SCHOOL OF SCIENCE - UNIVERSITY OF PADOVA
CATALOGUE OF ENGLISH LANGUAGE COURSES FOR ERASMUS, FOREIGN AND ITALIAN STUDENTS

ACADEMIC YEAR 2021-2022

First semester: October 1st, 2021, to January 15th, 2022
Winter exams session: January 17th, 2022, to February 26th, 2022
Second semester: February 28th, 2022, to June 11th, 2022
Summer exams session: June 14th, 2022, to July 23rd, 2022
Extra exams session: August 22nd, 2022, to September 24th, 2022

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/curriculum-chemistry
- 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/curriculum-materials
- 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. 2021/2022

- **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**
- **EVOLUTIONARY BIOLOGY ORD. 2018**
- **GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)**
- **INDUSTRIAL BIOTECHNOLOGY ORD. 2014**
- **INDUSTRIAL CHEMISTRY ORD. 2015**
- **MARINE BIOLOGY ORD. 2020**
- **MARINE BIOLOGY ORD. 2021**
- **MATERIAL SCIENCE ORD. 2015**
- **MATHEMATICS ORD. 2011**
- **MOLECULAR BIOLOGY (ORD. 2020)**
- **NATURAL SCIENCE ORD. 2014**
- **PHYSICS ORD. 2017**
- **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:** Prof. MICHELE LIGUORI

**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.

**Short program:** Bayes theorem and bayesian probability. Choice of prior. Bayesian inference and Monte Carlo Markov Chain (MCMC): Metropolis-Hastings, Gibbs and Hamiltonian sampling. Joint likelihood. Parameter marginalization. Bayesian evidence: model selection and comparison, information criteria. Fisher matrix 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. 3) Oral examination with discussion of the course topics.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2490/000ZZ/SCP8082722/NO

### 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/2021/LM/SC/SC2490/000ZZ/SCP9086348/NO

### 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/2021/LM/SC/SC2490/000ZZ/SCN1035986/NO

### 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:**
i) 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 Standr 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 inflaton; 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/2021/LM/SC/SC2490/000ZZ/SCP7081703/NO

ASTROPHYSICS LABORATORY 1: HIGH ENERGY INSTRUMENTATION

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

Lecturer: Prof. EUGENIO ALESSIO BOTTACINI

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 which includes supermassiva black holes, accretion disks, neutron stars, supernovae remnants 5) fitting of data, simulating 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/2021/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:
1) Basic principles of optics and image formation: Nature of light and geometrical nature of thin lenses and of conical sections. Concept of stigmatic and non stigmatic imaging. Optical copies and Lagrange invariant. Relevance of the position and size of the stop in an optical system and its effects on the overall property. 2) Two mirrors telescope: Schwarzschild, Cassegrain, Gregorian and Ritchey-Chretienne solutions. The problem of the background in astronomical imaging and in particular in the infrared. Definition of the thermal and non-thermal infrared portion of the spectra. Vignetting and field of view in Cassegrain telescopes. Difference between images formed by parabolic and spherical mirrors and the case of Arecibo-like design. Examples of telescopes and instrumentation employing the various concepts devised. 3) Adaptive and active optics. Basic definitions, Kolmogorov turbulence and isoplanatic angle, Fried's parameter and Greenwood frequency. Deformable mirrors and wavefront sensors in open and closed loop operations. Tip-tilt four quadrants sensing and Poissonian nature of photons effect on them. 4) Detectors: Charge Coupled Devices Detectors, principles of working and basic parameters. Quantum efficiency, charge transfer efficiency, read out noise. CCD principle of working and effects on the Poissonian apparent noise. Concept of the avalanche photo diodes and quenching. 5) Experiments in the optical laboratory: Poisson's spot, turbulence simulation and speckle formations. 6) Observations at the Asiago Astronomical Observatory: Speckle interferometry.
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:

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/2021/LM/SC/SC2490/000ZZ/SCP9086353/NO

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/2021/LM/SC/SC2490/000ZZ/SCN1035988/NO

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/2021/LM/SC/SC2490/000ZZ/SCP7081761/NO
Master’s degree in **ASTROPHYSICS AND COSMOLOGY ORD. 2019**, First semester

**Lecturer:** Prof. SABINO MATARRESE

**Credits:** 6 ECTS

**Prerequisites:**
Fundamentals of quantum mechanics and special relativity

**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/2021/LM/SC/SC2490/000ZZ/SCP906381/NO

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**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 (or of the two written partials) plus an oral exam (needed only if the score of the written exam is insufficient). 

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2490/000ZZ/SCP9086380/NO
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/2021/LM/SC/SC2490/000ZZ/SCP9086385/NO

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**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/2021/LM/SC/SC2490/000ZZ/SCQ0093378/NO

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**GRAVITATIONAL PHYSICS**

Master’s degree in ASTROPHYSICS AND COSMOLOGY ORD. 2019, Second semester
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/2021/LM/SC/SC2490/000ZZ/SCP7081719/NO

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**HIGH ENERGY ASTROPHYSICS**

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

Lecturer: Prof. ALBERTO FRANCESCHINI

Credits: 6 ECTS

Prerequisites:
The mandatory courses of 1st year of the Master Degree in Astronomy.

Short program:

Examination:
Oral discussion on the topics discussed during lectures.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2490/000ZZ/SCP3050183/NO

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**MATHEMATICAL AND NUMERICAL METHODS**

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

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/2021/LM/SC/SC2490/000ZZ/SCP9086342/NO

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**MULTIMESSERGNER ASTROPHYSICS**

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

**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. 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/2021/LM/SC/SC2490/000ZZ/SCP7081762/NO

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**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 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/2021/LM/SC/SC2490/000ZZ/SCP7081704/NO

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**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 fluidodynamics 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)

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2490/000ZZ/SCP7081805/NO

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**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 $e^+e^+\rightarrow hh$ 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/2021/LM/SC/SC2490/000ZZ/SCP7081697/NO

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**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. Basic knowledge of stellar evolution. Basic knowledge of stellar photometry and spectroscopy.

Short program:
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 the 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:
Valutazione delle relazioni sulle esperienze di laboratorio ed esame orale.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC2490/002PD/SCP9086350/NO

**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, photometric profiles, kinematics of galaxies.

Short program:

Examination:
Oral exam

More information:
https://en.didattica.unipd.it/off/2021/LM/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. HI 21 cm line. 12) Supernovae remnants and basics of evolutionary models. 13) Stellar
### OBSERVATIONAL COSMOLOGY

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

**Lecturer:** Prof. ALBERTO FRANCESCHINI  
**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:**  
2) The large scale structure of the Universe: Local properties. Angular and spatial correlation functions. Higher order correlations. Limber relation. Power-spectrum of the cosmic structures. Relationship of the power-spectrum and $\Omega(r)$. Observational data on the large scale structure. The initial power-spectrum of the perturbations.  
3D mapping of galaxies, clusters, AGNs. Counts-in-cells. Outline of fractal and topological analyses of the large-scale structure of the universe.  
6) The Cosmic Microwave Background (CMB): Discovery, observations from ground and from space. Origin of the CMB. Statistical description of the angular structure. Origin of the CMB angular fluctuations. Physical processes in operation on the large scales. Fluctuations on intermediate angular scales. Contributions of sources to the anisotropies on small scales. Cosmological re-ionization and its impact on CMB. Constraints of CMB observations on the cosmological parameters.  
The CMB spectrum, spectral distortions. The Sunyaev-Zeldovich effect. Polarization.  

**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:**  
1) Color-magnitude diagrams: transformation luminosity-magnitude and color-temperature, bolometric corrections, effect of reddening, metallicity and chemical composition.  
2) Definition of stellar population. historical background, present-day view. Stellar clusters as prototype of simple populations. The initial mass function.  
3) Determination of the physics and structure parameters of stellar population from photometry (age, reddening, metallicity).  
4) Chemical composition of stellar populations.  
5) Binaries, Blue Stragglers, X-ray Binaries, black holes and other exotic objects in star clusters.  
6) Population III stars. Hunting the first stars of the Universe.  
8) Galactic Bulge.  
10) Star formation history in dwarf galaxies and in the Milky Way.

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

**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:

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:

RADIATIVE PROCESSES IN ASTROPHYSICS

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

Lecturer: Prof. ROBERTO TUROLLA
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/2021/LM/SC/SC2490/001PD/SCP9086384/NO

THEORETICAL PHYSICS

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

Lecturer: Prof. ANDREA WULZER

Credits: 6 ECTS

Prerequisites:

Short program:

Examination:
Written. Solution of one or more problems.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC2490/001PD/SCP7081638/NO

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**CHEMISTRY ORD. 2018**

**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/2021/LM/SC1169/000ZZ/SCP9087639/NO

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**MAGNETIC SPECTROSCOPIES**

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

**Lecturer:** Prof. LORENZO FRANCO

**Credits:** 6 ECTS

**Prerequisites:**
Physics and quantum chemistry basics.

**Short program:**

**Examination:**
Oral examination
### 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. Photophysics and 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:**  

### 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:**  
1. Basics. Classification of solids  
2. Structure and Symmetry in Crystals  
3. Local order in fluids and amorphous solids  
4. Polymers  
5. Lattice dynamics  
6. Phonons and thermal properties  
7. Electrons in crystals  
8. Metals and semiconductors  
9. Physical properties of crystals. General principles  
10. Dielectric and optical properties of insulators  
11. Magnetic materials  
12. Devices based on inorganic and organic semiconductors.  

**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:**  

### PRINCIPLES AND APPLICATIONS OF ORGANOMETALLIC CHEMISTRY

**Master’s degree in** CHEMISTRY ORD. 2018, First semester  
**Lecturer:** Prof. ANDREA BIFFIS  
**Credits:** 6 ECTS  
**Prerequisites:**  
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 of 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/2021/LM/SC/SC1169/000ZZ/SCP9087645/NO

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/2021/LM/SC/SC1169/000ZZ/SCP9087646/NO

THEORETICAL CHEMISTRY

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

Lecturer: Dott. DIEGO FREZZATO

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/2021/LM/SC/SC1169/000ZZ/SCP9087641/NO

COMPUTER SCIENCE ORD. 2021
ADVANCED ALGORITHMS

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

Lecturer: Prof. DAVIDE BRESOLIN

Credits: 6 ECTS

Prerequisites:
The course requires familiarity with some basic algorithmic concepts, such as asymptotic complexity, searching and sorting algorithms, and basic data structures such as trees, lists, maps, and arrays. There are no preparatory courses.

Short program:
1) Algorithms on graphs: Graph basics and representation. Breadth-first and depth-first visits of a graph, with applications. Connected Components. Weighted graphs: shortest paths and minimum spanning trees. Data structures for disjoint sets. 2) Approximation algorithms: Tractable and intractable problems. NP-complete problems and approximation algorithms. Approximation for the vertex cover and for the set cover problems. The Traveling Salesman Problem: inapproximability and approximation algorithms for special cases. 3) Randomized algorithms: Main techniques and applications: Markov inequalities, Chernoff bounds, analysis of Quicksort, randomized algorithms for the minimum cut problem

Examination:
The exam is divided into a theoretical part and a practical part. The theoretical part consists of a written test held during the regular exam session. The practical part can be done in two different ways: - DURING THE COURSE: a group of maximum three students implements all the algorithms seen in the laboratories and submits the code and the obtained results. - AFTER THE COURSE: a single personal project. In this case the project must be carried out alone, not in a group.

More information:
https://en.didattica.unipd.it/off/2021/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/2021/LM/SC/SC2598/000ZZ/SCQ1098227/NO

ADVANCED TOPICS IN COMPUTER SCIENCE

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

Lecturer: Dott. LUCA PASA

Credits: 6 ECTS

Prerequisites:
No prerequisites.

Short program:
The course consists of series of lectures, illustrating advanced topics in computer science with the support of international experts.

Examination:
The student will deepen some chosen theme. A discussion in the form of a seminar or the development of a related project will then be used to assess to what extent the student masters the subject.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2598/000ZZ/SCP6076301/NO

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**ADVANCED TOPICS IN PROGRAMMING LANGUAGES**

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

**Lecturer:** Prof.ssa SILVIA CRAFA

**Credits:** 6 ECTS

**Prerequisites:**
Computer Programming and Object-Oriented Programming.

**Short program:**
The course illustrates some of the advanced topics of modern programming languages, such that: the use of types to reason about programs, advanced object-oriented topics (structural typing, dynamic type checking, mixins), the integration of functional programming and object-oriented programming. These concepts will be carried over by a foundational study based on theoretical formal methods and an insightful analysis of the Scala, Java8 and Rust languages. The students will also be exposed to the analysis and the discussion of concrete cases where new technologies have a controversial impact on society.

**Examination:**
To pass this course the student must succeed in a written test and either an oral examination about an advanced topic or the implementation of a programming project.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2598/000ZZ/SCQ1098229/NO

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**ARTIFICIAL INTELLIGENCE**

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

**Lecturer:** Prof. ALESSANDRO SPERDUTI

**Credits:** 6 ECTS

**Prerequisites:**
It is opportune to know basic notions of Probability Theory, Programming, and Algorithms.

**Short program:**
The structure and the topics of the course will be described in the following: - Introduction, Motivation, Intelligent Agents Architectures; - Problem Resolution and basics of Constraint-based Systems; - Adversarial Search; - Knowledge Processing by Propositional and First-order Logic; - Dealing with Uncertainty and Probabilistic Reasoning; - Basics of Machine Learning; - Basics of Computer Vision; - Basics of Natural Language Processing.

**Examination:**
The student must overcome a written exam. Moreover, the student must develop a project.

More information:
https://en.didattica.unipd.it/off/2021/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

**Prerequisites:**
The course has the following prerequisites: competences regarding the design and analysis of algorithms and data structures, knowledge of fundamental notions of probability and statistics, and programming skills in Java or Python.

**Short program:**
The course will cover the following topics: Introduction to the Big Data phenomenon. Programming frameworks: MapReduce, Apache Spark Reducing input size (Case study: clustering) Reducing output size (Case study: frequent itemsets) Streaming framework.

**Examination:**
The exam consists of a number of programming homeworks, assigned approximately every 2-3 weeks and to be carried out in groups of 2-3 students, and
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 and 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/2021/LM/SC/SC2598/000ZZ/SCP7079297/NO

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:

Examination:
Written and oral exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2598/000ZZ/SCQ1098231/NO

CRYPTOGRAPHY

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

Lecturer: Prof. ALESSANDRO LANGUASCO

Credits: 6 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. Migliardi; 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. Migliardi; 6 credits): Written Exam, Homeworks, oral test.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2598/000ZZ/SCQ0093658/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

**Prerequisites:**
Basic knowledge of Computer science, Databases. Basic knowledge of Probability and Statistics is useful although not essential.

**Short program:**
- Introduction to the course: Data analysis as a tool for decision support. Motivations and context for data mining.
- Simple linear and multiple linear regression model: estimation, confidence intervals, hypothesis test, p-value, prediction, model selection, residual analysis, spurious correlation, multicollinearity.
- Classification methods: logistic regression, linear discriminant analysis and extensions.
- Model selection criteria: cross-validation, adjusted R2, AIC, BIC, automatic selection.
- Regularisation: ridge regression and lasso.
- Principal components regression.
- Semiparametric regression: regression splines, smoothing splines, generalized additive models.

**Examination:**
The examination is composed by two parts. 1) The first part is a written examination carried out in laboratory using Moodle (35 minutes). The examination is about linear regression models and it includes questions with multiple choices and open questions. The questions regard the analysis of a real dataset, including numerical evaluations, interpretation of results from R and comments on graphical outputs. The first part of the examination will take place after the middle of the course. During the practical examination students are allowed to bring with them and consult a copy of the textbook, the slides of the course, the laboratory notes. 2) The second part is a practical examination carried out in laboratory (2 hours) and it is constituted by the analysis of a real data set using R. The student is required to collect the results of the analysis, with appropriate comments, in a brief report. During the practical examination students are allowed to bring with them and consult a copy of the textbook, the slides of the course, the laboratory notes. The final evaluation will be the mean of the results from the two parts. Students who do not take the first assessment in the middle of the course will have a written examination immediately after the practical final examination.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2598/000ZZ/SCQ01111799/NO

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**DEEP LEARNING**

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

**Lecturer:** Prof. ALESSANDRO SPERDUTI

**Credits:** 6 ECTS

**Prerequisites:**
It is advisable to have the basic knowledge related to Probability, Programming, and Algorithms.

**Short program:**
The topics covered in the course are as follows:
- Introduction to the course contents;
- Deep Feedforward Networks;
- Regularization for Deep Learning;
- Optimization for training Deep Models;
- Basic concepts for Convolutional Neural Networks;
- Recurrent Neural Networks and Transformers for sequence modelling;
- Autoencoder - Deep Generative Models;
- TensorFlow.
**ECONOMICS AND MANAGEMENT OF INNOVATION**

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

**Lecturer:** Prof.ssa KATIA CALDARI

**Credits:** 6 ECTS

**Prerequisites:**
No pre-requisite 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/2021/LM/SC/SC2598/000ZZ/SCP9087561/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

**Prerequisites:**
The course requires familiarity with automata theory, theory of computation and calculus. There are no preparatory courses.

