UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

Dipartimento di Scienze Fisiche, Informatiche e Matematiche

Master's Degree Programme in Physics

Applied Physics

Curriculum
Theoretical and Computational Physics / Experimental Physics

Department of Physics, Informatics and Mathematics
Modena Campus

2 years
Full time
ECTS credits: 120

Description of the study plan

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. The offered courses cover computational and laboratory skills, as well as competences in a spectrum of applied physics fields.
According to the emphasis that the student is willing to give to her/his training, this study plan can be set both within the Theoretical and Computational Physics Curriculum or within the Experimental Physics Curriculum. In the former case students familiarise with advanced techniques in high-performance computing and their applications in science and technology, while in the latter students acquire state-of-the-art laboratory knowledge in several fields of physics-driven technologies. Upon discussion with the coordinator, the study plan may be specifically tailored to meet the student's main interests, also including courses from other degree programmes at UNIMORE.
Within this study plan, we encourage Master thesis project to be in conjunction with research centers of external institutions, including companies running scientific collaborations with the department. Recent examples includes Total SA and Toyota R&D Lab in the automotive and enegy sectors, medical physics units at the Modena and Reggio hospitals, simulation of climate change at CNR (Bologna) and high-performance computing at CINECA (Bologna).

Theoretical and Computational Physics Curriculum

Advanced Quantum Mechanics

Year: I Term: I Hours: 48 CFUs: 6 SSD: FIS/02

A self-contained course reviewing--under various, mathematically rigorous, points of view--the fundamentals of the theory, studying problems at the basis of modern physics, such as the quantization of the electromagnetic field and its interaction with matter, and the relativistic wave equations and their interpretative issues.

Monte Carlo Methods in Physics

Year: I Term: II Hours: 48 CFUs: 6 SSD: FIS/02

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 Physics of matter

Year: I Term: I Hours: 48 CFUs: 6 SSD: FIS/03

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.

Transport phenomena in Semicond. and Nanostructures

Year: I Term: II Hours: 48 CFUs: 6 SSD: FIS/03

A complete and modern course on electronic transport in condensed matter systems, from the semi-classical statistical approaches to fully quantum state-of-the-art descriptions, with application to the experimental signatures exposing fascinating phenomena taking place in quantum semiconductor nano-devices down to single-molecule transistors.

Statistical Mechanics and Phase Transitions

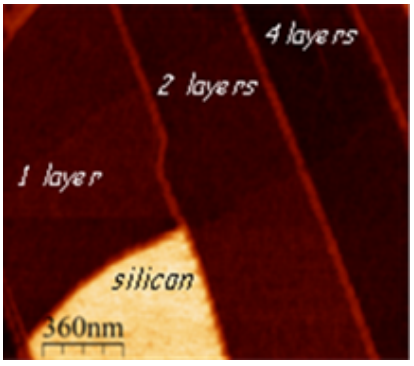
Year: I Term: II Hours: 48 CFUs: 6 SSD: FIS/03

An advanced course in classical and quantum statistical mechanics, dealing with modern theories and methods of phase transitions and critical phenomena, from mean-field to renormalization group theory, and the description of quantum condensates (BEC, superfluidity, superconductivity).

Synchrotron Radiation: basics and applications

Year: I Term: I Hours: 48 CFUs: 6 SSD: FIS/01

A course devoted to the working principles of synchrotrons and the use of emitted radiation, from description of single ultra-relativistic particles sources to essentials of instrumentation, storage rings, bending magnets, wigglers and undula-



Friction force map of a region that comprises monolayer, bi-layer and four-layer graphene, and SiO2 substrate. Color scale indicates friction force in the sequence SiO2>1L>2L>4L.

tors, free electron lasers, beam lines, with examples of ensuing popular techniques, X-ray diffraction, scattering and absorption, X-ray microscopy.

Computational topology

Year: I Term: II Hours: 36 CFUs: 6 SSD: MAT/03

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.

Medical Physics

Year: I Term: II Hours: 36 CFUs: 6 SSD: FIS/07

The course is intended to give to the participants a basic knowledge of the principal diagnostic techniques that makes use of ionizing and non-ionizing radiation in humans from a physical (technical) point of view.

Chemical Physics of Biomolecules

Year: I Term: I Hours: 36 CFUs: 6 SSD: FIS/07

A unique and multidisciplinary course devoted to 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.

Relativity

Year: II Term: I Hours: 48 CFUs: 6 SSD: FIS/02

In this course students learn the elegant mathematical framework of Special Relativity and General Relativity (GR), applying it to fascinating physical problems, including GR effects on planetary motion, light bending, black hole physics, and cosmology.

Laboratory of Computational Quantum Mechanics

Year: II Term: I Hours: 60 CFUs: 6 SSD: FIS/04

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, a parameter-free, atomistic and predictive description of materials.

Professionalizing Courses

HPC in sciences

Year: II Term: - Hours: 18 CFUs: 3

A course intended for students willing to deepen their HPC skills, mastering some of the more advanced HPC techniques, attending a few-days intensive course at CINECA (BO).

Research Integrity in Sciences

Year: II Term: I Hours: 18 CFUs: 3

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.

