ACADEMIC YEAR 2022-2023

First semester: October 3rd, 2022, to January 21th, 2023
Winter exams session: January 23rd, 2023, to February 25th, 2023
Second semester: February 27th, 2023, to June 17th, 2023
Summer exams session: June 19th, 2023, to July 22nd, 2023
Extra exams session: August 21st, 2023, to September 23rd, 2023

DOUBLE AND JOINT DEGREE PROGRAMMES

The University of Padua promotes joint or double degree programmes and guarantees ad hoc scholarships for participating students. Such international degree programmes are organised in cooperation with one or more partner institutions. A mobility period at the partner university is envisaged before or after attending a degree programme at the University of Padua. Upon completion of the international programme, students will obtain a double degree (two or more national degrees issued by the partner universities) or a joint degree (jointly issued by two or more of the partner universities), in compliance with the different national rules and the agreements signed by the partner institutions.

- Second-cycle degree in Chemistry – curriculum Chemical Sciences
  See information on https://www.chimica.unipd.it/corsi/corsi-di-laurea-magistrale/laurea-magistrale-chimica/double-degree
- Second-cycle degree in Material Science – curriculum Material Sciences
  See information on https://www.chimica.unipd.it/corsi/corsi-di-laurea-magistrale/laurea-magistrale-scienza-dei-materiali/double-degree
- Second-cycle degree in Mathematics – curriculum MAPPA (Mathematical Analysis and Probability)
  See information on http://mappa.math.unipd.it/
- Second-cycle degree in Molecular Biology – curriculum Génétique Moléculaire
  See information on https://biologia-molecolare.biologia.unipd.it/en/masters-degrees/double-degree/

MULTILATERAL JOINT STUDY PROGRAMMES - CONSORTIUM

- Second-cycle degree in Mathematics – curriculum ALGANT (International Integrated Master course in Algebra, Geometry and Number Theory)
  See information on http://lauree.math.unipd.it/algant/ and https://www.algant.eu/

The ALGANT consortium consists of eight universities on four continents and offers a two-year world-class integrated master's course in pure mathematics, with strong emphasis on Algebra, Geometry and Number Theory. The consortium is coordinated by Universiteit Leiden (The Netherlands). The other partners are: Université Bordeaux 1 (France), Université Paris-Sud - Paris 11 (France), Università di Milano (Italy), Concordia University (Canada), Chennai Mathematical Institute (India), Stellenbosch University (South Africa).

ERASMUS MUNDUS MASTER COURSES

The Erasmus Mundus Joint Master Degrees are prestigious Master's degree programmes jointly delivered by at least three Universities of three different European countries. The study period is to be carried out in at least two countries, and a double or joint degree is issued by the involved institutions upon programme completion. EU-funded grants are provided.
Catalogue of English Language Courses Index - A.Y. 2022/2023

- ASTROPHYSICS AND COSMOLOGY ORD. 2019
- CHEMISTRY ORD. 2018
- COMPUTER SCIENCE ORD. 2021
- CYBERSECURITY (ORD. 2020)
- DATA SCIENCE ORD. 2017
- ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021
- ENVIRONMENTAL SUSTAINABILITY AND EDUCATION ORD. 2022
- EVOLUTIONARY BIOLOGY ORD. 2018
- GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)
- INDUSTRIAL BIOTECHNOLOGY ORD. 2014
- INDUSTRIAL CHEMISTRY ORD. 2015
- MARINE BIOLOGY ORD. 2021
- MATERIAL SCIENCE ORD. 2015
- MATHEMATICS ORD. 2011
- MATHEMATICS ORD. 2022
- MOLECULAR BIOLOGY (ORD. 2020)
- PHYSICS OF DATA ORD. 2018
- PHYSICS ORD. 2021
- SANITARY BIOLOGY
- STATISTICAL SCIENCES ORD. 2014
- SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021

SECOND CYCLE DEGREES WITH ALL THE COURSE UNITS HELD IN ENGLISH

ASTROPHYSICS AND COSMOLOGY ORD. 2019

ASTRO-STATISTICS AND COSMOLOGY

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

Lecturer: Dott. ALESSANDRO RENZI

Credits: 6 ECTS

Prerequisites:
Short program:

Examination:
The exam is comprised of two phases. 1) Resolution of assigned homework during the course, eventually to undertake in group. 2) Oral examination with discussion of the course topics.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP8082722/NO

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ASTRONOMICAL INTERFEROMETRY

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

Lecturer: Prof. MAURO D'ONOFRIO

Credits: 6 ECTS

Prerequisites:
A good knowledge of the Fourier transform and Calculus is required.

Short program:
1) Fundamentals of optical and radio astronomy. 2) Optical and radio telescopes. Resolution and observational techniques. 3) Elements of interferometry. 4) Optical and radio interferometry. 5) The UV plan. 6) Image synthesis at optic and radio wavelengths. 7) Elements of disturbance and calibration of interferometric observations. 8) Data reduction tests of interferometric data in the computer laboratory.

Examination:
Oral exam about the topics discussed in the lectures.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP9086348/NO

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ASTRONOMICAL SPECTROSCOPY

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

Lecturer: Dott. STEFANO CIROI

Credits: 6 ECTS

Prerequisites:
Basic knowledge of Atomic Physics, Astronomy, Astrophysics 1 and 2, Laboratory of Astronomy.

Short program:
1) A brief introduction to spectroscopy as observational technique. 2) Characteristics of emission-line spectra: gaseous nebulae, Novae, Supernovae, Supernova remnants, star-forming regions, active galactic nuclei. 3) Fundamentals of atomic spectroscopy: atomic term symbols, energy levels, Grotrian diagrams, and selection rules. 4) Population of energy levels: Boltzmann and Saha equations, applications to some atomic species and comparison with absorption lines in stellar spectra. 5) Radiation transport. 6) Absorption lines and main broadening mechanisms. 7) Emission lines: collisional transitions, statistical equilibrium equations, two-level atom, optically thin recombination lines, dust extinction, forbidden lines, three-level atom. 8) Continuum sources: recombination, free-free, synchrotron. 9) Ionization equilibrium. 10) Ionization structure: the Stromgren sphere. 11) Thermal equilibrium.

Examination:
Oral exam on the topics discussed during the lectures.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCN1035986/NO

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ASTROPARTICLE PHYSICS

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

Lecturer: Prof. ANTONIO MASIERO

Credits: 6 ECTS

Prerequisites:
Taking for granted the notions of Quantum Mechanics and Relativity provided in previous undergraduate courses, the present course is self-consistent in so far as it intends to provide the necessary basic notions of relativistic quantum mechanics, quantum field theory and elementary particle physics, and cosmology.

Short program:
1) Introduction: the observable Universe and its expansion, dark matter, Big Bang relics; 2) Relativistic Quantum Mechanics: Klein-Gordon equation; Dirac equation; particles and antiparticles; discrete symmetries: P, T, C and CPT theorem; 3) Quantum Field Theory: Klein-Gordon and Dirac quantum fields; quantum electrodynamics (QED); elements of the scattering theory: S matrix, propagators, Feynman rules, cross sections and decay rates 4) Spontaneous Symmetry Breaking (SSB): SSB of discrete and continuous symmetries; Goldstone theorem; SSB of local (gauge) symmetries; Higgs mechanism; Higgs, finite temperature SSB. 5) The Standard Model (SM) of Particle Physics: Fermi theory; V-A theory; Yang-Mills theories; electroweak standard theory; SSB of the electroweak symmetry; CP violation; baryon and lepton number conservation; Higgs boson searches and discovery. 6) Neutrino Physics: Dirac and Majorana masses; see-saw mechanism; neutrino oscillations; solar and atmospheric neutrinos; Supernovae neutrinos; 7) Beyond the SM: Grand Unified Theories (GUTs); SSB and the gauge hierarchy problem; proton decay. 8) Elements of General Relativity: equivalence principle; curved space-time; energy-momentum tensor; Einstein equations. Schwarzschild solutions 9) Elements of the Standard Model of Cosmology and its interplay with the Stand Model of particle physics and their fundamental interactions. 10) Thermodynamics of the Early Universe: thermodynamical equilibrium; entropy; decoupling temperature. 11) Dark Matter (DM): observational evidence; Boltzmann equations; cold and hot DM; Weakly Interacting Massive Particles (WIMPs); particle physics DM candidates; cosmological limits of the neutrino masses; direct and indirect DM searches. 12) Unification of the fundamental interactions and Inflation: the problems of the horizon, flatness and lifetime of the Universe; the problem of the cosmological monopoles; inflation mechanism; quantum fluctuations of the inflation; inflation models; dark energy 13) Baryogenesis and the cosmic matter-antimatter asymmetry: Sacharov conditions; baryon and lepton violating interactions; matter-antimatter asymmetry and neutrino masses: leptogenesis.

Examination:
Oral examination.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP7081703/NO

ASTROPHYSICS LABORATORY 1: HIGH ENERGY INSTRUMENTATION

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

Lecturer: Dott. STEFANO CIROI

Credits: 6 ECTS

Prerequisites:
Knowledge of astronomy and/or physics at undergraduate level

Short program:
1) optics of high-energy telescopes: focusing optics, non-focusing optics, detectors 2) current and future space missions, orbits of space missions, earth's atmosphere, astrophysical and instrumental background 3) high-energy observations, archives and data analyses 4) imaging analysis, spectral analysis, timing analysis and their astrophysical context 5) fitting of data

Examination:
The oral exam will focus on topics addressed during lectures and on a report of a high-energy observation analyzed by the student group during the lab experience.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCQ0093339/NO

ASTROPHYSICS LABORATORY 1: INFRARED AND OPTICAL INSTRUMENTATION

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

Lecturer: Prof. ROBERTO RAGAZZONI

Credits: 6 ECTS

Prerequisites:
Fundamentals of Physics and Astronomy.

Short program:
**ASTROPHYSICS OF THE INTERSTELLAR MEDIUM**

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

**Lecturer:** Prof. GIOVANNI CARRARO

**Credits:** 6 ECTS

**Prerequisites:**
The course assumes that the students well know general physics (thermodynamics, fluid dynamics, electromagnetism) and basics of atomic physics.

**Short program:**
1) Introduction. 2) Equations of hydro-dynamics, turbulence, thermal balance in the interstellar medium. 3) Shock waves, Riemann problem 4) Magneto-hydrodynamics, Alfvén waves, Galactic magnetic field; generalized virial theorem; ambipolar diffusion 5) Numerical techniques for the solution of the magneto-hydrodynamic equations (Eulerian vs Lagrangian approaches). 6) General picture of the interstellar medium: HI, CO, H2, molecules. 7) Theories of star formation, Jeans criterion, sequential star formation. 8) HI regions, Stromgren sphere. 9) Effects on the interstellar medium of stellar winds and supernovae remnants 10) Chemical enrichment of the interstellar medium: basic equations

**Examination:**
Oral exam possibly integrated by the presentation of a topic related to the program agreed in advance with the teacher.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP9086353/NO

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**CELESTIAL MECHANICS**

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

**Lecturer:** Dott. STEFANO CASOTTO

**Credits:** 6 ECTS

**Prerequisites:**
Students are expected to be familiar with Rational Mechanics and Mathematical Analysis, including the elementary theory of Ordinary Differential Equations. A fair amount of curiosity about dynamical phenomena observed in the Solar and other planetary systems is useful, together with an interest in their precise modeling and computation and the design of exploration missions.

**Short program:**

**Examination:**
Evaluation of the homework and final project report. Oral presentation of final report and discussion of the results and other topics covered during the lectures.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCN1035988/NO

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**COSMOLOGY OF THE EARLY UNIVERSE**

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

**Lecturer:** Prof. NICOLA BARTOLO

**Credits:** 6 ECTS

**Prerequisites:**
Generally the bases useful to attend this course are provided by the various courses within a given chosen curriculum.

**Short program:**
General introduction. The problem of the initial conditions: primordial density perturbations at the origin of the formation of the Large Scale Structure of the Universe. - Short recall of the main problems of the standard cosmological model - Inflationary cosmology in the Early Universe as a solution to the problems of the standard model Modeling: - Inflationary models: vacuum energy and the inflation field; dynamics of a scalar field in a Friedmann-Robertson-Walker Universe; possible realizations of the inflationary scenario - Cosmological models of inflation and their main features (with examples also within high-energy particle physics) - Observational predictions of the inflationary models: from the quantum perturbations in an expanding universe to the primordial density perturbations; generation of primordial gravitational waves and their observability (cosmological and interferometric probes). Reheating phase and baryogengesis mechanisms Delta-N and in-in formalisms for the study of cosmological perturbations. Example: primordial non-Gaussianity Cosmological perturbations in General Relativity: - scalar, vector and tensor perturbations - gauge transformations - Einstein equations (linearly) perturbed around the Robertson-Walker metric Observational tests of the Early Universe

Examination:
Oral exam

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP7081761/NO

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**EXOPLANETARY ASTROPHYSICS**

Master’s degree in **ASTROPHYSICS AND COSMOLOGY ORD. 2019**, First semester

**Lecturer:** Prof. GIAMPAOLO PIOTTO

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge (at bachelor level) of Physics, Astronomy and Astrophysics.

**Short program:**

**Examination:**
Oral exam on the course program, with a presentation of one or more papers recently published

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP9086352/NO

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**FLUID AND PLASMA DYNAMICS**

Master’s degree in **ASTROPHYSICS AND COSMOLOGY ORD. 2019**, First semester

**Lecturer:** to be defined

**Credits:** 6 ECTS

**Prerequisites:**
None

**Short program:**

**Examination:**
Oral exam.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP9086351/NO

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**FUNDAMENTALS OF ASTROPHYSICS AND COSMOLOGY**
FUNDAMENTALS OF MODERN PHYSICS

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

Lecturer: Prof.ssa CHIARA MAURIZIO

Credits: 6 ECTS

Prerequisites:
Fundamentals of quantum physics and structure of matter.

Short program:

Examination:
Two partial written exams will be scheduled (one at about half-course and the other one at the end) in which the student has to solve exercises and discuss some open questions. The full exam is made of a written part (of the two written partials) plus an oral exam (needed only if the score of the written exam is
GALACTIC DYNAMICS

Master’s degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

Lecturer: Prof. ENRICO MARIA CORSINI

Credits: 6 ECTS

Prerequisites:

Short program:

Examination:
Oral exam on different topics discussed during lectures.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP9086385/NO

GENERAL RELATIVITY FOR ASTROPHYSICS AND COSMOLOGY

Master’s degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

Lecturer: Prof. MARCO PELOSO

Credits: 6 ECTS

Prerequisites:
Knowledge of Special Relativity

Short program:

Examination:
Questions on the topics presented during the course and solution of a simple / medium problem.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCQ0093378/NO

GRAVITATIONAL PHYSICS

Master’s degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

8/161
Lecturer: Prof. GIACOMO CIANI

Credits: 6 ECTS

Prerequisites:
Basic knowledge of general relativity is suggested, but not mandatory.

Short program:

Examination:
Oral examination aimed at verifying the conceptual understanding of the topics presented and the ability to correctly approach and analyze specific problems related to GW theory and detection.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP7081719/NO

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Lecturer: Prof.ssa MICHELA MAPELLI

Credits: 6 ECTS

Prerequisites:

Short program:

Examination:
Written exam (unless the covid-19 emergency requires to switch to an oral examination).

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP9086342/NO

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Lecturer: Prof.ssa ELISA BERNARDINI

Credits: 6 ECTS

Prerequisites:
This course is addressed to students with basic knowledge of elementary particles and their interactions and nuclear physics.

Short program:
The term "multi-messenger" is quite new and increasingly used in astronomy and astroparticle physics. It refers to combining information from different cosmic messengers (i.e. photons, cosmic rays, neutrinos and gravitational waves) to gain a deeper understanding of the astrophysical objects we observe in the sky. Visible light only reveals a very small portion of the mysteries of the Universe. Astronomical observations are nowadays routinely performed with different telescopes across the whole electromagnetic spectrum, from radio waves through visible light, all the way to gamma-rays. At the highest energies, the most violent processes in the Universe are at work. Whatever produces high energy gamma-rays, is expected to accelerate particles to energies that exceed the capabilities of man-made accelerators a billion times. Such particles can reach the Earth as cosmic rays, first discovered more than 100 years ago, still nowadays one of the most mysterious "messages" from our Universe. Cosmic rays may interact in the vicinity or their sources or even along their way to Earth, to produce elusive particles called neutrinos and gamma-rays. While cosmic rays are deflected during their journey by intergalactic magnetic fields, neutrinos and photons, being neutral particles, keep memory of their source's direction. Their trajectory becomes thus crucial to unravel the origin of cosmic rays. Neutrinos are extremely difficult to detect. Kilometric detectors are necessary to observe neutrinos at energies larger than a few tens of...
GeV. The year 2013 witnessed the first clear observation of neutrinos from distant astrophysical objects by the IceCube detector at the South Pole, opening a new observational window to the Universe. The most extreme astrophysical objects, connected with the most violent phenomena in our Universe, are often associated with black holes or neutron stars. Whenever two such compact objects orbit around each other, they are expected to produce gravitational waves. The year 2015 witnessed the first direct observation of gravitational waves emitted by two merging black-holes (GW150914), measured by the LIGO detectors in the USA. The discovery was celebrated by the Nobel-prize for physics. The year 2017 witnessed the triumph of multi-messenger astrophysics with the detection of gravitational waves from two merging neutron stars (GW170817), followed by a burst of gamma-rays (GRB 170817A). Just few days after another event celebrated the success of multi-messenger astrophysics: the first identification of a source of cosmic neutrinos, the blazar TXS 0506+056, helped by the electromagnetic observations that followed the detection of a high energy neutrino (iceCube-170922A). Both results greatly demonstrate the potential of multi-messenger astrophysics in observing and understanding the most extreme and mysterious phenomena in our Universe. This course will illustrate its foundations.

Examination:
Oral examination.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP7081762/NO

NUCLEAR ASTROPHYSICS

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

Lecturer: Prof. ANTONIO CACIOLLI

Credits: 6 ECTS

Prerequisites:
Elements of quantum mechanics, nuclear physics, and general physics

Short program:
Thermonuclear reactions. Definition of nuclear cross section, astrophysical S-factor, reaction rate, and Gamow peak. Nuclear burnings during hydrostatic and explosive stellar evolutionary phases. Elements of stellar modelling. Hydrogen burning: p-p chains, CNO, NeNa, MgAl cycles. Helium burning: triple-alpha reaction and alpha + 12C. Advanced nuclear burnings (C, Ne, O, Si). Neutron-capture reactions (s and r: slow and rapid) For each topic we provide an overview of the most relevant results in the recent literature. How to determine the reaction rate for several cases (direct capture, narrow resonances, broad resonances) How to perform a nuclear astrophysics experiment (every topic will be discussed with of existing experimental facilities and their most recent results) The environmental background and how to shield it (passive and active shielding) Underground experiment Brief discussion on ion beam accelerators Elements on detectors (gamma, neutrons, and charged particles) Experimental measurements of the cross section (from the experimental yield to the S-factor) Targets typology (gas, jet, and solid target). Target production techniques and how targets influence the experimental measurements. Brief discussion on indirect methods (Trojan Horse, ANC, …).

Examination:
A 10 minutes presentation on an aspect of the course (usually an astrophysical issue and a related reaction study) and some question related to the presentation and course program.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP7081704/NO

PLANETARY ASTROPHYSICS

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

Lecturer: Prof. FRANCESCO MARZARI

Credits: 6 ECTS

Prerequisites:
Basic courses of the 3--year period.

Short program:
1) Dynamical and physical properties of planets and exoplanets. 2) Planetary formation from circumstellar disks, migration and planet-planet scattering. Tidal interaction between planets and disks. 3) Magnetic fields of the planets, origin and morphology. 4) Plasma motion in planetary fields, Van Allen Belts, magnetospheres and solar wind. 5) Tidal interaction planet-satellite and planet-star, lengthening of the terrestrial day and Moon outward drift. 6) Physics of planetary interiors, state and structure equations. 7) Non-gravitational forces acting on planetary precursors: Poyting-Robertson drag, Yarkowski effect, gas drag. 7) Three-body problem: Lagrangian points (Trojan orbits), their stability, Hill's sphere and its applications (cataclysmic variables, asteroid satellites). 8) Secular perturbations in multiple planet systems. 9) Navier-Stokes equations for fluidynamics and their application to circumstellar disks 10) Mean motion resonances

Examination:
Oral exam. If the present medical emergency persists, the exam may be taken on line (Zoom or Skype)
SELECTED TOPICS IN MODERN ASTROPHYSICS

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

Lecturer: Dott. STEFANO BOVINO

Credits: 6 ECTS

Prerequisites: CONTENT NOT PRESENT

Short program: CONTENT NOT PRESENT

Examination: CONTENT NOT PRESENT

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP7081805/NO

SUBNUCLEAR PHYSICS

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

Lecturer: Prof.ssa DONATELLA LUCCHESI

Credits: 6 ECTS

Prerequisites: Principles of nuclear and sub-nuclear physics, principles of quantum mechanics, relativistic dynamics, quantum field theory, Feynman graphs, interaction radiation with matter.

Short program:
Introduction and recap Tools for calculation Detectors for particle physics experiments Cross section $e+e^+\rightarrow\mu^+\mu^-$ and $e+e^+\rightarrow h h$ Deep Inelastic Scattering The Gluon QCD, Partons and jets Electroweak interaction: introduction Experimental tests of Electroweak interaction Cabibbo Theory and Cabibbo-Kobayashi-Maskawa Matrix CP and T violation, the B meson system. Tests of CKM Neutrino and Standard Model Higgs Properties

Examination:
The exam will be based on an assignment given in advance to the students. It will be constituted by exercises or open questions and a discussion on open topics among those discussed during the lectures. During the discussion questions on the arguments of the class can be asked.

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/000ZZ/SCP7081697/NO

ASTROPHYSICS LABORATORY 2

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

Lecturer: Dott. LUCA MALAVOLTA

Credits: 6 ECTS

Prerequisites:
Basic knowledge of astronomy and astrophysics, stellar astrophysics, photometry and spectroscopy. Basic knowledge of computer science (Python 3).
Short program:
The objectives of the course will be achieved through the practical study of a topical scientific case, namely the characterization of extrasolar planets. A. Frontal lessons in the classroom. 1) Main problems in the acquisition of CCD images for photometry. 2) Techniques for extracting high precision photometry from digital images, from ground and from space. 3) Techniques for extracting high precision radial velocities and effects of stellar activity. 4) Research methods for extrasolar planets. Planetary transits. Brief summary of the state of research and characterization of extrasolar planets. Techniques of light curve analysis for the research of variability phenomena (including planetary transits). Techniques for the combined analysis of photometry and radial velocities for the characterization of extrasolar planets. B. Observational experience at the Asiago Observatory. Preparation and execution of observations of a planetary transit through the 182 cm Copernico telescope. (virtually or in presence depending on the sanitary provisions). The data will then be reduced and analyzed during the laboratory experience. C. Laboratory experience. 1) Reduction of planetary transit data. 2) Analysis of the light curve obtained at the Asiago Observatory in combination with data from space. 3) Measurement of orbital and physical parameters (such as the central time of transit, inclination of the orbit, radius of the planet, semi-major axis / radius ratio). Inclusion of radial velocities for the measurement of planetary mass and comparison of planetary density with internal composition models.

Examination:
Evaluation of laboratory reports. Oral presentation of the work done. Oral exam about the topics of the course.

More information:

### ASTROPHYSICS OF GALAXIES

Master’s degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

Lecturer: Prof. ALESSANDRO PIZZELLA

Credits: 6 ECTS

Prerequisites:
Basic knowledge of extra-galactic astrophysics. In particular, about morphology, photo-metric profiles, kinematics of galaxies.

Short program:

Examination:
Oral exam

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/002PD/SCN1035987/NO

### OBSERVATIONAL ASTROPHYSICS

Master’s degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

Lecturer: Prof. SERGIO ORTOLANI

Credits: 6 ECTS

Prerequisites:
Basic knowledge of general astronomy and physics.

Short program:
The first part is dedicated to instrumental techniques and observational aspects in photometry. One of the application is the instrumental and reddening corrections of the data. Then the interpretation of the near infrared color-magnitude and color-color diagrams of young stellar populations. The second part of the course is dedicated to the physical properties of the planets and to some basic concepts on the study of the extrasolar planets. The third part is a detailed analysis of emissions connected to the galactic interstellar medium evolution. 1) Basic concepts in astrophysics: magnitudes, distance modulus, metallicity indices. Distance measurements. 2) Signal-to-noise ratio of the observational data. Calibrations. 3) Interstellar reddening effects on the photometry. 4) Young stellar populations. HR diagrams and two color infrared diagrams. 5) General properties of the planets in the Solar System. 6) Atmosphere of the planets. Gas escape mechanisms. 7) Effective temperatures of the planets and greenhouse effect. 8) Origin and evolution of the Solar System. Urey and Lewis theory. Age of the Solar System. Formation of the Earth. 9) General characteristics of the planet Mars. 10) Basic principles of the extrasolar planets detection techniques. 11) The gas in the Galaxy. H1 21 cm line. 12) Supernovae remnants and basics of evolutionary models. 13) Stellar and interstellar maser sources.

Examination:
Oral or written exam with open questions on the topics discussed during the lectures.
**OBSERVATIONAL COSMOLOGY**

Master's degree in **ASTROPHYSICS AND COSMOLOGY ORD. 2019**. Second semester

**Lecturer:** Prof.ssa GIULIA RODIGHIERO

**Credits:** 6 ECTS

**Prerequisites:**

The course is self-consistent, having acquired the whole fundamental notions of mathematics and physics of the 3-year degrees in Astronomy or Physics.

**Short program:**


**Examination:**

Oral discussion

**More information:**


**STELLAR ASTROPHYSICS**

Master's degree in **ASTROPHYSICS AND COSMOLOGY ORD. 2019**. Second semester

**Lecturer:** Prof. ANTONINO MILONE

**Credits:** 6 ECTS

**Prerequisites:**

Fundamentals of stellar astrophysics (photometry, astrometry, spectroscopy, stellar evolution)

**Short program:**


**Examination:**

Oral exam based on the topics discussed during the lectures.

**More information:**

More information:

ADVANCED ASTROPHYSICS

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

Lecturer: Prof.ssa PAOLA MARIGO

Credits: 6 ECTS

Prerequisites:
General astrophysics, fundamentals of radiative processes and stellar evolution

Short program:

Examination:
Written and/or oral examination

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/001PD/SCP9086349/NO

COMPACT OBJECT ASTROPHYSICS

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, First semester

Lecturer: Prof. ROBERTO TUROLLA

Credits: 6 ECTS

Prerequisites:
Classical electrodynamics, special relativity, general astronomy and astrophysics

Short program:

Examination:
Oral examination

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2490/001PD/SCP9086349/NO

RADIATIVE PROCESSES IN ASTROPHYSICS

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

Lecturer: Prof. ROBERTO TUROLLA

Credits: 6 ECTS

Prerequisites:
Classical electrodynamics, special relativity, general astronomy and astrophysics

Short program:

Examination:
Oral examination

More information:
https://en.didattica.unipd.it/off/2022/LM/SC2490/001PD/SCP9086347/NO

THEORETICAL COSMOLOGY

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

Lecturer: Prof. SABINO MATARRESE

Credits: 6 ECTS

Prerequisites:
Fundamentals of Cosmology and Astrophysics

Short program:
General introduction • Derivation of the Friedmann eqs. from Einstein's eqs. (after a very synthetic introduction to the latter), assuming the Robertson-Walker line-element. The Cosmic Microwave Background (CMB) Radiation • Boltzmann eq. and hydrogen recombination: beyond Saha equation • The Boltzmann eq. in the perturbed universe: the photon distribution function • The collision term • Boltzmann eq. for photons in the linear approximation • Boltzmann eq. for cold dark matter (CDM) in the linear approximation • Boltzmann eq. for baryons in the linear approx. • Evolution eq. for the photon brightness function • Linearly perturbed Einstein's equations (scalar modes) • Initial conditions • Super-horizon evolution • Acoustic oscillations and tight coupling • Free-streaming – role of the visibility function • Evolution of gravitational potential and Silk damping • Temperature anisotropy multipoles • Angular power-spectrum of the temperature anisotropy • Sachs-Wolfe effect • Small angular scales: acoustic peaks and their dependence on cosmological parameters The gravitational instability • Gravitational instability in the expanding Universe • Boltzmann eq. for a system of collisionless particles and the fluid limit • The Zel'dovich approximation • The adhesion approximation • Solution of the 3D Burgers equation • Approach based on the Schroedinger equation. Statistical methods in cosmology • The ergodic and the “fair sample” hypotheses • N-point correlation functions • Power-spectrum and Wiener-Khintchine theorem • Low-pass filtering techniques • Up-crossing regions and peaks of the density fluctuation field • Gaussian and non-Gaussian random fields • The path-integral approach to cosmological fluctuation fields

Examination:
The exam of this course can be made in two alternative ways: 1. Oral interview on the main topics analyzed during the course. 2. (only for the students who attended the classes) Short written dissertation on a topic discussed during the course, to be agreed with the lecturer. The dissertation should contain a detailed of the chosen subject, based upon one or a few review articles (and or some cosmology textbook chapters). The content of this dissertation, to be discussed with the professor is expected to show how much the student has become acquainted with the main concepts presented in the lectures.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC2490/001PD/SCP9086384/NO

THEORETICAL PHYSICS

Master's degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites:
CONTENT NOT PRESENT

Short program:
CONTENT NOT PRESENT

Examination:
CONTENT NOT PRESENT

More information:
https://en.didattica.unipd.it/off/2022/LM/SC2490/001PD/SCP7081638/NO
CHEMISTRY OF ORGANIC MATERIALS

Master's degree in CHEMISTRY ORD. 2018, Second semester

Lecturer: Prof. ENZO MENNA

Credits: 6 ECTS

Prerequisites: General Organic Chemistry.

Short program:
The course program covers main application fields for advanced organic materials. Each application will be discussed with regard to: - theoretical bases required to understand how the material works - different chemical classes of materials - different kind of structures (polymers, oligomers, molecules, supramolecular systems and nanostructures) - synthesis and characterization of structures - structure-property relationships (e.g. effect of the substituent, of the supramolecular organization, …) - device fabrication techniques (e.g. thin layer deposition, self assembly of systems, …) - example of application both at research and commercial level. According to such scheme, the following topics will be considered in particular: - Fullerenes, nanotubes and other carbon nanostructures - Organic photovoltaic devices - Organic electroluminescent materials (OLED) - Supramolecular polymers - Self assembled layers of organic molecules - Organic molecules for non-linear optics - Advanced biomimetic materials: dry adhesives (gecko effect) and self healing materials. - Structural organic materials: main classes of plastic and engineering polymers, their application, synthesis and properties.

Examination:
Oral exam. The student can choose either English or Italian language. During 20-30 minutes, the student will be asked to expose briefly and rigorously some topics and to make connections among involved topics.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1169/000ZZ/SCP9087639/NO

MAGNETIC SPECTROSCOPIES

Master's degree in CHEMISTRY ORD. 2018, Second semester

Lecturer: Prof.ssa MARILENA DI VALENTIN

Credits: 6 ECTS

Prerequisites: Physics and quantum chemistry basics.

Short program:

Examination:
Oral examination

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1169/000ZZ/SCP9087644/NO

OPTICAL PROPERTIES OF MOLECULAR SYSTEMS

Master's degree in CHEMISTRY ORD. 2018, Second semester

Lecturer: Prof.ssa ELISABETTA COLLINI

Credits: 6 ECTS

Prerequisites: Knowledge of the subjects taught in the basic classes of physical chemistry.

Short program:
1. Electromagnetic fields (Maxwell's equations) 2. Dielectric properties of materials and molecules (linear and nonlinear regime) 3. Time dependent perturbation theory of spectroscopy in frequency and time domain 4. interaction with the bath: time correlation functions 5. Absorption, emission and scattering: a reinterpretation of well-known spectroscopic observables in terms of correlation functions (lineshape function) 6. Electronic and vibronic
transitions: absorption and emission. 7. Photochemistry of molecular aggregate systems a) Frenkel excitons b) Non radiative processes: energy transfer processes. 8. Time resolved spectroscopy for the study of the dynamics and photophysics of molecular systems. Response theory applied to linear and non linear optical spectroscopies. 9. Elements of non linear optical spectroscopy in the time and in the frequency domain.