**Short program:**

**Examination:**
Oral exam and/or project

**More information:**
https://en.didattica.unipd.it/off/2021/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:**
Imperative and object oriented programming

**Short program:**
The course introduces the functional language Haskell. In particular, the following aspects are studied:
- Pattern matching. Curried and higher-order functions. Type inference: what it is and how it is done. I/O. Parametric polymorphism. Lazy evaluation. Functors, applied functors and monads. Run-time support. Parsing with Monads

**Examination:**
The exam has a written and an oral part. The written part counts for 80% of the final grade and concerns the concepts and exercises studied during the course. The oral part is a discussion about the project that consists of a parser for a functional language.
GAME THEORY

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

Lecturer: ELVINA GINDULLINA

Credits: 6 ECTS

Prerequisites:
A course, even a basic one, on probability theory.

Short program:

Examination:
For all the students, in any event the exam includes a mandatory open-book written test, containing problems of game theory focusing on different topics of the course. Every exercise involves multiple questions, typically three. For the students with regular attendance to the course, the exam may also involve, if they want so, the development of a project in 1-3 person groups, on course-related topics applied to ICT. This is agreed half-way through the course together with the lecturer. If the written test is sufficient, students can directly finalize the passing score. Projects can be discussed with an oral exam after the written test. Oral exams are scheduled in the same day of written tests (even though students can decide to give the two parts on separate days). The project discussion integrates the mark of the written test.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2598/000ZZ/SCP6076299/NO

IT SERVICE MANAGEMENT

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

Lecturer: Dott. FRANCESCO CLABOT

Credits: 6 ECTS

Prerequisites:
The course does not require specific prior knowledge.

Short program:
The course describes the processes and roles that enable the IT department of a large scale company to work: the approach to problems, the responsibilities associated with each role, the tasks and how these should be carried out. The course deals with the relationships that need to be established and managed not only within the company, but also with customers and suppliers, through analysis and many real cases. At the base of the course, the ITSM method called "ITIL" (IT Infrastructure Library) which has now become a MUST for the company organisation, a set of practices for the management and provision of IT services. In addition to providing specific knowledge drawn from ITIL so as to enable students to easily pass the ITIL Foundation certification level, the course aims at explaining the nature of an IT department, its importance for companies and how its activity is deeply integrated in the production process. It is therefore necessary to transmit to students the mental attitude needed to operate in the IT field, with particular attention to the culture of the organisation, to the prevention of problems, to the management and control of activities, all fundamental areas for carrying out an effective and professional job. During the course, the theoretical concepts will be illustrated by numerous real case studies (examples).

Examination:
Multiple choice written test and small project/report on a concrete case.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2598/000ZZ/SCP7079401/NO

KNOWLEDGE REPRESENTATION AND LEARNING

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

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites:
Suggested basic knowledge of logics and statistics.

Short program:
(A) Logics for knowledge representation: (A.i) introduction to propositional logics, syntax, semantics, decision procedure. Satisfiability, weighted satisfiability, and best satisfiability. (A.ii) First order logics, syntax, semantics, resolution and unification. (A.iii) Fuzzy logics, syntax, semantics, and reasoning. (B) statistical relational learning: (B.i) Graphical models (B.ii) Markov Logic Networks (B.iii) Probabilistic prolog, (B.iii) Logic Tensor Networks

Examination:
Critical knowledge of the course topics. Ability to present and apply the studied material.

More information:
https://en.didattica.unipd.it/off/2021/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

**Prerequisites:**
There are no propaedeutical courses.

**Short program:**
The structure and themes of the course will be as follows: - Introduction to concurrency and mobility: from automata to reactive and concurrent systems. - Calculus of Communicating Systems (CCS), a basic language for the description of concurrent systems. Process equivalence: transition systems and bisimulation. - Hennessy-Milner logic and tools for verification. Mutual exclusion, deadlock freeness, fairness. Safety and liveness properties. Verification with automated tools. The Concurrency Workbench and the Mobility Workbench. - From specification languages ??to programming languages ??: advanced languages ??for concurrency (Google Go and channel-based concurrency, Erlang and the actor model, Clojure and functional concurrency) - Orchestration languages ??(ORC) and languages for service-oriented programming ??(Jolie).

**Examination:**
Class exercises, solution and oral discussion of some advanced exercises, presentation on a theme chosen by the student. Among the options, there is the possibility of realizing a small project.

**More information:**
https://en.didattica.unipd.it/off/2021/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.

**More information:**
https://en.didattica.unipd.it/off/2021/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

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25/221
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/2021/LM/SC/SC2598/000ZZ/SCP7079402/NO

MOBILE AND IOT SECURITY

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

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: Any object-oriented programming language.

Short program:
Theory: Android's security model, permissions, package management, user management, cryptographic providers, network security, credential storage, online account management, device security, SELinux, system updates and root access, Bluetooth/Bluetooth Low-Energy communication protocols. Practice: application security, Android's attack surface, debugging and analyzing vulnerabilities, exploitation of the user space software, Bluetooth/Bluetooth Low-Energy attacks.

Examination: Students have two options. (Option 1) Practical exam, where students solve exercises on Android security; (Option 2) Project, where students face a research objective assigned by the Lecturer and illustrate the achieved results in an oral presentation.
MOBILE PROGRAMMING AND MULTIMEDIA

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

Lecturer: Prof.ssa OMBRETTA GAGGI

Credits: 6 ECTS

Prerequisites: Operating Systems, Web Technologies

Short program:

Examination:
The exam will require the development of a project and an oral test.

More information:
https://en.didattica.unipd.it/off/2021/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

Prerequisites:
Basic notions of algorithms, data structures and programming, as acquired in course "Fundamental of Information Systems".

Short program:

Examination:
Written exam, and a mandatory project.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2598/000ZZ/SCP7079235/NO

REAL-TIME KERNELS AND SYSTEMS

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

Lecturer: Prof. TULLIO VARDANEVA

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

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/2021/LM/SC/SC2598/000ZZ/SCQ0093641/NO

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RUNTIMES FOR CONCURRENCY AND DISTRIBUTION

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

Lecturer: Prof. TULLIO VARDANEGA

Credits: 6 ECTS

Prerequisites:
The subject matter addressed by the class assumes familiarity with the architecture of traditional computer systems and networks, as well as with the organization and activity of operating systems for those architectures, especially regarding their support for concurrency, synchronization, handling of I/O, and networking. This notwithstanding, the class does not place explicit prerequisites for admission: the class activities are designed to aid students to refresh and deepen their prior knowledge in said ambit.

Short program:
Concurrency - Introduction: how concurrency came about and how to understand it - Processes, communication, and synchronization - A concrete model of concurrency and some desirable extensions - The timing dimension - Virtualization (brief) Distribution - Introduction: definitions and fundamental challenges - Communication, synchronization, and concurrency in a distributed system - The naming system and the notion of statelessness - Example technologies: Java RMI; Ada DSA, CORBA The frontier of Cloud Computing - Origin and motivation - The distinguishing traits of cloud-native applications - The dimensions of scalability.

Examination:
The exam consists of the write-up and presentation of a technical report that discusses the issues involved with and the solutions adopted in the development of an assignment proposed by the instructor and agreed to by the student. All assignments include a component of bibliographic study of the topic background and state of the art, and practical experiments about aspects of the problem at hand.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2598/000ZZ/SCQ0093640/NO

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SOFTWARE VERIFICATION

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

Lecturer: Prof. FRANCESCO RANZATO

Credits: 6 ECTS

Prerequisites:
Basic knowledge of programming languages. Formally prerequisite courses are not required.

Short program:
- Program semantics: This is a model of the dynamic behaviour of programs (in particular the input/output behaviour) by means of order and fixed point theory. (cf. https://en.wikipedia.org/wiki/Semantics_(computer_science) ) - Static program analysis and verification by abstract interpretation: Abstract interpretation is a well-known technique for approximating the semantics of programs that allows to specify how to statically deduce program properties and to prove their correctness. (cf. https://en.wikipedia.org/wiki/Abstract_interpretation ) - Dataflow program analysis: This is a technique for gathering information about the possible set of values calculated at various program points. A program’s control flow graph is used to determine those parts of a program to which a particular value assigned to a variable might propagate. The information gathered is often used by compilers (such as gcc and javac) when optimizing a program. (cf. https://en.wikipedia.org/wiki/Data_flow_analysis ) - Software verification tools: e.g., Clousot (Microsoft, USA), Interproc (INRIA, France), Jandom (Univ. Pescara, Italy) (cf. https://en.wikipedia.org/wiki/List_of_tools_for_static_code_analysis )

Examination:
Oral examination and/or software project, possibly split into distinct parts.
START-UP IN ICT

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

Lecturer: Dott. FABIO D'ALESSI

Credits: 6 ECTS

Prerequisites: None.

Short program:
- Introduction to innovation and entrepreneurship. - Innovation vectors: Internet of things, Blockchain, Augmented Reality. Cyber ??physical systems (edge, fog, cloud). Examples of business application. - Innovation processes: how should the start-up phase be managed, the most risky and intangible? Governance of the start-up phase. How do you calculate the value of a company in the start-up phase? - Institutional investors: business angels and venture capital. How do they work, what are their goals, what are they looking for? - Public support for the start-up phase, regulation and tools. Support programs in Italy and abroad. - Management of the equity of a start up. The equity of a start up for motivating the team and raising funds necessary to open partnerships. - Illustration of the themes for group projects (case studies) and methods of implementation. Insights and exercises on case studies, Laboratory on group projects (also with visits to companies or innovation stakeholders) - Innovation processes: when does the start-up phase end? What are the objectives of the next phase, i.e., the scale up phase? - Innovation processes: the scale up phase. How is the organization structured in the scale up phase? (testimonials: manager of IT companies) - Innovation processes: how to finance the scale up phase; public support for the scale up phase (testimonial from the world of banks)

Examination:
The students will form small groups (typically of 3 people), to work on the identification of a vector of innovation of interest, within a set of themes proposed by the instructor. Then they are required to define a value proposition to be submitted to the instructor and to external experts for a final evaluation. The project activity takes place in the second half of the semester.

More information:
https://en.didattica.unipd.it/off/2021/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

Prerequisites:
Basic knowledge of optimization methods and machine learning. Python programming language.

Short program:
The course consists of two parts: 1) Introduction to living matter (2 credits): 1.1) Introduction to organic chemistry, weak interactions and energy 1.2) Structure and function of DNA and proteins 1.3) Lipids, membranes and cellular transport 1.4) Experimental methods for structure determination 2) Computational Biochemistry (4 credits): 2.1) Biological Databases 2.2) Software libraries and concepts for sequence alignments and database searches 2.3) Sequence - structure relationship in proteins and structural classification 2.4) Methods for the prediction of protein structure from sequence, the CASP experiment 2.5) Methods for the prediction of protein function and interactions, the CAFA experiment 2.6) Non-globular proteins, disorder and structural repeats

Examination:
The exam covers three separate parts, which have to be all passed: (relative weights in parenthesis) 1) Written test of the biochemistry concepts (ca. 30%) 2) Software project (ca. 40%) 3) Project presentation and critical evaluation (ca. 30%)

More information:
https://en.didattica.unipd.it/off/2021/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/2021/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 programming and algorithms. It is also advisable to be familiar with basic concepts in probability and analysis of multivariate functions.

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 teacher, 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/2021/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

Prerequisites:
Students should be familiar with the fundamentals of the web (for instance as given in the introductory "Tecnologie Web" course), in particular HTML, CSS, XML, XSLT.

Short program:
+ Web Usability Usability and user interaction, multi-level analysis, how to build a successful web site. Comparison between the desktop and mobile worlds. + E-commerce The use case of e-commerce web sites, specialization of the client interaction. + Web Advertisement Advertisement and web sites, techniques and errors to avoid. + Web Search Web Site Search, Search Engine Optimization, text vs hypertext, the good and evil of the web, the Social Information Systems. + Web Naming The names of the Web, their uses and abuses. + Web of Knowledge Fundamentals of the Semantic Web, knowledge representation, ontologies, semantic querying, syntactic querying, web reasoning, complex systems.

Examination:
Each student must pass a written examination, and deliver a project. Above a certain minimum evaluation threshold, each student can optionally request
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/2021/LM/SC/SC2598/000ZZ/SCP6076298/NO

CYBERSECURITY (ORD. 2020)

FOUNDATIONS OF DATABASES

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

Lecturer: Prof. NICOLA FERRO

Credits: 6 ECTS

Short program:
Overview of database management systems + Gathering, analysis and design of user requirements + The Entity-Relationship (ER) model --- conceptual design + The Relational model and the relational database management systems --- logical design --- relational algebra --- mapping from conceptual to relational model + The SQL language --- data definition language --- data manipulation language --- advanced concepts (indexes, views, stored procedures, foreign data wrappers) + Programmatic access to databases --- the JDBC APIs for the Java programming language

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089516/NO

INTERNET OF THINGS AND SMART CITIES

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

Lecturer: Prof. LORENZO VANGELISTA

Credits: 6 ECTS

Prerequisites: Telecommunications' course; knowledge of the basic principles of telecommunications networks, especially the Internet protocols

Short program:
Introduction - Definition of Internet of things, its applications, scientific and market trends - The Internet of things and home automation - Internet of Things and industrial applications - Definition of Smart City, scientific and market trends Internet of Things - Different approaches: Long range cellular (M2M), long range unlicensed frequencies, short range, RFID - Key scientific topics: the physical layer, addressing and routing, security - Standardisation bodies and consortiums: ETSI M2M, IETF, IEEE, OMA lightweight M2M, Thread, OIC, etc. Allseen Alliance - Some key standards: ZigBee, 6LoWPAN, WiFi (802.11ah), Bluetooth Low Energy, SigFox, Lo-Ra, - Platforms for Internet of things: Xively, ThingWorx, OpenHAB - Analytics SmartCity - Definition of Smart City readiness for a city - Communication Architectures and applications - Regulatory issues and open data - Applications: metering, parking, monitoring - Analytics for Smart City - Privacy and security

Examination:
## BIG DATA COMPUTING (CHANNEL 1)

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

**Lecturer:** Prof. ANDREA ALBERTO PIETRACAPRINA  
**Credits:** 6 ECTS

### Prerequisites:
The course has the following prerequisites: competences regarding the design and analysis of algorithms and data structures, knowledge of fundamental notions of probability and statistics, and programming skills in Java or Python.

### Short program:
The course will cover the following topics: Introduction to the Big Data phenomenon. Programming frameworks: MapReduce, Apache Spark Reducing input size (Case study: clustering) Reducing output size (Case study: frequent itemsets) Streaming framework.

### Examination:
The exam consists of a number of programming homeworks, assigned approximately every 2-3 weeks and to be carried out in groups of 2-3 students, and of an individual written test comprising both theory questions and exercises.

### More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089513/NO

## BIG DATA COMPUTING (CHANNEL 2)

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

**Lecturer:** Prof. FRANCESCO SILVESTRI  
**Credits:** 6 ECTS

### Prerequisites:
The course has the following prerequisites: competences regarding the design and analysis of algorithms and data structures, knowledge of fundamental notions of probability and statistics, and programming skills in Java or Python.

### Short program:
The course will cover the following topics: "Introduction to the Big Data phenomenon; " Programming frameworks: MapReduce/Spark; " Reducing input size (Case study: clustering); " Reducing output size (Case study: frequent itemsets); " Streaming framework.

### Examination:
The exam consists of a number of programming homeworks, assigned approximately every 2-3 weeks and to be carried out in groups of 2-3 students, and of an individual written test comprising both theory questions and exercises.

### More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCP7079297/NO

## BIOMETRICS

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

**Lecturer:** Prof. SIMONE MILANI  
**Credits:** 6 ECTS

### Prerequisites:
In order to attend the course, students must possess a basic knowledge in Calculus and Probability Theory. Attendees will have the opportunity of testing their preliminary knowledge with an online test. Basic knowledge of Matlab software is required. Some preliminary knowledge on computer vision and machine learning can be useful (although not strictly necessary). Such topics are described in detail within the Computer Vision and Machine Learning courses.

### Short program:
Introduction to biometric systems. Part a: Biometric sensors a.1 Fingerprint acquisition systems a.1.1 Optical a.1.2 Capacitive a.1.3 Thermal a.1.4 RF sensors a.1.5 Ultrasonic a.2 Face and Iris recognition systems a.2.1 Digital Cameras a.2.2 Infrared Cameras a.2.3 Thermal Cameras a.2.4 3D depth sensors a.2.5 3D scanners a.2.6 Retinal scanning a.3 Other sensors a.3.1 Hyperspectral imaging a.3.2 Motion analysis systems a.3.3 DNA acquisition  
Part b: Biometric algorithms b.1 Face recognition systems b.1.1 Overview of face recognition systems b.1.1 Face alignment and normalization b.1.2
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 cognitive psychology 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:
Final evaluation will be performed by means of a written exam and the development of a final report (concerning one of the lab sessions chosen by the student). Reports must be handed in at least one day before the final exam. The final score will be made of a weighted average of the evaluation of the written exam (60%) and the final project (40%). The evaluation topics for the written exam will be clearly indicated during the course and in the course material. In case it is not possible to organize a written exam because of the Covid-19 emergency, the written test could be replaced by a remote oral exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089500/NO

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. Migliardi; 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. Migliardi; 6 credits): Written Exam, Homeworks, oral test.

DEEP LEARNING

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

Lecturer: Prof. ALESSANDRO SPERDUTI

Credits: 6 ECTS

Prerequisites:
It is advisable to have the basic knowledge related to Probability, Programming, and Algorithms.

Short program:
The topics covered in the course are as follows: - Introduction to the course contents; - Deep Feedforward Networks; - Regularization for Deep Learning; - Optimization for training Deep Models; - Basic concepts for Convolutional Neural Networks; - Recurrent Neural Networks and Transformers for sequence modelling; - Autoencoder - Deep Generative Models; - TensorFlow.

