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 (en) (ro)			Advanced quantum computing and quantum technologies				
2.2 Course coordinator			Michał Bączyk				
2.3 Seminar coordinator			Michał Bączyk, Alicja Chaszczewicz				
2.4. Year of study	**1**	2.5 Semester	**2**	2.6. Type of evaluation	**E**	2.7 Type of discipline	**DF**
2.8 Code of the discipline	PQE0005						

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	4
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	• Mathematical analysis • Algebra

4.2. competencies	• Calculus including functions, series, complex numbers • Programming basics

5. Conditions (if necessary)

5.1. for the course	white/blackboard, projector, computer
5.2. for the seminar /lab activities	Computer, equipment from the laser physics laboratory

6. Specific competencies acquired

Professional competencies	C1 Using the theoretical background of quantum mechanics in order explain the bahavior of microscopic systems. C2 Using interdisciplinary knowledge, solution patterns and tools, making experiments and interpreting their results C3 Using the tools of quantum mechanics and optics to construct exact models describing the behavior of quantum systems.
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	To present mathematical algorithms used and advanced methods used in quantum computing.
7.2 Specific objective of the discipline	Advanced techniques and algorithms used in quantum computing.

8. Content

8.1 Course	Teaching methods	Remarks
1. QML Theoretical Minimum 1		Theoretical details of parameter shift rule and circuit differentiation. Data uploading techniques. How to choose optimiser? Measurement strategies.

2. QML Theoretical Minimum 2		Different types of QML architectures. Convolutional Neural Networks, Autoencoders, GANs.
3. Ideas in Quantum		Students' presentations about the theoretical topic of interest chosen at the beginning of the semester from the list provided by the lecturers.
4. Case study 1		Block of four case study lectures will focus on what various implementation ideas are crucial for which business sectors. Invited speakers from companies and universities will provide insights into how quantum is deployed in areas like finance, life science or high-energy physics.
5. Case study 2		Block of four case study lectures will focus on what various implementation ideas are crucial for which business sectors. Invited speakers from companies and universities will provide insights into how quantum is deployed in areas like finance, life science or high-energy physics.
6. Case study 3		Block of four case study lectures will focus on what various implementation ideas are crucial for which business sectors. Invited speakers from companies and universities will provide insights into how quantum is deployed in areas like finance, life science or high-energy physics.

7. Case study 4		Block of four case study lectures will focus on what various implementation ideas are crucial for which business sectors. Invited speakers from companies and universities will provide insights into how quantum is deployed in areas like finance, life science or high-energy physics.
8. Quantum simulations as a gateway to industry		The lecture will focus on the area of quantum simulations which covers use cases in chemistry, life science and pharma and is believed to be one of the most promising near-term applications of quantum computers.
9. How to design a quantum pipeline? - on a quantum chemistry industry example		The lecture will provide detailed description of how to design quantum algorithms step by step taking into account hardware limitations and potential business value. The process will be demonstrated on the specific case of quantum chemistry.
10. How to test the potential for quantum advantage? - realm of quantum games		QML is hoped to provide advantage over classical state of the art solutions. The presentation will provide theoretical considerations when and where this advantage may be seen and what quantum features are crucial to obtain it. All of this demonstrated on specific instantiations of quantum games.

Bibliography

https://qiskit.org/learn/summer-school/quantum-computing-and-quantum-learning-2021
https://pennylane.ai/qml/demos_qml.html

8.2 Seminar / laboratory	Teaching methods	Remarks
1. Ideas in Quantum 1		Students will work on a specific publication of choice. They will be assigned a task to prepare a publication and a blog post about chosen topic.
2. Ideas in Quantum 2		Students will work on a specific publication of choice. They will be assigned a task to prepare a publication and a blog post about chosen topic.
3. Ideas in Quantum 3		Students will work on a specific publication of choice. They will be assigned a task to prepare a publication and a blog post about chosen topic.
4. Case study 1 in practice		Students will solve a Qiskit/Pennylane notebook related to the industry sector presented during the lecture.
5.Case study 2 in practice		Students will solve a Qiskit/Pennylane notebook related to the industry sector presented during the lecture.
6.Case study 3 in practice		Students will solve a Qiskit/Pennylane notebook related to the industry sector presented during the lecture.
7.Case study 4 in practice		Students will solve a Qiskit/Pennylane notebook related to the industry sector presented during the lecture.

8. Quantum chemistry project 1		Quantum chemistry project. A goal will to recreate the results of a paper chosen by the lecturer. Attention will be put to every step of preparing the quantum code pipeline.
9. Quantum chemistry project 2		Quantum chemistry project. A goal will to recreate the results of a paper chosen by the lecturer. Attention will be
		put to every step of preparing the quantum code pipeline.
10. Quantum chemistry project 3		Quantum chemistry project. A goal will to recreate the results of a paper chosen by the lecturer. Attention will be put to every step of preparing the quantum code pipeline.

Bibliography

https://qiskit.org/learn/summer-school/quantum-computing-and-quantum-learning-2021
https://pennylane.ai/qml/demos_qml.html

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

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10. Evaluation

Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Share in the grade (%)

10.4 Course	Presentation and research comprehension skills, individual coding skills, theoretical knowledge tested by an online exam	Presentation of a research paper	30%
		Project Quizz	40% 30%
10.5 Seminar/lab activities			
10.6 Minimum performance standards			
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Date

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Signature of course coordinator

Michał Bączyk

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Signature of seminar coordinator

Michał Bączyk

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Date of approval

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Signature of the head of department

Prof. dr. Laura Dioşan