless no force is exerted on it, a material object moves with the same speed. After Buridian, Copernicus did not need to explain why planets and the Earth revolve forever. (Unless they were set in motion billions of years earlier.) The notion of inertia, or the 'force' of inertia, is not applicable in modern didactics of physics; instead we talk about apparent forces or non-inertial systems. On the other hand, the definition of the inertial system as the one to which Newton' s first law applies is a sheer tautology. The term of 'inertia' should be substituted with the notion of conservation of linear momentum, which in the etymology of the Polish language is referred to as 'impetus', and so we return to Buridian…

Witelo's treatise on optics *Perspectiva* was most likely the academic handbook until the time of Kepler, who wrote a commentary to it. Witelo investigated the phenomenon of linear propagation of light, particularly focusing his attention on the law of reflection and on creating images in cylindrical and spherical mirrors. He came up with the idea of the periscope and he was close to formulating the law of refraction . With its axiomatic narration resembling that of Euclid's *Geometry*, Witelo's academic writing, however, is far from having empirical character of modern scientific studies and even far from Aristotelian treatise.

Not only does Witelo consider optics as scientific study pertaining to physics, but he also describes the structure of the eye, optical atmospheric phenomena and even the psychology of vision. The last one is particularly interesting as it does not make reference to 'optical illusions', but to Aristotelian concept of the ability of the human soul to *asses*. Witelo writes about stereoscopic vision, 'Once you see a surface which is perceivable for your senses, the ability to *asses* of your soul sends the message that actually your eyes see a three-dimensional object, even if your eyes do not see the depth of the object.'[13]

Apart from Copernicus, Witelo is the only Polish scholar whose (imaginary) portrait is to be found in the historic chamber of the University of Padua Rectorate.
'Which way is the cat looking?' If you are under an optical illusion, you think the cat is looking us straight in the face. As a matter of fact, the image printed inside a block of glass is turned in the opposite, face to the wall direction. For Witelo such kind of perception is not illusion, it is the ability of your soul to perform *judgements.*

[13] Witelo, Perspektywy IV, Form Polish translation, by Witold Wróblewski, Preface, translation validation and commentary Lech Bieganowski, Andrzej Bielski, Witold Wróblewski, Wydawnictwo Instytutu Historii PAN, Warszawa 1998, p. 153

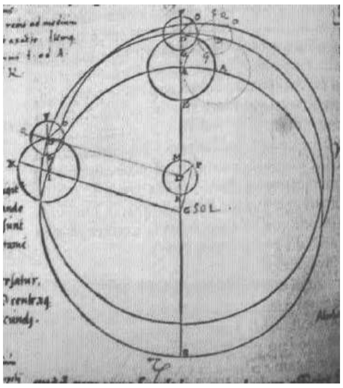
3.3. Copernicus: the Universe whose limits we are not able to determine

The frequently quoted saying (1473-1543), 'He halted the Sun and set the Earth into motion'' is not quite the accurate translation of the inscription etched on the pedestal of the Copernicus monument in Toruń. The inscription states, 'He halted the Sun and the firmament' [celioque]. Right! The vastness of firmament far exceeds the dimensions of the Sun.

Printed in several hundred copies, *De revolutionibus* has been considered one of the least frequently read books in history. And indeed, the text which is initially philosophical and written in a sort Ancient-Greek-like style, abounds in charts, coordinates of stars, calculations, diagrams etc. from Book 2 onwards. It is just a modern academic treatise.

Copernicus analyses in detail various aspects of the structure and properties of the Universe from the spherical shape of the Earth to the difficulty in observing the movement of the stars (i.e. so called parallax). 'If nothing of the kind [i.e. no kind of motion] is observable in base stars, it proves that they are very high above us, which makes even the one-year orbit movement around, or rather the lack of one, imperceptible for our eyes. (…) Even from the farthest planet, i.e. from Saturn, it is still very far to the base stars sphere, twinkling lights prove that.' Copernicus' work is undoubtedly the first ever modern scientific treatise based on reliable observation. (Copernicus carried out majority of astronomic observations himself, the eclipse of the Sun and the Moon, the conjunctions of planets, which occurred in his lifetime.)

The observations in question were supported with solid mathematical instrumentation. Copernicus is also the originator of astronomic charts, which resemble modern trigonometry charts. For Copernicus research work has neither axiomatic, as was the case with the work of Euclid, nor speculative character, as was the case with the work of Aristotle, but it relies on posing specific questions, even if (for a while or so) they unlikely to be answered. E.g. 'Why does water not dribble down from the Earth as it does from a globe of the world?' This question was answered after the introduction of the notion of gravitation by Newton. Copernicus' search for proper correction of circular orbits of the Earth was concluded by Kepler's discovery of elliptical orbits.



Having analysed Copernicus' life history and his achievement one can learn a lesson – if you challenge the unknown with a question nobody dared to ask before, you can arrive at surprisingly simple conclusions. 500 years later Albert Einstein displayed similar courage.The laconic and logical style of the text of *De revolutionibus* does not seem to be the reflection of personality a rebel who aimed at overthrowing the scientific procedures of his time. Beyond any doubt Copernicus is the origin of modern scientific methodology, which relies on experiment and theoretical analysis. The inscription on Copernicus monument in Toruń reads: 'He stopped the Sun and the firmament and set the Earth in motion.'

Copernicus observed that the orbits of the planets moving around the Sun are not circular in shape. Therefore he followed Ptolemy with his theory of *epicycles.* Copernicus is also an epitome of researcher's modesty when he admits, "The Universe whose limits we do not know, and probable are not even able to establish."

3.4. Galileo – Physics came down to earth from Heavens

It is said about Galileo that at his time, 'Physics was brought back down to earth from Heavens on the inclined plane.'/4 In other words, while understanding Copernicus' treatise required the sound knowledge of mathematics, Galileo presented the latest advances in science in a manner accessible to a commoner. Also, Galileo formulated the paradigm of modern natural science: i.e. an experiment has to be repeated, properly described and only afterwards can reliable conclusions be drawn.

It was Galileo who 400 years ago provided clear evidence in support of Copernican system and laid the foundations for further development of modern physics (kinematics, acoustics and optics). The son of violin maker, he searched for numerical relationships between physical parameters of objects, following the example set by Pythagoras who investigated the relationship between harmonic frequencies (the length of a string). His style of presentation resembles Plato's dialogues as in the following quotation, in which Galileo discusses the mathematic formula for displacement of an object in constant acceleration motion $s= ½\, at^2$.

"…Still such a conclusion is worthless, unless you know in what proportion velocity increases,which regularity has been unknown to all philosophers until today, but it was discovered and proved correct by a Scholar, our mutual friend, who in his manuscripts, yet unpublished but shown in confidence to me and some of his friends, reveals that the acceleration in linear motion of objects follows the pattern of subsequent odd numbers, in other words, having decided how many equal time units we need, if in the first unit, starting from a standstill, the object covers a specific distance, for example the length of a barrel, in the second unit – it is three barrels, in the third – five, in the fourth – seven and so on, following the odd numbers order, expressed differently: the sections covered by an object, which starts moving with constant acceleration from a standstill remain twofold inversely proportionate to the time, in which the sections in question are measured, or in other words that the ratio of subsequent sections equals that of times squared."

The above mathematical relationship can be illustrated in a manner which appeals to your students' imagination, i.e. with the help of an inclined plane model, with small bells suspended alongside it within the 1: 3: 7: 9 ratio distance. Once we let a small ball slide down the plane (best in near absolute darkness) the ball hits the bells at equal time intervals, which fact the audience receives with astonishment. Well, first we listen, then we measure the distances between the bells. The measurement unit for the inclined plane built at UMK is the length of a shoe, size 38. Pupils discover Galileo's mathematical realations themselves.

Galileo's study of accelerated motion inspired usto build a research 'path', first in the form of an interactive exhibition, later in the form of an interactive presentation. Students discover the laws of Physics by themselves. They answer questions like: 'How do objects move? Why do they move? After formulating the laws of motion and after discovering that the parameters of free fall do not depend on the object's inertia, the research path leads to more complex phenomena as rolling down, bouncing etc. The scenarios are by the author.

Using a telescope he made with his own hands, Galileo discovered mountain chains and valleys on the Moon, four satellites orbiting Jupiter and the phases of Venus. All those observations may be carried out by means of amateur binoculars and they should become didactic standard at all levels of teaching Physics. The division into two kinds of motion, constant velocity and accelerated motion, introduced by Galileo can be explained by means of a small glass ball sliding down a tilted table. It is the first experiment to be carried out in the first Physics class at any level.

3.5. The Cartesian method of reasoning

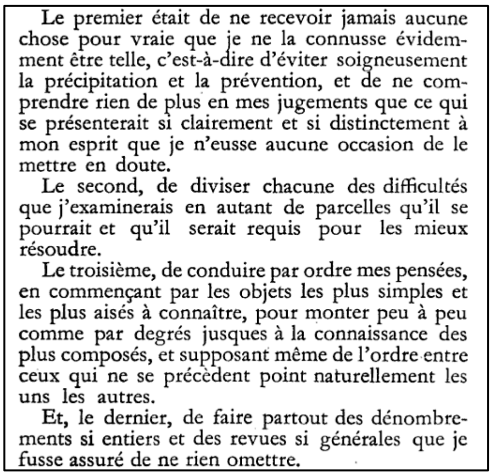
Galileo may have created the methodology of modern experimental natural science but it was René Descartes (1596-1650) who in his 'Discourse on the Method'[14] specified the general mode of reasoning, applicable to all sciences. He wrote:

'The first was never to accept anything for true which I did not clearly know to be such; that is to say, carefully to avoid precipitancy and prejudice, and to comprise nothing more in my judgement than what was presented to my mind so clearly and distinctly as to exclude all ground of doubt.

The second, to divide each of the difficulties under examination into as many parts as possible, and as might be necessary for its adequate solution.

The third, to conduct my thoughts in such order that, by commencing with objects the simplest and easiest to know, I might ascend by little and little, and, as it were, step by step, to the knowledge of the more complex; assigning in thought a certain order even to those objects which in their own nature do not stand in a relation of antecedence and sequence.

And the last, in every case to make enumerations so complete, and reviews so general, that I might be assured that nothing was omitted.'


Le premier était de ne recevoir jamais aucune chose pour vraie que je ne la connusse évidemment être telle, c'est-à-dire d'éviter soigneusement la précipitation et la prévention, et de ne comprendre rien de plus en mes jugements que ce qui se présenterait si clairement et si distinctement à mon esprit que je n'eusse aucune occasion de le mettre en doute.

Le second, de diviser chacune des difficultés que j'examinerais en autant de parcelles qu'il se pourrait et qu'il serait requis pour les mieux résoudre.

Le troisième, de conduire par ordre mes pensées, en commençant par les objets les plus simples et les plus aisés à connaître, pour monter peu à peu comme par degrés jusques à la connaissance des plus composés, et supposant même de l'ordre entre ceux qui ne se précèdent point naturellement les uns les autres.

Et, le dernier, de faire partout des dénombrements si entiers et des revues si générales que je fusse assuré de ne rien omettre.

A copy of the first edition of R. Descartes' 'Discourse on the Method' [Leyden, 1637; books.google.fr, directory password BCULVD2178290]. A copy of this piece exists (in the Stanford University Libraries) so it can be an authentic referent to the construction of knowledge about the method of scientific work according to Descartes.

In Descartes' discourse attention is drawn to the postulates of: 1) the necessity of questioning unverified knowledge, 2) the division of a problem into elementary issues, 3) the solving of problems starting from the simplest ones, 4) the synthesis of solutions and the control of their completeness. Descartes' explanation of cognitive behaviour turns out to be highly adequate to contemporary didactics as well. It constitutes the right methodological basis for a re-orientation of education from imparting to *constructing* knowledge. This constructing should take place step by step, using the method of successive approximations - if we were to refer to the language of mathematics. Each step in the reasoning involves the necessity of choice - left or right, as if on a forest path. Another step verifies the choice made.

Descartes' method assumes a strict bivalent logic: YES or NO, as Aristotle himself codified. This rule is significant in didactics and in pedagogy, too: every student's response has certain logical/moral consequences. There is no 'maybe so or so', as in other eccentric philosophies (and in quantum mechanics).

Descartes points to the necessity of looking for logical relations, even in not so obvious places. In other words, he avoids the 'hidden variables' which are present in e.g. some interpretations of modern physics. Here, the logic is strict and dichotomic.

[14] Full title: 'Discourse on the Method of Rightly Conducting One's Reason and of Seeking Truth in the Sciences', R. Descartes, 'Discours de la méthode: pour bien conduire sa raison, et chercher la vérité dans le sciences', Imprimerie de Ian Maire, Leyde, 1637, p. 29

3.5.a Scientific cognition according to Immanuel Kant

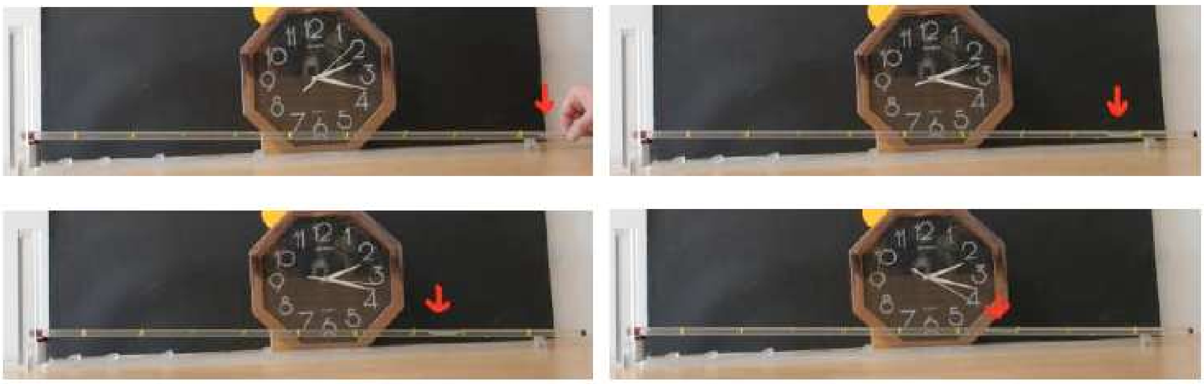
The contemporary scientific method paradigm, after Galileo and Descartes, has been widened into the general theory of cognition by Immanuel Kant (1724-1804), a lecturer at the University of Königsberg. In the discussion on the possibilities of cognition of the 'thing-in-itself', which has been ever-present since Plato's times, Kant paid attention to the decisive role of the subject of cognition on the result of the experiment. A scientists asks Nature not as a child but as a judge demanding clear-cut answers. Not: 'what is this?' but: 'is it true that on the 5th of March, at 5 p.m. on Długa Street you murdered Jan Kott with a knife?'

To quote T.S. Kuhn, the author of 'The Copernican Revolution', 'solving problems resembles much more a kids' puzzle, where in a picture you have to find an animal hidden in the scrub or clouds. The child will be looking for shapes similar to those of animals it already knows.'

Władysław Tatarkiewicz defines Kant's Copernican revolution: 'Similarly, the traditional opposition of experience and a priori thinking turned out to be faulty: for the thought is not the opposite but a basic element of experience.'[15]

Kant's revolution has a fundamental meaning for the whole of didactics and particularly for the didactics of physics: at the beginning of an experiment there is our idea about its result. The student has to be able to construct concept categories. We will go back to this topic while discussing the relation between the didactics of physics and the teaching of mother tongue.

From Kant's philosophy stems a rule that is important to contemporary didactics of physics based on the experiment: SPEA (situation – prediction– experiment – analysis). The basis of scientific cognition, especially in physics[16], is a precisely asked question, e.g. 'Do balls in oil fall in an accelerated motion?' We prepare an experiment, do the measurements, write down the results and then analyse them. In set SPEA rules, e.g. the accuracy of time measurement by a stopwatch, the density of oil, the length of the fall, the measuring segments and so on, the answer should be yes or no. Falling in oil is not a uniformly accelerated motion but rather a *uniform* motion.' The SPEA method is a realisation of Cartesian gradual solving of a problem, but the element of the previously prepared experiment is the element that renders Kant's research method.



An experiment prepared in detail in the SPEA methodology for checking the uniform motion: an adequately long tube, a small air bubble, previously marked segments on the tube, a slight inclination of the tube, oil that is not too sticky, a clock in the background, video recording.

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[15] cited from 'The History of Philosophy' by W. Tatarkiewicz, volume II, PWN Warszawa, p. 171

[16] Naturally, the rule of an experiment prepared in detail applies to other sciences, too. However, the degree of 'randomness' of some observations, e.g. the customs of an unknown tribe or fauna in a jungle, is higher than in experiments looking for the Higgs boson. However, in physics (astronomy) random observations such as the Kepler's supernova explosion are frequent and highly creative for the development of science.

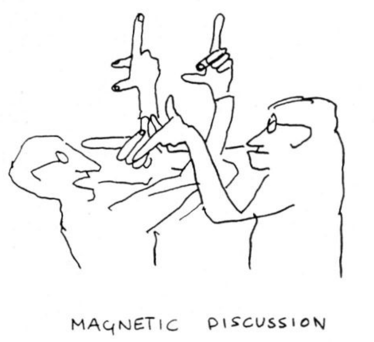
A proper use and *creation* of concept categories is extremely important in science, especially in physics. Physicists try to 'reserve' some of the expressions belonging to everyday language only for themselves, for instance 'uniform' or 'uniformly accelerated'. Out of respect for other fields of science and for preserving the autonomy of language development, the number of these 'reserved' categories should be as small as possible. A teacher should not be outraged if a student does not always match the reserved terminology: uniform ≈ steady ≈ monotonous ≈ slow.

At the same time new concept categories, with strictly set properties, extremely help both in simplifying teaching and in absorbing knowledge. Vectors, which are a generalisation of arrows that children use to describe motion, may be an example here (see the drawings in paragraph 3.6a). A vector, an 'ordered pair of points' in mathematics, becomes a free vector and begins to have an autonomous meaning in physics. The autonomy of the meaning of a velocity vector (the river's current) is shown in the sequence of photos below: the velocity of the river's current (vector-wise) is summed with the velocity of the boat (or an ice floe), no matter if they float along or across the river.

Fot. 4.4 Po Wiśle w Toruniu zimą żeglują tylko mewy na krze. Latem, łódka płynie w poprzek rzeki, ale jak mewy, też jest znoszona prądem (na tych zdjęciach w prawo).

A further extension of the concept of vector is the concept of the vector *product*. Let us introduce its definition in a constructivist way, posing a question: 'The sum of the addition of two vectors is another vector. What about the product of the multiplication of two vectors? How do you imagine the product of the multiplication of two arrows?'

The sense of introducing new categories lies in the possibility of reducing a bigger number of cases to one rule, defined by the properties of the new category. And so, in electromagnetism, numerous right- and left-hand rules (see the cartoon by Prof. Bruno Touschek) can be reduced to the properties of the vector product: the sense of vector ***c***, which is a product of $\boldsymbol{c} = \boldsymbol{a} \times \boldsymbol{b}$ results from the (right-hand) screw rule, which superimposes vector ***a*** on vector ***b***.



New concept categories, such as e.g. the vector product, are extremely useful both in the development of science and in simplifying the didactic message. Numerous right- or left-hand rules (beside a cartoon by an Austrian nuclear physicist Bruno Touschek) can be replaced by a single, general rule of *vectorial* multiplication of vectors.

In this way, the following are clearly defined: the sense of the Lorentz force $\boldsymbol{F} = q(\mathbf{v} \times \boldsymbol{B})$, the electrodynamic force $\boldsymbol{F} = I(\boldsymbol{l} \times \boldsymbol{B})$, the magnetic induction vector ***B*** around the linear conductor (from the Biot-Savart law) $\mathrm{d}\boldsymbol{B} = \mu_0 I (\boldsymbol{l} \times \boldsymbol{r})/4\pi r^3$, the moment of momentum $\boldsymbol{L} = m(\boldsymbol{r} \times \mathbf{v})$, the force momentum $\boldsymbol{M} = \boldsymbol{r} \times \boldsymbol{F}$)

The importance of Immanuel Kant to modern natural science comes from one more of his intuitions: predicting the synthetic *a priori* judgements. Kant divided judgements into two kinds – analytic and synthetic. Only the latter brings something actually new into our understanding of nature. 'Analytic judgements are those which state in the predicate only what is contained in the subject of a sentence, i.e. what belongs to the subject's definition or can be derived from it. (...) Analytic judgements explain the knowledge already possessed, while synthetic judgements broaden the knowledge.'[17]

A typical example of an analytic judgement is the answer to the question: 'What is gravity?' '- Earth's gravitation'. Etymologically – *gravitare* means gravitate. Such an answer does not allow for any further, important conclusions. Analytic judgements of this kind should be considered *tautologies*: 'Butter consists of butter' (according to the norm, 81% of butter is milk fat).

The second divison of judgements by Kant is the distinction of *a posteriori* and *a priori* judgements. The former are grounded in experience, the latter have their source in the mind alone. This is what W. Tatarkiewicz writes: 'The nature of analytic judgements is easy to comprehend, so is the nature of synthetic *a posteriori* judgements. The former analyse concepts alone, the latter are simply based on experience. But the synthetic *a priori* judgements that are left seem puzzling. How is it possible to say something about an object that is not included in its concept or derived from experience? And it is these judgements indeed that form the core of knowledge (...) Kant derived the belief that synthetic *a priori* judgements exist from two fields of study: mathematics and pure (mathematical, as it is referred to today) natural science.'[1]

The most revolutionary synthetic *a priori* judgement in the history of science was undoubtedly the formulation of Maxwell equations, particularly the resulting electromagnetic waves, as paraphrased by the picture below.

Pan Bóg powiedział:

$$\nabla \cdot \mathbf{E} = \rho/\varepsilon_0$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 I + \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

I stało się światło!

Ryc. 2.6. Prawa Maxwella w postaci tzw. różniczkowej. Odwrotność iloczynu stałych $\mu_0=4\pi\cdot 10^{-7}$ [SI] i $\varepsilon_0=8.85\cdot 10^{-12}$ [SI] jest równa kwadratowi prędkości światła w próżni, $1/\mu_0\varepsilon_0 = c^2$. Nie musisz tych równań rozumieć, ale dzięki nim mamy telefony komórkowe, radio i TV

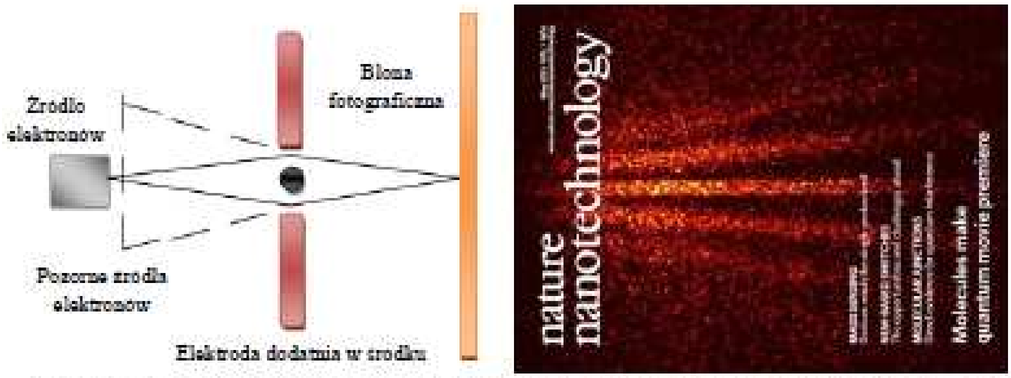
Another generalising judgment, but one which does not result from experience, is Albert Einstein's general theory of relativity. The question of what is (not) the difference between a lift going down and uniform motion, led Einstein, after several pages of mathematical considerations, to the prediction of the precession of Mercury's orbit and the warping of a light-ray near the Sun (or more precisely: warping that is two times greater than it would follow from Newton's theory). The surprising conclusion: gravitational field deforms space-time!

[17] W. Tatarkiewicz, 'Historia filozofii', volume II, PWN Warszawa, p. 165, translation K. Kowalski

3.6. Epistemological consequences of contemporary physics

The beginning of the 20^{th} century has fundamentally changed our views on the possibilities of discovering (and understanding) the world. A kind of a reductionist ('not everything can be discovered') revolution took place in mathematics, physics, astronomy. In 1900 David Hilbert posed the task of closing mathematics into a coherent whole, based on a finite number of mutually non-contradictory axioms. In 1931 Kurt Gödel showed that it cannot be proved that arithmetic is both coherent and complete.

A revolution in physics began also in 1900, with the formulation of the hypothesis of the quanta of electromagnetic radiation by Max Planck. If an electromagnetic wave behaves like a particle in some phenomena (e.g. photoelectric), then maybe an electron behaves like a wave as well? Does it mean that an interferential experiment can be performed on an electron beam, just like Young did it in 1809 with a beam of light passing through two apertures? Yes, and not only on an electron beam but even on a beam of heavy particles of phthalocyanine, see the photo below taken from the cover of “Nature”.



Rys. 2.73. a) Schemat układu do obserwacji interferencja elektronów (lub atomów) pochodzących z dwóch pozornych źródeł elektronów, b) prążki obserwowane w interferencji drobin ftalocyjaniny (Uniwersytet w Wiedniu, 2012, na zdjęciu okładka czasopisma „Nature”)

From an interferential experiment stems a serious difficulty of interpretation for electrons, which are undoubtedly almost point particles. If a single electron passes through accidentally but through *one* aperture, how does a group of electrons create a pattern closely corresponding to the interference of a plane wave on *two* apertures? Or one electron passes through two apertures at a time, or the next electron has the information through which aperture it 'needs' to pass for an interference pattern to be created on a screen.

The above difficulty is an example of restricting our possibility of gaining knowledge by Nature in itself. The experiment with electrons can be conveyed in such a way that we will know through which aperture each of them passed, but then the interference pattern disappears and only shadows of two separate apertures arise. Various interpretations of quantum mechanics sought the *mechanisms* of this phenomenon. The problem seems far more serious that just the wave-quantum *dualism*, where one time we see the heads, another time - the tails of a coin. The experiment with electrons suggests that despite the *mathematical* description, correctly formed by the creators of quantum physics, the phenomenon in itself *cannot* be understood, as Copernicus wrote several centuries earlier.

The equation which correctly describes the 'behaviour' of the electrons is the well-known Schrödinger equation:

$$\hat{H}\,\Psi(r,t) = i\hbar\,\frac{\partial}{\partial t}\,\Psi(r,t)$$

where H is the Hamiltonian operator (has a meaning of energy) and Ψ is the 'electron's wave function'. Such a statement, however, does not tell us much in didactic terms.

A shortened explanation of the importance of the wave function in the Schrödinger equation should be replaced by a more precise one: the square $|\Psi\ (x,\ t)|^2$ unit of the wave function means a probability of an electron being in a given place x at a given moment t. In other words, *if* we made an experiment, or more precisely - *many experiments* in exactly the same conditions, a certain number of the electrons would be in a point indicated by the coordinates (x, t).

In other words, until the moment of performing the experiment by us, only the single electron knows where it 'really' is at a given moment. A lot of different interpretations of the quantum mechanics ascribe their own understandings to the wave function. For us, the Schrödinger equation is one of the symptoms that Nature may be mathematically described but not necessarily and wholly imagined.

An additional, or rather alternative restriction results from the Heisenberg's uncertainty principle: we cannot precisely determine the position and the momentum of a particle simultaneously. Let us notice that the discussion on whether the product of the indeterminacy of the position and the momentum $\Delta x \Delta p$ is in the order of Planck's constant h, or that constant divided by π or by 2π lasts until today. We have some kind of unclarity in indeterminacy...

Einstein's special theory of relativity has imposed another constraint on our knowledge about the universe, but has also provided an interesting alternative vision. Because of the finite speed of light, independent of the observer's speed, we cannot look into the universe further than about 13,86 billion years, a number which results from multiplying the speed of light - 300 thousand kilometers per second by the age of the universe. It is like in the 17^{th} century picture, where fun was made of medieval cosmology beliefs. Unfortunately, the medieval scientists were right: you cannot look into the depth of the universe too far!

Not to mention that a constraint of our personal exploitation of the universe is the Newton's second law – a lot of time (and energy) is needed to gain the sub-light speed! Then, speculative travel in the carpet-like wrapped space-time requires huge changes of mass into energy: an immediate trip to Jupiter would absorb the mass of Mars?

More and more complicated issues – e.g. teleportation in quantum mechanics or dark energy and dark matter in cosmology show that despite the ability to *describe* phenomena correctly, we experience more and more trouble in *understanding* them. These inherent restrictions, not methodological but ontological, in our knowing of the world put the teacher in a less stressful situation. For every student's question they may answer: 'I don't know, but this often happens to scientists, too'.

3.7. European traditions of pedagogy

Pedagogy, understood mostly as the study of *upbringing*, which lies both in the field of the humanities (the study of culture) and the social studies, underwent deep paradigm changes in the modern times. Let us remind that in the Middle Ages and in the few subsequent ages, only religious organisations dealt with common education.

Among the creators of pedagogy and didactics, it is necessary to mention John Amos Comenius (1592-1670), one of the last leaders of a religious movement called 'the Unity of the Brethren'. He worked in Leszno, but moved to Amsterdam after the burial of his house by the citizens (after the Deluge). His 'Great Didactic' is a strictly religious work, as compared to others of that epoch. This is how Comenius defines the school's objectives: 'Schools are the workshops of humanity, for without a doubt they influence the process of a human being becoming a real human, that is: I. a sensible being, II. a being that controls its own and all other beings, III. a being that is to become joy for its Creator. In his vast piece of work Comenius gave a lot of tips on the organisation, content and forms of schooling. 'We shall simplify the schools' tasks by shortening the amount of knowledge, which will happen if we skip: I. what is useless, II. what is strange, III. what is petty.'[18]

Various philosophical schools proposed various approaches to education, from upbringing in harmony with nature (J. J. Rousseau, Switzerland, 1712-1778), through pedagogy understood as shaping the will and character in order to fulfill a definite role in the division of social tasks (J. F. Herbart, Prussia, 1776-1841), learning through action and treating school as a unit of social life (J. Deway, the USA, 1859-1952) to education based on the child's freedom, its creativity, movement and play (M. Montessori, Italy, 1870-1952). Except for J. J. Rousseau's idealism, the ideas of the above mentioned pedagogues were practically implemented in national and foreign education systems of certain periods. Still, various elements (Hebart's discipline and Montessori's freedom of the child) clash in contemporary national systems and the activities of single schools.

'School is play but a rod is a rod' – a paraphrase of Comenius's pedagogy from a table in the Department of Didactics of Physics of the Charles University in Prague

Montessori's didactic aids – learning spatial (and mathematical) relationships through practical manipulation of objects.

The Polish "school" of pedagogy has developed already at the beginning of XXth century and comprise names of J. Korczak, K. Sośnicki, W. Okoń, Cz. Kupisiewicz, S. Rudniański.

[18] J. A. Komensky, *Didattica magna*, page 143, http://pbc.up.krakow.pl/dlibra/docmetadata?id689&from=publication

3.8. Jean Piaget and the theory of the child's cognitive development

In the first half of the 20th century, along with the popularisation of the pre-school upbringing, attention was drawn to the child's developmental psychology. Jean Piaget is thought to be the creator of this field of study. Piaget distinguished four stages in the child's cognitive development:

1st stage – until 2 years of age – knowing the world through senses,
2nd stage – until 7 years of age – the activation of imagination,
3rd stage – 7-11 years of age – children understand simple cause-effect relations, but have problems with abstract concepts,
4th stage – from 12 years of age – the development of abstract thinking.

Piaget's theory made a considerable impact on the organisation of the cycles of teaching children in the education systems of many countries in the world. However, it seems to be very simplified. It may be used as an average of the whole population in different social and cultural conditions. Observing the behaviour of a single child in a beneficial cultural environment points to the fact that children are capable of abstract thinking at a very early stage of development.
Below are a few examples.

Paweł (2 ½ years): 'Fishy [fish] has spikes, a fork has spikes, everyone has spikes'

Maja (2 ½ years): firstly, she drew mountains with vertical teeth, then horizontal sea waves. While drawing a spiral she answers the question 'What is this?' - 'I don't know yet!'. The drawing itself has no meaning - it will be assigned a relevant concept category later. The same Maja, while playing with ropes of different lengths, puts them in an oscillatory motion and then in circular oscillation, as if checking the dependency of the fluctuation period on the length of the rope.

It seems that the human mind from a very early stage of development begins to use *projections* of objects, that is Kant's 'conceptual categories', not just concrete objects. Children at a very early stage of development are capable of performing/planning investigative tasks in order to check the cause-effect dependencies to which, in a sophisticated scientific research, we refer as the laws of physics.
Below is the example of Piotruś who, at the age of 2 ½, discovers the law of conservation of energy by himself (spontaneously organising an experiment). He finds out: 'a ball let on a plain uphill comes back on its own'!

Piotruś (almost 3 years old) discovers the law of conservation of energy: a ball let from a plain comes back 'on its own'. In fact, the ball's potential energy at the beginning of the plain turns into kinetic energy at the lowest point of the plain, then again into potential energy at the other and and so on, almost like a *perpetuum mobile* (the idea and the realisation of the exhibit - GK, Toruń, Festival of Science 2007, photo by A. Karbowski)

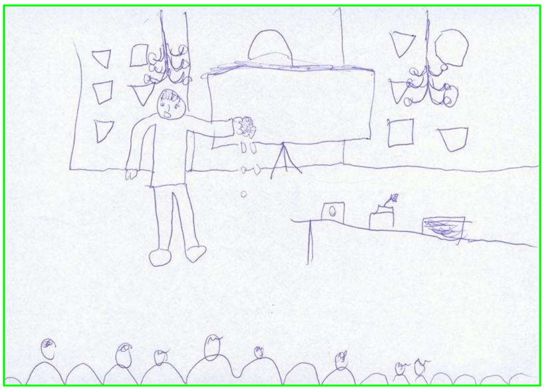
From (the criticism) of Jean Piaget's theory of children's psychological development come conclusions which are important to the practice of teaching physics at the early stages of development. Because the laws of physics are significant even for the simplest psycho-motor actions such as walking, jumping, throwing objects, it is possible to use simple experiments and objects on purpose, not so much to arouse interest in physics, but to create curiosity for investigation in general. The teacher's task is only to create a suitable problematic situation, arousing the exploratory activity.

3.8a. Beyond Piaget: physics for children

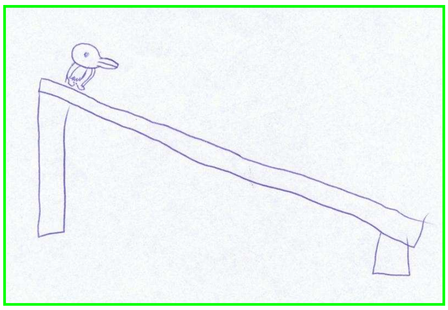
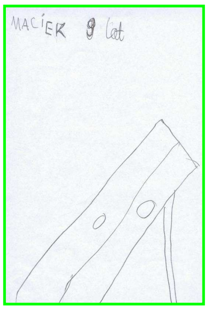
Contemporary means of accessing information and the individualisation of education point to the fact that children can cross Piaget's development schemes. The didactics of physics at the early school level is an example for that.

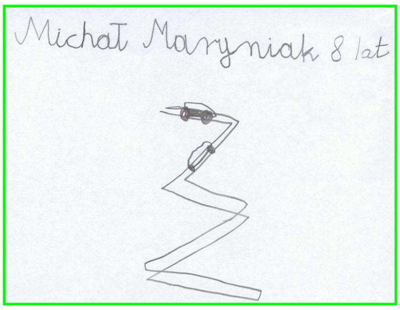
Substantial cognitive possibilities of children at an early school age (as well as the limitations of common school) lie at the grounds of success of the children's universities, an initiative present in any European countries for about 10 years. These universities have additional classes on Saturdays and Sundays for children who are interested. The initiative is paid. A series of performances done by the author point to a very high didactic efectiveness of an interactive, constructivist picturing of certain physical topics. These topics are e.g. issues of movement (including the notion of energy), electricity (including the notions of volt and ampere), sounds (harmonious analysis) and so on.

6-year-old children in the descriptions of experiments from the field of mechanics observed half a year before capture their physical essence, not just the observed images as in the pictures below. Some of the graphic relations have the form of a 'collective picture' but they are a minority. The second group is constituted by drawings of single experiments and not at all the most spectacular ones. It turns out that children remember the *conceptual content* of the experiments very well. Finally, the last group of the drawings are only schemes of the processes occurring, so the basic content of the presented *laws* of physics.

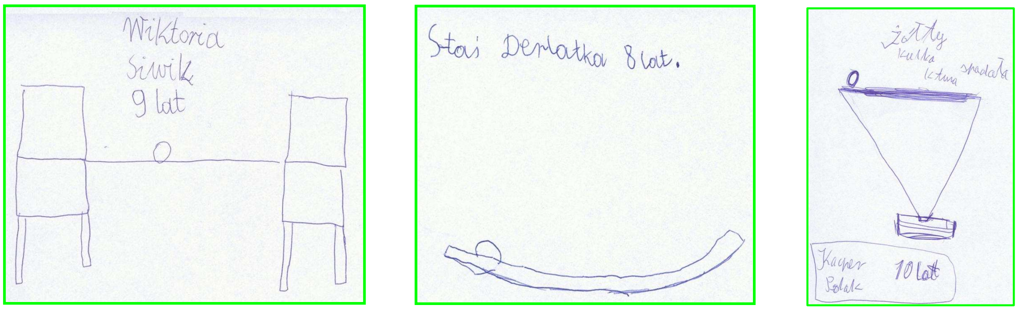


Veryfying the didactic results of the lecture 'Z górki na pazurki' (sliding downhill on your nails/hands) – reports from children prepared *ad hoc* after 5 months. The first group of drawings are the 'collective pictures', but even there we can see that the children noticed the key experiments, even if these experiments had not been spectacular. Daniel (7 years old) presents an experiment with 'the magic ball' in the foreground. The ball rolls uphill, contrary to Aristotle's predictions.

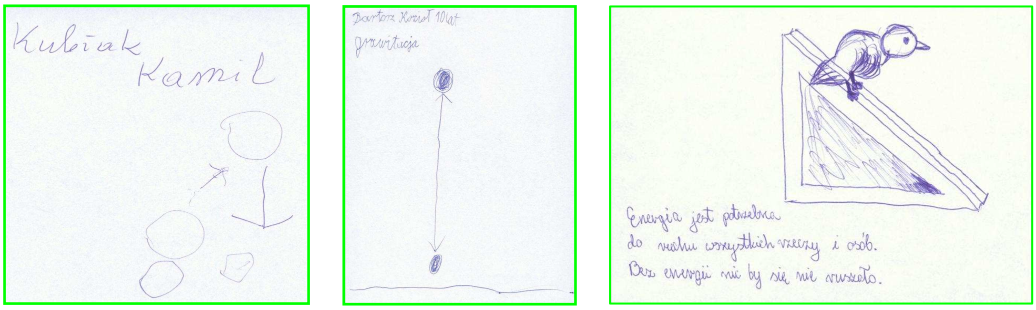


Verifying the didactic results of the lecture 'Z górki na pazurki' (cont.). The next group of drawings are the ones re-enacting the key experiments. a) the ducks going down is an illustration of the uniform motion, b) the balls rolling down on the same plain is an illustration of the uniformly accelerated motion, c) the experiment with two cars of different masses is an illustration of the independence of the gravitational acceleration from body weight.



Verifying the didactic results of the lecture 'Z górki na pazurki' (cont.). It is surprising that a few of the children asked put the experiments that were extremely easy and not at all spectacular in their drawings – balls on a bent plain and in a 'gravity' funnel. These two experiments were the core content of the lecture: 'How potential energy changes into kinetic energy and *vice versa*'.

It needs to be highlighted that the children drew without any instructions given beforehand, nor had they been told what to do earlier: 'Draw what you remember from the previous lecture'!



Verifying the didactic results of the lecture 'Z górki na pazurki' (cont.). The best mark for the ability to sum up the *laws* of physics was awarded to three above pictures. The first and second one present a conceptual *schema* of the experiment with the falling balls. The third one, judging from the 12-year-old girl's handwriting, is the clearest possible summary of the content of the lecture.

The above presented drawings were particularly surprising. The first and second one present *schemas* of the laws of physics concerning the falling and bouncing of balls. The arrows were not featured in any form in the lecture, so they are an autonomous extension of the observed phenomenon from the children's own pre-existing graphic means of expression. Finally, the third picture is the shortest possible summary of the lecture, which hidden topic was exactly: 'Why do bodies fall, slide down, bounce'. In this illustration we skipped only a few drawings, mainly from the older children, who had some grounded (and correct) pre-concepts of 'Bodies fall due to gravity'.

Not completely in accordance with Piaget's theory, even children at an early-school age are capable of generalising the observed events, which means they are capable of using abstract categories. Naturally, these usages are not some complicated reasonings, such as those from the field of theoretical physics: children draw arrows but are not aware that these arrows can be generalised to mean vectors. On the other hand, using such schemas proves that the notion of vector is not a very difficult one. It may be the excessive formalization of it that is not necessary: 'a vector as four attributes – direction, ...'. It is difficult to understand even for an older student.

The task of a responsible teacher is the stimulation of the student's abilities to gain knowledge on their own, through a proper use of their capacities - visual, manual, auditory, conceptual, artistic, practical etc.

3.9. Constructivism and cognitive science

Two schools of thought revolutionised didactics in the second part of the XXth century. These were: constructivism and cognitive science.

The term 'constructivism' is applied to two concurrent trends in sociology and philosophy. Among the creators of social constructionism (1966) are Berger and Luckman[19], who thought that the phenomena of the social world are constructed in mutual relations between individuals, negotiating the meanings ascribed to their own and other people's behaviours.

The already mentioned (pedagogical) constructivism of Piaget and Vygotsky narrows the meaning of this term to (self-reliant) construction of meanings by the student, in the process of social interaction. Two views on constructivism came into being independently, but both stress the importance of the social interaction. In Stanisław Dylak's interpretation this social constructing in education equals that the role of the teacher is brought to creating bridges between fields of knowledge. 'Education in its sense is creating bridges - with this approach school will take on a different role - less of a source of information and more of a place of verifying, systematising and consolidating knowledge.'[20]

Constructivist areas of knowledge are to be created together by the teacher and the student. Constructivism according to Dylak, however, is not entirely in line with the contemporary ways of *gaining* news and information, with the Internet, didactic television and the pauperisation of the transfer of scientific information by journalists. The amount of information gained by the students on their own, even at an early school age[21] exceeds the possibilities of performing the function of a 'knowledge-organiser' by the teacher in an effective way. *De facto*, gaining knowledge turns into *self-service* in a global supermarket with practically unrestricted resources. In constructivism as a model of self-reliant, unguided gaining of knowledge the authority of the teacher diminishes disproportionately.