Examination:
The student must pass a written exam. In addition, the student must develop a notebook agreed with the teacher.

More information: https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCP9087561/NO

DIGITAL FORENSICS

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

Lecturer: Prof. SIMONE MILANI

Credits: 6 ECTS

Prerequisites:
In order to attend the course, students must posses a basic knowledge in Calculus, Linear Algebra (including basic matrix operations, inversion and diagonalization), and Probability Theory (random variable, probability mass/density function and their properties). Basic knowledge of Matlab software is required. Some preliminary knowledge on image processing, local descriptors, and data classification are required. Such topics are described in detail within the Computer Vision and Machine Learning course. In case students did not attended the mentioned course, they can be provided with some online material to compensate the missing knowledge.

Short program:
Introduction to digital forensics. Data processing in legal issues. a.1) Disk forensics. a.1.1. Introduction, identification of evidences, data seize and acquisition, authentication, processing and analysis, documenting the results. Maintaining the "Chain of Evidence". a.1.2. Disk encryption, data encryption cracking, malicious use of encryption (ransomware). a.2) Network forensics. a.2.1. Data transmission protocols and web servers. a.2.2. Data tapping strategies: eavesdropping by sniffing, router information processing, server logs analysis, wireless traffic collection and processing, eavesdropping by malware. a.2.3. Intrusion detection. a.2.4. Identity theft and phishing. a.2.5. Anti-forensics strategies: encryption and obfuscation. The TOR protocol. a.3) Multimedia forensics. a.3.1. The acquisition of multimedia data. Digital camera and microphone models. a.3.2. Image/Video source authentication from noise (PRNU) or firmware identification (CFA interpolation, compression strategies). a.3.3. Multimedia data embedding: steganography and steganalysis, watermarking, a.3.4. Image/Video tampering strategies. Advanced solutions for tampering detection: pixel-based, format-based, camera-based, physically-based, geometric-based. a.3.5. Real cases examples. a.3.6. Audio source authentication. Audio tampering and its detection. a.3.7. Biometric traits. Facial recognition, voice identification, fingerprint analysis and matching. Image/video/audio quality enhancement for forensic investigation. a.4) Social network forensics. a.4.1. Data sharing and diffusion on social networks. a.4.2. Social network data pool; social footprint, communication pattern, images and videos, activity, applications. a.4.3. Strategies for user identification, localization (space and time), and profiling. b.1) Cybercrimes b.1.1. Fundamentals of criminal law: constitutional principles; definition of crime; essential elements of crime. b.1.2. Sources of international and supranational law on the prevention and repression of cybercrime. The transnational character of cybercrime. b.1.3. Definition of cybercrime; distinction between cybercrime in a narrow sense (computer crime) and cybercrime in a broader sense (computer-related crime). b.1.4. Analysis of some types of cybercrimes, in particular: unauthorized access to computer or telecommunications systems; illicit possession and diffusion of access codes; illegal interception, interruption or hindrance of computer or telecommunications systems; damages to computer systems and data; phishing; computer-related fraud; theft or unlawful use of a digital identity; computer privacy violations; computer crimes of copyright infringement; cryptolocker ransomware; cyberbullying; cyberterrorism. b.1.5. The criminal use of social media. b.1.6. Peculiar problems concerning the criminal responsibility of the ISP. b.2) Criminal Investigations b.2.1. Features of digital investigations. Immateriality, transnationality, cooperation. b.2.2. Types of digital investigations. Pretrial, reactive and proactive investigations. b.2.3. Means for obtaining evidence. Inspections, searches, seizures, interceptions of conversations or communications. b.2.4. Clone copy. Beat stream image. b.2.5. The role of the digital forensics expert and the right of defence.

Examination:
Final evaluation will be performed by means of a written exam and the development of a final project (to be document with a written report). Reports must be handed in at least one day before the final exam. The final score will be made of a weighted average of the evaluation of the written exam (60%) and the final project (40%). The evaluation topics for the written exam will be clearly indicated during the course and in the course material. In case it is not possible to organize a written exam because of the Covid-19 emergency, the written test could be replaced by a remote oral exam.
**ETHICAL HACKING**

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

**Lecturer:** Dott.ssa ELEONORA LOSIOUK  
**Credits:** 6 ECTS  
**Prerequisites:**  
No strict prerequisites on previous exams.

**Short program:**  
The course explains in detail what hackers are doing, how hacking activities occur, how hackers illegally manage to enter a computer system protected by security measures, and how to defend against them. Students will study the Ethical Hacking techniques. Namely, Casing the Establishment: the hacking techniques used to enumerate the targets completely. Endpoint and Server Hacking: the ultimate goals of any hacker including Advanced Persistent Threats. Infrastructure hacking: the way hackers attack the equipments our systems connect to. Application and Data Hacking: attacks to web/databases world as well as mobile hacking techniques. The countermeasures that can be used to hinder hackers' activities on the subsystems considered. Penetration testing execution standards.

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

More information:  

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**FORMAL METHODS FOR CYBER-PHYSICAL SYSTEMS**

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

**Lecturer:** Prof. DAVIDE BRESOLIN  
**Credits:** 6 ECTS  
**Prerequisites:**  
The course requires familiarity with automata theory, theory of computation and calculus. There are no preparatory courses.

**Short program:**  

**Examination:**  
Oral exam and/or project

More information:  

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**GAME THEORY**

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

**Lecturer:** ELVINA GINDULLINA  
**Credits:** 6 ECTS  
**Prerequisites:**  
A course, even a basic one, on probability theory.

**Short program:**  

**Examination:**
For all the students, in any event the exam includes a mandatory open-book written test, containing problems of game theory focusing on different topics of the course. Every exercise involves multiple questions, typically three. For the students with regular attendance to the course, the exam may also involve, if they want so, the development of a project in 1-3 person groups, on course-related topics applied to ICT. This is agreed half-way through the course together with the lecturer. If the written test is sufficient, students can directly finalize the passing score. Projects can be discussed with an oral exam after the written test. Oral exams are scheduled in the same day of written tests (even though students can decide to give the two parts on separate days). The project discussion integrates the mark of the written test.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCP7079401/NO

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<tr>
<th>HUMAN COMPUTER INTERACTION</th>
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<tr>
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<tr>
<td>Lecturer: Prof. LUCIANO GAMBERINI</td>
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<td>Credits: 6 ECTS</td>
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<tr>
<td>Prerequisites: There are no specific prerequisites.</td>
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<tr>
<td>Short program: Following the textbook we will explore the following topics: 1 What is Interaction Design? 2 The Process of Interaction Design 3 Conceptualizing Interaction 4 Cognitive Aspects 5 Social Interaction 6 Emotional Interaction 7 Interfaces 8 Data Gathering 9 Data Analysis, Interpretation, and Presentation 10 Data at Scale 11 Discovering Requirements 12 Design, Prototyping, and Construction 13 Interaction Design in Practice 14 Introducing Evaluation 495 15 Evaluation Studies: From Controlled to Natural Settings 16 Evaluation: Inspections, Analytics, and Models Detailed examples and training on research methods and techniques for the design and the evaluation of interactive systems will be discussed during lessons.</td>
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<tr>
<td>Examination: NOT ATTENDING: The exam will be oral with 3 questions on the book, one of which is proposed as an exercise (see the book for examples). In case of Corona Virus Emergency the oral exam will be given online. ATTENDING: The exam will be based on a personal research work to be carried out during the course as homework and on a short oral presentation and discussion test. A report will summarize the work done in a similar way to a scientific paper or a professional report. The research to be developed will be summarized in a report that will include the following points: 1 - Introduction, theoretical contextualization, benchmarking 2 - design / co-design process 3 - prototype development / modification (for those with less technical experience there are solutions) 4 - evaluation - data analysis (ex: UX, usability, presence, acceptance) 5 - results - final discussion. Any technology may be developed / adopted for research as long as it is interactive (e.g. web, robot, virtual / augmented reality, smart home devices, work tools, Arduino tools, vehicles, musical instruments, mobile / tablet apps).</td>
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<td>More information: <a href="https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCP7079403/NO">https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCP7079403/NO</a></td>
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<th>INFORMATION SECURITY</th>
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<tr>
<td>Master's degree in CYBERSECURITY (ORD. 2020), First semester</td>
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<tr>
<td>Lecturer: Prof. NICOLA LAURENTI</td>
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<td>Credits: 6 ECTS</td>
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<tr>
<td>Prerequisites: The class requires previous basic knowledge in: 1. communication or computer networks. 2. digital communications 3. algorithms and computational complexity 4. statistics, probability and information theory</td>
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<td>Short program: 1. Fundamental security notions and definitions. 2. Quantitative models and assessment of security level. 3. Cryptographic and non cryptographic security mechanisms. 4. Network security protocols at different layers. 5. Further security issues for wireless, ad hoc and mobile networks.</td>
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<tr>
<td>Examination: The exam is split into two parts: 1. A written exam with analytical questions and quantitative problems. 2. A traditional oral exam on the class topics The student must first take the written exam. If he/she passes the written exam, the student is admitted to the oral exam, after which he will obtain his/her final grade.</td>
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<td>More information: <a href="https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089463/NO">https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089463/NO</a></td>
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<th>LAW AND DATA</th>
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<td>Master's degree in CYBERSECURITY (ORD. 2020), First semester</td>
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<td>Lecturer: to be defined</td>
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MACHINE LEARNING

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

Lecturer: Prof. FABIO VANDIN

Credits: 6 ECTS

Prerequisites: Basic Knowledge of Mathematics, Probability Theory, Statistics, Linear Algebra, Algorithms, and basic Programming skills.

Short program:

Examination:
The evaluation of the acquired skills and knowledge will be performed using two contributions: 1. A written exam without the book, where the student must solve few problems, with the aim of verifying the acquisition of the main ingredients of a learning problem and of the main machine learning tools, the analytical ability to use these tools and the ability to interpret the typical results of a practical machine learning problem. 2. Computer simulations (optional) with the aim of acquiring the practical competences for using machine learning tools. These simulations, to be performed at home, allow to verify the ability of practically exploiting the acquired theoretical concepts. The student will have to provide a brief document explaining the employed methodologies used to solve the assigned problem together with the obtained results. The final grade will be based on the written test with a bonus up to 3 point for the students who will hand in also the lab assignments.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCP7079399/NO

METHODS AND MODELS FOR COMBINATORIAL OPTIMIZATION

Master's degree in CYBERSECURITY (ORD. 2020), 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/2021/LM/SC/SC2542/000ZZ/SCP8082660/NO
MOBILE AND IOT SECURITY

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

Lecturer: Dott.ssa ELEONORA LOSIOUK

Credits: 6 ECTS

Prerequisites:
Any object-oriented programming language.

Short program:
Theory: Android's security model, permissions, package management, user management, cryptographic providers, network security, credential storage, online account management, device security, SELinux, system updates and root access, Bluetooth/Bluetooth Low-Energy communication protocols.
Practice: application security, Android's attack surface, debugging and analyzing vulnerabilities, exploitation of the user space software, Bluetooth/Bluetooth Low-Energy attacks.

Examination:
Students have two options. (Option 1) Practical exam, where students solve exercises on Android security; (Option 2) Project, where students face a research objective assigned by the Lecturer and illustrate the achieved results in an oral presentation.

QUANTUM CRYPTOGRAPHY AND SECURITY

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

Lecturer: Prof. NICOLA LAURENTI

Credits: 6 ECTS

Prerequisites:
The class requires fundamental knowledge on quantum physics, quantum information, information theory, cryptography and security A brief review of the necessary notions in quantum information and technologies, in security and cryptography will be given at the start of class.

Short program:
Introduction: review of quantum information and technologies, security services, mechanisms and measures Quantum random number generators (QRNGs): discrete- and continuous- variable QRNGs, technological issues, Bell certified QRNGs, semi device independent QRNGs, randomness extractors, Quantum key distribution (QKD): protocols (prepare-and-measure, entanglement-based, continuous-variable), technological aspects and non idealities, attack models, post processing algorithms and security proofs, use of decoy states, device independent QKD, twin-field QKD, QKD networks, quantum memories and repeaters Other quantum security mechanisms: direct secret communication, quantum information commitment, quantum secret sharing, quantum digital signature.

Examination:
The students must submit individual reports for the laboratory experiences, and take a traditional oral exam with analytical questions and critical discussions on the class material.

QUANTUM INFORMATION AND COMPUTING

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

Lecturer: Prof. GIUSEPPE VALLONE

Credits: 6 ECTS

Prerequisites:
Linear algebra.

Short program:
PART I: general concepts What is a qubit: introduction to quantum mechanics Hilbert spaces, operators and projectors Quantum measurements Time evolution, decoherence Entanglement: definition, generation and detection Quantum state tomography Bell Inequalities PART II: Quantum Information Classical Information versus Quantum Information Quantum channels and no cloning Dense coding Teleportation Quantum Key distribution Quantum Random Number Generators Quantum Metrology PART III: Quantum Computation Classical Computation versus Quantum Computation From FFT to QFT
Examination:
The exam is constituted of three parts: - two homeworks (20%) - two reports on lab activity (20%) - oral (60%) The final grade will be the weighted average with the above reported percentage

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCP8082721/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.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089517/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.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089517/NO

SERVICE MANAGEMENT

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

Lecturer: Prof. MARCO UGO PAIOLA

Credits: 6 ECTS
Prerequisites:
Students should have a basic knowledge of management, business strategy and marketing fundamentals, as well as innovative value-creating strategies.

Short program:
This course unit aims to provide students with fundamental theoretical and professional competences useful to understand modern service business growth in B2B companies, with special attention to digital transformation processes. The course unit will cover the following topics: • Why services? The service imperative: servitization drivers and B2B services challenges and categories. • Are manufacturing firms fit for services? Resources, capabilities and organization; pricing challenges; sales and distribution channels management. • Service innovation and technology: using data and 4.0 technologies to improve the firm’s service footprint and renovate the business models. • Service strategy alignment: Building a service culture At the beginning of the course, a detailed course schedule will be provided with a more fine-grained representation of class contents.

Examination:
Attending students' knowledge and skills will be assessed through: • A written exam – students will be asked to answer 2 open questions (one related to a broad course topic, one related to a specific issue treated in the course). Skills C1, C2, C3, C4 will be assessed. • Group works – teams will work on themes agreed upon directly with selected local firms and apply the course's concept to a real case. They will have to prepare a presentation and a final report. Skills P1, P2, T1, T2, T3 will be assessed. Non attending students' knowledge and skills will be assessed through: • A written exam – students will be asked to answer 3 open questions (two related to a broad course topic, one related to a specific issue described in the course). Skills C1, C2, C3, C4 will be assessed.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089465/NO

SOFTWARE VERIFICATION

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

Lecturer: Prof. FRANCESCO RANZATO

Credits: 6 ECTS

Prerequisites:
Basic knowledge of programming languages. Formally prerequisite courses are not required.

Short program:
- Program semantics: This is a model of the dynamic behaviour of programs (in particular the input/output behaviour) by means of order and fixed point theory. (cf. https://en.wikipedia.org/wiki/Semantics_(computer_science) ) - Static program analysis and verification by abstract interpretation: Abstract interpretation is a well-known technique for approximating the semantics of programs that allows to specify how to statically deduce program properties and to prove their correctness. (cf. https://en.wikipedia.org/wiki/Abstract_interpretation ) - Dataflow program analysis: This is a technique for gathering information about the possible set of values calculated at various program points. A program's control flow graph is used to determine those parts of a program to which a particular value assigned to a variable might propagate. The information gathered is often used by compilers (such as gcc and javac) when optimizing a program. (cf. https://en.wikipedia.org/wiki/Data-flow_analysis ) - Software verification tools: e.g., Clousot (Microsoft, USA), Interproc (INRIA, France), Jandom (Univ. Pescara, Italy) (cf. https://en.wikipedia.org/wiki/List_of_tools_for_static_code_analysis )

Examination:
Oral examination and/or software project, possibly split into distinct parts.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089515/NO

STOCHASTIC PROCESSES

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

Lecturer: Prof. MICHELE ZORZI

Credits: 6 ECTS

Prerequisites:
The course requires preliminary knowledge of: Mathematical Analysis, Probability, random variables and random processes, networks and protocols. For the examples treated, a basic course in networks and protocols is useful (through not required).

