

ELECTIVE COURSE “NUCLEAR PHYSICS” FOR HIGH SCHOOL STUDENTS – SYNTHESIS OF TRADITIONAL TEXTBOOK WITH THE MODERN COMPUTER TOOLS

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An elective course “Nuclear Physics” was developed for high school students, including a traditional textbook, a computer application and various interactive educational materials and 3D models available on mobile devices using QR codes. The main idea of the course can be formulated as “From Nuclear Physics to Nuclear Technologies”. The elective course includes not only basic laws of nuclear physics, but also the application of these laws in nuclear astrophysics, in the synthesis of new elements, nuclear energy, nuclear medicine, ecology and radiobiology. Each chapter in the textbook provides links to additional digital materials: video lectures, examples of problem solving and additional materials for advanced study. At the end of the textbook, you can also find the references to a virtual practicum on nuclear physics, final tests, and approximate research and project works. The textbook pays special attention to the modern achievements of nuclear physics. It contains information of modern international experiments, conducted at JINR and other international scientific centers.

Keywords: Elective course, nuclear physics, video lectures, computer application, 3D modeling tools

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1. Introduction

One of the ways to develop the school education in Russia is the proposal to introduce elective courses in priority development areas as pre-profile training. These courses are encouraged to be used in extracurricular activities. Elective course for high school students is a course which should be chosen by a student from several courses corresponding to their specialization. The purpose of elective courses is to deepen knowledge of basic academic subjects, the development of cognitive interests, skills and professional self-determination.

When developing such courses, it is necessary to take into account the difficulties that face the authors: the need to adapt quite complex material for high school students, which is traditionally studied in universities; a small number of training hours devoted to study; the need for professional training of teachers on the issues being studied. One of the ways to overcome these problems is to include in the course computer training tools that use the means provided by modern information technologies to visualize complex phenomena, processes, and modern technical devices.

The article is devoted to the elective course “Nuclear Physics” for high school students, which includes a traditional textbook, a computer application and illustrative materials, available on mobile devices through using QR codes. It is assumed that the course will be studied optionally in grades 10 or 11 for six months or the entire school year. At the same time, teaching materials were developed in such a way as to facilitate their use by the teacher and within the framework of the main course of physics in the study of the relevant sections and topics.

The main idea of the course can be formulated as follows: “From nuclear physics to nuclear technology.”

2. Elective course “Nuclear Physics” for high school students

A team consisting of scientists and specialists from the Joint Institute for Nuclear Research (JINR), teachers from the National Research Nuclear University MEPhI (NRNU MEPhI) and developers of the InterGraphics LLC worked on creating an elective course “Nuclear Physics” for high school students. As a result of this collaboration, created course includes a traditional textbook [1] and additional multimedia educational resources combined into an electronic application (fig. 1). In addition, to facilitate understanding of complex physical processes and operation principles of modern experimental facilities, a series of illustrative materials were developed. These materials are available on mobile devices using QR codes printed on the pages of the textbook.

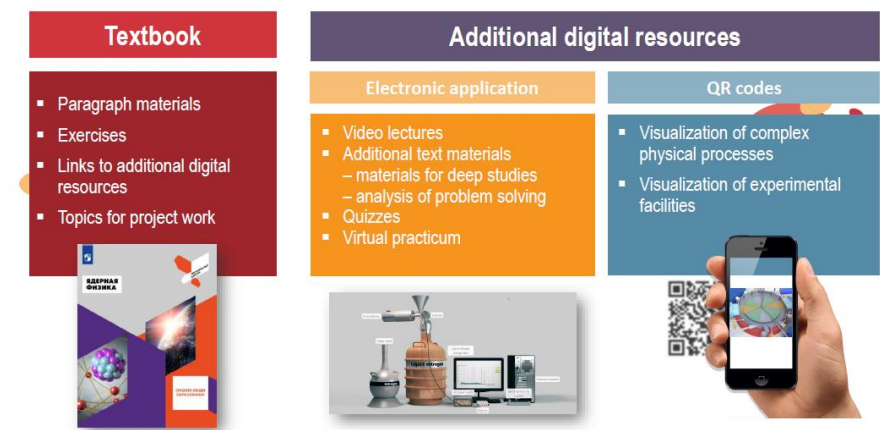


Figure 1. Materials for the course “Nuclear Physics”

In the textbook published by the Publishing House “Prosveshcheniye”, the content is divided into 11 sections. Each section ends with links to the materials of the computer application, and in the end of the textbook the topics for individual research works are given. These topics are currently very important, because with their help, students can implement their own project, which is mandatory for everyone under the new educational standards.