Constructivism is declared the preferred method of teaching by half of the teachers in Polish junior high schools.[22] Constructivism, as viewed in Polish literature of the topic, {assumes that knowledge is a construct of the human mind and arises out of the subject's own, diverse activity. The cognitive activity of a person means that they gain, store, interprets, creates and passes information while giving them certain subjective value, sense and meaning."[23] Here, we find an original meaning given to constructivism by Piaget in his works on children's developmental psychology. However, as shown by our studies, neither school cv, nor Polish textbooks (and in consequence teachers' acting) reflect principles of constructivism in educations – declared constructivistic attitudes remain "wishful thinking" and the process of teaching resembles frequently a linear transporting of pre-packed definitions to be learned.

In the further part of the book we will discuss how the authority, experience and wide knowledge can raise (social) constructivism to a higher level of efectiveness in teaching. A new approach, combining the recently popular in the USA and the EU *inquiry-based teaching*, interactive teaching and constructivism was given the name hyper-constructivism by us. The examples of lessons on mechanics presented in the previous paragraph were realised in this concept indeed: the students construct the knowledge on their own, but the teacher prevents the exploratory process from deviating.

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[19] P.L. Berger, L.T. Luckman, Społeczne tworzenie rzeczywistości, PIW Warszawa 1986
[20] St. Dylak, *Nauczyciel konstruktywista w szkolnej klasie*, UAM, 1996
[21] See: G. Karwasz, *Fizyka dla krasnoludków*, http://dydaktyka.fizyka.umk.pl/nowa_strona/?q=node/171
[22] *Creating Effective Teaching and Learning Environments, First Results from TALIS*, OECD 2009
[23] A. Kamińska, *Nauki przyrodnicze w edukacji wczesnoszkolnej,* Problemy Wczesnej Edukacji, 2011

Cognitive science (the study of cognition) is a field that combines elements of psychology, the theory of cognition, neuropsychology, and computer sciences. It studies the processes of acquiring and processing information by a human mind and the possible uses of the artificial intelligence processes. 'The cognitive revolution as originally conceived virtually required that psychology join forces with anthropology and linguistics, philosophy and history, even with the discipline of law'[24] – one of the creators of Cognitive Science, Jerome Bruner (born 1915), writes.

Cognitive science deals not just with the processes of learning, but with the processes of thinking in general. 'Here is the central hypothesis of cognitive science: Thinking can best be understood in terms of representational structures in the mind and computational procedures that operate on these structures.'[25] Representation is more than just a concept category– it is a subject or an idea, surrounded in a person's mind by associations, assigned to memory, evoking particular emotions. As P. Thagard writes, it is not the name of a university campus but its graphic plan, history of my living there, my place of studying and so on are the full representation of the notion 'campus'. Operations on the representations are the procedures which the objects in the mind undergo. For instance, there are many ways of adding 13 to 28 in the mind. One can add digit by digit, one can add 28 to 3 and magnify the result by 10, one can add 38 to 3. This simple example gives only a few possibilities, however, in more complicated minds the variants are numerous.

The following statement by Bruner is used for teaching physics. 'A good teacher is the one that can construct exercises (or better, provide the essential experiment to the student) from which come immediate and crystal clear presentations, such as a shoe falling to the floor on a storey above us implies the fall of a second shoe. A poor teacher, on the other hand, prepares sequences so complicated that only a genius could possibly describe in a concise way what the teacher had in mind.'[26]

Pairing cognitivism with neuroscience, with the use of very up-to-date methods of detecting weak magnetic fields enabled to diagnose e.g. dyslexia. It is not an inability to recognise graphic symbols, or associating them with phonemes, or incapability of auditory articulation of phonemes. It turns out that the part of the brain that is responsible for operations performed on symbols is quite far in electrical terms from the centres of the articulation of speech (the ability to read has not been given to us by evolution).

In normal children the signal of recognising a letter wanders on a kind of delay line for about 40 μs, so that the speech centre can activate at this time. In dyslexics this delay line is off. It is not the dyslexics who are slow at reading but the normal kids! Unfortunately, lack of the delay loop disorganises the sequence and dyslexic children get lost in reading. The solution is not accelerating their mental operations but their purposeful, precise and rhythmic decelerating.

Cognitive science developed at the time of building first computers for civilian use and its achievements serve not only the humanities but most of all the creation of artificial intelligence. The lesson for a methodology and cognitive science educator is as follows: you cannot classify any of the student's mental operations as aberration; all of them are caused by grounded, for some reasons, operational procedures in the mind of the student. A good teacher, in comfortable work conditions, would be able to find the source of these procedures and correct them.

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[24] J. Bruner, *Act of meaning*, Harvard University Press, 1991, p. 3,

[25] P. Thagard, *Mind. Introduction to Cognitive Science,* MIT Press, 2005 p. 11, http://books.google.pl/books?id=gjcR1U2HT7kC

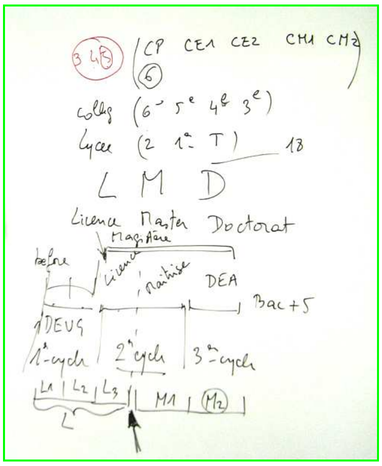
[26] J. Bruner, *On Knowing. Essays for the Left Hand,* Harvard University Press, 1964, p. 129,

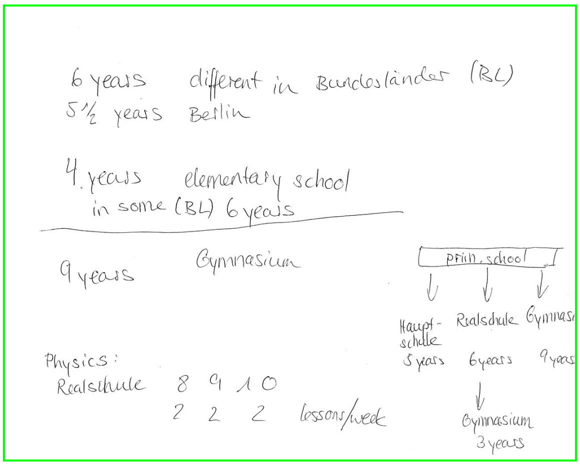
IV. Organization of education
4.1. Education systems in contemporary Europe

National education systems are constantly changing in order to accommodate the present educational structure to permanently evolving demands of cultural and economic development. However some of the features are common for all of Europe and are caused by traditions of didactic, pedagogic and also democracy, as it was described in previous chapter. Among such features one should indicate access to education by everybody as it is guaranteed by national constitutions, but associated with selective education of nation's elite and organizational variability of schools.

Comparison of educational system can be difficult due to the nature of observation „from within". The observer is therefore focused on system failures, which reflects (in a good sense) the diagnostic role of didactics. At the same moment observation „from outside" e.g. measuring by various kinds of international tests is also not objective. As OECD's Polish expert wrote regarding PISA tests which measure the performance of Polish gymnasium students: „the outcome is striking. While the average level of Polish students rose significantly, the difference between 17 year old students of vocational schools and other types of schools remained constant or event was increased. Thus stratification observed in old Polish school is still well and alive under the new name in upper high school.[27].

Below two modes of observing the educational system are shown: i) subjective, as seen by University faculty members and ii) "objective" as results from selected international statistics.



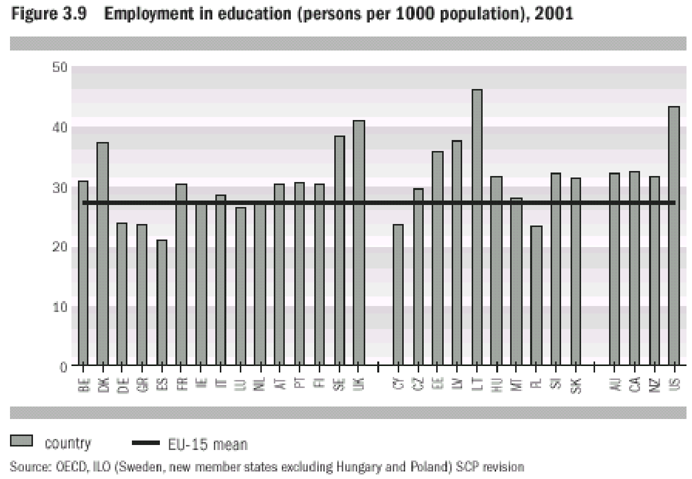


Educational system structure seen „from within" e.g. by a country's faculty staff: 1) French system with 5 years primary school, 4 years college and 2 years lyceum; 2) German system with 4 year primary school and 9 year college. Source – author's studies.

Despite many differences, this „comparision from within" sheds light on common features: a brief 4-5 years of primary schooling, with admission at age approx 5-6 years, few years of gymnasium (9 years in Germany). In France brief Lycee is augmented by, usually two years of private *ecole preparataire.* This is *de facto* a condition to prepare for an elite university (so-called Ecole Centrale) such as Ecole Normale in Paris. In the later, in prestigious science class (mathematics, physics, astronomy, biology, geology) counting about 100 students a year are in the future becoming the cadre of science faculties of all French universities.

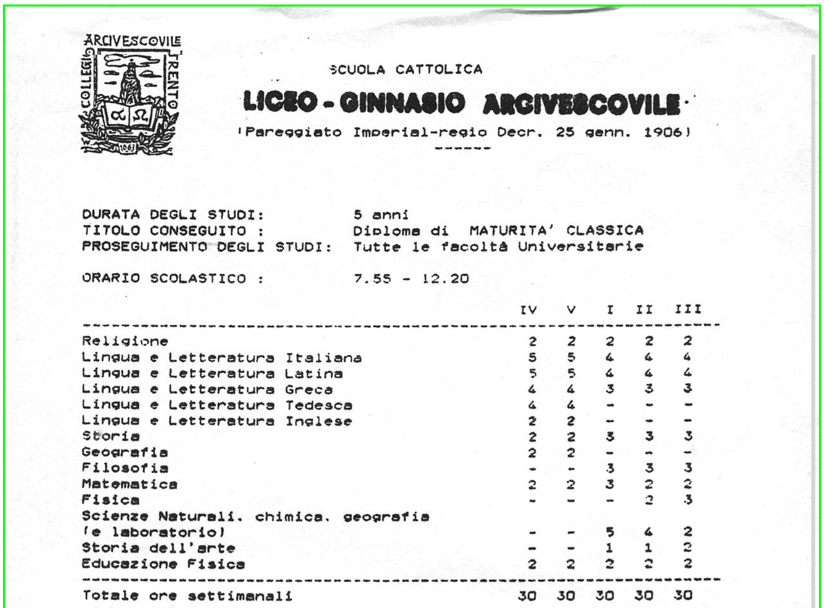
[27] M. Jakubowski, H. A. Patrinos, E. E. Porta, J. Wiśniewski, The Impact of the 1999 Educational Reform in Poland, OECD Working Paper Np. 49, OECD Directorate for Education, EDU/WKP(2010)12 www.oecd.org/pisa/pisaproducts/45721631

Similarly majority (2/3) of French industry are educated in Parisian Ecole Centrale. Therefore the illusion of uniform access to an education realised in a very brief lyceum is supplemented by *elite access to the best schools*. Systems working on similar principle, despite some differences, are place in UK and USA.



The international comparision of educational systemes on the employment in educational sector in 2001. In Poland it is 30-40% lower than in UK, USA, Sweden and Lithuania. Source OECD

All systems in all counties have its shortcomings and failures but also enjoy some outstanding elements. Italy's weakest link is the 3 year gymnasium but 5 year of lyceum works as equalizer. The program even in humanistic classes requires 11 hours of math in a cycle (see below).



SCUOLA CATTOLICA

LICEO - GINNASIO ARCIVESCOVILE

(Pareggiato Imperial-regio Decr. 25 genn. 1906)

DURATA DEGLI STUDI: 5 anni
TITOLO CONSEGUITO : Diploma di MATURITA' CLASSICA
PROSEGUIMENTO DEGLI STUDI: Tutte le facoltà Universitarie

ORARIO SCOLASTICO : 7.55 - 12.20

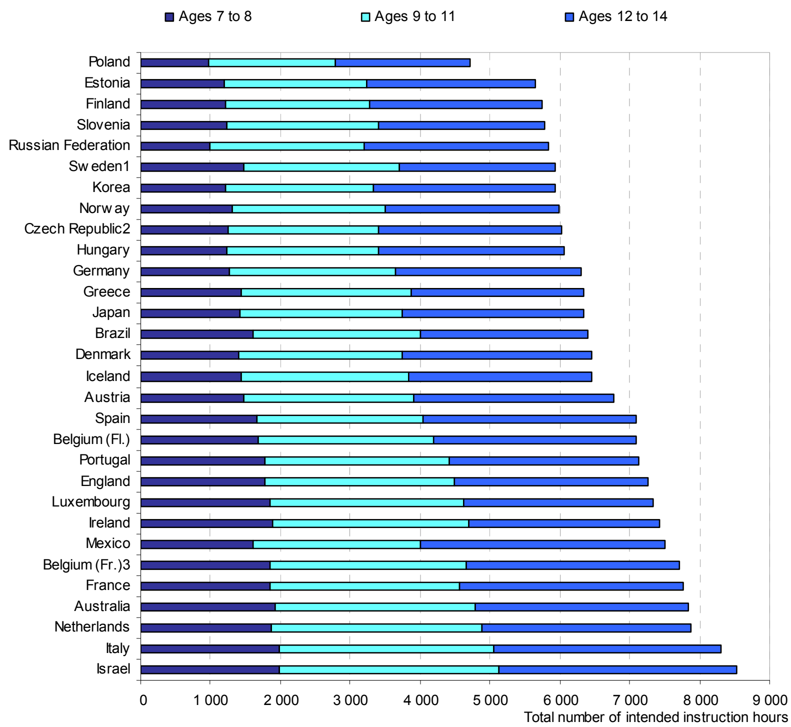
	IV	V	I	II	III
Religione	2	2	2	2	2
Lingua e Letteratura Italiana	5	5	4	4	4
Lingua e Letteratura Latina	5	5	4	4	4
Lingua e Letteratura Greca	4	4	3	3	3
Lingua e Letteratura Tedesca	4	4	-	-	-
Lingua e Letteratura Inglese	2	2	-	-	-
Storia	2	2	3	3	3
Geografia	2	2	-	-	-
Filosofia	-	-	3	3	3
Matematica	2	2	3	2	2
Fisica	-	-	-	2	3
Scienze Naturali, chimica, geografia (e laboratorio)	-	-	5	4	2
Storia dell'arte	-	-	1	1	2
Educazione Fisica	2	2	2	2	2
Totale ore settimanali	30	30	30	30	30

Multiaspect comparison of various educational systems hints that EU countries tend to build consistent schooling patch. Germany's cornerstone is 9 year gymnasium and strong vocational schools, French system with 2 year of lyceum and *ecole preparataire* is aimed to create intellectual elite, Italian system with 5 year long lyceum provides an excellent general knowledge but much weaker academic preparation. The positive and negative features of educational systems can be traced in performance of economic systems and place the respective country takes in international division of labour.

4.2. Education system in Poland

Polish educational system is described by the reform of 1997. At the time Minstry of Education was chaired by prof. Handke, a geologist of Akademia Górniczo-Hutnicza in Krakow. The main concept was to liberate the programme and cut the 8 year long primary school to two separate cycles loosely resembling italian reform of 1929 (adopted during the Mussolini governments and worked out by philosophy professor Gentilini).

This reform should be considered as a part of systematic preparations by Poland to a EU access which changed economy, law and social organization. In declarations the aim was to increase schooling time to 9 years (thus gymnasium) and provide cultural pluralism. In effect the international tests scores improved dramatically. Students taking part in these exams took lessons in a uniform system, which unlike previous one was not divided to vocational and general schools.

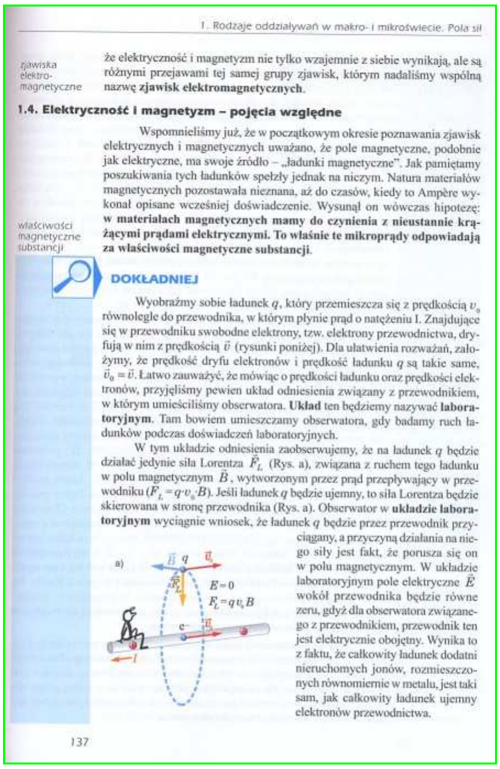


The count of school hours for 7-14 year old (OECD 2010). source : „Education at a Glance 2010: OECD Indicators"
http://www.oecd.org/document/52/0,3746,en_2649_39263238_45897844_1_1_1_1,00.html#d962010071P1G021.XLS

Unfortunately – as indicated by the OECD's data the changes in organization of education require the investment for example in extension of school hours. Graph above concerning 7-14 yrs age shows that Poland takes last position among 30 countries in that respect.

The declarative "programme pluralism" lead to paradoxical situation. Private and so called "civic" schools (operated by various organizations) failed to deliver expected educational change both locally and in national area. Only recently in Poland emerged *catholic schools* (in Austria there is 40% of such schools). In most cities (Gdynia, Szczecin, Warszawa) top schools are those with a long tradition and excepted "democratisation" does not appear in statistics.

Another failure is the "pluralism" in the content of schooling. It created competition between publishers in which (according to popular belief) the quality of the book counts less than marketing. To prove that we present graphic from physics. Two books from two publishers is presenting electromagnetism. Compared to German and French book, the Polish sis overloaded with details which are not functional to create the concept in the student's mind.


1. Rodzaje oddziaływań w makro- i mikroświecie. Pola sił

zjawiska elektro-magnetyczne

że elektryczność i magnetyzm nie tylko wzajemnie z siebie wynikają, ale są różnymi przejawami tej samej grupy zjawisk, którym nadaliśmy wspólną nazwę **zjawisk elektromagnetycznych**.

1.4. Elektryczność i magnetyzm – pojęcia względne

Wspomnieliśmy już, że w początkowym okresie poznawania zjawisk elektrycznych i magnetycznych uważano, że pole magnetyczne, podobnie jak elektryczne, ma swoje źródło – „ładunki magnetyczne". Jak pamiętamy poszukiwania tych ładunków spełzły jednak na niczym. Natura materiałów magnetycznych pozostawała nieznana, aż do czasów, kiedy to Ampère wykonał opisane wcześniej doświadczenie. Wysunął on wówczas hipotezę: **w materiałach magnetycznych mamy do czynienia z nieustannie krążącymi prądami elektrycznymi. To właśnie te mikroprądy odpowiadają za właściwości magnetyczne substancji**.

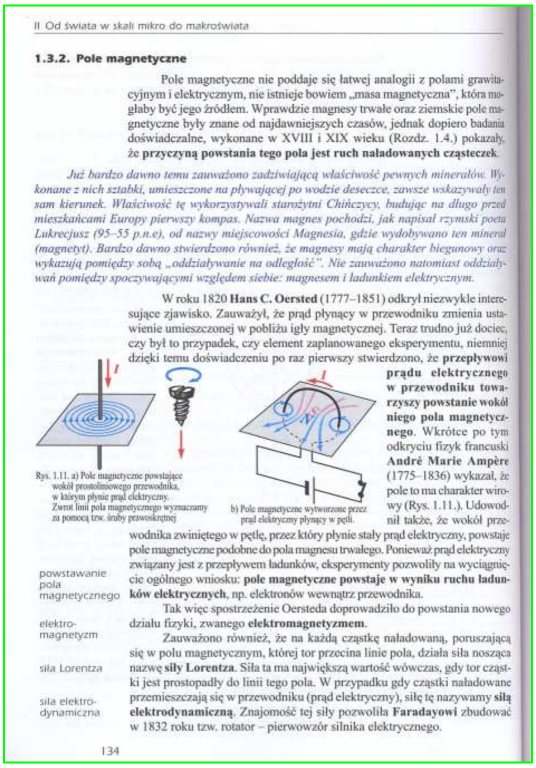
właściwości magnetyczne substancji

DOKŁADNIEJ

Wyobraźmy sobie ładunek q, który przemieszcza się z prędkością v_0 równolegle do przewodnika, w którym płynie prąd o natężeniu I. Znajdujące się w przewodniku swobodne elektrony, tzw. elektrony przewodnictwa, dryfują w nim z prędkością $\vec{v}$ (rysunki poniżej). Dla ułatwienia rozważań, załóżymy, że prędkość dryfu elektronów i prędkość ładunku q są takie same, $\vec{v}_0 = \vec{v}$. Łatwo zauważyć, że mówiąc o prędkości ładunku oraz prędkości elektronów, przyjęliśmy pewien układ odniesienia związany z przewodnikiem, w którym umieściliśmy obserwatora. **Układ** ten będziemy nazywać **laboratoryjnym**. Tam bowiem umieszczamy obserwatora, gdy badamy ruch ładunków podczas doświadczeń laboratoryjnych.

W tym układzie odniesienia zaobserwujemy, że na ładunek q będzie działać jedynie siła Lorentza $\vec{F}_L$ (Rys. a), związana z ruchem tego ładunku w polu magnetycznym $\vec{B}$, wytworzonym przez prąd przepływający w przewodniku ($F_L = q \cdot v_0 \cdot B$). Jeśli ładunek q będzie ujemny, to siła Lorentza będzie skierowana w stronę przewodnika (Rys. a). Obserwator w **układzie laboratoryjnym** wyciągnie wniosek, że ładunek q będzie przez przewodnik przyciągany, a przyczyną działania na niego siły jest fakt, że porusza się on w polu magnetycznym. W układzie laboratoryjnym pole elektryczne $\vec{E}$ wokół przewodnika będzie równe zeru, gdyż dla obserwatora związanego z przewodnikiem, przewodnik ten jest elektrycznie obojętny. Wynika to z faktu, że całkowity ładunek dodatni nieruchomych jonów, rozmieszczonych równomiernie w metalu, jest taki sam, jak całkowity ładunek ujemny elektronów przewodnictwa.

137


II Od świata w skali mikro do makroświata

1.3.2. Pole magnetyczne

Pole magnetyczne nie poddaje się łatwej analogii z polami grawitacyjnym i elektrycznym, nie istnieje bowiem „masa magnetyczna", która mogłaby być jego źródłem. Wprawdzie magnesy trwałe oraz ziemskie pole magnetyczne były znane od najdawniejszych czasów, jednak dopiero badania doświadczalne, wykonane w XVIII i XIX wieku (Rozdz. 1.4.) pokazały, że **przyczyną powstania tego pola jest ruch naładowanych cząsteczek**.

Już bardzo dawno temu zauważono zadziwiającą właściwość pewnych minerałów. Wykonane z nich sztabki, umieszczone na pływającej po wodzie deseczce, zawsze wskazywały ten sam kierunek. Właściwość tę wykorzystywali starożytni Chińczycy, budując na długo przed mieszkańcami Europy pierwszy kompas. Nazwa magnes pochodzi, jak napisał rzymski poeta Lukrecjusz (95–55 p.n.e), od nazwy miejscowości Magnesia, gdzie wydobywano ten minerał (magnetyt). Bardzo dawno stwierdzono również, że magnesy mają charakter biegunowy oraz wykazują pomiędzy sobą „oddziaływanie na odległość". Nie zauważono natomiast oddziaływań pomiędzy spoczywającymi względem siebie: magnesem i ładunkiem elektrycznym.

W roku 1820 **Hans C. Oersted** (1777–1851) odkrył niezwykle interesujące zjawisko. Zauważył, że prąd płynący w przewodniku zmienia ustawienie umieszczonej w pobliżu igły magnetycznej. Teraz trudno już dociec, czy był to przypadek, czy element zaplanowanego eksperymentu, niemniej dzięki temu doświadczeniu po raz pierwszy stwierdzono, że **przepływowi prądu elektrycznego w przewodniku towarzyszy powstanie wokół niego pola magnetycznego**. Wkrótce po tym odkryciu fizyk francuski **André Marie Ampère** (1775–1836) wykazał, że pole to ma charakter wirowy (Rys. 1.11.). Udowodnił także, że wokół przewodnika zwiniętego w pętlę, przez który płynie stały prąd elektryczny, powstaje pole magnetyczne podobne do pola magnesu trwałego. Ponieważ prąd elektryczny związany jest z przepływem ładunków, eksperymenty pozwoliły na wyciągnięcie ogólnego wniosku: **pole magnetyczne powstaje w wyniku ruchu ładunków elektrycznych**, np. elektronów wewnątrz przewodnika.

Rys. 1.11. a) Pole magnetyczne powstające wokół prostoliniowego przewodnika, w którym płynie prąd elektryczny. Zwrot linii pola magnetycznego wyznaczamy za pomocą tzw. śruby prawoskrętnej

b) Pole magnetyczne wytworzone przez prąd elektryczny płynący w pętli.

powstawanie pola magnetycznego

Tak więc spostrzeżenie Oersteda doprowadziło do powstania nowego działu fizyki, zwanego **elektromagnetyzmem**.

elektro-magnetyzm

Zauważono również, że na każdą cząstkę naładowaną, poruszającą się w polu magnetycznym, której tor przecina linie pola, działa siła nosząca nazwę **siły Lorentza**. Siła ta ma największą wartość wówczas, gdy tor cząstki jest prostopadły do linii tego pola. W przypadku gdy cząstki naładowane przemieszczają się w przewodniku (prąd elektryczny), siłę tę nazywamy **siłą elektrodynamiczną**. Znajomość tej siły pozwoliła **Faradayowi** zbudować w 1832 roku tzw. rotator – pierwowzór silnika elektrycznego.

siła Lorentza

siła elektro-dynamiczna

134

Excerpts from two Polish school books describing electromagnetism. Both present too formal approach and lack interdisciplinary and intersector knowledge.

Polish Education Ministry in 2012 published Programme Platform (Podstawa Programowa) which was aimed to uniform education. Unfortunately many experts agree that it reduced the demands for pupils. Particularly strange is the new topis "Nature" (Przyroda), it is exactly opposite to that in Great Britain. In the latter country "Nature" precedes physics, chemistry and biology in last classes of lyceum. Dangers to the quality of education are in (strange) sequence of content, lack of the didactic guidances whatsoever, and not enough quantity of properly qualified teachers.

C. Nauka wokół nas	17. Uczenie się	17.1	17.2	17.3	17.4
	18. Barwy i zapachy świata	18.1	18.2	18.3	18.4
	19. Cykle, rytmy i czas	19.1	19.2	19.3	19.4
	20. Śmiech i płacz	20.1	20.2	20.3	20.4
	21. Zdrowie	21.1	21.2	21.3	21.4
	22. Piękno i uroda	22.1	22.2	22.3	22.4
	23. Woda – cud natury	23.1	23.2	23.3	23.4
	24. Największe i najmniejsze	24.1	24.2	24.3	24.4

Selected contents of "Nature" subject in lyceum according to Programme Platform (Podstawa Programowa MEN). Vertical numbers are reflecting physics, chemistry, biology and geography of certain topics.

To resume, Polish schooling system is assembled from bits and pieces of loosely correlated topics. School is evaluated in a very formal way and there is no discussion regarding form and content of education. Detailed didactics is trying to break trough formal academic approach and everyday pragmatism of individual teacher.

4.3. Tasks for educational systems at the time of change

Only a century has passed since recent scientific revolution e.g. theory of quarks and theory of relativity and yet another revolution is simmering; in cosmology, elementary particle theory and solid state physics. In 20 years we may face the need of writing schoolbooks again.

Sheer pace of changes teaches us a new approach of a teaching of a subject; "yes it's true, but in few years it might be completely changed". The relation of a teacher to the topic (and its own knowledge) should remain critical. To predict future one need to know the past. Therefore, modern "teaching to teach" must include past and current ideas of a given discipline of science and show the problems that are open and unclear. Teacher must have a vast knowledge of the subject and a porftolio of teaching methodology, scientific gear, etc.

Such solutions are provided by systems of education in EU countries. Teachers have assigned the new tasks and simultaneously they get new teaching instruments. Many of such instruments like multimedia and computers in science labs are used across the spectrum of subjects. Thus it is necessary to adopt interdisciplinary approach to science.

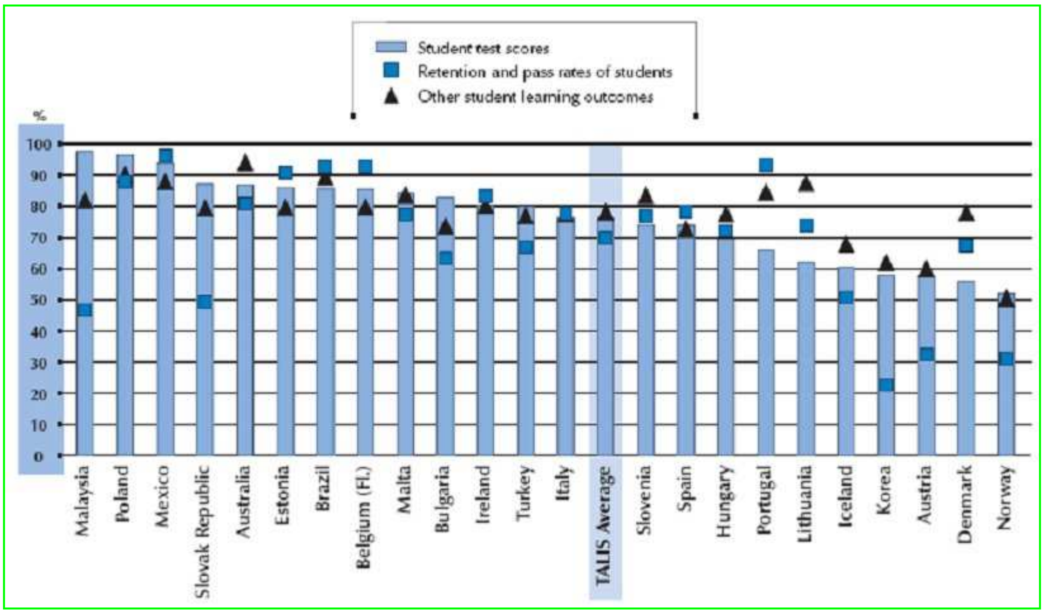
Interdisciplinary approaches of such kind are included in educational systems proposed for XXI century e.g. in UK (see graph below). In minimum curriculum in Science subjects such as chemistry, physics, astronomy are not divided. Starting Point to discussion is the structure of matter, its chemical and physical properties, chemical cycles of life. In physics discussion includes energy, radiation and electromagnetism. Classical topics of physics such as Newtonian dynamics, Galilean kinematics, etc. are missing. Such proposals must be considered as reflecting changes in a world external to the students and fitting to the social perception of science.

Table 4. Science explanations

SE1	Chemicals (the idea of a "substance")
SE2	Chemical change (the atomic/molecular model)
SE3	Materials and their properties (linking structure and function)
SE4	The interdependence of living things
SE5	The chemical cycles of life
SE6	Cells as the basic units of living things
SE7	Maintenance of life
SE8	The gene theory of inheritance
SE9	The theory of evolution by natural selection
SE10	The germ theory of disease
SE11	Energy sources and use
SE12	The idea of radiation
SE13	Radioactivity
SE14	The structure and evolution of the Earth
SE15	The structure of the Solar System
SE16	The structure and evolution of the Universe

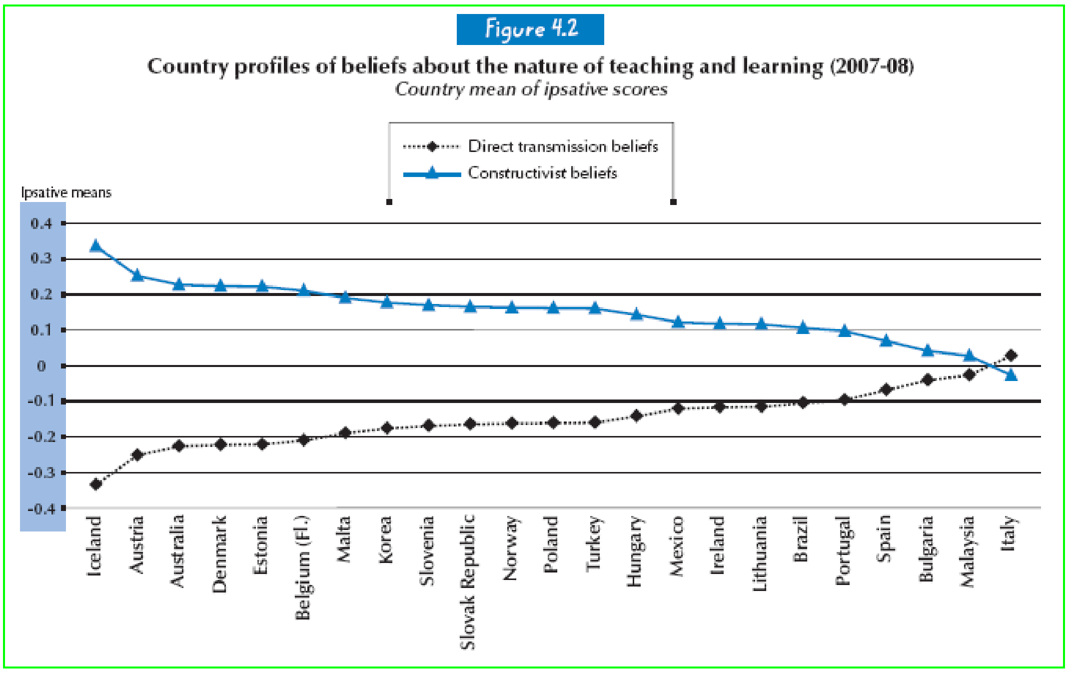
Source: R. Millar, *Twenty First Century Science: Insigths from the Design and Implementation of a Scientific Literacy in School Science*, Int. J. Science Education, No. 3, 2011

Regarding the methodology and organisation of teaching leading developed countries like Norway, Danmark, Austria and Republic of Korea feature decentralised, democratic system of management of the schools (see following graph). Poland is placed among the countries of most rigid education quality assessment system between Malaysia and Mexico.



Criteria of school assessment (2007-2008) student's tests scores (rectangles), number of students repeating class (squares), other scores (triangles). Poland is at the top in each category.

Democratisation of educational systems must be associated with changes in approach of individual teachers. Constructivistic approach of teachers should be considered as a step in a good direction (see next graph).



Teachers approaches declared by teachers. Source: TALIS Report, OECD 2009

As seen from the comparison above, majority of Polish teachers declare constructivistic approaches, while Italian colleagues do not show a similar attitude. However, as known from independent, Polish academic sources, these declarations frequently do not translate into practical implementations. The positive "mental terrain" of Polish teachers should be supported by the activity of institution supporting schools, like educational authorities, local centres for training, editors, science musea and so on.

V. Physics in the system of Sciences
5.1. Physics as a Science on Nature

Ancient Greeks, from the very early times of documented philosophy were interested in the elementary components of the surrounding world. Aristotle in his "Physics" considered mainly the motion of objects. He considered the subject of physics to be the whole material world, and even more – the Nature, which is different from sciences on beings non-accessible by senses, that he called "Metaphysics". The same Aristotle considered optics, harmony and astronomy as a bit more physical branches of mathematics[28]. In other place he writes: „Three are branches of the theoretical philosophy: mathematics, physics and theology."[29]

In Middle Ages, the seven *free* sciences, giving the title of *magister* and allowing to enter university studies of law, medicine or theology, were composed of:
- *trivium* (grammar, dialectics, rhetoric)
- *quadrivium* (arithmetic, geometry, music, astronomy).

Physics started to form-out from astronomy still in Middle Ages, in works of already mentioned J. Buridian, Witelo, Roger Bacon (Oxford, 1210?-1294). The latter was the precursor of experimental natural sciences: "Two are the ways of discovering, namely by argumentation and by experiments. An argumentation leads to conclusions, requires reasoning but does not assure the absolute certainty, does not remove doubts. The human mind reaches a certainty only observing the truth, and the truth can be achieved only via an experiment. Without the experiment it is not possibly to know anything with certainty."[30] At the same time Bacon underlines the role of mathematics in discovering: "It is not possible to know things of this world without knowing them mathematically".

Among the Middle Ages thinkers important for forming the modern ways of scientific reasoning, including physics, comprise first of all Wilhelm Ockham (c.a. 1300-1350), author of a commentary to "Physics" of Aristotle. Ockham formulated the famous principle called from his name "a razor": do not multiply beings above the necessity.

The principle of Ockham's razor finds important consequences in the evolution of the ideas in physics. These ideas, apparently useful like *flogiston* (the liquid transporting the heat) or ether, are removed from the repertory of physics, as soon as it turned out (experimentally or theoretically) that are not indispensable. One of criteria of judgment of the scientific theories is their simplicity.

In this sense even the theory of quarks is subject to epistemological critics. „If we realize that in order to explain the world we need three generations of quarks, each of them containing two and their anti-quarks, eight gluons, four intermediate bosons (W^+, W^-, Z^0, H), photon 3 neutrinos, so I miss the philosophy of Greeks with their four elements – earth, water, air and fire" wrote some time ago the editor-in-chief of „Scientific American". The picture comes form the book by prof. A. Góral *Meandry fizyki*, MON, 1982.

[28] Arystoteles, *Physics*, http://books.google.pl/books?id=zd6xl3pmiWoC, p. 28
[29] Aristotele, *Metafisica*, Bompiani, R. S. S. Libri, Milano, 2004, p. 283
[30] Following W. Tatarkiewicz, *Historia filozofii*, op. cit. , t. I, p. 256

The contemporary understanding of the physics is limited to un-live nature. In this way we introduce physics in the first chapter of "Torun tex-book in physics"[31] form gymnasium: starting from the definition of physics as a science on reversible phenomena.

Fizyka jako nauka

1.1 Zjawiska fizyczne

Czym zajmuje się fizyka? Odpowiadając, że zjawiskami „fizycznymi" popełniamy błąd logiczny zwany *tautologią*, czyli wyjaśnianiem pojęcia przez to samo pojęcie jak w stwierdzeniu, że w skład masła wchodzi masło (82%, sprawdź!) i woda.

Za zjawiska fizyczne tradycyjnie uważało się te, które nie prowadzą do żadnej zmiany oddziałujących *substancji*. Innymi słowy, zjawiska fizyczne to zjawiska powtarzalne i zazwyczaj odwracalne. I tak na przykład, dwie zderzające się piłeczki, stygnięcie herbaty w szklance, zaćmienie Słońca to zjawiska fizyczne. Piłeczki (o ile elastyczne) nie zmieniają ani kształtu, ani koloru po zderzeniu, zimną herbatę można ponownie podgrzać, a zaćmienie Słońca obejrzeć ponownie za kilka lat.

Nie jest tak w przypadku tzw. zjawisk *chemicznych*, zmieniających własności reagujących substancji. I tak, wymieszanie metalicznych kropelek rtęci z żółtym proszkiem siarki prowadzące do powstania czerwonego siarczku rtęci to zjawisko *chemiczne*. Stopienie siarki lub rosnący słupek rtęci w termometrze lekarskim (kiedyś tylko takie istniały) – to natomiast zjawiska fizyczne. Dzisiaj, rozgraniczenia na zjawiska *fizyczne, astronomiczne, chemiczne,* czy nawet *biologiczne* musimy uznać za nieco sztuczne.

Fot. 1.1 Zderzające się kulki, stygnąca woda w szklance, chmury na niebie, zaćmienie Słońca to zjawiska *fizyczne*.

Przytoczmy kilka *procesów* czyli zmian, jak reakcje chemiczne, stygnięcie, parowanie.

1° Po pierwsze, reakcje chemiczne są również odwracalne: np. wodorotlenek wapnia (czyli tzw. wapno gaszone) w zaprawie murarskiej powoli wiąże dwutlenek węgla z powietrza, zamieniając się w węglan wapnia. Z kolei węglan wapnia (czyli skała zwana „wapień") podgrzany do 1100° C uwalnia dwutlenek węgla i zamienia się w tlenek wapnia (wapno palone), który z kolei wymieszany z wodą daje wodorotlenek wapnia (wapno gaszone), który w zaprawie murarskiej ponownie wiąże dwutlenek węgla z atmosfery i zamienia się z powrotem w węgla wapnia itd., itd. Podobne procesy planuje się wykorzystać do magazynowania pod ziemią spalin z elektrowni, celem zredukowania efektu cieplarnianego.

Fot. 1.2 Rtęć utarta z siarką daje szary siarczek rtęci - jest to przykład procesu *chemicznego,* naturalny siarczek rtęci, cynober jest różowy.

This definition precisely divides physics from chemistry and biology, even if nowadays many of scientific disciplines mutually overlap. Moreover, one of the Noble winners in chemistry (or medicine) stated that these are physicists who invent wonderful experimental techniques that are later use in other sectors of science and of technology.

[31] G. Karwasz, M. Sadowska, K. Rochowicz, *Toruński po-ręcznik do fizyki. Mechanika. Gimnazjum I klasa*, Wyd. Nauk. UMK, 2010. (Torun tex-book for physics, Mechanics, Gymnasium, class I)

As we discuss below on picture below, limiting physics to reversible phenomena is not quite correct: cooling of water in a glass, petrol engines, weather and even the Universe as a whole are not reversible but are perfectly in research themes of physics.

2° Po drugie, nie wszystkie procesy fizyczne są *odwracalne*. Wymieszanie litra wody ciepłej z litrem wody zimnej daje dwa litry wody letniej, ale ponowne ich rozdzielenie nie jest możliwe. Gorąca szklanka herbaty, stygnąc, ogrzewa (choć bardzo niewiele) powietrze w kuchni, ale letnie powietrze z kuchni nie podgrzeje wody w szklance do wrzenia. Wszechświat się rozszerza, a przy tym stygnie i nic nie wskazuje na to, aby miał się ponownie skurczyć.

3° Po trzecie, także procesy *fizyczne* mogą powodować przemiany jednej substancji w drugą. Pierwiastek chemiczny radon, radioaktywny gaz szlachetny, powstaje z rozpadu promieniotwórczego innego pierwiastka, polonu, przypominającego chemicznie siarkę. Fizycy pracujący na wielkich akceleratorach potrafią zamienić jeden metal w drugi - np. aluminium w sód, sód z kolei zamienia się (w procesie rozpadu promieniotwórczego) w gaz, zwany neonem itd. Dzięki nauce, to co było niemożliwe, staje się niesłychanie proste. W tym sensie fizyka współczesna urzeczywistnia marzenia średniowiecznych *alchemików*, zamiany jednej substancji w drugą (choć nie zawsze w złoto i bez użycia *kamienia filozoficznego*).

