PHYS-491

# Magnetism in materials

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| Cursus | Sem. | Type |
|---|---|---|
| Ing.-phys | MA2, MA4 | Opt. |
| Physicien | MA2, MA4 | Opt. |

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|---|---|
| Language of teaching | English |
| Credits | 4 |
| Session | Summer |
| Semester | Spring |
| Exam | Oral |
| Workload | 120h |
| Weeks | 14 |
| **Hours** | **4 weekly** |
| Courses | 2 weekly |
| Exercises | 2 weekly |
| **Number of positions** | |


## Summary

The lectures will provide an introduction to magnetism in materials, covering fundamentals of spin and orbital degrees of freedom, interactions between moments and some typical ordering patterns. Selected experimental techniques and their application in current research will be presented.


## Content

1. Introduction (spin and orbital moments, Pauli matrices)
2. Isolated magnetic moments (diamagnetism, paramagnetism, Hund rules)
3. Crystal fields (ligand environment of magnetic ions, Jahn-Teller effect)
4. Interactions (dipole, direct exchange, super-exchange, anisotropic and asymmetric exchange)
5. Long-range magnetic order (ferromagnetism, Weiss model, critical behavior, excitations)
6. Long-range magnetic order (antiferromagnetism, incommensurate order, spin-glass)
7. Magnetism in metals (Pauli paramagnetism, Stoner mechanism, Landau levels)
8. Magnetism in metals (spin-density wave, RKKY, Kondo effect)
9. Measurement techniques 1 (magnetization, susceptibility)
10. Measurement techniques 2 (specific heat, ESR)
11. Measurement techniques 3 (NMR, muSR)

## Learning Prerequisites

### Required courses

Classical electrodynamics
Quantum Physics 1

### Recommended courses

Quantum Physics 2
Solid State Physics 1
Solid State Physics 2

## Learning Outcomes

By the end of the course, the student must be able to:

- Define fundamental sources of magnetism
- Explain the behavior of magnetic moments in magnetic fields
- Work out / Determine spin states from ligand environment
- Elaborate common magnetic interactions and their properties
- Contrast typical long-range ordered states in magnetism

- Discuss how magnetism arises in metals
- Demonstrate similarities and differences in low-dimensional magnetic systems
- Specify the role of a given experimental technique in investigation of magnetic materials

## Transversal skills

- Demonstrate the capacity for critical thinking
- Summarize an article or a technical report.
- Make an oral presentation.

## Teaching methods

Lectures with exercises.

## Assessment methods

Oral exam.

## Supervision

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|---|---|
| Office hours | Yes |
| Assistant.e.s | Yes |
| Others | Office hours: appointments can be arranged by email. |

## Resources

### Bibliography

"Magnetism in Condensed Matter Physics", Stephen Blundell (Oxford University Press, 2001)

### Ressources en bibliothèque

- Find the references at the Library

### Moodle Link

- https://go.epfl.ch/PHYS-491