COURSE OF STUDY *Physics (LM-17)*
ACADEMIC YEAR *2023-2024*
ACADEMIC SUBJECT *Non Equilibrium Phenomena*

General information	
Year of the course	1st
Academic calendar (starting and ending date)	2nd semester: March - May 2024
Credits (CFU/ECTS):	3
SSD	FIS/02
Language	English
Mode of attendance	Recommended, not compulsory

Professor/ Lecturer	
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Department and address	Dipartimento di Fisica, via Amendola 173
Virtual room	Team Class "Critical and Non equilibrium Phenomena"
Office Hours (and modalities: e.g., by appointment, on line, etc.)	Monday and Tuesday, 11.00-13.00 by appointment

Work schedule			
Hours			
Total	Lectures	Hands-on (laboratory, workshops, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
75	16	15	44
CFU/ECTS			
3	2	1	

Learning Objectives	Knowledge and understanding of basic thermodynamic description for non-equilibrium systems and its derivation on the basis of microscopic methods. Basic elements of the theory of stochastic processes, applied to Brownian motion and non equilibrium statistical physics.
Course prerequisites	Theory of statistical ensembles, knowledge of the general phenomenology of systems with phase transitions, of mean field and Landau theory, as studied in the course of statistical mechanics. Calculus and knowledge of general physics at the level of the three-year physics course. Thermodynamics at the level of an undergraduate textbook.

Teaching strategie	Lectures and exercises on blackboard in classroom.
Expected learning outcomes in terms of	
Knowledge and understanding on:	Knowledge and understanding of basic thermodynamic description for non-equilibrium systems and its derivation on the basis of microscopic methods and theory of stochastic processes.
Applying knowledge and understanding on:	Understanding the foundations, the paradigmatic models, and the techniques of analysis that make possible a description of systems with many degrees of freedom, even in absence of thermodynamic equilibrium.

	Development of the ability to apply theoretical methods acquired in the course to study equilibrium and dynamical properties of classical systems with interacting particles.
Soft skills	**Making informed judgments and choices:** Development of the ability to critically interpret and evaluate the most recent and significant scientific literature in the field of statistical mechanics for physical systems both in equilibrium and in the absence of thermodynamic equilibrium. Ability to analyse different research strategies for dynamical problems for systems with many interacting degrees of freedom. **Communicating knowledge and understanding:** Development of the ability to work in groups of 2-3 units, to whom it is proposed to solve problems of statistical mechanics and stochastic processes. Communication skills are also developed through the presentation of seminars, proposed to students on a voluntary basis, on subjects complementary to those of the course. **Capacities to continue learning:** Follow the current progress and further prospects within the areas of advanced statistical mechanics. Skills in the consultation of bibliographic material, databases and material on the web.
Syllabus	
Content knowledge	**Summary:** Non-equilibrium processes: mathematical description and basic models. Elements of non-equilibrium Thermodynamics. Basic non-equilibrium statistical mechanics theory. **Detailed Content:** **Non-equilibrium processes: mathematical description and basic models.** Non-equilibrium processes: mathematical description and basic models. Chapman-Kolmogorov equation. Fokker-Planck equation. Markov chains. Spectral properties and ergodicity. Monte Carlo methods. Examples of Markov chains. Brownian motion. Diffusion equation and Einstein relation. Langevin equation. Kramers-Moyal expansion. Relation with Fokker-Planck equation. Kramers equation. Ito and Stratonovich stochastic integrals. Mean escape time from a potential well. **Elements of non-equilibrium Thermodynamics.** Continuous description of fluid systems. Conserved variables and balance equations. Continuity and Euler equations. The Navier-Stokes equations. Balance equation for energy and general heat equation. Local formulation of the second principle of thermodynamics and of entropy production. Response and dissipation functions. Phenomenological relationships. Onsager theorem. The Curie principle. The complex response function. Dispersion relations. Sum rules.

	Non-equilibrium statistical mechanics.
	Origin of noise and memory terms in the Langevin equation. Generalized Brownian motion. Gaussian approximation. Critical slowdown and van Hove's theory.
	Time reversal. Dynamic correlation function. Response function and linear susceptibility. (Kubo relations). Fluctuations-dissipation theorem. Onsager regression principle. Reciprocity relations.
Texts and readings	L. Peliti, "Statistical Mechanics", Princeton University Press.
	R.K. Pathria, "Statistical Mechanics", Butterworth&Heinemann.
	K. Huang, "Statistical Mechanics", Zanichelli.
	S. Ma, "Modern Theory of Critical Phenomena", Westview Press.
	De Groot, P. Mazur "Non-equilibrium thermodynamics", Dover.
	P.M. Chaikin, T.C. Lubenski, "Principles of Condensed Matter", Cambridge University Press.
	R. Kubo, M. Toda, N. Hashitsume, "Non Equilibrium Statistical Mechanics", Springer.
	R. Zwanzig, "Nonequilibrium Statistical Mechanics".
Notes, additional materials	Notes avalaible for the whole program
Repository	Notes available on Team Class "Critical and Non equilibrium Phenomena"

Assessment	
Assessment methods	
Assessment criteria	**● Knowledge and understanding** o Capability to discuss models, concepts and mathematical principles introduced in the course. **● Applying knowledge and understanding** o Adequate comprehension, global and detailed knowledge of arguments and mathematical developments described throughout the course. **● Autonomy of judgment** o Ability to critically interpret the relevance of specific results in the context of theoretical and statistical physics. **● Communication skills** o Capacity to clearly discuss topics discussed in the course and their relevance in a more general context.
Final exam and grading criteria	Oral exam based on the previous listed criteria (60%) and written description of specific models and topics (40%)
Further information	
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