UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

Dipartimento di Scienze Fisiche, Informatiche e Matematiche

Master's Degree Programme in Physics · Curriculum Applied physics

Numerical methods and algorithms for applied physics

OVERVIEW OF THE STUDY PLAN

The ability to understand and simulate physical phenomena is at the heart of all current technologies and design of new (nano)materials which find application in a growing number of industrial applications. This study plan aims at training professionals with a broad spectrum of competences in scientific and technological fields where physical sciences are pivotal, and to develop skills which allow graduates to easily set their position in a company environment or to enroll in a PhD programme in applied physics sectors.

In particular, the suggested courses below aim at providing basic competences in several applied physics fields, as well as complementary advanced and up-to-date computer science and computational techniques to simulate the underlying pheomena and perform complex data analysis. Students familiarize with advanced techniques in high-performance computing and their applications in science and technology. Upon discussion with the coordinator, the study plan may be tailored to meet the student's main interests, also including courses from other degree programs at UNIMORE. Within this study plan, we encourage Master thesis projects to be in conjunction with research centers of external institutions, including companies running scientific collaborations with the department. Recent examples includes a number of large and medium size companies in the automotive and energy sectors, the CNR-Nano Research Institutue and the medical physics units at the Modena and Reggio E. Hospitals, simulation of climate change at CMCC (Bologna) and high-performance computing at CINECA (Bologna).

FIRST YEAR

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.

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.

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.

Fundamental of Nanosciences

Nanosystems are both quantum worlds with astonishingly new properties and the basis of new nanodevices. The course provides a conceptual and practical framework dealing with the physics and description of a set of prototype nanosystems, from nanotubes and graphene structures to nanocrystals, quantum wells, wires and dots.

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.

Quantum Information Processing

This course will give a graduate-level introduction to the theory behind quantum computers and quantum information processing (QIP) in general. The topics will range from basic QIP primitives e.g., teleportation, to quantum error correction passing through fundamental quantum computing algorithms e.g, Shor's factoring.

Physics Education: Theoretical and Experimental Methods

This course is about Physics Education methods and techniques, dedicated to those who are interested in teaching introductory physics at all levels, especially secondary schools and courses up to undergraduate level. The main topics include a theoretical/pedagogical background, examples of

An HPC system at CINECA capable of 20 PFlop/s (photo F Pierantoni). To simulate complex phenomena requires algorithms exploiting the sophisticated internal architecture of such top performing computers.

active learning, hands-on activities, how to capture and keep students' attention and the role of new technologies in the lab.

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.

Machine Learning and Deep Learning

A course covering most techniques for pattern and data analysis, offering a deep knowledge of the most important classification algorithms and models for automatically interpreting heterogeneous data. Learning techniques and methods will be covered in conjunction with basic supervised and unsupervised learning theory and methods. Eventually, deep learning techniques will be presented and students will be able to design, train and test a deep classification model for numerical data, temporal series and visual data.

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

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.

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.

PROFESSIONALIZING COURSES

HPC for sciences

Students willing to deepen their HPC skills, mastering some of the more advanced HPC techniques, may attend a few-days intensive course at CINECA (BO), a Tier-0 center of the EU HPC network and get the course in their study plan.
Updated list of courses at: eventi.cineca.it/en/hpc.

NOTES

Within the professionalizing activities, HPC courses can recognized up to 6 ECTS. Typical full-immersion courses last 2-3 days and will be recognized 3ECTS each. Alternatively, students in this study plan may enroll in Science-based innovation, which recognizes a set of team activities organized by UNIMORE conducted in collaboration with several companies or other large organizations (ONGs, hospitals, ect) to train students in innovation and entrepreneurship. The course is recognized if the candidate is admitted to one such activities (SUGAR, CBI) under appropriate calls which are issued yearly in May, while activities are conducted in the forthcoming academic year. Infos are available from the M.Sc. Coordinator.

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

Coordinator
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