Short program:

Examination:
The assessment of the knowledge and skills acquired is carried out by means of a written test divided into two parts. Part A, with a duration of 90 minutes and open-book, consists of eleven numerical questions grouped into four exercises. Each question has a value of three points. Part B, with a duration of 60 minutes and closed-book, consists of three theoretical questions (typically proofs of theorems seen in class). Each question has a value of eleven points. If the student scores at least 15 points in part A and the average score of part A and part B is at least 18, the latter can be accepted as the final grade. If the score in part A is less than 15 or the average of the two tests is less than 18, the exam is not passed. Even if the final exam can be passed by a successful
written exam (in two parts), the student can always ask to take an oral exam if he/she wants to improve the grade. In no case can the oral exam replace the written test. Examples of exams are available on the elearning platform course website, and are extensively covered in class.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089499/NO

WEB APPLICATIONS

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

Lecturer: Prof. NICOLA FERRO

Credits: 6 ECTS

Prerequisites:
Requested competencies: - good and proactive programming skills and, in particular, the object-oriented paradigm and its design principles; - good knowledge of the Java programming language; - foundations of database management systems and, in particular, entity-relationship model, relational model, SQL, JDBC; - computer networks and, in particular, the HTTP protocol

Short program:
+ Design methodologies for Web applications --- Introduction to Web engineering --- Requirement analysis --- Modelling Web applications (contents, hypertext, presentation) --- Architectures for Web applications + Development of Web 1.0 Applications --- Model-View-Controller (MVC) paradigm --- Web programming (HTML5, CSS3, Javascript) --- Web server and Web browser architecture --- Java servlet and Java Server Pages, Apache Tomcat --- Development tools: git for code management and maven for the build process + Web Services --- REST Web services + Development of Web 2.0 Applications --- Introduction to Rich Internet Applications (RIA) and mash-ups --- Introduction to JSON and XML --- AJAX and revised MVC paradigm + Notions on Web 3.0 applications: --- semantic representation of the data and RDF --- open linked data

Examination:
Written Exam at computer: + questions on the topics covered during the lectures (Moodle quiz) Project to design, develop, implement, code and document an actual full-stack Web application, carried out in student groups via homeworks + git repository containing the project source code and all the related material + report documenting the developed full-stack Web application application + oral presentation of the project outcomes + demo of the developed full-stack Web application application

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089467/NO

WEB APPLICATIONS

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

Lecturer: Prof. NICOLA FERRO

Credits: 6 ECTS

Prerequisites:
Requested competencies: - good and proactive programming skills and, in particular, the object-oriented paradigm and its design principles; - good knowledge of the Java programming language; - foundations of database management systems and, in particular, entity-relationship model, relational model, SQL, JDBC; - computer networks and, in particular, the HTTP protocol

Short program:
+ Design methodologies for Web applications --- Introduction to Web engineering --- Requirement analysis --- Modelling Web applications (contents, hypertext, presentation) --- Architectures for Web applications + Development of Web 1.0 Applications --- Model-View-Controller (MVC) paradigm --- Web programming (HTML5, CSS3, Javascript) --- Web server and Web browser architecture --- Java servlet and Java Server Pages, Apache Tomcat --- Development tools: git for code management and maven for the build process + Web Services --- REST Web services + Development of Web 2.0 Applications --- Introduction to Rich Internet Applications (RIA) and mash-ups --- Introduction to JSON and XML --- AJAX and revised MVC paradigm + Notions on Web 3.0 applications: --- semantic representation of the data and RDF --- open linked data

Examination:
Written Exam at computer: + questions on the topics covered during the lectures (Moodle quiz) Project to design, develop, implement, code and document an actual full-stack Web application, carried out in student groups via homeworks + git repository containing the project source code and all the related material + report documenting the developed full-stack Web application application + oral presentation of the project outcomes + demo of the developed full-stack Web application application

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2542/000ZZ/SCQ0089467/NO

WIRELESS NETWORKS

Master's degree in CYBERSECURITY (ORD. 2020), 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/2021/LM/SC/SC2542/000ZZ/SCP6076377/NO

**DATA SCIENCE ORD. 2017**

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**FINAL EXAMINATION**

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

**LECTURER:** to be defined  

**CREDITS:** 15 ECTS  

**SHORT PROGRAM:**  
The final exam consists in the presentation of the Master Thesis to the Committee of the Final Exam. The thesis (15 CFU) can be based on an internship (15 CFU) that may take place in a private company, a public institution or the University of Padova. The thesis is to be prepared under the guidance of a representative of the hosting institution (co-supervisor) and a Professor or Researcher of the University of Padova (supervisor).  

**MORE INFORMATION:**  
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079319/NO

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**BIG DATA COMPUTING**

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

**LECTURER:** Prof. ANDREA ALBERTO PIETRACAPRINA  

**CREDITS:** 6 ECTS  

**PREREQUISITES:**  
The course has the following prerequisites: competences regarding the design and analysis of algorithms and data structures, knowledge of fundamental notions of probability and statistics, and programming skills in Java or Python.  

**SHORT PROGRAM:**  
The course will cover the following topics: Introduction to the Big Data phenomenon. Programming frameworks: MapReduce, Apache Spark Reducing input size (Case study: clustering) Reducing output size (Case study: frequent itemsets) Streaming framework.  

**EXAMINATION:**  
The exam consists of a number of programming homeworks, assigned approximately every 2-3 weeks and to be carried out in groups of 2-3 students, and of an individual written test comprising both theory questions and exercises.  

**MORE INFORMATION:**  
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079297/NO

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**DEEP LEARNING**

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

**LECTURER:** Prof. ALESSANDRO SPERDUTI
FUNDAMENTALS OF INFORMATION SYSTEMS

Master's degree in DATA SCIENCE ORD. 2017, 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: numpyscipy (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 PostgresSQL 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/2021/LM/SC/SC2377/000ZZ/SCP7078720/NO

INTRODUCTION TO MOLECULAR BIOLOGY

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

Lecturer: Prof.ssa MARIA PENNUTO

Credits: 6 ECTS

Prerequisites: None


Examination:
Written verifications that can complement the evaluation. Oral exam: The student will be asked to present a subject of his/her own choice. We will ask two more specific questions to the student. The student may use slides on the subject of choice.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP8084903/NO

### MATHEMATICAL CELL BIOLOGY

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

**Lecturer:** Prof. MORTEN GRAM PEDERSEN  
**Credits:** 6 ECTS  
**Prerequisites:** Knowledge of differential equations, linear algebra, probability theory.

**Short program:**  

**Examination:**  
End-of-term project and written exam.

More information:  
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0093722/NO

### NETWORK SCIENCE

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

**Lecturer:** Prof. TOMASO ERSEGHE  
**Credits:** 6 ECTS  
**Prerequisites:** This course has the following prerequisites: knowledge in Probability Theory, and Computer Programming in any language which is appropriate for network analysis (e.g., MatLab, Python, C, Java); knowledge in Calculus and Linear Algebra; any further knowledge of networking processes in economics, biology, telecommunications, semantics, etc. might be useful.

**Short program:** The module will cover the following topics:  1. Basic network properties - graphs, adjacency matrix, degree distribution, connectivity, distance and diameter, clustering coefficient.  2. Network models - Erdos-Renyi model; Random graphs with general degree distribution; Power laws and scale free networks; Small world phenomena; Hubs; Network generation and expansion; Barabasi-Albert model; Preferential attachment; Evolving networks.  3. Centrality measures: Hubs and authorities; PageRank: teleportation, topic specific ranking, proximity measures, trust rank; betweenness, closeness, eigenvector and Katz centralities.  4. Other analytics: homophily (assortativity), polarisation, innovation, clustering, robustness, link prediction.  5. Community detection - Dendrograms; Girvan Newman method and betweenness; Louvain modularity optimisation; Spectral clustering; Measuring similarities in clustering outcomes; Algorithms for overlapping communities.  6. Network representation - Gephi and R/Python graphical functions; rationale of force directed graph layout algorithms.  7. Twitter Lab - How to extract a semantic network from Twitter data.

**Examination:**  
The verification of the expected knowledge and skills is carried out with the DEVELOPMENT OF A PROJECT aimed at verifying the ability to apply theory in interdisciplinary contexts, and which requires: the choice, the collection of data, and the analysis of a different network for each student; computer implementation (in any programming language known to the student) of the algorithms required for the analysis; the drafting of an essay; the oral presentation of the main project outcomes. A bonus of up to 3 points is available for attending students that take part to an INTERDISCIPLINARY PROJECT with social science students attending the twin course on SOCIAL NETWORK ANALYSIS.

More information:  
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP8082723/NO

### OMICS IN HUMAN DISEASE

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

**Lecturer:** Prof. DENIS DOMINIQUE MARTINVALET  
**Credits:** 6 ECTS  
**Prerequisites:** Basic knowledge of statistics and programming

**Short program:**

Examination:
The exam covers two separate parts: Evaluation of the biological knowledge about human and cellular biology relative to complex disease. Evaluation of the skills acquired during practicals with the evaluation of the project about the computational analysis of a complex disease.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0093738/NO

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**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. Linear optimization: Theory and algorithms (a) LP models for Data science; (b) Simplex method; (c) Interior point methods;
2. Convex sets and convex functions (a) Convexity: basic notions; (c) Convex functions: Basic notions and properties (gradients, Hessians..);
3. Unconstrained convex optimization (a) Models in data science; (b) Characterizations of optimal sets; (c) Gradient-type methods;
4. Constrained convex optimization (a) Models in data science; (b) Characterizations of optimal sets; (c) Polyhedral approximation methods;
5. 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 5 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/2021/LM/SC/SC2377/000ZZ/SCP7079229/NO

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**STATISTICAL LEARNING**

**Lecturer:** Prof. ALBERTO ROVERATO

**Prerequisites:**
- Basic probability theory;
- Multivariable calculus;
- Linear algebra;
- Basic computing skills

**Examination:**
written test and project work

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079226/NO

**Moduli del C.I.:**
- Statistical Learning 1 (Mod. A)
- Statistical Learning 2 (Mod. B)

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**STATISTICAL LEARNING 1 (MOD. A)**

**Lecturer:** Prof. ALBERTO ROVERATO

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

**Credits:** 12 ECTS

**Short program:**
Part 1: - Data: summary statistics, displaying distributions; exploring relationships - Estimation: point estimation; the sampling distribution of an estimator; accuracy of estimation; interval estimation - Hypothesis testing - Likelihood: the likelihood, likelihood for several parameters - Estimation: maximum likelihood estimation; properties of maximum likelihood estimates

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**STATISTICAL LEARNING 2 (MOD. B)**

**Lecturer:** Prof. ALBERTO ROVERATO
STOCHASTIC METHODS

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

Lecturer: Prof. MARCO FERRANTE

Credits: 6 ECTS

Short program:
1. Probability reviews. • discrete and continuous distributions • random variables, expectation and conditional expectation • Law of Large Numbers and Chernoff Bounds • approximation of probability distributions. 2. Markov chains and random walks • Discrete time Markov Chain and their stationary distribution • Monte Carlo (MCMC), convergence of MCMC-based algorithms. 3. High dimensional Gaussian random variables • Gaussian Annulus Theorem • Nearly orthogonal of independent random variables. 4. Introduction to Random Networks

Examination:
Written exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079197/NO

STRUCTURAL BIOINFORMATICS

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

Lecturer: Prof. DAMIANO PIOVESAN

Credits: 6 ECTS

Prerequisites:
Basic knowledge of optimization methods and machine learning. Python programming language.

Short program:
The course consists of two parts: 1) Introduction to living matter (2 credits): 1.1) Introduction to organic chemistry, weak interactions and energy 1.2) Structure and function of DNA and proteins 1.3) Lipids, membranes and cellular transport 1.4) Experimental methods for structure determination 2) Computational Biochemistry (4 credits): 2.1) Biological Databases 2.2) Software libraries and concepts for sequence alignments and database searches 2.3) Sequence - structure relationship in proteins and structural classification 2.4) Methods for the prediction of protein structure from sequence, the CASP experiment 2.5) Methods for the prediction of protein function and interactions, the CAFA experiment 2.6) Non-globular proteins, disorder and structural repeats

Examination:
The exam covers three separate parts, which have to be all passed: (relative weights in parenthesis) 1) Written test of the biochemistry concepts (ca. 30%) 2) Software project (ca. 40%) 3) Project presentation and critical evaluation (ca. 30%)

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079278/NO

SYSTEMS BIOLOGY

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

Lecturer: Prof. GABRIELE SALES

Credits: 3 ECTS

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

Short program:

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.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0094202/NO

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COGNITION AND COMPUTATION

Master's degree in DATA SCIENCE ORD. 2017, 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 cognitive psychology 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 elaborating one topic assigned during the course, which must be handed over on the day of the written exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0089498/NO

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DEEP LEARNING

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

Lecturer: Prof. ALESSANDRO SPERDUTI

Credits: 6 ECTS

Prerequisites:
It is advisable to have the basic knowledge related to Probability, Programming, and Algorithms.

Short program:
The topics covered in the course are as follows: - Introduction to the course contents; - Deep Feedforward Networks; - Regularization for Deep Learning; - Optimization for training Deep Models; - Basic concepts for Convolutional Neural Networks; - Recurrent Neural Networks and Transformers for sequence modelling; - Autoencoder - Deep Generative Models; - TensorFlow.

Examination:
The student must pass a written exam. In addition, the student must develop a notebook agreed with the teacher.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP9087561/NO

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FINANCIAL MATHEMATICS FOR DATA SCIENCE

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

Lecturer: Prof. MARTINO GRASSELLI

Credits: 6 ECTS

Prerequisites:
Stochastic analysis

Short program:

Examination:
Final examination based on: Written and oral examination.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0093689/NO

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FUNDAMENTALS OF INFORMATION SYSTEMS

Master's degree in DATA SCIENCE ORD. 2017, 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 sci-kit-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/2021/LM/SC/SC2377/000ZZ/SCP7078720/NO

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HUMAN COMPUTER INTERACTION

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

Lecturer: Prof. LUCIANO GAMBERINI

Credits: 6 ECTS

Prerequisites:
There are no specific prerequisites.

Short program:
Following the textbook we will explore the following topics: 1 What is Interaction Design? 2 The Process of Interaction Design 3 Conceptualizing Interaction 4 Cognitive Aspects 5 Social Interaction 6 Emotional Interaction 7 Interfaces 8 Data Gathering 9 Data Analysis, Interpretation, and Presentation 10 Data at Scale 11 Discovering Requirements 12 Design, Prototyping, and Construction 13 Interaction Design in Practice 14 Introducing Evaluation 495 15 Evaluation Studies: From Controlled to Natural Settings 16 Evaluation: Inspections, Analytics, and Models Detailed examples and training on research methods and techniques for the design and the evaluation of interactive systems will be discussed during lessons.
### Examination:

**NOT ATTENDING:** The exam will be oral with 3 questions on the book, one of which is proposed as an exercise (see the book for examples). In case of Corona Virus Emergency the oral exam will be given on-line. **ATTENDING:** The exam will be based on a personal research work to be carried out during the course as homework and on a short oral presentation and discussion test. A report will summarize the work done in a similar way to a scientific paper or a professional report. The research to be developed will be summarized in a report that will include the following points: 1 - Introduction, theoretical contextualization, benchmarking 2 - design / co-design process 3 - prototype development / modification (for those with less technical experience there are solutions) 4 - evaluation - data analysis (ex: UX, usability, presence, acceptance) 5 - results - final discussion. Any technology may be developed / adopted for research as long as it is interactive (e.g. web, robot, virtual / augmented reality, smart home devices, work tools, Arduino tools, vehicles, musical instruments, mobile / tablet apps).

**More Information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079403/NO

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<td><strong>Lecturer:</strong> Prof. MICHELE ROSSI</td>
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<td><strong>Credits:</strong> 6 ECTS</td>
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<td><strong>Prerequisites:</strong></td>
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<td><strong>Short program:</strong></td>
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<tr>
<th>Master's degree in DATA SCIENCE ORD. 2017, Second semester</th>
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<td><strong>Lecturer:</strong> to be defined</td>
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<td><strong>Credits:</strong> 6 ECTS</td>
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<td><strong>Prerequisites:</strong> Suggested basic knowledge of logics and statistics.</td>
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<td><strong>Short program:</strong> (A) Logics for knowledge representation: (A.i) introduction to propositional logics, syntax, semantics, decision procedure. Satisfiability, weighted satisfiability, and best satisfiability. (A.ii) First order logics, syntax, semantics, resolution and unification. (A.iii) Fuzzy logics, syntax, semantics, and reasoning. (B) statistical relational learning: (B.i) Graphical models (B.ii) Markov Logic Networks (B.iii) Probabilistic prolog, (B.iii) Logic Tensor Networks</td>
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<td><strong>Examination:</strong> Critical knowledge of the course topics. Ability to present and apply the studied material.</td>
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<tr>
<td><strong>Lecturer:</strong> Prof. FRANCESCO RINALDI</td>
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<td><strong>Credits:</strong> 6 ECTS</td>
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<td><strong>Prerequisites:</strong> Basic knowledge of - Real Analysis and Calculus; - Linear Algebra; - Probability theory.</td>
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<td><strong>Short program:</strong> 1. Linear optimization: Theory and algorithms (a) LP models for Data science; (b) Simplex method; (c) Interior point methods; 2. Convex sets and convex functions (a) Convexity: basic notions; (c) Convex functions: Basic notions and properties (gradients, Hessians...); 3. Unconstrained convex optimization (a) Models in data science; (b) Characterizations of optimal sets; (c) Gradient-type methods; (d) Block coordinate gradient methods; (e) Stochastic</td>
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optimization methods; 4. Constrained convex optimization (a) Models in data science; (b) Characterizations of optimal sets; (c) Polyhedral approximation methods; (d) Gradient projection methods; 5. 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 5 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/2021/LM/SC/SC2377/000ZZ/SCP7079229/NO

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**PROCESS MINING**

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

**Lecturer:** Prof. MASSIMILIANO DE LEONI

**Credits:** 6 ECTS

**Prerequisites:**
Basic notions of algorithms, data structures and programming, as acquired in course "Fundamental of Information Systems".

