Degree competences to which the subject contributes

**Transversal:**

- **02 SCS N3. SUSTAINABILITY AND SOCIAL COMMITMENT** - Level 3. Taking social, economic and environmental factors into account in the application of solutions. Undertaking projects that tie in with human development and sustainability.
- **06 URI N3. EFFECTIVE USE OF INFORMATION RESOURCES** - Level 3. Planning and using the information necessary for an academic assignment (a final thesis, for example) based on a critical appraisal of the information resources used.
- **07 AAT N2. SELF-DIRECTED LEARNING** - Level 2: Completing set tasks based on the guidelines set by lecturers. Devoting the time needed to complete each task, including personal contributions and expanding on the recommended information sources.

**Teaching methodology**

Theory classes: the teacher introduces fundamental concepts and few proofs, complementing them with key examples and demonstrations, as well as with the discussion of some applications.

Problem solving and guided activities: the teacher carries out the resolution of representative problems; students review fundamental concepts and solve some problems under the teacher's supervision.

**Learning objectives of the subject**
At the end of the course, the student must be able to:
- describe the physical foundations of material properties, and their response to applied external fields.
- possess the capability to approach the conceptual problems underlying current challenges in material science and technology.

<table>
<thead>
<tr>
<th>Study load</th>
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<tbody>
<tr>
<td><strong>Total learning time:</strong> 60h</td>
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<tr>
<td>Hours large group:</td>
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</table>
## Content

### Item 1. Physical Foundations of the Thermal Properties of Materials

<table>
<thead>
<tr>
<th>Learning time: 70h</th>
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<tbody>
<tr>
<td>Theory classes: 24h</td>
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<tr>
<td>Guided activities: 4h</td>
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<tr>
<td>Self study: 42h</td>
</tr>
</tbody>
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#### Description:

**Topic 1.1 Basic concepts**

**Topic 1.2 Applications. First part**

**Topic 1.3 Applications. Second part**
Systems with magnetic ions: classical and quantum paramagnetism.
Metallic crystals: electron gas, Fermi level, and work function.

#### Related activities:

Learning time: 70 h
Theory classes: 20 h
Problem-solving classes: 4 h
Guided activities: 4 h
Self study: 42 h

Learning time: 40h
- Theory classes: 15h
- Guided activities: 1h
- Self study: 24h

Description:
Topic 2.1 Charge transport and linear response to time-dependent electric fields
Learning time: 19 h
Classification of conductors in terms of the majority charge carriers: electron/holes, ions, protons; temperature dependence of the dc conductivity. Applications of ion and proton conductors, electrochemical devices. Effect of disorder and of electron repulsion on electronic properties; electron correlation and connection with magnetism; metal-insulator transitions.
Linear response theory, complex permittivity and complex conductivity. Polarization mechanisms with time-varying electric fields: conduction and space-charge effects in non-homogeneous media; glasses: relaxation dynamics, Debye model and derived phenomenological models; response at optical frequencies, plasmons and excitons; Drude-Lorentz model and Rayleigh-Lorentz model for optical and vibrational transitions.

Topic 2.2 Molecular and macromolecular materials: dynamic and electrical properties, and applications
Properties that are specific to organic materials: orientational and conformational degrees of freedom, isomerism and polymorphism. Dependence of the crystal structure and morphology on crystal growth conditions, molecular self-assembly, crystal design. Mesophases: orientationally disordered solids, plastic crystals, thermotropic and lyotropic liquid crystals, polymers, binary and colloidal systems.
Experimental techniques: dielectric spectroscopy, dynamic mechanical analysis, optical techniques. Relevance and applications of organic materials: mesophases in biological systems; encapsulation of pharmaceutical compounds, drug delivery; conjugates polymers and doped conducting polymers; applications in optoelectronics and electrochemistry: OLED, organic solar cells, liquid crystal displays, supercapacitors.

Topic 3.3 Functional properties of ferroic and multiferroics systems
### Item 3: Phase transitions in multiferroic materials

<table>
<thead>
<tr>
<th>Learning time: 28h</th>
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<tbody>
<tr>
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<tr>
<td>Theory classes: 16h</td>
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<tr>
<td>Self study: 12h</td>
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</tbody>
</table>

#### Description:

**Topic 3.1 Transitions at thermodynamic equilibrium and out-of-equilibrium systems.**

**Topic 3.2 Ferroic systems**

**Topic 3.3 Functional properties of ferroic and multiferroics systems**

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### Qualification system

The student’s final mark will be calculated as a weighted average of the marks obtained in the midterm exam, during the guided activities, and from the student’s mark on a report to be handed in and dealing with a relevant scientific or engineering topic, to be agreed upon between the student and the teachers. The relative weight of each mark will be as follows:

**Midterm Exam**: 30%
**Guided activities/Problem-solving classes**: 20%
**Research Report**: 50%
Bibliography

Basic:


Complementary:


Others resources:

During the course, the teachers will provide students with study material and sometimes recommend material available on-line, both from general sources such as Wikipedia or from specific websites such as that of the research group of the teachers (https://gcm.upc.edu/en).