



## COURSE DESCRIPTION CARD - SYLLABUS

Course name

Quantum algorithms [S2ETI2>AK]

### Course

Field of study

Education in Technology and Informatics

Year/Semester

1/1

Area of study (specialization)

–

Profile of study

general academic

Level of study

second-cycle

Course offered in

Polish

Form of study

full-time

Requirements

compulsory

### Number of hours

Lecture

30

Laboratory classes

15

Other

0

Tutorials

0

Projects/seminars

0

### Number of credit points

3,00

### Coordinators

dr Gustaw Szawiola

gustaw.szawiola@put.poznan.pl

### Lecturers

### Prerequisites

Programming, IT, and mathematical skills in line with the learning outcomes of engineering studies in the field of technical and IT education (first-cycle studies), in particular in the areas of quantum computing and higher mathematics (linear algebra, probability theory). Openness to expanding one's skills in the field of new technologies. Ability to work in a team.

### Course objective

The module presents key quantum algorithms, programming implementations of these algorithms, and selected applications. It also discusses the prospects for development and fundamental limitations of quantum algorithms conditioned by advances in quantum hardware.

### Course-related learning outcomes

Knowledge:

1. has advanced general and detailed knowledge of the canon and selected specialized quantum algorithmic solutions
2. is familiar with selected key quantum environments and programming platforms used in the implementation of quantum algorithms

3. has knowledge of development trends and the most important achievements and limitations of quantum computing, in particular in the field of quantum algorithms

#### Skills:

1. is able to assess the usefulness of quantum algorithms and propose their implementation in solving selected programming problems in the field of technology or exact sciences
2. is able to plan and conduct simple research programming experiments in the field of quantum algorithms, integrating the use of selected open platforms and programming libraries, both quantum and classical, including data analysis methods
3. is able to assess the practical value and limitations of quantum computers, platforms, and programming libraries in solving selected tasks with a simple experimental component in the field of quantum computing applications in technology and exact sciences

#### Social competences:

1. understands the links between developments in the field of computer science and the dynamics of quantum technologies and methods
2. understands the potential of using the latest knowledge in the field of quantum intelligence technologies to solve research and practical problems

### Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

#### 1. Lecture:

- form and components of assessment (percentage share):  
a summary test, including a test section (quiz) (weighted 60%) and a problem-solving section (weighted 40%); the average score from the laboratory is counted towards the problem-solving section.

- Assessment criteria/grade: in accordance with the study regulations.

#### 2. Laboratory

- Assessment format and components: Substantive assessment of the implementation of individual exercises on a 0-5 point scale per exercise.

### Programme content

I Tools for mathematical description and programming implementation of quantum algorithms.

II Selected issues in the canon of quantum algorithms.

III Selected applications and limitations of quantum algorithms.

### Course topics

#### Lectures

Part I: Tools for the mathematical description and programmatic implementation of quantum algorithms.

I.1 Characteristics of selected quantum hardware platforms (quantum computers) and quantum software development environments (Q-SDKs).

I.2 Mathematical representation of quantum register states and quantum measurements and their programmatic implementation in a selected quantum software development environment (Q-SDK).

I.3 Mathematical representation and programmatic implementation of quantum gates in a selected quantum software development environment (Q-SDK).

I.4 Synthesis and decomposition of quantum unitary operations. Construction and programmatic implementation of quantum circuits as models of quantum algorithms.

Part II: The Canon of Quantum Algorithms

II.1 Implementation of the Deutsch-Jozs, Bernstein-Vazirani, and Simon algorithms.

II.2 Implementation of Grover's algorithm.

II.3 Implementation of the quantum Fourier transform algorithm.

II.4 Implementation of the quantum phase estimation algorithm.

Part III: Selected applications and implementation limitations of quantum algorithms.

III.1 The Harrow-Hassidim-Lloyd algorithm for solving systems of linear equations.

III.2 Selected quantum cryptography algorithms - implementation of Shor's algorithm.

III.3 Quantum variational algorithms.

- III.4 Selected quantum machine learning algorithms.
- III.5 Problems and selected quantum error correction algorithms.

### Laboratory

1. Configuring a quantum development environment. Programming implementation of the CHSH quantum test circuit.
2. Performance testing of a quantum computer (simulator). Programming implementation of the Deutsch-Jozsa algorithm.
3. Implementation and complexity testing of Grover's algorithm.
4. Implementation and application of the quantum Fourier transform algorithm.
5. Implementation and accuracy testing of the quantum phase estimation algorithm.
6. Selected applications of the quantum variational algorithm.

### Teaching methods

- Lectures: conducted in both traditional (multimedia presentations, examples on the board) and problem-based (individual and group discussion of a given problem, quizzes) formats.
- Laboratory classes: carried out using elements of the method based on a project carried out in teams.

### Bibliography

#### Basic:

1. R. S. Sutor, Dancing with Qubits, Second Edition, Packt Publishing, Birmingham-Mumbai, 2024
2. R. S. Sutor, Dancing with Python. Learn to code with Python and Quantum Computing. Packt Publishing, Birmingham-Mumbai, 2021
3. Zasoby: <https://quantum.cloud.ibm.com/learning/en> oraz <https://quantum.cloud.ibm.com/docs/en>
4. publikacje oryginalne i przeglądowe z czasopism naukowe

#### Additional:

1. E. F. Combarro S. González-Castillo, A Practical Guide to Quantum Machine Learning and Quantum Optimization. Hands-on Approach to Modern Quantum Algorithms, Packt Publishing, Birmingham-Mumbai, 2023
2. B. Zygelman, A First Introduction to Quantum Computing and Information, Springer Cham 2018
3. S. Pattanayak, Quantum Machine Learning with Python, Apress Berkeley, CA, 2021
4. E. R. Johnston, N. Harrigan, M. Gimeno-Segovia, Programming Quantum Computers: Essential Algorithms and Code Samples, O'Reilly Media, Inc., 2019
5. M. Schuld, F. Petruccione, Machine Learning with Quantum Computers (Quantum Science and Technology) 2nd ed., Springer Cham, 2021
6. M. A. Nielsen (Autor), I. L. Chuang, Quantum Computation and Quantum Information: 10th Anniversary Edition, Cambridge University Press, 2010
8. N. S. Yanofsky (Autor), M. A. Mannucci, Quantum Computing for Computer Scientists, Cambridge University Press, 2008
9. Zasoby: <https://pennylane.ai/>

### Breakdown of average student's workload

|   | Hours | ECTS |
|---|-------|------|
| Total workload  | 75    | 3,00 |
| Classes requiring direct contact with the teacher   | 45    | 2,00 |
| Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation) | 30    | 1,00 |