Course unit English denomination	Modern topics in statistical physics
SS	PHYS-04/A
Teacher in charge	Gianmaria Falasco
Teaching Hours	24
Number of ECTS credits allocated	3
Course period	March - June 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (50% minimum of presence) ☐ No
Course unit contents	The course aims to provide an overview of recent developments in the statistical mechanics and thermodynamics of dissipative systems (mainly classical), i.e., open systems weakly coupled to multiple reservoirs (thermal, chemical, etc.). An introduction to the following topics will be provided, with varying emphasis depending on the participants' background: - Review of the mathematical background useful for the description of open systems: Langevin, Fokker-Planck, and Master equations; path integrals and functional methods. - Stochastic thermodynamics: definition of heat, work, entropy along stochastic trajectories; first and second law; time-reversal symmetry breaking and entropy production; fluctuation theorems. - Linear and non-linear response theory; Zubarev-MacLennan formalism for weakly driven systems; (differential) negative response. - A brief overview of the constraints on dissipative processes: information and Landauer's limit; energy transduction. - Large deviations and rare events: equations for generating functions; Donsker-Varadhan and Gartner-Ellis theorems; dynamical phase transitions. - Thermodynamic limit and metastability in dissipative systems: spectral theory of the Markov generator; Freidlin-Wentzell quasi-potential; out-of-equilibrium generalization of the Kramers-Arrhenius law.
Learning goals	The course is aimed at acquiring basic knowledge of the dynamics and

	thermodynamics of systems that are driven and maintained far from thermodynamic equilibrium. Through frequent analogies and comparisons with equilibrium statistical mechanics and thermostatics, the course will provide the foundation for understanding dissipative phenomena such as population inversion, energy transduction, and non-equilibrium phase transitions. Theoretical tools will also be provided to independently analyze multi-scale stochastic models.
Teaching methods	Oral lectures including applications in the form of worked examples of the general theory.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☐ Yes ☒ No
Prerequisites (not mandatory)	Introductory courses of Statistical Mechanics
Examination methods (if applicable)	Oral
Suggested readings	Instructor's notes, whose link will be shared with the participants. Books: Stochastic Thermodynamics, Peliti Luca, and Simone Pigolotti, Princeton University Press (2021); Kamenev Alex, An Introduction Field theory of non-equilibrium systems, Cambridge University Press (2023).
Additional information	Examples of specific systems analyzed in the lectures are molecular motors, biochemical reaction networks, electronic circuits (such as memories and clocks).