**Examination:**
Final oral exam with the possibility to choose between two modalities: 1. ‘classic’ oral exam in which the teacher will ask questions on the course content to verify the student’s preparation. 2. ‘journal club’ type exam in which the student will present the results of a more in-depth study of a topic addressed in the course.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1169/000ZZ/SCP9087642/NO

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**PHYSICAL CHEMISTRY OF THE SOLID STATE AND OF MATERIALS**

Master’s degree in **CHEMISTRY ORD. 2018**, Second semester

**Lecturer:** Prof.ssa CAMILLA FERRANTE

**Credits:** 6 ECTS

**Prerequisites:**
The student should be familiar with concepts and notions of classical physics (mechanics, dynamics and electromagnetism). A knowledge of elements of quantum mechanics, thermodynamics and spectroscopy is also required (at the level of a bachelor or first degree in chemistry) as well as the knowledge of intermolecular forces which are part of the program of Physical Chemistry IV.

**Short program:**

**Examination:**
Oral exam whereby the student should report and explain one or more argument discussed in the lectures. Aim of the exam is to verify the knowledge acquired by the student and her/his ability to elaborate on them.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1169/000ZZ/SCP9087640/NO

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**PHYSICAL METHODS IN ORGANIC CHEMISTRY**

Master’s degree in **CHEMISTRY ORD. 2018**, First semester

**Lecturer:** Prof.ssa ESTER MAROTTA

**Credits:** 6 ECTS

**Prerequisites:**
Good understanding of organic chemistry and basic concepts of NMR spectroscopy and mass spectrometry

**Short program:**

**Examination:**
Written test

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1169/000ZZ/SCP9087647/NO

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**PRINCIPLES AND APPLICATIONS OF ORGANOMETALLIC CHEMISTRY**

Master’s degree in **CHEMISTRY ORD. 2018**, First semester

**Lecturer:** Prof. ANDREA BIFFIS

**Credits:** 6 ECTS

**Prerequisites:**

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17/161
Basic knowledge in chemistry imparted in the undergraduate courses in Chemistry or Industrial Chemistry.

**Short program:**
Introduction Organometallic compounds: definition. Historical overview. General properties and preparation methods. Organometallic compounds in the periodic table: trends. Organometallic compounds of the main group elements The preparation methods, the properties and the applications of the most important organometallic compounds of the main group metals: nucleophilic organometallic compounds, organoelement compounds of group 13 and 14. Organometallic compounds of the transition metals The preparation methods, the properties and the applications of the most important classes organometallic compounds of the transition metals, such as compounds containing sigma M-C bonds, metal carbonyls, metal carbenes, metal olefin and metal alkyne complexes, allyl, polenyl and polyene complexes will be illustrated. Special attention will be given to applications in organometallic synthesis and catalysis.

**Examination:**
oral examination

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1169/000ZZ/SCP9087645/NO

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**PROTEIN STRUCTURE AND DYNAMICS**

Master's degree in CHEMISTRY ORD. 2018, First semester

**Lecturer:** Dott. MASSIMO BELLANDA

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge of physical-chemistry and biochemistry

**Short program:**

**Examination:**
Oral questions with the option to define with the lecturer a specific topic or a case study to discuss at the beginning of the exam.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1169/000ZZ/SCP9087646/NO

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**THEORETICAL CHEMISTRY**

Master's degree in CHEMISTRY ORD. 2018, Second semester

**Lecturer:** to be defined

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge in chemistry, physics and mathematics.

**Short program:**
1. Description of molecular stochastic dynamics: theory of stochastic processes, Fokker-Planck equation, stochastic differential equations; tools for the numerical solution; correlation functions and spectral densities; stochastic chemical kinetics. 2. Linear response theory: response of a classical system to weak perturbations. 3. Stochastic Thermodynamics: work fluctuation theorems and applications. 4. Laws of transformation under rotation: change of representation of scalar, vector and tensor properties under rotation of the reference frame; rotation of scalar fields; rotational stochastic dynamics. 5. Models for the dynamics of open quantum systems: density matrix and statistical ensembles, Bloch equations, quantum response theory for the computation of spectroscopic observables, models for the interaction with the environment and quantum master equations.

**Examination:**
Oral examination, with the possibility to analyse a specific problem and discuss a brief report on it.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1169/000ZZ/SCP9087641/NO
### ADVANCED ALGORITHMS

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

**Lecturer:** Dott. MICHELE SCQUIZZATO

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ1098249/NO

### ADVANCED TOPICS IN COMPUTER AND NETWORK SECURITY

Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

**Lecturer:** Prof. MAURO CONTI

**Credits:** 6 ECTS

**Prerequisites:**
No strict prerequisites on previous exams. However, it is suggested to have basic knowledge of networking, cryptography, and distributed systems (typically acquired in BSc degrees in Computer Science).

**Short program:**
Theory: RFID security, captcha, untrusted storage, smartphone security, attacks on smartphone, password protection, distributed Denial of Service attacks, deep learning, behavioural biometrics, VoIP security, secure content delivery, anonymous communications, keyloggers detection, anonymity in WSN, botnet detection, trusted HW, security of RFID ePassports, node replication attack in WSN, secure data aggregation in WSN, privacy issues in social networks, Google Android smartphone security, electronic voting, P2P botNet detection, taint mechanisms, browser security, privacy of location based services, Named Data Networking security, Named Data Networking privacy, cloud security, anonymity in wireless network, smartphone user profiling, SSL security issues in Android, circumvent censorship, secure messaging, operational technology security, cyber-physical systems security Laboratory: advanced security tools, including: traffic analysis with machine learning tools, data inference, Android security tools, advanced analysis of malware systems and advanced persistent threat; web security; social network analysis tools, trusted platform modules.

**Examination:**
Project with written essay + oral exam.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ1098227/NO

### ADVANCED TOPICS IN COMPUTER SCIENCE

Master's degree in COMPUTER SCIENCE ORD. 2021, First and Second semester

**Lecturer:** to be defined

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP6076301/NO

### ADVANCED TOPICS IN PROGRAMMING LANGUAGES

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

**Lecturer:** Prof.ssa SILVIA CRAFA

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ1098229/NO
**ARTIFICIAL INTELLIGENCE**

Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

**Lecturer:** Prof. ALESSANDRO SPERDUTI

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ0093639/NO

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**BIG DATA COMPUTING**

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

**Lecturer:** Prof. ANDREA ALBERTO PIETRACAPRINA

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP7079297/NO

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**BIOINFORMATICS**

Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

**Lecturer:** Prof. GIORGIO VALLE

**Credits:** 6 ECTS

**Prerequisites:**
There are no particular prerequisites other than what it is expected from a master student in informatics. However, a basic knowledge of genetics and molecular biology will help in the understanding of the biological motivations of bioinformatics. The course is in English, therefore the students should have a reasonable command of spoken and written English.

**Short program:**
This is a six credits course: five credits will be from lessons while one credit will be from practical activities, either the implementation of some algorithm or the in-depth investigation of the literature on given arguments. The lessons are divided in three main parts. The first part is an extensive introduction on Biology presented as a scientific field centered on Information. The mechanisms that facilitate the transmission and evolution of biological information is used to introduce some biological problems that require computational approaches and bioinformatics tools. The second part of the course describes the main algorithms used for the alignment of biological sequences, including those designed for “next generation sequencing”. The algorithms used for de novo genomic assembly are also described. Finally, the third part of the course covers several aspects of bioinformatics related to functional genomics, such as the analysis of transcription, gene prediction and annotation, the search of patterns and motifs and the prediction of protein structures. The role of Bioinformatics in individual genomic analysis and personalized medicine is also discussed.

**Examination:**
The exam will be articulated into three parts: 1) a practical session in which the student must describe a project of data analysis, that must be submitted at least two days before the date of the exam, 2) a quiz session on Moodle, that will take place at the beginning of the exam day, 3) an oral discussion in which the student must describe his/her project and answer questions on the topics of the course. A continuous process of assessment will be carried out throughout the course, to verify the level of understanding of the students.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP7079405/NO

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**COMPUTABILITY**

Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

**Lecturer:** Prof. PAOLO BALDAN

**Credits:** 6 ECTS

**Prerequisites:**
The course requires some familiarity with basic mathematical concepts such as relations, functions, sets, cardinality, partial orders, principles of induction. There are no propaedeutical courses.

**Short program:**

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Examination:
Written and oral exam.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ1098231/NO

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**CRYPTOGRAPHY**

Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

Lecturer: Prof. ALESSANDRO LANGUASCO

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ0093658/NO

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**CYBERPHYSICAL SYSTEMS AND IOT SECURITY**

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites:
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More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ2101239/NO

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**DATA MINING**

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

Lecturer: Prof.ssa ANNAMARIA GUOLO

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SC01111799/NO

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**DEEP LEARNING**

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

Lecturer: Prof. ALESSANDRO SPERDUTI

Credits: 6 ECTS
DEEP LEARNING

Master's degree in **COMPUTER SCIENCE ORD. 2021**, Second semester

**Lecturer:** Dott. NICOLÒ NAVARIN

**Credits:** 6 ECTS

**Prerequisites:**

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**Short program:**

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**Examination:**

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More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP9087561/NO

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ECONOMICS AND MANAGEMENT OF INNOVATION

Master's degree in **COMPUTER SCIENCE ORD. 2021**, First semester

**Lecturer:** Prof.ssa SILVIA RITA SEDITA

**Credits:** 6 ECTS

**Prerequisites:**

No pre-requirement required

**Short program:**

The course aims to address and deepen the following topics: - The main innovations that have influenced the evolution of the capitalist system. - Innovation in economic theories (Smith, Ricardo, Marx, neoclassical theory, Schumpeter, Nelson and Winter) - sources of innovation - types of innovation - innovation and firm strategies - innovation and competition

**Examination:**

The final written test will be based on open questions and, for attending students, also on their presentations during the course (such presentations are discretionary)

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ1098279/NO

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FORMAL METHODS FOR CYBER-PHYSICAL SYSTEMS

Master's degree in **COMPUTER SCIENCE ORD. 2021**, First semester

**Lecturer:** Prof. DAVIDE BRESOLIN

**Credits:** 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ0089514/NO

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FUNCTIONAL LANGUAGES

Master's degree in **COMPUTER SCIENCE ORD. 2021**, First semester

**Lecturer:** Dott. ALVISE SPANO'

**Credits:** 6 ECTS

**Prerequisites:**

Suggested a basic knowledge of lambda calculus, type systems and compiler constructions; experience in structured programming with strong-typed
languages.

**Short program:**

**Examination:**
Oral exam at the end of the course. Optional project. Optional exercises.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP6076299/NO

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**GAME THEORY**

Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

**Lecturer:** ELVINA GINDULLINA

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP7079401/NO

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**IT SERVICE MANAGEMENT**

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

**Lecturer:** Dott. FRANCESCO CLABOT

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ0093638/NO

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**KNOWLEDGE REPRESENTATION AND LEARNING**

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

**Lecturer:** to be defined

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ0093643/NO

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**LANGUAGES FOR CONCURRENCY AND DISTRIBUTION**

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

**Lecturer:** Prof. PAOLO BALDAN

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ1098228/NO

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**MACHINE LEARNING**
Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

Lecturer: Prof. FABIO AIOLLI

Credits: 6 ECTS

Prerequisites:
The student should be familiar with basic concepts in Probability and Analysis of multivariate functions. It is also advisable to have basic knowledge of Programming and Artificial Intelligence. The course does not have prerequisites.

Short program:
The course will cover the topics listed below - Introduction: When to apply Machine Learning techniques; Machine Learning Paradigms; Basic ingredients of Machine Learning. - Learning Concepts: The complexity of the Hypothesis Space; Complexity Measures; Examples of Supervised Learning Algorithms; - Decision Trees: Learning Decision Trees; Treatment of Numerical Data, Missing Data, Costs; Pruning Techniques and Derivation of Decision Rules. - Probabilistic Learning: Bayesian Learning; Examples of Application to Supervised and Unsupervised Learning (clustering); Optimal Bayes classifier; EM. - Neural Networks and Support Vector Machines: Introduction to Neural Networks; Classification Margin, Support Vector Machines for Classification and Regression, Kernel Functions. - Application Issues: Classification Pipeline, Data Representation, and Selection of Variables; Model Selection; Clustering; Ensemble Learning; Recommender Systems.

Examination:
The student has to pass a written examination and if deemed necessary by the teacher, an oral examination. There is also a project that can be replaced by activities during the course.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP8082660/NO

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MATHEMATICAL MODELS AND NUMERICAL METHODS FOR BIG DATA

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

Lecturer: Dott. WOLFGANG ERB

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP7079406/NO

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METHODS AND MODELS FOR COMBINATORIAL OPTIMIZATION

Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

Lecturer: Prof. LUIGI DE GIOVANNI

Credits: 6 ECTS

Prerequisites:
Basic notions of Operations Research, Linear Programming, and computer programming.

Short program:

Examination:
Oral examination about course contents and homework on the application of optimization methods to solve realistic problems. Each student may chose to present a short project concerning a case study about models and exact/heuristic solution methods for a realistic application of combinatorial optimization.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP7079402/NO

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MOBILE PROGRAMMING AND MULTIMEDIA

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

Lecturer: Prof.ssa OMBRETTA GAGGI

Credits: 6 ECTS
## MOBILE SECURITY

Master's degree in **COMPUTER SCIENCE ORD. 2021**, Second semester

**Lecturer:** Dott.ssa ELEONORA LOSIOUK  
**Credits:** 6 ECTS

More information:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP7080184/NO

## PROCESS MINING

Master's degree in **COMPUTER SCIENCE ORD. 2021**, First semester

**Lecturer:** Prof. MASSIMILIANO DE LEONI  
**Credits:** 6 ECTS

More information:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ2101240/NO

## REAL-TIME KERNELS AND SYSTEMS

Master's degree in **COMPUTER SCIENCE ORD. 2021**, Second semester

**Lecturer:** Prof. TULLIO VARDANEGA  
**Credits:** 6 ECTS  
**Prerequisites:** The class subject requires familiarity with the architecture of traditional computer systems as well as with the organization and activity of operating systems for those architectures, especially regarding their support for concurrency, synchronization and handling of I/O. The class does not place prerequisites on entry.

**Short program:**  
- Introduction: industrial needs (brief) and system architecture (outline)  
- Reliability and fault tolerance  
- Scheduling: taxonomy of algorithms  
- Synchronization policies that enable resource sharing  
- System-level issues: understanding the technology stack  
- Extension to distributed systems  
- Extension to multiprocessors

**Examination:** The exam takes one of two forms: one form consists in the production and presentation of a technical report that discusses the issues dealt with and the solutions adopted in the development of a comparatively small practical assignment which involves the analysis, design, implementation and verification of systematic improvements to a distributed concurrent application supplied by the instructor; the other form requires the study, critique and oral presentation of a fresh research paper, chosen by the student out of manuscripts selected by the instructor, which touches upon subjects addressed in class.

More information:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ0093641/NO

## RUNTIMES FOR CONCURRENCY AND DISTRIBUTION

Master's degree in **COMPUTER SCIENCE ORD. 2021**, First semester

**Lecturer:** Prof. TULLIO VARDANEGA  
**Credits:** 6 ECTS

More information:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ0093640/NO
SOFTWARE VERIFICATION

Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

Lecturer: Prof. FRANCESCO RANZATO

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ0089515/NO

START-UP IN ICT

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

Lecturer: Dott. FABIO D'ALESSI

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP7080377/NO

STRUCTURAL BIOINFORMATICS

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

Lecturer: Prof. DAMIANO PIOVESAN

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP7079278/NO

TYPE THEORY

Master's degree in COMPUTER SCIENCE ORD. 2021, Second semester

Lecturer: Prof.ssa MARIA EMILIA MAIETTI

Credits: 6 ECTS

Prerequisites: It is recommended to have followed an introductory course on logic but it is not strictly necessary.

Short program:
In the course the student will be introduced to the main type-theoretic concepts in order to being able to appreciate some key relevant applications of type theory in computer science, mathematics and even philosophy. He will be able to grasp the following aspects of the multifaceted nature of type theory: 1) The computational nature of type theory seen a typed-lambda calculus a' la Church: type theory will be presented as a paradigm of a functional programming where to type programs with their specification in order to verify their correctness in computer-aided way. 2) The set-theoretic nature of type theory which makes it suitable to formalize proofs done in constructive mathematics and to extract their computational contents. 3) The predicative nature of dependent type theory a' la Martin-Löf where types are defined in terms of an inductive generation process which extends recursive definitions. Examples of non-predicative constructions will be described by employing the use of paradoxes. 4) The availability of intensional versions of type theory and extensional ones. These versions allows to get some decidable properties of type-checking useful to build a feasible and trustable proof-assistant to formalize mathematical proofs expressed in an every-day mathematical language in a computer-aided way. The course will include a laboratory activity which will introduce the students to the use of a proof-assistant (the French Coq or the Italian Matita or the Swedish Agda).

Examination:
Oral examination after completing some recommended exercises presented during the lectures.

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ1098250/NO

VISION AND COGNITIVE SYSTEMS
Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

Lecturer: Prof. LAMBERTO BALLAN

Credits: 6 ECTS

Prerequisites:
The student should have basic knowledge of computer programming and algorithms, as well as mathematics, probability theory and statistics, linear algebra. It is also advisable to be familiar with basic concepts in machine learning and pattern recognition.

Short program:
The course will cover the topics listed below: - Introduction: From human cognition to machine intelligence and cognitive systems; brief intro to artificial intelligence, cognitive computing and machine learning; the AI revolution: current trends and applications, major challenges. - Cognitive Services: Basic concepts; Language, Speech, and Vision services; major providers and APIs (IBM Watson, AWS, Google Cloud); enabling technologies. - Machine Learning and applications: Classification; intro to deep learning and representation learning; training and testing; evaluation measures; algorithm bias. - Early Vision and Image Processing: Machine perception; image formation, sampling, filtering and linear operators; image gradients, edges, corners; designing effective visual features (SIFT and gradient based features); image matching. - Visual Recognition and beyond: "Teaching computers to see": bag-of-features, spatial pyramids and pooling; representation learning in computer vision, convolutional neural networks; R-CNN and segmentation; image captioning, multi-modal scenarios and beyond the fully-supervised learning paradigm. - Hands-on Practicals: What's in the box? How to build a visual recognition pipeline; using cognitive services for image recognition/understanding; combining different services and modalities.

Examination:
The student is expected to develop, in agreement with the instructor, a small applicative project. In addition, the student must submit a written report on the project, addressing in a critical fashion all the issues dealt with during its development. During the exam students are asked to present and discuss their project, and answer a few questions about the topics addressed in class.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ1097939/NO

WEB INFORMATION MANAGEMENT

Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

Lecturer: Prof. MASSIMO MARCHIORI

Credits: 6 ECTS

More Information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCP6076298/NO

WIRELESS NETWORKS FOR MOBILE APPLICATIONS

Master's degree in COMPUTER SCIENCE ORD. 2021, First semester

Lecturer: Prof. CLAUDIO ENRICO PALAZZI

Credits: 6 ECTS

Prerequisites:
Computer Networks

Short program:

Examination:
Students are evaluated through individual/team projects and oral finals focused on all the topics discussed in class.

More Information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2598/000ZZ/SCQ0093642/NO

CYBERSECURITY (ORD. 2020)
Master's degree in **CYBERSECURITY (ORD. 2020)**, Second semester

**Lecturer:** Prof. SIMONE MILANI  
**Credits:** 6 ECTS  
**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2542/000ZZ/SCQ0099500/NO

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**COGNITION AND COMPUTATION**

Master's degree in **CYBERSECURITY (ORD. 2020)**, First semester  
**Lecturer:** Prof. MARCO ZORZI  
**Credits:** 6 ECTS  
**Prerequisites:**  
The course requires preliminary knowledge of machine learning and probability theory. Familiarity with basic concepts of cognition and neuroscience may facilitate the understanding of the topics covered by the course.  
**Short program:**  
1. Introduction: computational and mathematical modeling in cognitive science and cognitive neuroscience. Overview of symbolic, emergentist and probabilistic approaches to simulate human cognition. 2. Probabilistic models of cognition: basics of Bayesian inference and probabilistic graphical models; inductive learning; probabilistic programming. 3. Neural network models of cognition: basics of neural computation; learning in neural networks; deep learning architectures. 4. Information coding in cognitive architectures: efficient coding, probabilistic coding, predictive coding. 5. Case studies: models of human perception and concept learning; language acquisition and language understanding; causal reasoning and decision making.  
**Examination:**  
Examination will consist in a written exam including open questions and multiple-choice questions. Each student will also be required to write an individual essay (or project report) assigned during the course and submit it (through the course Moodle) no later than the day before the written exam.  
**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2542/000ZZ/SCQ0089498/NO

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**CYBERSECURITY AND CRYPTOGRAPHY: PRINCIPLES AND PRACTICES**

Master's degree in **CYBERSECURITY (ORD. 2020)**, First and Second semester  
**Lecturer:** Prof. ALESSANDRO LANGUASCO  
**Credits:** 12 ECTS  
**Prerequisites:**  
For the first part (Prof. Languasco; 6 credits): The topics of the following courses: Algebra (congruences, groups and cyclic groups, finite fields), Calculus (differential and integral calculus, numerical series) both for the BA in Mathematics. For the second part (Prof. Conti and Prof. (to be determined); 6 credits): OS, Programming.  
**Short program:**  
**Examination:**  
For the first part (Prof. Languasco; 6 credits): Written exam in class; if, due to the pandemic situation, this will not be possible the written exam will be done using the available videoconferencing tools. For the second part (Prof. Conti and Prof. (to be determined); 6 credits): Written Exam, Homeworks, oral test.  
**More information:**
ETHICAL HACKING

Master's degree in CYBERSECURITY (ORD. 2020), First semester

Lecturer: Dott.ssa ELEONORA LOSIOUK

Credits: 6 ECTS

Prerequisites:
No strict prerequisites on previous exams.

Short program:
The course will cover the following topics:
- Network security: network analysis and monitoring; securing internet communications; packet sniffing and spoofing; TCP attacks; firewalls
- Hardware security: meltdown attack; spectre attack
- Web security: cross-site scripting attack; HTTP request smuggling
- Pwn: shellcode; buffer overflow; return-to-libc; format string attack; race condition vulnerability
- Reverse-engineering: static and dynamic analysis techniques; reversing in x86; reversing; patching; gdb; debuggers; symbolic execution

Examination:
Students have two options. (Option 1) Practical exam, where students solve exercises on the topics presented during the course; (Option 2) Project, where students face a topic assigned by the Lecturers and illustrate the achieved results in an oral presentation.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2542/000ZZ/SCQ0089518/NO

PRIVACY PRESERVING INFORMATION ACCESS

Master's degree in CYBERSECURITY (ORD. 2020), First semester

Lecturer: Dott. GUGLIELMO FAGGIOLI

Credits: 6 ECTS

Prerequisites:
- 

Short program:
- 

Examination:
- 

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2542/000ZZ/SCQ2101279/NO

SECURITY AND RISK: MANAGEMENT AND CERTIFICATIONS

Master's degree in CYBERSECURITY (ORD. 2020), Second semester

Lecturer: Dott. SIMONE SODERI

Credits: 6 ECTS

Prerequisites:
No strict prerequisites on previous exams.

Short program:
The course deals with the assessment of cyber risks that can damage a corporate information system, the methodologies to mitigate these risks and the necessary countermeasures to be applied with the aim of making the company or public institution secure from an IT point of view. Gradually students will be introduced to principles, concepts, and practices for governing, managing, and auditing cybersecurity in accordance with international standards, generally accepted professional best practices, certifications and reference frameworks. Course program: - Course Introduction; - Basic Concepts; - Planning for Cybersecurity; - Cybersecurity Operations and Management; - Security Assessment and use cases; - Certification and Frameworks for Organizations and management systems; - Certification of products and technologies; - Frameworks that describe the competencies; - Certification of people; - Most common Certifications available on the market; - Audit techniques and approach examples.

Examination:
Students will take an exam at the end of the course. The final exam covers all material for the semester.
DATA SCIENCE ORD. 2017

BIOLOGICAL DATA

Master's degree in DATA SCIENCE ORD. 2017, First semester

Lecturer: Prof. DAMIANO PIOVESAN

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2377/000ZZ/SCP7079337/NO

BIOLOGICAL DATA

Master's degree in DATA SCIENCE ORD. 2017, First semester

Lecturer: Prof. DAMIANO PIOVESAN

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2377/000ZZ/SCP7079337/NO

COGNITIVE, BEHAVIORAL AND SOCIAL DATA

Master's degree in DATA SCIENCE ORD. 2017, First semester

Lecturer: Prof. GIUSEPPE SARTORI

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2377/000ZZ/SCP7079219/NO

BIOINFORMATICS

Master's degree in DATA SCIENCE ORD. 2017, First semester

Lecturer: Prof. GIORGIO VALLE

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2377/000ZZ/SCP7079405/NO

BUSINESS ECONOMIC AND FINANCIAL DATA

Master's degree in DATA SCIENCE ORD. 2017, First semester

Lecturer: Prof.ssa MARIANGELA GUIDOLIN

Credits: 6 ECTS
LAW AND DATA

Master's degree in **DATA SCIENCE ORD. 2017**, First semester

**Lecturer:** Dott.ssa ELISA SPILLER

**Credits:** 6 ECTS

**Prerequisites:**
CONTENT NOT PRESENT

**Short program:**
CONTENT NOT PRESENT

**Examination:**
CONTENT NOT PRESENT

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2377/000ZZ/SCP7079231/NO

PROCESS MINING

Master's degree in **DATA SCIENCE ORD. 2017**, First semester

**Lecturer:** Prof. MASSIMILIANO DE LEONI

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge of algorithms, data structure and programming, as acquired in course "Fundamental of Information Systems" o in Bachelor's degrees in Computer Science or similar

**Short program:**
The course will cover the topics listed below: 1. MODELING VIA PETRI NETS - Basic concepts of Petri nets - Usage of Petri Nets to model business processes - Structural analysis of Petri Nets - Soundness of business process models: Principles and Verification - Usage of Woped as software tool to model and check the soundness of process models. 2. PROCESS MINING - Introduction to Process Mining and Event Logs - Basic Techniques for Process Discovery and Limitations - Advanced Techniques for Process Discovery: Heuristic Miner and Region Miner - Conformance checking based on token replay - Conformance checking based on alignments - Mining the Additional Perspectives on Decision, Time and Resource - Social Network Analysis - Usage of open-source and commercial software tools for the analysis of business processes through Process Mining. 3. BUSINESS PROCESS SIMULATION - Principle and Methodologies for simulation: definitions of warm-up and cool-down intervals, management of the simulation stochasticity via multiple, independent runs, analysis of the outcome - Definitions of the elements of a scenario of business process simulation: arrival rate, branching probabilities, resource pools, activity-duration probability distributions - Usage of BPMN for the specification of business process simulation models - Use of Process Mining to mine business process simulation models - Methodologies for the definition of "What-if" scenarios - Usage of BIMP as software tool to simulate business processes.

**Examination:**
Written Exam and Project

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2377/000ZZ/SCP7079399/NO

VISION AND COGNITIVE SYSTEMS

Master's degree in **DATA SCIENCE ORD. 2017**, First semester

**Lecturer:** Prof. LAMBERTO BALLAN

**Credits:** 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2377/000ZZ/SCQ1097939/NO

COGNITIVE, BEHAVIORAL AND SOCIAL DATA
HUMAN DATA ANALYTICS

Master's degree in DATA SCIENCE ORD. 2017, First semester

Lecturer: Prof. MICHELE ROSSI

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2377/000ZZ/SCP7079397/NO

OPTIMIZATION FOR DATA SCIENCE

Master's degree in DATA SCIENCE ORD. 2017, Second semester

Lecturer: Prof. FRANCESCO RINALDI

Credits: 6 ECTS

Prerequisites:
Basic knowledge of - Real Analysis and Calculus; - Linear Algebra; - Probability theory.

Short program:
1. Convex sets and convex functions (a) Convexity: basic notions; (c) Convex functions: Basic notions and properties (gradients, Hessians..); 2. Unconstrained convex optimization (a) Models in data science; (b) Characterizations of optimal sets; (c) Gradient-type methods; (d) Block coordinate gradient methods; (e) Stochastic optimization methods; 3. Constrained convex optimization (a) Models in data science; (b) Characterizations of optimal sets; (c) Polyhedral approximation methods; (d) Gradient projection methods; 4. Large scale network optimization (a) Network models in data science; (b) Methods for distributed optimization.

Examination:
- Written exam - Homeworks - Project (Optional) 1) Homeworks will periodically be assigned based on reading and lecture and will be due at given deadlines. 2) Written exam consists of 4 open questions. 3) Project (optional) can be requested to better analyze specific topics. Written exams represents 85% of grade. Homeworks represent 15% of grade. Project can integrate/replace the written exam.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2377/000ZZ/SCP7079229/NO

STATISTICAL METHODS FOR HIGH DIMENSIONAL DATA

Master's degree in DATA SCIENCE ORD. 2017, First semester

Lecturer: Prof. BRUNO SCARPA

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2377/000ZZ/SCP9087918/NO

ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021

COASTAL ENVIRONMENTS UNDER CLIMATE CHANGE
Master's degree in **ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021**, First semester

**EARTH SURFACE PROCESSES AND DEPOSITS**

Lecturer: Dott. ALVISE FINOTELLO  
Credits: 6 ECTS  
Prerequisites:  
Short program:  
Examination:  
More information:  

**ENVIRONMENTAL SUSTAINABILITY AND EDUCATION ORD. 2022**

**ENVIRONMENTAL BIOGEOGRAPHY**

Lecturer: Dott. FRANCESCO DAL GRANDE  
Credits: 6 ECTS  
Prerequisites:  
Basic knowledge of diversity of current living organisms (flora and fauna), basic ecology.  
Short program:  
- characteristics of European biodiversity, with reference to the main taxonomic groups present: - geographical diversity of the main taxonomic groups of Plants (angiosperms, gymnosperms, pteridophytes, bryophytes) and of Animals (mammals, birds, reptiles, amphibians, fish, insects, crustaceans, other arthropods, molluscs, etc.) present in Europe (e.g. overview of phytosociological alliances and their relationships with habitats in the European Nature Information System) in relation to environmental diversity and active processes.  
- spatial and temporal distribution of taxa, life forms, communities, biomes and natural or human-influenced ecosystems - patterns and dynamics of change in European flora and fauna over the last 15,000 years; - biogeographical regions of Europe; principles of their creation and development; - latitudinal and altimetric gradient concepts of biodiversity; - biodiversity scenarios for the 21st century; - EU 2030 Biodiversity Strategy; - Basic principles for studying biodiversity in the age of Big Data: advancing biogeography through high-throughput methodologies.  
Examination:  
Two partial examinations, one for each of the two parts, with the respective lecturers: Each partial examination will be oral for a total duration of approximately 30 minutes.  
More information:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2650/000ZZ/SCQ2101582/NO

**ETHICS AND ENVIRONMENTAL ECONOMICS**

Lecturer: to be defined
METHODS FOR WILDLIFE MONITORING

Master's degree in ENVIRONMENTAL SUSTAINABILITY AND EDUCATION ORD. 2022, Second semester
Lecturer: Prof. LUCIO BONATO
Credits: 12 ECTS

Prerequisites:
Basic knowledge on: diversity of extant living organisms, especially with respect to development and reproductive biology, ecology, behaviour; methods and tools of statistical analysis and data georeferentiation. Therefore it is strongly recommended to have already attended the following courses of the 1st year of the programme: Environmental Biogeography, Applied Ecology and Ecosystem Services, Applied Statistics for Natural Sciences.

Short program:
- general approaches and critical issues in searching, detecting, identifying, censusing and monitoring wildlife in the field; - main methods, tools and standards for searching, detecting, identifying, and censusing populations of species of the main ecological groups of fauna and flora, focussing on terrestrial and freshwater habitats: mammals, birds, fish, amphibians and reptiles, freshwater macroinvertebrates, soil arthropods, butterflies, dragonflies, beetles, algae, vascular plants, lichens; - methods for assessment of composition and structure of biocenoses, for zoonoses and vegetation; - designing and planning surveys and monitoring programs on species or communities in an area; - methods for bibliographic search; conventions and standard for communication of the results.

