SSM
Scuola Superiore Meridionale

Course title:

Statistical Mechanics: from basic concepts to applications in Complex Systems, Astrophysics and beyond.

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

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

Name and Contact details of unit organizer(s):

Prof: Mario Nicodemi
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Course Description [max 150 words]**:**

The course introduces the theory of Statistical Mechanics, from its fundamental concepts to more advanced applications in Complex Systems, Astrophysics and beyond.

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

1) *Theory of Probability*: Basic concepts of the Theory of Probability, The Generating Function, The Random Walk (RW), Einstein Theory of Brownian Motion, RW in Finance and other applications, Self-Avoiding RW (SAW).
2) *Statistical Mechanics*: Statistical description of the equilibrium states of a many-body system in physics, Postulate of Statistical Mechanics, Gibbs Entropy, Ensembles and state distributions.
3) *Ensemble Distributions*: The Microcanonical, Canonical, Gran Canonical Ensembles, Partition Function, its derivatives and ensemble averages, Free Energy Minimum and Energy Distribution, Virial Theorem, Generalised Forces and Thermodynamics Relations, The Arrow of Time.
4) *Basic applications to non-interacting systems*: The Classical Ideal Gas and its Equations of State, Two Levels Systems and the Ising Paramagnet, Classical and Einstein Quantum Harmonic Oscillators.
5) *Interacting classical gasses*: Calculation of the Configuration Integral, the Mayer expansion, van der Waals equation of state, Liquid-Gas Phase Transition and Diagram.
6) *Quantum Density Operator*: Quantum pure states and mixtures, Quantum Ensemble Averages and the Density Operator, Time evolution of the Density Operator, The von Neumann equation.
7) *Quantum Statistical Mechanics*: Quantum Microcanonical, Canonical and Gran Canonical Ensembles, Non-Interacting Systems of Fermions and Bosons, Second Quantization Description, Fermions and the Fermi-Dirac distribution, Bosons and the Bose-Einstein distribution. Statistical Mechanics of Free Quantum Particles.
8) *Classical limit of Quantum Statistical Mechanics*: Quantum Statistics in the Classical Limit, Quantum Ideal Gas in the Classical Limit in the Canonical Ensemble, Solution to the Gibbs Paradox.
9) *Applications of Fermi Statistics*: Ideal Fermi Gas, Sommerfeld Theory and applications in Condensed Matter (e.g., electrons in metals) and Astrophysics (e.g., white dwarfs and neutron stars).
10) *Applications of Bose Statistics*: Ideal Bose Gas, Photon gas and Black Body radiation, Planck formula, Cosmic Microwave Background radiation.
11) *Advanced Topics I*: Black Hole Thermodynamics, Derivation of Bekenstein-Hawking Entropy formula.
12) *Advanced Topics II*: Complex Systems in Physics. The interacting String. Entropy and Phase Transitions. Applications.

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

Final viva exam and problem solution during the course.

Suggested reading and online resources:

1. D. Chandler, *Introduction to Modern Statistical Mechanics*, Oxford University Press, 1987
2. F. Schwabl, *Statistical Mechanics*, Springer, 2000
3. R. Feynman, *Statistical Mechanics*, CRC Press, 19982.
4. Notes provided by the Lecturer.