Fot. 1.3 Fizyka zajmuje się *procesami*. Wytwarzanie prądu elektrycznego w elektrowni geotermicznej, wiatrowej lub w ogniwie słonecznym, to przykłady *procesów* fizycznych.

4° I wreszcie, po czwarte, zaćmienie Słońca to zjawisko *astronomiczne*, ale pamiętajmy, że ruch Ziemi wynika z prostych praw *fizyki*. Znając te prawa, przewidywanie zaćmień nie jest już wiedzą tajemną, ale da się *wyliczyć* na szkolnym kalkulatorze.

Fizyka współpracuje z innymi naukami przyrodniczymi, jak medycyna i biologia. Transport substancji biologicznych przez błony komórki zależy od obecności *jonów*. Wymiana jonów jest też podstawą działania bateryjek elektrycznych i ogniw paliwowych, a te urządzenia zaliczamy do obszaru badań fizyki. Z osiągnięć zaawansowanej fizyki, jak widać na zdjęciach poniżej, korzysta współczesna *medycyna*.

Fot. 1.4 Nowoczesne techniki badawcze w medycynie – rezonans magnetyczny, tomografia optyczna oka (UMK), tomografia pozytonowa (Centrum Onkologii w Bydgoszczy) – to wszystko urządzenia skonstruowane przez *fizyków*.

Source: G. Karwasz, M. Sadowska, K. Rochowicz, *Toruński po-ręcznik do fizyki,* op. cit.

Not entering the polemics with other sciences on mutual borders, the subject of interest for physics are both the tendencies of indicators in economics as well as neurotic ptrocesse in the brain. The list of applications of physics broadens continuously. Therefore it would be reasonable, following the followers of Aristotle, to define what physics is *not*: metaphysics, and leave other sciences, including humanities inside the sphere of interest of physics, and of didactics of physics as well.

5.2. Physics as an experimental science

Albert Einstein stated, that "this is experiment which does the final verifications of theories in physics". However, in 1919 when Lord Edington left England t Africa, to verify during the eclipse the correctness of the General Relativity Theory and after the observation sent to Einstein a report with congratulation, the latter was not surprised: "I knew well that my theory was correct".[32]

The check of Einstein's theory was a scientific travel prepared on purpose, but many discoveries in physics have (at least apparently) casual character. Apparently casual, as behind those discoveries there is always an attentive observation of the phenomena, which were not noticed by other observers. This was, for example the case of the two, different in sign electrical charges – apparently banal socks of Symmer (but also many other experiments, run among others by B. Franklin) closed a long, more that a century, discussion on two or one "electrical fluid". Note that an experiment similar to that of Symmer can be easily repeated "on spot" in any classroom, using a silk scarf, a pupil's nylon pullover or so no.

The history of electricity is reach in many other, key experiments. Luigi Galvani, a physician, observed during a thunder storm a contraction of the muscles of freshly prepared frog's legs with their nerves[33], if hand on an iron wire. He repeated the experiment touching the nerves with a silver knife a draw conclusion on the animal nature of the electricity. Only few years later a funny experiment of the school inspector in Como, Alessandro Volta, with two coins on the edge of his own tongue and later systematic investigations with tin and silver coins, and with zinc and copper plates in glasses with acid etc. proved the physical nature of the electricity. Till today, the Volta's batteries, using electrochemical reactions are of basic importance for the whole modern technology, from laptopts to cell telephones.

The real merit of Volta for the future development of physics relies not just in those spectacular inventions, but for many decennia completely useless in a practical life. Volta, a first scientists in the history gave the quantitative character to the electricity, performing with a common weights the measurement of the force between two parallel, charged metal plates. From this measurements the unit of "volt" is derived.

Galvani and Volta give example first of a casual discovery but later of systematic observation. Other Italian, Antonio Romagnosi (1767-1825), like Volta a citizen of Austria, made an experiment of the type "let's see what happens if…?" An advocate as profession, he put a rather high pile of silver (and tin) coins, in a way that the electrochemical voltage generated was big, connected the ends of the pile with a wire and placed a magnetic needle near to it: he observed the deviation of the needle when the circuit was closed. He was the first to link the electricity with the magnetism.

The case of Romagnosi is interesting also from another point of view. He presented his discovery at the competition announced by Napoleon in 1802, but sent his relation by a normal (non registered) post. The work has arrived to Paris, but Ampere expressed an opinion that "only a fool would consider electricity and magnetism as mutually related phenomena" and the Romagnosi's work was rejected. Let us add, that in the same commission, together with Ampere there was another scientist, Oersted… Romagnosi tried to protest, but with no results. The lesson is still actual: discoveries must be documented and published promptly.

The activity of Faraday is an example of another type of experimental persistence: searching a phenonema, which is generally expected but reveals reluctant to get discovered. After the

[32] Prof. E. Illenberger, Freie Universitat Berlin, private information
[33] Zob. G. Karwasz, A. Karbowski, *Experiment of Volta*, Foton, Lato 2008

"discovery" by Oersted (1817), showing the presence of the magnetic field around a conductor with electrical current, everybody searched a "symmetric" effect: creating electric current by a magnetic field. Unfortunately (or maybe fortunately) there is not full analogy between the magnetic and electric fields, as it is clear from Maxwell laws, see page 20. In order to generate the electric current, the magnetic field must variable. And it took years, until Faraday made correct experiments, around 1830.

And next, an excellent experiment from 1887 by a young Heinrich Rudolph Hertz (1857-1894) was an example of a long search, clearly directed, but tedious. Those were, obviously electromagnetic waves, predicted theoretically by Maxwell already in 1873, and observed by Hertz as micro-spark between two electrodes of the receiver antenna[34].

Great experiments run in world laboratories of physics like CERN are usually carefully planned, require huge financial resources and unify efforts both theoreticians as well as experimentalists from many countries. This does not change the fact, that some of the biggest discoveries in modern physics still coma as a *surprise*. Such was for example with the detection of the microwave background radiation coming from the times of Big Bang – that was discovered as a persistent noise disturbing the communication with space satellites, (Wilkinson, Penzias 1963). Frequently the discoveries are performed by small groups, working pretty independently: this happened with the confirmation of the gravitation waves, discovered after more than ten years of observation of one neutron star[35], PSR B1913+16.

Experimental aspects of physics reveal not only at the stage of discoveries, but also in successive developments: it is not only difficult to predict the new phenomena, but also their applications. In times of Volta (around 1796) his pile was useless and the source of light for almost a century were still burning candles. Many years of studies of a special type of variable stars, so called cefeids, gave to Hubble a clear evidence that the Universe expands; many years of studies of supernova in remote galaxies showed that the speed of this expansion was not constant in a scale of billion years that passed from Big Bang: in the Universe huge forces are observed acting on cosmological distances. In absence of any clear idea on the nature of these forces, for a moment we call them "dark energy:.

Resuming, a direct experiment:
– simple, with two balls or more complex, with two colliding carts controlled by a computer,
- planned, according to a pupils chart or invented "on spot"
- in classroom or made independently by a pupil at home,
remains in physics an extremely important element both scientifically and didactically. Even the most simple objects, like a double cone apparently moving upwards[36] or a falling pencil[37] may requires complex theoretical reasoning[38] and stimulate scientists, teachers and students to further, creative research.

Finally, from own experimental experience one must admit that even posing to the Nature a very clear, Kant-like question: "Si or No", the answer is usually unclear "Ni". Maybe such answer is wiser: we leave next question to our students: the Nature remains a white book with pages still to be written.

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[34] Voltage created in the antenna receiver like in Hertz exoeriment are of the order of few hudreds of volts, so spark are not easy to be observed. A way to overcome this difficulty can be using a small neon lamp between the receiver antenna; such lamps are still used in some radio indicators, see A. Krzysztofowicz, G. Karwasz, *Herzts' experiment (for desser)*, Foton, Lato 2004..

[35] R. A. Hulse i J. H. Taylor, Jr., pulsar discovered in 1974 r;. Noble Prize in 1993 r.

[36] See Karwasz i in. *Fizyka i zabawki*, CD-ROM, Pomorska Akademia Pedagogiczna, Słupsk, 2004, (Physics and toys)

[37] See, for ex. R. Cross, *the fall and bounce of pencils and other elongated objects*, Am. J. Phys. 74 (2006) 26

[38] See, for ex. Clark, *J. Phys.D* 2010..

5.3. Physics and mathematics

After the remarks on the role of experiment in physics, it remains important to determine the co-existence of mathematics and physics. The difficulties of Aristotle with categorizing harmony and optics to mathematics or physics do not disappear either today. The first part of optics is called “geometrical optics”; the harmony of a violin is based on mathematical dependencies between integer numbers, that were discovered by Pythagoras, but the harmony of the piano is based on logarithms of 1/12 power.

One has to discuss first of all the very structure of mathematics, that for Kant was the most important example of the synthetic science *a priori*, i.e. the science creative but not using the experiment. The importance of mathematics, frequently called the queen of all science relies in the fact, that on the basis of pure (speculative) reasoning one arrives to new, unexpected conclusions. Moreover, conclusions can correspond surprisingly well to the real world. It happened in Maxwell’s laws or in equations of quantum mechanics, that allow not only to describe the motion of electrons but also to projects new chemical compounds or medicines.

Didactically, a logic and deductive structure, for example of geometry, is an example for constructing the ways for reasoning by a pupil. The ability to deduce step-by-step can not be substitutes by any of internet sources. A laconic structure of axioms and the necessity of using a precise grammar of the proper language or foreign languages in expressing mathematical categories is difficult to be found in other sciences, physics including.

It is subjects of many theoretical discussions if the applicability of mathematics to the description of the real world is a proof of its absolute truth or it simply reflects the structure of our mind. Quite original was the idea of W. Boltzmann in this question. He thought that this was the biological evolution that selected *Homo sapiens* with his mathematical knowledge as a species that was superior to other monkeys: the monkeys that were not able to estimate correctly, for example the distance of a thrown stone, lost in the process of evolution.

Not agreeing completely with this idea of the great physicists we would say that human (concave) scull reflects perfectly the external world, with its physical complexity and mathematical dependencies.

Apart from the deductive and synthetic nature of mathematics it is worth mentioning also the physical reality as a source of mathematics. Pythagoras theorem, with numerous proofs, one more beautiful than previous, has to be known to ancient Egyptians for determining with a high accuracy proportion of pyramids. They used to do it probably with the proportions 3:4:5 and on distance of several hundreds meters: the risk of the construction error was too high! Similarly, an Egyptian “scriba” had to know how to calculate the area of a trapezium field near to Nile, at least for determining taxes.

So, does mathematics posses an inductive and experimental structure? No! Mathematics usually advances other science. Complex numbers were “invented” as a pure curiosity, as a square root of “-1”. Today, the analysis of electrical circuits, the sinus of the sum, the motion of an electron would be *physically* impossible to calculate: these are complex numbers, through Moivre’s relations that make the complicated problems almost as simple as elementary arithmetic. .

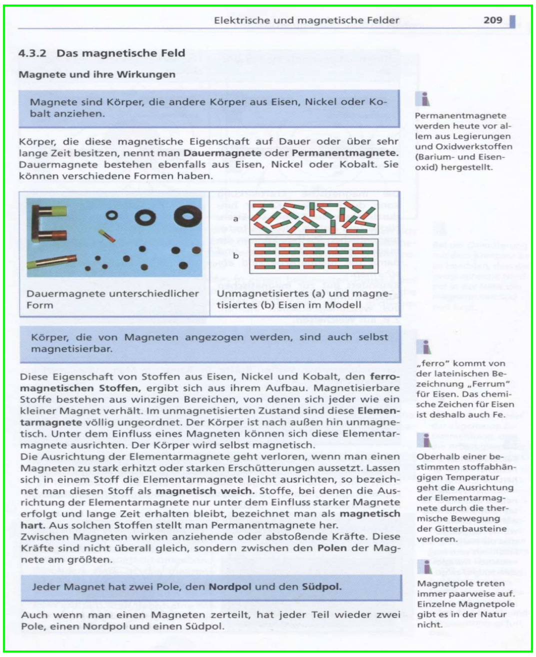
There are quite few examples in the history of physics that mathematics was “created” following the needs of physics: it was the case of the differential calculus, as it is difficult to imagine the velocity as a infinitely small ratio of the distance over time; it was also the case of the General relativity, in which the mathematical part was elaborated with the help of Einstein colleague, a mathematician, H. Grosmman.

Moreover, it seems that many of open problems of physics awaits new mathematics (or applying the existing one, but we ignore which one) in order to be solved. This is the case of the high-temperature superconductivity, at temperature of liquid nitrogen, in ceramics, which are at room temperature perfect isolators[39]. Not saying about the already mentioned dark energy that we not only lack the mathematics but even an idea where we should search this mathematics.

Physicist, specialized in didactics should be able to show the beauty and the simplicity of mathematics, the applicability of the mathematical description to different branches of physics, the explanatory and predictive role of mathematics for different physical phenomena. Then, the concept of a vector will not be an useless object for the pupil, with attributes to be learn by heart, but a versatile tool for the teacher. Similarly, for the teacher of mathematics, the vector will not be just a pair of points, with rules to add it coordinates, but an example of pulling a ship, adding velocities in a parabolic throw and so on.

5.4. Physics as a qualitative science

After previous remarks on a complementary role of the experiment and the mathematical description one should note the contradictive tendencies in teaching: 1) the domination of the mathematical formalism over experimental and practical aspects (like it is the case of some Italian textbooks); 2) teaching mainly practice – the example of a German textbook for vocational schools, on the picture below.



Elektrische und magnetische Felder 209

4.3.2 Das magnetische Feld

Magnete und ihre Wirkungen

Magnete sind Körper, die andere Körper aus Eisen, Nickel oder Kobalt anziehen.

Körper, die diese magnetische Eigenschaft auf Dauer oder über sehr lange Zeit besitzen, nennt man **Dauermagnete** oder **Permanentmagnete.** Dauermagnete bestehen ebenfalls aus Eisen, Nickel oder Kobalt. Sie können verschiedene Formen haben.

Dauermagnete unterschiedlicher Form

Unmagnetisiertes (a) und magnetisiertes (b) Eisen im Modell

Permanentmagnete werden heute vor allem aus Legierungen und Oxidwerkstoffen (Barium- und Eisenoxid) hergestellt.

Körper, die von Magneten angezogen werden, sind auch selbst magnetisierbar.

Diese Eigenschaft von Stoffen aus Eisen, Nickel und Kobalt, den **ferromagnetischen Stoffen,** ergibt sich aus ihrem Aufbau. Magnetisierbare Stoffe bestehen aus winzigen Bereichen, von denen sich jeder wie ein kleiner Magnet verhält. Im unmagnetisierten Zustand sind diese **Elementarmagnete** völlig ungeordnet. Der Körper ist nach außen hin unmagnetisch. Unter dem Einfluss eines Magneten können sich diese Elementarmagnete ausrichten. Der Körper wird selbst magnetisch.
Die Ausrichtung der Elementarmagnete geht verloren, wenn man einen Magneten zu stark erhitzt oder starken Erschütterungen aussetzt. Lassen sich in einem Stoff die Elementarmagnete leicht ausrichten, so bezeichnet man diesen Stoff als **magnetisch weich.** Stoffe, bei denen die Ausrichtung der Elementarmagnete nur unter dem Einfluss starker Magnete erfolgt und lange Zeit erhalten bleibt, bezeichnet man als **magnetisch hart.** Aus solchen Stoffen stellt man Permanentmagnete her.
Zwischen Magneten wirken anziehende oder abstoßende Kräfte. Diese Kräfte sind nicht überall gleich, sondern zwischen den **Polen** der Magnete am größten.

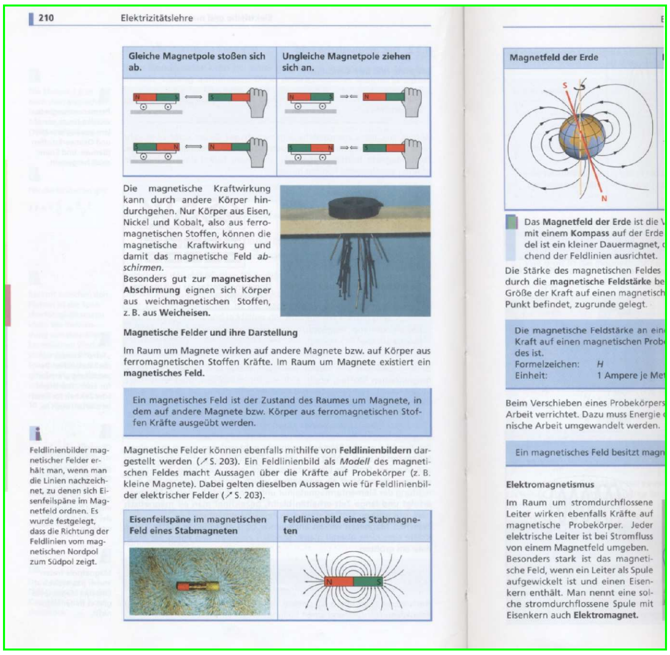
„ferro" kommt von der lateinischen Bezeichnung „Ferrum" für Eisen. Das chemische Zeichen für Eisen ist deshalb auch Fe.

Oberhalb einer bestimmten stoffabhängigen Temperatur geht die Ausrichtung der Elementarmagnete durch die thermische Bewegung der Gitterbausteine verloren.

Jeder Magnet hat zwei Pole, den **Nordpol** und den **Südpol.**

Auch wenn man einen Magneten zerteilt, hat jeder Teil wieder zwei Pole, einen Nordpol und einen Südpol.

Magnetpole treten immer paarweise auf. Einzelne Magnetpole gibt es in der Natur nicht.



210 Elektrizitätslehre

Gleiche Magnetpole stoßen sich ab.	Ungleiche Magnetpole ziehen sich an.

Die magnetische Kraftwirkung kann durch andere Körper hindurchgehen. Nur Körper aus Eisen, Nickel und Kobalt, also aus ferromagnetischen Stoffen, können die magnetische Kraftwirkung und damit das magnetische Feld *abschirmen.*
Besonders gut zur **magnetischen Abschirmung** eignen sich Körper aus weichmagnetischen Stoffen, z. B. aus **Weicheisen.**

Magnetische Felder und ihre Darstellung

Im Raum um Magnete wirken auf andere Magnete bzw. auf Körper aus ferromagnetischen Stoffen Kräfte. Im Raum um Magnete existiert ein **magnetisches Feld.**

Ein magnetisches Feld ist der Zustand des Raumes um Magnete, in dem auf andere Magnete bzw. Körper aus ferromagnetischen Stoffen Kräfte ausgeübt werden.

Magnetische Felder können ebenfalls mithilfe von **Feldlinienbildern** dargestellt werden (↗ S. 203). Ein Feldlinienbild als *Modell* des magnetischen Feldes macht Aussagen über die Kräfte auf Probekörper (z. B. kleine Magnete). Dabei gelten dieselben Aussagen wie für Feldlinienbilder elektrischer Felder (↗ S. 203).

Feldlinienbilder magnetischer Felder erhält man, wenn man die Linien nachzeichnet, zu denen sich Eisenfeilspäne im Magnetfeld ordnen. Es wurde festgelegt, dass die Richtung der Feldlinien vom magnetischen Nordpol zum Südpol zeigt.

Eisenfeilspäne im magnetischen Feld eines Stabmagneten	Feldlinienbild eines Stabmagneten

Magnetfeld der Erde

Das **Magnetfeld der Erde** ist die V
mit einem **Kompass** auf der Erde
del ist ein kleiner Dauermagnet, d
chend der Feldlinien ausrichtet.

Die Stärke des magnetischen Feldes
durch die **magnetische Feldstärke** be
Größe der Kraft auf einen magnetisch
Punkt befindet, zugrunde gelegt.

Die magnetische Feldstärke an ein
Kraft auf einen magnetischen Prob
des ist.
Formelzeichen: *H*
Einheit: 1 Ampere je Met

Beim Verschieben eines Probekörpers
Arbeit verrichtet. Dazu muss Energie
nische Arbeit umgewandelt werden.

Ein magnetisches Feld besitzt magn

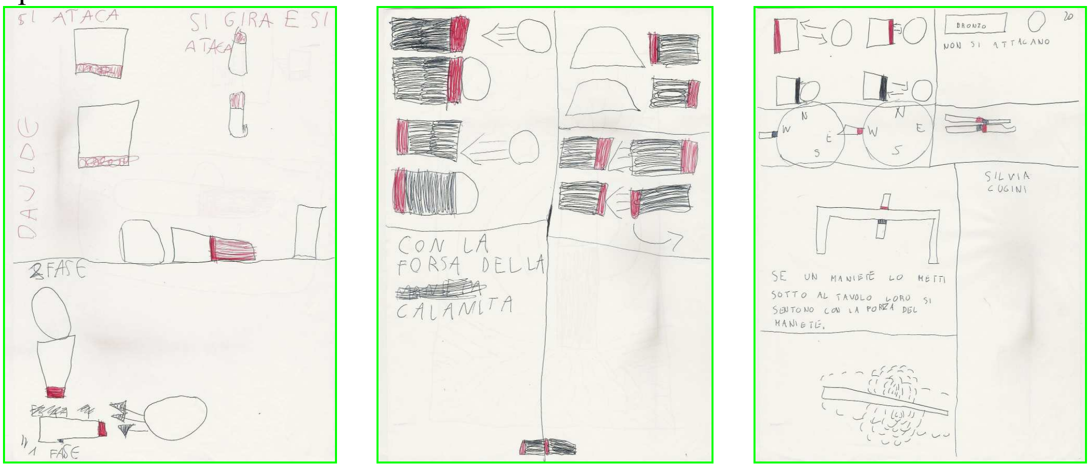
Elektromagnetismus

Im Raum um stromdurchflossene Leiter wirken ebenfalls Kräfte auf magnetische Probekörper. Jeder elektrische Leiter ist bei Stromfluss von einem Magnetfeld umgeben. Besonders stark ist das magnetische Feld, wenn ein Leiter als Spule aufgewickelt ist und einen Eisenkern enthält. Man nennt eine solche stromdurchflossene Spule mit Eisenkern auch **Elektromagnet.**

The German textbooks draw attention for three reasons: 1) physical phenomena are introduced in a concrete relation to practical applications, for example the ferromagnets on the first picture are present in many electronic circuits; 2) notions and terms are introduced gradually – first shown schemes of magnets do not have poles "N" and "S" signed but only two parts in different colours; 3) avoiding a mathematical descriptions of phenonena. Correctness of such an approach is also confirmed on the studies on children's perception

[39] Zob. np. G. Karwasz, *Modern experimental Physics: why we need new Mathematics?* Acta Univ. Lodensis, 2009.

presented below: children understand magnetic interactions even if they do not recognize magnetic poles; the idea of the magnetic field becomes present only at higher stages of comprehension [40].



Forming of ideas of the magnetism among children at 8-10 age: 1) the interactions with ferromagnetic substances, but without signing directions, 2) schemes of attracting and repulsing, 3) appearing of the idea of the magnetic field lines. Source: R. Viola, PhD Thesis, Universita' di Udine, 2009.

The title "Physics as a qualitative science" does not put into discussion previous statements on physics as a natural science, based on mathematics, this title has an important *didactical* meaning. Some trends to "mathemize" physics repel many pupils. Physics, unwillingly, become another playground to exercise mathematical skills. But this negates the very principle of physics: it should explain the real world and mathematics is only *auxiliary* in this task. The real world can be explained also verbally or in an illustrative manner not, only mathematically.

The role of the teacher is to present physics in a way to induce the student to independent observing the real world and discovering in it a whole *richness of physical phenomena.* For example, the Newton's law of (thin) lenses ha a beautiful mathematical form, but the interpretation of positive or negative values for the curvature of the lens, for the position of the object and image and of the amplifications present some difficulties even to university lecturers (and to make things worse, different textbooks adopt different conventions)

$$1/f = 1/p + 1/q$$

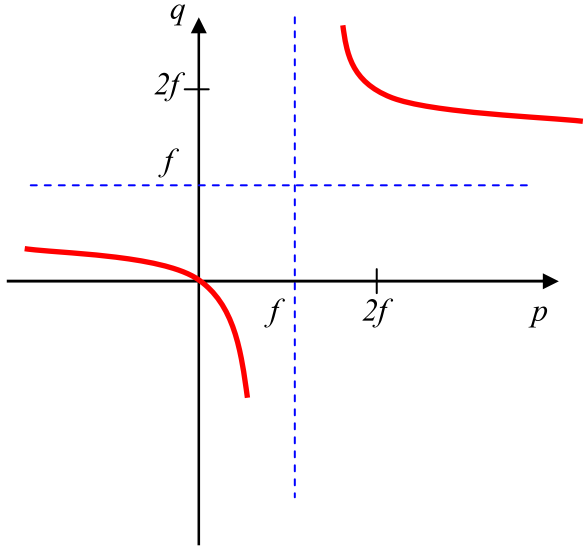
The mathematical beauty of this simple relation is striking. Unfortunately, this equation is governed by a series of assumptions for its validity and the differences between real behaviour of lenses and the theory are called "aberrations". There is quite a lot of these aberrations.
Three are (proved in university practice) methods of bettering the didactical efficiency of teaching the equation of lenses (and mirrors):

1. Geometrical treatment of optics: we draw lines ("radii") through the focal points and the middle of the lens – the construction is done on the paper with square grid in order to improve the precision of the drawing
2. Deepening the formalism, in order to show an analogy with the mathematical knowledge possessed by the student, if we write the equation in a following way:

[40] We use the expression „lines of the magnetic field" without introducing the term of magnetic induction, whcih would be more appropirate but is unclear for pupils.

$$q = \frac{fp}{p-f} = f + \frac{f^2}{p-f}$$

it resembles the equation of hyperbola $y = f^2/x$ but with asymptotes shifted right by f and up by f. The picture of such a hyperbola would be as following



Let's notice in particular that the function passes through the point (2*f*, 2*f*) and then the ratio $q/p = 1$ (the picture is equal to the object). The picture does not appear if $p = f$ (the object is placed in the focus – on the drawing these are points on the vertical asymptote). For $0 < p < f$ the value q is negatice, but the absolute values $|q/p| > 1$ (the picture is enlarged, like in a lens posed near to the observed postal stamp). A strange physically situation appears if we assume $p < 0$; this is like the object would be placed on the other side of the mirror. In other words, the mirror from concave become convex (and the lens from convex into concave).

3) The presented mathematical formalization required, in any case, referring to a physical reality ("the lens is near the postal stamp"). It is worth noting that a tee spoon, a glass, the frint surface of glasses, the bottom of a bottle, a round piece of plastic also "make things greater or smaller". There does not make sense to use terms "the image is enlarged" as the pupil in every case makes reasoning in categories "lens makes objects smaller".

A qualitative introducing into the problem of lenses teaches the youth (and adults) to search autonomously images enlarged/ reduced/ inverted/ deformed in a real world. This will stimulate that research curiosity, which in turn will trigger more systematic study which kind of lens and in which conditions gives the image enlarged or reduced.

Moreover, the traditional equation of thin lenses forgets a number of the whole variety of phenomena related to geometrical optics:

1) lenses non-thin, described by a different equation[41]
2) lenses and mirrors non-spherical, for examples cylindrical that were studied already by Witelo
3) lenses immersed in other backgrounds than air, for example in water – what is important while discussing the anatomy of human eye[42].

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[41] See G. Karwasz, M. Brozis, *Soczewki grubasy*, (Thick lenses) Foton, Jesień 2006.
[42] See G. Karwasz, T. Wróblewski, *Okulary dla płetwonurka* (Glasses for divers), Foton, Zima 2007

In the presented example, of thin lenses, the motto „physics as a qualitative science means the exchange of the didactical priority:

- starting not from the equation of the lens, through rather axiomatic assumptions *p*>, *q*>0 to rather mnemonic remembering how a lens works
- but from the concept that the glasses of a short-sighter (and convex street mirror) "make things smaller" and the convex lens ale (and concave mirror in the bathroom) sometimes make things smaller sometimes larger
- by autonomous trials of keeping a convex lens close and far from the object
- by systemizing the observation in writing
- the conclusions discussed by the whole class
- the resuming done by the teacher in the forma of a table p vs. q
- through the drawing $q = q\ (p)$ of a hyperbola shifted by $+f$ (and only for pupils with higher mathematical abilities), till eventually to the interpretation of this drawing.

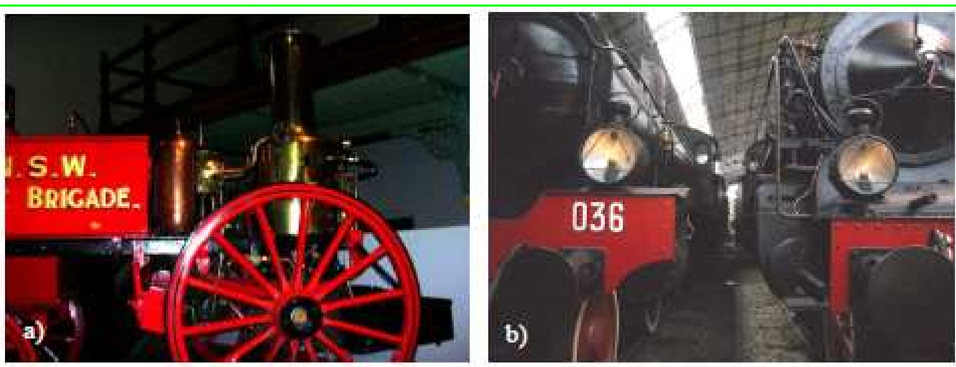
The change in the didactical sequence, and the change of the "gravity center" fo the lesson from an equation to a *practical* capacity of observing optical phenomena in the external world is the implementation of physics, as qualitative science. The teacher has to transmit only the ***concept*** of mirrors and lenses, but in a *permanent* way. The pupils should remember that there exists an (ideal) equation describing lenses and that the real lenses do not follow exactly this equation, not because of imperfections in their manufacturing but due to the very model adopted, simplifying the reality.

The same conclusions, on the simplifying character of physical models, will be useful for the pupils while trying to understand the laws of the free fall, of the uniform motion, of the gravity near Earth surface and so on. Knowledge and skill evolve into competences, in particular of the social and technological character.

5.5. Scientific and technological revolution of XIX i XXth centruries

The question of the scientific revolution and the technical progress constitutes a significant part of the Programme Basis of Polish Ministry of Education in the subject of Science in secondary schools. In teaching different disciplines – history, geography, economics, different aspects of the industrial revolution are stressed. Understanding the chronology of inventions and the mechanism of the scientific progress allow to systemize better single elements of knowledge.

The revolutions happened thanks to physics: the electricity and thermodynamic engines. The history of discoveries in electromagnetism we have already outlined briefly – the scientific curiosity preceded the technical applications. But sometimes technical inventions preceded the understanding of the very phenomena. I happened like this for ex. with the steam machine, which was first introduced in the industry and only later deserved a theoretical analysis. Similarly happened with the gasoline engine (Otto's cycle) and with high-pressure petrol engine (Diesel thermodynamic cycle). Automobile engines remain fascinating inventions and the interest of pupils in motorization can be used in teaching.

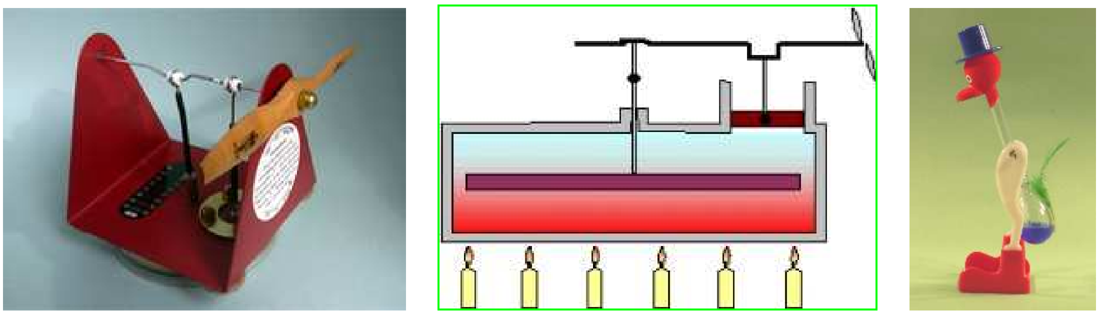


Fot. 2.1. Wykorzystanie maszyny parowej: a) samochód strażacki na parę z 1879 roku, „powerhouse" Museum w Sydney; b) lokomotywy parowe z początku XX wieku, Muzeum Nauki i Techniki w Mediolanie (Foto MK)

Source: G.Karwasz, M. Więcek, Modern Physics, op. cit.

But this didactical possibility (everyday technics → physics) is not always used sufficiently. In thermodynamic the cycle of Carnot is discussed, but it is not said clearly that this was a pure theoretical concept, elaborated by a young scientist at the beginning of XIXth century, much before practical realization of gasoline engines. However, Carnot's cycle is extremely important for understanding thermodynamics and some questions could be underlined:
1) both a heat source as a heat sink iare needed
2) Carnot's engine achieves the highest theoretically possible efficiency at given heat source and sink temperatures
3) temperature appearing in Carnot's formula are *absolute*: it is not easy to lower the temperature of the sink; more practical is to rise the temperature of the source: modern turbines in the electric power station work with as high as 1400-1500º C heat source temperatures, reaching therefore efficiencies above 40%
4) Carnot's cycle, differently from steam and gasoline engines is a closed cycle,
5) from the above it results that the change of entropy in the cycle is zero.

How can we show thermodynamic cycles in school laboratories? It is possible to use simple didactical objects, like in pictures below. One can also use their virtual presentations and explanations[43].



Two examples of a thermodynamic engines: Stirling's engine working in an open cycle (the photo and the scheme) and "drinking bird" working in closed cycle. Both engines s wet had in the process of can work with very small differences of temperature between the heat source and sink: Stirling's engine by placing it on the glass with hot water and the bird simply by spontaneous cooling of its wet head. A small efficiency of both engines results from the small difference of temperatures.

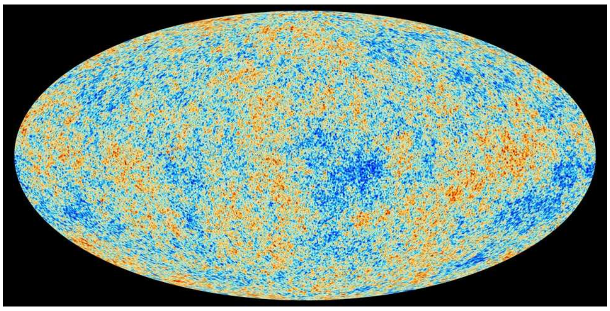
Relating the notions in physics with inventions and practical applications facilitate the didactical process and essentially improve the durability of the knowledge and its networking. The technical revolution and its products changed significantly the ways of teaching: we need know to explain the accelerated motion like Galileo did, i.e. with gun length but we can explore pupils interest in Formula 1 races, as we discussed it in our "Torun's tex-book in physics".

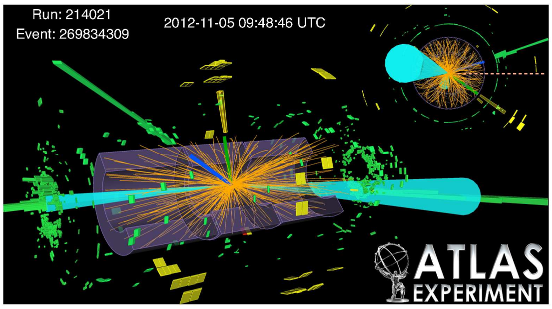
5.6. Research methodologies of modern physics

Modern research methodologies of natural sciences reached a high level of inter-disciplinarity, that even scientists make it difficult to follow. In physics of elementary particles modern experiment on great accelerators would not be possible without elements of artificial intelligence in distributed networks of computers. Similarly, the search of extraterrestrial beings use a world network of private computers – for a moment in vain. The same internet was created as a network for communicating data between great laboratories of elementary particles.

[43] G. Karwasz i in, *Fizyka i zabawki*, op. cit.

Strategic investigations of modern physics are run by multinational groups, within European or even world-wide laboratories, like CERN, European Space Agency, International Agency of Atomic Energy and so on. These studies have to answer some very basic questions n the nature of the matter and Universe. We note, among others:
- reaching the very remote past of Universe through studies of the microwave background radiation (Planck's mission);
- hunt for the particle "responsible" for the mass of quarks (Higgs' boson)
- studies of antimatter (if it interacts differently with gravity, for example).
Budgets of these researches amount tens billion of euro.



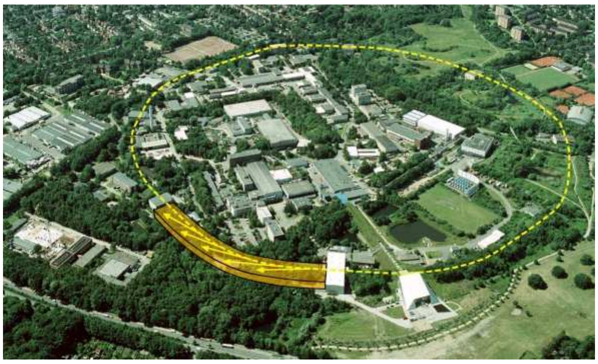


1. The map shows how the Universe looked alike at the age of 380 thousand years. At that stage it was fulfilled by the mixture of hot protons, electrons and photons. In the background radiation small fluctuations of the temperature are observed, which correspond to small differences of the density at that age of Universe. Thanks to those differences galaxies were formed and the whole present structure of the Universe. From Planck's mission we know that;
- only three types of neutrinos exist
- there is less dark matter that it was thought – only 68% but there is more dark energy
- the age of Universe is 13,82 billion years, i.e. 100 mln years more that it was estimated before
- in the first 10^{-32}s the Universe inflated to the size of a grapefruit and subsequently is grew more slowly [„Nature", elaborated by dr K. Rochowicz}

2. As far a the previous photo shows an entire Universe, the picture from CERN reproduces a scheme of the collisions between two protons, i.e. particles of 10^{-15} m size, lasting microseconds. The picture shows a decay of two ultra-heavy particles, analogues of electrons, called "tau". The analysis of traces of decaying particles indicates that in this collision Higgs' boson was created, i.e. "divine particle" following the expression of the Noble prize winner, Prof. L. Lederman. The studies of elementary particles require an ultra-high vacuum, ultra-strong superconductive magnets, extremely sensitive semiconductor detectors and huge-power computers. Accelerators in CERN consume electric power equivalent to that used by Toruń.

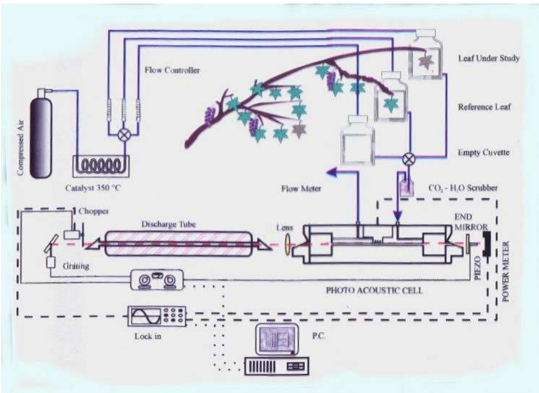
Research in great scientific centers serves not only our human curiosity. A specific type of accelerators for electrons, so-called synchrotrons, are source of electromagnetic radiation of high energy-quanta, corresponding to X-rays. At the same time this radiation is monochromatic and collimated, likes laser's beam. Thanks to these features the synchrotron radiation can be used to study not only crystals, like standard X-rays, but also nanostructures of delicate proteins and DNA. Even shorter (10^{-15} s) impulses of X-rays can be obtained from a laser in which instead of photons, free electrons travel in a vacuum tube. In this way it is possible to study, for a example, proteins not only in their crystallographic structures but also in water solutions[44].

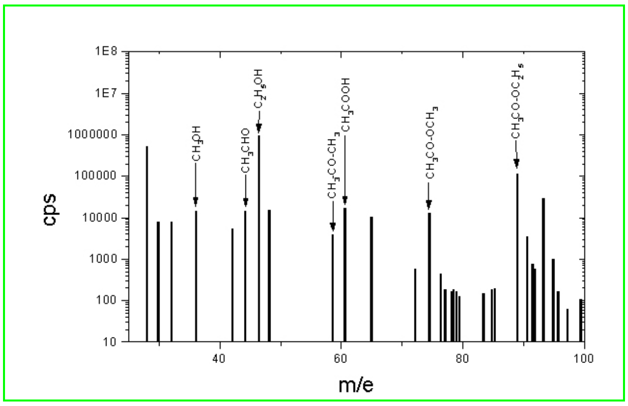
[44] Zob. H. Dodziuk, *Rentgenografia bez kryształów: rozprosz i zniszcz*, strona internetowa Zakładu Dydaktyki Fizyki UMK, http://dydaktyka.fizyka.umk.pl/Wystawy_archiwum/z_omegi/co%20piszczy%20w%20nauce.html (X-rays without crystals: diffract and destroy)

Synchrotron, a source of collimated X-ray radiation (DESA, Hamburg) and the structure of a protein reproduced from the diffraction pattern done on a crystallized protein. The very double helix of DNA discovered in 50'ies of last century was deduced from similar X-ray diffraction patterns.

Apart from discoveries in great scientific centers, a huge amount of research is done within "small-size" physics. Using so-called mass spectroscopy it is possible, for example, the analysis of exhaust gases from human lungs; it allows a prompt diagnosis of diabetics, for example. With the same type of spectroscopy in the gas phase, it is possible to control if strawberries are fresh of if coffee has been correctly roasted. A similar type of spectroscopy, so-called photo-acoustic allows to measure the stress of a plant after its leaves have been detached. From this research we know that plants (or fruits) communicate among them secreting a gaseous hormone, ethylene.





1. Two examples of biological applications of physics. The photo-acoustic spectroscopy allows to trace the secretion of a gaseous hormone of plants, ethylene. This hormone causes, for example the maturing of fruits; it is released by orchids during flowering, and stopped after emasculation. The grapes emit this hormone if a leave is damaged. [Source: dr A. Boschetti].

2. The proton-transfer spectroscopy allow a "soft" ionization, i.e. a process in which the electrical charge is delivered to the molecules (allowing its subsequent detection in mass spectrometers) – the molecule attaches a proton, H^+. This spectroscopy is particularly useful in analysis of flavours, like the roasted coffee, strawberries. Studies done a group of Swiss biologists (from University in Neuchâtel) showed that a leave bitted by a worm emits an smell that attracts a species of wasp that, in turn, deposit their eggs inside those worms[45]

Many different techniques are used in material science and engineering. Thesy sevr, for example, to identification of nano-defects in metals, much earlier than these defects cause a structural failure of the construction. The diagnosis can be performed with a beam of antimatter particles, called positrons[46]. It is not needed to say, how such studies are important, say, in aeronautics or in semiconductors used in space missions.

