Universidad Zaragoza

60035 - Statistical physics of critical phenomena and complex systems

Información del Plan Docente

Academic Year	2018/19
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
ECTS	5.0
Year	1
Semester	Second semester
Subject Type	Optional
Module	---

1.General information

1.1.Aims of the course

The spectacular success of microscopic physics should not conceal from students the importance of macroscopic physics, a field that remains very much alive. In this regard, Statistical Physics constitutes an essential part of our understanding of Nature, thus a fundamental subject in the background of physics education. It bridges the gap between the microscopic description of matter and fields and their macroscopic behavior. Phase changes of matter, namely transitions between dramatically different robust regimes of equilibrium macroscopic states, are accurate examples of general system crisis. Its importance relies not as much on the fact that its description and concomitant understanding focused on an unprecedented mathematical and theoretical physics research effort (decades long), as on the generality and insightfulness of the far-reaching results achieved.

This is an advanced course on Statistical Physics, with a particular focus on Phase Transitions and Critical Phenomena, as well as on Interdisciplinary Physics of Complex Systems. Although the content is largely theoretical, the course is designed so as to attract both, experimenters and theoreticians. It is highly recommended that students have a reasonably good previous background in Quantum Physics, Thermodynamics and Statistical Physics.

1.2.Context and importance of this course in the degree

1.3.Recommendations to take this course

2.Learning goals

2.1.Competences

2.2.Learning goals

2.3.Importance of learning goals

3.Assessment (1st and 2nd call)

3.1.Assessment tasks (description of tasks, marking system and assessment criteria)

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A continuous evaluation will take into account the personal work of the students throughout the course. The students will have to solve sets of (homework) exercises in almost every course section. 45% of the student's final mark will be based on the solutions presented.

Assessment also includes an exam comprising theoretical questions and some problems (30% of final mark). Finally, students will be assessed on analytical and computational techniques through a course project (25% of final mark).

4.Methodology, learning tasks, syllabus and resources

4.1.Methodological overview

The methodology followed in this course is oriented towards achievement of the learning objectives. It favors the development of research competences. A wide range of teaching and learning tasks are implemented, such as lectures, study, oral presentations, discussions, exercises, and projects.

4.2.Learning tasks

The course includes the following learning tasks:

- Lectures on the main topics of the course (3 ECTS)
- Practice sessions where students solve, individually or in groups, exercises and problem sets (1.2 ECTS)
- Study, oral presentation and class discussion, of selected research articles (0.8 ECTS).

4.3.Syllabus

The course will address the following topics:

1. Introduction. Some examples and phenomenology. Basic concepts: Order parameter, critical exponents, fluctuations, scaling and universality.
2. Review of Statistical Physics and Thermodynamics with an emphasis on fluctuations and correlation functions. Spontaneous symmetry breaking. Metastability.
3. Models: Percolation, Ising, XY, Heisenberg, Potts, Gaussian, Spherical. Transfer matrix. Exact solutions. Numerical methods.
4. Mean field theory: Ising, percolation, non-ideal gas. Variational derivation. Correlation functions. Critical exponents. Landau theory. Saddle-point approximation to the Landau-Ginzburg model.
5. The Landau-Ginzburg model. Spontaneous continuous symmetry breaking and Goldstaone modes. Spontaneous discrete symmetry breaking and domain walls. Scattering experiments and fluctuations. Correlation functions and susceptibilities. Lower critical dimension. Fluctuations corrections to saddle-point approximation. Upper critical dimensions and Ginzburg criterion.
6. Percolation: 1d, Bethe lattice, 2d, scaling hypothesis, scaling relations, geometric properties of clusters, critical exponents. Real space renormalization.
7. Scaling hypothesis. Widom formulation. Correlation length and hyperscaling hypothesis. Critical correlation functions and self-similarity.
8. Renormalization. Conceptual presentation (Kadanoff). Formalization (Wilson). Direct solution and renormalization approach to the Gaussian model. Epsilon (4-d) expansions. RG schemes in lattices (decimation, Migdal-Kadanoff, Niemeijer and Van Leeuwen cumulant expansions).
9. Dynamical models in critical phenomena. Criticality in stationary non-equilibrium states: self-organized criticality and its applications to Natural Sciences.
10. Interdisciplinary Complex Systems. Phase transitions in Network theory, Breaking of KAM tori, epidemies, synchronization, population dynamics, models of social interactions, evolutionary game theory.

4.4.Course planning and calendar

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Further information concerning the timetable, classroom, assessment dates and other details regarding this course, will be provided on the first day of class or please refer to the Faculty of Science http://ciencias.unizar.es/

4.5.Bibliography and recommended resources