# SYLLABUS

## Quantum computing with applications in cryptography and AI

University year 2025-2026

**1. Information regarding the programme**

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|---|---|
| 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 | Computer Science |
| 1.5. Study cycle | Bachelor |
| 1.6. Study programme/Qualification | Computer Science |
| 1.7. Form of education | Full time |

**2. Information regarding the discipline**

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|---|---|---|---|---|---|---|---|---|
| 2.1. Name of the discipline | **Quantum computing with applications in cryptography and AI** | | | | | Discipline code | | **MLE5216** |
| 2.2. Course coordinator | | | | | Mihoc Tudor Dan | | | |
| 2.3. Seminar coordinator | | | | | Mihoc Tudor Dan | | | |
| 2.4. Year of study | 3 | 2.5. Semester | 2 | 2.6. Type of evaluation | C | 2.7. Discipline regime | | Optional |

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

| | | | | | |
|---|---|---|---|---|---|
| 3.1. Hours per week | **5** | of which: 3.2 course | **2** | 3.3 seminar/ laboratory/project | **0/1/2** |
| 3.4. Total hours in the curriculum | 60 | of which: 3.5 course | 24 | 3.6 seminar/ laboratory/project | **0/12/24** |
| **Time allotment for individual study (ID) and self-study activities (SA)** | | | | | **hours** |
| Learning using manual, course support, bibliography, course notes (SA) | | | | | 24 |
| Additional documentation (in libraries, on electronic platforms, field documentation) | | | | | 20 |
| Preparation for seminars/labs, homework, papers, portfolios and essays | | | | | 16 |
| Tutorship | | | | | 2 |
| Evaluations | | | | | 3 |
| Other activities: | | | | | 0 |

| | |
|---|---|
| **3.7. Total individual study hours** | **65** |
| **3.8. Total hours per semester** | **125** |
| **3.9. Number of ECTS credits** | **5** |

**4. Prerequisites** (if necessary)

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| 4.1. curriculum | Basic knowledge of calculus and linear algebra. |
| 4.2. competencies | Basic programming skills in Python. |

**5. Conditions** (if necessary)

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| 5.1. for the course | Projector. |
| 5.2. for the seminar /lab activities | Laboratory with computers. Software: Anaconda, Python, Qiskit. |

**6.1. Specific competencies acquired [1]**

[1] One can choose either competences or learning outcomes, or both. If only one option is chosen, the row related to the other option will be deleted, and the kept one will be numbered 6.

| | |
|---|---|
| **Professional/ essential competencies** | • advanced programming skills in high-level programming languages;<br>• development and maintenance of software systems;<br>• use of software tools in an interdisciplinary context; |
| **Transversal competencies** | • application of organized and efficient work rules, of responsible attitudes towards the didactic-scientific field, to bring creative value to own potential, with respect for professional ethics principles and norms;<br>• efficient development of organized activities in an interdisciplinary group and the development of empathetic abilities for interpersonal communications, to relate to and cooperate with various groups;<br>• use of efficient methods and techniques to learn, inform, research and develop the abilities to bring value to knowledge, to adapt at the requirements of a dynamical society and to communicate efficiently in Romanian language and in an international language; |

**6.2. Learning outcomes**

| | |
|---|---|
| **Knowledge** | • The graduate has the necessary knowledge for using computers, developing software programs and applications, information processing;<br>• The graduate has the ability to develop, design and create new applications, systems or products using best practices of the field;<br>• The graduate has the necessary skills for computer program design and software systems analysis.<br>• The graduate is able to identify complex problems and examine related issues to develop solving options and implement solutions; |
| **Skills** | • The graduate has the ability to apply general rules to specific problems and produce relevant solutions;<br>• The graduate is able to combine diverse information to formulate solutions and generate ideas for developing new products and applications;<br>• The graduate has knowledge related to programming, mathematics, engineering and technology and has the skills to use them to create complex information technology systems; |
| **Responsibility and autonomy:** | • The graduate has the ability to understand and communicate information effectively;<br>• The graduate has the knowledge to select and use appropriate instructional procedures to facilitate the process of knowledge assimilation;<br>• The graduate is able to present and explain methods, algorithms, paradigms and techniques used in various branches of computer science; |

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

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|---|---|
| **7.1 General objective of the discipline** | • The goal is to provide attendees with a comprehensive understanding of quantum computing while fostering curiosity, critical thinking, and motivation to engage with this cutting-edge interdisciplinary area. |
| **7.2 Specific objective of the discipline** | • To provide students with a comprehensive understanding of quantum computing principles, techniques, and their applications in two key fields: cryptography and artificial intelligence (AI). |