[45] http://www.ionicon.com/applicationshowcases/biological-research, retrieved 20/09/2014
[46] Zob. np. G. Karwasz, *Application of positron annihilation techniques for semiconductor,* J. Compounds, 2005

5.7. Physics as an interdisciplinary science

The discussion on the scientific and technological revolution and on modern research methodologies applied to chemistry, biology, medicine, agriculture indicate clearly an interdisciplinary character of physics. These links come both from historical placement of physics as a science on Nature and from modern diagnostic techniques.

Links of physics with other natural sciences are mutual – both physics uses advances of other sciences as other disciplines use discoveries and inventions in physics. The technology of producing vacuum, generating high voltages and in consequences electrical discharges in rarefied gases allowed in the second half of XIXthe century to discover, via optical spectrum analysis, unexpected gases in the atmosphere, argon, krypton, xenon, and in the photosphere of Sun – helium. On the other hand, a meticulous chemical analysis, drop-by-drop, done by a young PhD student Maria Skłodowska, allowed to separate in uranium ore new elements, polonium and radium. In this way, thanks to chemistry, nuclear physics was born.

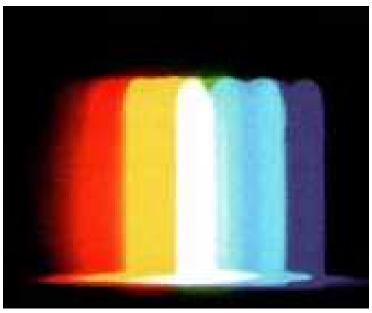
It is difficult to separate physics and chemistry even in such simple questions lie appearance of colours. How does the pH indicator work? What kind of plant is used for such indicators? Questions of chemistry are interlinked with physics and knowledge of lichens. The reasoning has to be done step-by-step, separating questions and rising the complexity:

1. The colour of a substance depends on many factors. Let us divide, for sake of simplicity, these factors into physical and chemical ones. Physical ways to get colours is for example the rainbow, the brilliant with colours CD, feathers of pigeons or a wing of blue Brazilian butterfly, *Morpho*. Apart from the rainbow, all other colours appear due to *diffraction* on micrometric gratings. Bluish "reflections" on a ruby-red flower bowl from Berlin is due vibrations of electrons on nano-grains of gold (plasmons).



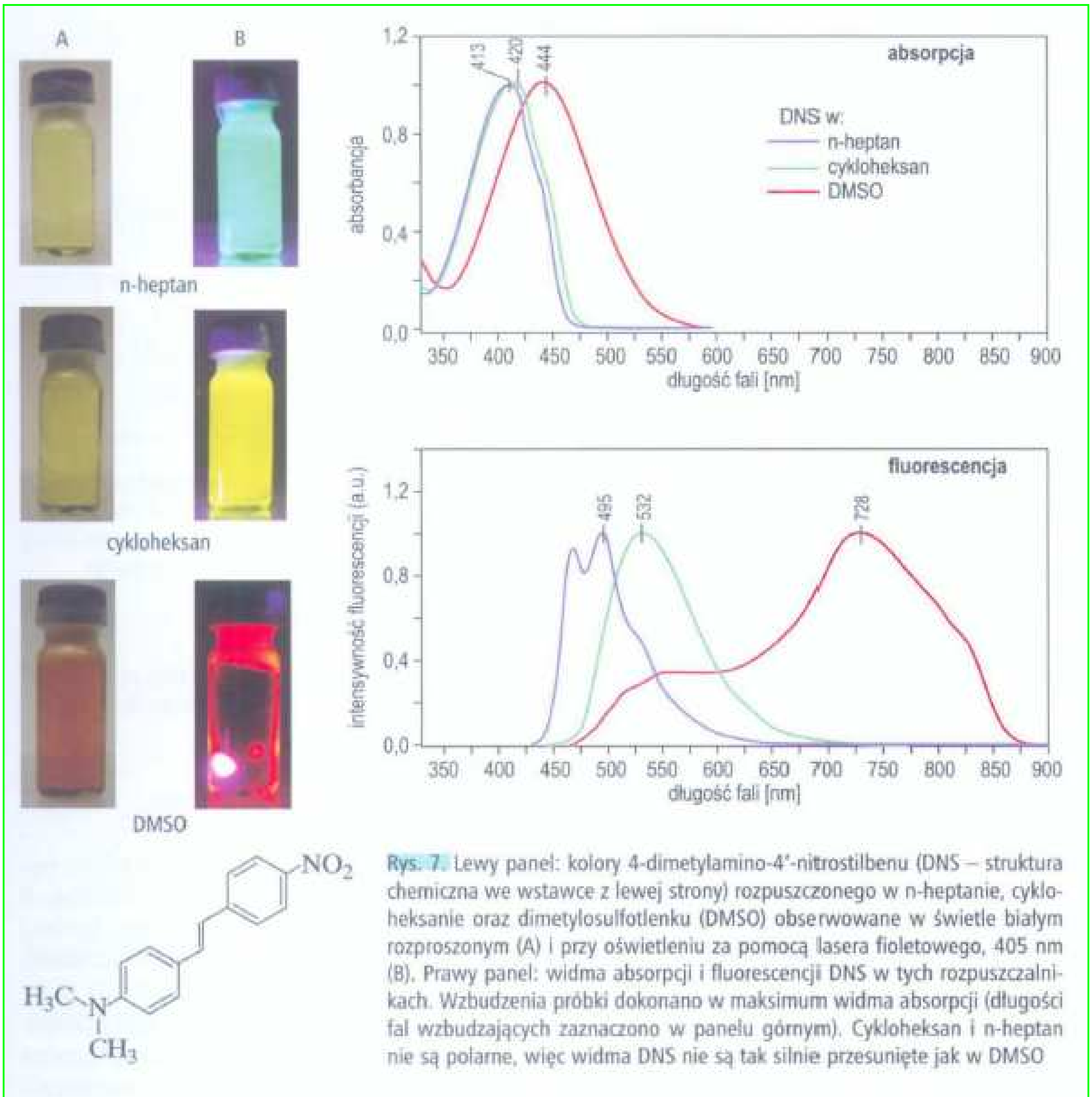
Physical ways of getting colours: 1) diffusion of white Sun light in atmosphere – complementary colours are seen on clouds and in the ceiling at the sunset (photo Carmen Busco, Sao Paolo) 2) 3D diffractions grating on wings of mate *Morpho melenaus* butterfly; 3) emission of blue light by plasmons – correlated electrons inside nano-grains of gold dispersed in glass (objects and photo GK)

2. Colours of fireworks or "neon" lamps result from electronic transitions in single atoms (in the gas phase). If the same atoms are placed in a crystalline structure, the colour of emission is different. This is the case, for example, of iron ions, which in ore are reddish but give violet transparency in amethyst, Fe-doped quartz.


3. „Chemical" ways of forming colours are the result of vibrations of electrons (i.e. of electronic transitions) in pretty complex molecules. Impinging light is absorbed in a determined range of wavelengths; for example the molecule of chlorophyll absorbs in the reange of red and violet, to perform the reactions of photosynthesis. Non-absorbed (i.e. reflected) light gives an impression of green colour.

4. The chemistry of colour is, generally, a complex process. Molecules not only absorb light at determined wavelength but also emit it (not necessarily at the same wavelengths). The leaves, if illuminated by intense violet light, emit in red – this is a kind of "security valve" defending the plants against the excessive absorption of photon's energy and therefore against burning. In solutions the emission and absorption spectra depend additionally on the type of solvent. In case of dyes from lichens (and the cabbage juice) these spectra depend also on the pH of the solution (i.e. on the concentration of H^+ ions). In presence of H^+ ions some of the chemical bounds in the molecule change their conformation, the equilibrium between two alternative forms changes and as a results also the spectra, i.e. the visible colour[47].



Rys. 7. Lewy panel: kolory 4-dimetylamino-4'-nitrostilbenu (DNS – struktura chemiczna we wstawce z lewej strony) rozpuszczonego w n-heptanie, cykloheksanie oraz dimetylosulfotlenku (DMSO) obserwowane w świetle białym rozproszonym (A) i przy oświetleniu za pomocą lasera fioletowego, 405 nm (B). Prawy panel: widma absorpcji i fluorescencji DNS w tych rozpuszczalnikach. Wzbudzenia próbki dokonano w maksimum widma absorpcji (długości fal wzbudzających zaznaczono w panelu górnym). Cykloheksan i n-heptan nie są polarne, więc widma DNS nie są tak silnie przesunięte jak w DMSO

[47] See M. Gagoś. G. Karwasz, *Barwa a struktura związku chemicznego*, (Colour and the chemical structure) Chemia w Szkole, 3/2012, str. 12.

The interdisciplinary character of physics, shown in above examples on a high, semi-scientific level, is visible also in the following Belgian text-book for lyceum. The “knowledge networking” of physics, as clearly seen below, is very wide and comprise: geology (natural magnet), history (the Chinese compass), physical phenomena and technological issues.

1 LES AIMANTS

1.1. Des roches magnétiques

Depuis les temps les plus reculés, les hommes ont remarqué que certaines pierres « magnétiques » ont la propriété de s'attirer entre elles en certaines zones, leurs **pôles**.

Ces corps, appelés **aimants**, sont constitués par de l'oxyde magnétique de fer Fe_3O_4 (fig. 1).

Fig. 1. Fragment de pierre magnétique.

1.2. Un instrument utile : la boussole

Les pierres « magnétiques » possèdent une autre propriété : libres de s'orienter, elles prennent toujours la même direction. Selon certains auteurs, deux siècles avant notre ère, les Chinois ont utilisé ce phénomène pour construire les premières boussoles (fig. 2).

Les boussoles actuelles (une aiguille aimantée mobile sur un pivot vertical au-dessus de la rose des vents) proviennent d'un lent perfectionnement de ces premières boussoles.

Fig. 2. Une boussole ancienne (Chine).

1.3. Les aimants artificiels

De nos jours, les aimants artificiels sont en acier ou en alliages et ils ont des formes variées (fig. 3) : barreau droit, aimant en U, aiguille aimantée...

Fig. 3. Quelques aimants artificiels bipolaires.

1.4. Pôle nord, pôle sud

- Les pôles d'un aimant ne sont pas identiques ; on distingue le **pôle nord** du **pôle sud**. Deux pôles de même nom se repoussent, alors que deux pôles de noms différents s'attirent.
- **Il est impossible d'isoler le pôle nord du pôle sud d'un aimant.** En effet, chaque fragment obtenu après avoir brisé un aimant en deux se comporte comme un nouvel aimant possédant un pôle nord et un pôle sud (fig. 4).

a. b.

Fig. 4. Expérience de l'aimant brisé : chaque fragment se comporte comme un nouvel aimant.

184 Partie 3 - Électrodynamique

The French (also Belgian) textbook for lyceum, differently from Italian or German ones, does not start from technical issues or mathematical formalism – on the first photo a magnetic rock (magnetite) is shown, then a Chinese compass from about Xth century (in Europe the compass was introduced much later, shortly before Columbus, and it was probably stolen from Turkish ship by a sailor from Italian town Amalfi); then a classroom experiment with iron fillings, this experiment introduces the two poles; the final photo shows that magnets always appear as di-poles, differently from electrical charges

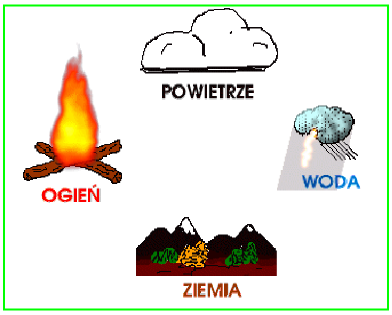
Referring to interdisciplinary questions, and particular to human science is particularly important after the recent programme reform in Poland: the majority of pupils in lyceum will study only the outline of physics. Relating the physical notions to geography, biology (pigeons use a magnetic senses in their navigations), human sciences can trigger and extra-scholar interest in physics and, therefore, rise the overall society competences in science and technology, and on the other hand improve the social image of physics.

5.8. Physics and human sciences

The question of unity or diversity of sciences is one of the fundamental problems not only for philosophers but also for organization of educational systems, for science polices and also for didactics. Can be different disciplines – natural sciences like mathematics, astronomy, physics, etc. treated on the same basis as the history, philosophy, pedagogy, ethics, aesthetics? Let us consider first this question first in its historical aspects and then in epistemological ones.

As the beginning of open (i.e. not secret[48])) access to the knowledge one has recognize the appearing in ancient Greece (on the Greek continent, and even more in colonies along the coast of the Mediterranean Sea) "lovers of wisdom", i.e. philosophers. Questions on: i) the nature of numbers and mathematical operations, ii) nature and structure of matter, iii) laws of astronomy, are linked to names like i) Pitagoras from Samos (ca. 572-497 BC, Zenon z Elei (ca. 490-430 BC), ii) Anaksagoras (ca. 500-428 BC), Demokryt (ca. 430-370 BC), iii) Ptolemeus. All those thinkers dealt not only with mathematics, harmony, physics, but generally with *philosophy* – the science on the causes and nature of existence.

„Anaksagoras have significantly changed the idea of Empedokles indicating the existence of many elements, that he called *homoimeris*. But those were not able to create things from their own power as they were in chaotic mixture (sfairos). The catalysis if generating things was a motion, and this motion was caused by a mind being outside world. So it is the mind or the spirit is the principle and homoimeries are only the components."[49]



Four elements of ancient Greeks – the picture comes from internet pages of CERN, describing so-called Standard Model of elementary particles, with three generations of quarks and leptons. Contemporary vision on the structure of matter is not simpler, as we already discussed it and as it is illustrated by another picture from the book of prof. A. Góral *Meandry fizyki*.

Taking into account that poems of "Iliad" and "Odyssey" formed (in oral form) probably sometime in XIth century BC, till the times of Aristotle it passed half a thousand years, a period enough long to fruit a whole richness of scientific ideas. All these centuries of the Greek philosophy tradition were resumed by already mentioned Aristotle – so that is him who defined what we call specific scientific disciplines today.

Aristotle remain, in the whole human history, a unique phenomenon. With his works he covered arguments which go beyond what we call "knowledge" today.. He discussed the range of objects that can be understood with senses but also what goes outside senses, and remains in the sphere of hypothesis. Works of Aristotle include zoology, astronomy, physics but also disciplines outside *science*, like ethics, aesthetics and metaphysics. The latter disciplines remain the domain what we call nowadays *philosophy*.

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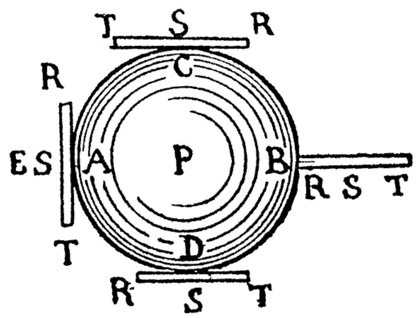
[48] Such a secret knowledge in Rome, till times of Julius Cesar was the calendar, for examples. By the way, Greeks never used calendar, what is the origing of Latin saying „ad calendam graecam", i.e. never. .
[49] http://pl.wikipedia.org/wiki/Anaksagoras

Aristotle, in his giant heredity, obviously used and systematized works of previous philosophers. However, his put the basis for the whole constructions of modern knowledge – from science to humanities. Can we speak about a *duality* of human knowledge if both disciplines were created by the same person?

In further human history there are not many such phenomena like Aristotle. Great doctors of Church (St. Bonaventura, St. Thomas) undertook philosophical question but not much in natural sciences. Already nominated Jean Buridian discussed question of *impetus*, i.e. of physics, but is not nominated in textbooks of philosophy. The next thinker, after Aristotle was just Copernicus who does not avoid philosophical question in his *De Revolutionibus*. Galileo's dialogue on "Two biggest systems" is again, more philosophical than mathematical, even if he discussed the astronomy. Instead, pure philosophy, not based on experiments neither calculations was the theme of writings by Giordano Bruno, who was a Monk from St. Dominique order.

Again, a come back to the "common denominator" between philosophy and physics (also mathematics) happened in persons of Descartes, Leibnitz and Newton. Te first of them discussed both the general methodology of reasoning as well optics and interaction of magnets, as we see it on his original drawings.

Rys. 45



Rys. 43

Descartes as an experimental physicists: configurations of magnetic poles from his work date 1644. Today, we even do not teach what Descartes already understood: that magnets can show moder than two poles.

Leibniz, together with Newton has introduced to mathematics the concept of differential calculus. His contribute to philosophy is the concept of atomic words, but formulated much more carefully than G. Bruno did: without drawing ethic conclusions. Newton at the same time of working on Principia Matematicae discussed questions of Holy Trinity. His writings were not fully agreeing with the official English Church dogmata.

The XVIIIth and XIXth centuries, of the materialism and positivism brought a separationa between humanities and philosophy on one side and "exact" sciences. Some philosphers from biological and physical laws used to draw conclusions on the whole organization of the material world, including human beings ("Man-machine, LeMetrie 1748 or much later ideas of completely mechanical world by E. Mach) but generally science and humanities remained separated.

Immanuel Kant had a great intuition on the beginning of the Solar System from a great nebulosa, but generally he did not enter scientific subjects. His followers, Hegel and later Engles and Marx tried to apply the scientific methodology to social and historic processes, with the well-known disastrous results. The divarication between the fast technological progress and various forms of philosophical utopia reached an apogeum at the second part of the XIXth century. The contemporary diffidence between science and humanities is, to a great extent, the heredity of this contrast.

Hans Gadamer[50] writes, that the paradigm of human sciences is different than that of natural ones. Human sciences are based on authorities and exact one - on the experiment. One can not agree in full with such a statement and division. Also in natural sciences we recall previous results, recalling in this way authorities. On the other hand, also in human, pedagogical, social, economic sciences we compare theories with their implementations and results induced by these implementation in given social and historical conditions. Human sciences get in this way an experimental verification, where the trial sample are the whole societies.

Scientific articles, say, in physics, always compare present data with earlier, not just as non-human numbers but with interpretations given by well recognizable persons – this exactly a piece of human-sciences methodology. Typical statements are like: "In N_2, Ramanan and Freeman in their measurement of electron swarms at low temperatures did not exclude existence of Ramsauer-Townsend minimum"[51], etc. The role of mentors and well-established personalities is not lower than in human sciences.

Great scientists, including Newton and Einstein discussed not only physics. Izaak Newton tried to explain prophecies and discussed theological principles. In his late papers he wrote that all nations initially had one religion, whose basic precepts were "to have one God, & and not to alienate his worship, nor prophane his name, to abstain from murder, theft, fornification, & all injuries; not to feed on the flesh or drink the blood of a living animal but to be mercifull even to bruit beasts; & to set up Courst of justices in all cities & societies for putting these laws in execution"[52].

Albert Einstein discussing ethic and philosophical themes writes in his book *How I see the world*: "The value of a person, for the society in which he lives depends first of all from the level, in which his actions, thoughts, emotions contribute to existence of other persons".[53] And later: „non without a clear reason in a contemporary epoch, oriented essentially towards materialism, scientists are the only persons deeply believing"[54].

On the other hand, modern philosophers discuss problems of natural sciences. Karl Popper (1902-1994), being a representing flag of positivism, wrote: "Physics and chemistry are similar, and it seems, there is no a great difference in the type of things, of which they talk, apart form the fact that chemistry understood in typical way does not have application at extremely high temperatures, and probably also very low. Therefore, it would be not surprising, if long-lived hopes to reduce chemistry to physics happened, a process that probably is already under way" [55]. The statement regarded the quantum physics that was formulated at the first part of XXth century and which was deduced by Popper from his general considerations on the methodology of science - a modern version of Ockham's razor. Unfortunately, quantum chemistry soon evolved into an independent scientific discipline contradicting Poper. In the second half of the XXth century new states of matter – hot plasmas in tokomaks and another state of matter at ultra-low temperatures, Bose-Einstein condensate added new arguments. .

The teacher, working with the most delicate "substance" as it is a young *personality*, must know the own answers to great questions of Humanities and to respect with delicateness the fragile autonomy of the pupil.

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[50] H. Gadamer, *Hermeneutyka*, PWN, 2012

[51] K. Fedus, G. Karwasz, *Ramsauer-Townsend minimum in methane. Modified effectve range analysis,* Eur.J. Phys. D, 2014

[52] R. Iliffe, *Newton. A very Short Introduction*. Oxford University Press, 2007, p. 127

[53] A. Einstein *Come vedo il mondo*, Newton& Compton Editori, Roma, 2002, p. 13, translation by author

[54] Tamże, str. 28

[55] K. R. Popper, *Wiedza obiektywna. Ewolucyjna teoria epistemologiczna.* PWN Warszawa, 2012.

5.9. Physics and the language

The common language uses a whole richness of expressions, which can (suddenly for the novice) become petrified in physics. Such an example is between "velocity" and "speed", petrified by some academic centres in Poland and which become an object of long polemics. What does mean in didactical practice the diversity of senses and meaning of the same worlds? This diversity translates, within the range of didactical tools of a lecturer into the best expression to describe: i) and object, ii) phenomena, iii) abstract categories. An expert teacher does not limit himself into recalling definitions but creates a whole scenario of nuances, colors, tastes in order to find the best meaning. Adding new adjectives, searching for complementary synonyms, asking additional questions is like trying different keys to open an unknown lock: the mind of every pupil in the classroom.

Let consider a concrete example in physics. In recent years some "experts" in didactics started to require a distinction between Polish "szybkość" and "prędkość" that both can be translated as speed or velocity. Even the best American textbooks, including "Feynmann's Lectures" were criticized for such a negligence. The discussion lasting several years drew out attention from real problems touching Polish school in the flow of rapid social changes and made more damage that profit. Even the description proposed by Galileo "uniform" and "uniformly accelerated" creates some problems in pupils' understanding: the difficulty is at the *semantic* and no physics level – pupils recognize immediately the type of movement of a ball rolling on a table but can not find a proper wording. Not saying about an imprecise expression "uniform movement on a circle" – if on the circle, for sure the velocity vector is not constant!

How can one cope with a imprecise definition? First, one can expand the range of meanings by using a kind of thesaurus – similar meanings. So, the movement with constant velocity on a straight line is a kind of "regular" and on the circle – periodic. Again, in Italian, the language of Galileo the expression would be more precise: uniform (if on the straight line) and *circular* if along a circle. In using words one have to proceed with caution. What was done with the problem in the new Polish cv basis? Simply, the circular movement has been removed from textbooks.

The richness of the language can be used in: 1) constructivistic discovering of the concepts, 2) making more precise these concepts, by *codifying* some words. A movement of a rolling ball or a walking teacher can be: slow →equal →regular →almost constant →dull → *uniform*.

Coming back tot the uniform circular movement: this is not only playing with meanings and worlds. The analogy is deeper, physical one: in both types of movement the *modulus* of the velocity is constant, so in both cases the kinetic energy, dependent on the square of velocity, does not change. In other words, the motion along a strait line in a space and around Sun on a circular (and also elliptic) trajectory is *eternal*. This removes all difficulties with the changing direction of the velocity, the presence of the centripetal force and so on. A proper constructivistic path using not mathematics (one should explain the scalar product of vectors to get the work) but exploring meanings of the mother language can bring similarly good didactical result.

The analysis of frequently used expression, in fortuitous or non-fortuitous way, if possible also in foreign languages, also common-people language, in different historical contexts, can enrich enormously the didactical process. For this reason the teacher of physics should stimulate in pupils the ability of precise expressing ideas, with correct grammar, with secure intonation and exact meaning. Disadvantages in proper writing and speaking mother language harmful for all disciplines, physics first.

5.10. Teaching physics and wandering of science

Modern science is based on Descartes' methodology – of step-by-step dychotomic construction of knowledge. Successive questions are formulated only after previous being solved. Different ways of research (experiment, theory, analogy and intuition) are complementary in this process.

The inflations of information, its accessibility in any moment, and on the other hand the rat-race to get the most appealing to the public scientific discovery causes that the above paradigms are sometimes short-circuited. Therefore, form time to time, sensational scientific information appears in press, like it happened in summer 2011 about neutrinos traveling between Italian laboratory of Gran Sasso and CERN with velocities exceeding the speed of light. Obviously, it turned-out in few weeks that some cables were wrongly attached. How a single teacher evaluate the quality of such sensational, but apparent, discovery?

Many times in history of sciences wrongly defined and/or simply non-existing concepts, like *flogiston*, *electrical fluid, electromagnetic ether*, were useful for further development of science. The didactical consequence of this historical experience with apparent failure of physics should be some kind of "politeness" and open mind in discussing alternative ideas. Laws of Descartes were formulated before laws of Newton but Descartes spoke about the momentum and was (still) not able to define it properly as a vector. However, his third law saying that the amount of momentum exchanged in collisions is always zero, is much more intuitive than the third law of Newton (action and reaction). In other words, a profound knowledge by the teacher not only the correct answer but also of the *reasons* for possible wrong answers brings the didactics to a really high, constructivistic level.

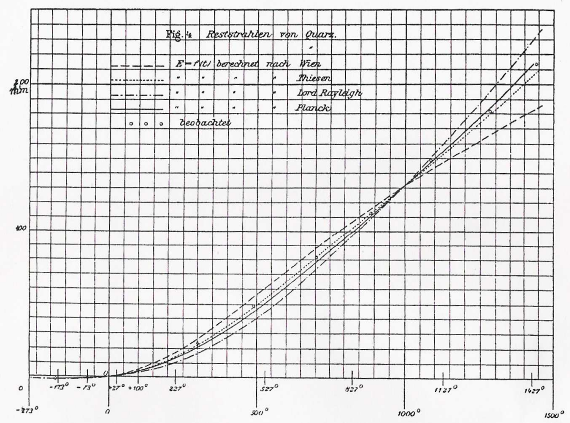
Also the biggest discoveries of modern physics, like X-rays or radioactivity were not free from errors. Wilhelm Röntgen correctly identified unknown rays as generated in halting ("bremstrahlung") of electrons on the anode and noticed its unusual penetrability but was not able to observe diffraction of those rays, so he classified tham as particles, not waves. Now we know that the wavelength of X-rays is too short to undergo diffraction on optical gratings. Only years latee, applying monocrystals, Bragg observed diffraction: the wavelength of X-rays is in the single Angstrom range and a crystal, with similar lattice constant is a perfect diffraction grating. Nowadays, monocrystal are used to get monochromatic X-rays and X-rays are used to reveal the crystallographic structure of unknown minerals nad crystals, including DNA.

Pierre and Maria Curie identified uranium ores, a in them radium and polonium as sources of another radiation leaving a black trace on the film and causing the ionization in air. They measured also the heat, seemed to be generated from nothing. Without other explanations, they thought (and wrote) on a possible extra-terrestrial radiation that was captured by uranium ores. Today we know that the cause for the heat is Einstein's $E = mc^2$. The lack of mass is so small that only exact measurements with mass spectroscopy several decades later allowed to trace the differences. A spectacular observation of the mass converting into energy was made in July 1945, in the atomic bomb explosion at the desert in Los Alamos.

Meanders in the development of science, numerous errors do not harm the successive development. The awareness of making errors and the ability to correct them is important to the scientist, teacher, pupil. Didactically, errors in the mind of the pupil have always their reasons. In meanders of physics those errors probably were done, and already corrected. As a proverb says: "We learn on errors. As we live short, and there is a risk to make not enough errors, it is better to learn on errors of others".

5.11. Physics in statu nascendi

Physics, differently from for example history or literaturem is frequently presented as a closed, finished (and polished) constructions. This note does not regard only the axiomatic ways of teaching Newton's laws or types of images formed by lenses, but activities of great physicists. After the discovery of Maxwell waves and the successes of Newton's mechanics and formulation of thermodynamics, at the end of XIXth century a common belief was that a further progress will be done only by rising precision of previous measurements. But already in December 1900, on Thursday lecture in Berlin, Planck was forced to formulate a completely revolutionary principle that energy in radiation can be exchanged only in quanta, something like Newton's *corpuscula.* This hypothesis was not *ad hoc* but a result of several months of intense trials with different formula, to explain the spectrum of a hot piece of iron (or ideally, so-called black body). Even if the divergence between those trials and experiment were tiny, Planck was not satisfied, until he found a correct formula, see picture below.



Rys. 3. Izochromaty, zmierzone przez Rubensa i Kurlbauma [15] dla kwarcu, porównane z wynikami teoretycznymi. Oś rzędnych przedstawia wychylenia galwanometru. Krzywe wyskalowano w ten sposób, by dawały jak najmniejsze różnice pomiędzy wartościami zmierzonymi i obliczonymi w temperaturze 1000°C.

Comparison of Planck's theory (from his original work from 1901) with other theories and experiments – the dependence of the radiation intensity on the wavelength of radiation. Tiny difference at long wavelength were the reason for one of the greatest revolutions in physics (and philosophy): theory of quanta.

Planck worked on an ambitious task: he wanted to unify Maxwell's laws with thermodynamics proposed by Boltzmann. He wanted to explain, in particular, why in thermal radiation there is a clear short-wave limit for their length. With some trial formula Planck managed to answer this question but than a discrepancy at longer waves remained. The only solution turned-out to be quanta. Einstein called them photons in 1905, but Planck was reluctant to accept this name for years. The revolutionary result of Planck was that the energy of single photons depends on their frequency, not on their intensity.

Planck's revolutions is an example, how apparently small problems, in the atmosphere of global scientific "relax", if studied in detail, can completely change our vision of world. Quantum mechanics which was consequence of Planck's quanta applied to atomic spectra led to completely new science – quantum mechanics. Now, with quantum chemistry new medicine and new photovoltaic dyers are projected on computers, not in laboratories.

Open problems in physics are many: from the high-temperature superconductivity (at 77K), till the dark mass, somewhere nearby, even in our Galaxy and dark energy, acting on cosmological scales. For thes problems we even do not have a faint idea, where should we search for solutions. For the superconductivity those can be fractal (not 3D space), for dark energy – 11 space dimensions or some completely new mathematics.

The teacher, in conditions of permanently changing human knowledge on the nature, finds it difficult to transfer some epistemological security to the pupil. Universities, and didactics of physics should play an important role in meritorious evaluation of physics *in statu nascendi*.

VI. Teaching principles in an age of internet

6.1. Traditional teaching principles

By teaching principles we understand a set of methods used in teaching and learning. These rules are generally adopted to teaching in class but also work in a process of individual learning by student and extra-scholastic activities. These rules are fairly general – they work in different levels of teaching as well as in different subjects. It could be compared to guides of a feature writing, which are different than those for writing the MA thesis. In respect of subject teaching different sets guide the steady motion and others accelerated motion.

Teaching methods used in physics can be different than those applied in other subjects but come from certain general rules. At first we introduce classical approach used in Polish literature and later how it is applied to physics also in context of trends present in Western Europe.

Rules described in this book are general, however they emerge from vast experience of author in solving the student's (and teacher) problems mainly in physics. Suggested classification and implementation of educational rules is not the effect of general typology. Rather it comes from the quest for general rules which will be useful for working on detailed rules. Following rules are different than traditional despite some similarities. A teacher can recall it during an interactive teaching process and cooperation with student when they hit a "educational knot" (i.e. a didactical problem).

Traditional approach calls for use of following rules (after Franciszek Bereźnicki[56])

1) the principle of demonstrability
2) the principle of accessibility
3) the principle of regularity
4) the principle of an informed and active participation
5) the principle of sustainability of the knowledge
6) the principle of effectiveness (W. Okoń)
7) the principle of individualization and collectivity
8) the principle of connection of theory and practice
9) the principle of the operability of knowledge (Cz. Kupisiewicz)
10) the principle of perpetual education

Different authors[57] are giving their own priorities to the above rules, however, a cumulative list is similar among different authors. Of course, these rules are not discovered in the twentieth century – they existed n didactics from very remote beginnings.

For example John Locke wrote in XVIIIth century in terms of the demonstrability and rising the grade of difficulty: *"I thought, therefore, that if one would adopt a toy for this purpose as they would normally are adopted to none, you could do some inventions to teach children to read at a time when they think that they're only having fun. For example, if a ball made of ivory [today can be made of plastic, GK], in the shape of a sphere is used for the lottery during folk play, with thirty-two or more of twenty four walls, and if on each of these walls stick a letter such A on one and B, C on the others. I would like you started only from those*

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[56] F. Bereźnicki, *op. cit.*

[57] W. Okoń *Wprowadzenie do dydaktyki* op. cit.. s. 171 (Introduction to didactics)
Cz. Kupisiewicz, *Podstawy dydaktyki ogólnej*, op. cit. s. 107 (Fundamentals of general didactics), PWN, Warszawa, 1976
J. Półturzycki, *Didactics,* PWN, Warszawa, 1972, p. 107

four letters, and when the boy can know it well, then add the other and so on. until on each wall will be one letter, and on the whole sphere the alphabet. " [58]

These rules divide subcomponents from the whole educational process as a kind of demands. Therefore such demands are simplifications, not taking into account the complex dependencies (target entity) ↔ stage of learning objectives ↔ content resources ↔ . Discussing individual rules resemble figuring out whether the collision of two spheres is applied the law of conservation of energy, law of conservation of momentum or the law of conservation of angular momentum. In fact, all three laws apply in the same range but using one or two of them are more effective only to solve a specific issue. Lets discuss some of these principles in their traditional terms.

Principle of durability of knowledge

Principle of durability of knowledge comes from the Latin maxim *Repetorium mater scienze*. Repeat the knowledge (or for example poetry) was the primary means of communication in illiterate societies. Today, the role of repetition as an adjuvant to remember is diminishing. What's more, the trend in learning is not to encumber any content memory, such as school rhymes. Of course, within the meaning of cognitive and developmental neuro-psychology this trend is not appropriate.

Avoiding mandatory content to remember does not create the appropriate functions in the brain, in terms of information technology we would say that does not reserve the appropriate *workspaces to store messages*. What's more, the teaching process should develop different forms of memory (commonly referred to different types of 'memory' - visual, auditory, spatial, etc..). How to do this? By supplementing the educational process – play a game but the game should be in remembering.

Detailed teaching recipes, based on psychological tests, tell us how should look the process of remembering and repeating to provide stable knowledge. Briefly speaking, remembering requires a certain minimum period of *stabilization* of knowledge – one should not to learn on the eve of the exam, but little before the exam the knowledge should be repeated. Of course, given a sheer volume of the student activities such prescriptions are often just empty demands. Another recipe says that the first repetition of already assimilated knowledge should be made few days after remembering, and the next few weeks / months later.

The principle of sustainability knowledge, treated pragmatically, should be combined with the objectives, as well as other principles of teaching. The famous recipe to prepare the exam just by remembering is a manifestation of such student pragmatism, of course-reaching to the border of absurdity. Remembering is as much needed (in addition to the said reservation of the structures in the memory), as far as is used in practical use of knowledge and supports the further steps of acquiring knowledge. Especially the latter goal is important: without properly established base of knowledge, it is not possible to proceed with further learning. Therefore, it is necessary for knowledge to last at least a in a medium term (a few weeks, a few years) of shelf life. We will return to this issue when discussing our principle of *recursive construction of knowledge* in section 6.3.

In addition to the knowledge of the medium-term sustainability, in preparing citizens for adult, long-term professional and private life, it is necessary to provide knowledge as durable as the ability to walk or ride a bike. It is in a sense and knowledge saved content "Lithuania, my homeland .." and skills, for example, making charts in Cartesian coordinates. In the

[58] J. Locke, *Myśli o wychowaniu*, Ossolineum, Wrocław- Kraków, 1959, p. 153 (Ideas on education), translation by author

teaching process, extract the kind of "must-have" grown man - make knowledge useful for durable.

In summary, the principle of sustainability knowledge associated with other teaching principles and objectives of the teaching takes three forms:
- memorization of knowledge as a way of mental training
- memorization of knowledge and skills as a necessary part of the learning chain
- memorization skills and knowledge as a necessary element in the future activities (so-called long-life learning) .

Practical implementations of the principle of permanent knowledge may vary, depending on specific options above.

Similarly, simplification, and even rather postulate the principle of conscious activity of students. Every teacher knows that full students activity can be triggered only in an psychological emergency or competition, quiz, exam, and it is not always that this activity goes in the desired direction. The activity of the students (and their attention) is in normal school or university rather a privilege, which rarely and briefly listeners bestow lecturer. Roman tips for speakers, confirmed by modern cognitive science, recommended a twenty minutes speech in order to keep the audience's attention. Note (and without it there is no activity) must, however, be by the teacher or by the author of the website gained and kept up a long time.

Very important is the principle of individuality and collectivity (individualization and socialization and W. Okoń) but it has different interpretations. Approach F. Bereźnicki "the teacher should interact with students individually abnormal in the form of adequate assistance aimed at leveling the underdog deficiencies and improvement better" is again just a postulate, as did many of the authors state, the examinee’s awareness of the contradiction between the norm and the individual.

Explanation would require the very concept of norm. Statistically, in a group of school children it is difficult to talk about the norm, as the assumption of certain target. In the end Zou can talk about the mean and standard deviation of the results (67% of students) from the average. Of course, high average in the group is desirable, if this average is the goal of the educational process. So do not always have to be. On the other hand, the individualization of the learning process required in the educational guidelines of the EU, requires the teacher complementary task - to prepare special tasks for the brightest students. Another addition, the principle of democratization of access to knowledge contained in the maxim "no-student left behind" imposes the need to work with the student weakest ...

The new version of the principle of connection between the theory and practice are the EU requirements of teach knowledge, skill and social competences. In physics only apparently no social competences can be transmitted. In any subject: electricity, gravity, acceleration correct competences can be determined. In electricity – the competence to choose a correct electrical power requirements for home appliances; in gravity – the knowledge that the geo-stationary satellites must circular above equator (for workers installing parabolic TV antennas); in acceleration – the knowledge that the friction, independently from the state of tires, can not exercise a force greater than mg where g is the gravity acceleration and m is the mass: in consequence, some curves can not be run above the permitted velocity, in order not to exceed the value of the centripetal force needed to complete the curve, and so on.

Modern implementations of didactical rules, required by the EU educational polices, are under constant evolution: for the teacher thy remain general road-signs, important to respect, but not removing the individual responsibility of the single teacher.

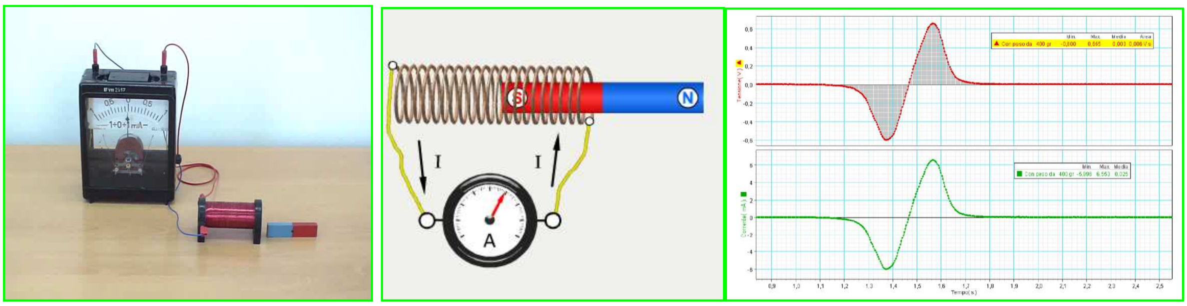
6.2. Hyper-constructivism principle

Socrates is considered as the inventor (or rather, the discoverer) of the heuristic method. During the discussions on the Athenian Agora, Socrates drove people to before the intended conclusions by skillfully asking questions. We call the Socratic method as obstetric method – as if knowledge dozed in the people's minds and philosopher only helped this knowledge to see the light of a day.

Socrates constructed knowledge based on the assumption that logical thinking can, even in the absence of other evidence, lead to the only (at least within the meaning of philosophy), real knowledge. There's no question that modern natural science has a huge amount of scientific and we can omit discussion about the existence or not of the philosophical truth. We are able to construct a *path of knowledge* with significantly less intuitive luggage than Socrates and with much greater degree of certainty. What's more, the path to knowledge in Socrates's time was closely marked. In today's teaching, the way to achieve the goal of teaching can be varied either due to the methodology (teaching aids) or due to the way of reasoning. Figuratively, the Socrates's method is to move *de facto*, by strictly delineated corridor, each turn of it reveals the curtains that cover the successive stages of reasoning. The aim of modern heuristic method is not to reach the end of the corridor but to reach a generally speaking the second, undiscovered side of the river through wihich, we go on the piles driven into the bottom.

Hyper-constructivist principle, in relation to the heuristic method, introduces other, wider objectives and other diverse methods. In this case the purpose of the educational process lies beyond the narrowly understood result of reasoning. It is he acquisition of broad knowledge in a particular subject. Let's give an example of electromagnetic induction (which we will explore again in par. 6.5). The path is mapped closely to the next experience: i) '- What we observe, when you insert a magnet to the coil? "Ii)" What we observe when we proclaim the magnet? "

Narrowly conceived goal of teaching would be a message of "sliding magnet coil causes current to flow", see fig. below.



Hyper-constructivist path in teaching the electromagnetic induction. The sequence of gradual discovery issues by the student. 1) The "SPEA" principle - the situation, prediction, experiment, analysis 2) a computer model illustrating the problem, 3) automatic measurement using a computer system of the amount, size and direction of the induced voltage.

A formal approach to the problem would focus on prediction by using a right hand, the direction of the emerging current. We had criticize such approach in other parts of this paper: it is formal and does not provide the student the essential *competencies* – neither conceptual nor practical. More important is the indication that the principle of Lenz is an example of the applicability of the principle of conservation of energy: the direction of the resulting current is such that the induced magnetic field opposes the external force. If the induced field were in the same direction as the external field – a *perpetuum mobile* would be constructed.

6.3. Recursive construction of knowledge

The principle described above is co-creation of knowledge, it is corresponding to traditional principle no. 4), ie. *„active and conscious participation of the students”*. This connects to another rule, recursive construction of knowledge (i.e., step by step). It is not only the principle of gradation of difficulty, but the realization of Cartesian, dichotomous discussion of problems, cf. chapter III. Guided by this principle a group of students discreetly let by a teacher, articulates a one statement after another, then is discussing it, verifies, accepts or rejects. After making sure that the whole group accepts a step and there is no (significant) concerns, the teacher shows a further possible and alternative steps - the prospects for further questions from the students.

Progressivity of the case reminds walk on stilts by the lake: after placing the feet on the next pole, Staging the second leg and is stabilized equilibrium, we start looking around where to put the next step (and how to possibly go back if the road would be wrong). Again, the recursive construction of knowledge requires that the teacher not only knew (usually the only) way correct, but also *knew why* others are incorrect.

