UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Advanced Statistical Mechanics and Disordered Systems

2627-2-F9103Q025

Aims

The course covers some key aspects of statistical mechanics in their relation to probability theory, theoretical computers science and machine learning, and focuses on interdisciplinary applications of statistical physics in these areas, as well as on classical theories of liquids leveraging artificial intelligence methods. Rather than the systematic learning of an extended corpus, the objective is the development of a synthetic view of the subject. The tools provided aim at making students autonomous in their ability to explore contemporary issues in statistical mechanics, especially in their interdisciplinary applications, also through the use of active learning open-ended exercises, and reading-group experiences.

Contents

The course content can be divided into two parts.
(i) A set of central topics in the statistical mechanics of complex systems, including the relationships between statistical mechanics and probability theory, the understanding and use of mean-field methods, and the statistical physics of disordered systems and combinatorial-optimization problems. This part of the course is presented with a mixture of lectures, active study material, and exercises.
(ii) A selected collection of exemplary topics from the the modern theory of classical liquids, using the hard-sphere fluid ad a guiding tool to keep the course's development directly accessible and computationally affordable. The scope of the course will range from Mayer's systematic virial expansions to the analytic solution of Percus-Yevick's equation. A number of topics will be treated in the style of a reading course, with an active involvement of students, also in view of developing the skills required for the final test.

Detailed program

- Probability and Statistical Physics. Universality theorems for independent random variables, Large Deviations, Maximum Entropy and ensemble theories.
- “50 Shades of Mean-Field”. Different mean-field approaches, as approxi- mations, algorithms, theories, and models (focused on spin systems).
- Disordered systems, spin glasses and optimization problems.
- Density expansions and equation of state. Mayer function. Diagrammatic method. Second virial coefficient.
- Radial distribution function. Approximate integral equations. The Percus- Yevick equation.
- Exact solution of the Percus-Yevick equation. Beyond the Percus-Yevick approximation.

Prerequisites

Knowledge of elementary statistical mechanics would be required to attend seamlessly this class, although the course will strive to be self-contained.

Teaching form

A number of diverse teaching strategies will put at work, including traditional lectures, active study and reading group material, and exercises.

Textbook and teaching resource

1. Luca Peliti, Statistical Mechanics in a Nutshell (Princeton University Press 2009)
2. James Sethna, Statistical Mechanics: Entropy, Order Parameters, and Complexity (Oxford, 1st ed. 2006, 2nd ed. 2021)
3. Hidetoshi Nishimori, Statistical Physics of Spin Glasses and Information Processing: An Introduction (Clarendon Press 2001)
4. Andrés Santos, A Concise Course on the Theory of Classical Liquids: Basics and Selected Topics (Springer 2016)
5. Jean-Pierre Hansen and Ian R. McDonald, Theory of Simple Fluids with Applications to Soft Matter (London Academic Press 4th ed. 2013)

Semester

First

Assessment method

The final exam is an oral test, based on an individual project, which consists in reproducing theoretically and computationally a preassigned topic. The oral examination is divided into two parts

1. Formal presentation (using blackboard and/or slides) of the project, clearly explaining the question and its motivations, the methods employed, and the results achieved.
2. Questions, free discussion and deepening of the points that emerged during the presentation.

Office hours

By appointment

Sustainable Development Goals

QUALITY EDUCATION