Subject identification

Subject	11017 - Information Theory
Credits	1.2 in-class (30 hours) 1.8 distance (45 hours) 3 totals (75 hours).
Group	Group 1, 2S
Teaching period	2nd semester
Teaching language	English

Lecturers

Lecturers	Timetable for student attention					
	Starting time	Finishing time	Day	Start date	Finish date	Office
María Rosa López Gonzalo rosa.lopez-gonzalo@uib.es	There are no defined sessions					

Degrees where the subject is taught

Degree	Character	Academic year	Studies
Master's Degree in Physics of Complex Systems	Optional		Postgraduate degree

Contextualisation

The publication "A Mathematical Theory of Communication" by Claude E. Shannon in 1948 is considered a masterpiece in Information theory and the birth of this discipline. Information theory is the science of operations on data such as compression, storage, and communication. Classically the unit of information is the bit, a binary variable of values 0 or 1. The information is quantified by using the mutual information, entropy, and relative entropy among others measurements. The generalization of the classical information theory to the quantum world constitutes a paramount step towards a more efficient, faster and safely way to handle information. Besides, the rapid progress of the present technologies at the nanosize scale has permitted the creation and controlled manipulation of qubits, which are the quantum counterparts of the classical bits. In a quantum bit the information is stored in the state of a quantum system. Quantum information differs from classical information in several respects and especially in its applications. For instance, states cannot be cloned because a quantum measurement destroys the state that is being measured. In a quantum world, quantum teleportation is achievable thanks to an inherent quantum property, the entanglement. For these reasons among others there are certain tasks that classically cannot perform in a reasonable time scale (polynomial time). However, using a quantum computer one can, for example, factorize a rather large number

(Shor´s factoring algorithm) in a polynomial time scale. Quantum systems such as ion traps, quantum dots, and etcetera have been proposed as suitable candidate to build a quantum computer.

Requirements

Recommendable

It is recommended to have taken introductory courses to Quantum Mechanics and Solid State Physics.

Skills

Specific

1. E16, E18.

Generic

1. TG1, TG2, TG3.

Content

Theme content

Part 1. Classic Information, Theory and Algorithms

* Information, Communication, Shannon entropy, mutual entropy. Basic applications to data compression and communication. Methods for entropy optimization. Complexity algorithms; Turing machines, Kolmogorov complexity.

Part 2. Quantum Information theory and Quantum Computation

Part 2. Chapter 1

* Basic concepts: quantum superposition, qubits, qudits. Pure and mixed collectivities. Density matrix theory. Nonlocality in Quantum Mechanics. Entanglement and Bell inequalities. Entanglement characterization: von Neumann entropy.

Part 2. Chapter 2

* Cryptography, basic notions, public keys, quantum cryptography: key distribution and authentication. Non-cloning theorem, quantum noise and quantum error correction.

Part 2. Chapter 3

* Quantum computation concepts: Unitary transformations, quantum gates. Algorithmic applications: Shor algorithm, Fourier transform, random number generators, teleportation algorithm.

Part 2. Chapter 4

* Building a quantum computer: harmonic oscillator, Ion traps systems, atoms in QED cavities, quantum dots, nuclear magnetic resonance. Limitations due to decoherence.

Part 2. Chapter 5

* Quantum networks and applications. Entanglement purification. Multipartite purification. Ideal communication and noisy channels. Error correction. Future challenges in Quantum information theory.

Teaching methodology

In-class work activities

Modality	Name	Typ.Gr.	Description
Theory classes		Large group (G)	* Lectures based on the discussion of the contents of the course * Emphasis will be put on examples to illustrate the main concepts * Practical training will be guide with a series of assignments

Distance education work activities

Modality	Name	Description
Individual self-study	Homework assignements	Grading: Students' work will be qualified according to their results in homework assignments (50%)Homework assignments
Group self-study	Presentation of a research article	Grading: Students' work will be qualified according to their results in homework assignments (50%) and a presentation on a related topic (research article) (50%).

Riscs especifics i mesures de protecció

Les activitats d'aprenentatge d'aquesta assignatura no comporten riscs específics per a la seguretat i salut de l'alumnat i, per tant, no cal adoptar mesures de protecció especials.

Workload estimate

Modality	Name	Hours	ECTS	%
In-class work activities		**30**	**1.2**	**40**
Theory classes		30	1.2	40
Distance education work activities		**45**	**1.8**	**60**
Individual self-study	Homework assignements	30	1.2	40
	Total	**75**	**3**	**100**

Modality	Name	Hours	ECTS	%
Group self-study	Presentation of a research article	15	0.6	20
	Total	**75**	**3**	**100**

At the beginning of the semester a schedule of the subject will be made available to students through the UIBdigital platform. The schedule shall at least include the dates when the continuing assessment tests will be conducted and the hand-in dates for the assignments. In addition, the lecturer shall inform students as to whether the subject work plan will be carried out through the schedule or through another way included in the Campus Extens platform.

Student learning assessment

Homework assignements

Modality	Individual self-study
Technique	Papers and projects **(Non-recoverable)**
Description	Grading: Students' work will be qualified according to their results in homework assignments (50%)Homework assignments
Assessment criteria	Students' work will be qualified according to their results in homework assignments (50%).

Percentage of final qualification: 50% following path A

Presentation of a research article

Modality	Group self-study
Technique	Oral tests **(Non-recoverable)**
Description	Grading: Students' work will be qualified according to their results in homework assignments (50%) and a presentation on a related topic (research article) (50%).
Assessment criteria	Oral presentation on a related topic (50%)

Percentage of final qualification: 50% following path A

Resources, bibliography and additional documentation

1 Lectures Notes
2 Homework assignments
3 Research articles
4 Nielsen, M.A. and Chuang, I.L. Quantum computation and quantum information. Cambridge University Press, 2000

Basic bibliography

* Nielsen, M.A. and Chuang, I.L. Quantum computation and quantum information. Cambridge University Press, 2000

Complementary bibliography

* http://ocw.mit.edu/courses/media-arts-and-sciences/mas-865j-quantum-information-science-spring-2006/

Other resources