Below we return to the question of why bodies fall, presenting a detailed scenario of questions. Each question involves the appropriate experience, *clearly* suggesting the correct answer. The sequence comes from an interactive lecture for children aged 6-10 years, see. chapter II for results of teaching.

1º Prof: - Why bodies do fall?
Class- Because it acts as a gravity
Prof .: - Yes, we already explained this, but this has no consequences.
Prof .: - There was a bearded philosopher, Aristotle, who claimed that bodies fall because they are heavy, and heavy bodies natural place is the center of the Earth.
[In the meantime, take off my jacket, pretending it's hot, Then I put ball on it]
Prof .: - See, that's true? Ball wanted to fly to the center of the earth and if not for the table, would push down.

2º Prof: But could the body jump bz itself? [And here comes the (unsuccessful) attempt of telepathy]
Prof: Now I'll show you a different experience.
[Sequence with the strip bent in the middle and a ball. In the first phase the ball is stopped at the lowest, the middle point of strip]
Prof: - Did you like this experience?
Aula: murmur of disapproval occurs, but do not allow her to articulate!
Prof: - And now I will show you how to train the ball . [huffs, puffs , growling and rubbing the ball]
Prof.: - Fly littel ball! [this time we do not stop it in the middle, but when I fly past the lowest point and rolls into the hill on the other side of the strip]
- And come back!
[Laughter in the room, sometimes shouting "- because you stopped it before"]

3º Prof .: - see? We have a new way of taming balls.
[Now lower the ball the same as before, just not on the jacket, but on the hard floor, of course, the ball bounces]

4º [sequence occurs with two balls, falling over one another and the lighter one bounces up to the ceiling.]
Children after 2-3 attempts answer themselves saying:

Aula: Because this lower passed energy to the upper.
5º This basically didactic aim has been achieved - an indication of the energy as a source of motion of bodies.

The lessons show about 20 other entertaining exhibits, but as you can see from the verification results, the experience of the rack and the balls remain well founded in the memory of the children.

Similarly, it is worth to create recursive path in other branches of physics: "What if we assume the following hypothesis ..." An example exploring the properties of emission spectra (the so-called linear and band ones), through the use of the subjectivity of the human eye we present in the interactive scenario "What color is the pink light?” in „Fiat Lux " exhibition.

6.4. Cognitive recipes

Cognitive science provides teaching many valuable suggestions. Let's start from recalling of what cognitive science is. It can be defined as the study of cognitive processes and in this sense teaching as the science of conscious and deliberate exploration would be one of the areas of cognitive science. Cognitive science as opposed to the teaching does not address the contents or objectives, so these two sciences have common research areas, but they are different. However, some of the discoveries of cognitive science shed new light on problems with apprehension and on other mental functions.

Cognitive Science builds on the achievements of psychology, neuroscience, pedagogy but also uses sophisticated methods of experimental brain research such as positron annihilation tomography or magnetic resonance imaging. Electrical signals that appear in a specific locations of the brain may be monitored not only in a static manner, but one can analyze their extremely quick time sequences. At the beginning of neurology of the brain, diagnosed which brain areas are active for specific functions (vision, speech) based on damage (surgical or war). Modern diagnostic methods, using sensors of very weak magnetic fields identify the actual activity of the brain with microsecond time resolution. This allows a substantial progress in understanding also processes of learning.

A good example is the problem of dyslexia. Until recently it believed that it was caused by underdevelopment of some brain functions in the process of reading and speaking. It was strange because people affected by dyslexia (and there are a large percentage of the population) showed no loss of visual function or function of speech. From the measurements carried out already in the XXI century, turned out that the reason for dyslexia is inappropriate to correlation the functions. After seeing the sign (and its recognition) at a specific location of the brain in people "normal" electrical signal is late with a specific fraction of a second (of the order of microseconds) before it reaches the center of speech. People with dyslexia do not have this delay: the signal goes to the speech area without (seemingly unnecessary) round-trip, which is too fast. People affected by dyslexia are not impaired, but rather over-developed.

What advice comes from that for teaching? Well, a cognitive process can not be too fast: at every point it is necessary to apparent slowdown the message, thus electrical signals in the brain will have time to hit on their intended place. Moreover, such "delays" (musically we would call them fermata) are properly quantized, longer or shorter, depending on the complexity of the signal, the listener response etc.

In a particular lesson, the individual elements of the educational process must be differentiated so that each student, with his individual characteristics, would be able to use his or her optimal ability to participate in the cognitive path.

Very important result of cognitive science is to identify the development of specific biological structures in the brain. These structures, for example of abstract thinking, appear at a specified age (the time of development of the brain). This results in two very important implications for education. First, it is pointless to communicate content and/or skills before in the brain will appear appropriate structures capable to digest such content/skills. Secondly, when these structures occur, it should be taken as soon as possible by the desired content/skills. Otherwise, they will be occupied by other skills. Extremely instructive here are different kinds of comparison with animals, which in some cases appear to be smarter than people.

Research on the human brain also provides information extremely optimistic (but imposing new duties for modern teaching). It seems that the only 10-15% of our intellectual capacity is used by modern man. This means that if you manage to reach the unused structures, abilities to learn and act as human will increase many folds. Conscious or unconscious, intentional or hidden, and finally voluntary or enforced these structures may become one of the major scientific issues XXI century.

Cognitive lesson for teaching implies the need to adapt mild control of cognitive capabilities of each particullar child, so that their own knowledge resources and opportunities they reached a goal satisfactory to the teacher. There will be one outcome for the extremely capable child's and another one for the child having manual or personal difficulties. Cognitivistics assigns each student a satisfactory pace of acquiring knowledge, with proper velocity, using the best own capacities and satisfying their individual psychological needs, see photo below.

Fot. 3.18. Zadania pedagogiczne w interaktywnych wykładach dla dzieci w ramach Uniwersytetu l wieku „UniKids": a) Spontaniczny podział ról w planowaniu eksperymentu – pomiar napięcia bateryjek; b) wspomaganie podmiotowości: „- No, powiedz wszystkim, co chciałeś!"; c) fascynacja zwycięża stres: „- Wreszcie mogę spróbować sam!" Który samochód zjedzie szybciej (Autor GK, Fot. MK)

Again, and in accordance with well-established principle in Western literature Pedagogical Contents Knowledge, modern implementation of this traditional principle requires close cooperation between:

- Physicist scientist indicating what is the current best-our-state-of-knowledge in a specific physical issue;

- Teaching, translating this advanced state of knowledge in the easiest possible explanation of the level of knowledge of the student;

- Educator, evaluating teaching behavior, and pointing to established non-substantive problems of perception student.

Referring to the initial discussion on general didactics and discipline didactics – concrete observations of teaching for a given target group, in a particular environment, and with clearly defined educational (i.e. knowledge, skills, social competences) give the *experimental* result: some methods and/or forms, and/or tools are better and some of them fail. We generalize observations, giving recipes for specific discipline didactics. Then, taking the whole set of indications, principles for general didactics can be re-formulated.

6.5. Cognitive paths: experiment, mathematics and language

Experience with strong neodymium magnet falling in a copper tube is proposed by some publishing houses in Poland as a means of enriching educational teaching electromagnetism. Recently we proposed a modified version of this experiment in which the tube is narrow longitudinal incision. The idea was immediately copied but not its meaning! What is the point of making longitudinal cuts in the tube?

Now, graduates high school, at least the "old school" more or less heard about integrals. It is (some) mathematical operation that has many uses, probably, and statistics and (for sure) in engineering and physics. Yet explaining what is the integral curvilinear, particularly after a closed contour, would put ino trouble majority of math and physicist graduates. Mathematically, a curvilinear integral can be converted to the integral of the "normal", in one dimension, but how it would look? And certainly this can not be so easily demonstrated show? Really?

Fig. 1 Two copper tubes and magnet falling inside - general reference of the implementation in the curvilinear integral Faraday's law of electromagnetic induction. The full tube falling magnet "levitates" hanging in the air and not touching the walls; longitudinally incised in the tube falls magnet "tumbling" and bumping against the walls

The second teaching observation, which prompted us to cut tube is induction law (electromagnetic), called in Poland (and England) Faraday's law in Russia is - Lenz and in Germany additionally - von Neumann. What the law says FLvN? The law determines the amount of current that is induced in a circuit (eg. the power generator) if INSERTED (or are bringing) to (from) this circuit magnet. This current, but rather the so-called. "Electromotive force" depends on the rate of change of "flux" of the magnetic field. Mathematically we can write this as

$$E = -\frac{\Delta\Phi}{\Delta t} \tag{1}$$

where E is the "electromotive force", in other words, the generated voltage and Φ - magnetic flux; $\Delta\Phi / \Delta t$ is the rate of change of flux Φ. Graphically, the stronger the magnet or faster it is inserted (or faster it is rotated in a power station), the higher voltage is generated.

Law (1) is sufficient in teaching at the level of middle and high school. At the university level, it is not entirely correct didactically. Now, Maxwell's law, which is a generalization of the laws of electricity and magnetism does not use the concept of electromotive force. Maxwell rights talk about the fields: electric and magnetic fields and relationships between them. On the right side of equation (1) have a magnetic field. And where is the corresponding electric field? Well, the electromotive force E is the integral of the electric field E, but integral particular, curved the closed profile.

$$\oint E \circ ds = -\frac{\Delta\Phi}{\Delta t} \tag{2}$$

Can you give pictorial form so complicated mathematical notation? Our copper tubes are used just for that. The integral on the left side of equation (2) is the integral of the closed profile. If nicked tube, the integral is not closed profile and the magnet falls differently than in the tube without cuts - bumping up against the walls and tumbling.

Obviously, for students who operate concepts of the electric field and the integral this explanation is sufficient. Unfortunately, the same principle of experiments as a leading teaching tool is not enough when the recipient does not have the appropriate conceptual scope. The trainer should construct a teaching path, preferably using other exhibits. General reference layer serves as terms of conceptual proper explanation, using the variety of ways verbalization phenomenon.

Let's practice this on the example of the falling magnet and tube. Tube with a magnet pass from student to student, until you hear the most appropriate verbalization. Scenario (based on lessons actually carried out in different groups of listeners) may be as follows:

N: - What do you see?
U1: - Magnet decreases like that.
N: How come?
U2: - Slower.
N: So?
U3: So as if it was repelled from the walls?
N: Yes?
U4: As if it was levitating.
Levitation is in this experience best (and only relevant) explanation. Why? Well levitation means that the falling body is supported by something. Thus, if the magnet does not touch anything? Letłs explain this by the second exhibit of the preview function - hanging magnets, see. Fig. 2 In the hanging magnet is immediately clear that the upper magnet is "hanging" in the air (or levitate), because it is repelled by a magnet bottom. So if the magnet in a tube "levitate", then there must be a magnet that repels it, and does it exactly upwards. Where did the magnet come from? Of course, from the currents in the tube that flow like the circumference of the magnet in Fig. 2, the tube along circles perpendicular to the axis. The two exhibits complement each other and form (quite complete) teaching path.

Fig. 2 What causes the upper magnet is "hanging" in the air? Of course, the repulsive force from the lower magnets. Magnets in Fig. have poles at the top and bottom (with brighter and darker side). The electric current flowing in a circle, ie. Around the perimeter of the magnet produces the same poles. The tube with magnets, electricity flows along the circumference of circles. If we cut these circles, levitation vanishes.

The cuts in the tube interrupt this current, so the induced magnet is not perfect and falling neodymium is "tumbling". Of course, the demonstrative lesson requires the student to perform experience or at least to see its virtual version.

The difficulty in explaining the phenomenon of induction results from the inability to use proper verbalization of the phenomenon and the lack of adequate examples and not with lact of mathematical knowledge. Unfortunately, numerous examples of Polish textbooks indicate that the teacher wants to tell what he knows, and not what the student should learn.

In summary, even in the natural sciences-mathematics, and perhaps especially in the mathematical sciences, the ability to search i) different meanings, ii) the different contexts of practical, iii) different cultural backgrounds [4], iv) different etymology of the word is sometimes used many times more important than the formal correctness.

VII. Applications of Physics in the Life Sciences[59]

7.1. Physics for geographers

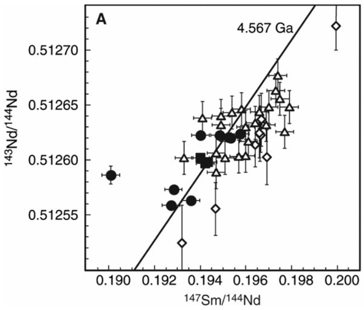
Earth is one of the larger laboratories, witch we know (the universe is larger). They are on the optics labs (rainbow and all other optical phenomena), thermodynamics (weather, ocean currents, volcanoes, etc.), mechanics (flattening, Coriolis force, interaction with the Moon), ionizing radiation (dating, radioactive elements) and others

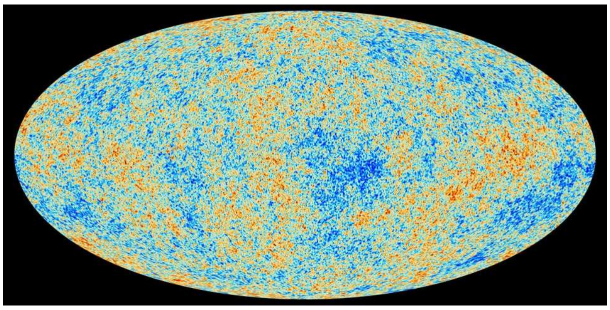
For starters, let us consider what is the age of the Earth, which we will write in this article.

Previously, scientists did not have the proper tools to provide this value. The only known work, from which you could count it was the Bible. This work gives the age of Adam and all his descendants. It also gives that God created the universe for six days and rested on the seventh. On this basis, until the early twentieth century it was thought that the Earth is about 6,000 years (centuries-error).

Some time after the discovery of the phenomenon of radioactivity was noted that a fairly simple way you can use it to date the age. Well, it was found that the activity of radioactive elements decreases with time. Introduced the term half life time, it is a period in which half the atoms of a given element apart to form another. These times can be very different, eg uranium - more than 4 billion years, rad - 1600 years, radon - 3.8 days, lead - 27 minutes, polonium - 3 minutes, bismuth - 20 minutes (in the following the collapse of the β arises again polonium, but another isotope, who lived just 0.16 milliseconds, etc.)

It is easy to see that by studying the activity of a given element can calculate the time elapsed since its inception. Historically, to determine the age of the Earth used uranium ^{238}U whose half life time is exactly $4,468*10^9$ years. Recently used for this purpose combinations of elements ^{147}Sm /^{144}Nd[60].





On this basis it was impossible to determine the exact age of the Earth at 4.457 billion years.

And the age of the entire universe - how to define it?

Historically, it was determined by using the observations of the oldest stars. today we use with a very accurate detection of the CMB radiation arising as a result of the Big Bang (which was the beginning of the universe).

The most accurate map of this radiation published in March 2013 an international team led by scientists from the European Space Agency (ESA) mission Planck[61,62]. Analyzing these data, the researchers found that the age of the universe is 13.82 billion years old. What was before? This is a topic for theologians and philosophers.

Inseparable companion of the Earth is moon. Somewhere around 4.5 billion years ago the Earth, not exactly sure yet formed, hit an object the size of Mars.

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[59] collaboration: MSc Krzysztof Służewski

[60] M. Boyet, R. W. Carlson, Science 309 No.. 5734 (2005) 576

[61] http://www.nature.com/news/planck-snaps-infant-universe-1.12671

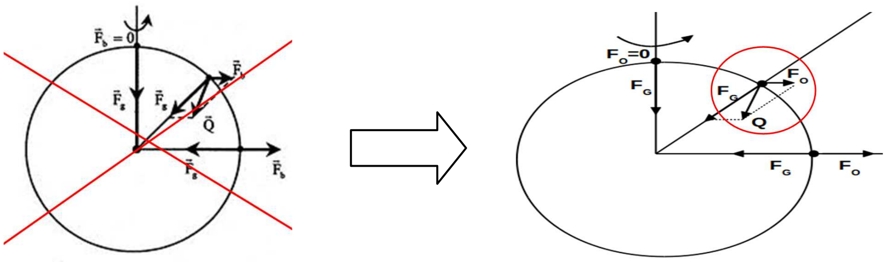
[62] http://dydaktyka.fizyka.umk.pl/Wystawy_archiwum/z_omegi/planck2013.html

He tore a powerful piece of matter and debris, which later formed the Moon. It was a tragic time in the history of the Earth. If such an event occurred in modern times, certainly all forms of life would have disappeared. Evolution would have to take place from the beginning.
At the beginning of its history, the Moon orbit the Earth closer than today. Now, each year, moving away from her by about 4 cm per year, i.e. 4 km 100,000 years.
By a strange coincidence angular sizes Moon as seen from Earth are almost the same as the angular size of the Sun as seen from Earth. As a result, during the total solar eclipse can admire the solar corona. The elliptical orbit of the Moon makes its angular sizes change. This allows us to observe the annular eclipse of the Sun.
4 billion years of existence of the Moon meant that he is a kind of balance with the Earth. Its circulation around the Earth is equal to the circulation around its own axis. In other words, is constantly returned to Earth the same side (only slightly sways). Earth Moon system can be compared to a canoe from Polynesia. With the smaller the float, the larger is balanced.



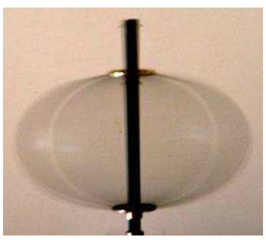
The moon is in balance with the Earth as a toy shown above.

What is the shape of the globe?
Copernicus wrote:
„*Także i wody morskie układają się do postaci kulistej [...]*
jako ląd i woda wspierają się na jednym środku ciężkości Ziemi, który jest zarazem środkiem jej objętości."
"*Also and marine waters are arranged to form a spherical [...]*
as land and water supported on a center of gravity of the Earth, which is also the measure of its volume. "
Today we know that it is a sphere, but a little flattened.

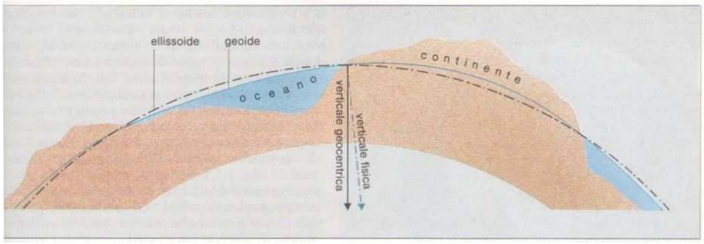


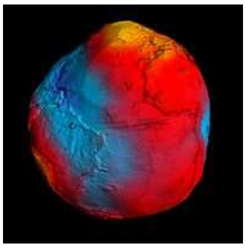
The Earth spins on its axis. Centrifugal force is formed, which extends a little Earth, the strongest on the equator.
We can see this very well by using a flattening spring.





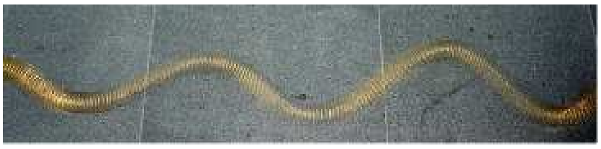
In the first image the spring does not move. On the other starts to rotate, and the third pivots already quite fast. You can see that the faster you move, the more flattened (like Earth).
From these drawings it appears that mass, which takes the rotating Earth is a perfect ellipsoid. Not so. Let's look at the picture below.





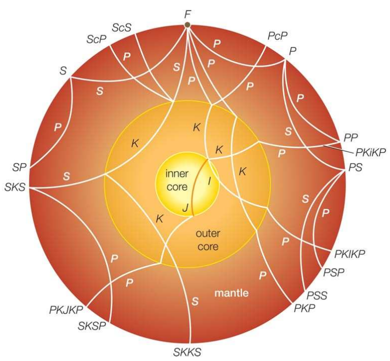
The figure shows the ellipsoid (dashed line) and the geoid (blue line) – a surface perpendicular at each point to the vector of gravity. The Earth's surface is very close to the second curve.
In March 2009, at the height of 250km GOCE satellite has been placed. He carefully measured the gravitational field of the Earth. As a result of his research was made following the model of the Earth.
Of course, altitude differences are exaggerated, that it was better to see the surface. Blue areas are below the red.

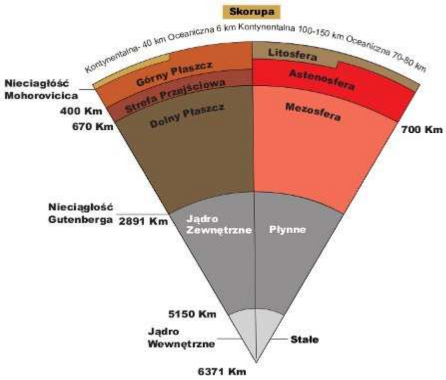
What is the internal structure of the Earth?
Mines have a depth of up to 4 km. The deepest hole made by man is little more than a 12-kilometer-long Russian borehole from the years 70/80 of the last century. Earth has a diameter of more than after 12,000 km, so as to find out how the interior? From time to time in certain places on the Earth's earthquakes occur. They propagate not only to its surface but also to the inside.



Transverse waves propagating on the spring

Longitudinal wave propagating in the spring





Caused by earthquake waves refract, diffract, or even bounce depending on the density of the medium through which pass.
Seismic waves moving inside the Earth (left fig. Above), caused by the earthquake in point F[63] are seen in many places on the surface. Break down, sag, or even bounce depending on the density of the medium through which pass. The entire globe is distributed network of seismographs. On the basis of the echo earthquakes whose epicenters we know we can find out how it is built in the center of the Earth (right fig. above).

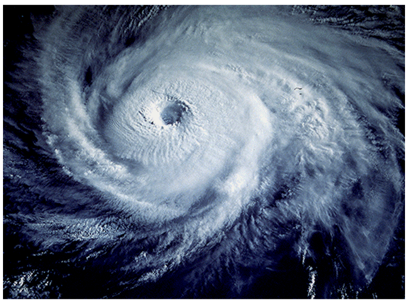
[63] http://everyhistory.org/earthquake1.html

It's like the internal structure of the fruit avocado. A thin outer shell, quite thick mantle and core.
In the upper mantle convection occurs relentless matter. Rocks colder fall down to the heat there. Then heated again flow into the upper, cooler layers of the upper mantle. This phenomenon can be modeled using the popular lamp - lava.

The shell is divided into tectonic plates, which are constantly in motion. These plates constantly rub against each other, are pressing, sometimes fall one under the other, and sometimes moving apart. As a result, in one place oceanic trench is formed in the second pile high mountains.

How is the Earth's magnetic field?
Inside the Earth's core. It consists mainly of fairly well-conductive alloy of nickel and iron. It consists of a liquid outer core and a solid (because of the enormous pressure) of the inner core. In the outer core material is constantly floating on its surface, and then drops to the inner core. As a result of the Coriolis force generated vortices - everything is very dynamic. Huge currents start to flow and thus was formed Earth's magnetic field. It is estimated that in the interior of the Earth, it is about 50 times larger than the outside.
We have already written about the Coriolis force. On the surface of the Earth it causes a lot of different effects. This force causes a deviation from the straight line path of movement of the body, moving in the rotating system.
With this force cyclones formed in the northern hemisphere rotate opposite to clockwise, in the Southern Hemisphere its rotating is accordance with clockwise[64,65].



With the power of Ciriolis force, wind in the northern hemisphere tends to twist to the right and to the south - to the left, in the northern hemisphere are strongly undercut the right banks of rivers, on the south - left. The Coriolis force must be taken into account also by gunners and people planning flights over long distances (eg other combustion).
In everyday life, we do not see exactly this force, which is why most of us do not work in an intuitive way.

An interesting phenomenon on Earth are the trade winds, which is warm, constantly blowing winds in the tropics. The humid air above the equator being heated rises to the top, and its pressure drops at the surface. Water vapor condenses, tropical storms formed.
Dry air has moved in the upper atmosphere in the northern hemisphere to the north and in the southern hemisphere to the south (+ course deviation associated with the Coriolis force).
Falls out of the tropics to form dry areas of high pressure. Then back in the lower atmosphere to equatorial trade winds just as. Sailors use these winds since prehistoric times.

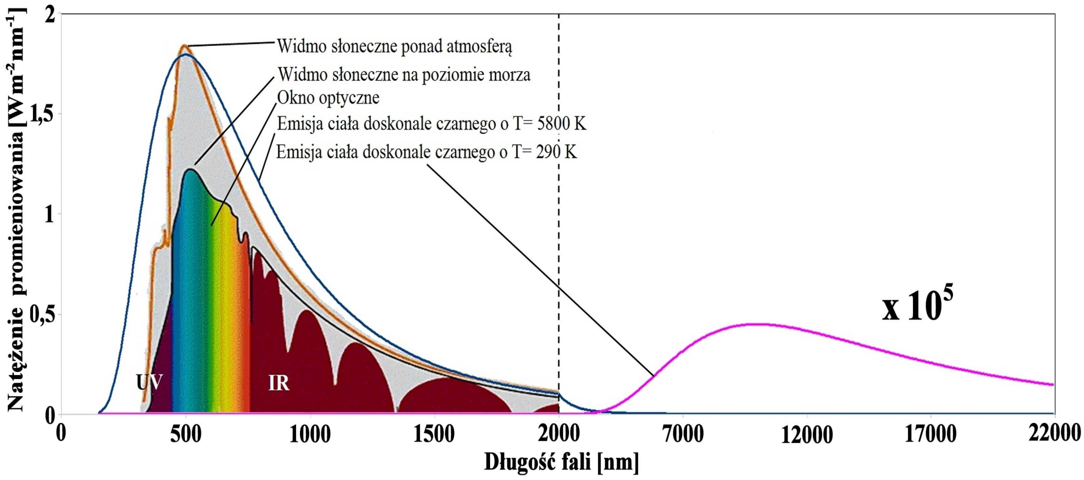
More: http://dydaktyka.fizyka.umk.pl/Ziemia/

[64] http://en.wikipedia.org/wiki/Coriolis_effect
[65] http://dsc.nrsc.gov.in/DSC/Cyclone/index.jsp

7.2. The greenhouse effect

The source of heat on Earth is the Sun. It is true, that from radioactive decay (^{41}K, with a series of ^{238}U and ^{232}Th) formed about 20 TW of heat, and from the cooling of the globe reaches the surface in addition almost 30 TW (tera = 10^{12}) but it is very little compared to 1,36 kW/m^2 ·π· (6370·10^3 m)^2 = 171x10^3 TW arriving constantly from the Sun [66].

What should be the temperature of the globe in approximately Earth without the atmosphere can be estimated using the model of a black body. If we assume that the object radiating into space is a sphere (surface $4\pi R^2$) the surface density and flux of energy radiated per unit time is I = ¼ ·1366 W/m^2 = 341 W/m^2 (factor ¼ comes from the comparison of the surface of the wheel πR^2 to surface of the sphere).
From the Stefan-Boltzmann law $I = \sigma T^4$,
where the constant $\sigma = 5{,}67\cdot10^{-8}$ Wm^{-2}K^{-4}, we obtain T = 278 K (ie, +5ºC). The solar constant I is the result of measurement using satellites[67]. A similar result for the equivalent temperature of the Earth's perfectly black can also be obtained from the geometric astronomical data.[68].



The figure above shows the dependence of the intensity of solar radiation on the wavelength (λ in nm) per unit area reaching the earth's surface. Maximum emission of a black body with T = 5800 K corresponding to the wavelength λ = 0.5µm. The emission maximum for T = 290 K corresponds to λ = 10µm. The intensity of radiation outside the atmosphere has a maximum value of about 2 W m^{-2} nm^{-1}. The intensity of radiation at T = 290 K have been multiplied by a factor of 10^5. Note on two types of scale OX (over 2000 nm is multiplied by a factor of 1/10). The power of radiation of the Sun at other wavelengths is negligibly small.
The sun does not illuminate the Earth all the time with the same intensity. The activity of the sun rising every 11 years, when they arrive sunspots [69] but changes in the amount of energy reaching the Earth does not exceed ± 0.1%. Nevertheless, the lack of spot light for extended

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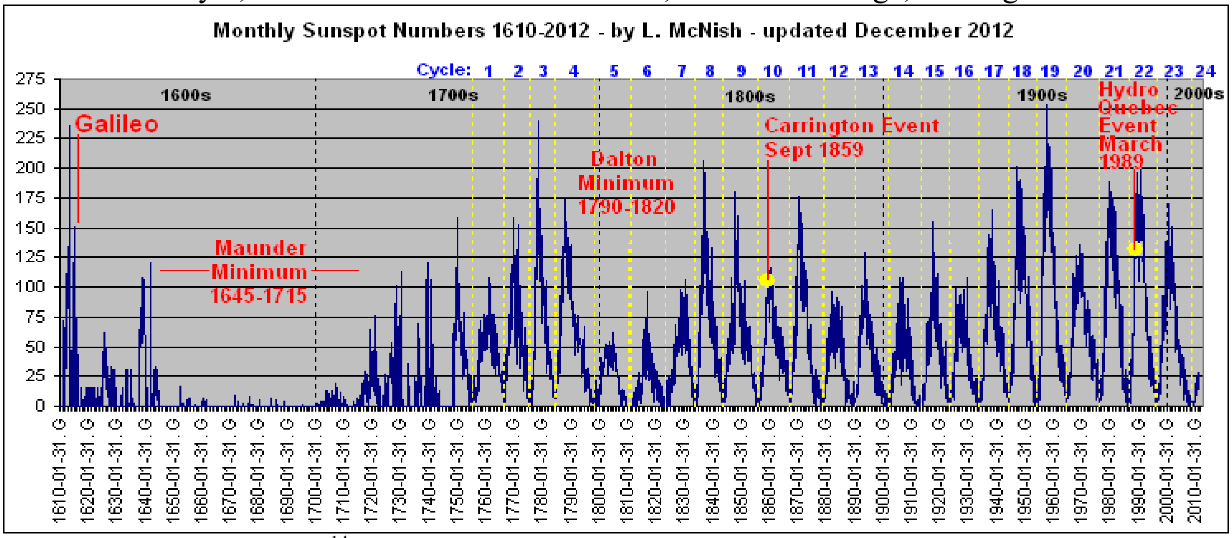
[66] As the radius of the Earth assumed R = 6370km, despite the fact that the Earth is not a sphere.
[67] See for example article *Construction of a Composite Total Solar Irradiance (TSI) Time Series from 1978 to present,* http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant
[68] If we know the surface temperature of the Sun (5780 K), the temperature of the Earth can be calculated without the Stefan-Boltzmann constant, using only astronomical data (radius of the Earth, the diameter of the sun 1.4 million km and the Earth-Sun distance of 150 million km), see. *Zadania czeskie* , ZDF UMK, „Temperatura Ziemi" http://physicstasks.eu/uloha.php?uloha=1091&filtr=000000000
[69] Sunspots, is basically a giant magnetic vortices reaching the surface of the sun. The increase in the amount of spots corresponds to an increase in "broken" vortex or solar eruption, ejecting into space increased amounts of ultra-hot plasma. There is as yet no convincing model of magneto-hydro-thermo-dynamics of the Sun explanatory cycles of 11 years.

periods of time, for example. Hevelius observed by the middle of the seventeenth century, clearly lead to a cool climate. The cooling is more or less from the time the Swedish Deluge to the Silent Seym, is called the Maunder minimum, or a small ice age, see. Fig. below.



Based on the analysis of ^{14}C in jars trees we can evaluate the activity of the Sun, also in early stages[70]. It seems that the solar activity was lower than usual at the end of the Middle Ages (minimum Wolf, around 1300 AD). Not the end, however, the temperature minima (averaged over the period of several years) correspond to the minima of solar activity.

Not only changes in solar activity affect the climate. We know, even with observation moraine landscape of northern Poland that at about one hundred thousand years there are great glaciation. Similarly, a long period are known Milankovitch cycles. It seems that for cycles tens and hundreds of thousands of years has been responsible "machinery" of the solar system.

Known since the time of Kepler, that the planets revolve around the sun in ellipses (a non-circular orbit suspected we also find in the work of Copernicus). Sun is at the focus of the ellipse, but rather a common focal ellipses for different planets. Ellipse can be flattened less (as in the case of Earth, with eccentricity e=0,0167) or more (as in the case of Mars, e=0,0935). That's not all! Specific geometry of the orbit of the planet, for example. Earth is periodically revised - flattening and inclination of the orbital plane (ie, the Earth's ecliptic) to the mean plane of the orbits of the other planets. Under the influence of Jupiter and Saturn axis of Earth's orbit is too slow rotation. Sam the earth's axis, rotating in space bittern, subject to precession, with a period of about 25 thousand. years (this movement already knew Copernicus); Moreover, it varies the inclination of the axis relative to the ecliptic (the 22,1° to 24,5°). Summing these movements is difficult, as it discusses the English version of Wikipedia[71]. Efektem są niewielkie zmiany nasłonecznienia, ale powodujące, zdaje się, zmiany temperatury od +2ºC do -8ºC, zob. rys. 6. Resulted in slight changes of sunshine, but cause, it seems, changes in temperature from +2°C to -8ºC. And finally, the longest of the postulated periodicity, approx. 140 million years old, may result from circulating around the solar system around the galactic center[72].

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70 Unstable isotope ^{14}C is formed under the reaction isotope neutron absorption ^{14}N and a proton is produced, according to the scheme $^{1}_{0}n + ^{14}_{7}N \rightarrow ^{1}_{0}n + ^{14}_{6}C + ^{1}_{1}p$. The neutrons in the atmosphere come under the so-called. cosmic radiation and is mainly solar wind.

71 Wikipedia, *Milankovitsch Cycles*, http://en.wikipedia.org/wiki/Milankovitch_cycles

72 Note, however, that a similar magnitude (200 million years) are also periods and clumping of the Earth's continental plates diverge, a very significant impact on climate through volcanic activity.

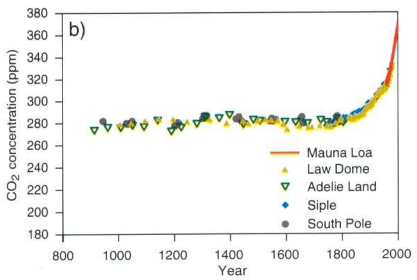
Previously made to calculate the temperature assumed, that the Earth is perfectly black, ie. absorbs all incident radiation. If so, for example for the Moon, it would be invisible: it is not true! A part of the radiation is reflected back into space - we are talking about the albedo factor, ie the reflectivity of radiation. It amounts 0.9 for snow, 0.4 for desert sand, 0.15 for the spruce forest, 0.1 for the ocean and for medium Earth 0.3. Taking into account the albedo in the earlier calculation gives a temperature of 254K, which is -18ºC. This would be the temperature of the Earth, if it would not have duvets from the atmosphere.

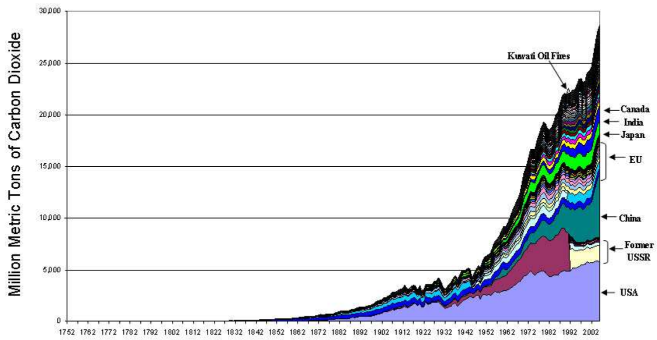
Having traced the complicated balance of heat on earth, it turns out has a surplus (Earth does not heat up) but there is no deficit. Scientists construct increasingly complex computer models of the "Global Climate Circulation". Figuratively can however say that the atmosphere like a duvet - it does not heat as heat, but prevents heat from escaping.
The overall balance of the atmosphere increases the effective (average) temperature on Earth, with -18°C for sand sphere without atmosphere (as it is on Mars) to + 15°C. These additional +33K is the natural greenhouse effect.
These additional +33 K is a "coincidence" happy for life on Earth - rather than average Siberian winter we have (on average) may afternoon!
The exact temperature depends on many factors; in the case of Europe, this is the example. warm sea current from the area of the Sargasso Sea.
This is a nice +15°C must exist on Earth for the last 2000 years, but at least 3-3.5 billion years to life arose, perpetuated, came ashore and evolved.
Can a man produces additional greenhouse effect by emitting greenhouse gases into the atmosphere and water vapor? Carbon dioxide is, but rather was 150 years ago, only 280 ppm (parts per million). And how is the water vapor? Depends on the humidity. The so-called. "100% RH" in Singapore, the only (at 29º C) 4% by volume of water vapor in the atmosphere. Amount of steam, which can "fit" in the air (in terms of partial pressure Dalton law) is from slightly above 0% to 100% by volume of 100 C (and at a pressure of 10^5 Pa). The relationship is stronger than a t^2 where, t is the temperature in degrees Celsius [73].
So: again positive feedback! Higher temperature means more water vapor in the atmosphere. Such positive feedback is more, for example decreasing the solubility of CO_2 in the oceans as the temperature rises or the release of methane from the Siberian thawing tundra. So the climate should be inherently unstable? It is possible that climate instability, on-off type are a permanent feature. Charts, temperature changes deduced from isotopic analysis of ice layers in Antarctica[74] suggest that the temperature rises suddenly, within several thousand years and then slowly decreases in cycles of about 100,000 years. Changes in the concentration of CO_2 appear to be the result of, not the cause of changes in temperature.
Climate change can not be equated with global warming. "Warming" is for physicists more energy "pumped" in the system thermodynamically in equilibrium. At any time, the amount of energy received and wasted is identical, but this balance is set at increasingly higher levels.
Global warming could also bring paradoxically dramatic cooling in Europe. Europe has a much warmer climate than, for example eastern coast of the USA, lying on the same latitude. South Korea, further south than Calabria at the end of the Italian "boot" record winter temperatures of up to -20ºC. The reason for the mildness of climate in Europe is the Gulf Stream. This current, like every thermodynamic engine is driven by the temperature difference between the Sargasso Sea and the ocean in the vicinity of Iceland, where the warm waters are cooling is passed deep into the ocean and return to the Sargasso Sea as icy deep-

[73] http://dydaktyka.fizyka.umk.pl/zabawki1/files/termo/psychometr_big-pl.html, http://en.wikipedia.org/wiki/Vapour_pressure_of_water
[74] http://commons.wikimedia.org/wiki/File:Vostok_Petit_data.svg measurements from the Soviet Vostok station, developed in collaboration with researchers from France and the USA.

sea current. Warming in the region of Iceland may weaken the Gulf Stream - Poland accrue Siberian winter.

Possible scenarios are the subject of numerous scientific, political and economic debate. Mathematical methods used for climate projections depend on the quality of experimental data and our knowledge of physical processes, biological as well as changes of civilization and technology. The most important factor feedback seems to CO_2 content in the atmosphere. It remained constant for the last few thousand years, paleontological high level, 280 ppm and from the beginning of the industrial age increases monotonically. The data in the following left figure are the results of the various analyzes, such isotopic Antarctic ice, as growth of trees and the composition of the atmosphere measured spectroscopically in an astronomical observatory in Hawaii ("Mauna Loa").





Right figure. The increase of CO_2 in the atmosphere from anthropogenic CO_2 emissions detailing the different parts of the world.

Is the increase in CO_2 will lead to a global rise in temperature? And if so, how much? It seems that from the beginning of the twentieth century the average temperature has risen by about 0,2 to +0.6ºC. This is slightly less than -0,7ºC during the Thirty Years' War, and much less than + 3°C in the days when dinosaurs lived at our latitudes. Unfortunately for us, can't the end of the predicted changes. Secondly, climatic fluctuations become burdensome in the modern world in which we travel, where agricultural productivity is getting closer to the possible frontiers in which humanity manages areas increasingly vulnerable to floods, flooding, droughts, typhoons and so on.

In conclusion on the Earth's climate is affected by very many factors. Some of them we know, others may not. Over time, some mechanisms have become, however, already clear. What can we say for sure?

a) Infrared absorption properties of CO_2 molecules are a significant cause of the natural greenhouse effect, whereby it is possible protein life on Earth.

b) Industrial activities of man has contributed to a significant (over 25%) increase in the CO_2 content in the atmosphere.

c) Does this increase will result in an increase in the average temperature of the Earth and/or lowering the temperature in Europe and/or global glaciation and/or violent hurricanes and/or drought? At the moment there is no indisputable evidence.

Data collection still continues. Who knows what conclusions lead for a few/several years?

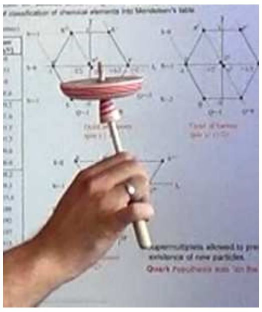
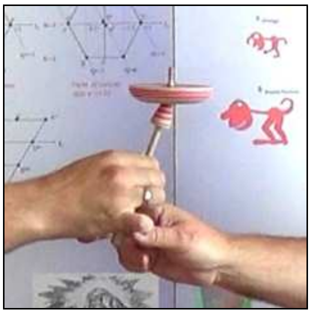
More: http://dydaktyka.fizyka.umk.pl/nowa_strona/?q=node/309 & G. Karwasz, K. Służewski, Ziemia pod pierzynką, czyli o naturalnym efekcie cieplarnianym, Foton, 121/2013, 37 - 49.

7.3. The angular momentum and gyroscopes

Everyone in my childhood playing with all kinds of sideburns (some play so far, as adults). Both children and adults are amazed that behave differently than everything that surrounds us around. Why did not capsize? Why the "wobbles" on the sides? Why, when it does not turn, rolls over as everything else? These and other questions (conscious and subconscious), make the donuts are so fascinating toy (or as we in the ZDF UMK is called PED-em - Prostym Eksponatem Dydaktycznym (Simple Exhibit Didactical)).
Tops are a favorite gathering of physicists-toymakers. Every science teacher should have them at least a few. Their forms and colors is an infinite number. They serve not only as a demonstration of the principle of conservation of angular momentum, but for example assist with the optics to make the color, of electromagnetism to generate a magnetic force or show of eddy currents. When on the acoustics are talking about ways to generate sound there as well as an example, we can use the corresponding sideburns. Uses donuts can be very much.
Large, child bittern, easy to spin will use in the first place to show the principle of conservation of momentum: "spinning top is maintained in a vertical position, because it behaves physical quantity called angular momentum." Although there is no formal angular momentum in the core curriculum, it is not the size of foreign intuitively. Only in comic cartoons happens that the racing wheel is turning block the fleeing cat. Privacy mechanics are in fact embedded in our basic motor system: stone still make it in my direction only when in my direction already doing (= principle of conservation of momentum). Clipped wheel car will roll always "straight".
The explanation of the principle of conservation does not have to use the same concept of angular momentum. Student simply say: "ongoing coin retains its direction of rotation, like the bittern untwisted".



