

PHYS-491

**Magnetism in materials**

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

Language of teaching	English
Credits	4
Session	Summer
Semester	Spring
Exam	Oral
Workload	120h
Weeks	14
<b>Hours</b>	<b>4 weekly</b>
Courses	2 weekly
Exercises	2 weekly
<b>Number of positions</b>	

**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)
4. Interactions (dipole, direct exchange, super-exchange, RKKY)
5. Long-range magnetic order (ferromagnets, antiferromagnets, spin-glass)
6. Magnetism in metals (Pauli paramagnetism, Stoner mechanism, SDW)
7. Critical behavior (correlation length, critical exponents)
8. Short-range order (planes, chains, clusters, MOF, super-paramagnets)
9. Measurement techniques 1 (units, magnetization, susceptibility)
10. Measurement techniques 2 (ESR, NMR,  $\mu$ SR)
11. Measurement techniques 3 (neutron scattering)
12. Current research examples 1 (geometrical frustration, spin-ice, spin-liquids)
13. Current research examples 2 (magneto-electric effect, skyrmions)

**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

Office hours	Yes
Assistants	Yes
Others	Office hours: appointments can be arranged by email.

### Resources

#### Bibliography

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