The computer application [2] is located on the JINR Educational Portal in the section “Scientists for School”. Each section of the textbook is provided with video lectures, additional materials for in-depth study, examples of problem solving presented in the computer application of the course. In addition, each section is also provided by interactive materials for knowledge quality control. At the end of the course, the final quiz is suggested to be passed, as well as the interactive virtual practicum on nuclear physics.

The full contents of the textbook are given below (fig. 2).

Introduction	CHAPTER 6. NUCLEAR ASTROPHYSICS
CHAPTER 1. CHEMICAL ELEMENTS. ATOMS AND MOLECULES. ISOTOPES	§ 16. The universe had a beginning
§ 1. Substance. Atoms and molecules	§ 17. The origin of the elements in the stars
§ 2. Properties of chemical elements. The periodic system of D. I. Mendeleev	Tasks to the chapter
Tasks to the chapter	Video lectures to the chapter
Video lectures to the chapter	Additional materials
Tests to the chapter	CHAPTER 7. SYNTHESIS OF NEW HEAVY AND SUPERHEAVY ELEMENTS
CHAPTER 2. ATOM AND ATOMIC NUCLEUS	§ 18. The reactions of the synthesis of new elements are heavier than uranium
§ 3. The structure of the atom	§ 19. Experiments in finding the “island of stability.”
§ 4. Isotopes	Additional materials
§ 5. The basic properties of nuclei	CHAPTER 8. RADIATION AND LIFE
Tasks to the chapter	§ 20. Cosmic radiation
Video lectures to the chapter	§ 21. The effect of radiation and methods of protection against it
Additional materials	Video lectures to the chapter
Tests to the chapter	CHAPTER 9. USE OF NUCLEAR TECHNOLOGIES
CHAPTER 3. THE PHENOMENON OF RADIOACTIVITY	§ 22. Nuclear power
§ 6. History of the discovery of radioactivity	§ 23. Nuclear medicine
§ 7. The law of radioactive decay. Types of decays	§ 24. Nuclear technology in industry
§ 8. Alpha, beta, and gamma decays	§ 25. Radiocarbon dating
§ 9. Natural radioactivity. Radioactive rows	Tasks to the chapter
Tasks to the chapter	Video lectures to the chapter
Video lectures to the chapter	CHAPTER 10. GLOBAL SOURCES OF ENERGY
Tests to the chapter	§ 26. Energy in human life
CHAPTER 4. RELATIONSHIP OF MASS AND ENERGY	§ 27. Sources of energy on Earth and their comparative analysis
§ 10. The relationship of mass and energy	Tasks to the chapter
§ 11. Division and synthesis	Video lectures to the chapter
Tasks to the chapter	CHAPTER 11. IN THE LABORATORIES OF SCIENTISTS
Additional materials	§ 28. Colliders and puzzles of the Universe
Tests to the chapter	§ 29. Neutron as an instrument of scientific research
CHAPTER 5. NUCLEAR REACTIONS	§ 30. Heavy ions and the safety of manned flights to Mars
§ 12. Nuclear reactions - the path to obtaining new items	§ 31. Neutrino physics on Lake Baikal
§ 13. Laws of conservation in nuclear reactions	Additional materials
§ 14. Nuclear reactions under the action of charged and neutral particles	Conclusion
§ 15. Characteristics of a nuclear reaction	Final test
Tasks to the chapter	Sample topics for individual projects
Video lectures to the chapter	Virtual research workshop in nuclear physics
Additional materials	Methodical materials for the workshop
Tests to the chapter	Appendix 1. D.I. Mendeleev Periodic table of the elements

Figure 2. The content of the elective course “Nuclear Physics”

The figure 3 shows the double page of the textbook from the first section with the QR code referring the reader to the interactive periodic table.