How do we show by means of heavy and flat fart wood propped on a stick and made by craftsmen from the town of Matsushima in northern Japan (pic. Below), the angular momentum is a quantity which can be moved from place to place. Support can be moved in translation, tilt, toss bittern, and the angular momentum (spin direction bittern) does not change. Similar experience, but bittern accelerated in a special electric saucer comes from Australia. But the experience of shifting momentum as well be made of a spinning on a stick (plastic) plate.


Even simpler way to illustrate the principle of conservation of angular momentum is Casually coins on the table? Children like animated films - the more absurd, the spontaneous laugh.

Had never been in these films the scene, Jinks the cat runs away from a runaway wheel of a car with a transverse street and the wheel turns for him? Children laugh at the sight of a cat chasing the wheel, because the principle of conservation of angular momentum is built into our system of psycho-motor.
The behavior of the angular momentum is used in artillery - threading inside of the pipe guns is a way to preserve the direction of flight of the projectile and thereby minimize the effects of air resistance. Range hanging around projectile is much closer and more unpredictable than the path of the projectile, which rotates around the direction of its movement.
They saw it too ancient Indians who were forming their darts shot in such a way that the in-flight rotated. Probably one of them producing shots before hunting accidentally stuck a pen darts askew, carelessly, spiral and then it turned out that the arrow is much more accurate than other shot.


Angular momentum is a vector, and like other vectors is added up. We'll start with astronomy. The principle of conservation of angular momentum is no less important than the conservation of energy and momentum - spin of the Earth allows you to maintain a constant inclination of its axis to the ecliptic. From the conservation of angular momentum in motion around the Sun due to Kepler's laws, in particular the second fixed surface plotted fields by the radius vector of the planet.
Difficult to remember the apparent movement of the Sun, the Moon, the sky and the planets are easy with this principle. The sun travels across the sky during the day from left to right and the moon (in one night) as well. But apart from that, the Moon moves every night with the right a bit more to the left (and the Sun during the year against the background of the zodiac in the same direction). Difficult it is to remember, unless you look at the solar system from above.
Sun and planets formed from the nebula spun [75] proto-planetary so they spin and orbit around the Sun in the same direction, keeping the initial angular momentum - looking from the North Pole of the Earth in the opposite direction clockwise, see. in reference beautiful animation modeled on Google's[76] Copernican figure "Harmony macrocosmic" Andreas Cellarius of the seventeenth century. Copernican Doodle is a beautiful illustration of the principle of conservation of angular momentum motion on a cosmic scale. Summary vector momentum of the solar system is directed to the drawing up - vectors of rotation of planets shoot moments and moments of shoots them around the sun are all set in the same direction (though not exactly the same, see. Further discussion of precession).

Principle of aggregation of moments of momentum, we can also show the scale of the classroom, using spectacular but very dangerous experiment with the bicycle wheel and swivel chair. Planting (strong) student on a rotating chair, holding the revs up a bicycle wheel

[75] Only Venus rotates in the opposite direction, once for 9 months and Uranus in "level". Presumably, during the ancient past any collision took place that changed the direction of rotation of the planets.
[76] http://www.google.com/doodles/nicolaus-copernicus-540th-birthday

axle vertically and we give them the student. After turning the wheel "upside down" (this requires a lot of force) chair, a student and a circle with its axis begin to spin in the opposite direction to the new direction of rotation (around its axis) bicycle wheels. The new total angular momentum of the whole system is equal to the initial moment the only wheels (see. video in web version).

You can begin the experience of the wheel held vertically (ie. With horizontal axis): when set by the student in the vertical axis of the wheel chair starts spinning. A little more difficult, however, to explain where is the initial angular momentum (oriented horizontally). Now, the system (seat + student + circle) is not an isolated system - is the force of friction chairs on the floor allows you to rotate the wheels on a vertical orientation, but also during this maneuver, the student is out of the chair "torn out" in the horizontal direction. It will be clear when discussing the precession.

To avoid falling (with the spinning chair, holding a heavy, untwisted wheel with spokes in the hands of) the student must press firmly to the back of the chair loins: in this way the center of gravity of the system (seat + wheel + student) situated on the axis of rotation of the chair and the smaller are the moments forces pulling the wheel from the hands of the student during maneuvering and overturning a chair.

The angular momentum $\boldsymbol{L}$ is calculated from the angular velocity $\boldsymbol{\omega}$ as

$$\boldsymbol{L}=\boldsymbol{I\omega} \quad (1)$$

where bold denote vectors (or matrices, or tensors).

I is called moment of inertia, for example $I=2/5\ mr^2$ for the ball with a mass m and radius r and so on. Others bodies, but in the school teaching - always axially symmetric. In general, the moment of inertia about any axis is mathematically a square matrix, and in terms of physical - tensor $\boldsymbol{I}_{\mu\nu}$ sizes (3x3). To obtain the angular momentum vector, we must multiply the angular velocity vector by the matrix

$$\boldsymbol{L} = \boldsymbol{I}_{\mu\nu}\boldsymbol{\omega} \quad (2)$$

How to multiply vector and matrix, we refer the reader to (still) an extraordinary book Rubinowicz W. and Krolikowski W.[77] (str. 288) (pg. 288) or any textbook econometrics. Mathematical difficulties prove to be a valuable methodology for the further analysis of traffic bittern, especially the spin of the Earth. Only if the rotation axis is the axis of symmetry of the bittern, the tensor becomes a number, and the vectors $\boldsymbol{L}$ and $\boldsymbol{\omega}$ are parallel, as in physics education, $\boldsymbol{L}=\boldsymbol{I\omega}$

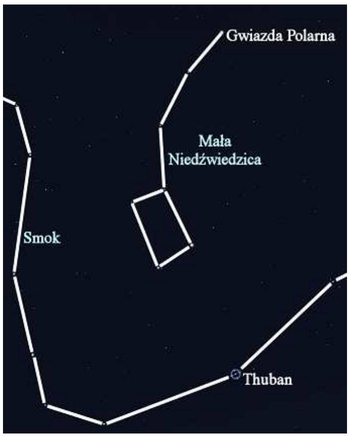
This is particularly the case that the rigid body rotates freely about a free fixed axis. That book Rubinowicz K. and K. Krolikowski states in this regard, ([5] p. 326): "rigid body can freely in the absence of forces and moments of external forces perform rotation around a fixed axis L (where ω=const), If this is the direction of the axis of the main inertia tensor, and passes through the center of mass of the body. "The main direction of inertia tensor for bittern is the axis of symmetry and straight to the perpendicular..

The introduction of the concept of angular momentum vector allows for further development of the nature trail, and this in the sense of the laws of physics (technology, geography) and not just fun. We know that the untwisted bittern as time begins to "wobble" and more specifically physically - its axis of rotation begins to slowly circle cone bittern is subject to precession.

The same precession of the Earth's axis of rotation shall be staggered full circle once for about 26,000 years. He knew this already Copernicus, the ancient writing of the three movements of

[77] W. Rubinowicz, W. Królikowski, Mechanika teoretyczna, Wydawnictwo Naukowe PWN, Warszawa, 2012.

the Earth: centrifugation, the circulation around the sun and shifting of the equinoxes[78], or the precession of the rotation axis. Amazingly accurately predicted the period of the precession - for 25,816 years. He did this also on the basis of their own observations so. equinox made, among others, on the walls of the castle in Olsztyn[79]).



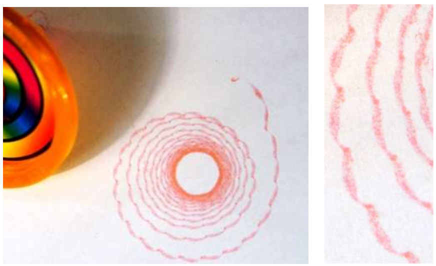
I do not know about the precession of the Egyptians: Pharaoh's burial chamber in the pyramid of Cheops was channel-telescope pointed at the polar star. Unfortunately, it's been a few thousand years and the star (Thuban in the constellation of the Dragon) is no longer the lodestar[80].

With a big toy sideburns can make the experience for determining the cause of precession. How does it show on the photo. 8, that is the force perpendicular to the axis of rotation. Pushing rapidly spinning top short, strong blow, for example. Of a pencil, as observed after impact deviates, but not in the direction of the force only in the direction perpendicular to the applied force, so as well as the axis of rotation.

As before, with its wheel axle bicycle we can show that the force applied causes the rotation of the axis in the perpendicular direction. Circle suspend axis balancing counterweight to the level rim revs up, then change some counterweight, see. movie in the web version. Unsustainable part of the force of gravity causes the precession of the wheel axis in the horizontal plane. By changing the counterweight changing reimbursement applied torque and we cause the rotation axis of the wheel to the left or right. Axis while slightly leaning forward.

Squareness three directions - the axis of rotation (or angular momentum), the force and direction of precession also explains cycling or the direction of the ongoing collapse of the coin. To turn on the bike to the left, the whole bike to lean to the left; coming down the left side of the coin at the same time turning path of the left.

If you already understand precession, you need a gadfly to the second illustration, the smaller the movement axis of the Earth - the so-called nutation. Nutation, are small circles relieved by the pole spinning top as you move to the pole of the precession cone. Imposed on the precession give "flourishes". Nutation of the Earth are caused mainly by the movement of the Moon around the Earth in the plane of the ecliptic accurately, and have a period of 18.6 years. Size nutation Earth's axis is such that the position of the Tropic of changes of several meters every year.



Moore: http://dydaktyka.fizyka.umk.pl/baczki oraz K. Służewski, G. Karwasz, Fizyka i zabawki - wyjść poza fenomenologię. O żyroskopach, systemie słonecznym i momencie pędu, Fizyka w Szkole, 3/2014, 25-32.

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78 http://dydaktyka.fizyka.umk.pl/nowa_strona/?q=node/371

79 A. Witkowska, O kalendarzu słonecznym Mikołaja Kopernika, Część II, Nauczanie Przedmiotów Przyrodniczych, 30, 2009. str. 25-29

80 On-line version: http://dydaktyka.fizyka.umk.pl/Pliki/KK_fragmenty/KK_r3_2_ISBN.pdf

VIII. Didactics of astronomy[81]

8.1. Summary

Until recently astronomy constituted an integral part of the school physics curriculum, which was reflected in the name of the course: physics and astronomy. Following the latest reform of the curriculum just physics was left. This does not mean that we should forget about astronomy. Its content can still be found while teaching physics. It should also be noted that the issues connected to astronomy naturally arouse students' interest, which might be used when mobilizing them to work independently.

In this chapter, we put a few items. After a brief introduction based on theoretical grounds of didactics and methodology of science we focus on practical examples of interdisciplinary learning, remembering also briefly the content of teaching astronomy in the current curriculum. Most attention is devoted to the methodology in practice, with particular emphasis on the use of Internet resources and capabilities of a computer in teaching activities.

8.2. Introduction

Modern astronomy changes quickly, even more dynamically change our views on the manner of its teaching. It is, moreover, not only in astronomy, but in general teaching, especially science, in the XXI century [1]. Drawing attention to the need for active shaping of attitudes towards the learning process, foster the making of activities aimed towards acquiring the knowledge and permanent skills upgrading resulted in a reflection on the existing methods of implementation of the educational process and its effects. Existing prior assumptions about the organization of education, the result of behavioral theories and assumptions were based on the result of the adoption of changes in the behavior of the system used for human interactions by means of incentives in the form of penalties, rewards and reactions related cause and effect relationship [2].

Recent decades have brought real information revolution: digital media and the Internet increasingly include all existing knowledge of mankind. Status of knowledge availability can therefore be called hyperinflation of information; the problem is not access to knowledge, but the possibility of ordering it and the use by the individual recipient [3]. The consequence of all-availability of information is the need to develop new teaching strategies, and in principle the construction of knowledge. In the traditional constructivistic approach, the role of the teacher is to organize and systematize the students' knowledge. Term *constructivism* involves primarily claims articulated most clearly by Piaget, Vygotsky and Bruner. Jerome Bruner, in his introductory lecture of the conference: *The Growing Mind: Vygotsky – Piaget* (Geneva, 1996) undertaking the issue of socio-cultural research, makes a comparison and synthesis of Piaget and Vygotsky's ideas in the context of the claims of constructivism. *According to Piaget, if the world can not be cognized directly, but only through the mediation of logical operations, then our knowledge is the design, construction to be tested in action - both its effectiveness and understanding of the world* (Bruner, 1996) [4].

In fact, the role of the teacher or lecturer seems to us more complicated - it is the analytical reasoning leading the group to choose (among all possible paths leading to the goal established by the teacher) the one that is the most convincing, yet scientifically and logically correct. This kind of teaching is called hyper-constructivism [5].

In the modern world, a precious circumstance is an opportunity to build knowledge based on real examples of tools and places where scientists are working. Of course we recognize the omnipresence of cyberspace - virtual "reality"; it is also dominant in astronomy. Tools useful in teaching astronomy include a number of simulations, demonstrations, models - from

[81] Author: dr Krzysztof Rochowicz

figurative representation of the place of the Earth in space, through interactive maps and atlases until the virtual planetarium and simulations of traveling in cyber-universe. A separate class of applications is the real sky observations using online telescopes [6].

8.3. Methodology of physics and astronomy - the example of the mutual influence of the two fields of knowledge

At the beginning it is worth considering the perspective in which we come to use physical or astronomical description of the world. There is no significant difference in the two approaches - both natural sciences deal with the study of matter and the properties of the phenomena occurring in the Universe, and the description of its general laws. Both also developed a suitable methodology, which is based on the assumption that the universe exists objectively and is knowable [7].
The scientific approach in physics is based on:

- observing things (bodies) and phenomena,
- performing experiments (including mental and computer based)
- drawing conclusions as a possible general theories,
- experimental verification of the proposed theory.

Similar assumptions characterize research approach in astronomy, provided, however, that the role of experimentation and experience is taken over here by observations.
You could also think about what really is the norm: the natural world around us in the environment of our planet or the cosmos with its vast space and time. Of course, taking into account the typical place in the universe, astronomical description should be used, but for us, the people, the natural place is the earthly environment, with the necessary ingredients for life - the atmosphere, water, organic matter, the attraction of our planet and the life-giving star - the sun. Hence physics, developed on the surface of the Earth, must at some point face the approximations of universal laws and rules that govern the universe, and taking into account all the phenomena such as presence of the atmosphere, manifesting itself by air resistance. Today we are keenly aware of this, but in the past it was the natural way – transferring observations being made in the Earth's environment onto the whole cosmos. How difficult it was to liberate ourselves from such a description, we can see by analyzing e.g. appearance of the principle of inertia in physics.
Aristotle believed that the source and purpose of the movement is the form. He defined the movement as "the realization of the possibilities of the form contained in the matter" and the deliberate pursuit of each body to the intended place, that is the Earth, which was once regarded as the center of the universe. The former is called natural movement, for instance the movement of the stars in the sky. In addition to the natural movement in the philosophy of Aristotle, there was still a sharp (forced) movement. It was created by a disturbance of the natural external force, for example thrust. According to Aristotle, "all movements need a reason; if the cause of traffic stops, traffic stops" [8].
This formulation follows directly from the observations made on the ground. However, if we assume that there are two types of traffic, the interpretation known to us from everyday life phenomena requires a qualitative change in the approach. It was John Buridan (approx. 1300-1358), in the wake of living in the sixth century John Filipone and living at the beginning of the second millennium AD Persian physician, philosopher and scientist Avicenna, claimed that after settting the body in motion it receives a certain property, which maintains this state - he called it a vengeance [9]. Buridan further held that the vengeance of the body increases with speed, and with the amount of matter - so we see a close relationship with the modern concept of momentum. In this approach we no longer need the "cause” supporting movement.

Motion is an inherent property of each body having momentum. This type of statement undoubtedly paved the path to the modern understanding of the motion of celestial bodies - from the laws of planetary motion, through Newtonian description, up to the concept of general relativity (see below).
It is worth mentioning that in VI. century John Filipone argued, that the movement can take place in a vacuum, and that the velocity of the falling body does not depend on its weight. We should also emphasize the coincidence of modern teaching methods with Filipone's views on the role of experimentation and reasoning in the construction of knowledge.
Kepler's laws are the strong confirmation of the theory of Copernicus and its generalization. They break with the Pythagorean canon, according to which the simplicity and elegance of the movement relied on its "unfold" on uniform circular motion. The laws deduced from empirical data were purely geometrical, this concept lacks dynamical approach. At the same time they became the inspiration and basis of consideration for Newton looking for a universal law governing the movements of bodies on the surface of the Earth and in space.
While studying protestant theology at Tübingen Johannes Kepler (1571-1630) became familiar in detail with the heliocentric theory of Copernicus and became its propagator. He was able to discover the trajectories of planets other than those proposed by all existing cosmological systems, which he owed to observation results of Tycho Brahe (1546-1601).
Brahe regularly recorded the position of the planets in their motion across the sky for many years, in particular, he made a large number of precise measurements of the position of Mars. Fortuitously for the efficacy of this method was that the Earth's orbit is almost exactly a circle, and the orbit of Mars is an ellipse with a relatively large eccentricity.
After the death of Tycho Brahe in 1601 the rich results of his measurements become the property of Kepler by Brahe's will. With them Kepler could graphically determine the orbit of Mars with respect to different points of the Earth's orbit. After many years of persistent calculations he came to the conclusion that the most appropriate curve is an ellipse. A deeper analysis enabled him to determine the precise planet's variable speed in its motion along an ellipse. The results of this work Kepler published in 1609 in *Astronomia Nova*.
The first law, as we remember, specifies that each planet of the solar system travels around the sun in an ellipse, in which one of the foci is the sun. This also applies to the Earth. When we raise the question: when the Earth is closer to the sun, the answer is usually not quick and obvious. Generally we hear that it is closer in summer, because then it is warm, but after short thought we find a contradiction - after all, when in "our" (northern) hemisphere there is summer, in the southern winter reigns, and vice versa. The seasons are in fact a consequence of inclination of the Earth's axis of rotation to the orbital plane and are not related to the distance (its changes in the range of 147.1 to 152.1 million km are only approx. 3% of the average value).
And with the distance it is exactly the opposite: the Earth is in orbit closest to the Sun approx. on Jan. 3, and farthest approx. on July, 3. And here Kepler's Second Law is worth quoting, according to which a smaller distance corresponds to the higher speed (in the case of the Earth - 30.29 km/s), while a greater distance - less speed (for the Earth 29.29 km/s). Differences in speed are not great, but make up the difference of 3-4 day duration of spring and summer compared to autumn and winter (compare the length of seasons!).
Observations of the Galilean moons of Jupiter, discovered in 1610, confirmed the accuracy of Kepler's first two laws of planetary motion. They also facilitated Kepler, after several years, the formulation of the third law, published in 1619 in *Harmonices Mundi* ("Harmony of the World").
The interpretation of "phenomenological" Kepler's laws is due to Newtonian theory of gravitation. The law of universal gravitation states that every object in the universe attracts every other object with a force that is directly proportional to the product of their masses and

inversely proportional to the square of the distance between their centers. This is a general physical law based on empirical observations of Newton, which he called induction (influence). It forms part of the foundations of classical mechanics and was formulated in work: *Philosophiae naturalis principia mathematica*, first publihed on July 5, 1687. In the modern language this law states: Between any pair of massive bodies there is an attractive force that acts on the line joining their centers, and its value increases with the product of their masses and decreases with the square of the distance. In his work, Newton presented a coherent theory of gravity, describing both objects falling on the ground, as well as the movement of celestial bodies. English physicist relied on his principles of dynamics and Kepler's laws regarding the distance of the planet from the sun.

For simplicity, we assume that the two planets move in a circular orbit. Kepler's third law will be as follows:

$$\left(\frac{R_1}{R_2}\right)^3 = \left(\frac{T_1}{T_2}\right)^2 (1),$$

where: R_1, R_2 – orbits' radii, T_1, T_2 – planets' orbital periods.

According to the vector description, each body moving in a circle is subjected to an acceleration:

$$a = \frac{v^2}{R}(2),$$

where: a– acceleration, v– velocity, R– circle radius, which according to the second law of dynamics means that the centripetal force is:

$$F_d = \frac{m_b v^2}{R}(3),$$

where m_b is inertial mass of the body.

For the motion of planets, the centripetal force is equal to the gravity F_g. Orbital speed can be calculated as:

$$v = \frac{2\pi R}{T}(4)$$

If we put (4) to (3) then we obtain:

$$F_g = \frac{m_b 4\pi^2 R}{T^2}(5),$$

The ratio of the planetary gravitational forces can be written as:

$$\frac{F_{g1}}{F_{g2}} = \frac{m_{b1} R_1 T_2^2}{m_{b2} R_2 T_1^2}(5),$$

If now in equation (5) we substitute (1) then we get rid of the orbital periods:

$$\frac{F_{g1}}{F_{g2}} = \frac{m_{b1} R_2^2}{m_{b2} R_1^2}(5),$$

According to this formula, the ratio of the gravitational force is proportional to the inverse ratio of the squares of the distance. If the planet is twice as far from the Sun, then the force of gravity is four times smaller. When the body is two times less massive, then the strength is two times smaller.

Newton found that the same force causes the planets' motion and falling apples from the tree. In this way, the great physicist, laid the groundwork for classical mechanics. In this perspective, gravity is the force of interaction for any massive bodies or particles.

Newton's theory of gravitation is a consistent general physical law based on empirical observations, in accordance with the method that is called induction (influence).

Difficulties with the classical theory of gravitation demonstrated themselves in the case of the perihelion motion of Mercury, considered since the mid-nineteenth century [10]. The effect explained by Schwarzschild was basically the first experimental confirmation of the general theory of relativity [11]. Today, a similar effect can be observed in the case of a binary pulsar PSR 1913 + 16, in which one full rotation of the perihelion lasts 85 years. The discovery of this object in 1974, was awarded by the Nobel Prize in 1993 (Hulse, Taylor). Usually priority in observational confirmation of the general theory of relativity goes to Eddington's expedition to observe the total solar eclipse on 29.05.1919 (and the effect of stars shifting in the celestial sphere in the surroundings of our daily star caused by shifting light beam trace in the gravitational field). Anyway astronomical observations often allowed the physics to improve. And today, the effect of the curvature of the light in the gravitational field we see more clearly and forcefully on many examples of gravitational lenses (images provided to us by e.g. Hubble Space Telescope). On the other hand, the method proposed by the Polish astronomer Bohdan Paczynski (microlensing observations) brings additional benefits in discovering new extrasolar planets [12].

8.4. New ideas of interdisciplinary teaching

We will attempt to answer the question: How to teach physics through astronomy? In recent years, the issue is considered in the series of scientific conferences and in the work of educators gathered in an informal group Better Physics leading website betterphysics.org. It is a good starting point to broaden the perspective of physics teaching by integrating elements of astronomy. You'll find e.g. links to conference materials, publications and papers on this subject there.

An interesting resource in English, available freely on the Internet (motionmountain.net), is a richly illustrated course of modern physics in an interdisciplinary perspective. The latest version (25.4 from May 2013) has been supplemented by videos and animations.

One should also refer to the offer virtual Institute of Physics (www.iop.org), based on the numerous organizations and physicists and educators from around the world. Among the rich resources there, we find e.g. *Teaching astronomy and space videos*, illustrating the wide range of issues relevant at the high school level. Mentioning the video, extremely valuable information and messages are prepared by the European Southern Observatory (www.eso.org) under the slogan ESO Cast - a high-quality movies informing about the work carried out using the largest ground-based telescopes and the latest astronomical discoveries.

8.5. Elements of astronomy in the current (Polish) curriculum

In the new curriculum we find more specific elements of astronomy for the first time in the requirements of teaching Environment for the second stage of education (classes IV-VI of primary school) in the form of issues "Earth in the Universe". According to the assumptions, the student:

1) describes the shape of the Earth with the use of the model - the globe;
2) lists the names of the planets and ranks them according to the distance from the Sun;
3) explains the assumptions of the heliocentric theory of Nicolaus Copernicus;
4) experimentally examines rectilinear propagation of light and its consequences, such as camera obscura, shadow;
5) examines the phenomenon of reflection of light from mirrors, surface scattering, reflective elements;
6) presents (using the model) the Earth's rotation and its movement around the Sun;
7) finds a relationship between the rotation of the Earth and the change of day and night;
8) shows the relationship between motion of the Earth and the changes of the seasons.

The commentary states: *"Issues relating to the Earth in the solar system are aimed at shaping students' skills to model and to explain the observed phenomena on its basis. Earlier exploration of rectilinear propagation and reflection of light enable them to explain the observed phenomena."*

Poor astronomical content is added in new curriculum for the third stage of education (high school). It is basically connected to a refinement of some of the items listed above in the contents of teaching geography (shape, movement of the Earth and their consequences), the commentary states.: „*Introduction of issues related to the movements of the Earth should be preceded by a reminder of the conclusions from direct observations made on the lessons of nature, and on: the change of sunrise or sunset time during the year, changes in the length of day and night and the altitude of the Sun at the time of ascendancy at different seasons. The most important geographical consequences of earth movements must be understood: succession of day and night, solar time, changes in lighting and length of day and night on Earth, changing altitude of the Sun at the time of culmination in different seasons and different latitudes.*"

Astronomy's another corner can be found in the fourth stage of education - high school. In the curriculum of physics we find the section "Gravity and elements of astronomy", where in addition to discuss the force of gravity as the cause of falling bodies and the role of the central body is the place to discuss such issues as artificial satellites of the Earth, the apparent motion of the planets against the stars, phenomena in the Sun - Earth - Moon system, distance measurements in astronomy - heliocentric parallax, the history of the solar system, the construction of the Galaxy, the expansion of the universe and the Big Bang. This portion of Astronomy will be presented to all high school students while closing their physics education in Class I.

Those students who choose the extended course of geography, will have a chance to get to know some of the issues of practical astronomy in the "Earth in the Universe" block. In this part the student:

1) explains the features of construction and specifies the location of the various celestial bodies in the Universe;
2) describes the bodies constituting the solar system;
3) shows the consequences of the Earth's movements;
4) calculates the Sun's upper culmination altitude anywhere on Earth on equinoxes and solstices;
5) calculates the latitude of any point on the Earth's surface on the basis of the sun's culmination on the equinoxes and solstices;
6) describes the differences between the astronomical, calendar and climatic seasons;
7) explains the cause of: polar days and nights, aurora borealis, solar and lunar eclipses;
8) indicates the presence of the Coriolis effects for the environment.

The others can only count on the gracious treatment of astronomy elements within the high school subject of "Nature". A detailed discussion of the astronomical issues in this area includes the presentation available on the website of the Department of Physics Education Nicolaus Copernicus University in Toruń, http://dydaktyka.fizyka.umk.pl/nowa_strona/?q=node/211

To conclude this brief overview of the presence of astronomical topics in Polish curriculum, we can see a number of scrolling issues, forming a kind of canon in education of a modern man. One should refer to the achievements of modern pedagogy and didactics, especially its constructivist trend. Under this system, learning is understood as the process of constructing new models and representations of the world by manipulating objects and using language and other cultural tools. It is a process of constant negotiation of meaning, together with the peers and with the teacher. The aim of modern education, more generally pedagogic is its modernization, which connects to the abandonment of the concept of enlightened man to the concept of innovative human [13]. Nowadays, encyclopedic knowledge, which for years dominated in school curricula, very quickly becomes obsolete. Therefore, one needs to pay attention to the education of a young man moving toward the innovation that extends the boundaries of education, among others, by looking at the human existence by means of technology and vice versa [14].

8.6. Methodology in practice

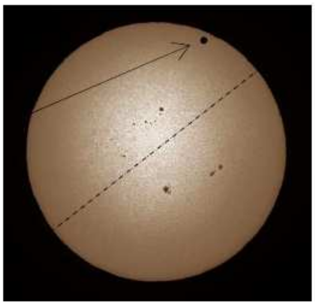
The department of Physics Education at Nicolaus Copernicus University in Toruń for many years undertakes actions in the field of popularization of physics and astronomy. It is worth mentioning for example about a series of lectures with demonstrations "Copernicus in the short T-shirt" [15]. More information and the latest communications can be found on our website Physics for everyone: dydaktyka.fizyka.umk.pl.
To introduce the theme of modern astronomical research we recommend a visit for example in NCU Observatory in Piwnice near Torun. Learning astrophysics might be started there by meeting an instrument that led to the pioneering work in this field. It is the Draper telescope, which over a hundred years ago made photographic overview of the whole northern sky stars' spectra. The photographic plates themselves would not have any significance however, if there would not be added the strenuous, painstaking, long-term work of Mrs. Annie Jump Cannon on the HD catalog, including identification of the spectra of more than 225,000 stars.
A great impression on visitors of Piwnice observatory makes the biggest Polish optical telescope with a mirror diameter of 90 cm. This instrument being worthy heir of Draper telescope, is capable of acquiring spectra of stars already in the modern, digital and automated way.
We also have the opportunity to stand under a giant 32-meter radio telescope antenna, to think a while about the vastness of the universe, to which view modern radio astronomy research has greatly contributed.

8.7. Living on a rotating planet

Discussing the Earth's place in the universe it is tempting to describe the phenomena observed in the sky from the perspective of a rotating planet orbiting the Sun. We can find such a description in "Modern Physics" by G. Karwasz and M. Wiecek (ZDF UMK 2012). In this section we trace some examples from this publication which demonstrate acquiring knowledge based on everyday experience and observations of the world around us. The authors start from well-known phenomena - sunrise and sunset and the sun wandering the sky - to present interesting and not always emphasized differences in Sun's appearance or apparent motion in the sky in the northern and the southern hemisphere, e.g. sundials - see photo below.

Fot. 4.2. Słońce, widziane z półkuli południowej zatacza na niebie łuk w „odwrotnym" kierunku: ze wschodu na zachód, ale w samo południe wskazuje geograficzną północ; zegary słoneczne w parku w Sydney mają odwrotny niż w Europie porządek godzin – liczby rosną w kierunku przeciwnym niż na tarczy zwykłego zegara

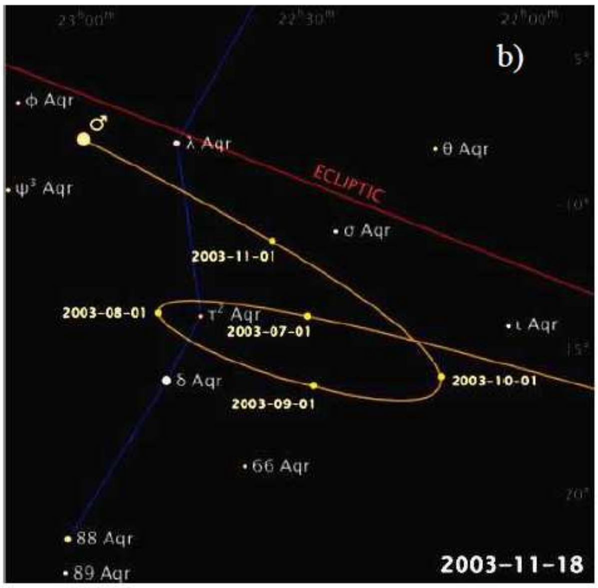
Somewhat less frequently we have the opportunity to see that what is obvious for the day, is going on well during the night. Although many students usually realize that the moon, like the sun, rises, goes higher and then gradually decreases, a similar conviction regarding the stars is not so common. Therefore, we use a photo of the night sky made with a stationary camera to demonstrate the effects of the Earth's rotation as traces (arcs) left by the stars - the longer, the farther from the pole the star is located. The changing position of the Big Dipper relative to the Polar Star and the horizon forms the basis for the development of "star clock" for determining the approximate time based on observations of the night sky.
The authors of the textbook "Modern Physics" have also pointed out the important fact having numerous consequences, that all the planets (and the Moon) orbit the Sun in approximately one plane. The annual cycle of the Earth results in an apparent shifting of the Sun along the ecliptic. Its name is derived from the Greek word for eclipse. Not every month brings this type of phenomenon in the Earth-Moon-Sun system. The reason for this is the fact that the plane of the Moon's orbit is inclined to the ecliptic plane at an angle of approx. 5 degrees, so not every full moon is accompanied by a lunar eclipse, and not every new moon is associated with a solar eclipse. A similar regularity also applies to the planets, for example Mercury and Venus can transit the solar disk, but they do not make it every time; on the contrary - transits of the planets are rare events (see below).



Do tranzytu dochodzi, gdy jedna z planet wewnętrznych (Merkury lub Wenus) znajdzie się pomiędzy Ziemią a Słońcem. Tranzyt planety Wenus zachodzi okresowo co: 8, 105, 8, 121 lat. Ostatni tranzyt Wenus obserwowany był w 2004 r., kolejny w 2012 r., następne będą w 2117 r. oraz 2125 r.

Fot. 4.12 Tranzyt Wenus na tle tarczy słonecznej godz. 6:25, 6/6/2012, Monte Bondone, szer. geogr. 46°N, foto Ch. Lavarian. Wenus to plamka w górnym prawy rogu, pozostałe ciemne punkty to plamy słoneczne. Linia przerywana to położenie ekliptyki (przy Słońcu wschodzącym)

While explaining the movement of the Earth and the Moon it is worth referring to daily observations of our natural satellite. Fairly well-known facts - Moon phases, the movement among the stars in the sky, the ability to observe the same side constantly – all is explained by the changes occurring in the Sun - Earth – Moon system; we should also highlight Moon’s importance for the stability of the Earth's rotation axis tilt, and thus Earth's climate. It should also be noted that the ability to watch one side of the moon does not mean that it does not rotate, but only that it is a rotation synchronous with the motion around the Earth. It is worth noting that not always in the distant past that has taken place and the influence of the Moon on the Earth still continues, which in the very distant future may lead to a synchronous rotation of both bodies (e.g. similar case: Pluto-Charon system).
Other facts, particularly important for the development of astronomy, but also for the view of our place in the universe, are associated with observations of planets - their appearance and position in the sky (see below).



Fot. 4.14. Dwa dowody na prawdziwość teorii Kopernika: **(a)** fazy Wenus[14], zaobserwowane po raz pierwszy przez Galileusza; **(b)** zapętlona (jeśli widziana z Ziemi) trajektoria Marsa na niebie[15].

Observations of this type are admittedly a little more difficult, they also require a longer time perspective. They allow, however, to appreciate the merits of our great astronomer Nicolaus Copernicus in building a new image of the solar system and awareness of the Earth's place in the Universe.

8.8. Astronomy in the computer

In the remainding part of this chapter we will show how useful tool the computer might be in the development of astronomical interest. Some recommended sources will demand using the Internet, but even the computer not connected to the network can greatly facilitate the presentation or explaining many phenomena. We begin with a short presentation of selected sites of astronomy, which is a good starting point for deepening your interest. We will present the software helpful in learning the sky and observations of celestial phenomena. We will discuss the selection of online telescopes available, pointing out their possible use. We devote a special attention to computer programs designed for independent experiments and exercises and an interesting educational projects in which everyone can get involved.

8.8.1. Internet astronomical sites

To start, let us mention some notable Internet sites:

- Astronomia.pl – www.astronomia.pl
- Educational service of PTA, Orion – www.pta.edu.pl/orion
- Portal to the Universe – www.portaltotheuniverse.org
- Heavens Above – www.heavens-above.com
- „Urania – Postępy Astronomii" – urania.pta.edu.pl
- „Astronomy" – www.astronomy.com
- „Sky & Telescope" – www.skyandtelescope.com
- International Astronomical Union – www.iau.org
- Hubble Space Telescope – hubblesite.org
- European Southern Observatory – www.eso.org
- Virtual Universe – www.wiw.pl
- Astro Vision – www.astrovision.pl
- Astronomical Picture gallery – gallery.astronet.pl
- Astrohobby.pl – www.astrohobby.pl

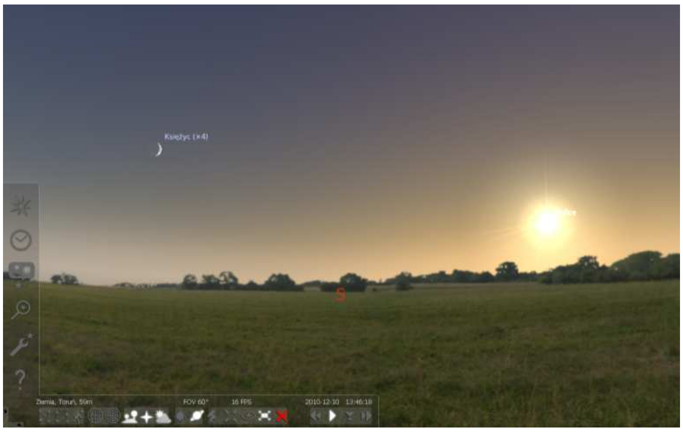
Virtual adventure with astronomy of an average user typically is started by entering the word "astronomy" in a search engine. It is worth noting that this discipline is one of the few examples where such automatic search does not direct us right away to Wikipedia, but to the Polish Astronomical Portal astronomia.pl (www.astronomia.pl). Portal is active since 2001 (now no longer fully updated), and its mission is to popularize science about the Universe and other as widely as possible. The website is primarily addressed to school children, students and amateur astronomers. Coordinated by astronomers and under the patronage of PTMA it puts a reliable knowledge administered in the most approachable way. On the home page one finds links to interesting sections, descriptions of celestial phenomena, ephemeris, but also a whole range of forms of social networking – users' forum, astronomical chat, tips and questionnaires. There is a place for a general description of astronomy as a science, its history and group of objects (planets, stars, galaxies), guidance on observation and instruments (heaven for beginners, astronomical diary, maps of heaven, information on binoculars, telescopes, photographing the sky), as well as extensive additional literature and further guidance in education (astronomy in school, studying astronomy) and even astrojokes.
Wikipedia (while maintaining a little reserve) is also a good source of ordered knowledge, making it easy to find information on the topic that interests you, reach out to the details and move in cyberspace through hyperlinks.
Among Polish-astronomical sites worth mentioning there is Orion Service of Polish Astronomical Society (the organization of professional astronomers): www.pta.edu.pl/orion We find there the current astro-news, a calendar of events in the sky, information about the bi-monthly "Urania - Progress of Astronomy " magazine, interesting and instructive exercises in astronomy, we are also given the opportunity to ask questions to astronomers.
If using English is not a problem for us (and it is almost a natural tool for most young people), it is web meeting with astronomy begin on the Portal to the Universe (www.portaltotheuniverse.org). This is a site created during the International Year of Astronomy 2009, which in a modern and condensed easier start in different topics and aspects of space science. In addition to traditional astro-news we find there, among other things: 3 pictures of the day (amateur, astronomy and NASA), and 2 photos of the week (from the Hubble Space Telescope and the ESO observatory in Chile - it is worth noting that, through these links we get access to the rich archives containing many thousands of photographs and described by professional astronomers), information, animations and pictures showing the actual appearance of the sun, moon and planets. With this site, we can notice unusual objects and phenomena - comets, auroras, International Space Station appearances (by the way, we get to the very interesting and offering additional opportunities page *Heavens Above,* www.heavens-above.com), get the information about the asteroids near Earth and the current state of the discoveries of planets outside the solar system (a link to the Encyclopedia of Extrasolar Planetary Systems). Worth noting is the attention of authors and the project coordinators of keeping up with current global trends, hence the numerous videos, links to blogs, twitter, iPad version etc.
Interesting and rich websites are also offered by magazines - Polish „Urania – Postępy Astronomii" (urania.pta.edu.pl), English „Astronomy" (www.astronomy.com) and American „Sky & Telescope" (www.skyandtelescope.com). You should check websites of various institutions and observatories, for example, the IAU (International Astronomical Union, www.iau.org), HST (Hubble Space Telescope, hubblesite.org) or ESO (European Southern Observatory, www.eso.org). Let us also mention that in already not updated website Wirtualny Wszechświat (www.wiw.pl) we can find the whole contest of two interesting books: The Evolution of Physics by Albert Einstein and Leopold Infeld and "The God Particle" by Leon Lederman.

8.8.2. Software for observing the sky

We will discuss some examples of programs and websites that can be used:

- Virtual planetarium – www.stellarium.org
- Google Sky – www.google.com/intl/pl/sky/
- Google Moon – www.google.com/moon/
- Google Mars – www.google.com/mars/
- Full Moon Atlas – www.lunarrepublic.com/atlas/index.shtml
- Mag7 Star Atlas – www.cloudynights.com/item.php?item_id=1052
- Simbad database – simbad.u-strasbg.fr/simbad/

Nicolaus Copernicus in the preface to his work *On the Revolutions of the Celestial Spheres* wrote: "What could be more beautiful than the sky, which, after all embraces everything that is beautiful." In today's world, especially in the cities, it is difficult to find a place that offers a breathtaking view. One does not always have the ability to quickly organize a trip to the planetarium. Meanwhile, even in the school laboratory, using the projector connected to a computer, we can offer students an interesting presentation of substitutes for the real sky, and the phenomena that take place therein, through many astronomical type programs of virtual planetarium, for example Stellarium (www.stellarium.org). This program is free of charge, available on any operating system, with beautiful graphics. It demonstrates a realistic appearance of the sky we can see with the naked eye or with binoculars or a telescope. The following brief description of the program is for the currently available version 0.10.0. After installing and starting the program we can watch the sky above the selected point in a given time.



Screenshot of the Stellarium program - daily sky and toolbars.

When you first use it, likely you will see the sky over Paris, as the program is prepared by the French author, but we can very easily make your own position. For example, the F6 key opens the location window where you need or click on the map or select your city from the list of cities in the world, or manually enter the coordinates.

In the lower left corner of the screen there is a status bar that displays the current position, the size of the field of view (FOV), the graphics performance (FPS) and the date and time. The remaining part of the screen is the image of the landscape and the sky. If the time and location of the user falls for the night hours, we see the stars, planets and the moon in their current setting; during the day the sun appears and possibly the moon. To change the viewing direction (default from the South), you can drag the mouse cursor across the sky, or use the arrow keys on the keyboard. With PgUp / PgDn keys (or mouse wheel) we zoom in / out. If the cursor is moved over the status bar, the latter comes out in the form of the taskbar, which allows easy control of selected tools of the program.

When you run Stellarium, date and time in the program are set up in accordance with the system clock on your computer, and the time begins to flow in a natural pace. However, the

possibilities of the program are in this respect much richer. We can decide ourselves how quickly time will pass, and even which way! To begin, let's try going into the future. Let's look at the rate of time passing buttons on the right side of the lower toolbar. When you put the cursor over the buttons, notice that a brief description of its purpose and keyboard shortcut appears on the screen. Let's use the right button Increase the rate of time passing. After a single click you cannot see much difference. However, if we look at the clock on the status bar, you'll see that it shows the time change at an accelerated pace. After the second click, the rate increases even more. If we look carefully, we should see the movement of the sun or the stars in the sky - due to the Earth's rotation. After the third click, these changes become evident, and time really is running out! As in the time-lapse movie, we see accelerated sunrises and sunsets and wandering stars in the night sky. Similarly, repeatedly pressing Reduce the rate of time passing, we can take a journey into the past.
Let us return to the normal speed of time (or the present - 2nd or 3rd button from right on the taskbar). To direct the gaze - or center of the screen - on any object, you can select it with the left mouse button and press the spacebar. Using the / key additionally brings us closer to an interesting object. Stellarium is more than just the stars in the sky. The figure below shows a selection of graphics and visual effects, such as drawings of constellations, the planets' names, lightening the atmosphere around the moon. The buttons on the taskbar allow you to turn them on and off.

