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BOOK 5

"MATHEMATICS, INFORMATICS AND PHYSICS"

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"MATHEMATICS, INFORMATICS AND PHYSICS"

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Education

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SOME PROBLEMS OF ATOMIC AND NUCLEAR PHYSICS TEACHING

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Abstract: *This paper sets out some specific problems arising in Atomic and Nuclear Physics learning process in specialized university courses as well as in General Physics and General Chemistry courses and suggests a transition from lectures to student-centered learning.*
Keywords: *Atomic and Nuclear Physics education, online education*

INTRODUCTION

It is well known that the quantum physical objects are inaccessible to the ordinary human senses. The physical quantities describing them are statistical. The complex mathematical apparatus of Quantum Mechanics presumes developed abstract thinking. All this imposes considerable intellectual efforts during the learning process. This work offers an option for transition from lecture to student-centered learning in which students are 'learning to learn' rather than passively present during the teaching process.

The lecturer has three main functions [9]:

1. He is a manager of the classroom.
2. He applies an individual approach to students and their learning difficulties.
3. He is a generous expert who shares his experience and knowledge if and only if the student needs it.

Some results obtained by data mining method confirmed unequivocally that there can be no uniform method of teaching that works effectively for all students simultaneously. An approach to the individual needs identifying is online testing of students during the learning process. The lecturer develops tests on unlearnt teaching content. Students work online with an open textbook and are encouraged to surf the INTERNET - space during the test. They may ask for assistance and their answers are valued at the moment. If a student does not like the result, he is entitled to repeat the test as many times as he wishes, retaining only the last assessment. He invests time in this study and the final test result affects his annual or semester rating. Thus the student is motivated to learn.

The student-centered method [4] may be enriched with specific proposals for self and mutual training of students through Power Point presentations. Attached is an indicative list of exemplary INTERNET – sites.

SELF TRAINING THROUGH POWER POINT

In student-centered learning the teacher is mainly a manager (appraiser) [9] while the students are expected to be the active part and the initiators of the learning process. Some of the educational challenges in Atomic and Nuclear Physics, described below, can be used alternately from a list of topics from which each student chooses one to study in detail. He has to work for a short time and needs the teacher to designate the initial range of INTERNET – sources for each topic, in order to save time and not to be confused at the very beginning. The sources offered by the teacher are not mandatory. The choice depends on the personal preferences and worldview, and on the ambitions of the student. Students work on their topics in order to present them to the group on a multimedia screen. Each student has the same time for his presentation and answers to any questions. The teacher summarizes, supplements and specifies which parts of the presentation may be included in preparing for the exam.

The proposed in this work concepts aim at students in upper courses-pedagogical specialties like Physics and Informatics, Chemistry and Informatics. The students are expected to have a common interest in the discipline as a part of their teaching future. The independent learning through presentations will find direct application as a motivation in this course and for their development as future teachers.

The APPENDIX displays an exemplary part of Power Point presentation devoted to quarks and elaborated by a student.

THE CHALLENGE OF NUCLEAR PHYSICS

It is known that in the quantum world special units of distance, work and energy, mass and momentum are used - **Å, fm, eV (MeV, GeV), MeV/c^2, MeV/c (GeV/c)**. If you find good examples, these units will not seem so abstract. It is difficult to assimilate the fact that in the natural system (**c = ħ = 1**) the units of all physical quantities are degrees of the length unit. You should look into the nature of conventional measuring systems and point out the reasons (usually aimed at convenience) for the introduction and use of one or other unit. It is also good to note that the electric charge of an electron is considered as negative only conventionally and that the existence of anti-particles follows from the properties of symmetry of physical laws [3, 2, 1].

It is useful to state the fact that at large velocities of the quantum objects (e.g. about **2/3** of the speed of light in vacuum **c**) their masses significantly increase compared to those at rest (**rest + mass** [8]).

Interesting is the history of creation of atomic models (**atomic + models** [7]), their advantages and disadvantages that led ultimately to the model of Rutherford. The latter can not explain why the atoms are stable systems and electrons do not fall onto the nucleus, according to the laws of classical Electrodynamics. Usually this fact is shocking to all audiences and requires more detailed consideration.

It is very difficult to fit to the traditional ideas the **atomic states discreteness** and the nature of **atomic spectra** - in addition to being discrete, their lines are not equidistant and consist of multiples of one basic frequency lines. To understand these features would help the examination of relevant examples - one option is to set the wavelengths of the first three lines in the visible spectrum of the hydrogen atom and to calculate the corresponding frequencies $\nu = c / \lambda$.

