I. I. Mechnikov Odesa National University
Faculty of Mathematics, Physics and Information Technologies
Department of Physics and Astronomy

Course Syllabus
Quantum informatics

Volume	3 credits, 90 hours
Semester, year of study	2 semester, 1st year of study
Days, time, place	According to schedule
Teacher(s)	Prof. Kulinskiy V.L
Contact Phone	0973779930
E-mail	kulinskij@onu.edu.ua
Workplace	Pastera st. 42, room 31
Consultations	Thursday, 14.30-17.00, Pastera st. 42, room. 31

COMMUNICATION

Communication with students: E-mail: kulinskij@onu.edu.ua; Google-Class (who has an account at onu.edu.ua)

COURSE SUMMARY

The subject of study of the academic discipline is the basic principles of quantum informatics, on which modern research in the field of quantum computing and quantum computing devices is based.

The study of the discipline "Quantum Informatics" is preceded by the disciplines of a foreign language for a professional orientation, elementary particle physics and nuclear astrophysics. Knowledge of the discipline "Quantum Informatics" lays the foundations for the preparation of a master's thesis for defense.

The goal of the course is to train specialists who are able to understand, combine and apply in their future professional activities the ideas and applied methods of quantum mechanics, which are now coming to the fore as a result of the combination of achievements in nanophysics and information technologies.

The task of the discipline is to prepare the formation of the following system of competencies in students, which includes:

Integral competence. Ability to solve complex tasks and problems of a research and/or innovative nature in physics and astronomy.

General competencies: ZK 01. Ability to apply knowledge in practical situations.

ZK 02. Knowledge and understanding of the subject area and understanding of professional activity.

ZK 04. Ability to learn and master modern knowledge.

ZK 06. Ability to identify, pose and solve problems.

Special (professional) competencies:

SK 03. Ability to present the results of research, as well as modern concepts in physics and/or astronomy to specialists and non-specialists.

SK 04. Ability to communicate with colleagues orally and in writing in the state and English languages regarding scientific achievements and research results in the field of physics and/or astronomy.

Learning outcomes provide the ability to:

know: new ideas, concepts and methods that have become firmly rooted in computer science and nanophysics over the past twenty years and now form the foundation for the further development of information technologies based on quantum logic circuits and algorithms;

be able to: apply the principles of quantum theory in computer science and information technologies, solve simpler problems of analysis and synthesis of circuits for quantum computing and evaluate the possibilities and effectiveness of their physical implementation,

which is provided by the program learning outcomes

PH07. Present research results in the form of reports at seminars, conferences, etc., carry out a professional written description of scientific research, taking into account the requirements, goal and target audience.

PH10. Apply theories, principles and methods of physics and/or astronomy to solve complex interdisciplinary scientific and applied problems.

PH13. Develop and teach physical and/or astronomical academic disciplines in higher, professional pre-higher, professional (vocational-technical) institutions, apply modern educational technologies and methods, provide the necessary consultative and methodological support to students.

COURSE DESCRIPTION

Forms and methods of teaching

The course will be taught in the form of lectures (30 hours) and the organization of independent work of students (60 hours).

Teaching methods

When teaching the discipline, interactive teaching methods and visual teaching methods are used. The basic teaching method is a combination of lectures and independent work. During lectures, the following teaching methods are used:

explanatory-illustrative method or information-receptive; problem-based presentation method; partial-search, or heuristic method. During independent work, the research method is used.

Content of the academic discipline

Topic 1. Elements of quantum informatics. Classical computing elements and circuits (bits, registers, logic elements). Quantum bits (qubits). Single-qubit gates (valves). Multi-qubit gates. Entangled states. Controlled gates for quantum computing. Physical models of qubits. Spins and polarized photons.

Topic 2. Fundamentals of quantum informatics. Measurement of the qubit state. Theorem on non-cloning. Quantum teleportation. EPR (Einstein-Podolsky-Rosen) - states. Hidden parameters. Bell's inequality. Violation of Bell's inequality.