**Short program:**
The course will cover the topics listed below:
1. MODELING AND ANALYSIS VIA THE BPMN LANGUAGE - Essential and Advanced Process Modeling in BPMN - Qualitative Analysis - Quantitative Analysis - Simulation-based analysis

**Examination:**
Written exam, and a mandatory project.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079235/NO

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**STATISTICAL LEARNING**

**Lecturer:** Prof. ALBERTO ROVERATO

**Prerequisites:**
basic probability theory; multivariable calculus; linear algebra; basic computing skills

**Examination:**
written test and project work

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079226/NO

**Moduli del C.I.:**
Statistical Learning 1 (Mod. A)
Statistical Learning 2 (Mod. B)

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**STATISTICAL LEARNING 1 (MOD. A)**

**Lecturer:** Prof. ALBERTO ROVERATO

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

**Credits:** 12 ECTS

**Short program:**
Part 1: - Data: summary statistics, displaying distributions; exploring relationships - Estimation: point estimation; the sampling distribution of an estimator; accuracy of estimation; interval estimation - Hypothesis testing - Likelihood: the likelihood, likelihood for several parameters - Estimation: maximum likelihood estimation; properties of maximum likelihood estimates

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**STATISTICAL LEARNING 2 (MOD. B)**

**Lecturer:** Prof. ALBERTO ROVERATO
Master's degree in **DATA SCIENCE ORD. 2017**, First and Second semester

**Credits:** 12 ECTS

**Short program:**

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**STOCHASTIC METHODS**

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

**Lecturer:** Prof. MARCO FERRANTE

**Credits:** 6 ECTS

**Prerequisites:**
Basic notions of differential and integral calculus, linear algebra and probability.

**Short program:**
1. Probability reviews. • discrete and continuous distributions • random variables, expectation and conditional expectation • Law of Large Numbers and Chernoff Bounds • approximation of probability distributions. 2. Markov chains and random walks • Discrete time Markov Chain and their stationary distribution • Monte Carlo (MCMC), convergence of MCMC-based algorithms. 3. High dimensional Gaussian random variables • Gaussian Annulus Theorem • Nearly orthogonal of independent random variables. 4. Introduction to Random Networks

**Examination:**
Written exam

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079197/NO

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**BIG DATA COMPUTING**

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

**Lecturer:** Prof. ANDREA ALBERTO PIETRACAPRINA

**Credits:** 6 ECTS

**Prerequisites:**
The course has the following prerequisites: competences regarding the design and analysis of algorithms and data structures, knowledge of fundamental notions of probability and statistics, and programming skills in Java or Python.

**Short program:**
The course will cover the following topics: Introduction to the Big Data phenomenon. Programming frameworks: MapReduce, Apache Spark Reducing input size (Case study: clustering) Reducing output size (Case study: frequent itemsets) Streaming framework.

**Examination:**
The exam consists of a number of programming homeworks, assigned approximately every 2-3 weeks and to be carried out in groups of 2-3 students, and of an individual written test comprising both theory questions and exercises.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079297/NO

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**BIOINFORMATICS**

Master's degree in **DATA SCIENCE ORD. 2017**, 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 and of some...
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/2021/LM/SC/SC2377/000ZZ/SCP7079405/NO

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**BIOLOGICAL DATA**

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

**Lecturer:** Prof. SILVIO TOSATTO

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge of computer science, optimization methods and machine learning. Python programming language.

**Short program:**
The course consists of four parts, corresponding to different types of biological data: 1) Sequences 1.1) DNA and proteins 1.2) Databases 1.3) Alignments 2) Structures 2.1) Protein folding 2.2) Databases 2.3) Structure prediction 3) Literature 3.1) Scientific papers 3.2) Databases 3.3) Text mining 3.4) Function 4) Interaction networks 4.1) Non-globular regions 4.2) Biological interactions 4.3) Databases 4.4) Emergent properties

**Examination:**
The exam covers three separate parts, which have to be all passed: (relative weights in parenthesis) 1) Mid-term test (ca. 17%) Open questions 2) Project (ca. 50%) Coding and analysis of biological dataset; written report 3) Final exam (ca. 33%) Oral, with questions on project and course

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079337/NO

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**BUSINESS ECONOMIC AND FINANCIAL DATA**

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

**Lecturer:** Prof.ssa MARIANGELA GUIDOLIN

**Credits:** 6 ECTS

**Prerequisites:**
Program of Statistical Learning course

**Short program:**
- General introduction to business, economic and financial data --Preliminary concepts and illustrative examples -Moving beyond the linear model --Linear regression model: main ideas and assumptions --Nonlinear regression models for new product growth - Beyond linearity: regression splines, local regression, generalized additive models (GAM) - Tree-based methods: Regression trees, Bagging, Boosting -Time series analysis: Exponential Smoothing and ARIMA models

**Examination:**
--Practical exam --Oral exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079231/NO

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**COGNITION AND COMPUTATION**

Master’s degree in **DATA SCIENCE ORD. 2017**, 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 cognitive psychology 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 elaborating one topic assigned during the course, which must be hand over on the day of the written exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0089498/NO

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**FUNDAMENTALS OF INFORMATION SYSTEMS**

Master’s degree in **DATA SCIENCE ORD. 2017**, 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., 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/2021/LM/SC/SC2377/000ZZ/SCP7078720/NO

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**INFORMATION RETRIEVAL**

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

**Lecturer:** Prof. NICOLA FERRO

**Credits:** 6 ECTS

**Prerequisites:**
Requested competencies: - good and proactive programming skills and, in particular, the object-oriented paradigm and its design principles; - good knowledge of the Java programming language;

**Short program:**
The course covers the full spectrum of information retrieval methodologies, starting from foundational approaches to offline system development, continuing with the new techniques for machine learning for search, and concluding with the most recent advances for online system development. More in detail, the course will address: - Offline system development: the student learns the foundations of information retrieval, covering text processing and indexing for efficient access and retrieval; and, basic and advanced retrieval models to match natural language queries to documents. The student learns how to evaluate the performance of an information retrieval system in terms of effectiveness, how to tune the different system parameters, and how to statistically validate the experimental results. Finally, the student learns the principles of Web search engines, Web crawling, search engine optimization, and knowledge graphs and semantic search. + Machine learning for search: the student learns the advanced applications of machine learning techniques for information search and filtering, namely recommender systems, learning-to-rank, and neural information retrieval. + Online system development: the student learns the principles of retrieval as interaction, i.e. the basics of search as a learning process for man and machine, by leveraging click models, A/B testing, interleaved comparison, and online learning-to-rank.

**Examination:**

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Individual written Exam with questions and exercises on the topics covered during the lectures (Moodle quiz). Project to design, develop, implement, code, document, and evaluate an actual information retrieval application, carried out in student groups via homeworks: + git repository containing the project source code and all the related material + report on the contents and state of the project as well as the evaluation of the performance of the developed system; + oral presentation of the project outcomes by using slides; + demo of the developed application.

More information:

### KNOWLEDGE AND DATA MINING

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

**Lecturer:** Dott. LUCIANO SERAFINI

**Credits:** 6 ECTS

**Prerequisites:**
Suggested basic knowledge of logics and statistics.

**Short program:**
(A) Logics for knowledge representation: (A.i) introduction to propositional logics, syntax, semantics, decision procedure. Satisfiability, weighted satisfiability, and best satisfiability. (A.ii) First order logics, syntax, semantics, resolution and unification. (A.iii) Fuzzy logics, syntax, semantics, and reasoning. (B) statistical relational learning: (B.1) Graphical models (B.ii) Markov Logic Networks (B.iii) Probabilistic prolog, (B.iii) Logic Tensor Networks

**Examination:**
Critical knowledge of the course topics. Ability to present and apply the studied material.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079318/NO

### LAW AND DATA

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

**Lecturer:** Dott.ssa ELISA SPILLER

**Credits:** 6 ECTS

**Prerequisites:**
No prerequisites

**Short program:**
All the info about the course are on Moodle - Introduction to Law and Legal Studies - Introduction to the EU Law - Introduction to the EU GDPR - The concept of data; personal, sensitive and economic data; big data - Property of data, choices in the management of data - The right to be forgotten - Civil and criminal aspects of profiling activity - Automatic data processing, human responsibilities - The Data Protection Officer and DP Authorities - Civil and criminal protection of privacy - Sanctioning powers and system - Open Data for the public interest - Big data (collection, analysis, processing) and their influence on fundamental rights - Digital Surveillance - Facial Recognition: Open Issues - Disinformation - Artificial Intelligence in the EU law

**Examination:**
Written Exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079399/NO

### MACHINE AND DEEP LEARNING (C.I.)

**Lecturer:** Dott. GIOVANNI DA SAN MARTINO

**Prerequisites:**
The student should be familiar with basic concepts in Mathematics, Probability Theory and Statistics, Linear Algebra, and basic Programming skills.

**Examination:**
The student must develop a small project and present a written report. The exam will consist of a short presentation and discussion of the project carried out, and an oral exam about all the topics covered in class.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0093685/NO
Moduli del C.I.:
Machine and deep learning (Mod. A)
Machine and deep learning (Mod. B)

MACHINE AND DEEP LEARNING (MOD. A)

Lecturer: Dott. GIOVANNI DA SAN MARTINO

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

Credits: 12 ECTS

Short program:
The course cover the topics listed below: - Introduction: Artificial Intelligence and Machine Learning, when and why you should use Machine Learning techniques; the main machine learning paradigms and their applications; the key ingredients of machine learning. - Supervised learning: the foundations and the basic models Linear Regression; space of hypotheses, representation and cost function; optimisation and gradient descent. Linear Classification Models; Logistic Regression; Regularisation and model selection. - Model complexity, its effectiveness and its evaluation Bias-Variance Tradeoff; how to deal with overfitting and underfitting problems; risk minimisation and learning theory; performance evaluation measures, examples and applications; diagnosing and debugging machine learning systems. - Supervised learning: neural networks and advanced models Artificial Neural Networks; perceptron, multilayer neural networks and deep learning; parameters learning, backpropagation and gradient descent. Support Vector Machines; kernel methods and nonlinear classification. "Alternative" approaches: non-parametric methods (k-NN) and their applications; decision trees and random forest. - Unsupervised learning Clustering: K-Means and the main approaches; PCA and dimensionality reduction. - Introduction to Recommender Systems and their application

MACHINE AND DEEP LEARNING (MOD. B)

Lecturer: Prof. ALESSANDRO SPERDUTI

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

Credits: 12 ECTS

Short program:
The topics covered in the course are as follows: - Introduction to the course contents; - Deep Feedforward Networks; - Regularization for Deep Learning; - Optimization for training Deep Models; - Basic concepts for Convolutional Neural Networks; - Recurrent Neural Networks and Transformers for sequence modelling; - Autoencoder - Deep Generative Models; - TensorFlow.

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. Linear optimization: Theory and algorithms (a) LP models for Data science; (b) Simplex method; (c) Interior point methods; 2. Convex sets and convex functions (a) Convexity: basic notions; (c) Convex functions: Basic notions and properties (gradients, Hessians,..); 3. 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; 4. Constrained convex optimization (a) Models in data science; (b) Characterizations of optimal sets; (c) Polyhedral approximation methods; (d) Gradient projection methods; 5. 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 5 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/2021/LM/SC/SC2377/000ZZ/SCP7079229/NO

PROCESS MINING

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

Lecturer: Prof. MASSIMILIANO DE LEONI

Credits: 6 ECTS

Prerequisites:
Basic notions of algorithms, data structures and programming, as acquired in course “Fundamental of Information Systems”.

**Short program:**
The course will cover the topics listed below:

3. **PROCESS MINING** - Introduction to Process Mining and Event Logs - Basic Techniques for Process Discovery and Limitations - Advanced Techniques for Process Discovery: Heuristic Miner and Inductive Miner - Conformance checking based on token replay - Conformance checking based on alignments - Mining the Additional Perspectives on Decision, Time and Resource - Social Network Analysis

**Examination:**
Written exam, and a mandatory project.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079235/NO

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### STATISTICAL LEARNING

**Lecturer:** Prof. ALBERTO ROVERATO

**Prerequisites:**
basic probability theory; multivariable calculus; linear algebra; basic computing skills

**Examination:**
written test and project work

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079226/NO

**Moduli del C.I.:**
Statistical Learning 1 (Mod. A)
Statistical Learning 2 (Mod. B)

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#### STATISTICAL LEARNING 1 (MOD. A)

**Lecturer:** Prof. ALBERTO ROVERATO

**Credits:** 12 ECTS

**Short program:**
Part 1: - Data: summary statistics, displaying distributions; exploring relationships - Estimation: point estimation; the sampling distribution of an estimator; accuracy of estimation; interval estimation - Hypothesis testing - Likelihood: the likelihood, likelihood for several parameters - Estimation: maximum likelihood estimation; properties of maximum likelihood estimates

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#### STATISTICAL LEARNING 2 (MOD. B)

**Lecturer:** Prof. ALBERTO ROVERATO

**Credits:** 12 ECTS

**Short program:**

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### STOCHASTIC METHODS

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

**Lecturer:** Prof. MARCO FERRANTE

**Credits:** 6 ECTS

**Prerequisites:**
Basic notions of differential and integral calculus, linear algebra and probability.

**Short program:**
1. Probability reviews. • discrete and continuous distributions • random variables, expectation and conditional expectation • Law of Large Numbers and
FINANCIAL MATHEMATICS FOR DATA SCIENCE

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

Lecturer: Prof. MARTINO GRASSELLI

Credits: 6 ECTS

Prerequisites:
Stochastic analysis

Short program:

Examination:
Final examination based on: Written and oral examination.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0093689/NO

FUNDAMENTALS OF INFORMATION SYSTEMS

Master's degree in DATA SCIENCE ORD. 2017, 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/2021/LM/SC/SC2377/000ZZ/SCP7078720/NO

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

**Lecturer:** ELVINA GINDULLINA

**Credits:** 6 ECTS

**Prerequisites:**
A course, even a basic one, on probability theory.

**Short program:**

**Examination:**
For all the students, in any event the exam includes a mandatory open-book written test, containing problems of game theory focusing on different topics of the course. Every exercise involves multiple questions, typically three. For the students with regular attendance to the course, the exam may also involve, if they want so, the development of a project in 1-3 person groups, on course-related topics applied to ICT. This is agreed half-way through the course together with the lecturer. If the written test is sufficient, students can directly finalize the passing score. Projects can be discussed with an oral exam after the written test. Oral exams are scheduled in the same day of written tests (even though students can decide to give the two parts on separate days). The project discussion integrates the mark of the written test.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079401/NO

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**HIGH DIMENSIONAL PROBABILITY FOR DATA SCIENCE**

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

**Lecturer:** Prof. MARCO FORMENTIN

**Credits:** 6 ECTS

**Prerequisites:**
A basic course in probability theory, basic knowledges of stochastic processes and a good command of undergraduate linear algebra. Some familiarity with metric, normed and Hilbert spaces and linear operators will be useful but not essential. Useful background will be reviewed during the course when needed.

**Short program:**
The course will cover as many aspects of the following topics as possible: - Preliminaries on random variables. Classical inequalities and limit theorems. - Concentration of sums of independent random variables: Hoeffding, Chernoff and Bernstein inequalities, sub-Gaussian and sub-exponential distributions. Applications to random graphs. - Random vectors in high dimension: concentration of the norm, covariance matrices and principal component analysis, high dimensional distributions, sub-Gaussian distributions in higher dimensions. Applications: Grothendieck's Inequality and semidefinite programming and maximum cut for graphs. - Non-asymptotic analysis of random matrices: nets, covering and packing numbers, bounds on sub-Gaussian matrices, covariance estimation and clustering. Applications to error correcting codes, community detection in networks and covariance estimation and clustering. - Concentration of Lipschitz functions on the sphere, Johnson--Lindenstrauss theorem, matrix Bernstein inequality, community detection in sparse networks. - Random processes: basic concepts, Slepian's inequality, bounds on Gaussian matrices, Sudakov's minoration inequality, Gaussian width, random projections of sets. - Chaining: Dudley's inequality, empirical processes, Vapnik-Chervonenkis dimension with applications to statistical learning theory.

**Examination:**
Weekly homework and oral exam. A final project is also possible.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0093688/NO

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**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/2021/LM/SC/SC2377/000ZZ/SCP7079397/NO
MACHINE AND DEEP LEARNING (C.I.)

Lecturer: Dott. GIOVANNI DA SAN MARTINO

Prerequisites:
The student should be familiar with basic concepts in Mathematics, Probability Theory and Statistics, Linear Algebra, and basic Programming skills.

Examination:
The student must develop a small project and present a written report. The exam will consist of a short presentation and discussion of the project carried out, and an oral exam about all the topics covered in class.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0093685/NO

Moduli del C.I.:
Machine and deep learning (Mod. A)
Machine and deep learning (Mod. B)

MACHINE AND DEEP LEARNING (MOD. A)

Lecturer: Dott. GIOVANNI DA SAN MARTINO

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

Credits: 12 ECTS

Short program:
The course cover the topics listed below: - Introduction: Artificial Intelligence and Machine Learning, when and why you should use Machine Learning techniques; the main machine learning paradigms and their applications; the key ingredients of machine learning. - Supervised learning: the foundations and the basic models Linear Regression; space of hypotheses, representation and cost function; optimisation and gradient descent. Linear Classification Models; Logistic Regression; Regularisation and model selection. - Model complexity, its effectiveness and its evaluation Bias-Variance Tradeoff: how to deal with overfitting and underfitting problems; risk minimisation and learning theory; performance evaluation measures, examples and applications; diagnosing and debugging machine learning systems. - Supervised learning: neural networks and advanced models Artificial Neural Networks; perceptron, multilayer neural networks and deep learning; parameters learning, backpropagation and gradient descent. Support Vector Machines; kernel methods and nonlinear classification. “Alternative” approaches: non-parametric methods (k-NN) and their applications; decision trees and random forest. - Unsupervised learning Clustering: K-Means and the main approaches; PCA and dimensionality reduction. - Introduction to Recommender Systems and their application.