Screenshot of the program Stellarium - selected graphic effects.

When we approach the cursor to the lower left edge of the screen, a second taskbar pops up. Its buttons open dialog boxes that enable the continued operation and configuration of the program. We encourage you to familiarize yourself with them, we ensure that after several attempts students will be able to recreate the appearance of the sky at any time and place. It depends on the imagination and ingenuity of the teacher or supervisor for what this program will be used. We can only suggest some selected applications:

- stars - basic information about the magnitudes, distances, colors; constellations of different cultures, legends about the constellations;
- day and night in different places on Earth; observations of sunrises and sunsets and its ascendancy;
- demonstrating the effects of the Earth's rotation - the apparent daily motion of the sky at different latitudes;
- annual change of the position of the sun above the horizon, changing the appearance of the sky - selected effects of the Earth's movement;
- movement of the Moon around the Earth - changing the position and phases of the moon, stars occultations;
- solar and lunar eclipses, discussion;
- observations of the planets - their finding, tracking, hiking, looking through binoculars and telescopes: the phases of Venus, the moons of Jupiter, the rings of Saturn;

- presentation of the sky from the surface of the moon and other solar system bodies;
- The Sun as a rotating star, sunspots;
- nebulae and star clusters - the birthplace of other suns and the final stages of their evolution;
- The Milky Way and other galaxies - islands in the Universe.

There might be of course much more useful applications of the program. With a little practice this type of program is almost inexhaustible source of enrichment of knowledge and passion for astronomy - the name "virtual planetarium" is therefore fully justified.
In addition to programs such as the planetarium we have a simple and user-friendly interactive pages that allows to explore the sky or the moon and Mars - respectively *Google Sky* (www.google.com/intl/pl/sky/), *Google Moon* (www.google.com/moon/) and *Google Mars* (www.google.com/mars/) – working on the same principle as the widely used *Google Earth* (www.google.com/intl/pl/earth/index.html). Strong educational aspect of these tools is worth mentioning. In the case of Google Sky apart from "normal" wandering across the sky with the one-click change of image scale we can call up the infrared or microwave image of this part of the sky. With the additional tools we can easily navigate among the planets of the solar system or constellations belonging to the zodiac.
Google Moon is a kind of map map based on photographs of our natural satellite (visible side and also invisible from the Earth) with marked landings of subsequent Apollo missions. The ability to accurately look at these places (additional films and animations as well as a description of the mission) is a huge advantage of this site. In the latest version, you can also view the detailed, three-dimensional models of landed spacecraft and lunar vehicles panorama of landing sites, unique footage and listen to stories and comments of the selenonauts themselves. Unusual experience is also provided by tracking very faithfully the reproduced sequence of approach and landing on the lunar surface.
Google Mars is, in turn, virtual exploration of the Red Planet's surface when viewed from the top. We can choose between the views: hypsometric maps, images in visible light and infrared. In additional options, you can browse the various forms of relief, such as plains, mountains, canyons, craters and dunes.
Those interested in learning lunar surface more accurately can find a variety of interactive maps and atlases, for example *Full Moon Atlas* (http://www.lunarrepublic.com/atlas/index.shtml). For advanced observers of the sky not only maps are available, but also atlases, for example *Mag7 Star Atlas* (http://www.cloudynights.com/item.php?item_id=1052), not to mention the public tools used by professional astronomers (eg. Simbad database – simbad.u-strasbg.fr/simbad/), where you can easily find all the information about the interesting object.

8.8.3. Observations with online telescopes

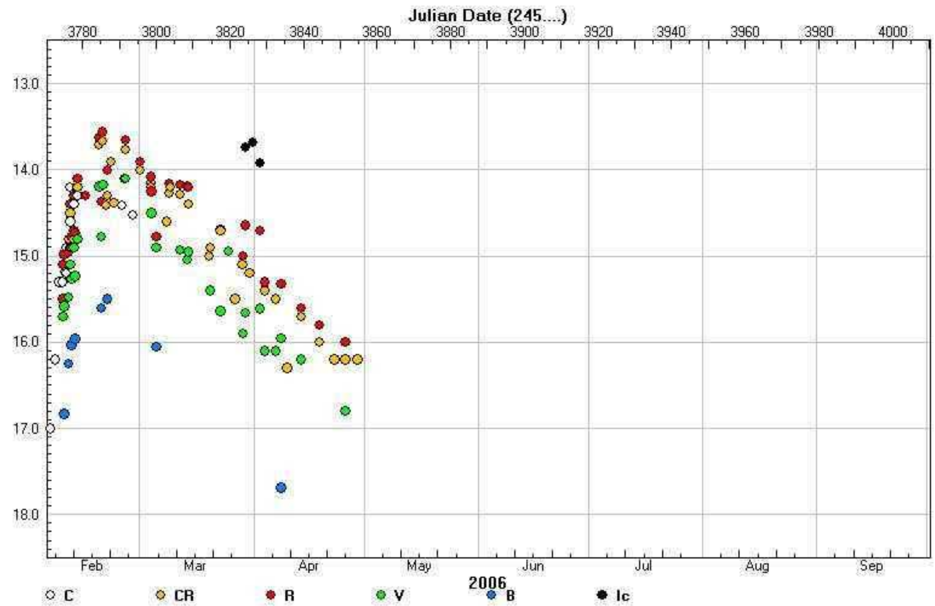
The great attraction of modern computer technology is the ability to use them to direct observations of the sky and recording the images in digital form, and then further processing or analysis. The availability of such tools varies, depending on their capabilities. So far, open for all users is NASA Microobservatory telescope (see below); to gain access to the other Polish coordinator of the EU-HOU prof. dr hab. Lech Mankiewicz from the Centre for Theoretical Physics in Warsaw (e-mail address: lech@cft.edu.pl) can help.
One of the simplest tools is the interactive Microobservatory online telescope, http://mo-www.cfa.harvard.edu/OWN/index.html. It's a small network of 14-centimeter automatically controlled telescopes, owned by the Harvard-Smithsonian Center for Astrophysics (USA), which perform digital photos (with sizes of 500 to 650 pixels) on demand. Anyone can place an order on the selected object photo, and within 48 hours one should receive an e-mail

information about the observations made along with a link to download the file (this should be done within a week - after this time archival observations are removed). Do not be discouraged to the English site (there are instructions in Polish, see the website of EU-HOU: www.pl.euhou.net), the service is really simple, almost intuitive. When you click Control Telescope button, you get to the page “Select your target”. You can choose only from the proposed list of objects, but fortunately it is quite extensive. We find there the objects of the solar system, stars, nebulae and galaxies. After this selection only a few more steps (separated by clicking the button Continue) separates us from obtaining your own images of the celestial objects! In the first step, we learn more about the object itself. In the second step we set the exposure time ourselves. This is in fact just an interactive fun, because once we choose the incorrect time, we get a message that the picture will be underexposed or overexposed. If you have done it correctly, and confirm your choice, you will be asked to give brief information about you: how old (range) are you and where do you live (state or outside the United States), and enter your e-mail address, on which information about the shooting will be sent. After confirming the correctness of the data only to wait remains. And indeed, everything works! Though you will not always get beautiful and successful image, because Microobservatory is photographing the night sky all the time, regardless of the weather. It happens so that your request should be repeated. But this only adds fun and attraction!

Great interest of Polish students and teachers deserves a project shared EU-HOU: optical telescopes controlled over the internet. Most emotions aroused by the possibility of using the powerful 2-meter telescopes of Las Cumbres Observatory Global Telescope (LCOGT) in Hawaii and in Australia (www.faulkes-telescope.com). It was thanks to prof. Lech Mankiewicz, the director of the Center for Theoretical Physics in Warsaw and the Polish coordinator of EU-HOU project, Jan Pomierny from Astronomia.pl portal and courtesy of the British Council students from initially five (ZST Grudziądz, MOA Niepołomice, I LO Olsztyn, V LO Toruń, ZSO nr 7 Szczecin), and now eleven schools (j.w. oraz XXVII LO im. Czackiego Warszawa, V LO Kraków, Publiczne Salezjańskie LO Kraków, Zespół Gimnazjów nr 3 w Dzierżoniowie, Zespół Szkół w Bełżycach, Planetarium w Łodzi, Olsztyńskie Planetarium i Obserwatorium Astronomiczne) in Poland as the first in Europe may, from September 2005, use these extraordinary devices. The author was lucky enough to be, with the group of V LO in Toruń students, among Faulkes (the name given in honor of the founder) telescope users from the outset. Since the observations are held in half-hour sessions, we have received time for five such sessions during several months. The huge telescope (the largest in the world, which can be used not only by professional astronomers) is the ideal tool for exploring and observing the so-called deep space - a world of star clusters, nebulae and galaxies. This type of objects could be observed by Polish schools students, and the British telescope team emphasized the excellent quality of these images (resulting from careful and perfect preparation) from the beginning.

Very soon came the idea of tracking supernovae. The first pictures done in Toruń at the beginning of November 2005 (it was SN 2005ip discovered a few days earlier) also encouraged remaining Polish schools to cooperate. After a few weeks, the first effects were seen (photo below).

Image of NGC 3938, 2005ay supernova is still visible (more than 8 months since the outbreak). The picture was taken in the V LO school in Torun, December 1, 2005.
We have seen that 2-meter telescope with a CCD camera and a set of color filters at roughly 60-second exposure allows you to tap into about 20th magnitude, which allows you to track changes in the glow of supernovae for several months after the explosion. Of the 500 schools - telescope users - we were pioneers in this field, which aroused great scientific recognition by project director Dr Paul Roche of Cardiff University. Other Polish schools also had the opportunity to show off their achievements (including e.g. project concerning the Hubble classification of galaxies, and study of the spatial extent of galaxies) during the session concluding the first months of the presence of the program in Poland, which was organized by the British Council in Warsaw on February 1, 2006. Session was graced by the presence of Princess Anne and the Minister of Education and Science, and later Minister of Science and Higher Education, prof. Michał Seweryński. Distinguished guests were impressed by the excellent quality of the work of Polish students in the project and their proficiency in the English language.
A few days after the meeting in Warsaw, supernova 2006X in bright spiral galaxy M100 was discovered. It was an opportunity that encouraged British participants to observe with Faulkes telescope and perform independent analysis of the object. SalsaJ astronomical image analysis program (available for download at www.pl.euhou.net) developed by astronomers in the EU-HOU framework provides, inter alia, the implementation of a fast and simple way of photometric measurements. Thus after a few weeks, a beautiful supernova light curve was obtained, observed even before maximum brightness.



Measurements of the supernova 2006X from M100 galaxy brightness in the

period February - April 2006, on the basis of photos taken with Faulkes telescope.
In recognition of the results achieved by Polish schools additional telescope users were added. The effects of using Faulkes telescopes are already noticed in the astronomy enthusiasts environment in Poland. Students have used it to prepare presentations for the National Youth Astronomy Seminar, whereby it must be emphasized that their success depends not only on the accessibility of tools offered by the EU-HOU program, but their work and passion for exploring the Universe, which thanks to them it is more easily to pursue.

8.8.4. Programs for experiments and exercises (simulators, exploratoria)
Recommended Internet resources:

- Exploratorium – www.exploratorium.edu
- Interactive simulations – phet.colorado.edu
- Open Source Physics – www.opensourcephysics.org
- EU-HOU Poland – www.pl.euhou.net
- Contemporary Laboratory Experiences in Astronomy (CLEA) – www3.gettysburg.edu/~marschal/clea/CLEAhome.html

In recent years, also in Poland, many interactive learning centers have arised, for example, Copernicus Science Centre. The first such place was organized in 1969 in San Francisco. The website of this institution (www.exploratorium.edu) is worth visiting to familiarize with it and possibly to use Internet tools prepared there. In addition to learning the secrets of the starry sky (Planetarium) one can be read with a simple idea to use paper clips stuck to the globe as an illustration of changing the length of the shadow cast by objects during the year at different latitudes (Seasons and Shadows) and constructing model explaining seasons (Modeling the Seasons) . An interesting idea is to convert your weight and age measured on Earth with the corresponding values on other planets (Your Weight ... and Your Age on Other Worlds). By the way, we are reminded (in explanation) law of universal gravitation and Kepler's laws. In The links one in particular should pay attention and use the topic Build a Solar System - it is interactive and very easy to use tool for comparing: giving the sample size of the Sun, we get in the adopted scale the sizes of all the planets and their distance from the central star. This is in itself a very interesting and educational tool, besides perfectly useful to build a real model of our solar system (or its selected items) in the school classroom, the hallway, the schoolyard or outside. By the way (under the Planets table) we have the opportunity to compare the size of the Sun with other stars and the distances to them and to the center of our Galaxy.
A useful site, helpful in illustrating and exploring the many natural phenomena and processes is the webpage of University of Colorado at Boulder interactive simulations, http://phet.colorado.edu. Although its main site is not available in Polish language version, the majority of the simulations is translated. Just press Play with sims to be convinced, how rich and diverse is the offer - we can move on the page presenting simulations recently added, on the left side at the top you will find links to the different areas of nature (physics, biology, chemistry, geography, mathematics), we can also choose the age range of interest to our students. When you click on a selected topic (or its icon), you get a list of available languages, we can now (or previously) run the applet (Java must be installed on your computer) or save it on disk. Great fun awaits us, not to mention the benefit flowing from the self-control experience and the possibility to analyze the effects of the changes.
A similar nature, but requiring a bit more browsing (please look at Browse materials!), have programs prepared by the project *Open Source Physics*, http://www.opensourcephysics.org/. In the field of astronomy, you'll find, among other things:
• excellent illustrations of historical models of the Solar System (geocentric and heliocentric);

• illustrated example of how observations of the Venus phases by Galileo excluded Ptolemy's model;
• analyze the conditions for the eclipses;
• binary systems analysis and star systems with a planet, or how we discover the presence of distant planets today.
A little more effort demanding, but also proportionately larger effects expected is the use of exercises based on original observational data or simulations of simple observations. In the first case, we encourage you to familiarize with the offer of EU-HOU Poland (www.pl.euhou.net). In the context of the issues discussed here it will be easiest to use the exercises link on the left to go to the site of the proposed themes of issues, for example: Planet Earth, Our Solar System, Milky Way, Local Group of galaxies and the universe. The exercises are inspired by the research, and have been prepared by scientists and designed and tested by teachers from the partner countries. The purpose of these exercises is not a transfer of comprehensive knowledge of astronomy, but rather to mobilize students to discover what the scientific work is, and how to take and interpret data in physics and mathematics. Each topic is a few or a dozen exercises (most of them have instructions in Polish, are also downloadable as a pdf file) and source material - usually a set of photos taken at one of the observatories. Their development is usually based on using SalsaJ (also downloadable from the EU-HOU - Software): multiplatform and multilingual tool for processing and picture analysis at school. Let us list some issues typical for modern astrophysics, which thanks to the EU-HOU project are understandable to everyone, often surprisingly simple:
• How to measure the radius of the Earth in summer at the lake?
• Discover the moons of Jupiter!
• The black hole at the center of the Milky Way
• How do you measure the universe: the distance to Cepheids
• How do we know that the universe is expanding?
• In the trace of extrasolar planets
We encourage you to familiarize yourself with these and other proposals, as it is actually excellent starting point for further independent research and study for the people interested in the world (and the universe) around us.
Some additional exercises based on real astronomical data, allowing a look at the methods of contemporary astronomers work, can be found at the Educational Service Orion http://www.pta.edu.pl/orion/astroex/exercises.html. This is the translation of materials prepared by the European Southern Observatory (ESO), dealing with the observations made with the largest telescopes, including the Hubble Space Telescope.
It is impossible not to mention the project *Contemporary Laboratory Experiences in Astronomy* (CLEA), developed for many years by Gettysburg College in USA (http://www3.gettysburg.edu/~marschal/clea/CLEAhome.html). It aims to present modern astronomical techniques (digital observations) and their use to enrich our knowledge about different objects. Each exercise is a separate computer program running in a Windows environment, equipped with clear and comprehensive instructions for the administrator and the user. Most of the tasks are carried out in two stages - collection of observational data (simulation of operating the optical or radio telescope, operating in different atmospheric conditions) and their development in terms of the result which interests us. Cross section by the subject, and therefore by the level of complexity of tasks happens here to be very extensive and certainly everyone will find inspirational topics. Let's give some examples:
• Radar measurements of the rotation period of Mercury
• Jupiter's moons and the speed of light
• H-R diagrams for star clusters
• Radio observations of pulsars

• Large-scale structure of the Universe
It is worth noting that every exercise brings simple, but concrete results. We have the opportunity to compare the result obtained with the literature and discuss possible sources of measurement uncertainty. By the way we learn the methodology for a wide range of astronomical research.

8.8.5 Educational projects

Recommended Internet resources:

- Galaxy Zoo – www.galaxyzoo.org/?lang=pl
- Cosmology@home – www.cosmologyathome.org
- Einstein@home – www.einsteinathome.org
- SETI@home – setiathome.berkeley.edu
- PlanetQuest – planetquest.jpl.nasa.gov

Internet projects can broadly be divided into the active or passive participation involving.
Active participation is based on joint work and is to provide, organize, classify, or search specific information. This type of projects may include, among others:

- Wikipedia – encyklopedia developed by volunteers;
- DMOZ – Open Directory Project – www pages catalogue;
- Galaxy Zoo – astronomical project in which participants classify and compare galaxies based on images taken automatically with 2.5-meter telescope of the Sloan Digital Sky Survey (in the latest edition also with the Hubble Space Telescope). More than 250,000 people already participated in the project, of which more than 10,000 were Polish! We can boast Polish language version: http://www.galaxyzoo.org/?lang=pl. The huge database is established, and the telescopes on Earth and in space are addressed by user findings. We can learn surprising things about the nature of galaxies. For example, formerly astronomers assumed that the galaxy looking red is probably an elliptical one. With the help of Galaxy Zoo users it was found that roughly one third of red galaxies are spiral galaxies! It was also found that blue elliptical galaxies are more common than we thought, which include also a small but significant proportion of galaxies forming a number of new stars - sometimes up to 50 times higher than the number of stars born in our galaxy.

Passive participation is based on the free sharing of computing power of your PC connected to the Internet. Typically, such a project is to use computing power to implement the tedious and time-consuming calculations necessary to solve the problem. This group of projects is embraced by a common name BOINC (*Berkeley Open Infrastructure for Network Computing*; see http://boinc.berkeley.edu/projects.php). There are more than 100 different projects, including several in the field of astronomy (e.g. *Cosmology@home*, *Einstein@home*, *SETI@home*, *PlanetQuest*).

- *Cosmology@home* – the project was established at the University of Illinois, it may contribute to a better understanding of the nature of the universe. Its purpose is to search for the model that would describe the universe in a best way, and find a group of models compatible with the available astronomical data and the physics of elementary particles. Users calculate predictions of millions of theoretical models described by different combinations of parameters. The calculation results are compared with all available data. In addition, the project can facilitate the planning of future observations and experiments and analysis of the resulting data (e.g. Planck satellite).

- *Einstein@home.* According to the theory given by Albert Einstein gravitational field changes cause changes in the curvature of spacetime. The simplest way to detect this phenomenon is through measuring continuously the distance between two points. Gravitational waves passing near, cause small changes in the distance. For this purpose, laboratory GEO 600 was built near Hanover in Germany, and LIGO laboratories in Louisiana and Washington, USA. To measure the distance scientists use very long, perpendicular laser tracks (600 m in GEO 600, and approx. 4 km in the LIGO) in these three labs. With such a considerable length it is possible to measure changes in the distance of the order of one millionth of the diameter of a hydrogen atom. Project Einstein @ home aims to explore data from all three laboratories for the detection of gravitational waves produced by rapidly rotating neutron stars, or pulsars.

- *SETI@home* – project brings together surfers to find alien civilizations. The participants of the project process the data received from radio telescopes around the world in the hope of finding a "cosmic radio noise" structured signals that could be a carrier of information transmitted by extraterrestrial civilizations. Currently, the SETI project – although it still cannot boast any real achievements - has more than two million volunteers and is the largest project of its kind.

- *PlanetQuest* – project aims to search for extrasolar planets by optical observatories. It is not possible to observe the planets directly. The search is based on attempts to detect the shadow cast by a planet passing through the shield of its stars, and more specifically - the characteristic "blinking" of a star (transits) caused by planets orbiting it. In the current phase, the project operates on the basis of the Kepler mission and deserves a little closer discussion.

Kepler Space Telescope was launched into orbit in 2009; its instrument is a mirror 95 cm in diameter, whose main objective is to determine the frequency of planetary systems in the universe and the diversity of their structures.
Browsing the mission website http://www.kepler.arc.nasa.gov/, we enter the forefront of astronomical research. Extremely user-friendly interface encourages self penetrating a particular topic, for example: Significant discoveries, How Kepler finds planets?, Mission, Science, Education. In the last section you will find many ideas and inspiration to work with students – it is really worth looking more closely at this offer (we recommend the *Planethunters* project, www.planethunters.org).
We should also discuss another useful and extremely instructive fun and learn feature, available in the Multimedia section - Interactives: Kepler Exoplanet Transit Hunt. It's only a simulation, but very suggestive and educationally well divided on next steps procedures. Below are step by step instructions; it is quite long, but - as the simulation are in English - we would like to make it simple and understandable for everyone. This may be treated as a lesson outline of astrophysics in high school: Finding the distance of "discovered" planet from its parent sun - simulation based on the results of Kepler space telescope.
After you click, you open a window with the text of the welcome and invitation to drag the mouse over the visual field of a "telescope" on the flashing star. The magnification explains the idea of transit and applied research methods. After clicking Next we see part of the sky dotted with stars, some of them "blink" in a characteristic way - are also marked with additional information about the spectral type (our Sun is of G2 type, hotter than this are types A and F, cooler - K and M). We can choose any star - click to open a screen with information about it, namely table with the statement of spectral types and their corresponding masses, radii and surface temperatures (all the stars belong to the main sequence, hence this unique

assignment). The selected object is distinguished by color and now drag the appropriate figures to notepad in the lower part of the screen (where the same color code is used to facilitate the procedure and prevent mistake). When you click "Next" it is time to prepare for the observation. Our task will be to record the "winking" of a star by green button "Record blink", after you run the simulation by pressing "Start". Of course, we will respond with some delay, but it is not important in the entire procedure. After a few "winks" (for the light curve, which runs almost horizontally, the vertical bars appear), our task is to determine the period of the emergence of these "winks" and their depth (it is set automatically according to the actual observations - we only read the value as the percent decrease in brightness). To make it easier both axes (horizontal: time and vertical: brightness) can be dragged with the mouse to the right place at the light curve. The value we read should be written in the notebook at the bottom (blue frame for period, a decrease brightness - in yellow) and click "Next". Now we must determine the distance of the "discovered" planet from its parent sun. Once again, enter the value of the period to the blue box. If you press the "Calculate" driven by impatience, the program will encourage us to a moment of thought, to read the comments (this is in fact the reminder of the third Kepler's law and the rules for using it), and to implement the conversion (Convert) of days to the part of the year, so to get a result in astronomical units (AU). This time - if you do not forget to specify the mass of the star – we get extremely valuable clue, as compared to our Earth in the solar system (because this is 1 AU), how the orbit of the planet is located. In general, we obtain a fraction of AU (this is partly the effect of selection, resulting from short-time application of the methods of discovering planets, but also a huge surprise - that in extrasolar systems planets may revolve around its parent star in orbits much tighter than, for example, Mercury around the Sun) and we rewrite the value to the notebook. After clicking "Next" we get the answer to a very important question: have we discovered planet prevailing conditions enabling origin of life (as we know), i.e. whether the liquid water can occur on it or not? The basic of this condition (necessary but not sufficient) is to find planets in the so-called ecosphere, or appropriate distance from its parent sun. The illustration of this range of possible distances is highlighted by blue belt. We have just to make sure that the correct figure refers to the star (at the beginning there are data for the Sun, but just click on the image of the star or to change the temperature). Our task now is to shift the planet to the right, previously designated distance (you can move or the planet itself, or the slider to select a numerical value). After successfully setting the stars and shifting we get a message "You got it!" and we will be asked to enter the answer to the above question, by writing letters respectively Y / N (yes/no), and click "Next". Then we calculate the characteristic temperature of the planet, depending mainly on the temperature and the size of the sun and its distance. Drag the relevant data, press "Calculate" and rewrite the result to the notebook. After another "Next" we calculate now (based on the size of the star and the amplitude of brightness) the radius of the planet compared to the Earth. Other screens is already a real treat. At first we get a graphical comparison of "discovered" planet with the Earth. On the next - the artistic vision of its surface (and even more importantly - the name of the actual object whose discovery helped to create this very interesting example). We can now choose another star and have fun, and learn again...

Summary

The proposal presented in this chapter describes the issues of teaching astronomy that have been developed basing on years of the author's experience, gained both from the practice of teaching Physics and Astronomy at high school and numerous teaching experience gained through working in the Department of Physics Education of NCU. The latter experience consists of classes conducted for students of NCU connected to the preparation for the teaching of physics and astronomy, numerous lectures with live demonstrations and presentations during the festival of arts and sciences, the nights of scientists, shows prepared by the DPE of NCU. Naturally, this set of issues is not exhaustive, it is only a scratch of contemporary issues and methodology on teaching the subject.

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IX. Computer Based Physics Laboratory [82]

9.1. Introduction

During the laboratory classes in the Computer Based Physics Laboratory students perform computer-aided experiments in physics in an innovative and efficient. For each class perform one exercise with a set of measuring Pasco, Logit or CoachLab, and after its completion they write a report which contains tables, charts, calculations, problem questions and content to take account of social competence.

The big attention is paid to the fact that students understand the role of physical experiment in the methodology of scientific research and are aware of the limitations of technology, for apparatus and methodology in contemporary research. Very important is also the knowledge of the basic laws of classical physics and quantum physics, and having knowledge of the basic components of matter and the basic types of interactions between them. During the course are also used computational methods of classical physics and quantum physics. Students acquire knowledge of current developments physics education and information and communication technology, particularly used in physics class.

Acquire the skills to perform basic measurements of physical quantities of classical physics, are able to develop and present the results of simple physics experiments in the form of reports and computer simulations. They acquire the skills of quantitative estimation of measured values and are aware of the approximations in the description of reality. Among the social skills play an important role awareness and understanding of the social aspects of the practical application of knowledge and skills associated with this responsibility, especially in the development of young people, especially in physics class at school. This allows students understand the need for popularization of knowledge of physical and extracurricular activities.

Computer controlled experiments in physics have four aspects [1]:

1. computer, which is to select an adequate standard of measurement and software for the analysis and presentation of measurement data,
2. physical - when measurements are used various kinds of sensors, for example, position, which uses a specific physical process. In this case, the propagation of ultrasonic waves,
3. electronic - signal from the sensor, for example. Voltage from the piezoelectric sensor is suitably amplified and converted into a sequence of bits transmitted to the computer,
4. teaching - the ability to select those experiments that the computer can perform faster and better present and analyze the results, so we can accurately and efficiently transfer knowledge of physics.

To measure the size of non-electrical transducers must be used, which will process the volume measured at the voltage [2]. In some cases, it is very simple, for example, a microphone converts the acoustic wave voltage. Similarly, a photodiode or a phototransistor can convert light to voltage. With such transducers is enough to make the calibration (calibration), that is, determine the rates, which allows you to calculate the numerical value of the quantity measured by the voltage indicated by the computer set.

Working with modern measuring equipment increases the effectiveness of teaching and motivates students and pupils for independent, often the research work. Enrichment of laboratory classes or lessons in the school of modern means of teaching brings many benefits. Independent or group analysis of the results enables the stimulation of activity among

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students and pupils to think creatively and to seek their own answers, teaches cooperation, discussion and develops the skill of argumentation.

9.2. Computer based study of uniform motion

Kinematics: the positional relationship of the time, rectilinear motion, drawing and analyzing graphs.

The main objective:

Understanding the principle of measuring the position of the moving body with a experimental setup Coach and computer.

Operational objectives:

- Acquisition of the ability to apply measurement console CoachLab II and ultrasonic position sensor for motion studies.
- Acquisition planning skills experiment presenting any motion and uniform motion.
- Learn to properly analyze the experimental data and the physical interpretation of the results.

Equipment and Materials:

- measuring interface Coachlab II or Coachlab II+,
- software Coach 5,
- ultrasonic position sensor,
- computer,
- car with an electric motor,
- table.

Background

In studying the rectilinear motion we accept such a reference system, which will allow the easiest movement description, e.g. axis x peel on the line along which the body moves. Location of the body, ie the coordinate point at which it is located, we set relative to a reference frame, usually the beginning of the x-axis (the axis zero point). Rectilinear uniform motion equation is as follows:

$$x(t) = x_o + vt \ .$$

Graph of the x(t) is a straight line, the position x is proportional to the time t. In the uniform motion of the body the speed is constant. The position of the body in a given time interval can be marked on the chart. The graph is a mathematical picture of the movement of the body. It is therefore important to understand how to interpret a graph of the position of the time.

Prediction and questions

Is it easy for you to obtain uniform motion? Can a person moving in the room can move with uniform motion? Is the toy car with an electric motor can move straight uniform motion on the table? How will change depending on the position graph since if you moved away from the position sensor and the like, when you approached him?

Safety Precautions

Follow the instructions included with the equipment and safety regulations.

Procedure

Sonic console to enter the measuring CoachLab II connect ultrasonic position sensor (entrance is at the rear of the console, Fig. 1). Position sensor CMA (Centre for Microcomputer Applications), like a bat, sends short pulses of ultrasound and record those reflected from obstacles (eg. Car). By calculating the Coach 5 program the time that elapses from the moment of sending the ultrasonic pulse to the moment of registration of his return, it is possible to determine the distance to an obstacle, which determine the position of the measured object. Position values in certain moments are used to calculate the speed or acceleration of a moving object by the program Coach 5.

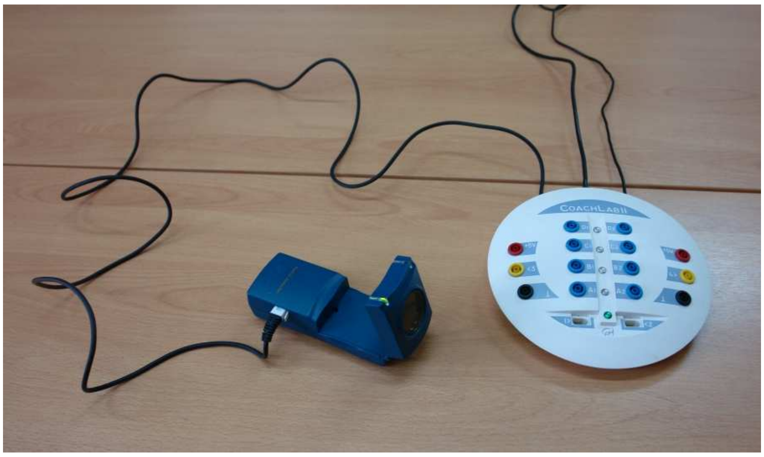
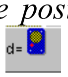


Fig. 1. The picture shows the connection of an ultrasonic distance sensor for measuring console CoachLab II (photo A. Karbowski).

In software Coach 5 select draft measurements in physics, and then load the project entitled *Measuring the position and speed*. By clicking the right mouse button on the icon of the motion sensor  select the option *Present chart*, which will display the chart in Coach 5.

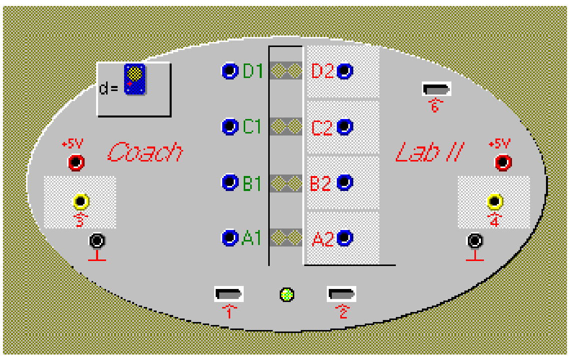


Fig. 2. View of measuring console CoachLab II with motion sensor icon in Coach 5.

1. The study of any motion

Press the green button *Start* on the screen and start a measurement of the position as a function of time. Stray from the position sensor, stop for a moment and start to approach the position sensor. At the same time observe the graph of position versus time x(t) drawn on the computer screen in real time. Please note that the program Coach 5 draws tens measurement points within one second.
An example of the position of the time chart for the above case is shown below:

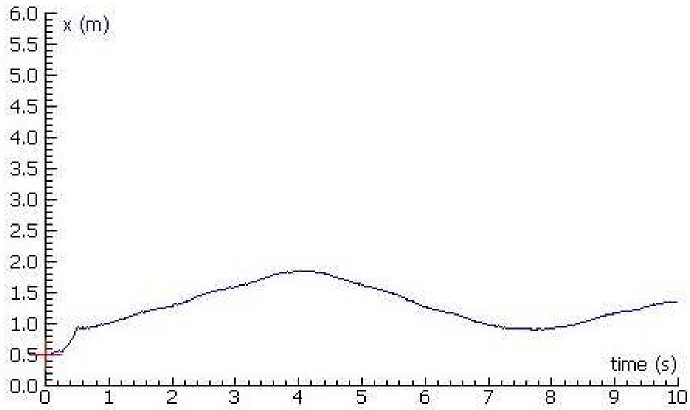


Fig. 3. Graph of body position as a function of time for any traffic.

2. The study of uniform motion

Check if the car battery is moving with uniform motion on the table straight. Make the appropriate measurements and perform an analysis of the movement. Perform a similar measurement for truck moving on a horizontal aluminum rail. Ultrasonic motion sensor place at the beginning of the track.

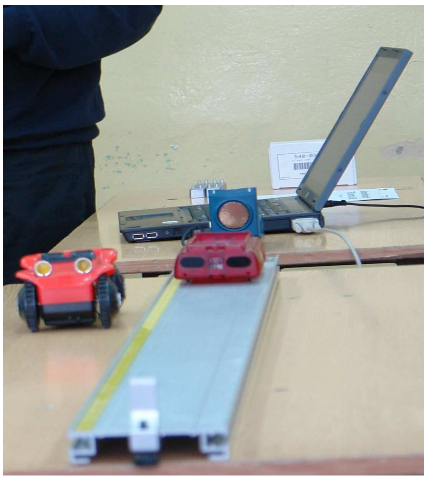


Fig. 4. Car battery (left) moves on a horizontal table and cart on horizontal aluminum track (photo A. Karbowski).

Sample results for this experiment are shown below:

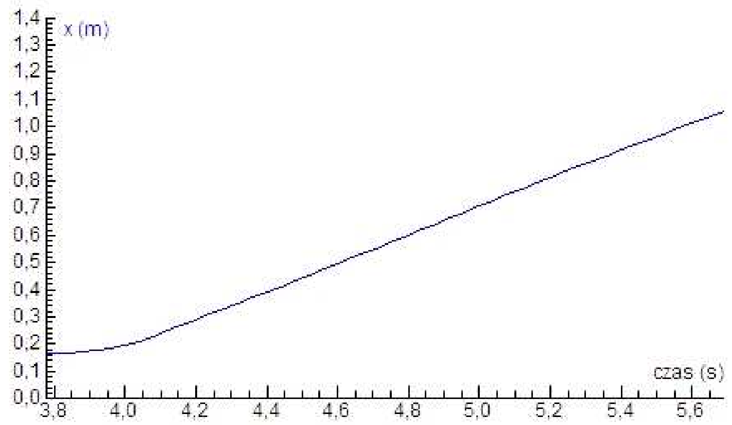


Fig. 5. Chart position of the cart as a function of time for study uniform motion.

The values of the cart position increase proportionally with time and are arranged on a straight line inclined at an angle to the horizontal. On this basis, we concluded that the cart was moving with uniform motion. To make sure of this even better, get a graph of speed versus time for motion discussed using the option (after pressing the right mouse button) *Process* and *Derivative*.

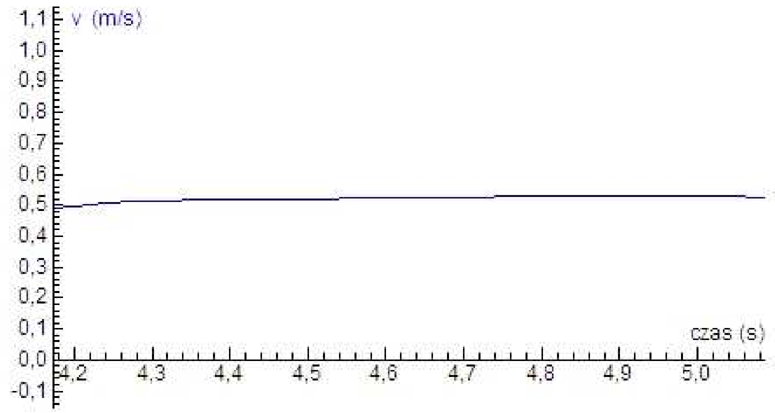


Fig. 6. Chart speed of the truck as a function of time, which is moving on a horizontal track.

Better smoothing of graphs can be achieved using the option *Filter Graph* available by pressing the right mouse button and selecting *Process*.

Analysis and calculations

1. Read from the resulting graph, for any motion (task 1), of which the highest speed instantaneous to moved away from the position sensor, and that approach to him.
2. Calculate the average speed when going away and average speed when approaching the motion sensor. Answer the question, whether we can easily obtain uniform motion as we walk around the classroom?
3. Calculate how fast the car was moving in the task 2. Was it a rectilinear uniform motion?
4. Read from the graph how long it lasted studied the movement of the car and what was the position of the start and end of the car?
5. Calculate the average speed of the car entire the journey.
6. A similar analysis of the results perform for truck moving along a horizontal track.

Discussion of results and conclusions

1. In the event of any movement, we can determine the instantaneous speed with which we move in the room and we can tell what type of movement observed in a given time interval.
2. Studying uniform motion, we can determine the speed at which the body moves, and determine whether this is actually the kind of motion.
3. When you walk in the room to obtain uniform motion for a long time is very difficult.
4. Find the literature examples of the use of measurements of the movement in science and technology.

Literature:

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9.3. Computer study of uniformly accelerated motion

The main objective:

Understanding the principle of measuring the position of the moving body with a experimental setup Coach and computer.

Operational objectives:

- Acquisition of the ability to apply measurement console CoachLab II and ultrasonic position sensor for motion studies.
- Acquisition planning skills experiment presenting the uniformly accelerated motion.
- Learn to properly analyze the experimental data and the physical interpretation of the results.

Equipment and Materials:

- computer,
- interface Coachlab II or Coachlab II+,
- software Coach 5,
- ultrasonic position sensor,
- cart,
- table,
- aluminium track.

Background

In examining the rectilinear motion we accept such a reference system, which will enable the easiest description of motion, for example axis OX peel on the line along which the body moves. The equation of motion for uniformly accelerated linear motion is as follows:

$$x(t) = x_o + v_{ox}t + \frac{1}{2}at^2 \quad .$$

Graph of x(t) is a parabola, which is the position x is proportional to the square of the time t. In uniformly accelerated motion *acceleration* is constant. The equation describing the velocity of the body is as follows:

$$v(t) = v_{ox} + at \ ,$$

while equation describing the position of the body as a function of time, when the $x_o = 0$ m and $v_o = 0$ m/s takes the following form:

$$x(t) = \frac{1}{2}at^2 \quad .$$

Galileo studying the movement of metal balls on a downward spiral discovered that sections of the road traversed in successive equal intervals are to each other as consecutive odd numbers, ie, 1, 3, 5, 7, 9 and so on. This is a mathematical consequence of the above formula, if successive periods of time as renumber n i n+1: $(n+1)^2 - n^2 = (2n + 1)$, or odd numbers.

Prediction and questions

Is moving down cart on an inclined plane moves uniformly accelerated motion? If so, does the acceleration of the cart depends on its mass? Is the acceleration of the cart depends on the angle of inclination equal (aluminum track)? Is falling down book moves with constant acceleration?

Safety Precautions

Follow the instructions included with the equipment and safety regulations.

Procedure

Connect the ultrasonic position sensor for measuring console CoachLab II (Sonic entrance is located at the back of the console). The Coach 5 program, select the project *Pomiary fizyczne*, and then load the project *Pomiar położenia i prędkości*.

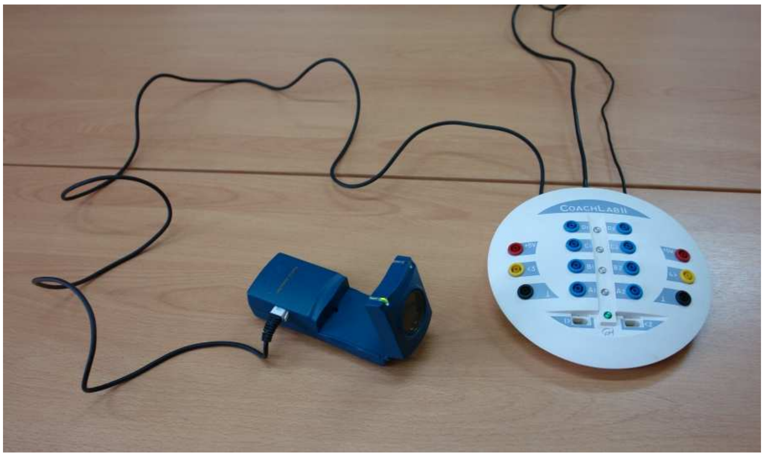
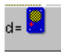


Fig. 1. The picture shows the connection of an ultrasonic distance sensor for measuring console CoachLab II (photo A. Karbowski).

By clicking the right mouse button on the icon of the motion sensor  select the option *Prezentuj wykres* and display the graph window on the computer screen.

1. Investigation of motion of the cart on an inclined plane

Place on top of an inclined plane (sloping table or sloping aluminum track) position sensor and within a few or several inches from his cart. Place the box on the cart well reflected ultrasonic waves.

