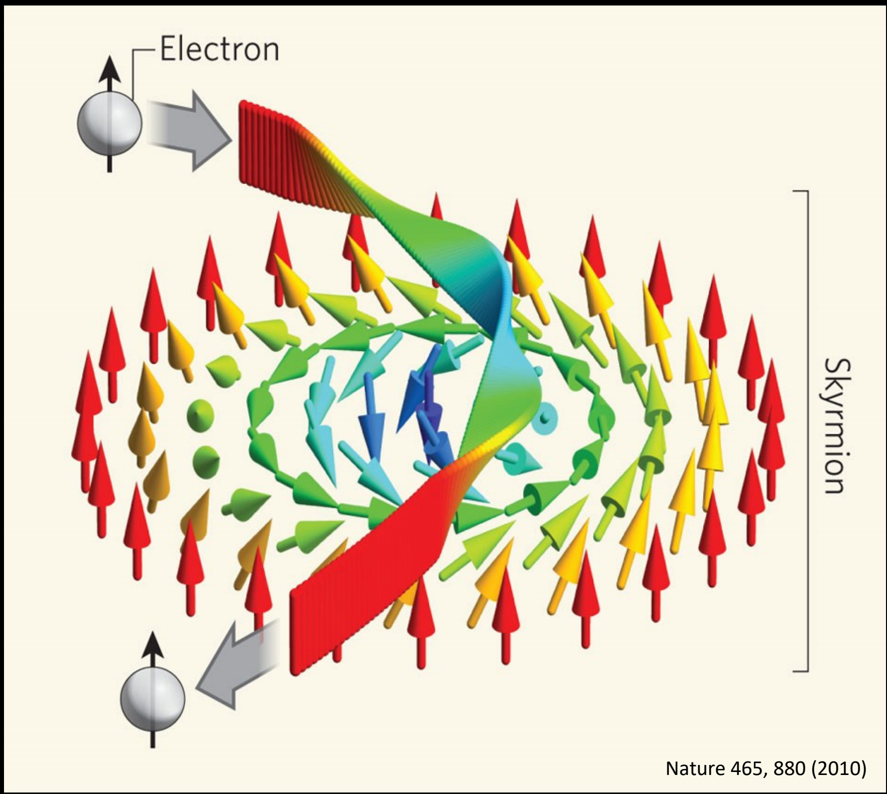
University of Glasgow | School of Physics & Astronomy



PHYS4010 Magnetism & Superconductivity

Course Information Guide

Course Details

PHYS4010 Magnetism & Superconductivity is a level 4 elective Physics Honours course. It is a recommended option for many physics degrees. Following the course will require up to 200 hours of learning effort, participating in lectures, tutorials, on-line learning activities and self-study of notes and textbook material. The course is delivered in Semester 2.

Lecturer: Dr Trevor Almeida
Room 308, Kelvin Building
trevor.almeida@glasgow.ac.uk

Recommended Texts:

- Magnetism and Magnetic Materials (J. M. D. Coey, Cambridge University Press)
- Fundamentals of Magnetism (Mathias Getzlaff, Springer)
- Low Temperature Physics (Christian Enss, Siegfried Hunklinger, published by Springer)

2022/23: Depending on University arrangements in place at the time of delivery, learning will take place via face-to-face lecture, normally on Mondays and Wednesdays 12:00 - 13:00. Additional learning activities prior/after lectures will be based on course notes, and may include text materials, quizzes, videos, questions and problem sheets.

All content is available via the Moodle page of the course.

Assessment

The course will be assessed via an examination in the April/May diet. The course provides 10 H-level credits.

Required Knowledge

Students are expected to have completed the Level 3 course P304H Quantum Mechanics and the Level 4 course PHYS4028 Solid State Physics. We will assume a familiarity with mathematical concepts such as the Fourier space. This course will have some overlap with P403H Atomic Systems.

Intended Learning Outcomes

The aim of this course is to introduce the physics and underlying properties of collective phenomena in materials. The course provides examples of how quantum physics, statistical mechanics and thermodynamics can be applied to understand phenomena emergent in complex many particle systems. By the end of the course, students should be able to: describe the key physical principles of magnetism and superconductivity; demonstrate a knowledge and understanding of the theory and applications of different magnetic orders (diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism) and the macroscopic behaviour of ferromagnets; and demonstrate a knowledge and understanding of the basic properties, phenomenology and applications of superconducting devices at low and "high" temperatures.

Course Outline

Details of the course content are listed below.

Magnetism

1. Introduction
   - Types of magnetic materials
   - Sources and magnitude of magnetic fields
   - Magnetic hysteresis
   - Main applications
2. Magnetostatics
   - Magnetic dipole moment
   - Magnetic fields
   - Magnetostatic energy, forces and torques
3. Magnetism of electrons
   - Orbital and spin moments of the electron
   - Spin-orbit coupling
   - Zeeman splitting
   - Orbital diamagnetism
4. Magnetism of the atom due to localised electrons
   - Orbital and spin moments of the atom
   - Hund's rules
   - Paramagnetism of localised moments: Brillouin theory
   - Crystal fields and quenching of orbital moments
5. Ferromagnetism
   - Mean field theory
   - Exchange interactions and Heisenberg Hamiltonian
   - Magnetic anisotropy
   - Magnetic domains and domain walls
6. Magnetic techniques
   - Magnetometry
   - Imaging
   - Scattering

7. Other types of magnetic materials
   - Antiferromagnets and ferrimagnets
   - Helimagnets
8. Nanomagnetism and spintronics
   - Magnetism at the nanoscale
   - Thin films
   - Magnetoresistance effects, magnetic data storage and memory devices

Superconductivity

1. Achievement of low temperatures, low temperature measurement
2. Bose-Einstein Condensation
   - Superfluidity and neutral atoms
   - Zero viscosity
   - Condensation in momentum space: ground state wavefunction

3. Qualitative description of superconducting phenomena
   - Type I superconductors and influence of B-fields,
   - Meissner effect and perfect diamagnetism

4. Phenomenological theory - the London equations
   - London penetration depth
   - Critical fields

5. Mean field theory of superconductivity
   - order parameter
   - Landau Ginzburg free energy with vector potential
   - current associated with gradient in phase
   - Type II superconductors
   - vortices and quantized currents

6. Microscopic theory
   - thermodynamics in terms of critical fields
   - coherence length
   - Cooper pairs and energy gap
   - Type I and Type II superconductors: normal metal path length

7. Applications of Superconducting devices
   - Magnets
   - Josephson junctions
   - DC SQUIDs
   - HighT_c superconductors, crystal structure, properties, applications