SYLLABUS

1. Information about the study programme

1.1 Institution of higher education	West University of Timisoara
1.2 Faculty	Faculty of Physics and Mathematics
1.3 Department of	Physics
1.4 Field of study	Physics
1.5 Study cycle	Master
1.6 Study programme	Advanced Research Methods in Physics

2. Information about the subject/discipline

2.1 Name	**Applications of Quantum Mechanics in Technology ARMP1203**						
2.2 Course coordinator	Lect. univ. dr. Gabriel Pascu						
2.3 Seminar coordinator	Lect. univ. dr. Gabriel Pascu						
2.4 Year of study	1	**2.5 Semester**	2	**2.6 Type of assessment**	E	**2.7 Type of discipline**	DS/ DOB

3. Total estimated time (hours of teaching per semester)

3.1 Number of hours per week	3	**3.2 course**	2	**3.3 seminar/laboratory**	1
3.4 Total hours in the curriculum	42	**3.5 course**	28	**3.6 seminar/laboratory**	14

Distribution of time:	**hours**
Study based on Instructions, course materials, bibliography and notes	30
Additional documentation library, specialized electronic platforms / field	40
Training seminars / laboratories, homework, essays, portfolios and essays	30
Tutoring	2
Examinations	3
Other activities	3

3.7 Total hours of individual study	**105**
3.8 Total hours per semester	**150**
3.9 Number of credits	**6**

4. Prerequisites (where applicable)

4.1 of curriculum	• Complements of Quantum Mechanics
4.2 of skills	• text interpretation, PC use

5. Conditions (where applicable)

5.1 for the course	• the dialogue takes place in a group, tasks are solved individually, followed by collective discussion; • materials: whiteboard, marker, projector, laptop, internet access, notebooks/sheets for notes, pen, apps (Powerpoint, Peardeck).
5.2 for the seminar/ laboratory	• students are divided into working teams, tasks are solved in groups; • materials: experimental setups, worksheets, pen, pencil, apps (QuTip, Qiskit).
5.3 for working with online platforms	• access to online platforms will be granted only based on e-uvt credentials (institutional e-mail addresses @e-uvt.ro); • official communication will be carried out only through institutional official channels (Gmail, Google Classroom - as applicable) and strictly between accounts linked to institutional e-mail addresses @e-uvt.ro; • teaching support and bibliography will be available on the Google Classroom platform (https://classroom.google.com), and students are required to use this platform to procure the provided study materials; • assignments given to students (papers, homework, reports, etc.) will be submitted exclusively in electronic format via the Google Classroom platform; • for scanning handwritten materials and generating pdf files, it is recommended to use either mobile applications such as Microsoft Lens / Adobe Scan or a PC scanner.

6. Discipline objectives - expected learning outcomes which contribute to the completion and passing the discipline

Knowledge	• define essential concepts; • use domain-specific terminology; • define advanced physical concepts, theories, and methods; • exemplify theoretical concepts; • verify calculations and interpret them; • compare formulas or results; • interpret analytical results expressed in different units of measurement; • justify the need for a given technique; • exemplify suitable analytical methods in concrete situations; • be familiar with the main types of analyses and techniques used; • develop algorithms for acquiring datasets required by a project through appropriately chosen instrumental measurements; • understand the concepts and phenomena underpinning specific methods and the instrumental methods of analysis and measurement specific to physics; • exemplify the benefits of certain methods or techniques; • answer questions within the studied disciplines; • apply theory to real cases; • identify specific analysis protocols; • identify strengths and weaknesses in a protocol; • corroborate theoretical data with practical data.