Examination:
Two partial examinations, one for each of two parts, with the respective teachers: - First part (7 CFU): general concepts and methodology, and specific methods for animals - Second part (5 CFU): specific methods for plants and vegetation Each partial examination will be oral and will comprise open questions, on at least five different topics chosen by the teacher within the program, for a total duration of about 30 minutes. The overall score will be calculated as the weighted average of the two partial scores of the two partial examinations (the weights will be proportional to the number of CFUs of the two parts). I.e.: overall score = 0.6 x (score of 1st part) + 0.4 x (score of 2nd part). The overall score will be approximated to the nearest unit.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2650/000ZZ/SCQ2101511/NO

EVOLUTIONARY BIOLOGY ORD. 2018

BEHAVIOURAL GENETICS

Master's degree in EVOLUTIONARY BIOLOGY ORD. 2018, First semester
Lecturer: Prof. MAURO AGOSTINO ZORDAN
Credits: 8 ECTS

Prerequisites:
Basic Genetics and possibly also Population Genetics. Ideally some background in programming with R (Rstudio)

Short program:
- Introduction to behavioural genetics: - Historical introduction: - Francis Galton, eugenics, racial laws and Nazism, behaviourism, birth of behavioural genetics; - Behaviour as gene-environment interaction (nature-nurture): Studies on human families - MZ and DZ twins and adoptive children; - Model organisms in behavioural genetics: Caenorhabditis, Drosophila, Zebrafish, mammals: rat, mouse, dog (behaviour and domestication). - Genetics of quantitative characters in the study of behaviour (behavioural quantitative traits) - Types of quantitative characters - Similarity between relatives and the concept of heritability - Artificial selection and realized heritability - Equation for the prediction of individual selection - Genetic models for quantitative characters - Components of phenotypic variation - Sources of genetic and environmental variation - Components of genetic variation - Covariance between relatives - Studies on twins and inferences on human heritability - Norm of reaction, threshold characters and genetic correlation - Norm of reaction and phenotypic plasticity - Threshold characters: Genes as risk factors in disease - Genetic correlation and correlated response - How to identify genes? Single genes or multiple genes? - Genes which influence quantitative characters - The number of genes which influence quantitative traits - Methods for mapping
(Quantitative Trait Loci) QTL - Candidate genes - Genome Wide Association (GWA) - Single Nucleotide Polymorphisms (SNP) - Physiological behaviour and its variations, considering also pathological aspects of selected behaviours - circadian rhythms, sleep - learning and memory - socialization, aggressiveness - locomotion - orientation and navigation - sexual orientation - seeking novelties - Description of the molecular mechanisms and the neuronal circuits involved in the control of some of the behavioural patterns described in the preceding section. - Practicals: Methods to study behaviour in animal models (partly taught class, partly laboratory simulations) - Design of equipment, computer hardware and software, numerical and statistical analysis of data (i.e. videos, movement tracking).

Examination:
Written exam, at the end of the course, using the Moodle platform.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1179/000ZZ/SCQ1097221/NO

COMPARATIVE PHYSIOLOGY

Master’s degree in EVOLUTIONARY BIOLOGY ORD. 2018, First semester

Lecturer: Prof.ssa ELISA GREGGIO

Credits: 6 ECTS

Prerequisites:
Knowledge of General Physiology, Physics (especially the fluid dynamics), Cell Biology (in particular the trans-membrane transport systems), Biochemistry, Zoology and Evolutionary History of Vertebrates.

Short program:
The contents of the program are divided into 4 parts: 1) Introduction (0.5 CFU). Adaptation responses to the environment. Concept of homeostasis. The perception of the environment (1.5 CFU). Relationship between sensory structures and adaptive needs. Photoreception; Mechanoreception; electroreception; thermoception; chemoreception; magnetoreception. The characteristics of the sensory organs will be discussed in an adaptive and comparative key. 3) The exchange of gas and their transport (1.5 ECTS). Respiratory systems: surfaces and mechanisms for the exchange and transport of respiratory gases; animals with aquatic and aerial respiration; respiratory mechanics; gas exchange and transport; breathing control and acid-base regulation; adaptation to diving. 4) Osmoregulation and excretion (1.5 CFU). Elimination of nitrogen compounds; osmoregulation problems in extreme environments; osmoregulation and osmoconformity in aquatic animals; gills as a system of osmoregulation in aquatic animals; renal excretory organs; function of the nephron of mammals; urinary systems of other vertebrates and extrarenal organs; nervous and endocrine regulation.

Examination:
The evaluation will be a written test with 6 open questions followed by an oral exam if necessary.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1179/000ZZ/SCP8084977/NO

ETHOLOGY

Master’s degree in EVOLUTIONARY BIOLOGY ORD. 2018, First semester

Lecturer: Prof. ANDREA AUGUSTO PILASTRO

Credits: 6 ECTS

Prerequisites:
Good knowledge in evolutionary biology, ecology, genetics, and zoology (advanced undergraduate course level)

Short program:
Main topics will regard the link between animal behaviour ecology and evolution, the development and control of behaviour: genes environment and neural mechanisms, the evolution of animal signals, adaptive responses to predators, foraging behaviour and optimality models, reproductive behaviour: male and female tactics, mating systems, parental care, sperm competition and sexual selection, sexual conflict, social behaviour, kin selection.

Examination:
Written test

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1179/000ZZ/SCN1031442/NO

EVOLUTION AND CONSERVATION

Master’s degree in EVOLUTIONARY BIOLOGY ORD. 2018, First semester

Lecturer: Prof. GIL GUASTONI ROSENTHAL

Credits: 6 ECTS

Prerequisites:
Good knowledge in evolutionary biology, ecology, genetics, zoology and botany (advanced undergraduate course level)

Short program:
Lectures will be in English. While evolutionary biology has important theoretical and practical implications in conservation, it has often been neglected. The reason for this probably originates from the mistaken belief that evolution acts too slowly to be relevant on an ecological timescale. In this course we will combine the fields of evolutionary and conservation biology to emphasize the importance of evolutionary theories in conservation programs. This course will therefore focus on genetic and evolutionary applications to the problems of conservation, while reflecting the diversity of concerns that are relevant to conservation biology. Particular emphasis will be put on themes like measures of phylogenetic diversity and uniqueness, population genetic structure of natural and managed populations including the identification of ‘evolutionary significant units’ and ‘management units’ for conservation, assessment of levels of genetic variation within species and populations. Description of the main genetic processes associated with conservation. Management of genetic diversity for conservation purposes. Genetic markers for the study of diversity. Ex situ management of residual genetic diversity. Assessments of the effect of sexual selection, mate choice and reproductive strategy on population conservation, forensic applications, methods for maximising genetic diversity during captive breeding programs and re-introduction schemes, effect of anthropogenic factors on evolutionary adaptation to local changes in the environment.

Examination:
Evaluation based on written exam. Oral test possible if required by the student (please contact the teacher in advance).

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1179/000ZZ/SCO2043741/NO

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Molecular Phylogeny

Master's degree in EVOLUTIONARY BIOLOGY ORD. 2018, Second semester

Lecturer: Prof. ALESSANDRO GRAPPUTO

Credits: 8 ECTS

Prerequisites:
It would be useful to have acquired basic knowledge of Genetics, Evolutionary Biology, Systematics and Bioinformatics

Short program:
The course is subdivided in two parts; one of a series of frontal lectures (48 hours) and one of practical experience in a laboratory (32 hours of which 16 h will be online). The study of molecular evolution is a field of research that merges the most recent progress in molecular biology with those in bioinformatics. In the course will be shown the principal of molecular evolution ad phylogeny. In particular will be considered: the divergent type of molecular data and the techniques for their acquisition; the alignment of sequences; the comparison of DNA and protein sequences to calculate the genetic distance; the mechanisms of molecular evolution and the theory of neutrality; the models of nucleotide substitution; the molecular identification of species (barcoding of life); The phylogenetic reconstruction methods of maximum parsimony, genetic distance, maximum likelihood and Bayesian inference; the concept of molecular clock; trees and supertrees; the positive selection at the molecular level and the methods to identify it, genome sequencing projects and phylogenomics; Phylogeny of key taxonomic groups and examples of recent phylogenetic works. Laboratory: Molecular identification of species (barcoding); genomic DNA extraction from unidentified samples, PCR and sequencing of mitochondrial genes; Bioinformatics lab of which 2 sessions in presence (8h) and 4 sessions online (16h): In presence: chromatogram reading and analysis; use of GenBank and the barcode database BOLD to identify species and other specific softwares; Online: Phylogenetic reconstruction with the main algorithms using MEGA, MrBayes and Fasttree. Use of the software BEAST to date evolutionary events with molecular data.

Examination:
The student assessment will be achieved by a written examination on a PC using the e-learning platform. The test will consist of 9 questions: 6 questions with open answer to assess the acquired knowledge, comprehension and ability to synthesize the concepts developed during the course 3 more focused questions on the interpretation of examples of phylogenetic relationships of specific taxonomic groups and the methods to reconstruct the tree.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1179/000ZZ/SCP8084997/NO

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GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)

Master's degree in GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020), Second semester

Lecturer: Prof.ssa RITA DEIANA

Credits: 6 ECTS

GEOPHYSICS FOR CULTURAL HERITAGE AND CIVIL ENGINEERING

Master's degree in GEOPHYSICS FOR CULTURAL HERITAGE AND CIVIL ENGINEERING, Second semester

Lecturer: Prof.ssa RITA DEIANA

Credits: 6 ECTS
## ADVANCED STATISTICS FOR PHYSICS ANALYSIS

Master's degree in **GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)**, Second semester  

**Lecturer:** Prof. ALBERTO GARFAGNINI  
**Credits:** 6 ECTS  

[More information](https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ1098758/NO)

## APPLIED GEODESY

Master's degree in **GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)**, Second semester  

**Lecturer:** to be defined  
**Credits:** 6 ECTS  
**Prerequisites:**  
-  
**Short program:**  
-  
**Examination:**  
-  

[More information](https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCP8082557/NO)

## APPLIED GEOPHYSICS

Master's degree in **GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)**, First semester  

**Lecturer:** Prof. GIORGIO CASSIANI  
**Credits:** 9 ECTS  

[More information](https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089219/NO)

## APPLIED HYDROLOGY

Master's degree in **GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)**, Second semester  

**Lecturer:** Prof. ANDREA D'ALPAOS  
**Credits:** 6 ECTS  

[More information](https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089235/NO)

## EARTHQUAKE GEOLOGY AND FAULT MECHANICS

Master's degree in **GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)**, First semester  

**Lecturer:** Prof. GIULIO DI TORO  
**Credits:** 6 ECTS
# Electromagnetism

**Master's degree in** Geophysics for Natural Risks and Resources (Ord. 2020), Second semester  
**Lecturer:** Dott. Alvise Raccanelli  
**Credits:** 6 ECTS  

More information:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ1098476/NO

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# Environmental and Engineering Geophysics

**Master's degree in** Geophysics for Natural Risks and Resources (Ord. 2020), First semester  
**Lecturer:** Prof. Jacopo Boaga  
**Credits:** 9 ECTS  

**Prerequisites:**  
Prerequisites are: the course of Applied Geophysics (1 year)  

**Short program:**  
The course has 3 parts: Part 1: Introduction to exploration geophysics methods and instruments for natural risk. Geophysical methods for hydrological risk and soil characterization for environmental aims. Part 2: Applied geophysics for the seismic risk. Introduction to applied seismology, seismic hazard and seismic risk. The seismic hazard in Italy and Europe. Global and local hazard maps. Response seismic scenarios. Coupled effects of seismic motion. Seismic response spectra. Geophysical methods for the seismic soil classification and for the local seismic response analysis. Part 3. Practical field work and exercise for the acquisition, the processing and the analysis of geophysical data for soil characterization. The course will focus on applied aspects of the several techniques with examples from literature and from teacher experiences. The methods will be compared in terms of limits and goals, in order to drive the most suitable choice of investigation case by case.  

**Examination:**  
Oral examination with discussion of a scientific paper from a list proposed by the Teacher.  

More information:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089230/NO

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# Exploration Seismology

**Master's degree in** Geophysics for Natural Risks and Resources (Ord. 2020), First semester  
**Lecturer:** Dott.ssa Ilaria Barone  
**Credits:** 6 ECTS  

More information:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089233/NO

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# Finale Exam

**Master's degree in** Geophysics for Natural Risks and Resources (Ord. 2020), Second semester  
**Lecturer:** to be defined  
**Credits:** 24 ECTS  

**Prerequisites:**  
-  

**Short program:**  
-
Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089258/NO

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**GEOLOGY FOR GEOPHYSICS**

Master's degree in **GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)**, First semester

**Lecturer:** Dott. VALERIO OLIVETTI

**Credits:** 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089221/NO

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**GEORESOURCES**

Master's degree in **GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)**, Second semester

**Lecturer:** Prof. MASSIMILIANO ZATTIN

**Credits:** 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089225/NO

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**GEOTECHNICS**

Master's degree in **GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)**, Second semester

**Lecturer:** Dott.ssa GIORGIA DALLA SANTA

**Credits:** 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089228/NO

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**GEOTHERMICS**

Master's degree in **GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)**, First semester

**Lecturer:** Prof. ANTONIO GALGARO

**Credits:** 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089232/NO

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**HIGH LEVEL PROGRAMMING**

Master's degree in **GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)**, First semester

**Lecturer:** Prof. MARCO ZANETTI

**Credits:** 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089439/NO
MACHINE LEARNING

Master's degree in GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020), First semester

Lecturer: Prof. PIETRO ZANUTTIGH

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCP8082660/NO

MANAGEMENT AND ANALYSIS OF PHYSICS DATASETS

Master's degree in GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020), Second semester

Lecturer: Dott. JACOPO PAZZINI

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089438/NO

MATHEMATICAL PHYSICS FOR THE EARTH SYSTEM

Master's degree in GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020), First semester

Lecturer: Prof. LAPO BOSCHI

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089222/NO

NUMERICAL METHODS FOR CONTINUOUS SYSTEMS

Master's degree in GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020), Second semester

Lecturer: Prof.ssa ANTONIA LARESE DE TETTO

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089198/NO

NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS

Master's degree in GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020), First semester

Lecturer: Dott. LUCA BERGAMASCHI

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089204/NO

NUMERICAL METHODS FOR GEOSCIENCES

Master's degree in GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020), Second semester

Lecturer: Prof. MANUELE FACCENDA
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<td>Prof. CARLO JANNA</td>
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<td>Dott.ssa ELOISA DI SIPIO</td>
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<td>First</td>
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<td>Dott. ANDREA TRIOSSI</td>
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SEISMIC RESPONSE OF BUILT STRUCTURES

Master's degree in GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020), First semester

Lecturer: Prof.ssa FRANCESCA DA PORTO

Credits: 6 ECTS

Prerequisites: -

Short program: -

Examination: -

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089440/NO

SOLID EARTH GEOPHYSICS

Master's degree in GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020), First semester

Lecturer: Dott. PIERO POLI

Credits: 9 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089227/NO

STATISTICAL MECHANICS OF COMPLEX SYSTEMS

Master's degree in GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020), Second semester

Lecturer: Prof. AMOS MARITAN

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCQ0089218/NO

STRUCTURE AND COMPOSITION OF THE DEEP EARTH

Master's degree in GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020), Second semester

Lecturer: Prof. FABRIZIO NESTOLA

Credits: 6 ECTS

Prerequisites: -

Short program: -

Examination: -

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2543/000ZZ/SCP8082536/NO
**METAGENOMICS AND INTERACTOMICS**

Master's degree in **INDUSTRIAL BIOTECHNOLOGY ORD. 2014**, First semester

**Lecturer:** Prof.ssa LAURA CENDRON

**Credits:** 6 ECTS

**Prerequisites:**
The Metagenomics module requires basic knowledge of molecular biology, microbiology and bioinformatics. The Interactomics module requires basic knowledge inherent in protein chemistry, covalent and non-covalent bonds, basic knowledge in biochemistry and physical chemistry.

**Short program:**
Introduction to metagenomics: application of various next-generation sequencing methods (second and third generation) including marker genes, total DNA and RNA-seq. Basic concepts related to the analysis of microbial communities’ structure, ecological indices, similarity measures. Amplicon sequencing analysis based on marker genes (16S rRNA, 18S rRNA, ITS). General discussion and use of specific software (QIIME, PICRUSt). Shotgun data analysis: approaches with and without the assembly process. Procedure of “binning” of metagenomic data: the challenge of complexity and the extraction of single genomes from the microbiome. Analysis of meta-transcriptomics data to have gene expression at the community level. Case studies: structure of the microbiome in environments of interest. Anaerobic digestion: degradation of organic matter by a microbiome composed of bacteria and archaea. Aquatic and soil environment: the complexity of the microbiome as approaches have changed over the years for environmental investigations and influences on the microbiome because of contamination. The human gut: the microbiome and its role in determining pathological states. Viromics: meta-approach from shotgun data and taxonomy. Conclusions and final remarks.

**Examination:**
Final test will be based on written examination, questions will evaluate acquired knowledge, ability to summarize answers and critical discussion. Test is based on topics covered during the course.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1731/000ZZ/SCQ0093458/NO

**PLANT ENGINEERING AND PHYTOREMEDIATION**

Master's degree in **INDUSTRIAL BIOTECHNOLOGY ORD. 2014**, First semester

**Lecturer:** Prof.ssa ELIDE FORMENTIN

**Credits:** 6 ECTS

**Prerequisites:** none

**Short program:**
Genetic engineering of plants aimed at applications in industry and agriculture - Introduction to environmental stresses with a focus on abiotic stresses. - Introduction to the transport mechanisms of water and solutes through biological membranes. - Plant responses to environmental stress: in particular the issues of water stress and oxidative stress at the molecular level will be addressed. - Molecular physiology of mineral nutrients, their absorption, transport and utilization. - Toxicity of pollutants and plant responses. - Genetic improvement for the use of plants for phytoremediation, cultivation in marginal land or the production of secondary metabolites for the pharmaceutical and cosmetic industry Phytoremediation. - Use of plants to decontaminate soils and water by containment, degradation or removal of the contaminant. - Examples of application of phytoremediation techniques.

**Examination:**
The exam is divided into two parts: 1. presentation and critical analysis of some works of literature (journal club). 2. written exam on the course contents.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1731/000ZZ/SCQ0093438/NO

**BIOENERGY PRODUCTION**
Master's degree in INDUSTRIAL BIOTECHNOLOGY ORD. 2014, First semester

Lecturer: Prof. TOMAS MOROSINOTTO

Credits: 6 ECTS

Prerequisites:
No specific prerequisites. Students should have a general background in basics of chemistry, metabolism, methods for genetic modification, plant biology.

Short program:
Introduction: current energy sources and the necessity of renewable fuels. Non-renewable resources (oil, natural gas, coal) and main processes for their transformation. Biotechnology for energy production: Hydrogen production from algae and bacteria. Production of bioethanol from ligno-cellulosic biomass. Production of biodiesel from oleaginous crops. Algae as biofuels producers. Evaluation of advantages and disadvantages with respect to plants. Production of biogas. Production of bio-syngas from ligno-cellulosic biomass. The biotechnological challenges for biofuels production: the optimization of conversion of solar into chemical energy. Examples of genetic engineering for biofuels. Exploitation of unicellular algae for wastewater treatment and bioremediation. The laboratory experiments will be as follows: - Biodiesel production from spent vegetable oil - Bioethanol production from corn starch

Examination:
The evaluation consists of two parts: 1. open-question written test on the class contents. 2. optional presentation and critical analysis of some recent scientific papers.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1731/000ZZ/SCQ1098018/NO

BIOREMEDIATION

Master's degree in INDUSTRIAL BIOTECHNOLOGY ORD. 2014, First semester

Lecturer: Prof.ssa PAOLA VENIER

Credits: 6 ECTS

Prerequisites:
The course Biochemical Reactors is a prerequisite. The course Genetic toxicology and Environmental chemistry is highly recommended. This is a multidisciplinary course facilitated by notions of environmental chemistry, microbiology, biochemistry, and toxicology.

Short program:

Examination:
The oral exam will be an interview on Part A and Part B. The student will discuss a case or a project of bioremediation mediated by microorganisms, to be previously agreed with the two teachers and aimed at evaluating the knowledge/skills acquired by the student during the course. The exam mode may change in an emergency.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1731/000ZZ/SCP9088082/NO

ENVIRONMENTAL PLANT BIOTECHNOLOGY

Master's degree in INDUSTRIAL BIOTECHNOLOGY ORD. 2014, Second semester

Lecturer: Prof. ALESSANDRO ALBORESI

Credits: 6 ECTS

Prerequisites:
Basic knowledge of Plant Physiology is recommended.

Short program:
The course will provide a general introduction to the major physical phenomena associated with global climate change that threaten the survival of certain species and limit crop productivity. Main challenges for our society are related to the characteristics and speed of global climate change. The following parameters will be considered: increase in atmospheric carbon dioxide concentration and other greenhouse gases; temperature increase; acidification of water (both marine and rain); ozone and stress from UV rays. During the course, the physiological limits of living organisms will be discussed. The concepts acquired in the general part will be applied to think at biotechnological strategies to improve plant productivity and plant stress resistance. (1) In order to generate crops and specimen adapted to current global climate change, several strategies will be considered. Constant monitoring of biodiversity allows the identification of species at greater risk of extinction and species with interesting characteristics. Flowering time and control of flower development is influenced by climate change and they have an impact on plant-animal interaction. Strategies to improve carbon dioxide fixation to improve plant productivity. Seed physiology for the control of soil seed bank and plant productivity. Plant resistance to desertification, water stress and resistance of plants to global warming. The role of epigenetic control will be considered. Plant resistance to flooding. (2) In order to reduce the environmental impact of modern agricultural practices, various possibilities will be considered. Algae and plants as indicators of global climate change. Improving crop nutrient efficiency through root architecture modifications. Phosphorus acquisition efficiency. The symbiotic associations between host plants and arbuscular mycorrhiza fungi/rhizobial bacteria as additional important strategies to enhance nutrient acquisition.

Examination:
Oral presentation on a relevant topic proposed by the student. Written test related to the topics covered during lectures.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1731/000ZZ/SCQ0093380/NO

### GENETIC TOXICOLOGY AND ENVIRONMENTAL CHEMISTRY

Master's degree in **INDUSTRIAL BIOTECHNOLOGY ORD. 2014**, Second semester

**Lecturer:** Prof.ssa PAOLA VENIER

**Credits:** 6 ECTS

**Prerequisites:**

**Short program:**
The following contents will be proposed in greater or lesser detail depending on the students' starting skills and curiosity. Part A (CHIM). Chemico-physical properties and main descriptor parameters in environmental chemistry. Evaluation of the distribution of pollutants in air, water, and soil. Chemical speciation and its influence on the distribution of contaminants in the environment and their toxicity. Examples and case studies (1.5 CFU). Macro and micro-pollutants of the environment: organic compounds, metals, emerging pollutants. Radionuclides and sources of radioactive pollution. European regulatory aspects. Examples of pollutants and case studies (1.5 CFU). Part B (BIO). Variety of toxic agents and possible adverse effects at different levels of biological organization. Toxicokinetics and toxicodynamics (in general). Biological targets, measures of exposure, effect, and susceptibility. Dose-response relationships with/without threshold, hormesis. Hazard, risk, damage. Symbols and safety rules. Criteria and methods for the identification of toxic agents, with particular attention to genetic and reproductive toxicology (1.5 CFU). Effects and responses induced by toxic chemical agents: examples selected among metalloids, metals, organic compounds, toxins. Microbial bioremediation (hints) (1.5 CFU).

**Examination:**
The exam will focus on Part A (CHIM, 3 CFU) and Part B (BIO, 3 CFU). The student will also discuss a topic chosen in agreement with the teachers during the course, based on scientific literature and related to both exam parts (for part B: toxic agent or biological process intended as function and dysfunction or method of investigation). Effective illustration of biotechnological and bioremediation aspects will be positively considered. Under emergency conditions, the examination mode may change.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1731/000ZZ/SCQ1097998/NO

### NANOSYSTEMS

Master's degree in **INDUSTRIAL BIOTECHNOLOGY ORD. 2014**, Second semester

**Lecturer:** Prof.ssa SABRINA ANTONELLO

**Credits:** 6 ECTS

**Prerequisites:**
B.Sc. level knowledge of Physical Chemistry and Organic Chemistry.
**Short program:**

**Examination:**
Written exam based on a series of tests, to be taken during the semester, and one final, to be taken on the first official date. Each test consists usually in four open questions that could require to draw graphs, report equations and make simple calculations.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1731/000ZZ/SCQ1097952/NO

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**INDUSTRIAL CHEMISTRY ORD. 2015**

### ADVANCED ORGANIC SYNTHESIS

Master's degree in **INDUSTRIAL CHEMISTRY ORD. 2015**, First semester

**Lecturer:** Dott. LUCA DELL’AMICO

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1170/000ZZ/SCQ2101101/NO

### ANALYTICAL CHEMISTRY OF INDUSTRIAL PROCESSES

Master's degree in **INDUSTRIAL CHEMISTRY ORD. 2015**, Second semester

**Lecturer:** Prof. MARCO FRASCONI

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1170/000ZZ/SCP9087648/NO

### BIOPOLYMERS

Master's degree in **INDUSTRIAL CHEMISTRY ORD. 2015**, First semester

**Lecturer:** to be defined

**Credits:** 6 ECTS

**Prerequisites:**
- 

**Short program:**
- 

**Examination:**
-
BIOPOLYMERS

Master's degree in **INDUSTRIAL CHEMISTRY ORD. 2015**, First semester

**Lecturer:** to be defined

**Credits:** 6 ECTS

**Prerequisites:**
- 

**Short program:**
- 

**Examination:**
- 

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1170/000ZZ/SCP9087649/NO

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PHYSICAL METHODS IN ORGANIC CHEMISTRY

Master's degree in **INDUSTRIAL CHEMISTRY ORD. 2015**, First semester

**Lecturer:** Prof.ssa ESTER MAROTTA

**Credits:** 6 ECTS

**Prerequisites:** Good understanding of organic chemistry and basic concepts of NMR spectroscopy and mass spectrometry

**Short program:**

**Examination:**
Written test

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1170/000ZZ/SCP9087647/NO

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PHYSICAL METHODS IN ORGANIC CHEMISTRY

Master's degree in **INDUSTRIAL CHEMISTRY ORD. 2015**, First semester

**Lecturer:** Prof.ssa ESTER MAROTTA

**Credits:** 6 ECTS

**Prerequisites:**
- 

**Short program:**
- 

**Examination:**
- 

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1170/000ZZ/SCP9087647/NO

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### Biodiversity and Behaviour

**Master's degree in Marine Biology Ord. 2021, First semester**

**Lecturer:** Prof. Gil Guastoni Rosenthal

**Credits:** 8 ECTS

**Prerequisites:**
To successfully follow this course, students are recommended to have taken at least two previous courses in ecology and/or evolutionary biology.

**Short program:**
Microevolution: population and quantitative genetics; the key role of evolution in shaping biodiversity. Behavioral strategies; sexual selection; animal communication; cognitive mechanisms; quantitative models of decision making, optimal foraging, and game theory. Biodiversity as the web of complex interrelationships between organisms, the contribution of the study of animal behavior to understanding the concept of biodiversity. The study of reproductive behaviour, parental care, mimicry and social life, using the most modern concepts of behavioral ecology. Anthropic pressures on aquatic species and habitats. Anthropic impacts on aquatic species behavior.

**Examination:**
The evaluation is organized in two parts: - the oral presentation of an article relating to the topics covered in class; - a written test with 2 open questions

**More information:**
[https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093498/NO](https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093498/NO)

### Ecology and Physiology of Global Changes

**Master's degree in Marine Biology Ord. 2021, Second semester**

**Lecturer:** Prof.ssa Laura Airoldi

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge of Marine Ecology and Biochemistry and Animal Physiology.

**Short program:**
1st module Airoldi 1) Introduction 2) The main drivers of ocean change and their pressures on ocean ecosystems 3) The consequences of global changes on key marine systems and human welfare 4) Unique ecological conditions of marine urban ecosystems – changes in the physical and chemical environment; changes in biogenic habitat cover and biodiversity; losers and winners in urban habitats and the spread of invasive species; altered connectivity 5) Indicators of environmental quality in urban environments (e.g. the human footprint, the Ocean health index, etc) and the challenges of managing multiple stressors 6) Conservation and restoration in an rapidly changing context We will elaborate on some concepts through discussion groups of relevant papers 2nd module Santovito Physiological responses to environmental temperature changes: thermal relationships between an animal and its environment; effects of temperature and thermal adaptation; body temperature and tolerance to temperature variations; thermoreception; thermoregulation mechanisms; homeothermia, pectilothermia and heterothermia; adaptations to extreme environmental conditions. Physiological responses to the increase in the environmental CO2 concentration: chemical and protein buffers; regulation of the acid-base balance of body fluids; cellular defense systems against hypercapnia; environmental acidosis. Physiological responses to the variation of the environmental O2 concentration: the cellular defense systems against hypoxia and hypoxia.

**Examination:**
There will be 6 exam sessions during the year, two for each exam session. The assessment will consist in a written test with both open and closed questions, possibly followed by an oral evaluation. The contents presented, as well as the activities carried out during the discussion groups and practical sessions, will form an integral part of the study program. The exam may be taken separately for the 2 modules. The exam grade awarded may be refused up to a maximum of two times.

**More information:**
[https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093618/NO](https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093618/NO)

### Farming and Feeding of Aquatic Species

**Master's degree in Marine Biology Ord. 2021, First semester**

**Lecturer:** Dott. Marco Birolo

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge (bacelor degree) of chemistry and biochemistry, animal biology, anatomy and physiology of aquatic species. It is suggested to have
previously taken the exam of Production, Inspection and quality of farmed organism.

**Short program:**

**Examination:**
Written exam (multiple choice, open answers and exercises). Working students can ask to be examined in oral form in order to evaluate their knowledge and competencies obtained with teaching methods different from frontal lessons, laboratory experiences and technical visits to fish farms (i.e. study of books and multi-medial documents, discussion of working experiences). During the lesson period, students can select one argument concerning fishery and aquaculture activities or a cultured fish species and present to the other students a powerpoint presentation. The technical contents and the quality of presentation will be evaluated and will concur to the final score of the exam.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093501/NO

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**FISH REPRODUCTION IN AQUACULTURE**

Master's degree in **MARINE BIOLOGY ORD. 2021**, First semester

Lecturer: Prof.ssa DANIELA BERTOTTO

Credits: 8 ECTS

**Prerequisites:**
Students are required to have basic knowledge in anatomy and physiology of fishes.

**Short program:**
Theory lectures will focus on: Sexuality and reproductive patterns in fishes. Anatomy of fish reproductive organs. Reproductive cycles and gonadal development. Endocrinology of reproduction. Artificial fertilization. Environmental control of reproduction. Reproductive dysfunctions in captivity and hormonal therapies. Assessment of gamete quality and cryoconservation. Sex determination, sex reversal and induction of sterility in fishes. Chromosome manipulation in fish. Reproduction and stress. Hints of bony fish embryo and larval development. The reproduction of molluscs and crustaceans will also be covered in a basic way to provide essential information on the reproduction and the first breeding phases of these animals in farming conditions. Lab sessions will focus on the evaluation of pre and post fertilization gamete quality, on embryo and larval development and mating.

**Examination:**
The exam includes at least two open questions based on the topics covered, and aimed at assessing comprehension, critical thinking skills and the ability to identify interrelationships between issues, as well as a good command of scientific language.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093499/NO

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**LIFE CYCLES AND ADAPTATIONS OF MARINE ORGANISMS**

Master's degree in **MARINE BIOLOGY ORD. 2021**, Second semester

Lecturer: Prof. GIANFRANCO SANTOVITO

Credits: 10 ECTS

**Prerequisites:**
Knowledge of Physics (especially fluid dynamics), Biochemistry, Cell Biology, Botany, Zoology, General Physiology, Plant Physiology and General Ecology.