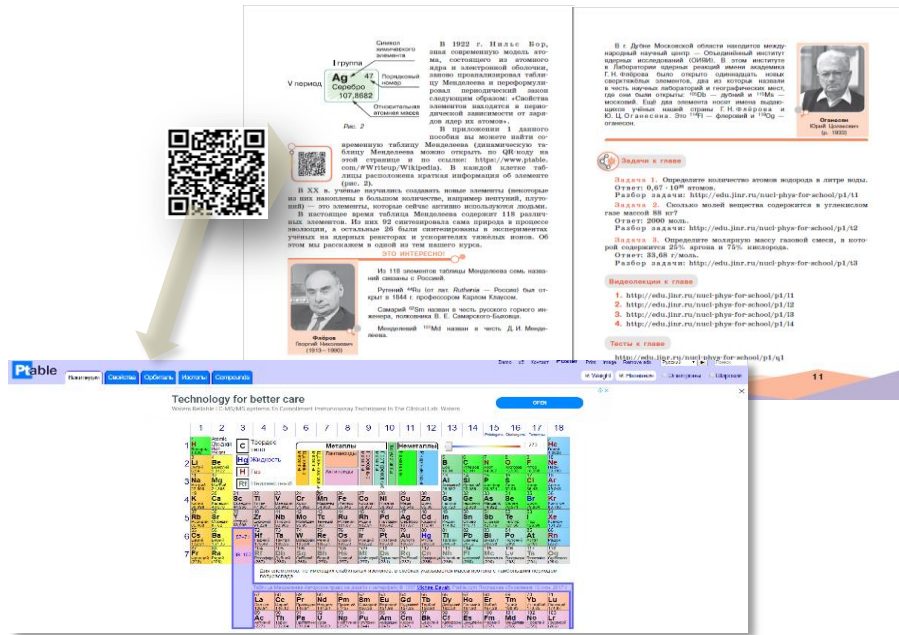


Figure 3. An example of the textbook double page with a QR code and the corresponding educational resource

Using the Internet links at the end of the section, the reader gets access to the materials of the computer application (fig. 4). Video lectures and examples of problem solving were recorded with the participation of teachers of the NRNU MEPhI who took part in the creation of this course.

Particular attention is paid to modern fundamental and applied research in the field of nuclear physics. High school students are told about the research carried out in large international research centers. For example, the textbook talks about nuclear astrophysics, nuclear planetology, experiments on the synthesis of new superheavy elements and the search for the stability island, nuclear energy and nuclear medicine, the method of nuclear carbon dating, etc. To facilitate understanding of these materials, using modern visualization and 3D modeling tools, multimedia educational resources have been developed, access to which can be obtained through the corresponding QR codes.

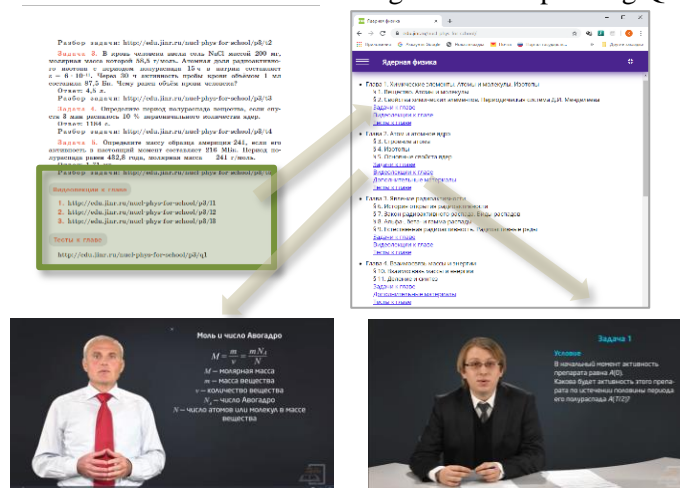


Figure 4. Video lectures as additional materials

The virtual practicum on nuclear physics includes the following laboratory works:

1. Basic measurements in nuclear physics. Virtual laboratory work with an oscilloscope and a signal generator
2. Basic measurements in nuclear physics. Virtual laboratory work with a radioactive source
3. Interaction of charged particles with matter. Virtual laboratory work on measuring the spectrum of alpha particles (fig. 5 a)

4. The interaction of gamma rays with matter. Compton effect. The birth of electron-positron pairs. Virtual laboratory work to measure the spectrum of gamma rays
5. Characteristic X-ray radiation. Mosley's Law. Virtual laboratory work on measuring the charge of the nucleus
6. Virtual laboratory work to study the process of spontaneous fission of Californium-252 using a two-arm time-of-flight spectrometer



Figure 5. a) Virtual Practicum on Nuclear Physics. Investigation of the interaction of charged particles with matter. Semiconductor detectors for alpha-particle registration b) Final Quiz

At the end of the course, the high school students have the opportunity to pass the final quiz, which includes a large number of test materials of various types (fig. 5 b).

3. Conclusion

In 2019, the elective course “Nuclear Physics” was presented at the professional training courses for physics teachers at North Ossetian State University named after K.L. Khetagurova, at international schools for physics teachers at JINR and CERN. Teachers expressed great interest in the presented materials, and many of them plan to use materials of the course when organizing lessons and electives in their schools.

References

- [1] N.I. Vorontsova et al. Nuclear Physics. 10–11 grades: textbook for high school. Edited by Yu.A. Panebrattsev, G.V. Tikhomirov//M.: Prosveshchenie 2019, 159 p.
- [2] Nuclear Physics for School // Available at: <https://edu.jinr.ru/nucl-phys-for-school/> (accessed 10.11.2019)