syllabus

1. Information regarding the programme

1.1 Higher education institution	**Babeş Bolyai University**
1.2 Faculty	**Faculty of Mathematics and Computer Science**
1.3 Department	**Department of Computer Science**
1.4 Field of study	
1.5 Study cycle	
1.6 Study programme / Qualification	**Quantum Computing and Communication** **(în limba engleză)**

2. Information regarding the discipline

2.1 Name of the discipline		**Basics of quantum computing**					
2.2 Course coordinator		Andrei Voicu Tomuț					
2.3 Seminar coordinator		Andrei Voicu Tomuț					
2.4. Year of study	**1**	2.5 Semester	**1**	2.6. Type of evaluation	**E**	2.7 Type of discipline	**DF**
2.8 Code of the discipline	PQE0004						

3. Total estimated time (hours/semester of didactic activities)

3.1 Hours per week	4	Of which: 3.2 course	2	3.3 seminar/ laboratory	2
3.4 Total hours in the curriculum	40	Of which: 3.5 course	20	3.6 seminar/ laboratory	20

Time allotment:	hours
Learning using manual, course support, bibliography, course notes	10
Additional documentation (in libraries, on electronic platforms, field documentation)	10
Preparation for seminars/labs, homework, papers, portfolios and essays	10
Tutorship	5
Evaluations	2
Other activities:	

3.7 Total individual study hours	35
3.8 Total hours per semester	75
3.9 Number of ECTS credits	3

4. Prerequisites (if necessary)

4.1. curriculum	•
4.2. competencies	•

5. Conditions (if necessary)

5.1. for the course	•

5.2. for the seminar /lab activities	•

6. Specific competencies acquired

Professional competencies	C1 Using the theoretical background of quantum mechanics in order explain the bahavior of microscopic systems. C4 Using interdisciplinary knowledge, solution patterns and tools, making experiments and interpreting their results
Transversal competencies	CT1 Honorable, responsible, ethical behavior, in the spirit of the law, to ensure the professional reputation CT3 Demonstrating initiative and pro-active behavior for updating professional, economical and organizational culture knowledge.

7. Objectives of the discipline (outcome of the acquired competencies)

7.1 General objective of the discipline	• C1.1 Identifying the notions, describing the theories and using the specific language. • C2.3 Applying the adequate analytical theoretical methods to a given problem.
7.2 Specific objective of the discipline	• CT1. Applying some rules of precise and efficient work, showing a responsible attitude regarding the scientific domain and teaching training for an optimal and creative development of the personal potential in specific situations, respecting the deontological norms.

8. Content

8.1 Course	Teaching methods	Remarks
1. Introduction to Qubits		- How to represent a qubit ? - Bloch sphere - QSphere - Matrix representation - Dirac notation
2. Quantum gets and circuits		- What operations can be done on a qbit? - one qubit gate - gates on multiple qubits -design a quantum circuit with a circuit editor (Uranium)
3. Phase kickback and Quantum Teleportation		- show the phase kickback phenomena.
4. Introduction to quantum algorithms		- Deutsch-Jozsa algorithm - Bernstein Vasirani algorithm -Simons's Algorithm

5. Quantum Fourier transform		- What's the QFT advantage over the FFT? - math behind QFT - intuition behind phase estimation
6. Quantum Phase Estimation		- What are the applications of phase estimation? - intuition behind phase estimation. -math behind phase estimation.
7. Grover Algorithm, Grover Algorithm for solving search problems		- What are the components of a grover algorithm? - intuition behind Grover. - How to build an oracle?
8. Introduction to variational algorithms		- What are the components of a VQE? - VQE applications
9. Variational algorithms, Variational algorithms in practice. Limitations		- VQE - QAOA - VQE implementations for solving certain tasks. - optimisations
10. Introduction to QML		-

Bibliography

1: Quantum Computing and Quantum Information : https://www.libris.ro/quantum-computation-and-quantum-information-BRT9781107002173--p1209861.html?gclid=Cj0KCQjwxveXBhDDARIsAI0Q0x0qkMQleAGNIx61WL5pxYv34Y72kNQ-9PzHC1ulpFYH4_gP62o3w9IaAjRwEALw_wcB
2: Machine learning with Quanutum Computers: https://aws.amazon.com/free/machine-learning/?trk=47c19629-d8aa-4623-8a84-0d2b98ae0aa7&sc_channel=ps&sc_campaign=acquisition&sc_medium=ACQ-P%7CPS-GO%7CNon-Brand%7CDesktop%7CSU%7CMachine%20Learning%7CML%7CND%7CEN%7CText&s_kwcid=AL!4422!3!608660397551!p!!g!!computer%20machine%20learning&ef_id=Cj0KCQjwxveXBhDDARIsAI0Q0x0vkmms4pi2PnfLoHoo2-0oUsslE0XvAcy77EjY_CtvfcNXG-A6-BoaArMREALw_wcB:G:s&s_kwcid=AL!4422!3!608660397551!p!!g!!computer%20machine%20learning

8.2 Seminar / laboratory	Teaching methods	Remarks

1. Qubits and circuits		- Bloch sphere and Qsphere in python - Design a quantum circuit with a circuit editor (Uranium) -introduction to Qiskit/ pennylane
2. Phase kickback and Quantum Teleportation		- implementation with Qiskit/ PennyLane - run the code on a real device
3. Introduction to quantum algorithm		- implementation with Qiskit/ PennyLane
4. Grover Algorithm		- implementation with Qiskit/ PennyLane
5. Grover Algorithm for solving search problem-		- implementation with Qiskit/ PennyLane
6. Variational algorithms		- implementation with Qiskit/ PennyLane
7. QML		- implementation with Qiskit/ PennyLane
8. Improving variational algorithms		- some experiments with the model hyperparameters

9. Variational algorithms in practice 1		- Study the influence of the ansatz.
10. Variational algorithms in practice 2		- Students will solve a problem using all the knowledge from this course.
11.		

Bibliography

- Qiskit textbook:https://qiskit.org/textbook/content/ch-ex/
- Pennylane tutorials: https://pennylane.ai/qml/demonstrations.html
- QSilver: https://gitlab.com/qworld/silver
- QBronze: https://gitlab.com/qworld/bronze-qiskit
- Quantum algorithm Zoo: https://quantumalgorithmzoo.org
- Uranium: https://uranium.transilvania-quantum.org

9. Corroborating the content of the discipline with the expectations of the epistemic community, professional associations and representative employers within the field of the program

- The content of the discipline provides the basics foundations for the students to advance in the fields of Quantum Computing and it is consistent with courses of similar content from other foreign academic centers. To adapt to the demands of the labor market, the content of the discipline has been harmonized with the requirements of the pre-university education, research institutes and the business environment.

10. Evaluation

Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Share in the grade (%)
10.4 Course	End of year examination	written exam	100
10.5 Seminar/lab activities			
10.6 Minimum performance standards			
¬ 50% achieved at the exams			

Date	Signature of course coordinator	Signature of seminar coordinator
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Prof. dr. Laura Dioşan

Date of approval

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Signature of the head of department

Prof. dr. Laura Dioşan