SSM
Scuola Superiore Meridionale

Course title:

Introduction to Statistical Mechanics

Duration [number of hours]**: 24**

PhD Program [MERC/MPS/SPACE]**: MERC**

Name and Contact details of unit organizer(s):

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Course Description [max 150 words]**:**

This course on Statistical Mechanics offering a deep dive into how microscopic behaviors give rise to macroscopic phenomena. Beginning with thermodynamics to establish foundational concepts, it transitions to statistical mechanics through random walks, illustrating how particle dynamics lead to emergent system properties. Starting from Postulates of Statistical Mechanics, bridging microstates with macro observables and revealing the statistical nature of thermodynamic laws, students will explore Canonical and Grand Canonical ensembles, critical for understanding equilibrium systems and predicting behavior under variable conditions. The course culminates with a focus on Critical Phenomena, addressing the complexities of phase transitions beyond classical thermodynamics. This journey aims to equip students with the analytical tools to model and understand physical systems across scales, highlighting the importance of statistical mechanics in explaining and predicting natural phenomena. Through theoretical and practical learning, students will uncover the intricate connection between microscopic interactions and the macroscopic world.

Syllabus [itemized list of course topics]**:**

<u>Overview of thermodynamics</u>
Laws of Thermodynamics, Entropy, Temperature, Thermal equilibrium, Heat Flows, Thermal Capacity, Legendre Transformation, Grand Potential, Variational Principles, Maxwell Relations

<u>Random walk - Introduction to Statistical Mechanics</u>
Non-equilibrium: unbounded random walk, Gaussian Approximation, Equilibrium: random walkers in a box.

<u>The Postulates of Statistical Mechanics</u>
Motion in Γ-Space, Averaging, Liouville Theorem, Ergodic Hypothesis.

<u>Connection with thermodynamics</u>
Degeneracy, Statistical definition of temperature, Entropy, Pressure, chemical potential, etc. in statistical mechanics, Continuous variables.

<u>Canonical ensemble</u>
The ensemble distribution, the partition function, energy distribution, Free energy, First law of thermodynamics, Canonical distribution for classical systems, Energy Equipartition Theorem, Maxwell-Boltzmann Distribution, Ideal gas, Harmonic oscillators, Paramagnetism.

<u>Grand canonical ensemble</u>
Introduction, Particle number distribution, Grand Thermodynamic Potential.

Critical phenomena

Gas-Liquid-Solid transition, Van der Waals theory, Ferromagnetic transition, Critical exponents, Ising Model, Broken Simmetry, Fluctuation-dissipation theorem, Mean fields, Exactly solvable models, Scaling laws and Universality, Renormalization group

Assessment [form of assessment, e.g., final written/oral exam, solutions of problems during the course, final project to be handed-in, etc.]**:**

Final written exam

Suggested reading and online resources:

Notes of the lessons
David Chandler - Introduction to Modern Statistical Mechanics
Kerson Huang - Meccanica Statistica