Skills	• deduce the working formulas for calculations with physical quantities, using appropriately the principles and laws of physics; • describe physical systems using specific theories and tools (experimental and theoretical models, algorithms, schemes, etc.) ; • apply the principles and laws of physics in solving theoretical or practical problems, under conditions of qualified assistance; • use the computer and calculation programs for the numerical simulation of the physical processes; • use high-level mathematical skills to solve conceptual and quantitative problems in physics; • describe critical experiments in the history of physics and explain how they led to revisions of our theoretical descriptions of nature; • analyse physical systems and provide order-of-magnitude estimates of quantities. This includes a knowledge of basic physical constants and key equations; • apply the full conceptual and methodological apparatus to solve complex problems under conditions of incomplete information; • apply (practice) knowledge in new situations.
Responsibility and autonomy	• assume responsibility for managing professional development; • participate in some concrete physics experiments; • critically analyze a specialized report, scientific communication with a medium degree of difficulty in the field of physics; • be autonomous in the context of handling laboratory equipment, including in situations requiring an interdisciplinary approach; • autonomously use information sources and resources for communication and assisted professional training (Internet portals, specialized software applications, databases, online courses, etc.) both in Romanian and in a language of international circulation.

7. Contents

The platform through which the course materials in electronic format and other learning/bibliographic resources can be accessed: Google Classroom

7.1 Course	Teaching method	Comments
Foundations of Quantum Mechanics for Technology (Postulates, superposition, entanglement, measurement, two-level systems as quantum resources)	exposition/ dialogue	2h
Qubits, States, and Quantum Circuits (Bloch sphere, multi-qubit states, universal gate sets, circuit construction principles)	exposition/ dialogue	2h
Quantum Frameworks and Simulation Tools (Qiskit, Cirq; simulating quantum states, noise models, running simple circuits)	exposition/ dialogue	2h
The Jaynes–Cummings Model and Light–Matter Interaction (Atom–cavity coupling, Rabi oscillations, dressed states, role in quantum hardware)	exposition/ dialogue	2h
Open Quantum Systems, Decoherence, and the Lindblad Equation (Noise channels, density matrices, Lindblad master equation, implications for hardware fidelity)	exposition/ dialogue	2h

Physical Realizations I: Photonic Qubits and Quantum Optics (Single-photon sources, interferometers, integrated photonics, continuous-variable systems)	exposition/ dialogue	2h
Physical Realizations II: Quantum Dots and Semiconductor Spin Qubits (Charge/spin qubits, optical/electrical control, coupling to cavities, scaling challenges)	exposition/ dialogue	2h
Physical Realizations III: Trapped Ions and Neutral Atoms (Ion traps, laser manipulation, Rydberg atoms, quantum simulation prospects)	exposition/ dialogue	2h
Physical Realizations IV: Magnetic Resonance Qubits - Nuclear Spins and Solid-State Defects (NMR ensembles, NV centers, donor spins, rare-earth ions, hybrid sensing applications)	exposition/ dialogue	2h
Physical Realizations V: Superconducting Circuits and Josephson Qubits (Transmons, flux/charge qubits, circuit QED, industrial scalability)	exposition/ dialogue	2h
Quantum Algorithms I: Foundational Examples (Deutsch-Jozsa, Grover's search, phase estimation as algorithmic primitives)	exposition/ dialogue	2h
Quantum Algorithms II: Shor's Algorithm and Quantum Simulation (Prime factorization, Hamiltonian simulation, HHL algorithm)	exposition/ dialogue	2h
Quantum Communication and Quantum Cryptography (Quantum teleportation, BB84, entanglement-based key distribution)	exposition/ dialogue	2h
Outlook and Emerging Applications of Quantum Technologies (NISQ devices, hybrid quantum-classical methods, sensing, metrology, future perspectives)	exposition/ dialogue	2h

Bibliography:
[1] Nielsen M.A., Chuang I.L., Quantum Computation and Quantum Information, Cambridge University Press, 2010.
[2] Kaye P., Laflamme R., Mosca M., An Introduction to Quantum Computing, Oxford University Press, 2007.
[3] Yamamoto Y., Imoto N., Principles of Quantum Computation and Information - Vols. I & II, World Scientific, 2005.
[4] Haroche S., Raimond J.M., Exploring the Quantum: Atoms, Cavities, and Photons, Oxford University Press, 2006.
[5] Wendin G., Quantum Information Processing with Superconducting Circuits: A Review, Reports on Progress in Physics, 80(10), 106001, 2017.