**8. Content**

| 8.1 Course | Teaching methods | Remarks |
|---|---|---|
| 1. Introduction—Mathematical Prerequisites | Exposition;<br>Dialog;<br>Presentation;<br>Interactive exposure; | |
| 2. Fundamental notions of quantum computing (Qubits and the Bloch Sphere) | | |
| 3. Qubit gates. Quantum circuits | | |
| 4. The phase kick-back phenomenon | | |
| 5. Quantum search algorithms | | |

| | | |
|---|---|---|
| 6. Schor's algorithm | | |
| 7. Quantum cryptography and post-quantum cryptography. Quantum Computing Attacks on RSA | | |
| 8. Quantum key distribution (QKD). Noise in QKD (eyedropper) | | |
| 9. Clustering Structure and Quantum Computing | | |
| 10. Quantum Pattern Recognition | | |
| 11. Quantum Classification | | |
| 12. Quantum Regression | | |


Bibliography

1. Nielsen, Michael A., and Isaac Chuang. "Quantum computation and quantum information." (2002): 558-559.
2. Gisin, Nicolas, et al., "Quantum cryptography." Reviews of modern physics 74.1 (2002): 145.
3. Yan, Song Yuan. "Cryptanalytic attacks on RSA." (2007).
4. Bruß, Dagmar, and Norbert Lütkenhaus. "Quantum key distribution: from principles to practicalities." Applicable Algebra in Engineering, Communication and Computing 10.4 (2000): 383-399.
5. Shor, Peter W., "Polynomial-time algorithms for prime factorization and discrete logarithms on a quantum computer." SIAM review 41.2 (1999): 303-332.
6. P. Wittek, Quantum machine learning: what quantum computing means to data mining, Academic Press, Elsevier, 2014.
7. S. D. Sarma, D. Dong-Ling, and D. Lu-Ming, Machine learning meets quantum physics, arXiv preprint arXiv:1903.03516, 2019.


| 8.2 Seminar / laboratory | Teaching methods | Remarks |
|---|---|---|
| 1. Quantum random number generators | Example;<br>Algorithms implementation; | |
| 2. Quantum FFT | | |
| 3. Deutsch's algorithm. The Deutsch–Jozsa algorithm | | |
| 4. Grover's Search | | |
| 5. Quantum Algorithm for Integer Factorization | | |
| 6. Quantum algorithm for discrete logarithms | | |
| 7. Quantum Neural Networks example | | |


Bibliography

1. Nielsen, Michael A., and Isaac Chuang. "Quantum computation and quantum information." (2002): 558-559.
2. Gisin, Nicolas, et al., "Quantum cryptography." Reviews of modern physics 74.1 (2002): 145.
3. Yan, Song Yuan. "Cryptanalytic attacks on RSA." (2007).
4. Bruß, Dagmar, and Norbert Lütkenhaus. "Quantum key distribution: from principles to practicalities." Applicable Algebra in Engineering, Communication and Computing 10.4 (2000): 383-399.
5. Shor, Peter W., "Polynomial-time algorithms for prime factorization and discrete logarithms on a quantum computer." SIAM review 41.2 (1999): 303-332.
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**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 course follows the scheme and structure used by the most important universities in USA and Europe;
- The course exists in the study program of major universities abroad.

**10. Evaluation**

| Activity type | 10.1 Evaluation criteria | 10.2 Evaluation methods | 10.3 Percentage of final grade |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 10.4 Course | The students must be able to exemplify and use basic and advanced concepts of quantum computing. | Colloquium | 50% |
| 10.5 Seminar/laboratory | The students must be able to implement the algorithms described in the course and discussed at the demonstrations during the laboratories. | Lab. assignments | 50% |
| 10.6 Minimum standard of performance | | | |
| • At least grade 5 (from a scale of 1 to 10) for both evaluation types. | | | |

**11. Labels ODD (Sustainable Development Goals)**[2]

*Not applicable.*

Date:
15.04.2025

Signature of course coordinator

Lecturer PhD. Tudor Dan Mihoc

Signature of seminar coordinator

Lecturer PhD. Tudor Dan Mihoc

Date of approval:
...

Signature of the head of department

Assoc. Prof. PhD. Adrian STERCA

[2] Keep only the labels that, according to the *Procedure for applying ODD labels in the academic process*, suit the discipline and delete the others, including the general one for *Sustainable Development* – if not applicable. If no label describes the discipline, delete them all and write „*Not applicable.*".