**Short program:**

**Examination:**
The verification will consist in a written test with open questions, eventually followed by an oral evaluation. Both the contents presented, and the activities carried out during practical sessions, will constitute an integral part of the study program.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093579/NO

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**MARINE BIODIVERSITY**

Master's degree in **MARINE BIOLOGY ORD. 2021**, First semester

**Lecturer:** Prof.ssa CARLOTTA MAZZOLDI

**Credits:** 9 ECTS

**Prerequisites:**
Knowledge of zoology, comparative anatomy, botany and systematic botany.

**Short program:**

**Examination:**
The evaluation consists of a written exam with open questions and a multiple-choice test. The questions will be focused on the knowledge of the course topics while the multiple-choice test will allow verifying the accurateness of the acquired knowledge.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093620/NO

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**MARINE CONSERVATION: PRINCIPLES AND APPLICATIONS**

Master's degree in **MARINE BIOLOGY ORD. 2021**, Second semester

**Lecturer:** Prof. ALBERTO BARAUSSE

**Credits:** 8 ECTS

**Prerequisites:**
No one.

**Short program:**
The course will focus on concepts and principles of marine conservation and management as well as on how they are applied, making use of real world examples and case studies whenever possible to show the management relevance of these topics. Principles of Marine Conservation: 1) Marine conservation, management and environmental protection 2) Major threats to marine biodiversity, such as climate change, fishing, alien species invasion, eutrophication, pollution, aquaculture, as well as recently recognized sources of impact (windfarms, etc.) 3) Extinction risks and drivers 4) The Ecosystem Approach 5) MPAs and spatial protection measures 6) Quantitative and modeling tools to support marine management and conservation: single species models, multispecies and ecosystem models, etc. 7) Stakeholder participation Applications of Marine Conservation 1) UN Sustainable Development Goals 2) Common Fisheries Policy 3) The EU approach to the protection of the sea: Water Framework Directive, Birds and Habitats Directives, Marine Strategy Framework Directive, Maritime Spatial Planning Directive 4) Citizen Science and NGOs 5) Nature based solutions

**Examination:**
Written exam.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093599/NO

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**MARINE ECOLOGY: PATTERNS AND PROCESSES**

Master's degree in **MARINE BIOLOGY ORD. 2021**, First semester

**Lecturer:** Prof.ssa LAURA AIROLDI

**Credits:** 6 ECTS
Prerequisites:
Basic knowledge of ecology, and biology of marine organisms.

Short program:
The lectures will cover a variety of coastal ecosystems. For each ecosystem we will analyse: • Main environmental characteristics • Main communities, their structure and distribution • Main ecological processes and functioning, with emphasis on experimental work focusing on some particularly well studied processes • Human-induced threats and conservation and restoration approaches The course is structured as follows: 1) Introduction to Marine Ecology 2) The physical environment and the marine biomes 3) Introduction to the concept of ecosystem services 4) Introduction to the concepts of habitat shifts and novel ecosystems 5) Intertidal rocky bottoms - experiments on the role of competition, predator-prey interactions and bottom up effects 6) Subtidal rocky bottoms and canopy forming macroalgae & kelp forests - experiments on the role of disturbance, trophic cascades, and the effects of sedimentation 7) Estuarine environments, saltmarshes, mangroves - experiments on the role of positive interactions and of the effects of excessive nutrient loads 8) Seagrasses – focus on productivity, trophic transfer and the role of microbial communities 9) Oyster reefs, coralligenous reefs, coral reefs and other biogenic reefs 10) Soft-bottoms and deep sea ecosystems 11) Artificial man-made habitats – focus on eco-design of marine artificial structures We will elaborate on some concepts through discussion groups of relevant papers. We will also carry out field excursions to visit coastal marine ecosystems of the region

Examination:
There will be 6 exam sessions during the year, two for each exam session: the first exam (which will take place immediately at the end of the course) will be written and will include about 20 questions both closed and open (the questions will cover all the topics of the course) while the next 5 session will be oral. The exam grade awarded may be refused up to a maximum of two times.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093552/NO

MARINE ECOTOXICOLOGY

Master’s degree in MARINE BIOLOGY ORD. 2021, First semester

Lecturer: Dott. MARCO MUNARI

Credits: 6 ECTS

Prerequisites: None

Short program:
1) Introduction to Ecotoxicology: origins and evolution of an interdisciplinary science (0.25 CFU) 2) Contaminants in the marine environment: traditional and emerging contaminants (0.25 CFU) 3) Contaminants and biota. Bioavailability, bioconcentration, bioaccumulation and biomagnification; routes of intake, sites of accumulation, biotransformation, detoxification and activation processes, elimination mechanisms (0.5 CFU) 4) Bioindicators, Biomonitoring, Biomarkers (1 CFU) 5) Case studies in the laboratory and in the field on the effects of exposure to contaminants at the cellular, organism, population and community level. Toxicity tests: acute and chronic tests, tests on early stages of fish and marine invertebrates (3 CFU) 6) Omics approach in ecotoxicological studies (1 CFU).

Examination:
Written verification, with multiple choice and open-ended questions.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ1097379/NO

MARINE MICROBIOLOGY

Master's degree in MARINE BIOLOGY ORD. 2021, First semester

Lecturer: Prof.ssa PAOLA VENIER

Credits: 6 ECTS

Prerequisites: None

Short program:
Introduction: historical development of marine microbiology; types of marine microorganisms and relative abundance, morpho-structural and habitat varieties, evolutionary peculiarities, current taxonomy (1.5 CFU). Methods to quantify, identify and characterize marine micro-organisms (0.5 CFU). Analysis *16S rRNA amplicon sequencing* in computer lab (1 CFU). Marine prokaryotes: main metabolic types; mixotrophy; syntrophy; extremophiles; variety, peculiarities and interactions in the Bacteria and Archaea domains. Marine microeukaryotes (in general) (0.5 CFU). Marine viruses: classification, structure, and replication strategies through examples (1 CFU). Marine microorganisms in the trophic network: microbial loop, viral shunt, biological pump, biogeochemical cycles (0.75 CFU). Marine microbial symbionts; microbial bioremediation in marine environment (0.75 CFU).

Examination:
Written examination (questionnaire) or oral examination (interview) depending on the number of participants. In emergency conditions, the examination mode may change. The student will be tested on the course contents (50%) as well as on one or two specific topics, previously agreed with the teacher and individually prepared (50%).

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MOLECULAR METHODS FOR MANAGEMENT AND AQUACULTURE

Master's degree in MARINE BIOLOGY ORD. 2021, First semester

Lecturer: Prof.ssa CHIARA PAPETTI

Credits: 6 ECTS

Prerequisites:
Basic knowledge of Ecology, Population Genetics, Botany, Zoology and Statistics. The course will be held in English, hence an understanding of written and spoken English is required

Short program:
Review of population genetics: factors that determine genetic variability. Characteristics of marine organisms and their effects at the genetic level. Effective population size. Environment and distribution of polymorphisms on a geographical and evolutionary scale. Types of molecular markers: mitochondrial markers, microsatellites, AFLP, SNPs. Laboratory methodologies. Types of data produced by molecular markers and associated analyzes. Analysis at the individual population level. Comparison between populations. Choice of markers in relation to the biological problem. Identification of individuals by genetic markers, marking and recapture with genetic methods, estimation of the historical size of the population, estimation of geographical differentiation, identification of stocks, and mixed stock assessment. During the course, examples and case studies will be presented in order to expand on some of the main themes, pointing out the sampling design, the methods and markers used, the characteristics of the species analyzed, and the data analysis. During the course, a molecular ecology laboratory will be proposed during which the main basic molecular biology techniques (e.g. DNA extraction, PCR, sequencing / genotyping) will be applied to the solution of an ecological problem. The data will be analyzed with the main molecular analysis software.

Examination:
The exam consists of three parts: two group works to be carried out during the course (presentation of molecular markers, 10 points and an interview with an expert, 10 points) and a written test (3-4 open-ended questions, 10 points) to be done during the usual exam session. Some changes to the evaluation plan and to the course general approaches may be agreed on with students. The exam grade is given by the sum of the scores obtained in all the parts. Details on the structure of the exam, subdivision of the scores between each part will be illustrated again during the first lessons and, upon request, also later. The exam rules will be made available also via moodle (descriptive slides and video recording). To facilitate understanding of the examination procedures and evaluation criteria, a simulation will take place during the course with some of the possible exam questions or by organizing study groups.

PATHOLOGY OF AQUATIC ORGANISMS

Master's degree in MARINE BIOLOGY ORD. 2021, First semester

Lecturer: Dott. SANDRO MAZZARIOL

Credits: 6 ECTS

Short program:
DISEASE AND PATHOLOGY of COMMERCIAL MARINE SPECIES (FISH & SEA FOOD) - Diagnostic methodology in fish pathology: the environmental survey, anamnestic data, clinical examination, sampling, technique of necropsy, identification of organs, histopathology, laboratory analyses. - Prevention and control applied to infectious diseases in aquaculture. - Non-specific and specific defense mechanisms, vaccination of farmed fish. - Infectious fish diseases (viral, bacterial and parasitic diseases). Main diseases of crustaceans and molluscs. POST-MORTEM INVESTIGATIONS ON SEA TURTLE AND MARINE MAMMALS - Basic anatomy and physiology of sea turtles and cetaceans. - Principle of Post-mortem techniques and tissue sampling. Ancillary examinations. Detection of evidences of human interaction. - Main diseases and pathology: virus, bacteria and parasites in a changing sea. - Relevant threats associated with human activities. - The use of collected data for the implementation of EU Directives (i.e. Habitat, Marine Strategy Framework Directive) and International Agreements (i.e. ACCOBAMS, ASCOBANS, RAC/SPA, etc.)

Examination:
The students will be assessed using a written examination.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ1097398/NO

PHARMACOLOGY, TOXICOLOGY AND WELFARE IN AQUACULTURE

Master's degree in MARINE BIOLOGY ORD. 2021, Second semester

Lecturer: Prof. MARCO DE LIGUORO

Credits: 8 ECTS

Prerequisites:
Basic knowledge of chemistry, biochemistry, biology, microbiology, anatomy and physiology is recommended.

Short program:
Pharmacotoxicology module (5 credits) General principles of pharmacokinetics and toxicokinetics. The use of pharmaceuticals and disinfectants in aquaculture, with particular reference to dosage forms, prescription, and administration methods. Different criteria and rules for the use of pharmaceuticals in food-producing and in ornamental fish: understanding the specific issues and the related legislation. Fate of active principles in the environment. Drug residues and contaminants from industrial and natural sources in fish products and in the aquatic compartment: risk assessment for the consumer and the environment. Laboratory activities: 1) Setting up aquatic toxicity tests on crustaceans - Acute immobilization test in Daphnia magna - Embryonic toxicity test in Daphnia magna 2) Processing of acute and chronic aquatic ecotoxicity test data - ECx calculation - Determination of LOEC and NOEC 3) Aquatic toxicity test on Rapidocelis subcapitata - Method for culturing the unicellular green alga - Algal cell count on Burker's chamber Welfare module (3 credits) Definition of animal welfare, related legislation and applicability to fish. Human interactions with fish and effects of such interactions on fish welfare. Fish physiology with particular reference to the welfare of farmed fish. The stress response and the ability to feel pain and fear in fish. The main factors affecting the welfare of farmed fish. Physiological, behavioural and health indicators for the evaluation of fish welfare in farming and related analytical methods. Laboratory activities: 1) Preparation of aquatic toxicity tests on crustaceans 2) Dissection of Sea Bass; sampling of tissue and organs for the evaluation of fish welfare; hematocrit and erythrocyte and leukocyte cells count by hemocytometer; preparation and evaluation of blood smear . 3) Radioimmunoassay, immunohistochemistry, protein assay and Western Blot analysis to evaluate fish welfare.

Examination:
There is an oral examination at the end of the Course. The exam includes at least five questions based on the topics covered, and aimed at assessing comprehension, critical thinking skills and the ability to identify interrelationships between issues, as well as a good command of scientific language.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093619/NO

SEAFood Sustainability, Production and Control

Master's degree in MARINE BIOLOGY ORD. 2021, Second semester

Lecturer: Prof.ssa ANGELA TROCINO

Credits: 6 ECTS

Prerequisites: None

Short program:
The module consists of two parts which refer to Production systems and product quality (40 hours, AGR/20, Prof. Angela Trocino) and hygiene and control of safety of fish products (24 hours, VET/04, prof. Luca Fasolato). AGR/20 Aquaculture and fisheries. Fish production and consumption in Italy and all over the world, main problems and perspectives. Definition, classification and description of aquaculture systems. Water quality and management in aquaculture. Nutritional and sensorial evaluation of fish products. Factors affecting fish quality. Freshness evolution. Production and quality of fresh, frozen and transformed fish products. Seminars, Active learning, visits at commercial plants. VET/04 Inspection and control of the hygienic status of fishery products, sector problems, regulatory context and role of the Food and Business Operator (FBO). Introduction to risks in the industry, intrinsic and extrinsic factors that influence microbiological risks in products. Foodborne pathogens of fish products and parasitic disease, notes on analytical methods. Control according to the EU regulations of freshness, Edible molluscs bivalves. Harvesting, packaging and labeling of live bivalve molluscs. Food fraud in the fish sector. HACCP procedures in the fish products sector. Laboratories activities and technical visits in production plants.

Examination:
The exam will consist of a written examination with open questions, multiple choices questions, and exercises.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2596/000ZZ/SCQ0093598/NO

MATERIAL SCIENCE ORD. 2015

PHYSICS OF DISORDERED MATERIALS

Master's degree in MATERIAL SCIENCE ORD. 2015, First semester

Lecturer: Prof. GIULIO MONACO

Credits: 6 ECTS

Prerequisites: Notions of quantum mechanics and physics of matter.

Short program:

**Examination:**
Oral examination and talk on a topic discussed during the course and chosen together with the student.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1174/000ZZ/SCQ1097162/NO

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**COMPUTATIONAL METHODS FOR MATERIALS SCIENCE**

Master's degree in **MATERIAL SCIENCE** ORD. 2015, Second semester

**Lecturer:** Prof. FRANCESCO ANCILOTTO

**Credits:** 6 ECTS

**Prerequisites:**
Elementary notions of quantum physics and solid state physics. Fundamentals of thermodynamics: principles, thermodynamic potentials. No prior knowledge of computer programming is required.

**Short program:**
Basic concepts of thermodynamics and classical statistical mechanics. Classical Molecular Dynamics simulations; numerical integration of Newton equations. Monte Carlo method; Metropolis algorithm. Simulations in various statistical ensembles. Common features of simulations methods: initial and boundary conditions; calculation of inter-particle interactions. Calculation of thermodynamic and transport properties. Interatomic interactions: force-fields; atomistic and coarse grained models. Variational methods for the solution of the Schrödinger equation. Hartree and Hartree-Fock theory. Elements of Density Functional Theory (DFT). First principles' simulations. The different computational methods will be discussed in relation their application to topics of interest for material science (crystals, surfaces, soft matter, nanostructured materials). In the computer exercises, students will carry out simple simulations, using open-source software packages of current use in materials science, and will learn how to interpret and present the results of simulations.

**Examination:**
Oral examination in which the students will discuss written reports, on the results of three numerical simulations (Monte Carlo, Molecular Dynamics and DFT calculations).

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1174/000ZZ/SCQ0090918/NO

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**CRYSTALCHEMISTRY OF MATERIALS FOR THE SUSTAINABLE BUILT ENVIRONMENT**

Master's degree in **MATERIAL SCIENCE** ORD. 2015, Second semester

**Lecturer:** Prof. LUCA VALENTINI

**Credits:** 6 ECTS

**Prerequisites:**
Fundamentals of materials science, mathematics, solid state physics and chemistry

**Short program:**
1) Introduction to industrial minerals, building materials and sustainable development. Societal impact of population growth and urbanization. 2) Historical use of building materials; classification of binders; cement production processes; crystal chemistry of cement phases. 3) Role of the solid-liquid interface in cement hydration; dissolution and adsorption processes; role of surface defects. 4) Study of the rheology of cementitious pastes and other materials; effect of organic polymers on the properties of cement mixes; visit to the rheometry laboratory; 3D printing techniques of binders. 5) Microstructural development and nucleation and growth processes; study of the microstructure of cementitious materials and its role in determining the engineering properties; visit to the 3D microtomography laboratory. 6) Durability and chemical and physical degradation processes of concrete. 7) Laboratory techniques and numerical modeling strategies for the study of cementitious materials; X-ray diffraction exercises and thermodynamic modeling. 8) Building materials and sustainability: circular economy approaches in the supply of raw materials; low-CO2 cements; building materials in developing countries; cementitious materials for extra-terrestrial constructions.

**Examination:**
1) Multiple choice written text and 2) oral presentation (PowerPoint) on a specific topic chosen by the student (approximately 15 minutes for the presentation and 15 minutes for the written test).
ELECTROCHEMISTRY OF MATERIALS

Master's degree in MATERIAL SCIENCE ORD. 2015, First semester

Lecturer: Prof. CHRISTIAN DURANTE

Credits: 6 ECTS

Prerequisites:
Knowledge of general chemistry (General and inorganic Chemistry), thermodynamics (Physical Chemistry), -ionic and electronic conduction - acid base properties -thermodynamic quantities - chemical kinetics and kinetic theories - atomic and molecular orbitals, band theory - properties of polymers, metals and gases.

Short program:

Examination:
Oral examination generally based on three topics: - electrochemical kinetic theory - electrochemical techniques/ electrodeposition techniques - energy conversion and storage devices/ properties of electrodic materials The possibility of carrying out the exam in written form with three intermediate tests will also be evaluated, in relation to student requests.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1174/000ZZ/SCCQ0090018/NO

FUNDAMENTALS OF NANOSCIENCE

Master's degree in MATERIAL SCIENCE ORD. 2015, Second semester

Lecturer: Prof. GIOVANNI MATTEI

Credits: 8 ECTS

Prerequisites:
Electromagnetism, Quantum Physics (particle in a box, quantum confinement), Solid State Physics (phononic and electronic structures of solids, thermal and optical properties).

Short program:

Examination:
1) Fundamentals of NanoScience (MSc in Materials Science) The exam is written (duration 2 h) with two open questions and a set of multiple-choice questions. 2) Introduction to NanoPhysics (MSc in PHYSICS) The exam is written (duration 2 h) with an open question and an exercise with numerical applications of the learned topics. 3) Fundamentals of NanoScience (MSc in Materials Engineering) The exam is written (duration 2 h) with one open question and a set of multiple-choice questions.
MATERIALS TECHNOLOGY

Master's degree in MATERIAL SCIENCE ORD. 2015, First semester

Lecturer: Prof. ALESSANDRO MARTUCCI

Credits: 6 ECTS

Prerequisites:
The course requires the knowledge of the Bachelor's Degree Fundamentals of Materials Science exam.

Short program:

Examination:
Oral exam.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1174/000ZZ/SCP9087651/NO

NANOFABRICATION

Master's degree in MATERIAL SCIENCE ORD. 2015, First semester

Lecturer: Prof. FILIPPO ROMANATO

Credits: 6 ECTS

Prerequisites:
third year courses in materials science, optics, matter structure

Short program:
Many of the impressive technical and scientific advances of the last two decades are based on the ability to control individual chemical-physical phenomena at the level of a few nanometers, that is, on the scale of size at which most natural phenomena occur. This control was obtained by developing micro and nano fabrication systems and processes for the realization of devices (also called lab-on-chip) capable of exchanging signals (detection and actuation) with systems of the size of a few nanometers, coining, in fact , the definition of nanotechnology. The course is aimed at students (materials sciences, physics) in view of the degree thesis for the broad correlation between physical, chemical, biochemical phenomena that nanofabrication processes require in view of the realization of nanostructures and nanodevices. Opening themes towards the research of nanosciences are discussed. The course will discuss the miniaturization process and the scale reduction process of many natural phenomena that distinguish the functioning of nanodevices.

The main nanofabrication technologies will be presented and examples of applications for the realization of nanoscience devices and experiments will be presented. After a general distinction between top-down and bottom-up processes, lithography technologies (UV, electronics, X-ray, ionic, imprinting, interferential etc), deposition processes (plasma assisted, in vapor or chemical phase, will be illustrated), sol-gel etc.) and subtraction in the gas phase (reactive ion etching, milling) or liquid (chemical etching). The manufacturing technology of silicon-based electronic devices will be reviewed. Simulation exercises for the design of nanosystems are proposed. The course is completed by visits to the nanofain Padua at the LaNN laboratory and in Trieste at the CNR nanofabrication laboratories at the Elettra synchrotron. During these visits there will be practical demonstrations of the lithographic processes treated during the classroom course.

Examination:
Deepening of a topic, preparation of a presentation, written discussion. Oral exam, presentation of the paper and verification of the learning of the main concepts of nano lithography.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1174/000ZZ/SCQ0090019/NO

OPTICS AND LASER PHYSICS

Master's degree in MATERIAL SCIENCE ORD. 2015, First semester

Lecturer: Prof.ssa TIZIANA CESCA

Credits: 6 ECTS
**Prerequisites:**
Topics learned in basic courses of Mathematics and Physics.

**Short program:**
Classical optics: - propagation of electromagnetic waves; - polarization, birefringence, interference and diffraction; - geometrical optics and matrix method; main optical instruments; Lasers: - the laser idea and properties of laser beams; - absorption, spontaneous emission, stimulated emission; - gain and population inversion; - optical cavities and pumping; - cw lasers; - pulsed lasers: Q-switch and mode-locking; - examples of main different laser types: gas lasers, solid-state lasers Introduction to Quantum Optics: - Photon statistics - buching and antibuching; - weak and strong coupling: Purcell effect and Rabi splitting.

**Examination:**
The exam is written and comprises two exercises and one open question.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1174/000ZZ/SCP7081800/NO

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**OPTICS OF MATERIALS**

Master's degree in **MATERIAL SCIENCE ORD. 2015**, First semester

**Lecturer:** Prof. MORENO MENEGHETTI

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge of electromagnetic wave propagation and of quantum mechanics.

**Short program:**

**Examination:**
Examination will be an oral test.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1174/000ZZ/SCP9087655/NO

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**ORGANIC FUNCTIONAL MATERIALS**

Master's degree in **MATERIAL SCIENCE ORD. 2015**, First semester

**Lecturer:** Prof.ssa MIRIAM MBA BLAZQUEZ

**Credits:** 6 ECTS

**Prerequisites:**
Organic Chemistry courses of the 1st cycle Degree: nomenclature of organic molecules, organic functional groups electrofile and nucleofile basicity and acidity addition reactions (alkenes) nucleophilic substitution (alcohols, halogenated compounds) Electrophilic aromatic substitution (reactions of aromatic compounds) Polymers: basic concepts

**Short program:**

**Examination:**
Written exam. 5 questions.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1174/000ZZ/SCP9087652/NO

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**PHYSICS AND TECHNOLOGY OF SEMICONDUCTORS**

Master's degree in **MATERIAL SCIENCE ORD. 2015**, First semester

**Lecturer:** Prof. DAVIDE DE SALVADOR
Credits: 8 ECTS

Prerequisites:

Short program:

Examination:
Oral exam. During the semester it will be possible to give a midterm oral exam about the first part of the course concerning on physical principal; at the end a second oral exam on the devices and processes will complete the final grade.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1174/000ZZ/SCP9087650/NO

SUPERCONDUCTING MATERIALS

Master's degree in MATERIAL SCIENCE ORD. 2015. Second semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites:
Solid State Physics

Short program:
The Course is divided into two main parts. A first part that by using a phenomenological approach presents the main properties of superconductors and the three main theories that describe their behavior. A second part focused on the characteristics of different superconducting materials and their applications, with special attention to particle accelerators. Other applications of superconductors will be presented by international experts (if possible) and by the students themselves, who will prepare each (or in groups) a specific small seminar. COURSE DETAIL: Introduction to cryogenics (history of helium liquefaction, helium phase diagram, thermal conduction in solids, thermal shielding, cryogenic refrigeration techniques), fundamental properties of superconductors (history of the discovery of superconductivity, zero resistance, ideal conductors and superconductors, Meissner effect, type I and type II superconductors, Vortices in SCs, flux quantization, isotopic effect, thermodynamic approach to SC, pinning, Josephson effect), fundamentals of the main phenomenological and microscopic theories (London theory, Ginzburg Landau theory, BCS ter theory), superconducting materials (BCS superconductors: elements and alloys, organic compounds, high Tc superconductors), commercial superconducting materials (NbTi, Nb3Sn, MgB2, REBCO, production and characteristics), introduction to accelerator technology (superconducting magnets, accelerator cavities), fundamentals of superconductivity in radio frequency (surface resistance in SCs, contributions to residual resistance, superheating critical field, limits to the performance of SRF cavities: multipacting, thermal breakdown, field emission, Q-diseases and possible solutions), materials for SRFs: bulk Nb and thin films, applications of superconductivity (seminars by international experts + student presentations).

Examination:
The evaluation exam on the knowledge and expected skills is based on an oral discussion (of about half an hour), in which open questions on the arguments of the course will be submitted

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1174/000ZZ/SCP9087678/NO

SUSTAINABLE ENERGY: MATERIALS AND TECHNOLOGIES
Master's degree in **MATERIAL SCIENCE ORD. 2015**, Second semester

**Lecturer:** Prof.ssa LAURA CALVILLO LAMANA

**Credits:** 6 ECTS

**Prerequisites:**
Fundamental concepts of Chemical Thermodynamics and Kinetics
Fundamental concepts of Electrochemistry

**Short program:**
LECTURES:
LABORATORY (3 experiments):
- (Photo)electrocatalytic hydrogen production using 2D nanocomposites as catalysts - Fuel cells: ethanol oxidation and oxygen reduction reaction on Pt-Sn/C catalyst - Photovoltaic cells

**Examination:**
Oral exam + laboratory reports

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1174/000ZZ/SCQ1097161/NO

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**MATHEMATICS ORD. 2011**

**HAMILTONIAN DYNAMICAL SYSTEM**

Master's degree in **MATHEMATICS ORD. 2011**, First semester

**Lecturer:** to be defined

**Credits:** 6 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**

**INTRODUCTION TO CELESTIAL AND HAMILTONIAN MECHANICS**

Master's degree in **MATHEMATICS ORD. 2011**, First semester

**Lecturer:** to be defined

**Credits:** 6 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC1172/011PD/SCQ0094154/NO
INTRODUCTION TO EVOLUTION PDES

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS


INTRODUCTION TO NON-LINEAR PDES

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS


JUMP PROCESSES

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS


LARGE DEVIATION AND APPLICATIONS

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS


MEAN FIELD GAMES

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS


MONTE-CARLO AND DETERMINISTIC METHODS FOR PARABOLIC EQUATIONS

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined
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DYNAMICAL SYSTEMS

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: Prof. LUIS CONSTANTINO GARCIA NARANJO ORTIZ DE LA HUERTA

Credits: 7 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1172/011PD/SCQ0094084/NO

FUNCTIONS THEORY

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: Prof. DAVIDE VITTONE

Credits: 8 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1172/011PD/SCQ0094119/NO

HARMONIC ANALYSIS

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: Prof. PAOLO CIATTI

Credits: 6 ECTS

More information:

INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: Prof.ssa LAURA CARAVENNA

Credits: 8 ECTS

More information:

INTRODUCTION TO STOCHASTIC PROCESSES

Master's degree in MATHEMATICS ORD. 2011, Second semester

Lecturer: Prof. BERNARDO D'AURIA

Credits: 8 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1172/011PD/SCQ0093964/NO
NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS

Master's degree in MATHEMATICS ORD. 2011, Second semester

Lecturer: Prof. MARIO PUTTI

Credits: 7 ECTS


STOCHASTIC ANALYSIS

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: Prof. DAVID BARBATO

Credits: 7 ECTS


STOCHASTIC METHODS FOR FINANCE

Master's degree in MATHEMATICS ORD. 2011, Second semester

Lecturer: Prof. MARTINO GRASSELLI

Credits: 7 ECTS


SYMPLECTIC MECHANICS

Master's degree in MATHEMATICS ORD. 2011, Second semester

Lecturer: Prof. FRANCESCO FASSO’

Credits: 6 ECTS


HAMILTONIAN DYNAMICAL SYSTEM

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites:

Short program:

Examination:

More information:
INTRODUCTION TO CELESTIAL AND HAMILTONIAN MECHANICS

Master’s degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: -

Short program: -

Examination: -


INTRODUCTION TO EVOLUTION PDES

Master’s degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: -

Short program: -

Examination: -


INTRODUCTION TO NON-LINEAR PDES

Master’s degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: -

Short program: -

Examination: -


JUMP PROCESSES

Master’s degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined
MONTE-CARLO AND DETERMINISTIC METHODS FOR PARABOLIC EQUATIONS

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: -

Short program: -

Examination: -


NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS AND CONTROL

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: -

Short program: -

Examination: -


STOCHASTIC CALCULUS

Master's degree in MATHEMATICS ORD. 2011, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: -

Short program: -
### STOCHASTIC CONTROL

Master's degree in **MATHEMATICS ORD. 2011**, First semester

**Lecturer:** to be defined

**Credits:** 6 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**

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### MATHEMATICS ORD. 2022

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### ALGEBRAIC GEOMETRY 1

Master's degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof. REMKE NANNE KLOOSTERMAN

**Credits:** 8 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**

---

### ALGEBRAIC GEOMETRY 2

Master's degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof. ERNESTO CARLO MISTRETTA

**Credits:** 6 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

---
COMMUTATIVE ALGEBRA

Master's degree in **MATHEMATICS ORD. 2022**, First semester

**Lecturer:** Prof.ssa ORSOLA TOMMASI

**Credits:** 8 ECTS

Prerequisites:

Short program:

Examination:


COMPLEX ANALYSIS

Master's degree in **MATHEMATICS ORD. 2022**, First semester

**Lecturer:** Prof. MASSIMO LANZA DE CRISTOFORIS

**Credits:** 6 ECTS

Prerequisites:

Short program:

Examination:


CRYPTOGRAPHY

Master's degree in **MATHEMATICS ORD. 2022**, First semester

**Lecturer:** Prof. ALESSANDRO LANGUASCO

**Credits:** 6 ECTS

Prerequisites:

Short program:

Examination:


HOMOLOGY AND COHOMOLOGY

Master's degree in **MATHEMATICS ORD. 2022**, Second semester
Lecturer: Prof. JAKOB SCHOLBACH
Credits: 6 ECTS
Prerequisites:
Short program:
Examination:

INTRODUCTION TO GROUP THEORY
Master's degree in MATHEMATICS ORD. 2022, First semester
Lecturer: Prof. ANDREA LUCCHINI
Credits: 8 ECTS
Prerequisites:
Short program:
Examination:

INTRODUCTION TO RING THEORY
Master's degree in MATHEMATICS ORD. 2022, First semester
Lecturer: Prof. ALBERTO TONOLO
Credits: 8 ECTS
Prerequisites:
Short program:
Examination:

NUMBER THEORY 1
Master's degree in MATHEMATICS ORD. 2022, First semester
Lecturer: Prof. MATTEO LONGO
Credits: 8 ECTS
Prerequisites:
Short program:
Examination:
NUMBER THEORY 2

Master's degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof. ADRIAN IOVITA

**Credits:** 6 ECTS

**Prerequisites:**

- 

**Short program:**

- 

**Examination:**

- 


REPRESENTATION THEORY OF GROUPS

Master's degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof.ssa GIOVANNA CARNOVALE

**Credits:** 6 ECTS

**Prerequisites:**

- 

**Short program:**

- 

**Examination:**

- 


RINGS AND MODULES

Master's degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof. JORGE NUNO DOS SANTOS VITORIA

**Credits:** 6 ECTS

**Prerequisites:**

- 

**Short program:**

- 

**Examination:**

- 


SYMPLECTIC MECHANICS
Master's degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof. FRANCESCO FASSO

**Credits:** 6 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**

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**TOPOLOGY 2**

Master's degree in **MATHEMATICS ORD. 2022**, First semester

**Lecturer:** Prof. ANDREA D'AGNOLO

**Credits:** 6 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/001PD/SCQ0094298/NO

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**ADVANCED ANALYSIS**

Master's degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof. GIOVANNI COLOMBO

**Credits:** 8 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0093998/NO

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**ADVANCED STOCHASTIC PROCESSES**

Master's degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Dott.ssa ALESSANDRA BIANCHI

