Quantum materials

Academic Year: (2023 / 2024) **Review date: 24-04-2023**

Department assigned to the subject: Materials Science and Engineering and Chemical Engineering Department

Coordinating teacher: GARCIA PEÑAS, ALBERTO

Type: Electives ECTS Credits : 3.0

Year : 2 Semester : 1

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Quantum physics
Advanced quantum physics

OBJECTIVES

This course offers students an overview on quantum materials with special focus on theoretical methods needed to describe typical phenomena. The syllabus will treat topics and concepts of transversal nature that are useful for related courses such as "Emergent Phenomena in Quantum Matter" and "Solid-state implementations of quantum technologies".

DESCRIPTION OF CONTENTS: PROGRAMME

1. Introduction to Quantum Materials
- Introduction
- Overview on experimental techniques

2. Introduction to Theoretical Solid-State Physics
- Bloch-Theorem and band theory
- Covalent bonding and tight-binding approximation
- Second quantization and interactions

3. Magnetism in quantum materials
- Basic concepts and introduction
- Magnetic moments in solids
- Diamagnetism and Paramagnetism
- Magnetic interaction
- Ferro and antiferromagnetism
- Spin systems and basic spintronic effects/devices

4. Superconductivity
- Basic concepts and phenomenology
- Introduction to Fermi liquid theory
- Meissner effect, penetration depth, coherence length
- Thermodynamics
- Basics of BCS theory
- High temperature and unconventional superconductors

5. Typical quantum materials
- Complex oxides
- Iron-based superconductivity
- Multiferroics
- Organic and molecular systems
- Two-dimensional materials

LEARNING ACTIVITIES AND METHODOLOGY

3 credits ECTS
14 classes (each 2x50min)

ASSESSMENT SYSTEM

60 % Final Exam (90min on Magnetism, Superconductivity, Quantum Materials)
40 % Partial Exam (60min on Introduction to Theoretical Solid State)

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

BASIC BIBLIOGRAPHY

- C. Kittel Solid State Phyics , Wiley.
- D. H. Martin Magnetism in Solids , London Iliffe Books Ltd..
- J. B. Goodenough Magnetism and the Chemical Bond , Wiley.
- K. Yosida Theory of Magnetism , Springer.
- M. Tinkham Introduction to Superconductivity, McGraw-Hill, Inc., New York, 1996, Reprint by Dover Publications Inc. Miniola , 2004
- N. W. Ashcroft, N. D. Mermin Solid State Physics , Holt, Rinehart and Winston.
- P. A. Cox Transition Metal Oxides , Oxford University Press.
- P. G. de Gennes Superconductivity of Metals and Alloys , Addison-Wesley.