Universidad Zaragoza

Academic Year/course: 2023/24

60035 - Statistical physics of critical phenomena and complex systems

Syllabus Information

Academic year: 2023/24
Subject: 60035 - Statistical physics of critical phenomena and complex systems
Faculty / School: 100 - Facultad de Ciencias
Degree: 538 - Master's in Physics and Physical Technologies
589 - Master's in Physics and Physical Technologies
ECTS: 5.0
Year: 1
Semester: Second semester
Subject type: Optional
Module:

1. General information

The study of the current physics of phase transitions and critical phenomena provides the student with a unique opportunity to combine discussions of exact solutions, numerical simulations, experimental results, basically intuitive ideas (e.g., renormalization group), and field theory methods in a way that illuminates similarities and differences, as well as strengths and weaknesses of these approaches. In addition, special emphasis is placed on the broad generality of the theory outside the domain of traditional physical systems, in scientific fields as diverse as population dynamics, neuroscience, and social, technological and biological systems.

It is aligned with SDG 4 Quality Education.

Previous training in quantum physics, thermodynamics and statistical physics is recommended.

2. Learning results

Upon the end the subject, the student will be able to:

- Consolidate advanced knowledge and the interrelation between the various fields of physics.
- Integrate knowledge, deal with complexity and make judgments with limited information in the field of physics.
- Deepen in the analysis, treatment and interpretation of experimental data.
- Work and communicate in an interdisciplinary field.
- Understand the general phenomenology of critical phenomena.
- Understand the phenomenon of universality and its application in physical reasoning.
- Know the appropriate approaches in the analysis of critical phenomena.
- Understand the concept of scale invariance and its application in the theory of critical phenomena.
- Understand the extension of the concepts of universality and scaling to different sciences.
- Recognize the common character underlying various fields of knowledge, concepts, models and techniques of statistical physics.

As a result of these competencies, the student should be able to:

- formulate and solve free energies in the mean-field approximation, as well as calculate the critical exponents in this approximation.
- calculate the partition function of appropriate model-systems using the transfer matrix method.
- design renormalization group transformations on simple models.
- analyse GR flowcharts and calculate critical exponents based on GR techniques.
- build models of diverse phenomena outside the domains of traditional physical systems and analyse them using the techniques and procedures of statistical physics.

3. Syllabus

1. Introduction to phase transitions. Basic concepts
2. Review of thermodynamics and statistical mechanics.

3. Phase diagrams and phase transitions
4. Thermodynamics of phase transitions
5. Mean Field Theories
6. Critical phenomena
7. Landau-Ginzburg theory
8. Statistical models for phase transitions
9. Scaling and universality: renormalization group
10. Emerging topics in phase transitions in condensed matter physics: magnetocaloric materials, multiferroics, liquid crystals, topological phase transitions, quantum
11. Interdisciplinary complex systems: phase transitions in network theory, epidemics, synchronization, population dynamics, social interaction models, evolutionary game dynamics.

4. Academic activities

- Master classes on the main topics of the subject.
- Interactive problem-solving sessions.
- Study, oral presentation, and group discussion of an academic work directly related to the subject.
- Seminars by researchers specializing in topics 10 and 11 of the program.

5. Assessment system

Continuous assessment of the student's learning through the solving of problems, questions in class and other activities proposed by the teachers. This activity will account for 40% of the final grade.

The remaining 60% will be assessed through the production of an academic work of the subject, which will be presented by the student in class at the end of the term. The assessment will take into account both the content of the work (40%), as well as its presentation and defence answering the questions of the teachers and classmates (20%).

Passing the subject by means of a single global test.

Although the subject is designed for students who can attend the lectures in person, there will be an exam on theoretical issues and exercises for those unable to attend, which can also be taken by students who do not pass the continuous assessment activities.