GDAŃSK UNIVERSITY
OF TECHNOLOGY

Subject card

Subject name and code	, PG_00069100		
Field of study	Technical Physics		
Date of commencement of studies	February 2027	Academic year of realisation of subject	2027/2028
Education level	second-cycle studies	Subject group	Specialty subject group
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	2	Language of instruction	Polish
Semester of study	3	ECTS credits	2.0
Learning profile	general academic profile	Assessment form	assessment
Conducting unit	Institute of Physics and Applied Computer Science -> Faculty of Applied Physics and Mathematics -> Faculties of Gdańsk University of Technology		
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Marcin Nowakowski	
	Teachers	dr inż. Marcin Nowakowski	

Lesson types

Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	15.0	0.0	15.0	0.0	0.0	30
E-learning hours included: 0.0						

Learning activity and number of study hours

Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
Number of study hours	30	2.0	18.0	50

Subject objectives

The course aims to familiarize students with the mechanisms of modern quantum technologies and methods for designing and implementing quantum algorithms in practice. Students will acquire a systematic understanding of the theoretical foundations of quantum computing, including superposition, entanglement, interference, and decoherence, and will learn how these phenomena are physically realized and used to solve computational problems difficult for classical computers. A key element of the course is to provide students with practical skills in programming quantum circuits and running them on available simulators (Qiskit) and real quantum processors (QPUs) available in the quantum cloud, such as the IBM Quantum Platform, along with an understanding of quantum computer architecture. Students will also utilize advanced machine learning methods to investigate the efficiency of quantum algorithms.

Learning outcomes

Course outcome	Subject outcome	Method of verification
[K7_W01] demonstrates advanced knowledge of key branches of physics, including quantum mechanics and molecular electronics.	Has knowledge of quantum algorithms and quantum engineering methods used in implementation of modern quantum computers.	[SW1] Assessment of factual knowledge
[K7_W04] possesses advanced knowledge of mathematical, numerical and simulation methods used in the description and modelling of physical phenomena.	Has knowledge of quantum computing and its use to model physical phenomena.	[SW3] Assessment of knowledge contained in written work and projects
[K7_U02] demonstrates advanced programming skills in a selected language and the ability to use specialised software packages.	Has knowledge of the methodology and techniques for programming quantum algorithms in the quantum environment using the Qiskit language.	[SU1] Assessment of task fulfilment

Subject contents	Course content – lecture Mathematical and physical foundations of quantum computing (Hilbert and Hilbert-Schmidt spaces, qubits, single- and multi-qubit gates, quantum measurement and channeling, quantum noise). Quantum Error Correction (QEC): Understanding theoretical models of decoherence and quantum noise channels. Fault-Tolerant Quantum Computing (FTQC): Understanding the threshold theorem. Computational Complexity and Device Taxonomy: Situating quantum algorithms within complexity theory (BQP, QMA classes). Understanding the fundamental differences and the transition path between contemporary, noisy, NISQ-era computers and the ultimate, universal quantum machines equipped with full error correction (LQC). Understanding the concept of quantum advantage/supremacy and identifying problem classes for which quantum algorithms offer speedups (e.g., BQP classes). Introduction to hybrid quantum-classical algorithms (e.g., VQE - Variational Quantum Eigensolver, QAOA - Quantum Approximate Optimization Algorithm) and their applications in optimization. Advanced quantum-classical neural networks. Exploring various physical architectures for quantum computers (superconducting qubits, ion traps, Rydberg atoms, photonics) and their specific advantages and disadvantages.		
	Course content – laboratory Mastering quantum computing programming environments and libraries (e.g., Qiskit, Cirq, Pennylane). Practical implementation of flagship quantum algorithms (e.g., Grover's search algorithm, Shor's algorithm, and the Fourier transform (QFT)). Preparing the environment in the IBM quantum cloud. Implementing quantum neural networks for analyzing the performance of quantum algorithms.		
Prerequisites and co-requisites	Linear algebra, probability theory, quantum mechanics, artificial intelligence methods. Knowledge of object-oriented programming languages and Python.		
Assessment methods and criteria	Subject passing criteria	Passing threshold	Percentage of the final grade
	Lab Project	60.0%	100.0%
Recommended reading	Basic literature	E. R. Johnston et al., Komputer Kwantowy, Helion, 2020. M. Le Bellac, Wstep do Informatyki Kwantowej, PWN, 2018	
	Supplementary literature	I. Goodfellow, Deep Learning, MIT, 2020	
	eResources addresses		
Example issues/ example questions/ tasks being completed	Implementation - Exponentially Accelerated Algorithms: Quantum Fourier Transform (QFT), Quantum Phase Estimation (QPE), and the basics of Shor's algorithm. Implementation - Quantum Error Correction (QEC): 3-qubit code, stabilizer codes (Steane code, Shor code), and the concept of surface codes. Implementation - Simulation of a quantum-classical neural network (GAN) evaluating the efficiency of n-qubit CSS codes. Simulation of Noise in Circuits: Introducing artificial noise into ideal simulations (using noise modules in Qiskit/PennyLane). Observing the impact of errors on algorithm results. VQE in Quantum Chemistry: Calculating the ground-state energy of a simple molecule (e.g., hydrogen H2) using the VQE algorithm in conjunction with a classical optimizer.		
Practical activites within the subject	Not applicable		