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| **Course title** | **Quantum Computation** |
| **School name and date** | Quantum Computation 11.07.2022 – 22.07.2022 |
| **Teaching staff** | dr Michał Studziński, dr Sergii Strelchuk |
| **Forms of classes, the realization and number of hours**  |
| 1. **Forms of classes**
 | Online lectures and problem solving sessions. |
| 1. **The realization of activities**
 | Online |
| 1. **Number of hours**
 | 60 (40 hrs of lectures and 20 hrs of problem solving sessions) |
| **Suggested prerequisite knowledge** |
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| **Brief description of the course** |
| Quantum mechanical processes can be exploited to provide new modes of information processing that are beyond the capabilities of any classical computer. This leads to remarkable new kinds of information-theoretic protocols which were previously deemed impossible as well as algorithms (so-called quantum algorithms) that can offer a dramatically increased efficiency for the execution of some computational tasks. In addition to such potential practical benefits, the study of quantum information and computation has great theoretical interest, combining concepts from information theory, computational complexity theory and quantum physics to provide striking fundamental insights into the nature of these disciplines. |
| **Course contents** |
| 1. Introduction to the formalism of quantum information theory. Linear algebra: vector spaces, linear operators, Dirac notation, the tensor product Hilbert space and Dirac notation
2. Framework of quantum mechanics and quantum information

a) Density operators formalism (partial trace, Schmidt decomposition and purification, separability and entanglement), measurement, concept of a quantum channel, Stinespring dilationb) Postulates of quantum mechanics1. Quantum model of computation

a) The quantum circuit model and the circuit model of quantum computationb) Quantum gates and circuitsc) Universality of the quantum circuit modeld) Efficient simulation of arbitrary two-qubit gates with a standard universal set of gatese) Implementing measurements by quantum circuitsf) Applications of quantum information: No-cloning theorem, quantum teleportation, superdense coding1. Introduction to quantum computing

a) Fundamentals of famous quantum algorithms (Deutsch-Jozsa, Grover,Shor ) and their applications, encryption breaking by quantum computersb) Linear combination of unitaries (LCU) as the one of the most important techniques in designing quantum algorithmsc) Quantum complexity classes + relationship to classical complexityd) The concept of quantum error correction, elements of fault tolerant quantum computing1. Advanced topics in quantum computing and simulation

a) The quantum phase estimation algorithm and applications; b) Amplitude amplification and applications; c) The Harrow-Hassidim-Lloyd quantum algorithm for systems of linear equations; d) Hybrid Quantum-Classical computational models (Pauli-based Computation and Variational Quantum Eigensolver) e) Quantum simulation for local hamiltonians |
| **Literature** |
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| **Contact** | michal.studzinski@ug.edu.pl |