



UNIVERSITÀ  
DEGLI STUDI DI MILANO-BICOCCA

## COURSE SYLLABUS

### Quantum Simulation

2324-1-F9102Q024

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#### Aims

The aim of this course consists of enabling to identify which architecture (gate model, adiabatic, measurement based) of quantum computer is most suitable for solving a given problem by a quantum algorithm, and to program both simulators of quantum computers and actual quantum computers. Fundamental of quantum algorithms and their applications including quantum chemistry and quantum neural networks are introduced.

#### Contents

The mathematical tools of quantum mechanics relevant for quantum computing are introduced, together with their connection with actual up to date hardware. Quantum hardware technologies are compared, with special emphasis on superconducting and trapped ion quantum computers. Next, major quantum algorithm with actual implementation are introduced, for both gate model quantum computers and adiabatic quantum computers. Practical examples of implementations of algorithms are developed during the laboratory activity.

#### Detailed program

Principles of quantum mechanics, the Qubit: Bloch Sphere and Single Qubit Rotations, Two qubits gates, Entanglement, Di Vincenzo criteria and Physical implementation (Superconducting, Ions), Architectures: Gate model, Adiabatic Quantum Computer, Measurement based (or One Way) Quantum Computer. Fundamental Algorithms: Search Algorithms, Quantum Fourier Transform, Quantum annealing algorithms, Variational quantum algorithms, Quantum Boltzmann machine, Introduction to Quantum Chemistry, Quantum Neural Networks

## **Prerequisites**

Linear algebra, Dirac notation of quantum mechanics, unitary operators, Ising model (from the "AI models for Physics" Course, held during the same semester).

## **Teaching form**

Lectures and laboratory programming activity. Both of them will be held in presence. Attendance both to lectures and practical examples is warmly recommended.

The programming activity refers to the program by computational lessons in which students can simulate the models. The computational part will take place in Python.

## **Textbook and teaching resource**

Nielsen and Chuang "Quantum Computation and Quantum Information"

Rieffel and Polack "Quantum Computing a Gentle Introduction"

Morita and Nishimori, Mathematical Foundation of Quantum Annealing (Free online PDF) <https://arxiv.org/pdf/0806.1859.pdf>

Stefano Olivares, Lecture Notes on Quantum Computing (Free online PDF) [https://sites.unimi.it/olivares/wp-content/uploads/2021/08/lectures\\_qc\\_olivares\\_v5.0.pdf](https://sites.unimi.it/olivares/wp-content/uploads/2021/08/lectures_qc_olivares_v5.0.pdf)

## **Semester**

Second

## **Assessment method**

Students are required to prepare a written report on one of the laboratory activities (or alternative, develop an independent project), the exam will then consist in oral questions on the topics covered during lectures.

## **Office hours**

Wednesday 17-18

## **Sustainable Development Goals**

INDUSTRY, INNOVATION AND INFRASTRUCTURE

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