**Credits:** 7 ECTS

**Prerequisites:**

**Short program:**
CALCULUS OF VARIATIONS

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. ROBERTO MONTI

Credits: 8 ECTS

Prerequisites: -

Short program: -

Examination: -


DIFFERENTIAL EQUATIONS

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. MARTINO BARDI

Credits: 6 ECTS

Prerequisites: -

Short program: -

Examination: -


DIFFERENTIAL GEOMETRY

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. DAVIDE BARILARI

Credits: 8 ECTS

Prerequisites: -

Short program: -

Examination: -

DYNAMICAL SYSTEMS

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. LUIS CONSTANTINO GARCIA NARANJO ORTIZ DE LAHUERTA

Credits: 7 ECTS

Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094084/NO

FUNCTIONS THEORY

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. DAVIDE VITTONE

Credits: 8 ECTS

Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094119/NO

HARMONIC ANALYSIS

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. PAOLO CIATTI

Credits: 6 ECTS

Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0093960/NO

INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof.ssa LAURA CARAVENNA
INTRODUCTION TO STOCHASTIC PROCESSES

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. BERNARDO D'AURIA

Credits: 8 ECTS

Prerequisites: -

Short program: -

Examination: -


NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. MARIO PUTTI

Credits: 7 ECTS

Prerequisites: -

Short program: -

Examination: -


STOCHASTIC ANALYSIS

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. DAVID BARBATO

Credits: 7 ECTS

Prerequisites: -

Short program: -
STOCHASTIC METHODS FOR FINANCE

Master’s degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof. MARTINO GRASSELLI

**Credits:** 7 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0093961/NO

SYMPLECTIC MECHANICS

Master’s degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof. FRANCESCO FASSO

**Credits:** 6 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094082/NO

BROWNIAN MOTION AND ASSET PRICING

Master’s degree in **MATHEMATICS ORD. 2022**, First semester

**Lecturer:** to be defined

**Credits:** 4 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094142/NO
CONTINUOUS PROCESSES - ADVANCED

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: to be defined Course not activated for the a.y. 2022/2023

Credits: 4 ECTS

Prerequisites:

Short program:

Examination:


CONTROL OF MARKOV CHAINES

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: to be defined

Credits: 4 ECTS

Prerequisites:

Short program:

Examination:


CONVEX ANALYSIS - ADVANCED

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: to be defined Course not activated for the a.y. 2022/2023

Credits: 4 ECTS

Prerequisites:

Short program:

Examination:


DISCRETE PROCESSES

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: to be defined
FUNCTIONAL ANALYSIS

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: to be defined

Credits: 8 ECTS

Prerequisites: -

Short program: -

Examination: -


GEOMETRY AND DIFFERENTIAL EQUATIONS

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: to be defined

Credits: 4 ECTS

Prerequisites: -

Short program: -

Examination: -


GERMAN 1 AND 2

Master's degree in MATHEMATICS ORD. 2022, First and Second semester

Lecturer: to be defined Course not activated for the a.y. 2022/2023

Credits: 4 ECTS

Prerequisites: -

Short program: -
MONTE-CARLO

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: to be defined

Credits: 4 ECTS

Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094140/NO

NON-PARAMETRIC STATISTICS

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: to be defined Course not activated for the a.y. 2022/2023

Credits: 4 ECTS

Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094094/NO

NUMERICAL METHODS FOR TIME-DEPENDENT PROBLEMS

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: to be defined Course not activated for the a.y. 2022/2023

Credits: 4 ECTS

Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094147/NO
OPTIMIZATION

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: to be defined Course not activated for the a.y. 2022/2023

Credits: 4 ECTS

Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094091/NO

POISSON PROCESS

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: to be defined Course not activated for the a.y. 2022/2023

Credits: 4 ECTS

Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094145/NO

STATISTICAL LEARNING

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: to be defined Course not activated for the a.y. 2022/2023

Credits: 4 ECTS

Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094146/NO

ADVANCED ANALYSIS

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. GIOVANNI COLOMBO
CALCULUS OF VARIATIONS

Master's degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof. ROBERTO MONTI

**Credits:** 8 ECTS

**Prerequisites:** -

**Short program:** -

**Examination:** -

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0093998/NO

CONTROL OF MARKOV CHAINES

Master's degree in **MATHEMATICS ORD. 2022**, First semester

**Lecturer:** to be defined

**Credits:** 4 ECTS

**Prerequisites:** -

**Short program:** -

**Examination:** -

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094093/NO

DIFFERENTIAL EQUATIONS

Master's degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof. MARTINO BARDI

**Credits:** 6 ECTS

**Prerequisites:** -

**Short program:** -
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<th>Master's degree in Mathematics Ord. 2022, First semester</th>
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GEOMETRY AND DIFFERENTIAL EQUATIONS

Master’s degree in MATHEMATICS ORD. 2022, First semester

Lecturer: to be defined

Credits: 4 ECTS

Prerequisites:
-

Short program:
-

Examination:
-

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0094088/NO

HARMONIC ANALYSIS

Master’s degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. PAOLO CIATTI

Credits: 6 ECTS

Prerequisites:
-

Short program:
-

Examination:
-

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0093960/NO

INTRODUCTION TO STOCHASTIC PROCESSES

Master’s degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. BERNARDO D'AURIA

Credits: 8 ECTS

Prerequisites:
-

Short program:
-

Examination:
-

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2651/003PD/SCQ0093964/NO

MONTE-CARLO

Master’s degree in MATHEMATICS ORD. 2022, First semester

Lecturer: to be defined
NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS

Master’s degree in MATHMATICS ORD. 2022, Second semester

Lecturer: Prof. MARIO PUTTI

Credits: 7 ECTS

Prerequisites: -

Short program: -

Examination: -


OPTIMIZATION

Master’s degree in MATHMATICS ORD. 2022, First semester

Lecturer: to be defined Course not activated for the a.y. 2022/2023

Credits: 4 ECTS

Prerequisites: -

Short program: -

Examination: -


STOCHASTIC METHODS FOR FINANCE

Master’s degree in MATHMATICS ORD. 2022, Second semester

Lecturer: Prof. MARTINO GRASSELLI

Credits: 7 ECTS

Prerequisites: -

Short program: -
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<td>ALGEBRAIC GEOMETRY 1</td>
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<td>Prof. REMKE NANNE KLOOSTERMAN</td>
<td>8 ECTS</td>
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</table>
ALGEBRAIC GEOMETRY 2

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. ERNESTO CARLO MISTRETTA

Credits: 6 ECTS
Prerequisites: -
Short program: -
Examination: -


CALCULUS OF VARIATIONS

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. ROBERTO MONTI

Credits: 8 ECTS
Prerequisites: -
Short program: -
Examination: -


COMMUTATIVE ALGEBRA

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof.ssa ORSOLA TOMMASI

Credits: 8 ECTS
Prerequisites: -
Short program: -
Examination: -


COMPLEX ANALYSIS

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. MASSIMO LANZA DE CRISTOFORIS
CRYPTOGRAPHY

Master's degree in **MATHEMATICS ORD. 2022**, First semester

**Lecturer:** Prof. ALESSANDRO LANGUASCO

**Credits:** 6 ECTS

**Prerequisites:**

- 

**Short program:**

- 

**Examination:**

- 

**More information:**


DIFFERENTIAL EQUATIONS

Master's degree in **MATHEMATICS ORD. 2022**, Second semester

**Lecturer:** Prof. MARTINO BARDI

**Credits:** 6 ECTS

**Prerequisites:**

- 

**Short program:**

- 

**Examination:**

- 

**More information:**


DIFFERENTIAL GEOMETRY

Master's degree in **MATHEMATICS ORD. 2022**, First semester

**Lecturer:** Prof. DAVIDE BARILARI

**Credits:** 8 ECTS

**Prerequisites:**

- 

**Short program:**

- 
DYNAMICAL SISTEMS

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. FRANCESCO FASSO

Credits: 7 ECTS

Prerequisites:

Short program:

Examination:

More information:

ELEMENTARY MATHEMATICS FROM A SUPERIOR POINT OF VIEW

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. LUIGI TOMASI

Credits: 6 ECTS

Prerequisites:
The mathematical prerequisites are those covered by basic courses of the Bachelor's Degree in Mathematics, in particular Algebra, Geometry, Mathematical Analysis, Probability and Foundations of Mathematics.

Short program:
The course will discuss, from an epistemological, historical and didactic point of view, those topics and ideas of basic mathematics that constitute the fundamental themes of the Mathematics curriculum in secondary school: Arithmetic and Algebra -Geometry -Relations and functions (in particular, Mathematical Analysis) -Data and Forecasting (in particular, Probability). In particular, the following topics will be specifically developed (some will be requested in the students' reports): -Solution of algebraic equations in radicals, with hints on the history of classical algebra -Straightedge and compass constructions: the classical problems of geometry; points of the plan that can be constructed with straightedge and compass; constructible numbers; constructible regular polygons, with historical notes. - Elementary number theory topics: Pythagorean triples, prime numbers, fundamental theorem of arithmetic, congruence relation, Euclid's algorithm for the gcd; divisibility criteria; the Euler functions d(n), sigma(n), phi(n); decimal fractions and period of a fraction. The principle of mathematical induction. - Definitions, theorems and proofs in mathematics teaching (in secondary school); types of proofs; indirect proofs; proofs by contradiction; proofs by induction. - Axiomatic systems for geometry (Euclid, Hilbert, Choquet,...) and teaching of geometry in secondary school: some approaches to teaching geometry in secondary school. "Paths" for the teaching of geometry in secondary school. -Sequences and functions; the definition of limit; definition of derivative and definition of definite integral; epistemological, historical and didactic considerations. -Probability; the definitions of probability; basic theorems of probability. These elementary mathematics topics will be presented "from a superior point of view", that is, with critical attention to their foundations, their history and their current teaching (in secondary school). During the course, the use of technological tools for teaching and learning mathematics in secondary school will also be proposed, underlining their methodological value, with frequent examples of use of mathematical software (in particular, the use of the GeoGebra software will be proposed).

Examination:
Oral exam plus an in-depth written report on a fundamental topic (assigned by the teacher) covered in the course. The report will be presented in the last part of the course or, alternatively, in the first part of the exam.

More information:

FUNCTIONS THEORY

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. DAVIDE VITTONE

Credits: 8 ECTS

Prerequisites:
HAMILTONIAN MECHANICS

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. PAOLO ROSSI

Credits: 6 ECTS

Prerequisites:

Short program:

Examination:

More information:

HARMONIC ANALYSIS

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. PAOLO CIATTI

Credits: 6 ECTS

Prerequisites:

Calculus and Advanced Calculus, and, possibly, basics in real and complex analysis. A basic knowledge of Lebesgue integration and Lebesgue spaces, together with the basics in Hilbert space theory is highly recommended. Some knowledge of holomorphic function theory would be also helpful.

Short program:

Examination:
The final exam will be a take-home exam, consisting of roughly eight questions, and a discussion of the topics considered during the lectures.

More information:

HOMOLOGY AND COHOMOLOGY

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. JAKOB SCHOLBACH

Credits: 6 ECTS

Prerequisites:

Short program:

Examination:

More information:
INTRODUCTION TO GROUP THEORY

Master’s degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. ANDREA LUCCHINI

Credits: 8 ECTS

Prerequisites:

Short program:

Examination:

More information:

INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS

Master’s degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof.ssa LAURA CARAVENNA

Credits: 8 ECTS

Prerequisites:

Short program:

Examination:

More information:

INTRODUCTION TO RING THEORY

Master’s degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. ALBERTO TONOLO

Credits: 8 ECTS

Prerequisites:

Short program:

Examination:

More information:
INTRODUCTION TO STOCHASTIC PROCESSES

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. BERNARDO D'AURIA

Credits: 8 ECTS

Prerequisites: -

Short program: -

Examination: -


MATHEMATICAL LOGIC 2

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Dott. SAMUELE MASCHIO

Credits: 6 ECTS

Prerequisites: Basic notions of algebra, geometry and analysis. The knowledge of axiomatic methods and basics of set theory is preferable, but not necessary.


Examination: Oral exam.


MODERN PHYSICS

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: to be defined

Credits: 8 ECTS

Prerequisites: -

Short program: -

Examination: -


NUMBER THEORY 1

Master's degree in MATHEMATICS ORD. 2022, First semester
NUMBER THEORY 2

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. ADRIAN IOVITA

Credits: 6 ECTS
Prerequisites: -
Short program: -
Examination: -


NUMERICAL LINEAR ALGEBRA AND LEARNING FROM DATA

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Dott. FABIO MARCUZZI

Credits: 7 ECTS
Prerequisites: -
Short program: -
Examination: -


NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. MARIO PUTTI

Credits: 7 ECTS
Prerequisites: -
Short program: -
Examination: -
## OPERATIONS RESEARCH

**Master's degree in** [MATHEMATICS ORD. 2022], First semester

**Lecturer:** Prof. FRANCESCO RINALDI  

**Credits:** 8 ECTS  

**Prerequisites:**  
Basic Knowledge of Linear Algebra and Calculus.

**Short program:**  
- Basics of linear programming.  
- Integer linear programming models.  
- Methods for integer linear programming (branch-and-bound, cutting planes, column generation).  
- Totally unimodular matrices.  
- Nonlinear programming models.  
- Methods for nonlinear programming.  
- Software tools for optimization.

**Examination:**  
The exam is divided into two parts: Written Test and Project. The final grade is determined by two elements: 1) Project (max score 10 points): must be requested by email and delivered within 3 days from the date of the exam. 2) Written exam (max score 24 points). NOTES: - Students interested in studying specific aspects of the subject can ask for an integrative project (theoretical / practical) that partially replaces the written test (max score 12 points). - The exam is passed if the final score for the project is at least 6 points and for the written test is at least 12 points. - The project grades have no expiration date.

**More information:**  

## OPTIMIZATION

**Master's degree in** [MATHEMATICS ORD. 2022], Second semester  

**Lecturer:** to be defined  
Course not activated for the a.y. 2022/2023

**Credits:** 6 ECTS  

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**  

## REPRESENTATION THEORY OF GROUPS

**Master's degree in** [MATHEMATICS ORD. 2022], Second semester

**Lecturer:** Prof.ssa GIOVANNA CARNOVALE

**Credits:** 6 ECTS  

**Prerequisites:**

**Short program:**

**Examination:**
RINGS AND MODULES

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. JORGE NUNO DOS SANTOS VITORIA

Credits: 6 ECTS

Prerequisites:

Short program:

Examination:


STOCHASTIC ANALYSIS

Master's degree in MATHEMATICS ORD. 2022, First semester

Lecturer: Prof. DAVID BARBATO

Credits: 7 ECTS

Prerequisites:

Short program:

Examination:


STOCHASTIC METHODS FOR FINANCE

Master's degree in MATHEMATICS ORD. 2022, Second semester

Lecturer: Prof. MARTINO GRASSELLI

Credits: 7 ECTS

Prerequisites:

Short program:

Examination:


SYMPLECTIC MECHANICS

Master's degree in MATHEMATICS ORD. 2022, Second semester
TOPOLOGY 2

Master's degree in MATHMATICS ORD. 2022. First semester

Lecturer: Prof. ANDREA D'AGNOLO

Credits: 6 ECTS

Prerequisites:

Short program:

Examination:

More information:

MOLECULAR BIOLOGY (ORD. 2020)

APPLIED STATISTICS

Master's degree in MOLECULAR BIOLOGY (ORD. 2020). First semester

Lecturer: Prof. DAVIDE RISSO

Credits: 6 ECTS

Prerequisites:
The style is informal and only minimal mathematical notation will be used. There is no real prerequisite except elementary algebra. However, a previous introductory course in statistics is recommended.

Short program:

Examination:
Written exam

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/007PD/SCP8085059/NO
### BEHAVIOURAL GENETICS

**Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester**

**Lecturer:** Prof. MAURO AGOSTINO ZORDAN  
**Credits:** 6 ECTS

**Prerequisites:**  
Basic Genetics and possibly also Population Genetics. Ideally some background in programming with R (Rstudio)

**Short program:**  
- Introduction to behavioural genetics: - Historical introduction: - Francis Galton, eugenics, racial laws and Nazism, behaviourism, birth of behavioural genetics; - Behaviour as gene-environment interaction (nature-nurture): Studies on human families - MZ and DZ twins and adoptive children; - Model organisms in behavioural genetics: Caenorhabditis, Drosophila, Zebrafish, mammals: rat, mouse, dog (behaviour and domestication). - Genetics of quantitative characters in the study of behaviour (behavioural quantitative traits) - Types of quantitative characters - Similarity between relatives and the concept of heritability - Artificial selection and realized heritability - Equation for the prediction of individual selection - Genetic models for quantitative characters - Components of phenotypic variation - Sources of genetic and environmental variation - Components of genetic variation - Covariance between relatives - Studies on twins and inferences on human heritability - Norm of reaction, threshold characters and genetic correlation - Norm of reaction and phenotypic plasticity - Threshold characters: Genes as risk factors in disease - Genetic correlation and correlated response - How to identify genes? Single genes or multiple genes? - The number of genes which influence quantitative traits - Methods for mapping (Quantitative Trait Loci) QTL - Candidate genes - Genome Wide Association (GWA) - Single Nucleotide Polymorphisms (SNP) - Physiological behaviour and it's variations, considering also pathological aspects of selected behaviours. - circadian rhythms, sleep - learning and memory - socialization, aggressiveness - locomotion - orientation and navigation - sexual orientation - seeking novelties - Description of the molecular mechanisms and the neuronal circuits involved in the control of some of the behavioural patterns described in the preceding section. - Practicals: Methods to study behaviour in animal models (partly taught class, partly laboratory simulations) - Design of equipment, computer hardware and software, numerical and statistical analysis of data (i.e. videos, movement tracking).

**Examination:**  
Written exam, at the end of the course, using the Moodle platform.

**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/007PD/SCQ1097221/NO

### CELL BIOLOGY

**Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester**

**Lecturer:** Prof.ssa CHIARA RAMPAZZO  
**Credits:** 9 ECTS

**Prerequisites:**  
Basic level of Cell Biology, Molecular Biology and Genetics

**Short program:**  
The 9 CFU course is organized in about 7 CFU of frontal lectures and 2 CFU dedicated to the presentation and discussion of recent articles on specific topics. The discussion of the articles is an integral part of the program. Lectures will cover 7 main topics: 1) Physical principles behind the most common microscopy techniques (1 CFU). 2) Chromatin Biology and nuclear organization to address fundamental questions about cellular differentiation and nuclear reprogramming. Chromosome territories and subdomains. Nucleoli and nuclear lamina (2CFU) 3) Centromeric and telomeric chromatin (1 CFU). 4) polycomb complexes, facultative heterochromatin and bivalent chromatin in pluripotent stem cells (1 CFU) 5) Symmetric / asymmetric cell division and cell polarity (1 CFU) 6) Main principles of autophagy and related diseases 7) Quiescence and senescence in mammalian cells. Abnormal signal transduction pathways in cancer development. Immortalization and transformation, role of telomerases. Cancer stem cells (2CFU).

**Examination:**  
The knowledge acquired by the student will be evaluated with a written exam organized in two parts. First part (1 CFU) described in the course contents at section 1 will be assessed with one open question that include a long answer. the second part (6 CFU) described in the course content at section 2 to 4 will be assessed with open questions that include short or longer answer. The final grade is expressed as a weighted average between the two parties.

**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/007PD/SCP8085218/NO

### COMPUTATION AL ANTHROPOLOGY

**Master's degree in MOLECULAR BIOLOGY (ORD. 2020), Second semester**

**Lecturer:** Prof. LUCA PAGANI  
**Credits:** 6 ECTS

**Prerequisites:**
Prior knowledge needed for the classes in Computational Anthropology is that normally provided for students at the final class of the first degree in Molecular Biology. Particularly, the basic understanding of Genetics, Statistics, Phylogeny, and Evolutionary Biology in their fundamental principles and processes, is required. Students must also be familiar with the Unix/Shell environment. No prior knowledge is requested about specific contents in Population Genetics and Genomics, however scientific contents of the "Anthropology" course may be of great help during this course.

Short program:
The course aims at blending basic knowledge within the fields of Molecular Anthropology and Human Population Genetics with practical (bioinformatic) skills, transferable to the expanding occupational sectors of Personal Genomics and Ancestry analyses. The following topics will be explored from a theoretical and a practical/applicative angle: 1) Genetic admixture and local ancestry; 2) Ancestry deconvolution and ancestry-specific analyses; 3) Population differentiation among human groups, both at a genome-wide and at a locus-specific level; 4) Effect on the genome of natural selection events; 5) Introgression events between Homo sapiens and Archaic humans; These general objectives are addressed through critical discussion of case-studies taken from primary scientific literature on Molecular Anthropology, and through extensive hands on exercise in a computer lab.

Examination:
Examination will be based on a practical exercise of approximately 3 hours, to be carried out in the computer room. The exercise will include the main topics of the course and will be comparable to what already experienced during the hands on lectures. Final evaluation will be based upon the obtained results and will follow a discussion with the teacher about the information and procedures carried out to solve the exercise.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/007PD/SCP9085072/NO

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### EPIGENETICS AND EPIGENOMICS

**Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester**

**Lecturer:** Prof. CARLO FIORE VISCOMI

**Credits:** 6 ECTS

**Prerequisites:**
Knowledge of the fundamental principles of Genetics, Biochemistry, and Molecular Biology. The course aims at providing the students of the master’s degree in Molecular Biology with advanced knowledge of the most up-to-date concepts in epigenetics and epigenomics, with a particular focus on their role in human diseases.

**Short program:**
Introduction: What is epigenetics? (0.2 CFU) The composition of chromatin: the epigenome and molecules involved in chromatin regulation (0.8 CFU) Technologies for analysing the nuclear genome transcriptional activity: (e.g.: high-resolution FISH of genes in transcription factories, 3C, 4C, 5C and HiC of chromatin for resolving co-localized and co-transcribed sequences, genome-wide Mapping of DNase I hypersensitive sites) (0.5 CFU) Proximal and distant DNA regions involved in genome regulation; DNA and chromatin modifications and regulation of genome expression (internal and external factors) (0.5 CFU) Examples of dynamic changes in the three-dimensional architecture of chromatin and gene regulation; The protein non-coding part of the genome with its principal products: Micro RNAs: biogenesis, regulation and activities; specific examples of miRNA actions; interactions with other epigenetic molecules; network of interactions between miRNA and mRNAs (with original papers, e.g: miRNA 27a and 142 and metabolism modulation; miR-208b and miR-499 and muscle performance) (0.5 CFU) Long non-coding RNAs (LncRNAs): the discovery (ENCODE project, full-length mapping) biogenesis, evolution, regulation and activities by illustrating examples (original papers) of specific actions of LncRNAs (e.g. as GASS as decoy, HOTAIR as scaffold, PVT1 as protein modifier, MD-1 and as microRNA sponge); circular RNAs (e.g.: CDR1as as cytoplasmic sponge), other non-coding RNA classes (0.5 CFU) Reversibility of epigenetic patterns: approaches for genome reprogramming (nuclear transfer, cell fusion, cell extracts, cloned genes or proteins, mRNAs) (0.5 CFU) The epigenetic basis of gene imprinting: genomic imprinting, differential expression of paternal and maternal alleles, control of monoallelic expression of imprinted genes; examples of imprinting; establishing differentially methylated genomic regions; disorders & imprinting. (0.5 CFU) Epigenetic regulation in Mendelian disorders: chromatin diseases and gene modifiers (e.g. FSHD, Duchenne MD, Rett syndrome, mitochondrial diseases), diseases caused by heterochromatin dysregulation (inappropriate gene silencing, heterochromatin reduction). (0.4 CFU) Epigenetic modifications and multifactorial syndromes. (0.2 CFU) Regulating the epigenome in the therapy of human diseases (0.2 CFU) Epigenetic control of the mitotic cell cycle (0.2 CFU) Epigenetics of cancer: uncontrolled replication, epigenetic changes leading to transformation, abnormal patterns of methylation, histone modifications and cancer, epigenetics of tumour metastasis. (0.2 CFU)

**Examination:**
written final exam (open questions) in presence or online (only in the presence of the conditions accepted by the University).

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/007PD/SCP9087941/NO

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### FUNDAMENTALS OF INFORMATION SYSTEMS

**Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester**

**Lecturer:** Prof. GIORGIO MARIA DI NUNZIO

**Credits:** 12 ECTS

**Prerequisites:**
The student should have basic knowledge of computer programming and problem solving skills.

**Short program:**
The course is structured into 3 submodules: - Python Programming (for Data Science) This submodule provides students with the foundational coding skills
they need as data scientists. First, the basics of the Python programming language are covered (i.e., built-in data types, functions, I/O, etc.) along with the environment which is used throughout the class (i.e., Jupyter Notebook). Afterwards, students will dig into a set of the most up-to-date data science Python packages; those are: numpy/scipy (for numerical/scientific computing), pandas (for data manipulation), matplotlib/seaborn (for data visualization), and finally scikit-learn (for learning from data). - Databases This submodule is dedicated to data storage, and it covers the following topics: Relational databases, Logical and Physical Design of a Relational Database. SQL Language: Data Definition and Data Manipulation Language, Database Query The PostgreSQL database: Creation and Definition of a Database, SQL Queries. Non Relational databases, graph databases, Cypher query language. Neo4j database: Creation and Definition of a Database, Graph Query Language. - Algorithmic Methods: Preliminaries: definition of problem, instance, solution, algorithm. Models of computation. Analysis of algorithms: correctness and running time. Asymptotic analysis. Basic data structures: lists, stacks, queues, Trees and their properties. Dictionaries and their implementation. Priority queues. Graphs: representation of graphs. Basic properties. Graph searches and applications. Divide and Conquer paradigm: the use of recursion. Case study: sorting. Eventually, at the end all the modules, students will be able to implement all the stages of a typical machine learning pipeline: from collecting data to building predictive models for solving efficiently a data analysis/prediction problem.

Examination:
Written exam.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/007PD/SCP7078720/NO

Master's degree in MOLECULAR BIOLOGY (ORD. 2020). Second semester

Lecturer: Prof. GABRIELE SALES

Credits: 9 ECTS

Prerequisites:
Bioinformatics fundamentals (courses “Informatica e Bioinformatica” and “Bioinformatica II”). Solid knowledge of molecular biology, genetics and biochemistry.

Short program:
1. The statistical programming system R (1.5 CFU) - Basic commands and the interface to the operating system - Package installation; using BioConductor - The graphical environment RStudio - Using notebooks for analysis and reporting - Transformation of tabular data - Plot generation 2. Sequence alignment for NGS (1.5 CFU) - Burrows–Weeler transform, genome indexing - Using alignment programs: Bowtie, TopHat and STAR - Quality control - Computing quality metrics with FastQC and QoRTs - Expression quantification - Practical abundance estimation with RSEM and STAR 3. Transcriptomic assembly (1 CFU) - Software methods for short reads: the Trinity software. - Combining multiple assemblies with EvidentialGene. - Annotation methods: BLAST, InterproScan. 4. Introduction to omic and open data (0.5 CFU) - Programmatic access to databanks: BioMart. 5. Gene expression analysis (1 CFU) - Data normalization - Exploratory analyses - Differential expression tests - Functional analysis for the interpretation of results 6. DNA variant analysis (1 CFU) - Quality filters - Statistical tests - Main variants DB: use and analysis - Software for variant germinal variant calling: VarScan, DeepVar. 7. Introduction to single cell data analysis (0.5 CFU) - Seurat workflow

Examination:
The evaluation of the acquired knowledge will be based on a written exam based on open questions. The final evaluation will also keep into account the activity of the student in the analysis of a case study and the preparation of a report on his findings. This will gauge the establishment of the proper knowledge, the scientific lexicon, the ability to discuss critically and to summarize the topics discussed in the lectures.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/007PD/SCQ0094199/NO

Master's degree in MOLECULAR BIOLOGY (ORD. 2020). First semester

Lecturer: Dott.ssa ENRICA CALURA

Credits: 6 ECTS

Prerequisites:
Notions of molecular biology and genomics techniques, notions of programming and knowledge of the first year course topics.

Short program:
Course Introduction: (4 ore – 0.5 CFU) • What is integrative biology? • Big Data in biology • Digital DNA: practical, high-capacity, low-maintenance information storage in synthesized DNA • Why modern biology is integrative: history and evolution of bioinformatics Summary and recall of RNA-sequencing: (4 hours – 0.5 CFU) • Experimental design of omic experiments: types of experimental design; how to choose the right experimental setting according to the biological questions. • Microarrays - RNAseq vocabulary and NGS technologies • Transcriptomic data analysis: brief recall of RNAseq differential expression. • Long-read human genome sequencing and its applications The omic data integration in cancers (2 hours – 0.25 CFU) • Basis of cancer genomics and molecular biology of cancers • Omics and multi-omics in cancer Computational resources for the integration of biological data (2 hours – 0.25 CFU) Types of tools, utilities and functions • Tips for evaluation of computational resource R programming base (4 hours – 0.5 CFU) • Introduction to R (data types and data structures, basic commands); • The R world useful for biology (RStudio, R packages, Bioconductor, quick GitHub detour, R markdown) Integrating microRNA and gene expression: (6 hours – 0.75 CFU) • Biogenesis and mechanisms of microRNA • System biology of microRNA: the miRNAome complexity • miRNA bioinformatics tools • Computational principles and practice of circulating microRNA trafficking and regulation Pathways and networks for biological data integration (8 hours – 1 CFU) • Gene set and analysis • Biological networks: the pathway model • Pathway types, graphical notation and data formats • Evolution, drawbacks and challenges in knowledge representation of metabolic pathway • Evolution, drawbacks and challenges of cell signaling pathway databases • Multi-omic data integration in pathway analyses Transcriptionome regulation (4 hours – 0.5 CFU) • Transcription factor and computational motif
finding  •  Chromatin Immunoprecipitation (ChIP-seq) data analysis • ChIP-seq motif analysis and TF interactions • Epigenomics data integration (6 hours - 0.75 CFU) • DNA-Methylation (MeDip-seq, MRE-seq, MG and RR bisulfite seq, SMRT sequencing) • Nucleosome position (MNase-seq) • Histone modification (Histone mark ChIP-Seq) • Chromatin accessibility (DNAse-Seq, ATAC-Seq) • Higher order chromatin interactions (Hi-C) Spatial Transcriptomics (2 hours – 0.25 CFU) ESERCITAZIONI (16 hours – 1 CFU) 1. Surfing and evaluation of Multi-omic Cancer Data 2. Surfing and evaluation of Multi-omic Cancer Webtools 3. Pathway analyses with R programming 4. ChIP-seq case study with R programming

Examination:
Written exam

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/007PD/SCQ0094218/NO

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**MICROBIAL METAGENOMICS**

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, Second semester

**Lecturer:** Prof. STEFANO CAMPANARO

**Credits:** 6 ECTS

**Prerequisites:**
The course requests basic knowledge regarding molecular biology, microbiology and bioinformatics.

**Short program:**
Introduction to metagenomics. First part- Methods Next generation sequencing for metagenomics. Second generation sequencing (Illumina) and third generation sequencing (Nanopore/PacBio) deeply influenced the metagenomic field. Amplicon libraries, shotgun DNA libraries, RNA-seq for metatranscriptomics (0.4 CFU). Basic concepts regarding microbial community analysis. Structure of the microbial communities, ecological indices, similarity measures (0.2 CFU). Marker genes based analysis. Amplicon sequencing analysis using different marker genes (16S rRNA, 18S rRNA, ITS, viral markers, other examples) (0.4 CFU). Video lessons Rob Knight - 16S amplicon sequencing. General resume regarding marker gene analysis and the use of specific software (QIIME, Mothur) (0.1 CFU). Metagenomic inference. How to infer the genetic composition of a microbiome starting from amplicon sequencing data using PICRUSt (0.3 CFU). Analysis of shotgun metagenomic reads. Approaches and software used for analyzing shotgun sequence data without performing the assembly process (0.2 CFU). Metagenomic assembly and binning. Approaches to the assembly of shotgun reads, the challenge of the microbial communities. Extraction of single genomes from the metagenome: the binning approach (0.6 CFU). Metatranscriptomics. Analysis of RNA-seq data to analyze the gene expression at community-level (0.6 CFU). Video lessons Rob Knight - Statistical analyses. Statistical approaches to the study of metagenomics (0.2 CFU). Metabolic flux balance analysis. Methods to the investigation of metabolic fluxes in complex microbial populations (0.4 CFU). Second part – Structure of the microbiome in some selected environments. Anaerobic digestion metagenomics. Degradation of complex organic matter is performed by a multi-layer microbiome composed by Bacteria and Archaea (0.3 CFU). Marine metagenomics. The structure of the marine microbiome, how approaches changed during the years for the investigation of this complex microbial community (0.3 CFU). Soil metagenomics. The composition of the soil microbiome described from a number of examples (0.3 CFU). Human gut metagenomics. The human gut microbiome, its role in determining specific diseases (0.3 CFU). Viruses metagenomics. The metagenomics of viruses performed from shotgun sequencing data (0.2 CFU). Conclusions and final remarks (0.1 CFU). Journal club. Students will select a paper and will present in critical way methods and findings (0.1 CFU). Laboratory. The practical laboratory is composed of two sections, the first is based on analysis of 16S rRNA amplicon sequences using QIIME, and the second on the analysis of shotgun sequencing data using metagenomic assembly and binning (1 CFU).