The semi-classical – semi-quantum **theory of Bohr** of the hydrogen atom with its postulates and consequent **quantization** of fundamental physical quantities such as radius of the orbit and energy of the electron should also be illustrated with appropriately chosen examples. It is important to consider the negative sign of the **bound state energy** [6] of the electron.

The corpuscular - wave nature of light and the main characteristics of **photon** - especially the **zero rest mass** - also pose problems. As is known, the phenomena which found their explanation in the wave theory are interference, diffraction and polarization, while in other phenomena such as **heat emission**, **photoelectric effect** and **effect of Compton** light behaves like a beam of particles - photons. Moreover – it is necessary to emphasize that this duality (**wave-particle duality**) is inherent to all micro-particles, and is not only physical but also a philosophical problem. It is difficult to imagine the photon as an object with such properties, which on top of that we are not able to observe directly. In this connection it is worth paying particular attention to the **wavelength of the de Broglie** (**matter wave**) and its dependence on the mass of the particle, and the experimental confirmation of the presence of typical wave phenomena in beams of elementary particles, marking the beginning of electrongraphy and neutrongraphy.

In examining the laws of heat emission it is difficult to perceive such quantities as **emissivity** and **absorptance**, respectively **spectral** and **total emissivity** and **absorptance** – they should be well clarified. A large percentage of students find it difficult to answer the question what determines the color of objects even on the exam. For some of them, the concept of **black body** remains very uncertain. The same goes for the famous problems named **ultraviolet catastrophe** and **thermal death of the Universe** although they have been properly clarified during the lectures.

Atomic and Nuclear Physics provide a good opportunity to reveal the role of conservation laws for physical quantities **energy, linear momentum, angular momentum, electric charge** - for example when considering the external photo effect, the effect of Compton, at deriving the **Rutherford formula**. Unfortunately, many students believe that the **threshold frequency** of the photo effect is always in the red end of the spectrum. Especially useful in this case are the tables containing the threshold frequency and the **work function** data for different metals.

Interesting is the reaction of the student audience to the interpretation of the **spin** of electron as an internal degree of freedom inherent to all micro-particles and resulting from the relativistic wave equation of Dirac, which should not be associated with rotation around their own axis. In this regard it is worth considering the internal degree of freedom of **quarks**, fantastically named **color;** the **s-strange, c-charm, b-bottom, t-top, u-up and d-down quarks**. In comparison, even their fractional with respect to **e** electric charge doesn't seem so strange. On this background, the valid for all three **angular momenta - orbital, spin and total** - relation with the corresponding quantum number **(**e. g. $\left|\vec{j}\right| = \sqrt{j(j+1)}\hbar$**)** in a combination with appropriate examples does not seem so strange and even the precession of $\vec{l}$ and $\vec{s}$ around $\vec{j}$ seems more natural. All this shouldn't be perceived as an abstract and unnecessary theory - therefore it is important to describe the experiments proving the **discrete orientation** of the mechanical and **magnetic momenta** (**space quantization**).

Some students can't reproduce correctly the ranges of the electron state **quantum numbers**. The **Periodic table** of chemical elements provides a good opportunity for self-control and self-knowledge through solving concrete problems – for example the way of occupation of the **electron shells** and **sub-shells**. An interesting topic for reflection gives the **Pauli exclusion principle**, inherent to **fermions**. A suitable form of examination in this case is a test.

Especially beneficial is the topic of **X-rays and spectra**. Besides a thorough examination of their applications in various fields, a strongly positive effect has the observation of predictive nature of the **law of Moseley** for the frequency of the **characteristic X-ray radiation** in dependence of the atomic number **Z**, thanks to which the existence of more than 90 chemical elements has been predicted.

NUCLEAR SYSTEMS - ARENA OF STILL UNCLARIFIED STRONG INTERACTION

Although the lectures on Nuclear Physics follow these on Atomic Physics, they also pose a number of interesting questions to lecturers and students. At the outset it is necessary to distinguish between the names of objects **neutron**, **neutrino** and **nucleon**, which are often surprisingly replaced one by another.

Considerations of the **high nuclear density** and the lack of sharp borders and center of the nuclei, which seem contrary to the classical idea of core, impress the audience and these facts should be approached carefully.

