UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Fisica e Chimica - Emilio Segrè
ACADEMIC YEAR	2022/2023
MASTER'S DEGREE (MSC)	PHYSICS
SUBJECT	STATISTICAL PHYSICS
TYPE OF EDUCATIONAL ACTIVITY	B
AMBIT	50340-Microfisico e della struttura della materia
CODE	22671
SCIENTIFIC SECTOR(S)	FIS/03
HEAD PROFESSOR(S)	MANTEGNA ROSARIO NUNZIO Professore Ordinario Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	6
INDIVIDUAL STUDY (Hrs)	98
COURSE ACTIVITY (Hrs)	52
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	1
TERM (SEMESTER)	2° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**MANTEGNA ROSARIO NUNZIO** Tuesday 15:00 17:00 Studio del docente presso l'Edificio 18 di Viale delle Scienze previa comunicazione email all'indirizzo rosario.mantegna@unipa.it Professor's office located at Building 18 in Viale delle Scienze upon previous email agreement to rosario.mantegna@unipa.it

DOCENTE: Prof. ROSARIO NUNZIO MANTEGNA

PREREQUISITES	None.
LEARNING OUTCOMES	Knowledge and understanding: Consolidation of the background in thermodynamics and understanding of basic concepts of statistical physics. Acquisition of knowledge in the field of critical phenomena. Introduction to problems of non-equilibrium statistical mechanics. Presentation of examples of applications of statistical physics methodology to multifractal phenomena, complex networks and agent based models. Ability to apply knowledge and understanding: Ability to apply the knowledge acquired in different contexts and to perceive the interdisciplinary value of the theories and methodologies learned. Ability to use the knowledge acquired to understand some current topics of frontier research in statistical physics. Autonomy of judgment: Ability to evaluate the limits of approximations for the physical theories considered in describing model physical systems and / or many-body systems. Communication skills: Ability to present the key concepts of statistical physics. Learning skills: Ability to independently deepen current research topics that use statistical physics concepts and methodologies.
ASSESSMENT METHODS	The final examination consists of a written test followed by an oral test. The written test concerns the analytical or computational resolution of some problems and / or questions concerning the main topics of statistical physics. The oral exam consists of an interview concerning the enunciation and discussion of the topics developed during the course and the setting of the resolution of problems proposed to the candidate. In addition to the candidate's knowledge and ability to apply them, this test also assesses the possession of scientific language properties and clear and direct presentation skills. The assessment, suitably graded, will be formulated on the basis of the following conditions: a) Only basic knowledge of the studied models and applications of statistical physics and limited ability to apply them independently, sufficient ability to analyze the phenomena presented and to present the procedures followed (mark 18-21); b) Good knowledge of the studied models and applications of statistical physics and ability to apply them independently to situations similar to those studied, fair ability to analyze the phenomena presented and to show the procedures followed (marks 22-25); c) In-depth knowledge of the studied models and applications of statistical physics and ability to apply them to each physical phenomenon proposed, albeit with some hesitation, good ability to analyze the phenomena presented and to show the procedures followed (vote 26-28); d) In-depth and widespread knowledge of the studied models and applications of statistical physics and ability to apply them promptly and correctly to each physical phenomenon proposed, excellent ability to analyze the phenomena presented and excellent communication skills (grade 29-30L).
EDUCATIONAL OBJECTIVES	(i) Introducing the student to the statistical physics of many-body systems by highlighting the nature and characteristics of critical phenomena. (ii) Understanding the meaning of the concepts of phase of a system, emergency, critical state, scaling laws and universality. (iii) Introduction to the main concepts of physics of non-equilibrium systems. (iv) Presentation of applications of methodologies and concepts of statistical physics in many-body systems of physical and interdisciplinary nature.
TEACHING METHODS	The teaching activity consists of lectures and tutorials. The aim of the lectures is to provide the theoretical basis of the teaching contents. The presentation of the contents is interspersed with tutorials carried out in the classroom. Tutorials have both an analytical and numerical (i.e. computer assisted) character and are focused on systems and processes presented during lectures.
SUGGESTED BIBLIOGRAPHY	R.K. Pathria & P.D. Beale. Statistical mechanics (Third edition). 2011 Academic press. ISBN 978-0-12-382188-1 R. Livi and P. Politi. Nonequilibrium Statistical Physics. A modern perspective. 2017. Cambridge University Press ISBN 978-1-107-04954-3

SYLLABUS

Hrs	Frontal teaching
2	Introduction to the Course. Microcanonical ensemble. Boltzmann Entropy. Gibbs paradox.
2	Canonical ensemble. Energy fluctuations and thermodynamic limit. Shannon entropy. Partition function for systems with independent elements and for systems with interacting elements.
2	Grand canon ensemble. Fluctuation of the number of particles in the absence and in the presence of phase transitions
2	Phase transitions, general considerations. Van der Waals real gas model.
2	Ising model. Mean field solution.
2	Critical exponents in the mean field solution of the Ising model.

SYLLABUS

Hrs	Frontal teaching
2	Exact solution of the one-dimensional Ising model.
2	Correlation function. Correlation function in 1D Ising. 2D Ising model. Modeling of 2D Ising model of Kramers and Wannier.
2	Onsager solution of the Ising 2D model. Determination of the Energy per spin and the Specific Heat per Spin.
2	The critical exponents. Thermodynamic relationships and inequalities of the critical exponents (Rushbrooke and Griffiths).
2	Landau's phenomenological theory. Free energy with cubic term in the order parameter.
2	The scaling hypothesis in Landau's theory. Equality of critical exponents in Landau's theory. Kadanoff's scaling hypothesis. Decimation of a system. Critical exponents and dimensionality of the host space. Fluctuations of the order parameter and Ginzburg criterion. Higher critical dimension.
2	Brief introduction to stochastic processes. Examples of probability density function and distribution function of a stochastic process. Brownian motion. Markovian and non-Markovian stochastic processes.
2	Linear response theory.
2	Percolation. Percolation on 1D lattice. Average size value of a cluster to which a randomly selected site belongs. Correlation function. Lattice animals for D> 1. Definition of Cayley tree.
2	Percolation in a Bethe lattice. Site percolation on 2D square lattice. Finite size effect. Comments on the role of the finite size effect in the 2D Ising model.
2	Erdos-Renyi model. Exponential random graphs.
2	Markov chains. Master equation and detailed balance.
2	Markov chains and Monte Carlo method.
2	Agent models. Kirman model.

Hrs	Practice
12	Partition function. Ideal gas in the ultrarelativistic limit. Variant of the van der Waals system. Ising system with three spins. Renormalization of the 1D Ising model. Landau theory with cubic term. 1D percolation and Cayley tree percolation. Ergodic but out of equilibrium Markov chain. Energy and specific heat of a few spin Ising model. Monte Carlo simulation of a 1D and 2D ising model.