Syllabus

Subject

Subject / Group	11288 - Entangled Quantum Systems / 1
Degree	Master's Degree in Advanced Physics and Applied Mathematics
Credits	3
Period	Second semester
Language of instruction	English

Professors

Lecturers	Office hours for students					
	Starting time	**Finishing time**	**Day**	**Start date**	**End date**	**Office / Building**
Antonio Borrás López toni.borras@uib.es	15:00	16:00	Monday	03/09/2018	26/07/2019	F.127

Context

Subject

Quantum entanglement has recently revealed to be extremely useful because of its technological relevance. It is a crucial resource in quantum cryptography, quantum teleportation and quantum computation. The research in quantum entanglement theory has also enabled a deeper understanding on various aspects of quantum physics. While the entanglement detection and quantification for bipartite pure states has been quite well understood for a long time, a lot of effort has recently been devoted to properly characterize this phenomenon in multipartite and mixed states. We will study how to detect and quantify quantum entanglement in all these different cases, as well as its main applications.

Lecturer

Antoni Borrás (PhD in Physics, Universitat de les Illes Balears, 2009) is a researcher in the Nuclear, Atomic and Molecular Physics Group. His main research line is Quantum Information Theory, with an special focus on Entanglement Theory. He is an expert on maximally entangled multipartite states and on the relation between entanglement and the speed of evolution of quantum states.

Requirements

Date of publication: 02/07/2018

Recommended

Quantum mechanics at an introductory level

Skills

Specific

* ESQ4: Knowledge on quantum entangled states and their applications .
* CE1 - Students must possess the learning skills that enable them to combine specialized knowledge in Astrophysics and Relativity, Geophysical Fluids, Materials Physics, Quantum Systems or Applied Mathematics, with the versatility that provides an open training curriculum .
* CE2 - Students must possess the ability to use and adapt mathematical models to describe physical phenomena of different nature .
* CE3 - To acquire edge-line knowledge in the international scientific research context and demonstrate a full comprehension of theoretical and practical aspects, together with the scientific methodology .

Generic

* CG1: Systematic understanding of a field of study and mastery of the skills and methods of research associated with that field .
* CB6 - Possess the knowledge and its understanding to provide the basis or opportunity to be original in developing and/or applying ideas, often within a research context .
* CB7 - Students can apply the broader (or multidisciplinary) acquired knowledge and ability to solve problems in new or unfamiliar environments within contexts related to their field of study .
* CB10 - Students gain the learning skills that enable them to continue studying in a way that will be largely self-directed or autonomous .

Basic

* You may consult the basic competencies students will have to achieve by the end of the Master's degree at the following address: http://estudis.uib.cat/master/comp_basiques/

Content

Range of topics

1. Quantum entanglement and its applications
   Entanglement detection. Separability criteria: PPT, reduction, majorization, q-entropies. Inclusion relations among separability criteria

2. Entanglement characterization
   Distinguishable particles. Bipartite and multipartite systems. Indistinguishable particles.

3. Entanglement creation and distribution
   Entanglement, q-entropies and degree of mixedness. Quantum gates. Entanglement probability distributions created by unitary operations

4. Temporal evolution of entangled states

Teaching methodology

In-class work activities (1 credits, 25 hours)

Modality	Name	Typ. Grp.	Description	Hours
Theory classes	Lectures	Large group (G)	The main topics of the subject will be explained by the lecturer in these theory classes	18
ECTS tutorials	Tutorials	Small group (P)	Individual or group tutorials	5
Assessment	Project presentations	Large group (G)	Project presentations	2

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 Aula Digital platform.

Distance education tasks (2 credits, 50 hours)

Modality	Name	Description	Hours
Individual self-study	Project	The students will study in detail one of the topics covered in the subject or a paper on the field of quantum entanglement theory. They will present their main conclusions and write a report on it.	25
Individual self-study	Problems	The students will solve the list of proposed problems.	25

Specific risks and protective measures

The learning activities of this course do not entail specific health or safety risks for the students and therefore no special protective measures are needed.

Student learning assessment

Frau en elements d'avaluació

In accordance with article 33 of Academic regulations, "regardless of the disciplinary procedure that may be followed against the offending student, the demonstrably fraudulent performance of any of the evaluation elements included in the teaching guides of the subjects will lead, at the discretion of the teacher, a undervaluation in the qualification that may involve the qualification of "suspense 0" in the annual evaluation of the subject".

Project presentations

Modality	Assessment
Technique	Oral tests **(non-retrievable)**
Description	Project presentations
Assessment criteria	

Final grade percentage: 20%

Project

Modality	Individual self-study
Technique	Papers and projects **(retrievable)**
Description	The students will study in detail one of the topics covered in the subject or a paper on the field of quantum entanglement theory. They will present their main conclusions and write a report on it.
Assessment criteria	

Final grade percentage: 50%

Problems

Modality	Individual self-study
Technique	Papers and projects **(retrievable)**
Description	The students will solve the list of proposed problems.
Assessment criteria	

Final grade percentage: 30%

Resources, bibliography and additional documentation

Basic bibliography

* O. Gühne and G. Tóth. *Entanglement detection*. Physics Reports **474**, 1(2009).
* R. Horodecki et al. Quantum entanglement. Rev. Mod. Phys. **81**, 865 (2009).
* M. Plenio and S. Virmani. *An introduction to entanglement measures* **7**, 1 (2007).

Complementary bibliography

* M.A. Nielsen and I.L. Chuang. *Quantum Computation and Quantum Information*. Cambridge University Press (2000).
* V. Vedral. *Introduction to Quantum Information Science*. Oxford University Press (2006).