Surprising turns also the fact that, like electrons in the shell the nucleons in the core also have quantum mechanical momenta that are being summed according to the same (seeming very strange) vector rules. Confusing is the presence of an extra degree of freedom - **isospin**, through which the electrically neutral and positively charged nuclear particles such as **neutron** and **proton**, can be treated as states of a single particle-**nucleon** with different isospin projections. This shows once again that nuclear forces are quite different from the electric ones.

It is difficult to get the nature of the **mass defect** and of the **binding energy**, which can be well understood in the light of the possible nuclear and thermonuclear reactions (**fission and fusion reactions**).

Nuclear interaction is very intense and quite different from the other known interactions in nature. Quite disturbing for the audience are the **charge independence**, the **non-central** and **exchange** nature of **nuclear forces**. The virtual nature of **π-mesons** is difficult to perceive. It is necessary to trace out briefly the historical facts accompanying the theoretical prediction of the nuclear field quant by Yukawa and the following registering of mesons in cosmic rays by Powell and Occhialini twelve years later. This is an appropriate illustration of the power of theory in modern Physics.

Undoubtedly, the lack of accurate analytical expression for nuclear forces makes very strong impression on students, expecting perhaps some kind of modification of the laws of Newton and Coulomb for gravitational and electrostatic forces, respectively. The model description of nuclear systems by a set of parameters with values specified through comparison with the experiment is an alternative approach. Without considering each of the up-to-date **nuclear models** in detail, their classification should be clarified. It is good to emphasize that each model explains only particular properties of nuclei.

Radioactivity is a topic that is usually met with great interest. The **law of radioactive decay** looks like the known laws of **light** and **X-rays absorption**. Against this background, the **half-life time** $T_{1/2}$ (**decay period**), the **mean life time τ** and their relation to **decay constant λ** seem to be understood quite naturally.

α- and **β- decay** give a good opportunity to assimilate the knowledge not only in Atomic and Nuclear Physics but also in Chemistry. Particularly striking is the **tunnel effect** (**tunneling**) in **α-**decay as a phenomenon alien to classical Physics, but possible in the quantum world. **β- decay** is a good illustration of the importance of the energy conservation law - its apparent violation has led to the theoretical prediction of **neutrino**. More difficult is to comprehend the idea of transforming neutrons into protons and vice versa, which explains the β^- **- and** β^+ **- decay**.

It seems that most impressive in terms of **linear and angular momentum, energy and electric charge conservation laws** are **γ- radiation** and the possibility of creation of **electron - positron pairs** and the reverse process - their **annihilation**.

The topic of **nuclear reactions** as a manifestation of the strong interaction provides an interesting opportunity to consider the meaning of the concept of **channels of the reaction**. Besides the well-known conservation laws, here are also valid conservation lows concerning the **number of nucleons**, **parity** and **isospin**. It is useful, except the general formulation, to consider proper examples of different types of nuclear reactions. This section provides good opportunities for students testing. With definite interest is being met the **(n, p)** - reaction in which atmospheric nitrogen is converted into β^- **-** activated carbon with a very large half-life, which reaction has given the basis to **radiocarbon analysis** and the possibility of dating archaeological finds.

Special attention should be paid to the topics of **nuclear fission and fusion** which are examined in detail in all textbooks.

CONCLUSIONS

In this work is stated an opportunity for self-education of students of teaching specialties Physics and Informatics and Chemistry and Informatics. This approach has the following advantages over the traditional lecture training [5]:

• Moving towards student - centered learning
• Accentuation on the managerial role of the lecturer
• Individual training
• Use the maximum capacity of all students
• Learning how to study Atomic and Nuclear Physics, instead of only present in class during lectures
• Building skills for active learning in which students demonstrate their individuality, learning orientation and style
• Each student is dynamically self-developing by demonstrating his own learning products (artifacts)

This work is part of a project, which highlights the student-centered learning of Atomic and Nuclear Physics. The list of concepts can be used in the preparation of objective **online** tests. They would provide the tutor with an automatic statistics for individual performance of students (Blackboard platform [10]). The list can be modified, for example by eliminating those concepts which are not a serious problem for a group of students.

With the annexation of Bulgaria to the European Union, after becoming a member of the Atlantic one, the English language becomes a necessity. Inevitably escalates the need for basic computer literacy and acquiring skills for solving practical problems using the computer (e.g. http://cnets.iste.org/). The above-described method involves the joint efforts of lecturers in Physics, Computer science and English. The training of the twenty first century is inevitably interdisciplinary.