Suggested free choice courses

Numerical algorithm for Signal and Image Numerical Processing

Year: - Term: I Hours: 36 CFUs: 6 SSD: MAT/08

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. (in Italian)

Mathematical methods of machine learning

Year: - Term: I Hours: 42 CFUs: 6 SSD: MAT/08

An introduction to mathematical methodologies for Machine Learning, including numerical methods for deterministic and stochastic optimization and their application to large-scale machine learning problems. (in italian)

Experimental Physics Curriculum

Laboratory of condensed matter physics

Year: I Term: I-II Hours: 48 CFUs: 6 SSD: FIS/01

A hands-on course to familiarize with the most used techniques in material research (electron microscopies, X-ray diffraction, electronic spectroscopies), designing and performing own experiments from scratch.

Magnetism and Spintronics

Year: I Term: II Hours: 48 CFUs: 6 SSD: FIS/01

A course devoted to quantum and statistical description of magnetic phenomena, from atomic level to collective effects, experimental techniques for magnetic characterization, and advanced applications in spintronics, magnetic recording, molecular magnetism, quantum technologies.

Characterization of Nanostructures

Year: I Term: II Hours: 48 CFUs: 6 SSD: FIS/01

An advanced course on characterization of 0D (dots, clusters), 1D (stripes, wires, tubes), and 2D (surfaces, films, buried layers) quantum systems and related devices, covering dimensionally-related physical properties and technological applications, modern experimental methodologies and instruments, and current approaches to nano-fabrication, with short stages at the characterization and/or fabrication facilities.

Quantum Physics of matter

Year: I Term: I Hours: 48 CFUs: 6 SSD: FIS/03

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

Year: I Term: II Hours: 48 CFUs: 6 SSD: FIS/03

An advanced course in classical and quantum statistical mechanics, dealing with modern theories and methods of phase transitions and critical phenomena, from mean-field to renormalization group theory, and the description of quantum condensates (BEC, superfluidity, superconductivity).

Monte Carlo Methods in Physics

Year: I Term: II Hours: 48 CFUs: 6 SSD: FIS/01

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.

Advanced Photonic

Year: I Term: I Hours: 48 CFUs: 6 ING-INF/02

The course aims at providing knowledge and design skills-set of the most popular optical and photonic components such as couplers, gratings, interferometers, optical amplifiers, and specialty fibers.

Medical Physics

Year: I Term: II Hours: 36 CFUs: 6 SSD: FIS/07

The course is intended to give to the participants a basic knowledge of the principal diagnostic techniques that makes use of ionizing and non-ionizing radiation in humans from a physical (technical) point of view.

Fundamental of Nanosciences

Year: I Term: I Hours: 48 CFUs: 6 SSD: FIS/03

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.

Nano-mechanics

Year: II Term: I Hours: 48 CFUs: 6 SSD: FIS/01

An advanced course to provide insight into elastic, thermal and kinetic properties of nano systems and their role in nano-technology, treating nano-materials, nano-tribology (friction, wear, contact mechanics), nano-electromechanical systems (NEMS), and nano fluidics. Students will master state-of-the-art approaches to design, perform and interpret miniaturized mechanical experiments directly inside electron microscopes like SEM or TEM, or STM/AFM microscopes.

Laboratory of Computational Quantum Mechanics

Year: II Term: I Hours: 60 CFUs: 6 SSD: FIS/04

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, a parameter-free, atomistic and predictive description of materials.

Professionalizing Courses

Science-Based Innovation

Year: II Term: - Hours: 36 CFUs: 6

This course trains students for innovation and entrepreneurship, in a path based on concrete experiences close to the entrepreneurial realities, enrolling in one of the Design Thinking programs run by UNIMORE.

Suggested free choice courses

Synchrotron Radiation: basics and applications

Year: - Term: I Hours: 48 CFUs: 6 SSD: FIS/01

A course devoted to the working principles of synchrotrons and the use of emitted radiation, from description of single ultra-relativistic particles sources to essentials of instrumentation, storage rings, bending magnets, wigglers and undulators, free electron lasers, beam lines, with examples of ensuing popular techniques, X-ray diffraction, scattering and absorption, X-ray microscopy. A visit to to ELETTRA labs in Trieste ends the course.

Physics of Semiconductors

Year: - Term: I Hours: 48 CFUs: 6 SSD: FIS/01

The course deals 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, and solar cells.

Coordinators

Prof. Mauro Ferrario
mauro.ferrario@unimore.it
Prof. Guido Goldoni
guido.goldoni@unimore.it

www.fim.unimore.it/site/en/home/teaching/physics-courses/msc-degree.html

For B.Sc. students

Students enrolled in the B.Sc. (Laurea Triennale) in Modena, who intend to follow this study plan, are suggested to attend some of the following optional courses during their B.Sc studies: Argomenti avanzati di Fisica Moderna, Elettronica e acquisizione dati and Laboratorio di fisica computazionale (if set within the Theoretical and Computational Physics curriculum) or Elettronica e acquisizione dati, Fisica Nucleare e Rivelatori and Spettroscopia (if set within the Experimental Physics curriculum);

Notes

The course Science-based innovation 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 (ICARO, SUGAR, CBI, …) under appropriate calls which are yearly issued in May for activities to be conducted in the forthcoming academic year. Students have still the option to follow a non-restricted professionalizing course if not admitted. Infos are available from the M.Sc. Coordinator.

HPC for sciences is the choice for a curriculum with a strongly computational character, or for students interested to computational physics applied to technology and recognizes highly specialized HPC courses held at CINECA in Bologna.

Among free choice courses, students may want to attend courses from other applied disciplines, like Advanced Algorithms.