**Examination:**
Final test will be based on written examination, questions will evaluate acquired knowledge, ability to summarize answers and critical discussion. Test is based on topics covered during the course.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/007PD/SCP9087942/NO

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**MODELS IN GENETIC DISEASE RESEARCH**

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof. MAURO AGOSTINO ZORDAN

**Credits:** 4 ECTS

**Prerequisites:**
The course consists in a series of specific seminars dealing with the general topic of genetic diseases and the model organisms employed to study the molecular mechanisms involved in the physiopathology of the diseases. Consequently, all of the courses entailed by the Master's degree are considered preparatory to this course.

**Short program:**
The course is organized as a series of one-hour seminars on topics dealing mainly with genetic diseases and the use of model organisms in genetic disease research. Topics typically touch upon molecular aspects of select genetic diseases and on the application of models such as in vitro mammalian cells, yeast, Drosophila, zebrafish and mouse to study the pathogenetic mechanisms of specific genetic defects.

**Examination:**
The final exam will be written and consists in reading a scientific paper dealing with the subject exposed in one of the seminars and, on the basis of the paper's content, writing an abstract, which for the occasion, will have been concealed from the original paper.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/007PD/SCP9087942/NO
MOLECULAR BIOLOGY OF DEVELOPMENT

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), Second semester

Lecturer: Prof. FRANCESCO ARGENTON

Credits: 8 ECTS

Prerequisites:
The students should have already acquired the fundamentals on eukariotic cellular biology, on control of gene expression, differentiation, histology and developmental biology.

Short program:
1) Presentation of the course, history and principles of developmental genetics (1.5 CFU): cell fate analysis, organizers and transplants, mutagenesis, cellular asymmetry, chemoaffinity hypothesis, sex determination, lateral inhibition, somitogenesis. 2) Cellular Developmental Mechanisms (0.5 CFU): Survival, Apoptosis, Shape, Movement, Differentiation, Gene Expression 3) Morphogenetic theory (0.5 CFU); reaction-diffusion theory, French flag theory. 4) Genetic pathways controlling development, their function and visualization (1.5 CFU): Wnt, TGFβ, BMP, HH, Notch 5) germ layers induction and regionalization of the main axes (DV, AP, LR) in vertebrates and Drosophila, Examples of organ formation. (1 CFU) 6) Basic concepts of stem cell biology and techniques. Adults stem cells. (0.5 CFU) 7) Early mouse and human development from zygote to gastrulation (0.5 CFU) 8) Murine and human pluripotent stem cells. JAK/STAT and FGF pathways (0.5 CFU) 9) Reprogramming (0.5 CFU)

Examination:
Three essay on open questions on theoretical, practical and critical topics of the class. For the laboratory experience, students must prepare a written report of their practicals on whole mount analysis of development. Students are also asked during the progress of the class to present a developmental genetic topic.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/007PD/SCP8085071/NO

STRUCTURAL BIOCHEMISTRY AND BIOPHYSICS

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: Prof.ssa LAURA CENDRON

Credits: 9 ECTS

Prerequisites:
General Biochemistry concepts. Basic Mathematics and Physics courses.

Short program:
The course will be divided in two parts. The first will be devoted to the introduction of basic principles of Biophysical techniques focused on structural and functional characterization of biological macromolecules, supramolecular assemblies and cells. In the second part, three recently described paradigms in the analysis of sensorial system study will be introduced. Such examples will be proposed mainly focusing on the Biophysical Methods that allowed disclosing important links between structure and function of macromolecules. First part A. Basic principles about protein structure B. Protein sequences analysis, alignment and structure prediction C. X-ray crystallography 1. Crystalization techniques in biochemistry. 2. Crystals, mathematical lattice, symmetry in crystals, space groups. 3. Production of X-rays; 4. Diffraction of X-rays (waves, interference); 5. Single crystal X-ray diffraction; Bragg's law; X-rays diffraction pattern; structure factors; the concept of Resolution 7. X-ray data collection, indexing and processing 8. From diffraction data to the protein model 9. The phase problem and solution methods, MIR, MAD, MR 10. Structure refinement; The R index; Treatment and analysis of structural data; D. Single particle CryoElectron Microscopy (CRYO-EM): basic concepts and applications of electron microscopy on single particle specimens 1. Basic concepts 2. Instruments 3. Sample preparation 4. Data collection and treatment 5. From 2D projections to 3D reconstruction E. Nuclear magnetic resonance (NMR) NMR spectroscopy applied to protein studies: Basic concepts and technique introduction; F. Examples of structural data usage in the investigation of relevant questions in biochemistry as well as for purposes related to applied research; Second part: 1. Energy transformation in biology: from the physiological mechanisms to the biophysical methods used to study physiology, which are based on the interaction between energy and matter 2. Sound energy and the molecular mechanisms of the perception of different frequencies. 3. Visual perception and the molecular basis of photoreception. Leading from physiology to exploit light as a tool to investigate the molecular mechanisms of biology. 4. Advanced optical microscopy methods: technology beyond human eye 5. Non-visible electromagnetic radiation: (patho)physiological mechanisms and biophysical methods in biology that exploit these light wavelengths 6. Heart as a fluidic pump: from the electric signal (and its molecular mechanisms) to the mechanic work 7. The use of the magnetic properties of the matter to investigate the biomolecules: protein NMR in physiology and comparison with other structural biology methods 8. Magnetoreception in nature and its molecular mechanisms: how can the earth magnetic field be detected by live being? 9. The problem of signal to noise ratio in physiology and in the measuring instruments.

Examination:
Written or oral examination. Both general and specific questions for each of the two parts of the course will be proposed.
### SYSTEMS BIOLOGY

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof. GABRIELE SALES  
**Credits:** 6 ECTS

**Prerequisites:**  
The basic knowledge deriving from the subjects of the first year of the Master Degree

**Short program:**  
Introduction to Systems Biology. (0.25 CFU) Basics of Derivatives, Integrals and Differential Equations Mathematical Modeling. (0.25 CFU) Static Network Models. (0.5 CFU) Markov Models. (0.5 CFU) Mutual Information, Relevance Networks and Bayesian Networks. (0.5 CFU) The Mathematics of Biological Systems. (0.5 CFU) Parameter Estimation from Noisy Data: Grid Searches, Hill Climbing, Genetic Algorithms. (0.5 CFU) Signaling Systems. (0.5 CFU) Population Systems. (0.5 CFU) SIR Model Simulation. (0.5 CFU)

**Examination:**  
The evaluation of the acquired knowledge will be based on a written exam based on 4 open questions. This will gauge the establishment of the proper knowledge, the scientific lexicon, the ability to discuss critically and to summarize the topics discussed in the lectures.

### APPLIED STATISTICS FOR GENETICS

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof. DAVIDE RISSO  
**Credits:** 6 ECTS

**More information:**  

### BIOCHEMISTRY FOR GENETICS

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof.ssa ILDIKO SZABO  
**Credits:** 8 ECTS

**More information:**  

### BIOCHEMISTRY OF DISEASES

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof. LUCA SCORRANO  
**Credits:** 8 ECTS

**Prerequisites:**  
Biochemistry, Physiology and Pathology

**Short program:**  
Introduction to class. Course organization. Distribution of material, designing and interpreting an experiment in biology how to critically read a research paper (w/example) Metabolic flexibility Interorganelar contact sites angiogenesis adipocyte biology neurodegeneration Design and analysis of a conditional knockout mouse Introduction to the lab rotation experiments Presentation of the lab rotation experiments by students Critical presentation of a paper by students course wrap up: questions, doubts, answers

**Examination:**
Evaluation of the overall active participation to classes and tutorials (30%) Evaluation of the lab report (30%) Evaluation of the final public presentation (40%)

More information:

### COMPUTATIONAL ANTHROPOLOGY

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, Second semester

**Lecturer:** Prof. LUCA PAGANI

**Credits:** 6 ECTS

More information:

### EPIGENETICS AND EPGENOMICS

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof. CARLO FIORE VISCOMI

**Credits:** 6 ECTS

More information:

### HUMAN PHYSIOLOGY

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined

**Credits:** 9 ECTS

More information:

### INTEGRATIVE BIOLOGY AND NETWORK ANALYSIS

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Dott.ssa ENRICA CALURA

**Credits:** 6 ECTS

More information:

### MATHEMATICAL MODELING FOR BIOLOGISTS

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, Second semester

**Lecturer:** to be defined

**Credits:** 2 ECTS

More information:
# MODELS IN GENETIC DISEASE RESEARCH

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof. MAURO AGOSTINO ZORDAN  
**Credits:** 4 ECTS  

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# MOLECULAR ANTHROPOLOGY

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester  
**Lecturer:** Prof. LUCA PAGANI  
**Credits:** 8 ECTS  
**Prerequisites:** -  
**Short program:** -  
**Examination:** -  

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# MOLECULAR GENETICS

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester  
**Lecturer:** Prof.ssa MILENA BELLIN  
**Credits:** 6 ECTS  

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# SYSTEMS BIOLOGY

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester  
**Lecturer:** Prof. GABRIELE SALES  
**Credits:** 6 ECTS  

---

# APPLIED STATISTICS

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester  
**Lecturer:** Prof. DAVIDE RISSO  
**Credits:** 6 ECTS
Prerequisites:
The style is informal and only minimal mathematical notation will be used. There is no real prerequisite except elementary algebra. However, a previous introductory course in statistics is recommended.

Short program:

Examination:
Written exam

More information:

### CELL BIOLOGY

Master’s degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

Lecturer: Prof.ssa CHIARA RAMPAZZO

Credits: 9 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/006PD/SCP8085218/NO

### COMPUTATIONAL ANTHROPOLOGY

Master’s degree in **MOLECULAR BIOLOGY (ORD. 2020)**, Second semester

Lecturer: Prof. LUCA PAGANI

Credits: 6 ECTS

More information:

### FUNDAMENTALS OF INFORMATION SYSTEMS

Master’s degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

Lecturer: Prof. GIORGIO MARIA DI NUNZIO

Credits: 12 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/006PD/SCP7078720/NO

### GENOMICS AND NGS DATA ANALYSIS

Master’s degree in **MOLECULAR BIOLOGY (ORD. 2020)**, Second semester

Lecturer: Prof. GABRIELE SALES

Credits: 9 ECTS

More information:

### MICROBIAL METAGENOMICS
Master's degree in MOLECULAR BIOLOGY (ORD. 2020), Second semester

Lecturer: Prof. STEFANO CAMPANARO

Credits: 6 ECTS


MODELS IN GENETIC DISEASE RESEARCH

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: Prof. MAURO AGOSTINO ZORDAN

Credits: 4 ECTS


MOLECULAR BIOLOGY OF DEVELOPMENT

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), Second semester

Lecturer: Prof. FRANCESCO ARGENTON

Credits: 8 ECTS


APPLIED STATISTICS

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: Prof. DAVIDE RISSO

Credits: 6 ECTS

Prerequisites:
The style is informal and only minimal mathematical notation will be used. There is no real prerequisite except elementary algebra. However, a previous introductory course in statistics is recommended.

Short program:

Examination:
Written exam


BIOCHEMISTRY

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: Prof.ssa ILDIKO SZABO

Credits: 8 ECTS
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<td>GENOMICS AND NGS DATA ANALYSIS</td>
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<td>Second semester</td>
<td>Prof. GABRIELE SALES</td>
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<td>Prof.ssa BARBARA BALDAN</td>
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<td>Prof. FRANCESCO ARGENTON</td>
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Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, Second semester

**Lecturer:** Prof.ssa DANIELA PIETROBON

**Credits:** 10 ECTS

**More information:**

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### ADVANCED COURSE IN CELL DYNAMICS

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined

**Credits:** 3 ECTS

**Prerequisites:**
- 

**Short program:**
- 

**Examination:**
- 

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094394/NO

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### AGING: BASIS AND NEURO-RELATED DISEASES

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined

**Credits:** 3 ECTS

**Prerequisites:**
- 

**Short program:**
- 

**Examination:**
- 

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094455/NO

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### BACTERIAL GENETIC: FROM EVOLUTION TO ENGINEERING

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined

**Credits:** 3 ECTS

**Prerequisites:**
- 

**Short program:**
- 

**Examination:**
- 

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094455/NO
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Lecturer: to be defined
Credits: 3 ECTS
Prerequisites:

Short program:

Examination:

More information:
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**CELLULAR BIOLOGY OF CANCER**

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

Lecturer: to be defined
Credits: 3 ECTS
Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094438/NO

**CELLULAR NEUROBIOLOGY AND DEVELOPMENT**

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

Lecturer: to be defined
Credits: 3 ECTS
Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094454/NO

**EPIGENETICS**

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

Lecturer: to be defined
Credits: 3 ECTS
Prerequisites:

Short program:

Examination:
### EVOLUTION AND DEVELOPMENT

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined  
**Credits:** 3 ECTS  
**Prerequisites:**  
**Short program:**  
**Examination:**  

More information:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094442/NO

### GENETIC PREDISPOSITION TO CANCER

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined  
**Credits:** 3 ECTS  
**Prerequisites:**  
**Short program:**  
**Examination:**  

More information:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094445/NO

### GENETICS AND EPIGENETICS OF MULTIFACTORIAL DISEASES

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined  
**Credits:** 3 ECTS  
**Prerequisites:**  
**Short program:**  
**Examination:**  

More information:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094444/NO

### GENOMIC ANALYSIS OF CANCERS
Master’s degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined

**Credits:** 3 ECTS

**Prerequisites:**

- 

**Short program:**

- 

**Examination:**

- 

**More information:**

https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094441/NO

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**GENOMICS**

Master’s degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined

**Credits:** 3 ECTS

**Prerequisites:**

- 

**Short program:**

- 

**Examination:**

- 

**More information:**

https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094449/NO

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**HUMAN EVOLUTIONARY GENETICS**

Master’s degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined

**Credits:** 3 ECTS

**Prerequisites:**

- 

**Short program:**

- 

**Examination:**

- 

**More information:**

https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094450/NO

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**HUMAN GENETICS AND HEMATOLOGY**

Master’s degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined

**Credits:** 3 ECTS

**Prerequisites:**

- 

**Short program:**

-
HUMAN GENETICS AND NEUROBIOLOGY

Master’s degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined

**Credits:** 3 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094440/NO

MICROBIOLOGY: HOST-PATHOGENS INTERACTIONS

Master’s degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined

**Credits:** 3 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**
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MOLECULAR GENETICS OF HUMAN DISEASES

Master’s degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** to be defined

**Credits:** 3 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445//SCQ0094448/NO
NEURODEVELOPMENT, PREMATURITY, HOMEOSTASIS

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: to be defined

Credits: 3 ECTS

Prerequisites: -

Short program: -

Examination: -


NORMAL AND PATHOLOGICAL INTRACELLULAR SIGNALISATION

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: to be defined

Credits: 3 ECTS

Prerequisites: -

Short program: -

Examination: -


OPTOGENETICS

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: to be defined

Credits: 3 ECTS

Prerequisites: -

Short program: -

Examination: -


RNASEQ ANALYSIS

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: to be defined
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**APPLIED STATISTICS**

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof. DAVIDE RISSO

**Credits:** 6 ECTS

**More information:**
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**BEHAVIOURAL GENETICS**

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof. MAURO AGOSTINO ZORDAN

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCQ1097221/NO

**BIOCHEMISTRY**

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof.ssa ILDIKO SZABO

**Credits:** 8 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCP8085067/NO

**BIOCHEMISTRY OF DISEASES**

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof. LUCA SCORRANO

**Credits:** 8 ECTS

**Prerequisites:**
Biochemistry, Physiology and Pathology

**Short program:**
Introduction to class. Course organization. Distribution of material, designing and interpreting an experiment in biology how to critically read a research paper (w/example) Metabolic flexibility Interorganellar contact sites angiogenesis adipocyte biology neurodegeneration Design and analysis of a conditional knockout mouse Introduction to the lab rotation experiments Presentation of the lab rotation experiments by students Critical presentation of a paper by students course wrap up: questions, doubts, answers

**Examination:**
Evaluation of the overall active participation to classes and tutorials (30%) Evaluation of the lab report (30%) Evaluation of the final public presentation (40%)

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCP8085083/NO
CELL BIOLOGY

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof.ssa CHIARA RAMPAZZO  
**Credits:** 9 ECTS  
**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCP8085218/NO

COMPUTATIONAL ANTHROPOLOGY

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, Second semester

**Lecturer:** Prof. LUCA PAGANI  
**Credits:** 6 ECTS  
**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCP8085072/NO

EPIGENETICS AND EPIGENOMICS

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof. CARLO FIORE VISCOMI  
**Credits:** 6 ECTS  
**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCP9087941/NO

GENOMICS AND NGS DATA ANALYSIS

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, Second semester

**Lecturer:** Prof. GABRIELE SALES  
**Credits:** 9 ECTS  
**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCQ0094199/NO

MICROBIAL METAGENOMICS

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, Second semester

**Lecturer:** Prof. STEFANO CAMPANARO  
**Credits:** 6 ECTS  
**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCP9087942/NO

MODELS IN GENETIC DISEASE RESEARCH

Master's degree in **MOLECULAR BIOLOGY (ORD. 2020)**, First semester

**Lecturer:** Prof. MAURO AGOSTINO ZORDAN
MOLECULAR AND CELL BIOLOGY OF PLANTS

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: Prof.ssa BARBARA BALDAN

Credits: 9 ECTS

Prerequisites:
Students should have already acquired a basic knowledge of Cell Biology, Plant Biology, Biochemistry and Molecular Biology.

Short program:
Ca2+-mediated signal transduction in response to biotic and abiotic stresses in plants: Ca2+ as intracellular messenger; methods of measuring intracellular Ca2+ concentration; calcium transients and calcium signatures (1 CFU). Plant hormones (auxins, gibberellins, cytokinins, ethylene, abscissic acid): biosynthesis, actions, transport and developmental effects; signal transduction pathways (2 CFU). Growth and development: Shoot and root apical meristems: their establishment and maintenance. Determination of the developmental axes and the involved genes. Molecular aspects of lateral organ formation (0.5 CFU). Blue light and red light responses: light perception, signal transduction and plant responses to light environmental conditions (0.5 CFU). Plant reproductive development: floral meristem development, floral organ identity genes, ABCDE model to explain the flower development; the control of flowering (1 CFU). Molecular aspects in micro and macro-gametogenesis; self-incompatibility during the pollen-pistil interactions; genes involved in control of double fertilization; embryo, seed and fruit development (2 CFU). Plant–microorganism interactions: cellular and molecular surveys about mycorrhiza, Rhizobium-Leguminosae symbiosis and plant-Agrobacterium interaction (1 CFU). 1 CFU (16 h) of practical work on the following topics: 1) Somatic embryogenesis in the model system Daucus carota, tobacco micropropagation; 2) Isolation of protoplasts from cell suspension cultures of Arabidopsis thaliana transgenic lines; fluorescence imaging of intracellular compartments; 3) Beneficial plant-microbe interactions: staining and observation of arbuscules in Lotus japonicus roots; 4) Visit to the Botanical Garden of the University of Padova.

Examination:
To verify the acquired knowledge, the exam will be in written form, with open questions on theoretical topics dealt with during the course, as well as questions concerning the practical activity carried out in the laboratory. The active participation to the discussions proposed during teaching classrooms will also be considered.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCP8085062/NO

MOLECULAR ANTHROPOLOGY

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: Prof. LUCA PAGANI

Credits: 8 ECTS

Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCP8085071/NO
MOLECULAR BIOLOGY OF DEVELOPMENT

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), Second semester

Lecturer: Prof. FRANCESCO ARGENTON

Credits: 8 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCQ2101381/NO

MOLECULAR GENETICS

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: Prof.ssa MILENA BELLIN

Credits: 6 ECTS

More information:

NEUROBIOLOGY

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), Second semester

Lecturer: Prof.ssa DANIELA PIETROBON

Credits: 10 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCP8085065/NO

STRUCTURAL BIOCHEMISTRY AND BIOPHYSICS

Master's degree in MOLECULAR BIOLOGY (ORD. 2020), First semester

Lecturer: Prof.ssa LAURA CENDRON

Credits: 8 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2445/005PD/SCQ0094201/NO

PHYSICS OF DATA ORD. 2018

ADVANCED STATISTICS FOR PHYSICS ANALYSIS

Master's degree in PHYSICS OF DATA ORD. 2018, Second semester

Lecturer: Prof. ALBERTO GARFAGNINI

Credits: 6 ECTS

Protein evolution Key concepts in protein evolution. Comparative sequence analysis, concept of scoring matrices. Local and global sequence alignment for integrating PPI data. Finding protein interaction interfaces. Practical: Computational analysis of a PPI network (Barabasi 2021) - 8th week

Lecture: Interaction networks Network approach in biology. Protein interactions through experiments. Protein interaction databases. Bayesian approaches for experimental design and forecasting. Applications: power spectrum estimation in cosmological datasets (Cosmic Microwave Background and Large Scale Structure), MCMC for cosmological parameter estimation, component separation, Gravitational Wave data analysis. Fisher matrix forecasting for future cosmological surveys. Parts of the program might undergo changes, according to the composition and the competences of the class.

Examination: The exam is comprised of two phases. 1) Resolution of assigned homework during the course, eventually to undertake in group. 2) Oral examination with discussion of the course topics.

More information: https://en.didattica.unipd.it/it/off/2022/LM/SC/SC2443/000ZZ/SCP8082557/NO

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Dott. ALESSANDRO RENZI

Credits: 6 ECTS

Prerequisites: Probability and statistics: definition of probability, probability distributions, mean value, variance and covariance, Bayes Theorem, basics of statistical estimation theory, maximum likelihood, confidence intervals, hypothesis testing. Cosmology: Hubble law, Robertson-Walker metric, Friedmann-Robertson-Walker equations. Cosmological perturbations: Jeans instability, power spectrum, growth factor.


Examination: Written exam on the topics covered during the course, oral exam about a project to be carried out by students in groups

More information: https://en.didattica.unipd.it/it/off/2022/LM/SC/SC2443/000ZZ/SCP8082722/NO

Master's degree in PHYSICS OF DATA ORD. 2018, Second semester

Lecturer: Prof.ssa MONIKA FUXREITER

Credits: 6 ECTS

Prerequisites: Basic statistical mechanics, statistics, programming. Chemistry and biology at high-school level.


Examination:
The evaluation will be based on a project, which requires an integration of the knowledge gained in lectures and practicals. The project for each student will be different and have to be solved individually. The evaluation projects will be ‘real-life’ problems, linked to clinical data or biomedical research by research groups at the University of Padova, simplified to the extent that the students can solve them. Each project have to be completed with a written summary, which specifically includes i) the definition of the problem for the computer ii) reasons for method selection iii) concise description of the method, iv) brief description of the algorithm or flow-chart, v) results, vi) interpretation of results and vii) concluding section and future work. The projects evaluates the overall understanding of applying computational approaches to bio-problems. The projects require independent thinking and application of the lecture and practical materials. There is ample time to solve them and consultation opportunities are provided. The projects are presented as a written summary and possibly a short oral presentation.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCQ0093478/NO

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**COMPUTATIONAL ASTROPHYSICS**

Master's degree in **PHYSICS OF DATA ORD. 2018**, First semester

**Lecturer:** Prof.ssa MICHELA MAPELLI

**Credits:** 6 ECTS

**Prerequisites:** Basics of a programming language. Basics of Mathematical Analysis I and II. Basics of Kinematics and Dynamics (General Physics I), in particular Newton's theory of gravitation. Previous experience in the field of astrophysics is not requested, but is welcome.

**Short program:**
--- TOPIC nr. 1: Evolution of binary stars and the formation of binary compact objects --- 1.1- General introduction to the evolution of binary stars in astrophysics (mass transfer, common envelope, tidal forces). The formation of binary black holes and double neutron stars. 1.2- Population-synthesis and stellar evolution codes: simulating single and binary stellar populations. 1.3- Discussion of possible projects for topic nr. 1 --- TOPIC Nr. 2: N-body simulations, dynamics of stellar systems and the formation of binary black holes --- 2.1- General introduction to the astrophysical N-body problem. 2.2- N-body simulations: definition of an N-body simulation; concept of computational complexity; N-body units. 2.3- Examples of numerical algorithms to solve the astrophysical N-body problem: Euler, Leapfrog schemes. 2.4- Generation of the initial conditions for an N-body simulation (position, velocities, masses) via Monte Carlo methods. 2.5- Direct N-body codes for collisional systems: Hermite scheme, block time-step algorithm, regularization algorithms. 2.6- How to interface population synthesis with direct N-body codes. 2.7- Special purpose hardware, graphics processing units and high-performance computing in astrophysics. 2.8- Tree codes, softening. 2.9- Algorithms for gas dynamics: smoothed particle hydrodynamics, mesh codes, adaptive mesh refinement codes, hybrid moving mesh codes. 2.10- Sub-grid physics: star formation, sink particles, supernovae, radiative transfer. 2.11- General introduction to star cluster dynamics. 2.12- Binary black hole formation/disruption through close dynamical encounters. 2.13- Discussion of possible projects for topic nr. 2. --- TOPIC Nr. 3: Semi-analytic codes for binary black hole dynamics and cosmic evolution --- 3.1- Limitations of N-body simulations. 3.2- Semi-analytic codes for black-hole dynamics. 3.3- Semi-analytic codes for cosmic evolution of stars, galaxies, black holes. 3.4- Discussion of possible projects for topic nr. 3.

**Examination:**
Oral exam to discuss the final project, considering both its numerical and scientific aspects. In addition, each student will produce a report about the project and will make the scripts developed during the project available at least three days before the oral examination.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP9087518/NO

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**FINAL EXAMINATION**

Master's degree in **PHYSICS OF DATA ORD. 2018**, First semester

**Lecturer:** to be defined

**Credits:** 22 ECTS

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118/161
Short program:
The exam yielding the master title consists in the discussion of written document describing critically the scientific work produced by the candidate. Such document must be original in its essence and include an appropriate bibliography. The title is received once the candidate gathers at least 120 CFU's, respecting the maximum number of exams as indicated in the didactic regulations. The candidate shall also pass the final test which consist in the discussion in front of a committee of a thesis. The final test envisages an internship in a research center or a private company where the student will work on tasks compatible with the educational path of the master program. The committee judging the final test will be nominated by the Director of the Physics and Astronomy department. English is the language to be used for both the thesis and final test. The final grade expressed as a fraction of 110 will be based on the sum of: a. the weighted average of the grades gathered for the exams. The weight is determined by the CFU associated to each exam. b. the grade of the final test itself c. a possible grade granted to the student in recognition to her educational career. The specific contribution of each of these elements is determined by the Physics and Astronomy department upon advice from the faculty members affiliated to the master program. A "Laude" will be added to a final grade so computed exceeding 110 by a sufficient amount.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP8082717/NO

FUNDAMENTALS OF ASTROPHYSICS AND COSMOLOGY

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. SABINO MATARRESE

Credits: 6 ECTS

Prerequisites:
Fundamental concepts of quantum mechanics and special relativity

Short program:

Examination:
Oral interview.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP9086381/NO

GAME THEORY

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: ELVINA GINDULLINA

Credits: 6 ECTS

Prerequisites:
CONTENT NOT PRESENT

Short program:
CONTENT NOT PRESENT

Examination:
CONTENT NOT PRESENT
GENERAL RELATIVITY

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. MARCO PELOSO

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP7079401/NO

INFORMATION THEORY AND INFERENCE

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Dott. MICHELE ALLEGRA

Credits: 6 ECTS

Prerequisites:
-

Short program:
-

Examination:
-

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCQ0093479/NO

LABORATORY OF COMPUTATIONAL PHYSICS (C.I.)

Lecturer: Prof. MARCO ZANETTI

Prerequisites:
-

Examination:
-

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP8082524/NO

Moduli del C.I.:
LABORATORY OF COMPUTATIONAL PHYSICS
LABORATORY OF COMPUTATIONAL PHYSICS (MOD. B)

LABORATORY OF COMPUTATIONAL PHYSICS

Lecturer: Prof. MARCO ZANETTI

Master's degree in PHYSICS OF DATA ORD. 2018, First and Second semester

Credits: 12 ECTS

LABORATORY OF COMPUTATIONAL PHYSICS (MOD. B)

Lecturer: Prof. MARCO BAIESI

Master's degree in PHYSICS OF DATA ORD. 2018, First and Second semester
### LIFE DATA EPIDEMIOLOGY

**Master's degree in PHYSICS OF DATA ORD. 2018, First semester**

**Lecturer:** Dott.ssa CHIARA POLETTO

**Credits:** 6 ECTS

**Prerequisites:**
The course requires some previous knowledge on: - Probability theory. - Differential equations.

**Short program:**
Epidemics: motivation and applications (both to life sciences and ICT) Epidemics through compartmental models Solutions of epidemic models through differential equations Demography and equilibria Extended models and complex contagions Time-variable trends and temporal networks Network epidemics Metapopulation for spatial diffusion Data-driven models and integration in computational epidemiology Epidemiology data: surveillance, problems, and biases Statistical and mechanical methods Maximum likelihood fit Public health scenarios: analysis and forecasts

**Examination:**
Written exam on the topics covered during the course, oral exam about a project to be carried out by students in groups

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP8082719/NO

### MACHINE LEARNING

**Master's degree in PHYSICS OF DATA ORD. 2018, First semester**

**Lecturer:** Prof. PIETRO ZANUTTIGH

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP8082660/NO

### MANAGEMENT AND ANALYSIS OF PHYSICS DATASET (C.I.)

**Lecturer:** Dott. JACOPO PAZZINI

**Prerequisites:**
-

**Examination:**
-

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP8082533/NO

**Moduli del C.I.:**
MANAGEMENT AND ANALYSIS OF PHYSICS DATASET (MOD. A)
MANAGEMENT AND ANALYSIS OF PHYSICS DATASET (MOD. B)

### MANAGEMENT AND ANALYSIS OF PHYSICS DATASET (MOD. A)

**Lecturer:** Dott. ANDREA TRIOSSI

**Master's degree in PHYSICS OF DATA ORD. 2018, First and Second semester**

**Credits:** 12 ECTS

### MANAGEMENT AND ANALYSIS OF PHYSICS DATASET (MOD. B)

**Lecturer:** Dott. JACOPO PAZZINI

**Master's degree in PHYSICS OF DATA ORD. 2018, First and Second semester**
MODELS OF THEORETICAL PHYSICS

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. AMOS MARITAN

Credits: 6 ECTS

Prerequisites:
Good knowledge of mathematical analysis, calculus, elementary quantum mechanics and basic physics.

Short program:

Examination:
The first part of the verification of the acquired knowledge will evaluate the weekly exercises and the participation of the students in the class discussions. The second part is oral, and it will be based on a discussion on the various topics of the course.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP8083597/NO

MOLECULAR SIMULATIONS

Master's degree in PHYSICS OF DATA ORD. 2018, Second semester

Lecturer: Prof.ssa MONIKA FUXREITER

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCQ1098979/NO

NEURAL NETWORKS AND DEEP LEARNING

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: to be defined

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP9087899/NO

NUCLEAR PHYSICS

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof.ssa SILVIA MONICA LENZI

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP7081658/NO

PHYSICAL MODELS OF LIVING SYSTEMS
Master's degree in **PHYSICS OF DATA ORD. 2018**, First semester

**Lecturer:** Prof. SAMIR SIMON SUWEIS  
**Credits:** 6 ECTS

**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCQ1097938/NO

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**PHYSICS OF COMPLEX NETWORKS: STRUCTURE AND DYNAMICS**

Master's degree in **PHYSICS OF DATA ORD. 2018**, Second semester

**Lecturer:** Prof. MANLIO DE DOMENICO  
**Credits:** 6 ECTS  
**Prerequisites:** -  
**Short program:** -  
**Examination:** -  

**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCQ2101383/NO

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**PHYSICS OF COMPLEX SYSTEMS**

Master's degree in **PHYSICS OF DATA ORD. 2018**, First semester

**Lecturer:** Prof. ANTONIO TROVATO  
**Credits:** 6 ECTS

**More information:**  
https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP7081763/NO

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**QUANTUM INFORMATION AND COMPUTING**

Master's degree in **PHYSICS OF DATA ORD. 2018**, First semester

**Lecturer:** Prof. SIMONE MONTANGERO  
**Credits:** 6 ECTS  
**Prerequisites:**  
Quantum mechanics and elements of programming.  