MACHINE AND DEEP LEARNING (MOD. B)

Lecturer: Prof. ALESSANDRO SPERDUTI

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

Credits: 12 ECTS

Short program:
The topics covered in the course are as follows: - Introduction to the course contents; - Deep Feedforward Networks; - Regularization for Deep Learning; - Optimization for training Deep Models; - Basic concepts for Convolutional Neural Networks; - Recurrent Neural Networks and Transformers for sequence modelling; - Autoencoder - Deep Generative Models; - TensorFlow.

MATHEMATICAL CELL BIOLOGY

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

Lecturer: Prof. MORTEN GRAM PEDERSEN

Credits: 6 ECTS

Prerequisites:
Knowledge of differential equations, linear algebra, probability theory.

Short program:

Examination:
End-of-term project and written exam.
MATHEMATICAL MODELS AND NUMERICAL METHODS FOR BIG DATA

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

Lecturer: Dott. WOLFGANG ERB

Credits: 6 ECTS

Prerequisites:
Basic knowledge in mathematical analysis and linear algebra Background in linear algebra and matrix theory; - Type of matrices: diagonal, triangular, symmetric, positive definite - Spectrum of matrices: eigenvalues, eigenvectors and eigenspaces - Matrix factorizations: LU, Cholesky, QR, SVD, Schur Background in mathematical analysis - metric and normed linear spaces - continuity - sequences and convergence Basic programming skills in Matlab or Python.

Short program:
1. Numerical methods for large eigenvalue problems • The power method • Krylov subspace iterations for sparse systems of equations • Krylov-type methods for large eigenvalue problem: Arnoldi (and sketches of Lanczos) • Singular value decomposition (SVD) VS eigenvalue decomposition • Best rank-k approximation 2. Numerical analysis of big data: graph and network clustering • Graphs, the graph Laplacian, graph signals, the Cheeger constant • Spectral graph theory and the graph Fourier transform • Spectral clustering • K-Means algorithm and K-center clustering • Principal component analysis and dimensionality reduction 3. Numerical analysis of big data: network centralities • Perron-Frobenius Theorem • Centrality based on eigenvectors (HITS and Pagerank) • Centrality based on matrix functions 4. Multitask Data Analysis • Tensor decompositions: Tucker decomposition, canonical singular value decomposition, canonical poliadic decomposition • Numerical methods for tensor decompositions and tensor eigenproblems • Applications: Face Recognition Using Tensor SVD and Tensor Data Fusion • Kernel methods for data analysis

Examination:
Written examination at the end of the course

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079406/NO

NETWORK SCIENCE

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

Lecturer: Prof. TOMASO ERSEGHE

Credits: 6 ECTS

Prerequisites:
This course has the following prerequisites: knowledge in Probability Theory, and Computer Programming in any language which is appropriate for network analysis (e.g., Matlab, Python, C, Java); knowledge in Calculus and Linear Algebra; any further knowledge of networking processes in economics, biology, telecommunications, semantics, etc. might be useful.

Short program:
The module will cover the following topics: 1. Basic network properties - graphs, adjacency matrix, degree distribution, connectivity, distance and diameter, clustering coefficient. 2. Network models - Erdos-Renyi model; Random graphs with general degree distribution; Power laws and scale free networks; Small world phenomena; Hubs; Network generation and expansion; Barabasi-Albert model; Preferential attachment; Evolving networks. 3. Centrality measures: Hubs and authorities; PageRank: teleportation, topic specific ranking, proximity measures, trust rank; betweenness, closeness, eigenvector and Katz centralities. 4. Other analytics: homophily (assortativity), polarisation, innovation, clustering, robustness, link prediction. 5. Community detection - Dendrograms; Girvan Newman method and betweenness; Louvain modularity optimisation; Spectral clustering; Consensus clustering; Measuring similarities in clustering outcomes; Algorithms for overlapping communities. 6. Network representation - Gephi and R/Python graphical functions; rationale of force directed graph layout algorithms. 7. Twitter Lab - How to extract a semantic network from Twitter data.

Examination:
The verification of the expected knowledge and skills is carried out with the DEVELOPMENT OF A PROJECT aimed at verifying the ability to apply theory in interdisciplinary contexts, and which requires: the choice, the collection of data, and the analysis of a different network for each student; computer implementation (in any programming language known to the student) of the algorithms required for the analysis; the drafting of an essay; the oral presentation of the main project outcomes. A bonus of up to 3 points is available for attending students that take part to an INTERDISCIPLINARY PROJECT with social science students attending the twin course on SOCIAL NETWORK ANALYSIS.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP8082723/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. Linear optimization: Theory and algorithms (a) LP models for Data science; (b) Simplex method; (c) Interior point methods; 2. Convex sets and convex functions (a) Convexity: basic notions; (c) Convex functions: Basic notions and properties (gradients, Hessians...); 3. 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; 4. Constrained convex optimization (a) Models in data science; (b) Characterizations of optimal sets; (c) Polyhedral approximation methods; (d) Gradient projection methods; 5. 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 5 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/2021/LM/SC/SC2377/000ZZ/SCP7079229/NO

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Lecturer: Prof. ALBERTO ROVERATO

Prerequisites:
basic probability theory; multivariable calculus; linear algebra; basic computing skills

Examination:
written test and project work

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079226/NO

Moduli del C.I.:
Statistical Learning 1 (Mod. A)
Statistical Learning 2 (Mod. B)

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**STATISTICAL LEARNING**

**STATISTICAL LEARNING 1 (MOD. A)**

Lecturer: Prof. ALBERTO ROVERATO

Credits: 12 ECTS

Short program:
Part 1: - Data: summary statistics, displaying distributions; exploring relationships - Estimation: point estimation; the sampling distribution of an estimator; accuracy of estimation; interval estimation - Hypothesis testing - Likelihood: the likelihood, likelihood for several parameters - Estimation: maximum likelihood estimation; properties of maximum likelihood estimates

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**STATISTICAL LEARNING 2 (MOD. B)**

Lecturer: Prof. ALBERTO ROVERATO

Credits: 12 ECTS

Short program:

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**STOCHASTIC METHODS**

Master's degree in **DATA SCIENCE ORD. 2017**, First semester
Lecturer: Prof. MARCO FERRANTE

Credits: 6 ECTS

Prerequisites:
Basic notions of differential and integral calculus, linear algebra and probability.

Short program:
1. Probability reviews. • discrete and continuous distributions • random variables, expectation and conditional expectation • Law of Large Numbers and Chernoff Bounds • approximation of probability distributions. 2. Markov chains and random walks • Discrete time Markov Chain and their stationary distribution • Monte Carlo (MCMC), convergence of MCMC-based algorithms. 3. High dimensional Gaussian random variables • Gaussian Annulus Theorem • Nearly orthogonal of independent random variables. 4. Introduction to Random Networks

Examination:
Written exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079197/NO

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STRUCTURAL BIOINFORMATICS

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

Lecturer: Prof. DAMIANO PIOVESAN

Credits: 6 ECTS

Prerequisites:
Basic knowledge of optimization methods and machine learning. Python programming language.

Short program:
The course consists of two parts: 1) Introduction to living matter (2 credits): 1.1) Introduction to organic chemistry, weak interactions and energy 1.2) Structure and function of DNA and proteins 1.3) Lipids, membranes and cellular transport 1.4) Experimental methods for structure determination 2) Computational Biochemistry (4 credits): 2.1) Biological Databases 2.2) Software libraries and concepts for sequence alignments and database searches 2.3) Sequence - structure relationship in proteins and structural classification 2.4) Methods for the prediction of protein structure from sequence, the CASP experiment 2.5) Methods for the prediction of protein function and interactions, the CAFA experiment 2.6) Non-globular proteins, disorder and structural repeats

Examination:
The exam covers three separate parts, which have to be all passed: (relative weights in parenthesis) 1) Written test of the biochemistry concepts (ca. 30%) 2) Software project (ca. 40%) 3) Project presentation and critical evaluation (ca. 30%)

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079278/NO

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BIOINFORMATICS

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

Lecturer: Prof. GIORGIO VALLE

Credits: 6 ECTS

Prerequisites:
There are no particular prerequisites other than what 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 and 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/2021/LM/SC/SC2377/000ZZ/SCP7079405/NO

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### BIOLOGICAL DATA

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

**Lecturer:** Prof. SILVIO TOSATTO  
**Credits:** 6 ECTS

**Prerequisites:**  
Basic knowledge of computer science, optimization methods and machine learning. Python programming language.

**Short program:**  
The course consists of four parts, corresponding to different types of biological data: 1) Sequences 1.1) DNA and proteins 1.2) Databases 1.3) Alignments 2) Structures 2.1) Protein folding 2.2) Databases 2.3) Structure prediction 3) Literature 3.1) Scientific papers 3.2) Databases 3.3) Text mining 3.4) Function 4) Interaction networks 4.1) Non-globular regions 4.2) Biological interactions 4.3) Databases 4.4) Emergent properties

**Examination:**  
The exam covers three separate parts, which have to be all passed: (relative weights in parenthesis) 1) Mid-term test (ca. 17%) Open questions 2) Project (ca. 50%) Coding and analysis of biological dataset; written report 3) Final exam (ca. 33%) Oral, with questions on project and course

More information:  
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079337/NO

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### COGNITIVE, BEHAVIORAL AND SOCIAL DATA

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

**Lecturer:** Prof. GIUSEPPE SARTORI  
**Credits:** 6 ECTS

**Prerequisites:**  
Notions of machine learning

**Short program:**  
The aim of the course is to provide an overview of concrete data science applications in behavioural science, cognitive science, neuroscience and social science. The course gives an underground of methods to analyse and learn behavioural, cognitive and brain functional/structural data. It provide a review of studies, with several examples of recent practical applications, also according with the students interests. Limits in the state of the art and future directions will be discussed. The course contents are the following:  
• Basic concepts of human brain cognitive functioning (attention, memory, learning, language, etc.) and how to measure it  
• Basic concepts of social psychology and social behaviour (preferences, judgments, group identity, etc.) and how to measure it  
• What are behavioural measures and how to measure them (e.g., RT); implicit and explicit behavioural measures (e.g., the IAT)  
• Extracting and predicting information from behaviour (e.g. lie detection, predicting malicious behaviour from social networks activity, fake online reviews, security applications, etc.)  
• What are psychophysiological measures and how to measure them (e.g., HR variability, SCR, facial expressions, EEG, fMRI, etc.)  
• Extracting and predicting information from psychophysiological measures  
• Extracting and predicting information from brain activity: mind reading applications (e.g., psychopathology detection, reconstructing visual experiences from brain activity, brain computer interface devices, etc.)  
• Social and behavioural data for marketing application (e.g. skill assessment and prediction, psychology of taxes, predicting preferences and personality from social networks activity, sentiment analysis, etc.)  
• Issue related to the application of machine learning in behavioural research (e.g. the problem of reproducibility)

**Examination:**  
Oral exam and project

More information:  
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079219/NO

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### GAME THEORY

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

**Lecturer:** ELVINA GINDULLINA
Credits: 6 ECTS

Prerequisites:
A course, even a basic one, on probability theory.

Short program:

Examination:
For all the students, in any event the exam includes a mandatory open-book written test, containing problems of game theory focusing on different topics of the course. Every exercise involves multiple questions, typically three. For the students with regular attendance to the course, the exam may also involve, if they want so, the development of a project in 1-3 person groups, on course-related topics applied to ICT. This is agreed half-way through the course together with the lecturer. If the written test is sufficient, students can directly finalize the passing score. Projects can be discussed with an oral exam after the written test. Oral exams are scheduled in the same day of written tests (even though students can decide to give the two parts on separate days). The project discussion integrates the mark of the written test.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079401/NO

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**HUMAN DATA ANALYTICS**

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

Lecturer: Prof. MICHELE ROSSI

Credits: 6 ECTS

Prerequisites: -

Short program:
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Examination:
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More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079397/NO

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**LAW AND DATA**

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

Lecturer: Dott.ssa ELISA SPILLER

Credits: 6 ECTS

Prerequisites:
No prerequisites

Short program:
All the info about the course are on Moodle - Introduction to Law and Legal Studies - Introduction to the EU Law - Introduction to the EU GDPR - The concept of data; personal, sensitive and economic data; big data - Property of data; choices in the management of data - The right to be forgotten - Civil and criminal aspects of profiling activity - Automatic data processing, human responsibilities - The Data Protection Officer and DP Authorities - Civil and criminal protection of privacy - Sanctioning powers and system - Open Data for the public interest - Big data (collection, analysis, processing) and their influence on fundamental rights - Digital Surveillance - Facial Recognition: Open Issues - Disinformation - Artificial Intelligence in the EU law

Examination:
Written Exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079399/NO
MATHEMATICAL CELL BIOLOGY

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

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites:
Knowledge of differential equations, linear algebra, probability theory.

Short program:

Examination:
End-of-term project and written exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0093722/NO

NETWORK SCIENCE

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

Lecturer: Prof. TOMASO ERSEGHE

Credits: 6 ECTS

Prerequisites:
This course has the following prerequisites: knowledge in Probability Theory, and Computer Programming in any language which is appropriate for network analysis (e.g., Matlab, Python, C, Java); knowledge in Calculus and Linear Algebra; any further knowledge of networking processes in economics, biology, telecommunications, semantics, etc. might be useful.

Short program:
The module will cover the following topics: 1. Basic network properties - graphs, adjacency matrix, degree distribution, connectivity, distance and diameter, clustering coefficient. 2. Network models - Erdos-Renyi model; Random graphs with general degree distribution; Power laws and scale free networks; Small world phenomena; Hubs; Network generation and expansion; Barabasi-Albert model; Preferential attachment; Evolving networks. 3. Centrality measures: Hubs and authorities; PageRank: teleportation, topic specific ranking, proximity measures, trust rank; betweenness, closeness, eigenvector and Katz centralities. 4. Other analytics: homophily (assortativity), polarisation, innovation, clustering, robustness, link prediction. 5. Community detection - Dendrograms; Girvan Newman method and betweenness; Louvain modularity optimisation; Spectral clustering; Consensus clustering; Measuring similarities in clustering outcomes; Algorithms for overlapping communities. 6. Network representation - Gephi and R/Python graphical functions; rationale of force directed graph layout algorithms. 7. Twitter Lab - How to extract a semantic network from Twitter data.

Examination:
The verification of the expected knowledge and skills is carried out with the DEVELOPMENT OF A PROJECT aimed at verifying the ability to apply theory in interdisciplinary contexts, and which requires: the choice, the collection of data, and the analysis of a different network for each student; computer implementation (in any programming language known to the student) of the algorithms required for the analysis; the drafting of an essay; the oral presentation of the main project outcomes. A bonus of up to 3 points is available for attending students that take part to an INTERDISCIPLINARY PROJECT with social science students attending the twin course on SOCIAL NETWORK ANALYSIS.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP8082723/NO

OMICS IN HUMAN DISEASE

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

Lecturer: Prof. DENIS DOMINIQUE MARTINVALET

Credits: 6 ECTS

Prerequisites:
Basic knowledge of statistics and programming
Short program:

Examination:
The exam covers two separate parts: Evaluation of the biological knowledge about human and cellular biology relative to complex disease. Evaluation of the skills acquired during practicals with the evaluation of the project about the computational analysis of a complex disease.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0093738/NO

BUSINESS ECONOMIC AND FINANCIAL DATA

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

Lecturer: Prof.ssa MARIANGELA GUIDOLIN

Credits: 6 ECTS

Prerequisites:
Program of Statistical Learning course

Short program:
- General introduction to business, economic and financial data --Preliminary concepts and illustrative examples -Moving beyond the linear model --Linear regression model: main ideas and assumptions --Nonlinear regression models for new product growth - Beyond linearity: regression splines, local regression, generalized additive models (GAM) - Tree-based methods: Regression trees, Bagging, Boosting -Time series analysis: Exponential Smoothing and ARIMA models

Examination:
--Practical exam --Oral exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079231/NO

COGNITION AND COMPUTATION

Master's degree in DATA SCIENCE ORD. 2017, 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 cognitive psychology 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 elaborating one topic assigned during the course, which must be hand over on the day of the written exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0089498/NO

COGNITIVE, BEHAVIORAL AND SOCIAL DATA

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

Lecturer: Prof. GIUSEPPE SARTORI

Credits: 6 ECTS

Prerequisites:
Notions of machine learning

Short program:
The aim of the course is to provide an overview of concrete data science applications in behavioural science, cognitive science, neuroscience and social science. The course gives an underground of methods to analyse and learn behavioural, cognitive and brain functional/structural data. It provide a review of studies, with several examples of recent practical applications, also according with the students interests. Limits in the state of the art and future directions will be discussed. The course contents are the following:

• Basic concepts of human brain cognitive functioning (attention, memory, learning, language, etc.) and how to measure it • Basic concepts of social psychology and social behaviour (preferences, judgments, group identity, etc.) and how to measure it • What are behavioural measures and how to measure them (e.g., RT); implicit and explicit behavioural measures (e.g., the IAT) • Extracting and predicting information from behaviour (e.g. lie detection, predicting malicious behaviour from social networks activity, fake online reviews, security applications, etc.) • What are psychophysiological measures and how to measure them (e.g., HR variability, SCR, facial expressions, EEG, fMRI, etc.) • Extracting and predicting information from psychophysiological measures • Extracting and predicting information from brain activity: mind reading applications (e.g., psychopathology detection, reconstructing visual experiences from brain activity, brain computer interface devices, etc.) • Social and behavioural data for marketing application (e.g. skill assessment and prediction, psychology of taxes, predicting preferences and personality from social networks activity, sentiment analysis, etc.) • Issue related to the application of machine learning in behavioural research (e.g. the problem of reproducibility)

Examination:
Oral exam and project

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079219/NO

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HUMAN COMPUTER INTERACTION

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

Lecturer: Prof. LUCIANO GAMBERINI

Credits: 6 ECTS

Prerequisites: There are no specific prerequisites.