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НЯКОИ ПРОБЛЕМИ ПРИ ОБУЧЕНИЕТО ПО АТОМНА И ЯДРЕНА ФИЗИКА

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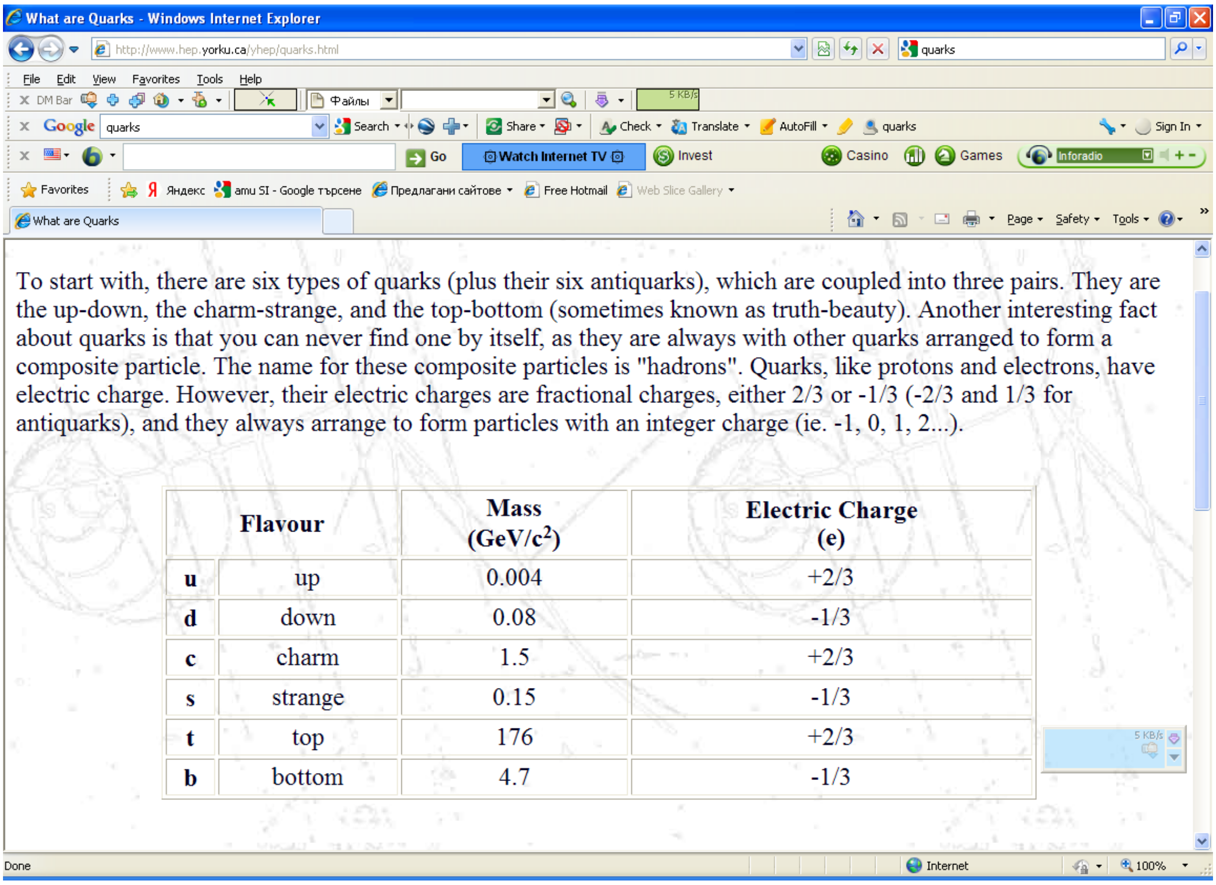
Резюме: *В тази работа са изложени някои специфични проблеми, възникващи в процеса на обучение по Атомна и ядрена физика както в специализираните университетски курсове, така и в курсовете по Обща физика и Обща химия и се предлага преход от лекционно към студентски центрирано обучение.*

