COURSE OF STUDY *Physics (LM-17)*

ACADEMIC YEAR *2024-2025*

ACADEMIC SUBJECT *Modeling of Complex Systems*

General information	
Year of the course	1st
Academic calendar (starting and ending date)	2nd semester: March – May 2025
Credits (CFU/ECTS):	6
SSD	FIS/07
Language	English
Mode of attendance	Recommended, not compulsory

Professor/ Lecturer	
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Department and address	Farmacia – Scienze del Farmaco, quarto piano, stanza 523 bis
Virtual room	Teams: qh43wj4
Office Hours	By appointment: Mon 15-17, Wen 15-17

Work schedule			
Hours			
Total	Lectures	Hands-on (laboratory, workshops, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
150	40	15	95
CFU/ECTS			
6	5	1	

Learning Objectives	Knowledge of fundamental graph theory models and application to real complex systems.
Course prerequisites	None

Teaching strategies	The course has the dual objective of providing the basic elements that characterize complex systems and the analysis methods useful for examining real cases. For this reason, the course will be characterized by both frontal lessons aimed at transmitting knowledge and laboratory exercises on the PC to put this knowledge into practice.
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 mathematical tools commonly used in basic and applied research fields o Knowledge of advanced computer tools commonly used in basic and applied research o Knowledge of complex systems o Basic concepts of complex networks and graph theory
Applying knowledge and understanding on:	o Ability to identify the essential elements of a phenomenon 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 Modeling real systems with complex networks and using network-based measurements for statistical learning
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 Ability to understand the underlying dynamics of complex systems. *Communicating knowledge and understanding* o Competence in communication in Italian and English in advanced fields of Physics o Computer skills related to (big) data analytics o Scientific programming (Python) o Data/results visualization with appropriate scientific language o Ability to work in a group *Capacities to continue learning* o Acquisition of basic knowledge tools for continuous learning and knowledge updates o Problem solving skills o Modeling **real-**world systems o Knowledge of a big-data analytics tool o Basic introduction to programming in Python
Syllabus	
Content knowledge	*Graph theory: from basic definitions to networks' algebra. The Laplacian matrix, eigenvalues and eigenvectors. Network Models. Random graphs: the Erods-Renyi model. Random matrix theory. Small-world networks. Scale-free networks. Structural and topological property of a network. From global to nodal properties: node centrality. Community detection. Weighted networks: an outline.* *Laboratory: Programming applications with Python to real-world networks. Case study (to be discussed with the student)*
Texts and readings	*Network Science, Barabasi. A first course in Network Theory, Estrada-Knight.*
Notes, additional materials	*Teacher's notes and slides*
Repository	*Teams: qh43wj4*

Assessment	
Assessment methods	Laboratory Reports (20%), Oral exam (80%), speed award (+ 3/30) The final exam will consist of an oral presentation on a case study agreed with the teacher. The case study will allow the student to show the knowledge acquired in theoretical and applied terms; in fact, the presentation must consist of both a theory part that describes the methodologies adopted and an application part where the results of the analyses conducted will be shown. The presentation must have a minimum duration of 20 minutes.
Assessment criteria	the student - knows the basic principles of graph theory; - knows and knows how to use the complex network models in different situations; - knows and knows how to measure the topological properties of a network; - knows and know how to measure the centrality measures of a node; - knows how to write a technical report;

	- knows how to present the results of an experiment in written and oral forms.
Final exam and grading criteria	*The final grade is awarded out of thirty. The exam is considered passed when the grade is greater than or equal to 18.* *The exam consists of the oral presentation of a case study agreed with the teacher, half of the judgment will therefore focus on the knowledge acquired and half on its correct application.*
Further information	
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