**Short program:**  

**Examination:**  
The exam will be a final project composed of programming, data acquisition, and analysis, which will be discussed orally.
QUANTUM INFORMATION WITH ATOMS AND PHOTONS

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Dott. PIETRO SILVI

Credits: 6 ECTS

Prerequisites: 

Short program: 

Examination: 

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP8082721/NO

STAGE

Master's degree in PHYSICS OF DATA ORD. 2018, Second semester

Lecturer: Prof. MARCO ZANETTI

Credits: 8 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP8082711/NO

STATISTICAL MECHANICS

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. ENZO ORLANDINI

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP7081659/NO

STATISTICAL MECHANICS OF COMPLEX SYSTEMS

Master's degree in PHYSICS OF DATA ORD. 2018, Second semester

Lecturer: Prof. AMOS MARITAN

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP8082536/NO

THEORETICAL PHYSICS

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. PIERPAOLO MASTROLIA

Credits: 6 ECTS
THEORETICAL PHYSICS OF THE FUNDAMENTAL INTERACTIONS

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. PARIDE PARADISI

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP7081638/NO

VISION AND COGNITIVE SYSTEMS

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. LAMBERTO BALLAN

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2443/000ZZ/SCP7081657/NO

PHYSICS ORD. 2021

HADRONE PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: to be defined

Credits: 6 ECTS


ACCELERATOR PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Dott. ANDREA PISENT

Credits: 6 ECTS

Short program:
1. Introduction, particle accelerators for research and applications, like medicine, cultural heritage and energy. Definition of acceleration and luminosity, various kind of accelerators, electrostatic and radiofrequency. 2. Focusing of a charge particle beam, paraxial optics, magnetic quadrupoles and multipoles. Periodic focusing systems and alternating gradient, stability of beam transport, role of resonances. Courant and Snyder invariant, emittance. Circular orbits, equations of motion in magnetic dipoles, dispersion and chromaticity. 3. Ion sources, electrostatic acceleration and injectors. The beam acceleration with an RF field. Phase stability principle. How to produce bunched beams. 4. Linear accelerators and RF cavities. The challenge of intense beams, the space charge, the instabilities, the beam halo and small losses. 5. How the same basic principles apply to different kind of accelerators, linacs, cyclotrons,
synchrotrons, colliders. Some example of relevant accelerators (realized and under construction).

**Examination:**
Oral exam on the topics developed in the course, with the possibility of starting from a topic chosen by the student. The aim is to ascertain the learning of the fundamental concepts underlying modern accelerators.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCQ1098082/NO

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**ADVANCED PHYSICS LABORATORY**

Master's degree in **PHYSICS ORD. 2021**, Second semester

**Lecturer:** Prof. GIAMPAOLO MISTURA

**Credits:** 6 ECTS

**Prerequisites:**
Laboratory courses of previous years and basic skills in optics and electronics

**Short program:**
General experimental techniques for the physics laboratory, in particular: electronics, optics, cryogenics and vacuum.

**Examination:**
Written report and oral exam.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCQ0093559/NO

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**APPLICATIONS FOR THERAPY**

Master's degree in **PHYSICS ORD. 2021**, First semester

**Lecturer:** to be defined

**Credits:** 12 ECTS

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCP7081919/NO

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**ASTROPARTICLE PHYSICS**

Master's degree in **PHYSICS ORD. 2021**, Second semester

**Lecturer:** Prof. FRANCESCO D'ERAMO

**Credits:** 6 ECTS

**Prerequisites:**
Theoretical Physics of the Fundamental Interactions (MOD. A and MOD. B) in the first semester.

**Short program:**

**Examination:**
Oral exam.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCP7081703/NO

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**ATOMIC AND PLASMA PHYSICS**

Master's degree in **PHYSICS ORD. 2021**, First semester

**Lecturer:** to be defined
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<th>Course</th>
<th>Master's degree in PHYSICS ORD. 2021, First semester</th>
<th>Lecturer: to be defined</th>
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<td>HEAVY ION REACTIONS</td>
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<td>Prof.ssa GIOVANNA MONTAGNOLI</td>
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Prerequisites:
Knowledge of the basic concepts of quantum mechanics and of nuclear physics is required
INTRODUCTION TO RADIATION DETECTORS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. ROBERTO STROIILI

Credits: 6 ECTS

Prerequisites: Knowledge of electromagnetic phenomena, electromagnetic waves included. Basic notions about special relativity and quantum mechanics.

Short program:

Examination:
Oral.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCP7081437/NO

MANY BODY THEORIES IN NUCLEAR PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: to be defined

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCQ0093558/NO

METROLOGY AND DATA ANALYSIS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: to be defined

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCP7081917/NO

NUCLEAR ASTROPHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester
Lecturer: Prof. ANTONIO CACIOLLI

Credits: 6 ECTS

Prerequisites:
Elements of quantum mechanics, nuclear physics, and general physics

Short program:
Thermonuclear reactions. Definition of nuclear cross section, astrophysical S-factor, reaction rate, and Gamow peak. Nuclear burnings during hydrostatic and explosive stellar evolutionary phases. Elements of stellar modelling. Hydrogen burning: p-p chains, CNO, NeNa, MgAI cycles. Helium burning: triple-alpha reaction and alpha + 12C. Advanced nuclear burnings (C, Ne, O, Si). Neutron-capture reactions (s and r: slow and rapid) For each topic we provide an overview of the most relevant results in the recent literature. How to determine the reaction rate for several cases (direct capture, narrow resonances, broad resonances) How to perform a nuclear astrophysics experiment (every topic will be discussed with of existing experimental facilities and their most recent results) The environmental background and how to shield it (passive and active shielding) Underground experiment Brief discussion on ion beam accelerators Elements on detectors (gamma, neutrons, and charged particles) Experimental measurements of the cross section (from the experimental yield to the S-factor) Targets typology (gas, jet, and solid target). Target production techniques and how targets influence the experimental measurements. Brief discussion on indirect methods (Trojan Horse, ANC, ...).

Examination:
A 10 minutes presentation on an aspect of the course (usually an astrophysical issue and a related reaction study) and some question related to the presentation and course program.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCP7081704/NO

NUCLEAR REACTIONS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: to be defined

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCQ0093547/NO

NUCLEAR STRUCTURE: PROPERTIES AND MODELS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: to be defined

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCQ1098039/NO

QUANTUM MECHANICS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: to be defined

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCQ0093543/NO

RADIOACTIVITY AND NUCLEAR MEASUREMENTS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. MARCO MAZZOCCH

Credits: 6 ECTS

Prerequisites:
The student must have attended the courses of "Introduction of Nuclear Physics" and "Nuclear Physics"

Short program:

Examination:
Oral examination. The student will be asked some questions concerning the different topics presented during the lectures. It is also foreseen a detailed analysis of one of the arguments by the student.


RELATIVISTIC QUANTUM THEORY: NUCLEAR PROCESSES

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: to be defined

Credits: 6 ECTS


SUBNUCLEAR PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof.ssa DONATELLA LUCCHESI

Credits: 6 ECTS

Prerequisites:
Principles of nuclear and sub-nuclear physics, principles of quantum mechanics, relativistic dynamics, quantum field theory, Feynman graphs, interaction radiation with matter.

Short program:
Introduction and recap Tools for calculation Detectors for particle physics experiments Cross section e+e-\rightarrow\mu+\mu- and e+e-\rightarrow hh Deep Inelastic Scattering The Gluon QCD, Partons and jets Electroweak interaction:introduction Experimental tests of Electroweak interaction Cabibbo Theory and Cabibbo-Kobayashi-Maskawa Matrix CP and T violation, the B meson system. Tests of CKM Neutrino and Standard Model Higgs Properties

Examination:
The exam will be based on an assignment given in advance to the students. It will be constituted by exercises or open questions and a discussion on open topics among those discussed during the lectures. During the discussion questions on the arguments of the class can be asked.


THEORY OF ATOMS, NUCLEI AND COLLISIONS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: to be defined

Credits: 12 ECTS
WEAK INTERACTIONS

Master's degree in **PHYSICS ORD. 2021**, Second semester

**Lecturer:** to be defined

**Credits:** 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/004PD/SCQ1098119/NO

ADVANCED OPTICS AND METROLOGY

Master's degree in **PHYSICS ORD. 2021**, First semester

**Lecturer:** Prof. GIACOMO CIANI

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge of geometric optics, structure of matter and quantum mechanics.

**Short program:**

**Examination:**
Oral exam

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/002PD/SCQ0093551/NO

ADVANCED PHYSICS LABORATORY A

Master's degree in **PHYSICS ORD. 2021**, Second semester

**Lecturer:** Prof. GIAMPAOLO MISTURA

**Credits:** 6 ECTS

**Prerequisites:**
Laboratory courses of previous years and basic skills in optics and electronics

**Short program:**
General experimental techniques for the physics laboratory, in particular: electronics, optics, cryogenics and vacuum.

**Examination:**
Written report and oral exam.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/002PD/SCP7081700/NO

ADVANCED PHYSICS LABORATORY B

Master's degree in **PHYSICS ORD. 2021**, First semester

**Lecturer:** Prof. MARCO BAZZAN
ADVANCED TOPICS IN PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: Laboratory courses of preceding years and basic skills in optics and electronics

Short program: General experimental techniques for the physics laboratory, in particular: electronics, optics, cryogenics and vacuum techniques.

Examination: Written report and oral examination.


BIOLOGICAL PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. FULVIO BALDOVIN

Credits: 6 ECTS

Prerequisites: Basic understanding of thermodynamics and statistical mechanics. Basic elements of probability theory. Lectures and study material are in English.


Examination: The exam consists of two parts: a written test based on a list of exercises delivered during the lessons (use of textbook and lecture notes is allowed); an oral test on the topics of the course and, optionally, on a further topic chosen by the student.


BIOPHOTONICS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. FABIO MAMMANO

Credits: 6 ECTS

Prerequisites: The course requires knowledge of Electromagnetism, Optics, and Biological Physics.

Short program: Scalar diffraction theories: the Kirchhoff formulation, the Rayleigh-Sommerfeld formulation, the Huygens-Fresnel principle. The principle of Fermat, matrix

Examination: The verification of the expected knowledge and skills is carried out with an exam divided into two phases. In the first phase, a written exam is carried out which consists in answering to questions on three topics drawn by lot from among those studied in depth during the course. In the second phase, an oral test is carried out which consists in the presentation by the student of a scientific article on optical super-resolution techniques. The final grade is expressed as the average in the judgments of the two tests.


FUNDAMENTALS OF ASTROPHYSICS AND COSMOLOGY

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. SABINO MATARRESE

Credits: 6 ECTS

Prerequisites: Fundamental concepts of quantum mechanics and special relativity

INTRODUCTION TO MANY BODY THEORY

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. PIER LUIGI SILVESTRELLI

Credits: 6 ECTS

Prerequisites:
Metodi Matematici

Short program:

Examination:
Oral exam and home-work exercises.

More information:

INTRODUCTION TO NANOPHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. GIOVANNI MATTEI

Credits: 6 ECTS

Prerequisites:
Electromagnetism, Quantum Physics (particle in a box, quantum confinement), Solid State Physics (phononic and electronic structures of solids, thermal and optical properties)

Short program:

Examination:
1) Fundamentals of NanoScience (MSc in Materials Science) The exam is written (duration 2 h) with two open questions and a set of multiple-choice questions. 2) Introduction to NanoPhysics (MSc in PHYSICS) The exam is written (duration 2 h) with an open question and an exercise with numerical
applications of the learned topics. 3) Fundamentals of NanoScience (MSc in Materials Engineering) The exam is written (duration 2 h) with one open
questions and a set of multiple-choice questions.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/002PD/SCP7081718/NO

### MATHEMATICAL PHYSICS

Master's degree in **PHYSICS ORD. 2021**, Second semester

**Lecturer:** Prof. PAOLO ROSSI

**Credits:** 6 ECTS

**Prerequisites:**
Basics of algebra and differential geometry.

**Short program:**
Smooth bundles on smooth manifolds (general definitions, local description, sections, examples) Vector bundles (definitions local description, sections, linear connections, parallel transport, covariant derivative, examples) Principal bundles (short reminder on Lie groups, their representations and actions on manifolds, general definitions, local description, sections, principal connections, associated vector bundles, examples) Characteristic classes (time permitting, Chern-Weil approach to Stiefel-Whitney and Chern classes) Applications (gauge theories of various origin)

**Examination:**
To be decided depending also on the number of students. Either a traditional oral exam on the entire program, or a written exam containing both simple exercises and questions on theory.

More information:

### MODELS OF THEORETICAL PHYSICS

Master's degree in **PHYSICS ORD. 2021**, First semester

**Lecturer:** Prof. AMOS MARITAN

**Credits:** 6 ECTS

**Prerequisites:**
Good knowledge of mathematical analysis, calculus, elementary quantum mechanics and basic physics.

**Short program:**

**Examination:**
The first part of the verification of the acquired knowledge will evaluate the weekly exercises and the participation of the students in the class discussions The second part is oral, and it will be based on a discussion on the various topics of the course.

More information:

### NANOFABRICATION

Master's degree in **PHYSICS ORD. 2021**, First semester

**Lecturer:** Prof. FILIPPO ROMANATO

**Credits:** 6 ECTS

**Prerequisites:**
third year courses in materials science, optics, matter structure

**Short program:**
Many of the impressive technical and scientific advances of the last two decades are based on the ability to control individual chemical-physical phenomena at the level of a few nanometers, that is, on the scale of size at which most natural phenomena occur. This control was obtained by developing
micro and nano fabrication systems and processes for the realization of devices (also called lab-on-chip) capable of exchanging signals (detection and actuation) with systems of the size of a few nanometers, coining, in fact, the definition of nanotechnology. The course is aimed at students (materials sciences, physics) in view of the degree thesis for the broad correlation between physical, chemical, biochemical phenomena that nanofabrication processes require in view of the realization of nanostructures and nanodevices. Opening themes towards the research of nanosciences are discussed. The course will discuss the miniaturization process and the scale reduction process of many natural phenomena that distinguish the functioning of nanodevices. The main nanofabrication technologies will be presented and examples of applications for the realization of nanoscience devices and experiments will be presented. After a general distinction between top-down and bottom-up processes, lithography technologies (UV, electronics, X-ray, ionic, imprinting, interferential etc), deposition processes (plasma assisted, in vapor or chemical phase, will be illustrated); sol-gel etc.) and subtraction in the gas phase (reactive ion etching, milling) or liquid (chemical etching). The manufacturing technology of silicon-based electronic devices will be reviewed. Simulation exercises for the design of nanosystems are proposed. The course is completed by visits to the nanofain Padua at the LaNN laboratory and in Trieste at the CNR nanofabrication laboratories at the Elettra synchrotron. During these visits there will be practical demonstrations of the lithographic processes treated during the classroom course.

Examination:
Deepening of a topic, preparation of a presentation, written discussion. Oral exam, presentation of the paper and verification of the learning of the main concepts of nano lithography.

More information:

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NON-PERTURBATIVE QUANTUM FIELD THEORY

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. PIERALBERTO MARCHETTI

Credits: 6 ECTS

Prerequisites:
Theoretical physics of the fundamental interactions and Quantum field theory or Models of theoretical physics and Structure of matter

Short program:
Quantum field theory (QFT) is a common framework in many branches of physics, exhibiting an unexpected unity in the description of elementary quantum processes that deeply modified our view of physical reality. Many of the key results of QFT are obtained through a perturbative expansion, but there are crucial areas of applications that do not rely on it. The aim of the course is to provide a view of some results in these areas, with examples both in elementary particle and condensed matter physics, emphasizing the underlying common features. Examples are only outlined, but not discussed in detail and in the following program are between brackets. Some topics in the program might be alternative, depending on the interests and knowledge of the students. Proposed program 1) Reconstruction theorem: What precisely a QFT is, how one can reconstruct quantum fields out of correlation functions, how they are related to experiments. 2) Quantum solitons: kinks (phi4, polyacetilene), vortices (Higgs model, superconductors), monopoles (Dirac, t'Hooft-Polyakov, spin ice), and their role in the phase transitions. 3) Anomalies: chiral anomaly (the eta mass problem in QCD) and parity anomaly (topological insulators, graphene).

Examination:
Oral examinations

More information:

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NUCLEAR PHYSICS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof.ssa SILVIA MONICA LENZI

Credits: 6 ECTS

Prerequisites:
Quantum mechanics

Short program:
Program of Nuclear Physics 2021/2022 First part: Nuclear Structure and Nuclear Models • Introduction: The nucleus as a laboratory of Quantum Mechanics • Symmetries and the Nuclear Force • Theoretical Models: 1) Collective Models: The nuclear deformation, Surface vibrations, Rotating nuclei 2) Microscopic Models: Mean-field Models, Interacting Shell Model The Nilsson Model • Experimental tools in nuclear structure Second part: Nuclear reactions Introduction • Nucleon-Nucleon Scattering • Nuclear Reactions • Interactions between heavy ions • Direct nuclear reactions between heavy ions • Multi-nucleon transfer reactions between heavy ions • Compound nuclear reactions • Fusion reactions below the Coulomb barrier • Superheavy nuclei • Reactions of astrophysical interest

Examination:
The exam consists on an oral examination that includes the discussion of the exercises proposed during the course, and eventual presentation of a research work on one of the several subjects proposed by the professors.
OPTICS AND LASER PHYSICS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof.ssa TIZIANA CESCA

Credits: 6 ECTS

Prerequisites:
Topics learned in basic courses of Mathematics and Physics.

Short program:
Classical optics: - propagation of electromagnetic waves; - polarization, birefringence, interference and diffraction; - geometrical optics and matrix method; main optical instruments; Lasers: - the laser idea and proprieties of laser beams; - absorption, spontaneous emission, stimulated emission; - gain and population inversion; - optical cavities and pumping; - cw lasers; - pulsed lasers: Q-switch and mode-locking; - examples of main different laser types: gas lasers, solid-state lasers Introduction to Quantum Optics: - Photon statistics - buching and antibuching; - weak and strong coupling: Purcell effect and Rabi splitting.

Examination:
The exam is written and comprises two exercises and one open question.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/002PD/SCP7081800/NO

PHYSICS LABORATORY

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Dott. FRANCESCO RECCHIA

Credits: 6 ECTS

Prerequisites:
Physics laboratory courses of the first three years.

Short program:
This course propose to the students some modern physics experiments that allow the approach to measurement techniques in use for the study of Fundamental Interactions, Matter and Astrophysics. Each student will carry out three experiments. The experiments proposed are: 1) Cosmic Rays 2) Compton Scattering 3) Positronium decay 4) Gamma-ray imaging 5) Fast timing 6) Plasma Physics 7) X-ray fluorescence 8) Natural radioactivity and radon counting. In the first five experiments the students will be trained to the use of scintillator for the detection of particles and gamma-rays and to the use of the relative electronics. Multiparameter events will be constructed exploiting timing coincidences between multiple detectors. The data will be analysed using the ROOT data analysis framework. In the Plasma Physics experiment the students will study the conditions that allow the formation of plasma starting from a small quantity of neutral gas. They will study the physical characterisations of the plasma by means of electronics measurements. The students will have to deal with vacuum and residual gas measurement techniques. The X-fluorescence and natural radioactivity experiments will be performed using high-resolution semiconductor detectors (Silicon and HPGe). They will train the students to spectroscopy techniques of the X and gamma radiation and to the relative analysis techniques.

Examination:
Written report by the group on the experiments performed. Individual interview with presentation of one of the experiment and possible short questions about the other two experiments. The presentation will concern the description of the physical phenomena, the experimental apparatus with the relative electronics and the data taking and analysis.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/002PD/SCP7081617/NO

PHYSICS OF COMPLEX SYSTEMS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. ANTONIO TROVATO

Credits: 6 ECTS

Prerequisites:
Students are expected to already know the main concepts of equilibrium statistical mechanics, including phase transition, critical exponents and the renormalization group.

Short program:

Examination:
Examination based on the choice and on the oral presentation of a specific topic related to the ones taught during the course. During the oral presentation, possible connections with other parts of the program will be the subject of further questions. The presentation will focus either on a book chapter or on a scientific research paper, generally but non necessarily a review. It is also possible to focus on a computational mini-project related to the topics taught in the course.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/002PD/SCP7081763/NO

<table>
<thead>
<tr>
<th>PHYSICS OF FLUIDS AND PLASMAS</th>
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<tbody>
<tr>
<td>Master's degree in PHYSICS ORD. 2021, First semester</td>
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<tr>
<td>Lecturer: Dott. TOMMASO BOLZONELLA</td>
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<tr>
<td>Credits: 6 ECTS</td>
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<tr>
<td>Prerequisites: None</td>
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<td>Examination: Oral exam.</td>
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<tr>
<th>PHYSICS OF NUCLEAR FUSION AND PLASMA APPLICATIONS</th>
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<tr>
<td>Master's degree in PHYSICS ORD. 2021, First semester</td>
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<tr>
<td>Lecturer: Dott.ssa LIDIA PIRON</td>
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<td>Credits: 6 ECTS</td>
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<td>Prerequisites: Knowledge of electromagnetism principles. A knowledge of the different plasma descriptions (kinetic, two-fluids, magnetohydrodynamics) is useful but not required, since essential notions will be provided during the course.</td>
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<tr>
<td>Examination: Oral exam.</td>
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PHYSICS OF SEMICONDUCTORS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. DAVIDE DE SALVADOR

Credits: 6 ECTS

Prerequisites:

Short program:

Examination:
Oral exam. During the semester it will be possible to give a midterm oral exam about the first part of the course concerning on physical principle; at the end a second oral exam on the devices and processes will complete the final grade.

More information:

QUANTUM INFORMATION AND COMPUTING

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. SIMONE MONTANGERO

Credits: 6 ECTS

Prerequisites:
Quantum mechanics and elements of programming.

Short program:

Examination:
The exam will be a final project composed of programming, data acquisition, and analysis, which will be discussed orally.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/002PD/SCP7081798/NO
### SOLID STATE PHYSICS

**Master's degree in PHYSICS ORD. 2021, First semester**

**Lecturer:** Prof. FRANCESCO ANCILOTTO  
**Credits:** 6 ECTS  
**Prerequisites:** Knowledge of elements of elementary quantum mechanics. Knowledge of elements of elementary Statistical Mechanics (distribution functions, statistical ensembles, ensemble averages, etc.)

**Short program:**
Chemical bonds in solids; The structure of crystals; Bravais lattices and bases; Simple crystal structures; Reciprocal lattice; Diffraction by periodic structures and experimental techniques; The Bragg law; Adiabatic approximation; Lattice dynamics; Harmonic approximation, The dynamical Matrix; phonons; Monoatomic and diatomic linear chains; Spectroscopy of phonons; Thermal properties of crystals; Lattice specific heat; Anharmonic effects: thermal expansion, thermal conductivity of insulating materials; “free” electrons model; Electronic specific heat; electrostatic screening in a Fermi gas.; Bloch theorem; Band structure; “quasi-free” electron approximation; “tight binding” approximation; Examples of band structures; Transport phenomena; The Drude model; Hall effect in metals; Semiclassical model; The concept of “hole”; Electrical and thermal conductivity in metals; Law of Wiedemann and Franz; Semiconductors; Cyclotron Resonance; Carriers concentration in intrinsic and extrinsic semiconductors; “Doping” and dopant states; electron and hole mobility; Electrical conductivity in semiconductors; Hall effect in semiconductors; The Fermi surface in real metals. Superconductivity.

**Examination:**
Oral exam

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/002PD/SCP7081660/NO

### STATISTICAL MECHANICS

**Master's degree in PHYSICS ORD. 2021, First semester**

**Lecturer:** Prof. ENZO ORLANDINI  
**Credits:** 6 ECTS  
**Prerequisites:** Statistical Mechanics (course given at the third year of the laurea triennale) Thermodynamics

**Short program:**

**Examination:**
The verification of the acquired knowledge takes place through a common written test with 1-2 exercises to be solved analytically and 1-2 open questions on basic concepts. In this way we should be able to test the knowledge, the scientific vocabulary, the ability to synthesis and critical discussion acquired during the course. The second part of the exam will be oral and will be based on a discussion on the various topics discussed in class.

**More information:**
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/002PD/SCP7081659/NO

### STRUCTURE OF MATTER

**Master's degree in PHYSICS ORD. 2021, Second semester**

**Lecturer:** Prof. LUCA SALASNICH  
**Credits:** 6 ECTS  
**Prerequisites:** All the exams of the B.Sc. in Physics.

**Short program:**

Examination:
Colloquium of about 30 minutes.

More information:

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TEACHING AND LEARNING PHYSICS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof.ssa ORNELLA PANTANO

Credits: 6 ECTS

Prerequisites:
Core knowledge of classic and modern physics.

Short program:
Physics teaching and learning: main topics and approaches in physics education research. Core ideas in physics, scientific practices and crosscutting concepts in natural sciences. Historical development of physics ideas that carry special significance for physics teaching and learning. Different theoretical approaches to students' understanding of physics content and student difficulties, and their application in physics teaching. The role and importance of student interest, motivation and metacognition in learning physics. Student-centered approaches to physics teaching and learning. The role of laboratory work and technologies in physics learning and teaching. Educational potential of out-of-school settings: benefits and opportunities offered by experiences outside the classroom. Physics education research in different areas of physics, for example: mechanics, waves, optics, electromagnetism, relativity and quantum mechanics. Application of didactical methods and technologies for the design of teaching and learning sequences for specific physics topics.

Examination:
The examination will consist of two parts: (1) written assignments during the course (40%); (2) a final educational project on a selected topic in physics (60%).

More information:

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THEORY OF STRONGLY CORRELATED SYSTEMS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. LUCA DELL'ANNA

Credits: 6 ECTS

Short program:

Examination:
Oral examination

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/002PD/SCP7081742/NO

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ADVANCED PHYSICS LABORATORY A

Master's degree in PHYSICS ORD. 2021, Second semester
Lecturer: Prof. GIAMPAOLO MISTURA  
Credits: 6 ECTS  
Prerequisites: Laboratory courses of previous years and basic skills in optics and electronics  
Short program: General experimental techniques for the physics laboratory, in particular: electronics, optics, cryogenics and vacuum.  
Examination: Written report and oral exam.  

ADVANCED PHYSICS LABORATORY B  
Master's degree in PHYSICS ORD. 2021, First semester  
Lecturer: Prof. MARCO BAZZAN  
Credits: 6 ECTS  
Prerequisites: Laboratory courses of preceding years and basic skills in optics and electronics  
Short program: General experimental techniques for the physics laboratory, in particular: electronics, optics, cryogenics and vacuum techniques.  
Examination: Written report and oral examination.  

ADVANCED QUANTUM FIELD THEORY  
Master's degree in PHYSICS ORD. 2021, First semester  
Lecturer: Prof. MARCO MATONE  
Credits: 6 ECTS  
Prerequisites: Students are assumed to have adequate knowledge of both canonical quantization and the path integral formulation of quantum field theory. In particular, we assume the knowledge of the path integral quantization of the phi^4 theory and of Quantum Electrodynamics.  
Examination: The exam consists of an oral test that can begin with a short seminar on a topic to be agreed with the teacher.
ADVANCED TOPICS IN PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Dott. JEAN-SEBASTIEN CAUX

Credits: 6 ECTS

Prerequisites: CONTENT NOT PRESENT

Short program: CONTENT NOT PRESENT

Examination: CONTENT NOT PRESENT


ADVANCED TOPICS IN THE THEORY OF THE FUNDAMENTAL INTERACTIONS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Dott. LUCA DI LUZIO

Credits: 6 ECTS

Prerequisites: A basic knowledge of theoretical physics of the fundamental interactions, in particular of quantum field theory.

Short program:

Examination:
Problems assigned during the course and oral exam.


APPLIED ELECTRONICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. PIERO GIUBILATO
Credits: 6 ECTS

Prerequisites:
- Basic solid-state physics on semiconductors (crystal lattice, Fermi distribution, levels energy distribution, etc.)
- Analogue electronics (linear networks, active and passive devices, amplifiers, operational amplifiers, filters, etc.)
- Standard programming languages (syntax, structure, use of libraries, etc.)
- Basic knowledge of computational software (e.g. Mathematica, Matlab)

Short program:
PART 1 - Devices (1 weeks)
- Basic knowledge of device physics, diode and transistor, either BJT or MOS.
- Principle of working of the diode and the transistor (BJT and MOS).
- Simplified physical model of the MOS transistor (implants, gate, oxide) and how this influences its performances (parasitic capacitance, power consumption, etc.)
- Quick overview of some basic circuits using diodes and transistor for specific purposes (rectifier, voltage pump, etc.).
- MOS transistor dynamic behavior, linear region, inversion region, saturation region, power consumption, speed, parasitics, etc.
PART 2 - Digital logic building blocks (2 weeks)
- Basic microelectronics manufacturing concepts (lithography, feature size, etc.).
- Basic logic gates (NOT, AND, NAND, ...) and their realization with CMOS transistors.
- Boolean algebra basics REVIEW (DeMorgan’s theorems) and its applications to basic gates combinations.
- Digital microelectronics basics: analog computers, noise margin, integration processes, microprocessors, Moore's law, the limit of scaling, analog/digital signal interface.
- Different level of design (system, behavioural, RTL, gates, transistor, device, ...) and the associate languages/tools.
- HDL languages and simulation tools of the trade: SPICE, what it is and how it works, ideal elements vs. real elements, MOS transistor basic model, example of IV curves for a MOS, response of an inverter and an operational amplifier.
- Verilog language scope and basics, concept of synthesis and simulation code, modules encapsulation, timebase definitions, some elementary syntax and constructs (especially the synchronous blocks like always, etc.).
- Slicing an operation in time to allow higher clock frequencies, latency and speed.
- Timing verification, corner cases, setup and hold times.
- Complex systems behavior and modelling, with special focus on radiation tolerance/resistance and mitigation techniques and topologies.

Examination:
Oral exam

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081701/NO

ASTROPARTICLE PHYSICS

Master’s degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. FRANCESCO D’ERAMO

Credits: 6 ECTS

Prerequisites:
Theoretical Physics of the Fundamental Interactions (MOD. A and MOD. B) in the first semester.

Short program:
1) Standard Cosmological Model
2) Particle Physics in the Early Universe
3) Matter/Antimatter Asymmetry and Baryogenesis
4) Neutrino Masses and Leptogenesis
5) Observational Evidence for Dark Matter
6) Thermal Dark Matter Candidates: Production and Constraints
7) Searches for WIMPs
8) Strong CP Problem and Axions
9) Dark Energy and Quintessence Models
10) Inflationary Universe and Reheating

Examination:
Oral exam.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081703/NO

COSMOLOGY OF THE EARLY UNIVERSE

Master’s degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. NICOLA BARTOLO

Credits: 6 ECTS

Prerequisites:
Generally the bases useful to attend this course are provided by the various courses within a given chosen curriculum.