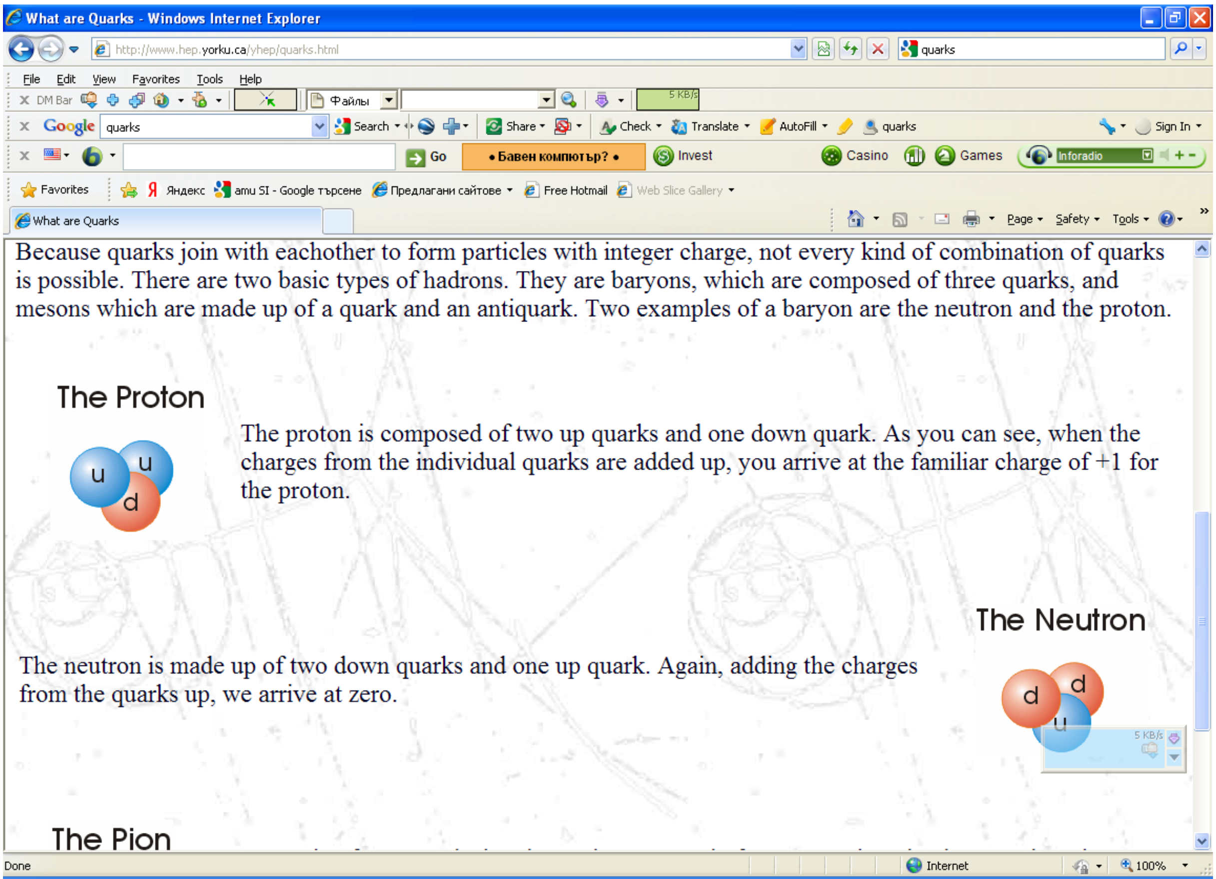
Ключови думи: *обучение по атомна и ядрена физика, обучение онлайн*

APPENDIX: A part of students Power Point presentation devoted to quarks



To start with, there are six types of quarks (plus their six antiquarks), which are coupled into three pairs. They are the up-down, the charm-strange, and the top-bottom (sometimes known as truth-beauty). Another interesting fact about quarks is that you can never find one by itself, as they are always with other quarks arranged to form a composite particle. The name for these composite particles is "hadrons". Quarks, like protons and electrons, have electric charge. However, their electric charges are fractional charges, either 2/3 or -1/3 (-2/3 and 1/3 for antiquarks), and they always arrange to form particles with an integer charge (ie. -1, 0, 1, 2...).

	Flavour	Mass (GeV/c^2)	Electric Charge (e)
u	up	0.004	+2/3
d	down	0.08	-1/3
c	charm	1.5	+2/3
s	strange	0.15	-1/3
t	top	176	+2/3
b	bottom	4.7	-1/3



Because quarks join with eachother to form particles with integer charge, not every kind of combination of quarks is possible. There are two basic types of hadrons. They are baryons, which are composed of three quarks, and mesons which are made up of a quark and an antiquark. Two examples of a baryon are the neutron and the proton.

The proton is composed of two up quarks and one down quark. As you can see, when the charges from the individual quarks are added up, you arrive at the familiar charge of +1 for the proton.

The neutron is made up of two down quarks and one up quark. Again, adding the charges from the quarks up, we arrive at zero.

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