Short program:
Following the textbook we will explore the following topics: 1 What is Interaction Design? 2 The Process of Interaction Design 3 Conceptualizing Interaction 4 Cognitive Aspects 5 Social Interaction 6 Emotional Interaction 7 Interfaces 8 Data Gathering 9 Data Analysis, Interpretation, and Presentation 10 Data at Scale 11 Discovering Requirements 12 Design, Prototyping, and Construction 13 Interaction Design in Practice 14 Introducing Evaluation 495 15 Evaluation Studies: From Controlled to Natural Settings 16 Evaluation: Inspections, Analytics, and Models Detailed examples and training on research methods and techniques for the design and the evaluation of interactive systems will be discussed during lessons.

Examination:
NOT ATTENDING: The exam will be oral with 3 questions on the book, one of which is proposed as an exercise (see the book for examples). In case of Corona Virus Emergency the oral exam will be given on-line. ATTENDING: The exam will be based on a personal research work to be carried out during the course as homework and on a short oral presentation and discussion test. A report will summarize the work done in a similar way to a scientific paper or a professional report. The research to be developed will be summarized in a report that will include the following points: 1 - Introduction, theoretical contextualization, benchmarking 2 - design / co-design process 3 - prototype development / modification (for those with less technical experience there are solutions) 4 - evaluation - data analysis (ex: UX, usability, presence, acceptance) 5 - results - final discussion. Any technology may be developed / adopted for research as long as it is interactive (e.g. web, robot, virtual / augmented reality, smart home devices, work tools, Arduino tools, vehicles, musical instruments, mobile / tablet apps).

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079403/NO

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LAW AND DATA

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

Lecturer: Dott.ssa ELISA SPILLER

Credits: 6 ECTS

Prerequisites: No prerequisites

Short program:
All the info about the course are on Moodle - Introduction to Law and Legal Studies - Introduction to the EU Law - Introduction to the EU GDPR - The concept of data; personal, sensitive and economic data; big data - Property of data, choices in the management of data - The right to be forgotten - Civil and criminal aspects of profiling activity - Automatic data processing, human responsibilities - The Data Protection Officer and DP Authorities - Civil and criminal protection of privacy - Sanctioning powers and system - Open Data for the public interest - Big data (collection, analysis, processing) and their influence on fundamental rights - Digital Surveillance - Facial Recognition: Open Issues - Disinformation - Artificial Intelligence in the EU law

Examination:
Written Exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079403/NO
BIG DATA COMPUTING

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

Lecturer: Prof. ANDREA ALBERTO PIETRACAPRINA

Credits: 6 ECTS

Prerequisites:
The course has the following prerequisites: competences regarding the design and analysis of algorithms and data structures, knowledge of fundamental notions of probability and statistics, and programming skills in Java or Python.

Short program:
The course will cover the following topics: Introduction to the Big Data phenomenon. Programming frameworks: MapReduce, Apache Spark Reducing input size (Case study: clustering) Reducing output size (Case study: frequent itemsets) Streaming framework.

Examination:
The exam consists of a number of programming homeworks, assigned approximately every 2-3 weeks and to be carried out in groups of 2-3 students, and of an individual written test comprising both theory questions and exercises.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079399/NO

BIOINFORMATICS

Master's degree in DATA SCIENCE ORD. 2017, 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 and 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/2021/LM/SC/SC2377/000ZZ/SCP7079297/NO

BIOLOGICAL DATA

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

Lecturer: Prof. SILVIO TOSATTO

Credits: 6 ECTS

Prerequisites:
Basic knowledge of computer science, optimization methods and machine learning. Python programming language.

Short program:
The course consists of four parts, corresponding to different types of biological data: 1) Sequences 1.1) DNA and proteins 1.2) Databases 1.3) Alignments 2) Structures 2.1) Protein folding 2.2) Databases 2.3) Structure prediction 3) Literature 3.1) Scientific papers 3.2) Databases 3.3) Text mining 3.4) Function 4) Interaction networks 4.1) Non-globular regions 4.2) Biological interactions 4.3) Databases 4.4) Emergent properties

Examination:
The exam covers three separate parts, which have to be all passed: (relative weights in parenthesis) 1) Mid-term test (ca. 17%) Open questions 2) Project (ca. 50%) Coding and analysis of biological dataset; written report 3) Final exam (ca. 33%) Oral, with questions on project and course

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079337/NO

### BUSINESS ECONOMIC AND FINANCIAL DATA

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

**Lecturer:** Prof.ssa MARIANGELA GUIDOLIN

**Credits:** 6 ECTS

**Prerequisites:** Program of Statistical Learning course

**Short program:**
- General introduction to business, economic and financial data
- Preliminary concepts and illustrative examples
- Moving beyond the linear model
- Linear regression model: main ideas and assumptions
- Nonlinear regression models for new product growth
- Beyond linearity: regression splines, local regression, generalized additive models (GAM)
- Tree-based methods: Regression trees, Bagging, Boosting
- Time series analysis: Exponential Smoothing and ARIMA models

**Examination:**
- Practical exam
- Oral exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079231/NO

### COGNITION AND COMPUTATION

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

**Lecturer:** to be defined

**Credits:** 6 ECTS

**Prerequisites:** The course requires preliminary knowledge of machine learning and probability theory. Familiarity with basic concepts of cognitive psychology 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.
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 elaborating one topic assigned during the course, which must be hand over on the day of the written exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0089498/NO

### COGNITIVE, BEHAVIORAL AND SOCIAL DATA

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

**Lecturer:** Prof. GIUSEPPE SARTORI

**Credits:** 6 ECTS

**Prerequisites:** Notions of machine learning

**Short program:**
The aim of the course is to provide an overview of concrete data science applications in behavioural science, cognitive science, neuroscience and social science. The course gives an underground of methods to analyse and learn behavioural, cognitive and brain functional/structural data. It provide a review of studies, with several examples of recent practical applications, also according with the students interests. Limits in the state of the art and future directions will be discussed. The course contents are the following: • Basic concepts of human brain cognitive functioning (attention, memory, learning, language, etc.) and how to measure it • Basic concepts of social psychology and social behaviour (preferences, judgments, group identity, etc.) and how to measure it • What are behavioural measures and how to measure them (e.g., RT); implicit and explicit behavioural measures (e.g., the IAT) • Extracting and predicting information from behaviour (e.g., lie detection, predicting malicious behaviour from social networks activity, fake online reviews, security applications, etc.) • What are psychophysiological measures and how to measure them (e.g., HR variability, SCR, facial expressions, EEG, IRMI, etc.) • Extracting and predicting information from psychophysiological measures • Extracting and predicting information from brain activity: mind reading applications (e.g., psychopathology detection, reconstructing visual experiences from brain activity, brain computer interface devices, etc.) • Social and behavioural data for marketing application (e.g. skill assessment and prediction, psychology of taxes, predicting preferences and personality from social networks activity, sentiment analysis, etc.) • Issue related to the application of machine learning in behavioural research (e.g. the problem of reproducibility)

Examination: Oral exam and project

More information: 
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079219/NO

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**Fundamentals of Information Systems**

Master's degree in Data Science Ord. 2017, 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/2021/LM/SC/SC2377/000ZZ/SCP7078720/NO

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**Network Science**

Master's degree in Data Science Ord. 2017, First semester

**Lecturer:** Prof. Tomaso Erseghe

**Credits:** 6 ECTS

**Prerequisites:**
This course has the following prerequisites: knowledge in Probability Theory, and Computer Programming in any language which is appropriate for network analysis (e.g., Matlab, Python, C, Java); knowledge in Calculus and Linear Algebra; any further knowledge of networking processes in economics, biology, telecommunications, semantics, etc. might be useful.

**Short program:**
The module will cover the following topics: 1. Basic network properties - graphs, adjacency matrix, degree distribution, connectivity, distance and diameter, clustering coefficient. 2. Network models - Erdos-Renyi model; Random graphs with general degree distribution; Power laws and scale free networks; Small world phenomena; Hubs; Network generation and expansion; Barabasi-Albert model; Preferential attachment; Evolving networks. 3. Centrality measures: Hubs and authorities; PageRank: teleportation, topic specific ranking, proximity measures, trust rank; betweenness, closeness, eigenvector and Katz centralities. 4. Other analytics: homophily (assortativity), polarisation, innovation, clustering, robustness, link prediction. 5. Community detection - Dendrograms; Girvan Newman method and betweenness; Louvain modularity optimisation; Spectral clustering; Consensus clustering; Measuring similarities in clustering outcomes; Algorithms for overlapping communities. 6. Network representation - Gephi and R/Python graphical functions; rationale of force directed graph layout algorithms. 7. Twitter Lab - How to extract a semantic network from Twitter data.

**Examination:**
The verification of the expected knowledge and skills is carried out with the DEVELOPMENT OF A PROJECT aimed at verifying the ability to apply theory in interdisciplinary contexts, and which requires: the choice, the collection of data, and the analysis of a different network for each student; computer implementation (in any programming language known to the student) of the algorithms required for the analysis; the drafting of an essay; the oral presentation of the main project outcomes. A bonus of up to 3 points is available for attending students that take part to an INTERDISCIPLINARY PROJECT with social science students attending the twin course on SOCIAL NETWORK ANALYSIS.


### PROCESS MINING

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

**Lecturer:** Prof. MASSIMILIANO DE LEONI

**Credits:** 6 ECTS

**Prerequisites:**
Basic notions of algorithms, data structures and programming, as acquired in course “Fundamental of Information Systems”.

**Short program:**
The course will cover the topics listed below:
3. **PROCESS MINING** - Introduction to Process Mining and Event Logs - Basic Techniques for Process Discovery and Limitations - Advanced Techniques for Process Discovery: Heuristic Miner and Inductive Miner - Conformance checking based on token replay - Conformance checking based on alignments - Mining the Additional Perspectives on Decision, Time and Resource - Social Network Analysis

**Examination:**
Written exam, and a mandatory project.

More information: https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079235/NO

### BIOLOGICAL DATA

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

**Lecturer:** Prof. SILVIO TOSATTO

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge of computer science, optimization methods and machine learning. Python programming language.

**Short program:**
The course consists of four parts, corresponding to different types of biological data:
1) **Sequences**
   1.1) DNA and proteins
   1.2) Databases
   1.3) Alignments
2) **Structures**
   2.1) Protein folding
   2.2) Databases
   2.3) Structure prediction
3) **Literature**
   3.1) Scientific papers
   3.2) Databases
   3.3) Text mining
   3.4) Function
4) **Interaction networks**
   4.1) Non-globular regions
   4.2) Biological interactions
   4.3) Databases
   4.4) Emergent properties

**Examination:**
The exam covers three separate parts, which have to be all passed: (relative weights in parenthesis) 1) Mid-term test (ca. 17%) Open questions 2) Project (ca. 50%) Coding and analysis of biological dataset; written report 3) Final exam (ca. 33%) Oral, with questions on project and course


### BUSINESS ECONOMIC AND FINANCIAL DATA

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

**Lecturer:** Prof.ssa MARIANGELA GUIDOLIN

**Credits:** 6 ECTS

**Prerequisites:**
Program of Statistical Learning course

**Short program:**
- General introduction to business, economic and financial data
- Preliminary concepts and illustrative examples
- Moving beyond the linear model --Linear
**Regression Models: Main Ideas and Assumptions**
- Nonlinear regression models for new product growth
- Beyond linearity: regression splines, local regression, generalized additive models (GAM)
- Tree-based methods: Regression trees, Bagging, Boosting
- Time series analysis: Exponential Smoothing and ARIMA models

**Examination:**
- Practical exam
- Oral exam

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079231/NO

### COGNITIVE, BEHAVIORAL AND SOCIAL DATA

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

**Lecturer:** Prof. GIUSEPPE SARTORI

**Credits:** 6 ECTS

**Prerequisites:**
Notions of machine learning

**Short program:**
The aim of the course is to provide an overview of concrete data science applications in behavioural science, cognitive science, neuroscience and social science. The course gives an underground of methods to analyse and learn behavioural, cognitive and brain functional/structural data. It provide a review of studies, with several examples of recent practical applications, also according with the students interests. Limits in the state of the art and future directions will be discussed. The course contents are the following:

- Basic concepts of human brain cognitive functioning (attention, memory, learning, language, etc.) and how to measure it
- Basic concepts of social psychology and social behaviour (preferences, judgments, group identity, etc.) and how to measure it
- What are behavioural measures and how to measure them (e.g., RT); implicit and explicit behavioural measures (e.g., the IAT)
- Extracting and predicting information from behaviour (e.g. lie detection, predicting malicious behaviour from social networks activity, fake online reviews, security applications, etc.)
- What are psychophysiological measures and how to measure them (e.g., HR variability, SCR, facial expressions, EEG, IRMI, etc.)
- Extracting and predicting information from psychophysiological measures
- Extracting and predicting information from brain activity: mind reading applications (e.g., psychopathology detection, reconstructing visual experiences from brain activity, brain computer interface devices, etc.)
- Social and behavioural data for marketing application (e.g. skill assessment and prediction, psychology of taxes, predicting preferences and personality from social networks activity, sentiment analysis, etc.)
- Issue related to the application of machine learning in behavioural research (e.g. the problem of reproducibility)

**Examination:**
Oral exam and project

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079219/NO

### GAME THEORY

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

**Lecturer:** ELVINA GINDULLINA

**Credits:** 6 ECTS

**Prerequisites:**
A course, even a basic one, on probability theory.

**Short program:**

**Examination:**
For all the students, in any event the exam includes a mandatory open-book written test, containing problems of game theory focusing on different topics of the course. Every exercise involves multiple questions, typically three. For the students with regular attendance to the course, the exam may also involve, if they want so, the development of a project in 1-3 person groups, on course-related topics applied to ICT. This is agreed half-way through the course together with the lecturer. If the written test is sufficient, students can directly finalize the passing score. Projects can be discussed with an oral exam after the written test. Oral exams are scheduled in the same day of written tests (even though students can decide to give the two parts on separate days). The project discussion integrates the mark of the written test.
HIGH DIMENSIONAL PROBABILITY FOR DATA SCIENCE

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

Lecturer: Prof. MARCO FORMENTIN

Credits: 6 ECTS

Prerequisites:
A basic course in probability theory, basic knowledges of stochastic processes and a good command of undergraduate linear algebra. Some familiarity with metric, normed and Hilbert spaces and linear operators will be useful but not essential. Useful background will be reviewed during the course when needed.

Short program:
The course will cover as many aspects of the following topics as possible: - Preliminaries on random variables. Classical inequalities and limit theorems. - Concentration of sums of independent random variables: Hoeffding, Chernoff and Bernstein inequalities, sub-Gaussian and sub-exponential distributions. Applications to random graphs. - Random vectors in high dimension: concentration of the norm, covariance matrices and principal component analysis, high dimensional distributions, sub-Gaussian distributions in higher dimensions. Applications: Grothendieck's Inequality and semidefinite programming and maximum cut for graphs. - Non-asymptotic analysis of random matrices: nets, covering and packing numbers, bounds on sub-Gaussian matrices, covariance estimation and clustering. Applications to error correcting codes, community detection in networks and covariance estimation and clustering. - Concentration of Lipschitz functions on the sphere, Johnson–Lindenstrauss theorem, matrix Bernstein inequality, community detection in sparse networks. - Random processes: basic concepts, Slepian's inequality, bounds on Gaussian matrices, Sudakov's minoration inequality, Gaussian width, random projections of sets. - Chaining: Dudley's inequality, empirical processes, Vapnik-Chervonenkis dimension with applications to statistical learning theory.

Examination:
Weekly homework and oral exam. A final project is also possible.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0093688/NO

HUMAN COMPUTER INTERACTION

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

Lecturer: Prof. LUCIANO GAMBERINI

Credits: 6 ECTS

Prerequisites:
There are no specific prerequisites.

Short program:
Following the textbook we will explore the following topics: 1 What is Interaction Design? 2 The Process of Interaction Design 3 Conceptualizing Interaction 4 Cognitive Aspects 5 Social Interaction 6 Emotional Interaction 7 Interfaces 8 Data Gathering 9 Data Analysis, Interpretation, and Presentation 10 Data at Scale 11 Discovering Requirements 12 Design, Prototyping, and Construction 13 Interaction Design in Practice 14 Introducing Evaluation 15 Evaluation Studies: From Controlled to Natural Settings 16 Evaluation: Inspections, Analytics, and Models Detailed examples and training on research methods and techniques for the design and the evaluation of interactive systems will be discussed during lessons.

Examination:
NOT ATTENDING: The exam will be oral with 3 questions on the book, one of which is proposed as an exercise (see the book for examples). In case of Corona Virus Emergency the oral exam will be given on-line. ATTENDING: The exam will be based on a personal research work to be carried out during the course as homework and on a short oral presentation and discussion test. A report will summarize the work done in a similar way to a scientific paper or a professional report. The research to be developed will be summarized in a report that will include the following points: 1 - Introduction, theoretical contextualization, benchmarking 2 - design / co-design process 3 - prototype development / modification (for those with less technical experience there are solutions) 4 - evaluation - data analysis (ex: UX, usability, presence, acceptance) 5 - results - final discussion. Any technology may be developed / adopted for research as long as it is interactive (e.g. web, robot, virtual / augmented reality, smart home devices, work tools, Arduino tools, vehicles, musical instruments, mobile / tablet apps).