Short program:
General introduction. The problem of the initial conditions: primordial density perturbations at the origin of the formation of the Large Scale Structure of the Universe. - Short recall of the main problems of the standard cosmological model - Inflationary cosmology in the Early Universe as a solution to the problems of the standard model Modeling: - Inflationary models: vacuum energy and the inflation field; dynamics of a scalar field in a Friedman-Robertson-Walker Universe; possible realizations of the inflationary scenario - Cosmological models of inflation and their main features (with examples also within high-energy particle physics) - Observational predictions of the inflationary models: from the quantum perturbations in an expanding universe to the primordial density perturbations; generation of primordial gravitational waves and their observability (cosmological and interferometric probes). Reheating phase and baryogenesis mechanisms Delta-N and in-in formalisms for the study of cosmological perturbations. Example: primordial non-Gaussianity Cosmological perturbations in General Relativity: - scalar, vector and tensor perturbations - gauge transformations - Einstein equations (linearly) perturbed around the Robertson-Walker metric Observational tests of the Early Universe

Examination:
Oral exam

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081761/NO
Short program:
Fundamental concepts of galactic and extra-galactic astrophysics • The classification of galaxies • Statistical properties of the galaxy population • Groups and clusters of galaxies Fundamental concepts of Cosmology * Main components of the Universe. Observational evidence for the existence of dark matter and dark energy. • Expanding Universe and Cosmological Principle. • Robertson-Walker line-element. Geometrical properties. • Hubble constant and deceleration parameter. • Distances in Cosmology; redshift and Hubble law (low-redshift approximation). • Derivation of Friedmann equations (dust case); Newtonian and relativistic contributions • Friedmann models. • Cosmological constant: Einstein's static solution and de Sitter solution. Dynamical dark energy • Cosmological solutions for the spatially flat case. Universe models with non-zero spatial curvature. • Exact treatment of the Hubble law. Thermal history and early Universe • Number density, energy density and pressure of a system of particles in thermodynamic equilibrium. • Entropy conservation in a comoving volume. • Time-temperature relation in the Early Universe. • Shortcomings of the standard cosmological model: horizon, flatness problems, etc. • Inflation in the Early Universe; solution of the horizon and flatness problems. • Kinematics and dynamics of inflation; the "inflaton". • Old, new and chaotic inflation; slow-roll dynamics (basic account). • Baryon asymmetry in the Universe (basic account) • Primordial nucleosynthesis of light elements. • Hydrogen recombination: Saha equation. Matter-radiation decoupling. Cosmic Microwave background. • General definition of decoupling. Dark matter: general properties • Boltzmann equation in Cosmology and cosmic relics. • Hot/Cold/Warm Dark matter: definition, present abundance and general cosmological properties. Elements of stellar astrophysics • Gravitational contraction and conditions for hydrostatic equilibrium. • Adiabatic index and equilibrium. • Conditions for gravitational collapse. • Jeans theory of gravitational instability. • Contraction of a protostar. • Star formation and degenerate electron gas. • The Sun: general properties, radiative diffusion, thermonuclear fusion. • Stellar nucleosynthesis. • Stellar cycles. • Hertzsprung-Russell diagram. • Basics of stellar structure. Clayton model: Minimum mass of a star; maximum mass for a Main-Sequence star. • End-points of stellar evolution: white dwarfs, neutron stars, Chandrasekhar mass, black holes. The formation of cosmic structures • Linear evolution of perturbations in the expanding Universe (basic principles). • Spherical collapse of a cosmic proto-structure. • Mass-function of cosmic structures: Press-Schechter theory.

Examination:
Oral interview.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP9086381/NO

GENERAL RELATIVITY

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. LUCA MARTUCCI

Credits: 6 ECTS

Prerequisites:
Theoretical Physics is recommended.

Short program:
The Equivalence Principle; spacetime geometry; dynamics of point particles on curved spacetimes; Einstein’s equations; Newtonian limit; gravitational waves; spacetime symmetries and maximally symmetric spaces; the Schwarzschild solution and its properties; Schwarzschild black holes; more on black holes (Penrose diagrams, charged and rotating black holes); black hole thermodynamics.

Examination:
Questions on the topics presented during the course and solution of a simple problem.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081661/NO

INTRODUCTION TO MANY BODY THEORY

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. PIER LUIGI SILVESTRELLI

Credits: 6 ECTS

Prerequisites:
Metodi Matematici

Short program:

Examination:
Oral exam and home-work exercises.
INTRODUCTION TO RADIATION DETECTORS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. ROBERTO STROILI

Credits: 6 ECTS

Prerequisites:
Knowledge of electromagnetic phenomena, electromagnetic waves included. Basic notions about special relativity and quantum mechanics.

Short program:

Examination:
Oral.

MEDICAL PHYSICS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Dott.ssa LAURA DE NARDO

Credits: 6 ECTS

Prerequisites:
Knowledge of radiation-matter interaction phenomena, principles and methods for detecting particles and electromagnetic radiation, radioactive decays.

Short program:
• Biological and health effect of ionizing radiations. • Introduction to dosimetry of ionizing radiation. • Radiation detectors for dosimetry and related metrology aspects. • Basic concepts in image processing: image properties, noise and contrast, frequency domain; filtering, edge detection and image enhancement, transformations, segmentation; image quality. • Imaging in diagnostics: images production with X rays and radioactive tracers (scintigraphy and gamma camera, tomography with single-photon emission (SPECT), tomography with positron emission (PET and TOF-PET), hybrid scanners). • Principles of radiotherapy with photons, electron and hadrons. Internal radiotherapy and radionuclide therapy. • Medical radionuclides production. • Introduction to magnetic resonance imaging (MRI). • Introduction to echography imaging. • Principles of hyperthermia.

Examination:
Oral examination. The exam will focus on the topics covered during the lessons. Furthermore, the student will prepare a presentation (Power Point or similar) on a detailed analysis of one or more recent scientific works related to one of the topics of the course or the result of a simulation / data analysis. The topic of the presentation will be agreed with the teacher. This presentation will allow to evaluate the communication skills, the degree of judgment autonomy and the learning abilities of the student.

MULTIMESSENGER ASTROPHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof.ssa ELISA BERNARDINI

Credits: 3 ECTS

Prerequisites:
This course is addressed to students with basic knowledge of elementary particles and their interactions and nuclear physics.

**Short program:**

The term "multi-messenger" is quite new and increasingly used in astronomy and astroparticle physics. It refers to combining information from different cosmic messengers (i.e., photons, cosmic rays, neutrinos and gravitational waves) to gain a deeper understanding of the astrophysical objects we observe in the sky. Visible light only reveals a very small portion of the mysteries of the Universe. Astronomical observations are nowadays routinely performed with different telescopes across the whole electromagnetic spectrum, from radio waves through visible light, all the way to gamma-rays. At the highest energies, the most violent processes in the Universe are at work. Whatever produces high energy gamma-rays, is expected to accelerate particles to energies that exceed the capabilities of man-made accelerators a billion times. Such particles can reach the Earth as cosmic rays, first discovered more than 100 years ago, still nowadays one of the most mysterious "messages" from our Universe. Cosmic rays may interact in the vicinity or their sources or even along their way to Earth, to produce elusive particles called neutrinos and gamma-rays. While cosmic rays are deflected during their journey by intergalactic magnetic fields, neutrinos and photons, being neutral particles, keep memory of their source's direction. Their trajectory becomes thus crucial to unravel the origin of cosmic rays. Neutrinos are extremely difficult to detect. Kubic-kilometer detectors are necessary to observe neutrinos at energies larger than few tens of GeV. The year 2013 witnessed the first clear observation of neutrinos from distant astrophysical objects by the IceCube detector at the South Pole, opening a new observational window to the Universe. The most extreme astrophysical objects, connected with the most violent phenomena in our Universe, are often associated with black holes or neutron stars. Whenever two such compact objects orbit around each other, they are expected to produce gravitational waves. The year 2015 witnessed the first direct observation of gravitational waves emitted by two merging black-holes (GW150914), measured by the LIGO detectors in the USA. The discovery was celebrated by the Nobel-prize for physics. The year 2017 witness the triumph of multi-messenger astrophysics with the detection of gravitational waves from two merging neutron stars (GW170817), followed by a burst of gamma-rays (GRB 170817A). Just few days after another event celebrated the success of multi-messenger astrophysics: the first identification of a source of cosmic neutrinos, the blazar TXS 0506+056, helped by the electromagnetic observations that followed the detection of a high energy neutrino (IceCube-170922A). Both results greatly demonstrate the potential of multi-messenger astrophysics in observing and understanding the most extreme and mysterious phenomena in our Universe. This course will illustrate its foundations.

**Examination:**

Oral examination.

**More information:**

https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081762/NO

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### NON-PERTURBATIVE QUANTUM FIELD THEORY

**Master’s degree in PHYSICS ORD. 2021, First semester**

**Lecturer:** Prof. PIERALBERTO MARCHETTI

**Credits:** 6 ECTS

**Prerequisites:**

Theoretical physics of the fundamental interactions and Quantum field theory or Models of theoretical physics and Structure of matter

**Short program:**

Quantum field theory (QFT) is a common framework in many branches of physics, exhibiting an unexpected unity in the description of elementary quantum processes that deeply modified our view of physical reality. Many of the key results of QFT are obtained through a perturbative expansion, but there are crucial areas of applications that do not rely on it. The aim of the course is to provide a view of some results in these areas, with examples both in elementary particle and condensed matter physics, emphasizing the underlying common features. Examples are only outlined, but not discussed in detail and in the following program are between brackets. Some topics in the program might be alternative, depending on the interests and knowledge of the students. Proposed program 1) Reconstruction theorem: What precisely a QFT is, how one can reconstruct quantum fields out of correlation functions, how they are related to experiments. 2) Quantum solitons: kinks (phi4, polyaetilene), vortices (Higgs model, superconductors), monopoles (Dirac, t'Hooft-Polyakov, spin ice), and their role in the phase transitions. 3) Anomalies: chiral anomaly (the eta mass problem in QCD) and parity anomaly (topological insulators, graphene).

**Examination:**

Oral examinations

**More information:**

https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP9088179/NO

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### NUCLEAR ASTROPHYSICS

**Master’s degree in PHYSICS ORD. 2021, Second semester**

**Lecturer:** Prof. ANTONIO CACIOLLI

**Credits:** 6 ECTS

**Prerequisites:**

Elements of quantum mechanics, nuclear physics, and general physics

**Short program:**

Thermonuclear reactions. Definition of nuclear cross section, astrophysical S-factor, reaction rate, and Gamow peak. Nuclear burnings during hydrostatic and explosive stellar evolutionary phases. Elements of stellar modelling. Hydrogen burning: p-p chains, CNO, NeNa, MgAl cycles. Helium burning: triple-alpha reaction and alpha + 12C. Advanced nuclear burnings (C, Ne, O, Si). Neutron-capture reactions (s and r: slow and rapid) For each topic we provide an overview of the most relevant results in the recent literature. How to determine the reaction rate for several cases (direct capture, narrow resonances,
NUCLEAR PHYSICS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof.ssa SILVIA MONICA LENZI

Credits: 6 ECTS

Prerequisites:
Quantum mechanics

Short program:
Program of Nuclear Physics 2021/2022 First part: Nuclear Structure and Nuclear Models • Introduction: The nucleus as a laboratory of Quantum Mechanics • Symmetries and the Nuclear Force • Theoretical Models: 1) Collective Models: The nuclear deformation, Surface vibrations, Rotating nuclei 2) Microscopic Models: Mean-field Models, Interacting Shell Model The Nilsson Model • Experimental tools in nuclear structure Second part: Nuclear reactions Introduction • Nucleon-Nucleon Scattering • Nuclear Reactions • Interactions between heavy ions • Direct nuclear reactions between heavy ions • Multi-nucleon transfer reactions between heavy ions • Compound nuclear reactions • Fusion reactions below the Coulomb barrier • Superheavy nuclei • Reactions of astrophysical interest

Examination:
The exam consists on an oral examination that includes the discussion of the exercises proposed during the course, and eventual presentation of a research work on one of the several subjects proposed by the professors.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081658/NO

PHYSICS LABORATORY

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Dott. FRANCESCO RECCHIA

Credits: 6 ECTS

Prerequisites:
Physics laboratory courses of the first three years.

Short program:
This course propose to the students some modern physics experiments that allow the approach to measurement techniques in use for the study of Fundamental Interactions, Matter and Astrophysics. Each student will carry out three experiments. The experiments proposed are: 1) Cosmic Rays 2) Compton Scattering 3) Positronium decay 4) Gamma-ray imaging 5) Fast timing 6) Plasma Physics 7) X-ray fluorescence 8) Natural radioactivity and radon counting. In the first five experiments the students will be trained to the use of scintillator for the detection of particles and gamma-rays and to the use of the relative electronics. Multiparameter events will be constructed exploiting timing coincidences between multiple detectors. The data will be analysed using the ROOT data analysis framework. In the Plasma Physics experiment the students will study the conditions that allow the formation of plasma starting from a small quantity of neutral gas. They will study the physical characterisations of the plasma by means of electronics measurements. The students will have to deal with vacuum and residual gas measurement techniques. The X-fluorescence and natural radioactivity experiments will be performed using high-resolution semiconductor detectors (Silicon and HPGe). They will train the students to spectroscopy techniques of the X and gamma radiation and to the relative analysis techniques.

Examination:
Written report by the group on the experiments performed. Individual interview with presentation of one of the experiment and possible short questions about the other two experiments. The presentation will concern the description of the physical phenomena, the experimental apparatus with the relative electronics and the data taking and analysis.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081617/NO
QUANTUM FIELD THEORY

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. GIANGUIDO DALL'AGATA

Credits: 6 ECTS

Prerequisites: Relativistic quantum mechanics. Classical field equations and canonical quantization of fields.

Short program:
1. The LSZ Reduction Formula. 1.1 A new approach to Quantum Field Theory. 1.2 Correlators and the LSZ reduction formula. 2. The Path integral in Quantum Mechanics. 2.1 Intuitive introduction to path integrals. 2.2 From Schroedinger equation to the path integral. 2.3 The partition function. 2.4 Operators and time ordering. 2.5 The continuum limit and non-commutativity. 3. Perturbation Theory. 3.1 Correlators and scattering amplitudes. 3.2 Free field theory. 3.3 Perturbation theory. 3.4 Feynman Diagrams. 3.5 Borel resummation*. 3.6 Exact results - localization*. 4. Effective and quantum action. 4.1 Wilsonian effective action. Integrating out fields. 4.2 The 1pl effective action. 5. Path integral quantization of ? ?. 5.1 Dimensional analysis. 5.2 The free theory. 5.3 The interacting theory. 5.4 The Coleman-Weinberg potential. 6. Quantising spin 1/2 and spin 1 fields. 6.1 Path integral for Dirac fermions. 6.2 Path integral for photons. 7. Perturbative renormalization. 7.1 Divergences. 7.2 Superficial degree of divergence and BPHZ theorem. 7.3 1-loop propagator in ? ?. 7.4 On-shell renormalisation. 7.5 Dimensional regularization. 7.6 ? ? at two loops. 7.7 QED Renormalization. 8. The Renormalization Group. 8.1 Renormalization and integrating out degrees of freedom. 8.2 The Callan-Symanzik equations. 8.3 Anomalous dimensions. 8.4 Renormalization group flow. 8.5 Counterterms and the continuum limit. 8.6 Polchinski equations. 8.7 The local potential approximation. 8.8 The Gaussian Critical point and Landau poles. 8.9 The Wilson-Fisher critical point. 8.10 Zamolodchikov's C-theorem. 9. Symmetries. 9.1 Symmetries in quantum field theories. 9.2 Ward-Takahashi identities. 9.3 Current conservation in QFT. 10. Quantization of non-abelian gauge theories. 10.1 Classical Yang-Mills theories. 10.2 Gauge fixing and the path integral. 10.3 Faddev Popov determinants and ghosts 10.4 BRST symmetry and the physical Hilbert space

Examination:
The examination is oral. It will be performed with general questions on the topics of the course, including the derivation of the main results and possibly the resolution of simple problems.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081702/NO

RADIOACTIVITY AND NUCLEAR MEASUREMENTS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. MARCO MAZZOCCO

Credits: 6 ECTS

Prerequisites: The student must have attended the courses of "Introduction of Nuclear Physics" and "Nuclear Physics"

Short program:

Examination:
Oral examination. The student will be asked some questions concerning the different topics presented during the lectures. It is also foreseen a detailed analysis of one of the arguments by the student.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081740/NO
**SOLID STATE PHYSICS**

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. FRANCESCO ANCILOTTO

Credits: 6 ECTS

Prerequisites:
The knowledge of the elements of elementary quantum mechanics. The knowledge of the elements of elementary statistical mechanics (distribution functions, statistical ensembles, ensemble averages, etc.)

Short program:
- Chemical bonds in solids; The structure of crystals; Bravais lattices and bases; Simple crystal structures; Reciprocal lattice; Diffraction by periodic structures and experimental techniques; The Bragg law; Adiabatic approximation; Lattice dynamics; Harmonic approximation; The dynamical Matrix; phonons; Monoatomic and diatomic linear chains; Spectroscopy of phonons; Thermal properties of crystals; Lattice specific heat; Anharmonic effects: thermal expansion, thermal conductivity of insulating materials; "free" electrons model; Electronic specific heat; electrostatic screening in a Fermi gas.; Bloch theorem; Band structure; "quasi-free" electron approximation; "tight binding" approximation; Examples of band structures; Transport phenomena; The Drude model; Hall effect in metals; Semiclassical model; The concept of "hole"; Electrical and thermal conductivity in metals; Law of Wiedemann and Franz; Semiconductors; Cyclotron Resonance; Carriers concentration in intrinsic and extrinsic semiconductors; "Doping" and dopant states; electron and hole mobility; Electrical conductivity in semiconductors; Hall effect in semiconductors; The Fermi surface in real metals. Superconductivity.

Examination:
Oral exam

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081660/NO

**STANDARD MODEL**

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. PARIDE PARADISI

Credits: 6 ECTS

Prerequisites:
Students should be familiar with the fundamental aspects of field theory, quantum electrodynamics and the calculation of amplitudes for physical processes through Feynman diagrams.

Short program:

Examination:
Oral examination

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081698/NO

**STATISTICAL MECHANICS**

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. ENZO ORLANDINI

Credits: 6 ECTS

Prerequisites:
Statistical Mechanics (course given at the third year of the laurea triennale) Thermodynamics

Short program:

Examination:
The verification of the acquired knowledge takes place through a common written test with 1-2 exercises to be solved analytically and 1-2 open questions on basic concepts. In this way we should be able to test the knowledge, the scientific vocabulary, the ability to synthesis and critical discussion acquired during the course. The second part of the exam will be oral and will be based on a discussion on the various topics discussed in class.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081659/NO

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**SUBNUCLEAR PHYSICS**

Master's degree in PHYSICS ORD. 2021, Second semester

**Lecturer:** Prof.ssa DONATELLA LUCCHESI

**Credits:** 6 ECTS

**Prerequisites:** Principles of nuclear and sub-nuclear physics, principles of quantum mechanics, relativistic dynamics, quantum field theory, Feynman graphs, interaction radiation with matter.

**Short program:**
Introduction and recap Tools for calculation Detectors for particle physics experiments Cross section $e^+e^-\rightarrow\mu^+\mu^-$ and $e^+e^-\rightarrow hh$ Deep Inelastic Scattering The Gluon QCD, Partons and jets Electroweak interaction: introduction Experimental tests of Electroweak interaction Cabibbo Theory and Cabibbo-Kobayashi-Maskawa Matrix CP and T violation, the B meson system. Tests of CKM Neutrino and Standard Model Higgs Properties

**Examination:**
The exam will be based on an assignment given in advance to the students. It will be constituted by exercises or open questions and a discussion on open topics among those discussed during the lectures. During the discussion questions on the arguments of the class can be asked.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081697/NO

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**TEACHING AND LEARNING PHYSICS**

Master's degree in PHYSICS ORD. 2021, First semester

**Lecturer:** Prof.ssa ORNELLA PANTANO

**Credits:** 6 ECTS

**Prerequisites:** Core knowledge of classic and modern physics.

**Short program:**
Physics teaching and learning: main topics and approaches in physics education research. Core ideas in physics, scientific practices and crosscutting concepts in natural sciences. Historical development of physics ideas that carry special significance for physics teaching and learning. Different theoretical approaches to students' understanding of physics content and student difficulties, and their application in physics teaching. The role and importance of student interest, motivation and metacognition in learning physics. Student-centered approaches to physics teaching and learning. The role of laboratory work and technologies in physics learning and teaching. Educational potential of out-of-school settings: benefits and opportunities offered by experiences outside the classroom. Physics education research in different areas of physics, for example: mechanics, waves, optics, electromagnetism, relativity and quantum mechanics. Application of didactical methods and technologies for the design of teaching and learning sequences for specific physics topics.

**Examination:**
The examination will consist of two parts: 1) written assignments during the course (40%); 2) a final educational project on a selected topic in physics (60%).

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCQ1097889/NO

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**THEORETICAL PHYSICS OF THE FUNDAMENTAL INTERACTIONS**

**Lecturer:** Prof. PIERPAOLO MASTROLIA

**Prerequisites:** Principle of Theoretical Physics

**Examination:**
Written and oral exam

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP9087856/NO

Moduli del C.I.:
Theoretical physics of the fundamental interactions (Mod. A)
Theoretical physics of the fundamental interactions (Mod. B)

THEORETICAL PHYSICS OF THE FUNDAMENTAL INTERACTIONS (MOD. A)

Lecturer: Prof. PIERPAOLO MASTROLIA

Master's degree in PHYSICS ORD. 2021, First semester

Credits: 12 ECTS

Short program:

THEORETICAL PHYSICS OF THE FUNDAMENTAL INTERACTIONS (MOD. B)

Lecturer: Prof. PARIDE PARADISI

Master's degree in PHYSICS ORD. 2021, First semester

Credits: 12 ECTS

Short program:

THEORY OF STRONGLY CORRELATED SYSTEMS

Lecturer: Prof. LUCA DELL'ANNA

Master's degree in PHYSICS ORD. 2021, First semester

Credits: 6 ECTS

Short program:

Examination:
Oral examination

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2382/001PD/SCP7081742/NO

SANITARY BIOLOGY

APPLIED STATISTICS
Master's degree in **SANITARY BIOLOGY**, First semester

**Lecturer**: Prof.ssa ALESSANDRA ROSALBA BRAZZALE

**Credits**: 6 ECTS

**Prerequisites**: The style is informal and only minimal mathematical notation will be used. There is no real prerequisite except elementary algebra. However, a previous introductory course in statistics is recommended.

**Short program**:  

**Examination**: Written exam on moodle platform

**More information**:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC1177/000ZZ/SCN1028731/NO

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**BIOCHEMISTRY OF DISEASES**

Master's degree in **SANITARY BIOLOGY**, First semester

**Lecturer**: Prof. LUCA SCORRANO

**Credits**: 8 ECTS

**Prerequisites**: Biochemistry, Physiology and Pathology

**Short program**:  
Introduction to class. Course organization. Distribution of material. designing and interpreting an experiment in biology how to critically read a research paper (w/example) Metabolic flexibility Interorganellar contact sites angiogenesis adipocyte biology neurodegeneration Design and analysis of a conditional knockout mouse Introduction to the lab rotation experiments Presentation of the lab rotation experiments by students Critical presentation of a paper by students course wrap up: questions, doubts, answers

**Examination**: Evaluation of the overall active participation to classes and tutorials (30%) Evaluation of the lab report (30%) Evaluation of the final public presentation (40%)

**More information**:  
https://en.didattica.unipd.it/off/2022/LM/SC/SC1177/000ZZ/SCP5073118/NO

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**HUMAN PHYSIOLOGY**

Master's degree in **SANITARY BIOLOGY**, First semester

**Lecturer**: Prof. LUIGI BUBACCO

**Credits**: 9 ECTS

**Prerequisites**: The class requires previous knowledge of basic Biochemistry, cell Biology and General Physiology

**Short program**:  
The Central Nervous System (8 hours) Neurons: Cellular and Network organization and Properties, Efferent Division: (10 hours) Autonomic and Somatic Motor Control. Sensory Physiology. Muscles physiology (8 hours) Control of Body Movement Cardiovascular Physiology (10 hours) Blood Flow and the Control of Blood Pressure and functional properties of Blood Respiratory Physiology (8 hours) Mechanics of Breathing, Gas Exchange and Transport The Kidneys (8 hours) Fluid and Electrolyte Balance Digestion (8 hours) Energy Balance and Metabolism. Endocrine Control of Growth and Metabolism (8 hours) Reproduction and Development (8 hours)

**Examination**: Written exam, four open questions to be answered in two hours
MOLECULAR BIOLOGY AND GENETICS OF CANCER

Master's degree in SANITARY BIOLOGY, First semester

Lecturer: Prof. GIANLUCA OCCHI

Credits: 8 ECTS

Prerequisites:
The course has no specific prerequisites. Basic knowledge in cell biology, molecular biology is, however, desirable.

Short program:
1. Introduction on the molecular basis of cancer (0.25 CFUf) 2. Carcinogenesis and Cancer Genetics (2.5 CFUf) - Oncogenes and Signal Transduction - Tumor Suppressor Genes - DNA Repair Pathways and Human Cancer - Epigenetics and Cancer - Infectious Agents and Cancer - Notes on environmental Carcinogenesis 3. Cancer Biology (2.25 CFUf + 0.25 CFUp) - Cancer Stem Cells and the Microenvironment - Regulation of the Cell Cycle - Cell Growth - The Metabolism of Cell Growth and Proliferation - Apoptosis, Necrosis, and Autophagy - Cellular Senescence - Tumor Angiogenesis - Invasion and Metastasis - Inflammation and Cancer 4. Tumor Genomics (1 CFUf + 1 CFUp) - Use of next-gen sequencing in cancer - Cancer System Biology - Computational pan-Cancer Analysis 5. Molecular Pathology and Diagnostic (0.25 CFUp) - Biomarkers for diagnosis, risk, and therapy assessment 6. Notes on the molecular basis of cancer therapy These topics will be addressed in frontal lessons, specific seminars, and journal clubs. Internationally acknowledged experts in the field of tumor molecular oncology will be invited to hold seminars on specific topics. Practicals During the bioinformatic practicals, cutting-edge databases of omic tumor data will be presented in the context of research in molecular oncology. Tools for the consultation and analysis of these data will be also illustrated. During Practicals, students will be invited to complete a small group research project. In addition, journal club will be held by the students on specific course topics. Finally, seminars will be held by invited experts in molecular oncology (1.25 CFUf).

Examination:
An oral exam will be held. The journal club and activities in the bioinformatic laboratories will be also scored.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC1177/000ZZ/SCN1032657/NO

STATISTICAL SCIENCES ORD. 2014

INTRODUCTION TO STOCHASTIC PROCESSES

Master's degree in STATISTICAL SCIENCES ORD. 2014, First semester

Lecturer: Prof. BERNARDO D'auria

Credits: 9 ECTS

Prerequisites:
A basic course in Probability.

Short program:

Examination:
To be defined

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SS1736/000ZZ/SCQ0093538/NO

MACHINE LEARNING

Master's degree in STATISTICAL SCIENCES ORD. 2014, First semester
THEORY AND METHODS FOR INFERENCE

Master’s degree in STATISTICAL SCIENCES ORD. 2014, Second semester

Lecturer: Prof.ssa ALESSANDRA SALVAN

Credits: 9 ECTS

Prerequisites:
First year Master courses at the level of the courses Probability Theory and Statistics (Advanced) at the Department of Statistical Sciences.

Short program:

Examination:
1/3 homework, 1/3 final written exam, 1/3 written and oral presentation reviewing one or two recent research papers.

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SS1736/000ZZ/SCP4063246/NO

SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021
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<td>CIRCULAR AND SUSTAINABLE WASTE MANAGEMENT</td>
<td>Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021</td>
<td>First semester</td>
<td>Prof.ssa MARIA CRISTINA LAVAGNOLO</td>
<td>9 ECTS</td>
<td><a href="https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095491/NO">https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095491/NO</a></td>
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<td>ECONOMICS FOR THE CIRCULAR ECONOMY</td>
<td>Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021</td>
<td>Second semester</td>
<td>to be defined</td>
<td>6 ECTS</td>
<td><a href="https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095593/NO">https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095593/NO</a></td>
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<td>EUROPEAN UNION ENVIRONMENTAL AND ENERGY LAW</td>
<td>Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021</td>
<td>Second semester</td>
<td>Prof. BERNARDO CORTESE</td>
<td>6 ECTS</td>
<td><a href="https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095594/NO">https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095594/NO</a></td>
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<td>GREEN CHEMISTRY AND INNOVATIVE CHEMICAL PROCESS</td>
<td>Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021</td>
<td>First semester</td>
<td>Prof. MAURO CARRARO</td>
<td>9 ECTS</td>
<td><a href="https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095518/NO">https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095518/NO</a></td>
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<td>HEALTH AND ENVIRONMENT IN CIRCULAR ECONOMY</td>
<td>Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021</td>
<td>Second semester</td>
<td>to be defined</td>
<td>6 ECTS</td>
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OPERATIONS AND SUPPLY CHAIN MANAGEMENT

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, Second semester

Lecturer: to be defined

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095738/NO

PSYCHOLOGY, POLICY MAKING, AND EDUCATION TO A CIRCULAR ECONOMY

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, Second semester

Lecturer: Prof. ENRICO RUBALTELLI

Credits: 6 ECTS

Prerequisites: -

Short program: -

Examination: -

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095721/NO

RENEWABLE ENERGY TECHNOLOGIES

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First semester

Lecturer: Prof. MICHELE DE CARLI

Credits: 6 ECTS

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095318/NO

SYNTHETIC BIOTECHNOLOGY

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First semester

Lecturer: Prof.ssa ELISABETTA BERGANTINO

Credits: 6 ECTS

Prerequisites: -

Short program: -

Examination: -

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095718/NO
UNDERSTANDING STATISTICS OF CIRCULAR ECONOMY

Master’s degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, Second semester

Lecturer: Prof.ssa FRANCESCA BASSI

Credits: 6 ECTS

Prerequisites:

- 

Short program:

- 

Examination:

- 

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095722/NO

WATER RESOURCES MANAGEMENT IN THE CIRCULAR ECONOMY

Master’s degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, Second semester

Lecturer: Dott.ssa GIULIA ZUECCO

Credits: 6 ECTS

More information: https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/000ZZ/SCQ1095580/NO

BIOREFINERIES AND SUSTAINABLE ENERGY PRODUCTION AND STORAGE FOR CIRCULAR ECONOMY

Master’s degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First semester

Lecturer: Prof. TOMAS MOROSINOTTO

Credits: 15 ECTS

Prerequisites:

- 

Short program:

- 

Examination:

- 


LIFE CYCLE ASSESSMENT

Master’s degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First semester

Lecturer: Prof.ssa ANNA STOPPATO

Credits: 6 ECTS

Prerequisites:

- 

Short program:

-
SUSTAINABILITY STRATEGIES AND ENERGY ECONOMICS (C.I.)

Lecturer: Prof. ARTURO LORENZONI

Prerequisites:

Examination:

More information:

Moduli del C.I.:
Energy Economics (Mod. B)
Sustainability strategies and Innovation management for Circular economy (Mod. A)

ENERGY ECONOMICS (MOD. B)

Lecturer: Prof. ARTURO LORENZONI

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First semester

Credits: 12 ECTS

Short program:

SUSTAINABILITY STRATEGIES AND INNOVATION MANAGEMENT FOR CIRCULAR ECONOMY (MOD. A)

Lecturer: Prof.ssa VALENTINA DE MARCHI

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First semester

Credits: 12 ECTS

Short program:

CIRCULARITY IN BIOMASS PRODUCTIONS

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, Second semester

Lecturer: Prof.ssa MICHELA ZANETTI

Credits: 6 ECTS

Prerequisites:

Short program:

Examination:

More information:
https://en.didattica.unipd.it/off/2022/LM/SC/SC2590/001PD/SCQ1095715/NO

MATERIALS DESIGN AND SELECTION FOR CIRCULAR ECONOMY
Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First semester

**SUSTAINABLE MATERIALS AND RECYCLING FOR CIRCULAR ECONOMY (C.I.)**

Lecturer: Prof.ssa GABRIELLA SALVIULO

Prerequisites: -

Examination: -


Moduli del C.I.:
- New plastics economy: polymers, biopolymers and their recycling (Mod. C)
- Recycling and transformation of inorganic materials (Mod. B)
- Sustainable mineral (geo)-resources and critical raw materials (CRM) (Mod. A)

**NEW PLASTICS ECONOMY: POLYMERS, BIOPOLYMERS AND THEIR RECYCLING (MOD. C)**

Lecturer: Prof. STEFANO MAMMI

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First and Second semester

Credits: 21 ECTS

Short program: -

**RECYCLING AND TRANSFORMATION OF INORGANIC MATERIALS (MOD. B)**

Lecturer: Prof. MANUELE DABALA'

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First and Second semester

Credits: 21 ECTS

Short program: -

**SUSTAINABLE MINERAL (GEO)-RESOURCES AND CRITICAL RAW MATERIALS (CRM) (MOD. A)**

Lecturer: Prof.ssa GABRIELLA SALVIULO

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First and Second semester

Credits: 21 ECTS

Short program: -