Emergent phenomena in quantum matter

Academic Year: (2023 / 2024) **Review date: 26-04-2023**

Department assigned to the subject: Physics Department

Coordinating teacher: TORRONTEGUI MUÑOZ, ERIK

Type: Electives ECTS Credits : 3.0

Year : 2 Semester : 1

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

The student must have taken the compulsory courses of the master.

OBJECTIVES

Acquire some knowledge of the main emergent quantum properties and the materials that present them. Understand the collective effects that appear due to strong electronic correlations.

Know the applications of topology to quantum materials and the different kind of materials that present topological properties.

Understand the effect of disorden in condensed matter quantum systems.

Know the main ways to simulate the emergent properties of quantum matter in the lab.

DESCRIPTION OF CONTENTS: PROGRAMME

· Introduction and basic concepts in correlations
- Fermi liquid theory.
- Hubbard model and Mott physics.
- Spin-charge separation and Luttinger liquids.
- Kondo effect.
- Broken symmetry phases.
- Materials with strong correlations.

· Topological quantum matter
- Graphene and Dirac materials.
- Topological insulators and semimetals.
- Hall effects.
- Topological superconductivity.

· Disorder and localization
- Introduction to Anderson localization.
- Many-body localization.

· Simulations of quantum matter
- Ultracold quantum gases in Optical lattices.
- Other platforms and digital quantum simulations.

LEARNING ACTIVITIES AND METHODOLOGY

Formative activities: Theoretical clases, tutorships, group and individual work.

Teaching methodology:

Lectures by the teacher with audiovisual support, in which the main concepts of the subject will be develop and the complementary bibliography will be presented.

Critical readership by recommended text by the teacher, specially manuals and academic articles.

Problem solving individually or in groups.

Oral presentations and discussions with the teacher as moderator.

Preparation of reports, individually or in teams, on topics proposed by the teacher to go deeper into the main topics of the subject.

ASSESSMENT SYSTEM

SE1. FINAL EXAM. Global assessment of knowledge, skills and capacities acquired throughout the course.
SE2. CONTINUOUS EVALUATION. Assesses papers, projects, class presentations, debates, exercises, internships and workshops throughout the course.

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

BASIC BIBLIOGRAPHY

- BA. Bernevig, TL. Hughes. Topological Insulators and Topological Superconductors, Princeton University Press..
- D. Hangleiter, J. Carolan, K. Thébault Analogue Quantum Simulation, Springer, 2022
- E.D. Mattuck. A guide to Feynmann Diagrams in the Many Body problem, Dover Books on Physics..
- Patrik Fazekas Lecture notes on Electron Correlations and Magnetism, World Scientific Publishing Company..
- Phillipe Nozieres, David Pines Theory of Quantum Liquids, Advanced Books Classics. .
- Piers Coleman Introduction to many body physics, University Press..
- SQ. Shen Topological Insulators: Dirac equation in Condensed Matter, Springer, 2012
- Y. Nazarov, Y. Blanter Quantum Transport , Cambridge University Press, 2012

ADDITIONAL BIBLIOGRAPHY

- P.W. Anderson More is differen, Science, 177, 393, 1972
- M. Imada, A. Fujimori, Y. Tokura Metal-insulator transitions, Rev. Mod. Phys. 70, 1039 , 1998
- MZ. Hasan & CL. Kane Colloquium: Topological Insulators, Rev. Mod. Phys. 82, 3045 , 2010

BASIC ELECTRONIC RESOURCES

- . Superconductividad (web de divulgación): https://wp.icmm.csic.es/superconductividad/
- . Emergence of Quantum Phases in Novel Materials: https://wp.icmm.csic.es/emergence/