Methods and technologies of applied physics

OVERVIEW OF THE STUDY PLAN

Mastering modern technologies often requires a deep understanding of underlying physical mechanisms, and the ability to gather many different competences and professionals to develop advanced applications. This study plan aims at training physics 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.

This study plan is geared towards acquiring a variety of advanced laboratory techniques and their applications 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, possibly 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 include a number of large and medium size companies in the automotive and energy sectors, the CNR-Nano Research Institute, and the medical physics units at the Modena and Reggio E. Hospitals.

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.

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.

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.

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.

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.

Advanced Photonics

A course aiming 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.

SECOND YEAR

Synchrotron Radiation: basics and applications

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. Examples of ensuing popular Techniques: X-ray diffraction, scattering, Absorption and X-ray microscopy. A visit to to ELETTRA labs in Trieste ends the course.

**Elementary particles**

A course introducing the elementary constituents of matter and their interactions, as well as the role of symmetries and their violation, up to the most recent discoveries in the field (neutrino masses, Higgs boson, multi-quark states).

**SUGGESTED FREE CHOICE COURSES**

**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”.

**Magnetism and spintronic**

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.

**PROFESSIONALIZING COURSES**

**Science-based innovation**

A team activity to train 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.

**NOTES**

Within the professionalizing activities, Science-based innovation is a restricted entrance activity organized by UNIMORE in collaboration with selected companies or large organizations. Appropriate calls are issued yearly in May. Activities (which include short staying at research centers abroad) are conducted in the forthcoming academic year. If not admitted, students have still the option to follow other non-restricted professionalizing activities organized by the M.Sc. Infos are available from the M.Sc. Coordinator.