CS 399 QUANTUM COMPUTING
IES Abroad Madrid

DESCRIPTION:
This seminar will introduce Quantum computing to ENG students, covering topics from the origins and fundamental concepts of quantum physics to the design of quantum circuits and their execution on real quantum systems.
Quantum computing is widely regarded as one of the most promising technologies for addressing complex problems that are intractable with classical computing.
IES Madrid has been offering this seminar since 2022.

CREDITS: 1 credits

CONTACT HOURS: 15 hours

LANGUAGE OF INSTRUCTION: English

INSTRUCTOR: Javier Machín, jav.machin@gmail.com

PREREQUISITES: Being enrolled in STEM programs

ADDITIONAL COST: None

METHOD OF PRESENTATION:
Lectures and Labs. During labs we will design and run quantum circuits with the tools provided by IBM Quantum Platforms.

REQUIRED WORK AND FORM OF ASSESSMENT:
- Best Kahoot result during the course – 40%
- Second best Kahoot result during the course- 40%
- Evidence of submitting a quantum circuit in a real Quantum Computing unit (QPU) – 10%
- Participation – 10%

Key Dates
Midterm Exam (At least one kahoot will be conducted during the first three sessions)
Final Exam (At least a second kahoot will be conducted during the last three sessions))
Evidence of submitting a quantum circuit in a real QPU must be delivered before 1 week after last class

Course Element
- "Kahoots": During the seminar we will run at least two "Kahoots" to evaluate student's comprehension of main concepts.
- Brief delivery (one/two pages) showing the design of a circuit and its execution in a real quantum system

LEARNING OUTCOMES:
By the end of the course, students will be able to:
- Demonstrate the knowledge of fundamentals of this new computing discipline that is the Quantum computing
- Being able to act as "Quantum computing ambassador", articulating the capabilities of QC vs the Classical computing
- Integrate the knowledge got during the seminar in order to design quantum circuits and running them in real QPUs.

ATTENDANCE POLICY:
As a member of our class community, you are expected to be present and on time every day. Attending class has an impact on your learning and academic success. For this reason, attendance is mandatory for all IES Madrid classes, including course related excursions. Absences will only be justified in cases of documented medical or family emergencies. Assessed work, including exams, tests and

presentations will be justified and rescheduled accordingly. Otherwise, they will be graded as 0. Please be aware that after the third unexcused absence (courses meeting twice a week) and two unexcused absences (courses meeting once a week), your final grade will decrease by five percentage points (out of 100) for each subsequent absence. For courses meeting twice a week, 7 or more absences, and for courses meeting once a week, 4 or more absences, will result in a failing grade. For more information, please refer to the Orientation Handbook.

CONTENT:

Choose an item	Content	Assignments
Session 1	**Lecture 1 Introduction to Quantum Computing.** • The second quantum revolution and concept of Quantum computing • Qubits and Quantum Phenomena • HW, SW and applications in QC	• Study of documentation provided by professor • Quantum Computing Expert Explains One Concept in 5 Levels of Difficulty | WIRED https://www.youtube.com/watch?v=OWJCfOvochA
Session 2	**Lecture 2: Quantum states and operator** • Concept of Qubit and Schrodinger's cat • The most beautiful equation in Math's • Bloch's sphere and Pauli's gates	• Study of documentation provided by professor • Design of first simple quantum circuits
Session 3	**Lecture 3: Superposition** • Concept and mathematization of superposition • Hadamard gate and circuits	• Study of documentation provided by professor • Design and run quantum circuits with Hadamard gate
Session 4	**Lecture 4: Entanglement** • Concept of entanglement • CNOT gate • Circuits and Bell's states	• Study of documentation provided by professor • Design and running quantum circuits with CNOT gate to create Bell states
Session 5	**Lecture 5: Interference and measurement and All together!** • Interference • Measurement • Quantum circuits and evolution of states	• Study of documentation provided by professor • Design and run quantum circuits combining several gates and studying evolution of quantum states
Session 6	**Lecture 6: Hot topics in QC** • QC algorithms • Quantum advantage. • Quantum communications	• Study of documentation provided by professor • Summarize the main concepts learned during the course

COURSE-RELATED TRIPS:

- N/A

REQUIRED READINGS:

- Documentation provided by professor for every lecture and uploaded in canvas.
- Quantum Computing Expert Explains One Concept in 5 Levels of Difficulty | WIRED
  https://www.youtube.com/watch?v=OWJCfOvochA

RECOMMENDED READINGS:

- Thomas G. Wong, Introduction to Classical and Quantum computing

INSTRUCTOR BIOGRAPHY:

Javier Machín is MSC in Physics and BSc in Economics.
He has over 30 years of experience in Information technology, mainly in IT services in IBM.
In the last years in IBM, he was QC ambassador and certified instructor in Quantum computing and design thinking.
Currently, Javier is a professor in several universities and run multiple seminars in different corporations and institutions in several sectors, mainly regarding Quantum computing, AI, and Risk management.