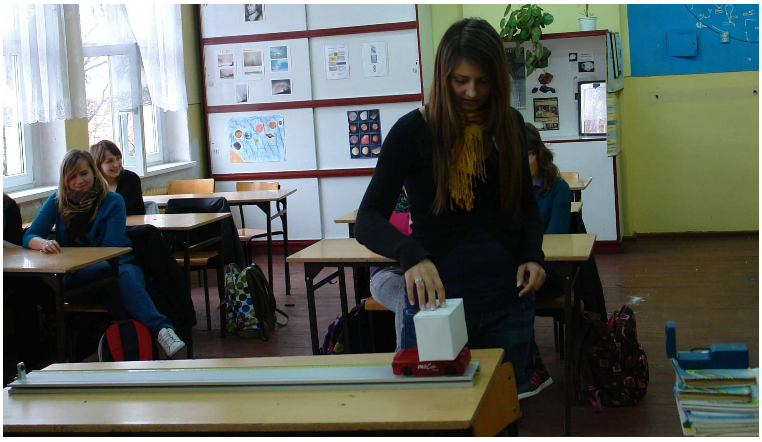


Fig. 2. Cart with box reflecting ultrasonic waves on an inclined plane. Schoolgirl takes experience during physical activities rings in Middle School No. 1 in Chelmza, which conducted the author (photo A. Karbowski).

Press the green Start button and start the measurement of the position as a function of time. At the same time observe the graph of x(t) drawn on the computer screen in real time. Take several measurements for the case when the cart pulls down equally. Get a chart speed versus time for motion discussed using the option (after pressing the right mouse button) *Process* and next *Derivative*. Better smoothing of graphs can be obtained using the option *Filter Graph* available after pressing right mouse button and selecting *Process*.

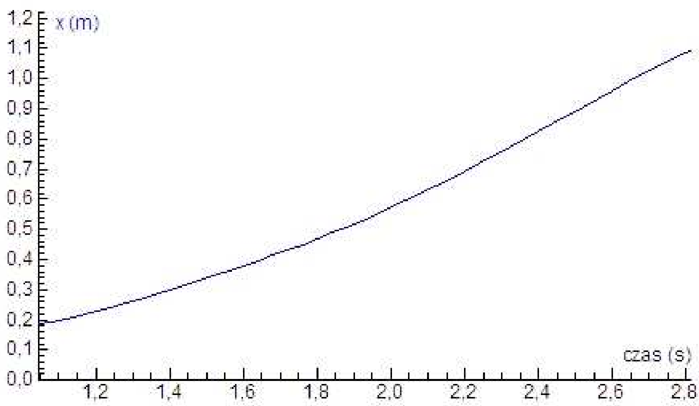


Fig. 3. Chart position x in the function of time for the wheelchair rolling off the slippery slope down.

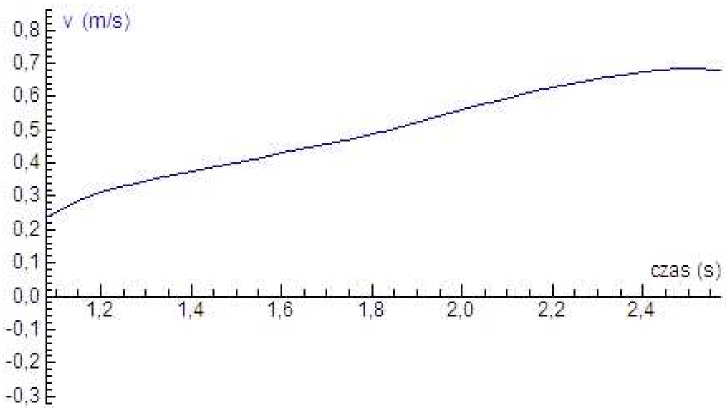


Fig. 4. Chart speed of the cart as a function of time when the cart moves down.

Analyzing the graphs of position, velocity and acceleration as a function of time, make sure that this is indeed a uniformly accelerated motion.

2. Motion study falling body

Place the sensor position on the table. Examine the vertical projection of notebook or notepad A4 falling from the top of approx. 1 m above the table. Set the measurement time for 3 seconds, and the frequency of measurement *Frequency* to 25 per second. Get a chart speed versus time for motion discussed using the option (after pressing the right mouse button) *Process* and next *Derivative*. Better get smoothed graphs using option *Graph Filter* is available when you press the right mouse button and selecting *Process*.

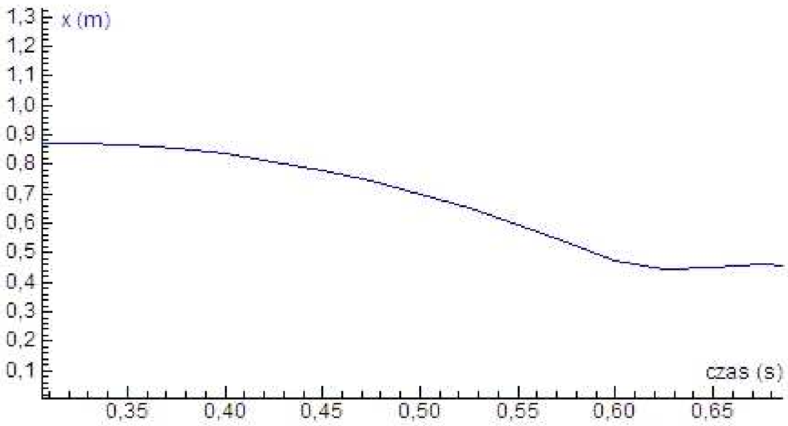


Fig. 5. Graph of position versus time for falling notebook.

Note that the notebook fall time is very short and is only approx. 0.3 s. Consider whether using a manual stopwatch could accurately measure the time of fall notebook?

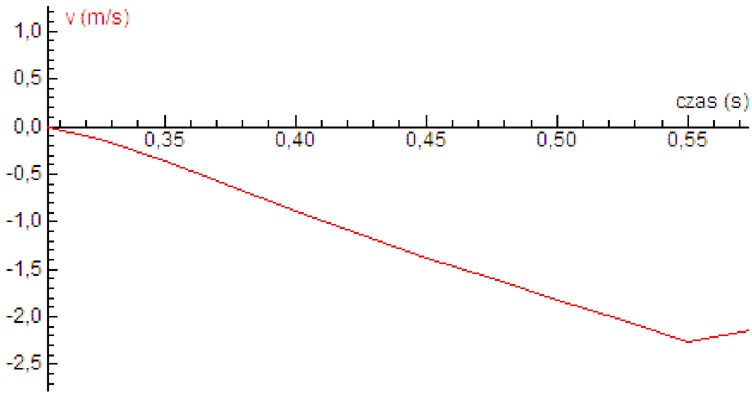


Fig. 6. The graph of velocity versus time for falling notebook.

The maximum speed that a falling book received was 2.3 m/s. Is based on the data in the chart above, you can calculate the acceleration, which fell issue?

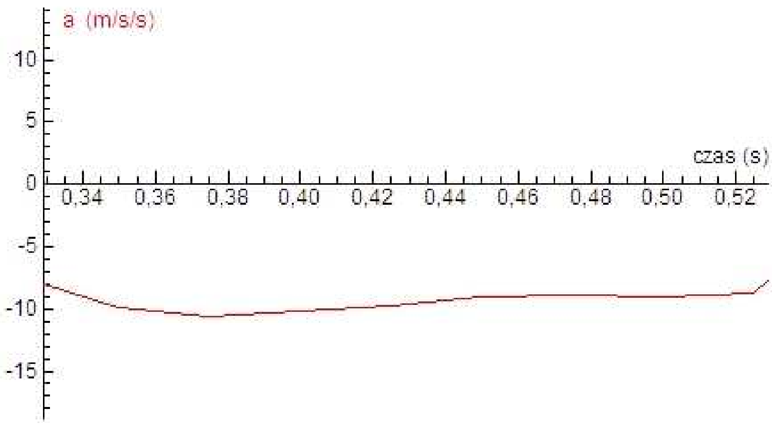


Fig. 7. The graph of acceleration versus time for falling notebook.

Calculations

1. In the case of task 1 read from the graph the highest value of the instantaneous speed of the trolley, calculate the value of the average speed of the trolley. From the graph of acceleration versus time read the value of the acceleration of the truck and answer what kind of traffic moving truck on a slippery slope. Or to speed down the wheelchair rolling off depends on the mass and equal inclination angle? Make several experiments and check it out.
2. Studying the movement of a falling body in the task 2 specify how the velocity of the body. Read the maximum value of the velocity of the body and calculate the average speed of the body. Based on the graph of acceleration versus time check whether the body actually moves uniformly accelerated motion. Read the value of the acceleration of the body. Answer the question what forces act on the falling body?
3. Calculate the acceleration with which the book was falling straight down. Why is it other than the acceleration due to gravity?

Discussion of results and conclusions

1. In the case of task 1 read data from graphs and justify what kind of traffic moving truck on a slippery slope. What forces act on the trolley?
2. Studying the movement of a falling body in the task 2 specify how the velocity of the body. Chart speed as a function of time is a straight line inclined at an angle to the axis of time. From the graph of acceleration versus time which can be obtained from ginseng accelerate the body decreases. This is not the acceleration of gravity g, because the body works apart from gravity force of air resistance.
3. Find in the literature examples of the use of measurements of the movement in science and technology.

Literature:
[1] Karwasz G., Komputer w szkolnym laboratorium fizycznym, Postępy Fizyki, tom 60, zeszyt 6, 2009.
[2] Szydłowski H., Pomiary wspomagane komputerowo, Postępy Fizyki, tom 60, zeszyt 6, 2009.
[3] Szydłowski H., Pomiary fizyczne za pomocą komputera, Wyd. UAM, Poznań 1999.
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9.4. Computer study of motion uniformly delayed

The main objective:

Understanding the principles of recording and analyzing the motion parameters using a computer setup Pasco.

Operational objectives:

- Acquisition of the ability to plan and carry out an experiment presenting the motion uniformly delayed.
- Understanding the methods of recording movement uniformly delayed in the appropriate frame of reference.
- Learn to correct analysis of the obtained experimental data and the physical interpretation of the results.

Equipment and Materials:

- measuring interface ScienceWorkshop 750 (Pasco),
- software DataStudio,
- ultrasonic position sensor,
- computer,
- cart,
- table
- aluminium track.

Background

Examining the rectilinear motion of the accepted reference system that allows the simplest description of motion of, for example, the axis OX peel on the line along which the body moves. The equation of motion for uniformly delayed linear motion is as follows:

$$x(t) = x_o + v_{ox}t - \frac{1}{2}at^2 \ .$$

Graph of the x(t) is a parabola, the x position is proportional to the square of the time t. Uniformly delayed movement operates a force which gives the body a constant negative acceleration (deceleration). The equation describing the velocity of the body is as follows:

$$v(t) = v_{ox} - at ,$$

while equation describing the position of the body as a function of time, when the $x_o = 0$ and $v_o = 0$ takes the following form:

$$x(t) = \frac{1}{2}at^2 .$$

Preliminary questions

The cart entering the slippery slope from bottom to top is moved uniformly delayed? If so, does the acceleration of the cart depends on its mass? Is the book moving in the air, from bottom to top, moves with constant acceleration?

Safety Precautions

Follow the instructions included with the equipment and safety regulations.

Procedure

To the digital input 1 and 2 console Pasco measurement company, for example, 750 ScienceWorkshop connect ultrasonic position sensor. In DataStudio window, click on the *Displays* and *Graph* and select *Position, Velocity* and *Acceleration*. In this way, you will see three windows showing the graphs of x(t), v(t) and a(t).

Fig. 1. The figure shows how to connect an ultrasonic position sensor Console measuring ScienceWorkshop 750.

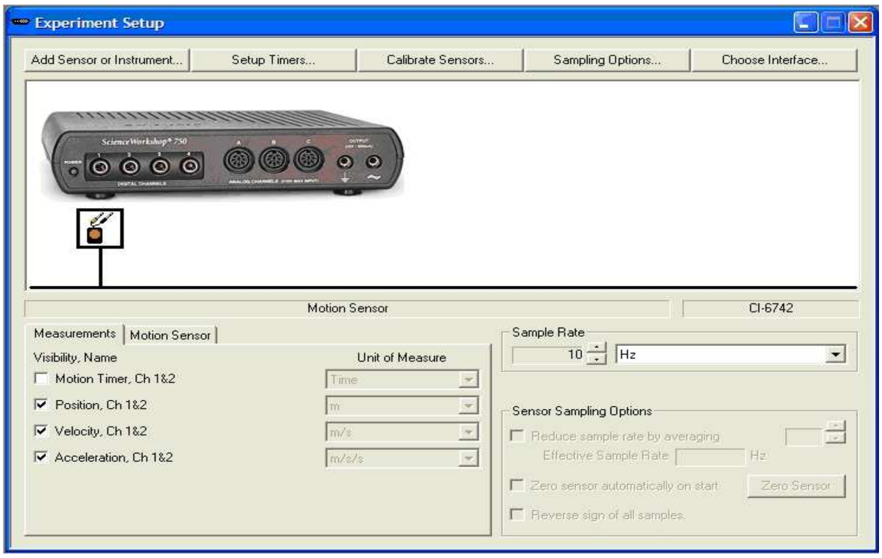

Fig. 2. View ScienceWorkshop 750 measuring console and connected to the ultrasonic distance sensor in the computer program DataStudio.

1. Study of movement of the cart on an inclined plane

At the bottom of the inclined plane (sloping table or sloping aluminum rail), place the position sensor and within a few or several inches from his wheelchair. Press the *Start* button in

DataStudio program. Then give the initial velocity of trolley pushing it for a while and letting go upwards equal.
Exemplary results of the measurements are shown in the graph below (Fig. 3).

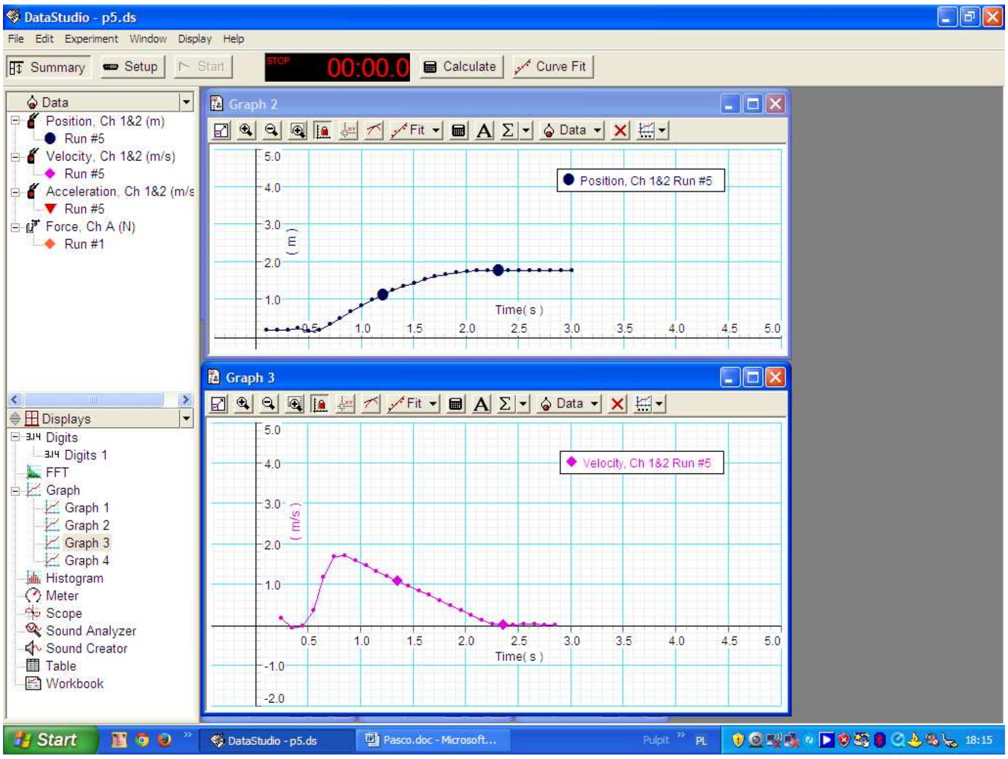

Fig. 3. Sample measurements wheelchair who enters a uniformly delayed up equally presented in the DataStudio.

Here in Fig. 3 is a graph of position versus time. Position values form a curve on a graph and grow more slowly over time. The bottom graph is a graph of velocity versus time. The cart was at the moment have a maximum initial velocity of 1.8 m/s, and the top speed of the trolley was equal to 0 - carriage stopped.

2. Studies of the vertical projection upwards

Investigate the vertical projection of notebook or notepad A4 tossing it up over the ultrasonic motion detector. Set the measurement time of 5 s, and the frequency measurement (*Frequency*) to 25 per second.
Analyzing the graphs of velocity and acceleration verify book moves upward uniform motion delayed, and falls downwards uniformly accelerated motion.

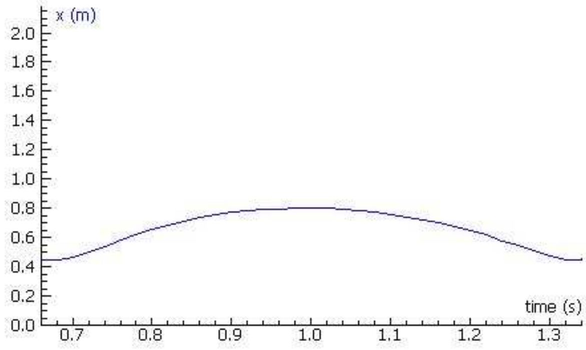

Fig. 4. Graph of body position as a function of time for notebook, which is moved up.

Example results of this experiment are shown for the above.

Calculations

1. Calculate the time delay moving truck moving upwards equal. Use the definition of acceleration $a = \frac{\Delta v}{\Delta t}$. Read the values from the graph v(t).
2. By changing the angle of inclination equal repeat measurements and explore how the accelerating the carriage depends on the angle of inclination equal.
3. The top elevational notebook obtained, for example, graphs of x(t), v(t) and a(t), that are not perfectly regular. The results from the irregularity of the body during running variable air resistance force and the uncertainty of measurement when measuring the position of the body.

Discussion of results and conclusions

1. In the case of task 1 read data from graphs and justify what kind of traffic moving truck on a slippery slope when you rode "uphill". What are the forces acting on the truck?
2. Investigate body movement moving up (task 2) specify how the velocity of the body. Chart speed as a function of time is a straight line inclined at an angle to the axis of time. From the graph of acceleration versus time which can be read from the acceleration of the moving body. This is not the acceleration of gravity g as the body works, in addition to gravity, air resistance force.
3. Find in the literature examples of the use of measurements of the movement in science and technology.

Literature:

[1] Karwasz G., Komputer w szkolnym laboratorium fizycznym, Postępy Fizyki, tom 60, zeszyt 6, 2009.
[2] Szydłowski H., Pomiary wspomagane komputerowo, Postępy Fizyki, tom 60, zeszyt 6, 2009.
[3] Szydłowski H., Pomiary fizyczne za pomocą komputera, Wyd. UAM, Poznań 1999.
[4] Karwasz G., Sadowska M., Rochowicz K., Toruński poręcznik do fizyki. Mechanika. Gimnazjum I klasa, Wyd. Naukowe UMK, Toruń, 2010
[5] Szydłowski H., Pracownia fizyczna, PWN, Warszawa, 1989.

9.5. Computer study of the phenomenon of beats

The main objective:

Understanding the basic principles of production, sound recording and analysis using a computer and a set of measuring Coach program.

Operational objectives:

- Reminder of basic describing sound waves, such as intensity, pitch and timbre.
- Understanding the physical basis for the phenomenon of beats and their description.
- Acquisition of the ability to use the capabilities of the COACH 5 to study the phenomenon of beats.

Equipment and Materials:

- measuring interface Coachlab II or Coachlab II+,
- software Coach 5,
- sound sensor,
- computer,
- two tuning forks,
- metallic object loading forks,,
- hammer.

Background

Beats arise when overlapping of two waves with frequencies slightly different from each other, the effect is most pronounced when the power is approximately equal. To produce such a two pitch rumbling use, facing each other, one tunable tacking additional mass, and vibration induced by a. Produced in this way acoustic wave, which is a combination of two waves of different frequencies, is a modulated wave (responsible for the beat is just the modulation). The frequency of the carrier wave and the frequency of modulation frequencies we can associate with the source (ie. Frequencies of both tuning fork) using the appropriate trigonometric formulas. We do therefore superposition (imposition) of two waves of different but a little different frequencies; These waves describe the functions ψ_1 and ψ_2 :

$$\psi_1 = A\cos(\omega_1 t + \varphi_1)$$
$$\psi_2 = A\cos(\omega_2 t + \varphi_2) \qquad (1)$$
$$\omega_1 \approx \omega_2 \ .$$

After adding we obtain:

$$\psi = \psi_1 + \psi_2 = A\,[\cos(\omega_1 t + \varphi_1) + \cos(\omega_2 t + \varphi_2)]\ . \qquad (2)$$

After applying the formula for the sum of cosines formula (2) can be written as follows:

$$\psi = \left[2A\cos\left(\frac{\omega_1 t + \varphi_1 - \omega_2 t - \varphi_2}{2}\right)\right]\cdot\cos\left(\frac{\omega_1 t + \varphi_1 + \omega_2 t + \varphi_2}{2}\right) \qquad (3)$$

or

$$\psi = \left[2A\cos\left(\frac{\omega_1 - \omega_2}{2}\cdot t + \varphi'\right)\right]\cdot\cos\left(\frac{\omega_1 + \omega_2}{2}\cdot t + \varphi''\right)\ . \qquad (4)$$

Equation (4) is interpreted as follows: Factor enclosed in square brackets is responsible for changing the amplitude of vibration, or modulation. It changes slowly as (ω_1-$\omega_2 \to 0$). The second factor is responsible for the carrier wave. The above equation can be written as follows:

$$\psi = [2A \cos(\omega_{mod} t + \varphi')] \cdot \cos(\omega_{noś} t + \varphi'') \quad (5)$$

where:

$$\omega_{mod} = \frac{\omega_1 - \omega_2}{2} \quad i \quad \omega_{noś} = \frac{\omega_1 + \omega_2}{2}. \quad (6)$$

Dividing equation (6) the parties by 2π we can get:

$$f_{mod} = \frac{f_1 - f_2}{2} \quad i \quad f_{noś} = \frac{f_1 + f_2}{2}. \quad (7)$$

where f is frequency.

Safety Precautions

Follow the instructions included with the equipment and safety regulations.

Procedure

Determination of the frequency modulation (f_{mod}) and frequency of the carrier wave (f_{nos}).

1. For measuring CoachLab II console, connect the sound sensor, eg. For measuring input 1.

Fig.1. The figure shows how to connect to the console sound sensor measuring CoachLab II.

2. The program Coach 5 for measuring input 1 console measuring drag and drop the icon of the probe.

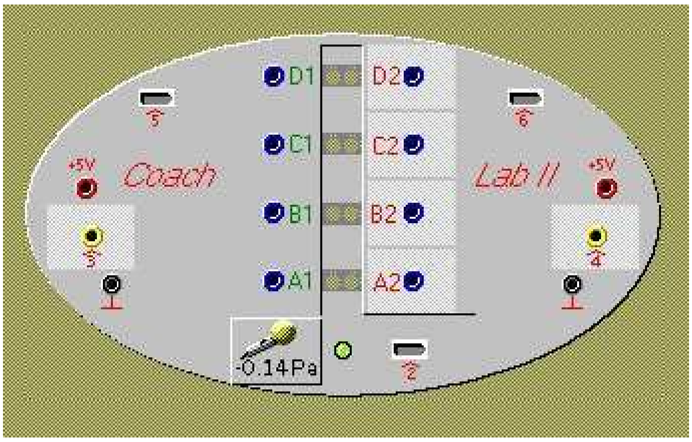

Fig. 2. View console measurement in Coach 5 program.

1. In one of the windows place a graph of pressure (-45 Pa to 45 Pa) as a function of time. Measuring parameters for time select as follows: measuring time - 5 s, the number of measurements within 1 second - in 1000.

2. Set two tuning forks holes opposite each other at a distance of approx. 5 cm. Place additional metal element in the cradle of one of the tuning fork to the frequency of the wave generated was slightly lower than the frequency of the wave produced by the second tuning fork.

3. Strike hard hammer fork tuning fork and set it on both the microphone as close to the hole (between the two tuning forks). Sign resulting acoustic wave and analyze waveform enlarged.

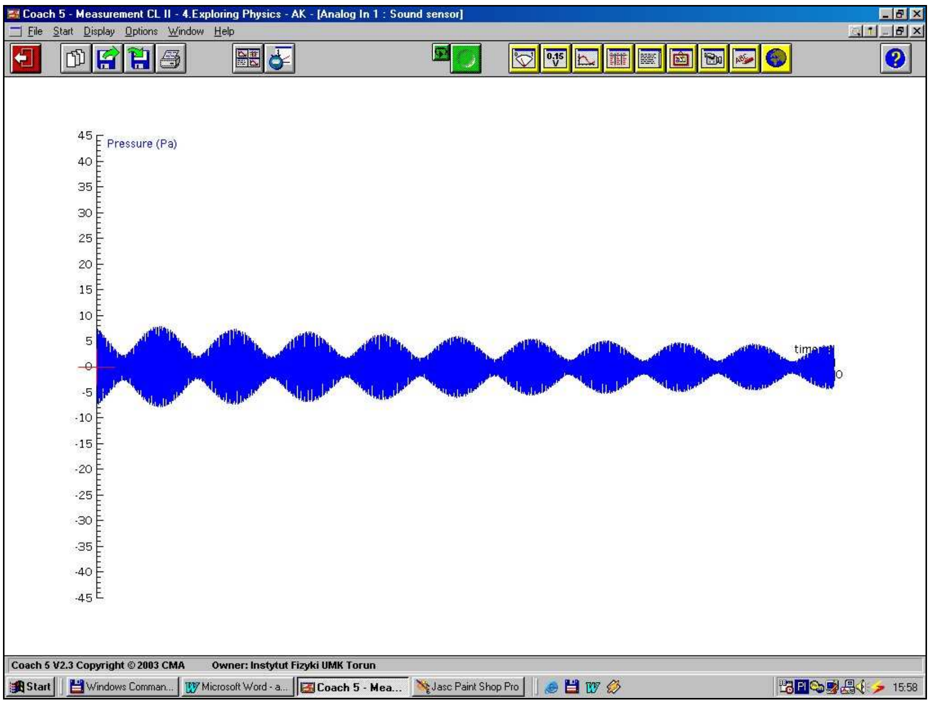

Fig. 3. Beats recorded using a set of measurement and Coach 5 program.

Calculations

On the basis of knowledge of the modulation frequency and the frequency of the carrier wave frequencies calculate co-creating beats f_1 and f_2.

1. Determine the modulation frequency f_{mod}

Using Coach 5 read the modulation period, using the guidance contained in the following figure. Read the time on the horizontal axis in the range selected by the frame.

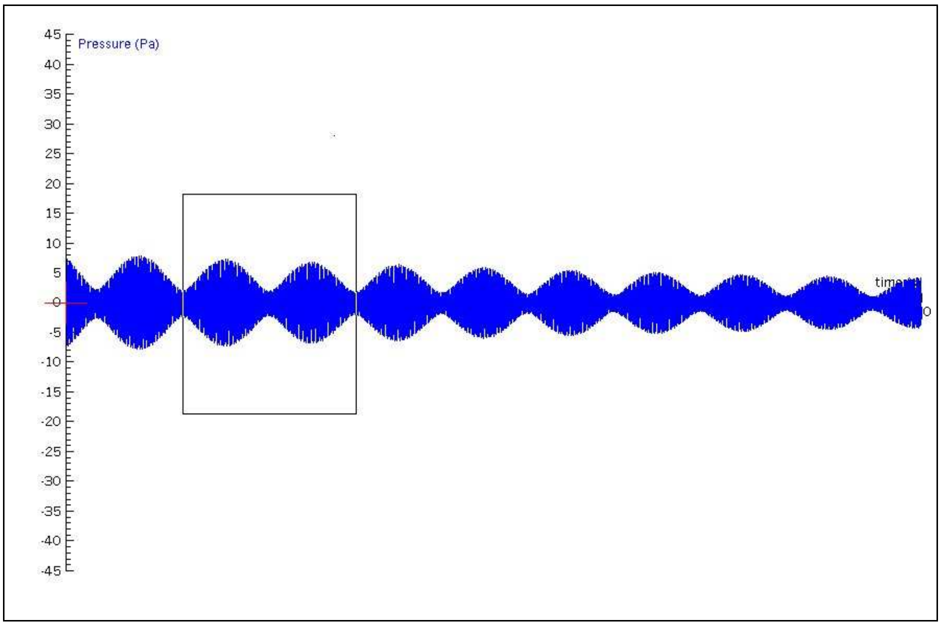

Fig. 4. Cover modulation period by frame.

2. Determine the frequency of the carrier wave f_{nos}

For this purpose, use of the Fourier transform using the following options (when you press the right mouse button): *Analyse, Signal analisis, Fourier transform.*

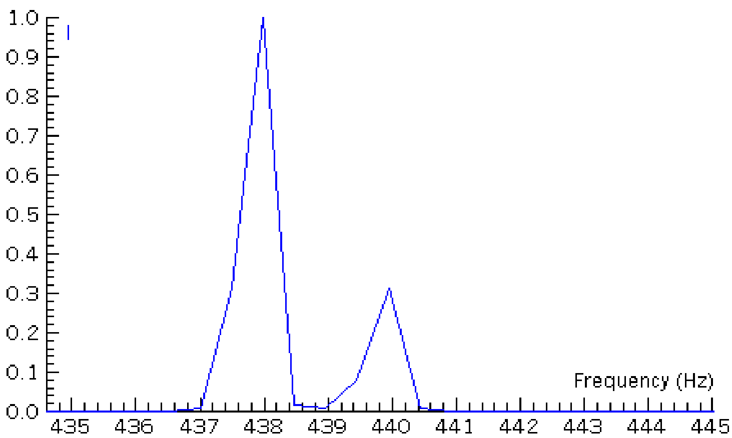

Fig. 5. The frequency spectrum of the investigated acoustic wave.

Transform formula (7) and calculate frequency f_1 i f_2 .

Discussion of results and conclusions

1. The natural frequency of the tuning fork fork with additional mass depends on where it fastened.
2. The higher the additional weight is attached to the forks of the tuning fork, the lower the frequency of the vibration produced.
3. Frequency modulation and frequency of the carrier wave depends on the frequency difference tuning fork, which is the place of attachment of the added mass to one of the forks.
4. The frequency of vibration of the tuning fork depends also on the temperature of the fork.
5. Consider where the beat phenomenon occurs in your environment.
6. Find examples in the literature use the phenomenon of beats in science and technology.

Literature:

[1] Karwasz G., Komputer w szkolnym laboratorium fizycznym, Postępy Fizyki, tom 60, zeszyt 6, 2009.
[2] Szydłowski H., Pomiary wspomagane komputerowo, Postępy Fizyki, tom 60, zeszyt 6, 2009.
[3] Szydłowski H., Pomiary fizyczne za pomocą komputera, Wyd. UAM, Poznań 1999.
[4] Karwasz G., Więcek M., Fizyka współczesna. Toruński poręcznik do fizyki, Materiały dydaktyczne Zakładu Dydaktyki Fizyki UMK, Toruń, 2011
[5] Karwasz G., Sadowska M., Rochowicz K., Toruński poręcznik do fizyki. Mechanika. Gimnazjum I klasa, Wyd. Naukowe UMK, Toruń, 2010
[6] Szydłowski H., Pracownia fizyczna, PWN, Warszawa, 1989.

9.6. The study of thermal phenomena

The main objective:

Understanding the basic principles of temperature measurement using a computer and data logger LOGIT with sensors.

Operational objectives:

- Reminder of basic quantity in thermodynamics, such as temperature and heat.
- Understanding the thermal phenomena occurring during rest and exercise.
- Understanding the mechanism of heat transfer by radiation.

Equipment and Materials:

- data logger Logit,
- software Insight,
- two temperature sensor,
- computer,
- cups,

Safety Precautions

Follow the instructions included with the equipment and safety regulations.

Procedure

1. Check if there is a difference in the temperature of the human body at rest and during exercise.

To measure the use LOGIT data logger with temperature sensor. The temperature sensor hold in his clenched hand and turn the temperature by pressing the *Start* button in program Insight. Wait until the temperature stops growing, then follow 10 squats. Compare the results obtained at rest and during physical exercise (Fig. 1).

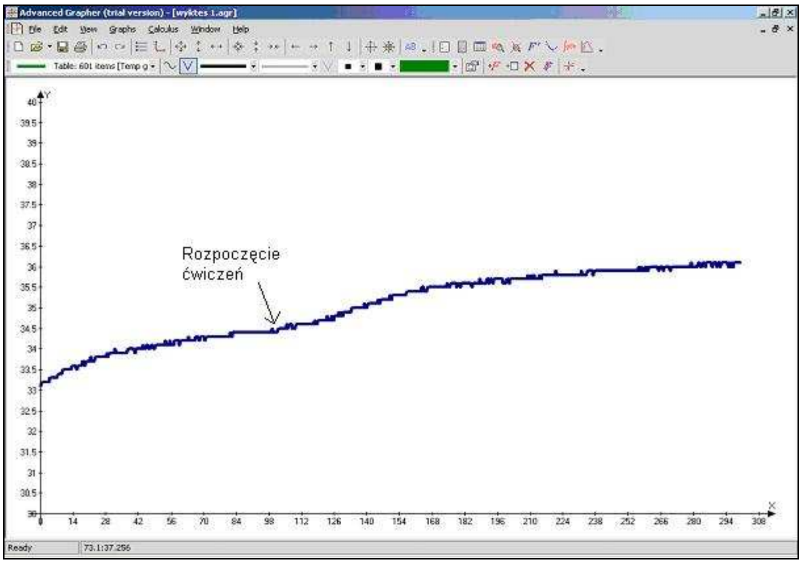

Fig. 1. The measured temperature of the human body during rest and exercise.

The graph (Fig. 1) it can be seen that at the time of exercising the human body temperature increase. The energy consumed muscles turned to the work done (physical exercises) and spun off in the form of heat and there was an increase in body temperature. Simultaneously, we observed the phenomenon of perspiration, which is designed to remove excess heat from the body. The body temperature is lowered by the evaporation of water from the skin surface. The water molecules to escape from the skin and other water molecules (transition from liquid to gas) must have a certain energy, and reduce the evaporation of the average kinetic energy of molecules of the skin and water remaining on the skin. In this way, the body is cooled.

2. How does the temperature of the body when the skin surface was sprayed with deodorant?

Keep in clenched hand sensor, turn on the measurement by pressing the *Start* button, and after determining the temperature (it takes approx. 20 s) spray skin using deodorant.

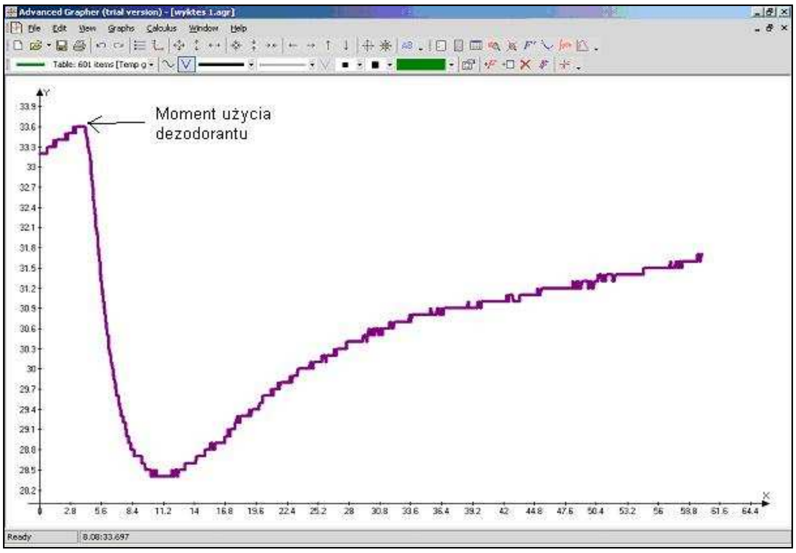

Fig. 2. The graph presents the changes of body temperature at the place of use of deodorant.

At the time of use of the deodorant can be observed a sudden drop in temperature. We explain this in that the liquid exists in the can along with the gas, which expands when leaving the can while substantially reduce its temperature and small drops of liquid. Cool deodorant reach the surface of her skin cooling. Then, deodorant, begins to evaporate and reduces the average kinetic energy of the molecules of the skin, which we observe in the graph (Fig. 2) as decrease the temperature and we feel it as a cooling body.

3. Heat transfer by radiation

For measurements use a data logger and two identical temperature sensors. To one aluminum can attach with adhesive tape in the form of two radiators of aluminum foil strips. Then both containers pour hot water portions, that is a little to one box and a little to the other to change, and immerse in any temperature sensors. Sample measurement results are shown in the chart (Fig. 3).
At the beginning of the temperature difference of water in the cans is similar. Analyzing the data in the graph can be seen that after approx. 20 minutes can radiator will have a lower temperature than the box without a heat sink. Conclusion: the larger the surface heat exchange (radiator), the exchange is faster.

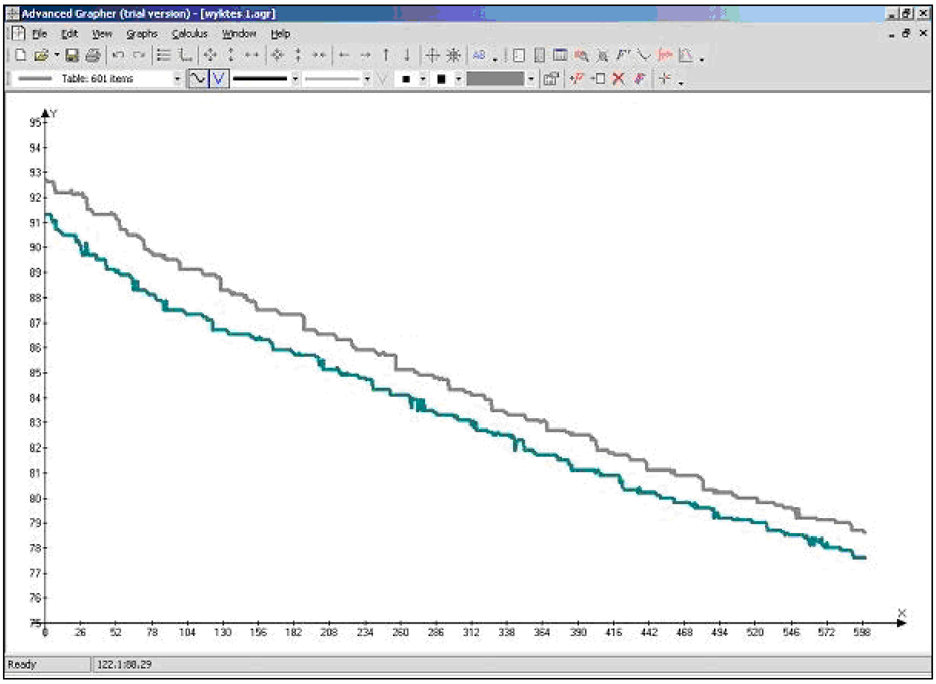

Fig. 3. The graph shows the changes in water temperature in the box with the radiator and without radiator.

Therefore, in our homes we use in the radiator fins, and automotive coolers, whether domestic refrigerators plurality of tubes which contain the coolant. In nature, it can be observed that the elephant has big ears and so it captures the excess heat to the environment.

4. What kind of soil is more favorable for plant growth?

To carry out experiments using the data logger LOGIT, the same two temperature sensors, two significantly differing soil types (sand and garden soil), and a high-power lamps.
Sand and pour down into the container so as to be positioned separately. Next just under the surface of sand and earth placed temperature sensors and light the lamp and start the measurement by pressing the *Start* button. Sample measurement results are presented in the following graph (Fig. 4).
Analyzing the results, we can see a rapid increase in temperature of the earth garden and much slower for the sand, while after approx. 5 minutes and 40 seconds turn off the lamp and the effect reverses land quickly gives up its heat to the surroundings, while the sand much slower. The density of the sand is greater than the earth (assuming that both substrates are dry or contain a minor amount of water). The sand has a much larger heat capacity than land, that is, to increase the temperature of the sand by one Kelvin, you need to provide him with more energy than garden soil. Another factor influencing the rate of surface temperature increase the thermal conductivity of the substrate. Also in this case the sand has a much higher coefficient of thermal conductivity than black garden soil. The most important factor to explain the results obtained during the experiment is the color of the substance. The sand is bright, and the garden soil dark, almost black. It is easy to observe, what is the difference, if on a sunny day clad black pants and a white shirt, and then sit in the sun. The dark material absorbs considerably more thermal radiation than clear.

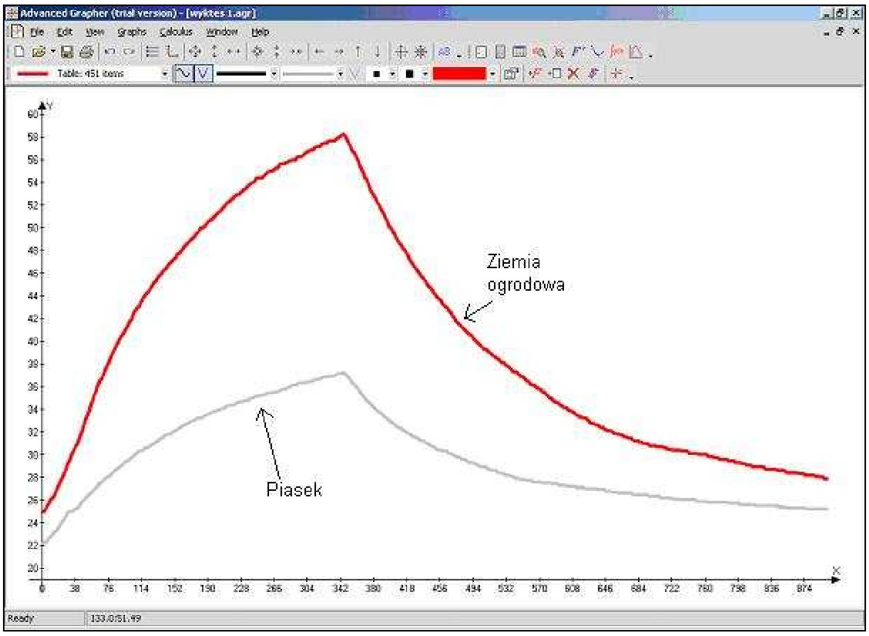

Fig. 4. The graph shows the change in temperature for the black garden soil and sand, which were heated by lamps with high power.

In the second part of the experiment we observe the opposite situation. Earth quickly captures (radiates) heat to the surroundings, and the sand more slowly. In this case are the importance of different parameters of the two substrates. Earth is porous, which has a larger surface area, while being more breathable and additionally acting as an insulator is not stored thermal energy in the deeper layers in the surface layer only. The sand acts on the contrary, the surface is relatively smooth. In the case of plants it is very important, because this black earth remains at greater depths for longer moist and does not dry out so quickly.

Literature:

[1] Karwasz G., Komputer w szkolnym laboratorium fizycznym, Postępy Fizyki, tom 60, zeszyt 6, 2009.
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