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230851 - QM - Quantum Matter

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering
Teaching unit: 748 - FIS - Department of Physics
Academic year: 2019
Degree: MASTER'S DEGREE IN ENGINEERING PHYSICS (Syllabus 2018). (Teaching unit Compulsory)
ECTS credits: 5 Teaching languages: Catalan, Spanish, English

Teaching staff

Coordinator: Mazzanti Castrillejo, Ferran.

Others: Mazzanti Castrillejo, Ferran.
Boronat Medico, Jordi

Opening hours

Timetable: Attendance will be scheduled dynamically, with previous appointment with the teacher.

Prior skills

The student should be familiar with the foundamental concepts of quantum mechanics, together with its mathematical grounds. The students must be also familiar with Dirac's notation, must know what a Hamiltonian is, and must be able to solve basic problems in quantum mechanics. She/he should know what a wave function is. The student must also know what a stationary state is, and be able to build up the time evolution of a system once its stationary states are known. He should also know the basics of angular momentum theory in quantum mechanics.

Requirements

Quantum Physics.
Quantum Mechanics.

Degree competences to which the subject contributes

Basic:

CB6. (ENG) Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación
CB7. (ENG) Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio.
CB8. (ENG) Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicio.
CB10. (ENG) Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.

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Teaching methodology

MD1 - Master classes: The contents of the course are exposed in the classroom by a teacher without the active participation of the students.
MD2 - Exposition classes: students are required to perform an oral presentation of a subject that they have prepared previously. This activity can be asked to be individual or in group.
MD4 - Group work: Learning activity that has to be done through collaboration between the members of a group.
MD5 - Report work: students have to present a written report related to the subject.
MD6 - Problem solving: In the problem solving activity, the teaching staff presents an exercise / problem that the students must solve, whether working individually or in a team.
MD8 - Search for information: The search for information, organized as actively seeking information on the part of the students, allows the acquisition of knowledge directly, but also the acquisition of skills and attitudes related to the obtaining of information.

Learning objectives of the subject

At the end of the course, the student must:
1) Understand and be able to solve perturbation theory problems in quantum mechanics. These include time-independent perturbation theory problems in the non-degenrate and degenerate cases, as well as time-dependent ones.
2) Understand and be able to use variational methods in qauntum mechanics.
3) Understand basic concepts of scattering theory in quantum mechanics. Be able to solve basic problems related to scattering processes.
4) Understand the formalism of first and second quantization applied to many body quantum systems, as well as its application to simple systems.
5) Understand the magnetic properties of quantum matter as well as its basic microscopic formulation.
6) Know the most elementary models describing many-body quantum systems on the lattice.

Study load

Total learning time: 125h	Hours large group:	44h	35.20%
	Self study:	81h	64.80%

Content

1. Introduction

Learning time: 2h

Theory classes: 0h
Self study : 2h

Description:

1.1 What problems can be solved in quantum mechanics, and which ones can not be solved exactly.
1.2 Relevance of approximate solutions in quantum mechanics. Approximate solutions from perturbation theory and variatinal methods.
1.3 Relevance of scattering theory in quantum mechanics. Relation to experiments.
1.4 Discussion about many-body quantum theory as the proper way to understand the physics of several interacting entities.
1.5 Introduction to the physics of magnetic systems and its behaviour at the quantum level.
1.6 Discussion about the physics of many particles on the lattice.

2. Perturbation Theory and Variational Methods

Learning time: 24h

Theory classes: 8h
Self study : 16h

Description:

2.1 Time independent perturbation theory: non-degenerate case.
2.2 Time independent perturbation theory: degenerate case.
2.3 Time dependent perturbation theory. Fermi's golden rule.
2.4 Variational methods.

3. Scattering Theory in quantum mechanics.

Learning time: 36h

Theory classes: 24h
Self study : 12h

Description:

3.1 Formulation of the problema. Cross section and differential cross section. Lipmann-Scwinger equation.
3.2 T matrix and Bohr approximation.
3.3 Partial wave expansions and boundary conditions.
3.4 Low energy scattering: scattering length and effective range.

4. The many-body problem in quantum mechanics.	Learning time: 39h Theory classes: 14h Self study : 25h

Description:
4.1 Description of the problem.
4.2 Particle ndistinguilibility. Bose and Fermi statistics. Symmetries of the wave function and symmetries of the operators.
4.3 Second quantization. Creation and anihilation operators. Oerators and observables in second quantization.
4.4 Hartree-Fock approximation. Gross-Pitaevskii equation and Bogoliubov approximation.

5. Magnetic systems.	Learning time: 12h Theory classes: 8h Self study : 4h

Description:
5.1 Polarized and unpolarized free system.
5.2 Ferromagnetic states of matter. Single-particle excitations and particle.hole excitations. Magnons.
5.3 Superconductivity and Cooper pairs. Introduction to BCCS theory.

6. Physics of lattice systems.	Learning time: 12h Theory classes: 4h Self study : 8h

Description:
6.1 Quantum systems on discrete lattices.
6.2 The Hamiltonian of a many-body system on the lattice.
6.3 Fermi and Bose Hubbard models.

Qualification system

Depending on the number of students, students will have to either pass a written exam, or present in class a report about something related to the subject of the course, which will also have to be written and delivered to the professor. This will contribute a 60% of the final score, while the remaining 40% will be otained from the resolution of exercices and/or problems.

Regulations for carrying out activities

Will be decided as the course goes on.

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230851 - QM - Quantum Matter

Bibliography

Basic:

Sakurai, J.J.; Napolitano, J. Modern quantum mechanics. 2nd ed., international ed. Essex (England): Pearson, 2014. ISBN 9781292024103.

Cohen-Tannoudji, C.; Diu, B.; Laloë, F. Quantum mechanics. Singapore: Wiley-VCH, 2005. ISBN 9780471569527 (O.C.).

Fetter, A.L.; Walecka, J.D. Quantum theory of many-particle systems [on line]. Mineola: Dover, 2003 [Consultation: 25/10/2018]. Available on: <https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=1894791>. ISBN 9780486134758.

Lipparini, E. Modern many-particle physics: atomic gases, quantum dots and quantum fluids. World Scientific, 2003. ISBN 9789812383464.

Mahan, G.D. Many-particle physics. 3rd ed. New York: Kluwer Academic : Plenum Publishers, 2000. ISBN 9781441933393.