Master's Degree Programme in Physics · Curriculum Experimental nano and bio-physics

Physics of Biological Systems

OVERVIEW OF THE STUDY PLAN

This study plan is designed to train students in the investigation of how biologically relevant systems - from proteins, to DNA, to entire cells - work and interact, using both the concepts of physics and advanced techniques favoring the quantitative approach. Students attending this study plan will be able to adopt analytical physical models to describe biological processes which can be directly compared to experimental evidence. Students will also gain confidence with advanced techniques, particularly nanotechnological ones, which are exploited to investigate biological systems from the single molecule up to the cellular scale.

Students will acquire a multidisciplinary background which allow to continue their academic training attending a PhD program in Physics, Nanotechnology or Biotechnology, such as the Graduate School in Physics and Nanoscience program organized at UNIMORE. Students willing to pursue an applied physics career may also find courses in medical physics and signal and image processing. The study plan will allow students a smooth entry in many production sectors of a modern economy in an international context.

This study plan is connected to ongoing research activities carried out in collaboration with several research centers in Italy and worldwide, including Univ. of Bologna (Italy), the School of Medicine, Washington University, St Louis (USA), and the Institute for Nanoscience CNR-NANO located in Modena (www.nano.cnr.it) which also collaborates to the courses. The thesis project will be carried out within one of the groups that are active in the biophysical research of the department and/or in collaborating research groups, possibly within the Erasmus program.

FIRST YEAR

Laboratory of condensed matter physics

A lab course to become familiar with a few of the most used experimental techniques in material research (electron microscopies, X-ray diffraction and electronic spectroscopies) and challenge your experimental skills by designing and performing experiments from scratch.

Laboratory of Nanofabrication

A hands-on course introducing to the main nanofabrication techniques employed in nanoscience research and in the semiconductor industry. The presentation of top-down and bottom-up approaches will be followed by a laboratory activity with optical, electron-beam and ion-beam lithographies, and with nanocluster deposition.

Physics of Semiconductors

A course dealing with functional concepts of modern optical and electronic devices, from carrier and defect engineering, transport and carrier recombination dynamics, nanostructured semiconductors, up to their applications to transistors, laser, LEDs and solar cells.

Quantum Physics of matter

An advanced course on matter-light and matter-electron interactions, using quantum linear response theory to discuss elementary excitations of material systems and their spectral features: electronic and phonon excitations, excitons, plasmons, polaritons.

Statistical Mechanics and Phase Transitions

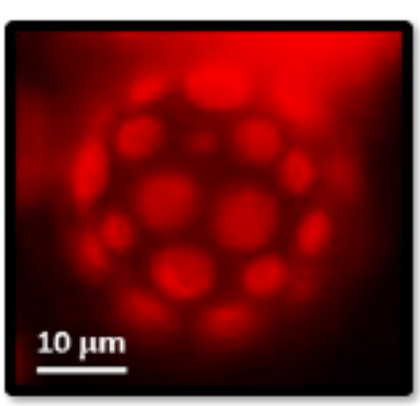
An advanced course in classical and quantum statistical mechanics, from the theoretical foundations to phase transitions and critical phenomena, including quantum condensates (Bose-Einstein condestates, superfluids, superconductors). Attendees will be introduced to modern theoretical methods, from mean-field methods to statistical field theory and renormalization group theory.

Monte Carlo Methods in Physics

A random walk in the fields of Statistical and Quantum Mechanics introducing the Monte Carlo numerical approach, Markov processes, and Brownian motion, with "in silico" modeling of phase transitions and calculation of quantum properties of simple microscopic models.

Chemical Physics of Biomolecules

A unique and multidisciplinary course for students interested in acquiring advanced theoretical understanding of chemical physics, with an emphasis on biomolecules and their application to nano-bio-physics and nano-medicine.



Epi-fluorescence microscopy image of a Giant Unilamellar Vesicle (GUV) presenting a phase separation with Liquid Disordered domains (the red ones) and Liquid Ordered domains (the darker ones)

Biological Physics with laboratory

An introduction to the quantitative analysis of biological processes with the methods of physics and mathematics together with hands-on experiences using the most advanced biophysical techniques. The students will learn how to predict the behavior of some biological phenomena and how to analyze in a quantitative way experimental data.

Numerical algorithms for signal and image processing

This course introduces the basic properties of Fourier transform as a tool for signal analysis, from continuous to discrete settings. Applications to signal and image filtering and compression will be presented also with some laboratory activity in the Matlab environment.

SECOND YEAR

Nanomechanics

This advanced course of interdisciplinary character, involving knowledge from physics, chemistry, and engineering, will focus on material interfaces and their (nano)mechanical applications. The course will combine experimental and theoretical-computational approaches to provide insights into fundamental interactions and processes occurring at nano-scale contacts. Nano-scale interactions rule, in fact, the material behavior under the effects of mechanical forces up to the macro-scale. Experiments of adhesion and friction will be carried out both in laboratory and in silico.

Laboratory of Computational Quantum Mechanics

A course with hands-on tutorial sessions dealing with electronic structure computational techniques as applied to condensed matter systems, with special emphasis on Density Functional Theory, the state-of-the-art parameter-free, atomistic and predictive description of materials.

SUGGESTED FREE CHOICE COURSES

Medical Physics

The course is intended to provide the attendees with a basic knowledge of some of the principal diagnostic techniques making use of ionizing and non-ionizing radiation in humans from a physical (technical) point of view. Computational topology A course to familiarize with tools, algorithms, and computational issues in topology for Data Science ensuing from the observation that “data has shape and shape matters”, with an eye to problems arising in shape analysis, topological inference, and manifold learning.

PROFESSIONALIZING COURSES

Good Practices in Research

A practical introduction to soft skills needed in industrial and academic research. How to present your results at a conference, or in a paper, and get it published. How to keep your data, when you need to worry about intellectual property. How to build a path that suites your aspirations, write your CV and apply for a high-tech job. All this is also put into context: the structure of research organization and funding in Italy and Europe, with its risks, challenges, and opportunities.

Research Integrity in Sciences

A course starting from the study of recent cases of scientific misconduct, such as falsification, fabrication, plagiarism, to discuss actual aspects and concepts of research integrity, which is increasingly considered an essential aspect of research.

NOTES

Among free choice courses, the student may include specific courses from the Biology or Engineering programs at the University of Modena and Reggio Emilia. Ask the study plan coordinator for further indications.

Where: Modena, Scientific Campus
Duration: 2 years
ECTS credits: 120

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