Topic 3. Quantum algorithms and protocols. Deutsch and Deutsch-Joshy algorithms. Search in an unordered database. Grover's algorithm. Simon's algorithm. Fast Fourier transform. Shor's algorithm. Elements of quantum cryptography. Dense coding. Disposable notebook. Secret key transfer protocols.

Topic 4. Ways to implement quantum computing. Quantum computers on Rydberg atoms. Quantum computers on ions in laser traps. Computers on arrays of quantum dots, superconducting elements.

ecommended reading

References

Basic

1. Адамян В.М., Завальнюк В.В. Вступ до квантової теорії інформації (конспект лекцій), Одеса 2019 (наукова бібліотека ОНУ).
2. Остапов С.Е., Добровольський Ю.Г. Квантова інформатика та квантові обчислення - Чернівці: ЧНУ, 2021. - 99 с.
3. Лебедь О. О., Дейнека О. Ю., Рибалко А. В., Гаращенко В. І. Основи квантового комп'ютера та квантової інформатики : навч. посіб. /. - Рівне : НУВГП, 2014. - 151 с.
4. Kitaev A., Shen A., Vyalyi M. Classical and Quantum Computation, AMS 2002 (https://www.ams.org/books/gsm/047/gsm047-endmatter.pdf)
5. Stig Stenholm, Kalle-Antti Suominen. Quantum approach to informatics, John Wiley & Sons, Inc., Hoboken, New Jersey, 2005, 238 p. (https://onlinelibrary.wiley.com/doi/book/10.1002/0471739367)

Additional

1. Вакарчук І.О.. Квантова механіка, 3-тє видання, Львів: ЛНУ ім. Івана Франка, 2007, 848 с. (наукова бібліотека ОНУ)
2. Ткачук В.М.. Фундаментальні проблеми квантової механіки, Львів: ЛНУ ім. Івана Франка, 2011, 143 с. (наукова бібліотека ОНУ)

15. Resources

1. http:// www.theory.caltech.edu/~preskill/ph219/ph219_2015-16

2. IBM Quantum Experience

3. http://theorphys.onu.edu.ua/uk/textbooks

ASSESSMENT

The academic discipline "Quantum Informatics" is assessed on a 100-point scale. Final semester control - credit.

Methods of current control:

Current control is carried out based on the results of students' independent control work, defense of an individual task.

Criteria for evaluating the performance of independent work

The evaluation criteria are: completeness of the task, structure and quality of answers and additional questions from the teacher.

Criteria for evaluating control work

The evaluation criteria are the correctness and completeness of the answer to the test questions, justification of correct and correction of errors as a result of personal defense of the work. The number of points is determined by the sum of correct answers, taking into account the logical connections between tasks during computer processing of the test results. The student's activity in the process of classes is also assessed: oral questioning, performance of independent work; solving problems.

When assessing the level of material mastery in points, the general criteria for assessing the academic achievements of higher education applicants are used according to the regulations of ONU named after I.I. Mechnikov. The final grade is given by the sum of the points of the current and final control according to the scale given below.

Independent work of students. Forms of independent work of students are: preparation of theoretical material (lectures). The goal of independent work of the student is to ensure solid knowledge of theoretical material in quantum informatics..

The deadlines for submitting/performing independent work tasks are determined by the teacher.

COURSE POLICY

Determined by regulatory documents/Regulations that are in force at ONU named after I.I. Mechnikov (https://onu.edu.ua/uk/geninfo/official-documents).

The deadline for completing course tasks is determined by the teacher. In case of good reasons, the teacher allows the postponement of the deadline for completing tasks. Recalculation of debts - with the permission of the dean's office.

Each student must remember about academic integrity, which is ensured by independent performance of educational tasks, tasks of current and final control, proper reference to sources of information in the case of performing creative works, compliance with the norms of the legislation on copyright and related rights, provision of reliable information about the results of their own scientific activities.

For violation of academic integrity, students may be held academically liable in accordance with the Regulations on Academic Integrity at I.I. Mechnikov ONU. (https://onu.edu.ua/pub/bank/userfiles/files/documents/acad-dobrochesnost.pdf).

Attendance at classes for a 1st-year student is mandatory, as is timely arrival at classes.