7.2 Laboratory	**Teaching method**	**Comments**
Introductory Quantum Mechanics Calculations (Two-level systems, entanglement measures, measurement probabilities, expectation values)	problem solving	2h
Simulating Quantum Circuits in Qiskit (basics gates; single- and two-qubit gates; measurement statistics)	simulation	2h
Lindblad Dynamics with QuTiP (Solving master equations, amplitude damping, dephasing, extracting relaxation times)	simulation	2h
Photonics and Interferometry (Michelson/Mach-Zehnder interferometer, beam splitters, phase shifts, quantum vs classical interference)	experiment	2h
Relaxation and Decoherence: T_1 and T_2 in NMR (Spin echoes, nuclear spin relaxation times, simulations of T_1/T_2 processes)	experiment, problem solving	2h
Implementing Quantum Algorithms on Circuits (Grover search, Phase Estimation, circuit depth and fidelity under noise)	simulation	2h
Simulating Quantum Cryptography Protocols (BB84, teleportation, eavesdropping effects, secure key generation)	simulation	2h

Bibliography:
[1] DiVincenzo D.P., Loss D. (eds.), Experimental Aspects of Quantum Computing, Springer, 2005.
[2] Kok P. et al., Linear optical quantum computing with photonic qubits, Reviews of Modern Physics, 79, 135, 2007.
[3] Vandersypen L.M.K., Chuang I.L., NMR techniques for quantum control and computation, Reviews of Modern Physics, 76, 1037, 2004.
[4] Johansson J.R., Nation P.D., Nori F., QuTiP: An open-source Python framework for the dynamics of open quantum systems, Comp. Phys. Comm., 183, 1760-1772, 2012.
[5] Scherer A. et al., Programming Quantum Computers: Essential Algorithms and Code Samples, O'Reilly Media, 2019.

8. Corroboration of the course contents with the epistemic expectations of the community representative, professional associations and representative employers of the programme itself

The course *Applications of Quantum Mechanics in Technology* is designed in line with the expectations of the scientific community, industry groups, and employers in quantum computing and related fields. It balances core theoretical foundations with hands-on training in simulation tools and quantum programming, while placing strong emphasis on the study of physical realizations of qubits - an area recognized as equally, if not more, critical than algorithms and software for advancing practical quantum computation. By covering diverse hardware platforms, open-system dynamics, and key applications such as algorithms and cryptographic protocols, the course equips students with the interdisciplinary knowledge and skills most valued in research, industry, and the growing quantum technology workforce.

9. Use of tools based on generative artificial intelligence

To complete the tasks defined in the assessment section, the use of generative AII tools is permitted for generating ideas / slogans / designs / images /text rewriting, editing / reviewing.
The most well-known examples of generative AII tools include, but are not limited to: ChatGPT, Google Gemini, Copilot for text, or MidJourney for images.
Each student will specify, in a statement written separately for each assignment, according to the model in Annex 3 of the Regulation on the use of generative artificial intelligence in the educational process at UVT, the tool they used, how it was used, and the part of the assignment in which it was used. The statement will be included by the student at the beginning of the submitted assignment.

10. Evaluation

Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Percentage of the final mark
10.4 Course	Written exam consisting of 3 subjects from the topics covered in the course (one of low difficulty, one of medium difficulty, and one of high difficulty), each graded with 3 points (total of 10 points, including 1 point awarded by default).	written, summative	50%
10.5 Seminar	Homework and semester activity consisting of completing assignments, using software tools, and participating in discussions on the covered topics.	continuous assessment, portfolio	50%
10.6 Minimum performance standards			
Course: comprehensive treatment of one subject and partial treatment of another subject among the 3 from the written exam. Laboratory: completion of at least half of the assignments and active participation in at least half of the sessions.			

Date of submission:
30.01.2026

Titular of the course:
Lect. univ. dr. Gabriel Pascu

Date of approval in department:

Laboratory titular:
Lect. univ. dr. Gabriel Pascu

HEAD OF THE DEPARTMENT:
Conf. univ. dr. Nicoleta Adina Ștefu