האוניברסיטה העברית בירושלים
THE HEBREW UNIVERSITY OF JERUSALEM

The Hebrew University of Jerusalem

Syllabus

Quantum Computing for Physicists - 77523

Last update 27-08-2024

HU Credits: *4*

Degree/Cycle: *2nd degree (Master)*

Responsible Department: *Physics*

Academic year: *0*

Semester: *1st Semester*

Teaching Languages: *English and Hebrew*

Campus: *E. Safra*

Course/Module Coordinator: *Erez Zohar*

Coordinator Email: *erez.zohar@mail.huji.ac.il*

Coordinator Office Hours:

Teaching Staff:

Prof. Erez Zohar

<u>Course/Module description:</u>
Quantum computing is a contemporary and diverse research field, combining quantum physics and computer science, centered at the development, algorithms and performance of quantum computers.
The course will focus on quantum information and computation theory, from a physical perspective unlike the algorithmic one, used in parallel computer science courses. It will include more physical, quantum mechanical and entanglement aspects, as well as focus on algorithms relevant for solving physical problems.

<u>Course/Module aims:</u>
The course's aim is to present the quantum computing field to the students, including up to date and modern results, and equip them with the essential background knowledge and toolbox allowing them to carry out research in the field.

<u>Learning outcomes - On successful completion of this module, students should be able to:</u>
• Understand and design quantum algorithms and operations
• Apply quantum computation methods for physical problems
• Read and understand contemporary research works in the field
• Conduct research in the field of quantum computing and information

<u>Attendance requirements(%):</u>
0

Teaching arrangement and method of instruction: Frontal teaching, combined with discussions in class and homework exercises for submission.

<u>Course/Module Content:</u>
1. Introduction and Motivation
2. Foundations of Quantum Mechanics: pure and mixed states, density matrices, entanglement, measurements – orthogonal and generalized, quantum channels, open systems
3. Quantum Correlations and Entanglement Theory: Bell states, Einstein's locality and hidden variables, Bell inequalities, superdense coding, quantum teleportation, quantum key distribution
4. Quantum Circuits and complexity: introduction (classical circuits), quantum

circuits, accuracy and universality
5. Physical Implementations of Quantum Computing – an introduction: trapped ions, the Cirac-Zoller gate
6. Quantum Algorithms: black-box, periodicity and factorization, quantum searching

7. Physical quantum algorithms: quantum simulation, finding Hamiltonian eigenstates and energies, the local Hamiltonian problem and its complexity
8. Introduction to Quantum Error Correction (it time allows)

Required Reading:
The course include detailed lecture notes, covering the material taught in class as well as extra material.

Additional Reading Material:
1. John Preskill's lecture notes on quantum information and computing.
2. Nielsen and Chuang – Quantum Information and Computation
3. Kitaev, Shen, and Vyalyi – Classical and Quantum Computation
4. Aaronson – Quantum Computing Since Democritus

Grading Scheme:
Written / Oral / Practical Exam 100 %

Additional information: