COURSE OF STUDY *Physics (LM-17)*

ACADEMIC YEAR *2024-2025*

ACADEMIC SUBJECT *Computational Physics*

General information	
Year of the course	1st
Academic calendar (starting and ending date)	1st semester: September - December 2024
Credits (CFU/ECTS):	6
SSD	FIS/01
Language	English
Mode of attendance	Compulsory

Professor/ Lecturer	
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Department and address	Dipartimento Interateneo di Fisica, Via Amendola 173, 70126 Bari (BA)
Virtual room	j34o0tm
Office Hours (and modalities: e.g., by appointment, on line, etc.)	Thursday 11 am

Work schedule			
Hours			
Total	Lectures	Hands-on (laboratory, workshops, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
150	32	30	88
CFU/ECTS			
6	4	2	

Learning Objectives	To acquire abilities in the numerical solutions of differential equations; complex networks analysis; Monte Carlo methods and their applications to Statistical Mechanics models.
Course prerequisites	Background knowledge on classical mechanics and statistical physics

Teaching strategies	Lectures in the multimedia room. Development of matlab routines beamed on the room screen.
Expected learning outcomes in terms of	
Knowledge and understanding on:	o Understanding the scientific method, the nature, and the methods of research in Physics o Knowledge of advanced computational techniques o Knowledge of the main data analysis techniques and their application to solve concrete physics problems.
Applying knowledge and understanding on:	o Ability to use analogy to apply known solutions to new problems (problem solving) o Ability to design and implement experimental or theoretical procedures to solve problems in academic and industrial research or to improve existing results

	o Ability to use analytical and numerical mathematical computation tools o Ability to use electronic and computer technologies and their application to experimental data acquisition o Capability to apply the main methods to extract information from complex physics datasets. The students will be able to gather, summarise and visualise the statistically relevant features of a dataset; furthermore, they will learn how to qualitatively and critically compare theoretical predictions with the experimental data. o Capability to numerically solve differential equations arising in physics and complex systems science.
Soft skills	● **Making informed judgments and choices** o Ability to work with increasing levels of autonomy, including taking responsibility in project planning and managing facilities o Knowledge and skills acquired in this course will allow a greater level of autonomy in the evaluation of methodologies to simulate physical systems and to analyze data from Complex Systems. ● **Communicating knowledge and understanding** o Acquire competence in communication in Italian and English in advanced fields of Physics o Enable transition from theoretical physical models towards the numerical implementation and analysis of the corresponding simulations ● **Capacities to continue learning** o Acquire of basic knowledge tools for continuous learning and knowledge updates o Follow the current progress and further prospects within the area of simulation and analysis of complex systems. o Discuss models and methods introduced in the course and assess the reliability of the description by numerical simulations.
Syllabus	
Content knowledge	An introduction to MATLAB Numerical solution of differential equations. Euler's method. Euler-Cauchy method. Verlet method. Applications: Lotka-Volterra model of prey-predator systems, SIR model for the spreading of infections, real pendulum, Foucalt's Pendulum, motion of a planet in the gravitational field of the Sun. Introduction to Complex Networks. Implementation of complex networks models: Erdos networks, Watts-Strogatz model, Barabasi-Albert model. Finding communities in complex networks, Spectral methods and optimization of modularity. Spreading models of informations, ideas and viruses on complex networks. Random walks in two and more dimensions. Self-avoiding walks. Diffusion limited aggregation. Random sampling and Monte Carlo method. Monte Carlo Integration: rejection method, importance sampling, filtering techniques. Monte Carlo methods for the simulation of physics phenomena. Markov chain method. Metropolis algorithm. Statistical mechanics ensembles. The case of the two-dimensional Ising model of ferromagnets: phase transition and critical exponents.

	Techniques to assess and extract the statistical features of a physics datasets and comparison with model predictions. Visualisation and graphical representation of datasets and their properties.
Texts and readings	Rubin Landau, Manuel Paez, Cristian Bordeianu, Computational Physics. --: Wiley-VCH
Notes, additional materials	
Repository	

Assessment	
Assessment methods	Oral exam consisting in a discussion about the reports on the programming activities developed during the course. (100%)
Assessment criteria	Capability to translate the physical problem in a computer program aiming at highlighting the physical behaviour of the system; capability to analyse data from complex systems. Adequate comprehension and global knowledge of concepts and arguments at the basis of the computational methods described throughout the course.
Final exam and grading criteria	Oral exam consisting in a discussion about the reports on the programming activities developed during the course. (100%)
Further information	
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