Syllabus

1. Data about the program of study

1.1 Institution	Technical University of Cluj-Napoca
1.2 Faculty	Automation and Computer Science
1.3 Departament	Computer Science
1.4 Field of study	Computer Science and Information Technology
1.5 Cycle of study	Bachelor of Science
1.6 Program of study / Qualification	Computer science / Engineer
1.7 Form of education	Full time
1.8 Subject code	103.00

2. Data about the subject

2.1 Subject name	***Basics of Quantum Information***				
2.2 Course responsible / lecturer	CS1 dr. Liviu Zarbo - liviu.zarbo@itim-cj.ro				
2.3 Teachers in charge of applications	CS Levente Mathe - levente.mathe@itim-cj.ro AC Larisa Pioras-Timbolmas - larisa.timbolmas@itim-cj.ro				
2.4 Year of study	II	2.5 Semester	1	2.6 Assessment *(E/C/V)*	E
2.7 Type of subject	*DF – fundamental, DD – in the field, DS – specialty, DC – complementary*				DC
	DI – compulsory, DO – elective, Dfac – optional				DFac

3. Estimated total time

3.1 Number of hours per week	3	of which:	Course	2	Seminar		Laboratory	1	Project	
3.2 Number of hours per semester	42	of which:	course	28	Seminar		Laboratory	14	Project	
3.3 Individual study										
(a) Manual, lecture material and notes, bibliography										10
(b) Supplementary study in the library, online and in the field										10
(c) Preparation for seminars/laboratory works, homework, reports, portfolios, essays										10
(d) Tutoring										0
(e) Exams and tests										3
(f) Other activities:										0

3.4 Total hours of individual study (sum of (3.3(a)...3.3(f)))	33
3.5 Total hours per semester (3.2+3.4)	75
3.6 Number of credit points	3

4. Pre-requisites (where appropriate)

4.1 Curriculum	Linear Algebra Mathematical Analysis Physics Programming
4.2 Competence	

5. Requirements (where appropriate)

5.1. For the course	
5.2. For the applications	

6. Specific competences

6.1 Professional competences	Basic high-school level or first year undergraduate physics: mechanics, electricity and magnetism, optics Basic knowledge of linear algebra and calculus, first year undergraduate student level Basic programming knowledge, first year undergraduate student level
6.2 Cross competences	

7. Course objectives

7.1 General objective	Developing general knowledge relevant to applications in the field of quantum computation and quantum communications
7.2 Specific objectives	1. Assimilating the basics of quantum computation: qubits, quantum gates, quantum circuits, quantum algorithms 2. Developing the basic skills for developing quantum algorithms 3. Understanding the basics of quantum communications protocols.

8. Contents

8.1 Curs	Nr.ore	Teaching methods	Notes
1. Introductory notions. • From classical to quantum computing • The dual behavior of the quantum objects • Tunneling • Double slit experiment	2	Blackboard, video-lectures, discussions of examples, problem solving	
2. Quantum states • Notations • Probabilities • Matrix and vector representation of quantum states • Qubits • Pure states and mixed states	2		
3. Observables and quantum measurement 1 • Observables and operators • The Heisenberg principle • Projective measurements • The Stern-Gerlach experiment	2		
4. Observables and quantum measurement 2 • Quantum state vectors. • Observables and operators, the density matrix. • Probabilities and expectation values. • Partial measurements	2		
5. Qubits • The two-level system and real life examples • Quantum gates • Superpositions and entanglement of qubits • The Bloch sphere.	2		
6. Qubit control • Larmor precession. • Rabi oscillations • Functioning of quantum gates.	2		
7. Quantum measurement and applications 1. • The no-cloning theorem • Quantum teleportation • Quantum sensing • Quantum tomography	2		
8. Quantum measurement and applications 2. • Quantum random number generation • Quantum communication protocols (BB84).	2		
9. Quantum Communication • Quantum cryptography notions • Quantum communication networks.	2		
10. Quantum computation and simulations • digital and analog quantum computers. • Quantum simulations – concepts/applications.	2		
11. Quantum circuits and algorithms • The Uranium platform	2		

• Using online quantum computing resources (e.g. IBMQ)			
12. Quantum algorithms 1. • Deutsch-Josza algorithm. • Grover algorithm	2		
13. Quantum algorithms 2. • Quantum Fourier transform • RSA and Shor's algorithm	2		
14. Physical platforms for quantum computing • Superconducting qubits • Cold atoms • Ion traps	2		

Bibliography

1. Nielsen and Chuang, Quantum Computation and Quantum Information, Cambridge University Press (2010).
2. Ioan Burda, Introduction to Quantum Computation, Universal Publishers (2005).
3. David McIntyre, Quantum Mechanics: A Paradigms Approach, Pearson Addison-Wesley (2012).
4. Cohen-Tannoudji, Quantum Mechanics, Wiley-VCH; 2nd edition (2019).

8.2 Aplications (seminar/laboratory/project)	No.hours	Teaching methods	Notes
1. Visualising qubit operations: Bloch sphere, single qubit gates, destructive and constructive interference (Quantum Odyssey)	2	Lab work in INCDTIM Quantum Software lab, using tools such as Uranium, Quantum Oddyssey, Google Colab.	
2. Quantum circuits in Q. Odyssey: vectors, eigenvalues, basis change	2		
3. Generating entanglement in quantum circuits (quantum gates: CNOT, SWAP, Toffoli). Visualisation in Q. Odyssey, circuits on the Uranium platform.	2		
4. Time evolution of qubits and their observables: visualization in Python	2		
5. Uranium platform: multiqubit quantum circuits and quantum measurements; Deutsch algorithm	2		
6. Quantum oracles, Grover's algorithm (Uranium, Q. Odyssey)	2		
7. The Quantum Fourier Transform	2		

Bibliography

1. Nielsen and Chuang, Quantum Computation and Quantum Information, Cambridge University Press (2010).
2. Ioan Burda, Introduction to Quantum Computation, Universal Publishers (2005).
3. David McIntyre, Quantum Mechanics: A Paradigms Approach, Pearson Addison-Wesley (2012).
4. Cohen-Tannoudji, Quantum Mechanics, Wiley-VCH; 2nd edition (2019).

9. Bridging course contents with the expectations of the representatives of the community, professional associations and employers in the field

10. Evaluation

Activity type	Assessment criteria	Assessment methods	Weight in the final grade
Course	Solving 2 problems + 1 theory set of questions	Written exam	60%
Seminar			
Laboratory		Periodic lab quizzes	40%
Project			
Minimum standard of performance:			

Date of filling in:	Teachers	Title Firstname NAME	Signature
	Course	Dr. Liviu Zarbo	
	Aplications	Levente Mathe	
		Larisa Pioras-Timbolmas	

Date of approval in the department 20.02.2024	Head of Departament, Prof. dr. eng. Rodica Potolea
Date of approval in the Faculty Council 22.02.2024	Dean, Prof. dr. eng. Mihaela Dinsoreanu