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079403/NO

HUMAN DATA ANALYTICS

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

Lecturer: Prof. MICHELE ROSSI
**LAW AND DATA**

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

**Lecturer:** Dott.ssa ELISA SPILLER

**Credits:** 6 ECTS

**Prerequisites:**
No prerequisites

**Short program:**
All the info about the course are on Moodle - Introduction to Law and Legal Studies - Introduction to the EU Law - Introduction to the EU GDPR - The concept of data; personal, sensitive and economic data; big data - Property of data, choices in the management of data - The right to be forgotten - Civil and criminal aspects of profiling activity - Automatic data processing, human responsibilities - The Data Protection Officer and DP Authorities - Civil and criminal protection of privacy - Sanctioning powers and system - Open Data for the public interest - Big data (collection, analysis, processing) and their influence on fundamental rights - Digital Surveillance - Facial Recognition: Open Issues - Disinformation - Artificial Intelligence in the EU law

**Examination:**
Written Exam

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP7079397/NO

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**MATHEMATICAL CELL BIOLOGY**

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

**Lecturer:** Prof. MORTEN GRAM PEDERSEN

**Credits:** 6 ECTS

**Prerequisites:**
Knowledge of differential equations, linear algebra, probability theory.

**Short program:**

**Examination:**
End-of-term project and written exam.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCQ0093722/NO

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**NETWORK SCIENCE**

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

**Lecturer:** Prof. TOMASO ERSEGHE

**Credits:** 6 ECTS

**Prerequisites:**
This course has the following prerequisites: knowledge in Probability Theory, and Computer Programming in any language which is appropriate for network analysis (e.g., MatLab, Python, C, Java); knowledge in Calculus and Linear Algebra; any further knowledge of networking processes in economics, biology,
telecommunications, semantics, etc. might be useful.

Short program:
The module will cover the following topics: 1. Basic network properties - graphs, adjacency matrix, degree distribution, connectivity, distance and diameter, clustering coefficient. 2. Network models - Erdos-Renyi model; Random graphs with general degree distribution; Power laws and scale free networks; Small world phenomena; Hubs; Network generation and expansion; Barabasi-Albert model; Preferential attachment; Evolving networks. 3. Centrality measures: Hubs and authorities; PageRank; teleportation, topic specific ranking, proximity measures, trust rank; betweenness, closeness, eigenvector and Katz centralities. 4. Other analytics: homophily (assortativity), polarisation, innovation, clustering, robustness, link prediction. 5. Community detection - Dendrograms; Girvan Newman method and betweenness; Louvain modularity optimisation; Spectral clustering; Consensus clustering; Measuring similarities in clustering outcomes; Algorithms for overlapping communities. 6. Network representation - Gephi and R/Python graphical functions; rationale of force directed graph layout algorithms. 7. Twitter Lab - How to extract a semantic network from Twitter data.

Examination:
The verification of the expected knowledge and skills is carried out with the DEVELOPMENT OF A PROJECT aimed at verifying the ability to apply theory in interdisciplinary contexts, and which requires: the choice, the collection of data, and the analysis of a different network for each student; computer implementation (in any programming language known to the student) of the algorithms required for the analysis; the drafting of an essay; the oral presentation of the main project outcomes. A bonus of up to 3 points is available for attending students that take part to an INTERDISCIPLINARY PROJECT with social science students attending the twin course on SOCIAL NETWORK ANALYSIS.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2377/000ZZ/SCP8082723/NO
### CARBONATE FACIES ANALYSIS FOR PALEOCLIMATE RECONSTRUCTIONS

**Master's degree in** **ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021**, Second semester

**Lecturer:** Prof. NEREO PRETO

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge of sedimentary geology, sedimentology and chemistry.

**Short program:**
Part 1: carbonate rocks, depositional environments, carbonates and climate (ca. 2.5 CFU mostly lectures) - Carbonate rocks in hand sample and under the microscope; the classification of carbonate rocks, or: where does the carbonate comes from? - Precipitation of carbonate sediments in seawater as a suite of chemical and biological processes; - The concepts of carbonate factory and carbonate platform; - Types of carbonate platform; - Phanerozoic reefs, and present threats; - the Mg/Ca of seawater and the evolution of carbonate producers; - causes and effects of ocean acidification, today and in the past, i.e.: how ocean acidification can be identified in the geological record? What are the effects of the surging acidification on the chemistry of seawater and on carbonate-secreting marine organisms? Part 2: Carbonate petrography (ca. 2 CFU mostly lab.) - Skeletal and inorganic carbonate grains; - Fabrics of carbonate rocks; - Microbial carbonates; - Porosity of carbonate rocks; - Carbonate cements and carbonate diagenesis; - The origin of sedimentary dolomite, dolomitization processes, and the "dolomite problem". Part 3: C and O stable isotopes in carbonates (1.5 CFU mostly lab + field) A case study will be selected in which carbonates yield a climatic signal (e.g., a perturbation of the carbon cycle, or a T shift, etc.). On this case study, an exercise on how to extract the climatic and/or diagenetic signal from carbonates, without falling into the many pitfalls of oxygen and carbon isotopic analysis in fossil carbonates, will be held. This exercise will entail: - Introduction to C and O stable isotopes (a very brief recall of what everyone should know already); - Field excursion: logging a carbonate succession, sampling for thin sections and isotopic analyses; - Lab: carbonate microfacies of the field excursion materials; - Lab: sampling with dental drill - how to choose components; - Isotopic Ratio Mass Spectrometer: functioning and see the instrument; - Lab: sample preparation and set up of the instrument (preparation of a run); - Lab: representing and interpreting results with cross-plots, plot VS log, etc. and assessment of the diagenetic processes.

**Examination:**
The exam is based on practicals and a written test. The practicals are reports on the lab activities. The written test will include open questions on the contents of the lectures and labs, to which the student will answer with a brief explanatory text, and/or with schemes and sketches.

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### DIGITAL GEOLOGICAL MAPPING

**Master's degree in** **ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021**, Second semester

**Lecturer:** Prof. GIORGIO PENNACCHIONI

**Credits:** 6 ECTS

**Prerequisites:**
Basic geological knowledge and geological mapping skill

**Short program:**
The geographical mapping and survey activities are nowadays performed with advanced technical approaches both in the field and at the stage of data analysis. The course will give particular emphasis on small-scale (km-scale or lower) mapping, Digital Outcrop Models reconstructions and analysis and simplified 3D geo-modelling applied on different geological contexts, application of different approaches of close range remote sensing. The main contents can be listed as follows: • Methodology and approaches of high scale geological mapping in geo-structural, stratigraphic and applied geomorphological contexts • Stratigraphic and structural description of geological cores and BHTV acquisitions • Field Move application for geological mapping • Data integration in GIS platforms • Photogrammetry, Digital Outcrop Models reconstruction and 3D geological analysis. • Principle of hyperspectral remote sensing and close range applications • Basic concepts and applications of 3D Geological models

**Examination:**
Evaluation of the products derived from the practical activities and oral presentation

**More information:**

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### EARTH INTERIOR AND EVOLUTION

**Master's degree in** **ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021**, First semester
**Lecturer:** Prof. GIORGIO PENNACCHIONI

**Credits:** 12 ECTS

**Prerequisites:**
General knowledge of the basic concepts of the different geological disciplines (mineralogy, petrography, geophysics, structural geology, stratigraphy).

**Short program:**

**Examination:**
Oral test with open questions on the main themes illustrated in the frame of the course

**More information:**

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**EARTH SURFACE PROCESSES AND DEPOSITS**

Master's degree in **ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS** ORD. 2021, First semester

**Lecturer:** Prof. MASSIMILIANO GHINASSI

**Credits:** 12 ECTS

**Prerequisites:**
Basic concepts of geology (structural geology, geodynamic settings), sedimentology (textural features of the main types of sediments and sedimentary rocks, sedimentary processes), geomorphology (main morphogenetic processes and recognition of landforms) and stratigraphy (temporal and spatial variability of depositional systems); basic experience in geological and geomorphological field survey.

**Short program:**
1. SEDIMENT TRANSPORT AND FACIES ANALYSIS landscape evolution from the catchment to a basin scale Description of sediments: basic concepts Trational transport (bedforms) En-mass transport (debris flow-turbiditic currents) Erosive features Soft sediment deformations 2. SURFACE PROCESSES and REMOTE SENSING FOR Remote sensing: theory and methods Remote sensing: satellites and sensors Conventional Aerial photographs LIDAR and Structure From Motion technique Digital Elevation Models: methods, sources, analyses 3. DEPOSITIONAL ENVIRONMENTS AND GEOMORPHOLOGICAL HAZARDS 3.1 Slope and upstream environments Subaerial slopes, colluvial fans and alluvial fans Geomorphological hazards in the mountain catchments Landslide recognition and classification 3.2 Fluvial systems River styles, torrents, type of bars, overbank features Fluvial geomorphology, between natural dynamics and anthropogenic activity 3.3 Coastal systems Deltas, wave-dominated coasts, tide-dominant coasts Coastal erosion and examples of coastal management Evolution of alluvial and coastal plains during late Quaternary: deposits, landforms, soils 3.5 Marine processes Depositional systems from shelf to deep basin

**Examination:**
Oral test with open questions on the main themes illustrated in the frame of the course

**More information:**

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**GEOLOGICAL RESOURCES AND SUSTAINABLE DEVELOPMENT**

Master's degree in **ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS** ORD. 2021, First semester

**Lecturer:** Prof. PAOLO NIMIS

**Credits:** 12 ECTS

**Prerequisites:**
Short program:

Examination:
Interview

More information:

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### ISOTOPE GEOCHEMISTRY

**Master’s degree in ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021, Second semester**

**Lecturer:** Dott.ssa CHRISTINE MARIE MEYZEN

**Credits:** 6 ECTS

**Prerequisites:**
All students must have a solid understanding of basic principles in chemistry, geology, mineralogy, igneous and metamorphic petrology.

**Short program:**
The course is designed to provide an introduction to the principles and applications of isotope geochemistry. We first focus our interest on what factors govern nucleus stability and trigger radioactivity. An understanding of how stable and radioactive nuclides are generated is then achieved by studying nucleosynthetic processes. The foundations of stable isotope geochemistry are then reviewed. A special emphasis is put on their use in cosmochemistry, geothermometry, hydrology and paleoclimatology. Isotopic systems discussed include the classic long-lived radiogenic systems (Rb-Sr, Sm-Nd, Lu-Hf and U-Th-Pb) as well as extinct radioactivities. Applications as chronometers or tracers are focused on a wide range of topics ranging from processes and timescales relevant to the formation of the planet and solar system, the evolution of the Earth system to environmental issues. Course consists of lectures, and practical sections to work through solving problems. DETAILED COURSE CONTENT: 1. Introduction 2. Atoms and nuclei: their physics and stability 3. Radioactivity 4. Nucleosynthesis: when, where and how chemical elements are formed? 5. Principles of stable isotope geochemistry 6. Tracing the hydrologic cycle with O and H isotopes 7. Law of radioactive decay and geochronometry 8. The Rb-Sr isotope method and its applications 9. The Sm-Nd isotope method and its applications 10. The Lu-Hf isotope method and its applications 11. The U-Pb, Th-Pb and Pb-Pb isotope methods and its applications

**Examination:**
Course learning goals will be assessed by written examinations.

**More information:**

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### METAMORPHIC PETROLOGY

**Master’s degree in ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021, Second semester**

**Lecturer:** Prof. OMAR BARTOLI

**Credits:** 6 ECTS

**Prerequisites:**
In order to take full advantage of the course and be able to fully follow the classes, the student needs basic knowledge of petrography, geochemistry and mineralogy, as well as of English.

**Short program:**
The course will provide deep insight into the main aspects of metamorphic petrology, such as: - Metamorphism: review of the basic concepts (definition and limits of metamorphism, factors controlling metamorphism, metamorphic grade, concept of metamorphic facies, types of metamorphism) - Equilibrium
Examination:
The acquired knowledge and skills will be assessed through an oral examination in English

More information:

MINERAL PROCESSES AND ENVIRONMENTAL APPLICATIONS

Master's degree in ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021, Second semester

Lecturer: Prof. LUCA VALENTINI

Credits: 6 ECTS

Prerequisites:
Basic knowledge of geology, sedimentary geology, paleontology, geomorphology...

Short program:

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).

More information:

PAST LIFE AND CLIMATES

Master's degree in ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021, First semester

Lecturer: Prof.ssa CLAUDIA AGNINI

Credits: 12 ECTS

Prerequisites:
Basic knowledge acquired during the BSc course (general geology, sedimentary geology, paleontology, geomorphology...)

Short program:
1st Module: Past life One of the basic paradigms of geology is that the present is the key to the past. In recent years, however, and especially considering the increasingly important role played by humans in changing our Planet, scientists are turning that basic tenet around to the past is the key to the future. A proxy-based approach is fundamental to reconstruct past conditions. Proxies are physical, chemical and biological materials preserved in the geologic record allowing for the estimation of climatic or environmental parameters. Proxy-based reconstructions span all timescales, from year-to-year variations to those that occurred over millions of years and provide a tool in order to better understand how climate and environments has varied trough time both before and after human-related alteration of the Earth. In this context this course will focus on: 1) Main geological archives (sediments, corals, trees, ice cores, speleothems, instrumental datasets). Completeness, Resolution and time frame. 2) Main proxies in terms of their rationale, calibration (direct, indirect) and possible applications with the final aim to reconstruct past environments and climates. Proxies considered are: • Biotic: Terrestrial (pollen and spores; plant macrofossils) and aquatic (foraminifers, calcareous nanofossils, ostracodes, diatoms, radiolarians and silicoflagellates, corals, dinoflagellates cysts, mollusks); • Chemical: composition of shells; biomarkers, elemental analysis; • Physical: Sediment Composition. Types of minerals and fossils; The information acquired will be applied by means of a discussion of a case study and would serve to emphasize the potential of the fossil record in reconstructing the past (e.g., modern analogues) as well as interpreting changes observed in perturbated present day environments. 2nd Module: Past Climates Compelling evidence indicates that, since the early days of its Byr-long history, our planet had to cope unceasingly with changes in regional and global climates, which occurred on different time scales and amplitudes. However, predictive models proved to fail short when attempting precise forecasts of future climate trends, since the Earth climate system is complex, manifold and hardly predictable in its behavior. Crucial insights are provided by investigating the climate history in the Geologic past, which holds the key for understanding the future of our planet. The Course will be organized as follows: 1 - Introduction to the Climate System (2.5 CFU), Climate: definitions and calculation of the Earth radiative balance. Elements of descriptive and dynamic Oceanography. The astronomical theory of climate. Stable oxygen isotopes for paleoclimate reconstructions. 2 - Past climates of the Earth (3 CFU) The great Proterozoic and Paleozoic glaciations. Mesozoic: from the Early Triassic wastelands to the Cretaceous Thermal Maximum. Paleogene: the beginning of the Southern Hemisphere Glaciation. The Neogene and the Northern Hemisphere Glaciation. The Pleistocene: evolution of climate cycles and orbitally-paced glacial dynamics. High-frequency climate variability: the Holocene. Climate cycles at the centennial and decadal scales. Open discussion (class lab).

Examination:
1st Module: Past life The knowledge/skills acquired during the course is/are checked by means of a written examination during which the concepts, the scientific terminology, the synthesis ability and the critical spirit will be evaluated. 2nd Module: Past Climates Student's grades will be ascertained by means of an oral, open-question exam, in order to gauge the ability of the candidate to engender connections between different subjects and to establish critical and original approaches to the matter in question.


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**QUANTITATIVE METHODS FOR EARTH SCIENTISTS**

Master's degree in **ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021**, First semester

**Lecturer:** Dott. RICCARDO BIONDI

**Credits:** 6 ECTS

**Prerequisites:** Basic knowledge of mathematics and physics.

**Short program:**
- Initial review of basic concepts: single variable functions and multivariate functions; derivatives and partial derivatives; integrals; the study of functions, vectors and matrices; basic notions of probability and statistics with applications. - Methods for data analysis: Probabilistic treatment of geophysical data; Frequency and probability functions; Using statistics to describe and summarize datasets; Fitting a probability distribution of actual data; Probability distributions for relevant variables for earth scientists; Regression analysis (covariance and correlation, correlation coefficient, linear and non-linear regression). - Time series analysis. - Analysis of spatial data: Different interpolations methods; Application to actual data. - Basics of numerical methods and applications: Resolution of linear systems; Introduction to the numerical solution of ordinary and partial differential equations; Finite difference and finite element methods.

**Examination:**
Written and oral exam. Students will also have to develop a short project in which they apply the theoretical tools acquired during the course to a specific problem that they themselves propose, and that will be discussed during the exam.


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**DIGITAL GEOLOGICAL MAPPING**

Master's degree in **ENVIRONMENTAL GEOLOGY AND EARTH DYNAMICS ORD. 2021**, Second semester

**Lecturer:** Prof. GIORGIO PENNACCHIONI

**Credits:** 6 ECTS

**Prerequisites:** Basic geological knowledge and geological mapping skill

**Short program:**
The geological mapping and survey activities are nowadays performed with advanced technical approaches both in the field and at the stage of data analysis. The course will give particular emphasis on small-scale (km-scale or lower) mapping, Digital Outcrop Models reconstructions and analysis and simplified 3D geo-modelling applied on different geological contexts, application of different approaches of close range remote sensing. The main contents can be listed as follows: • Methodology and approaches of high scale geological mapping in geo-structural, stratigraphic and applied geomorphological contexts • Stratigraphic and structural description of geological cores and BHTV acquisitions • Field Move application for geological mapping • Data integration in GiS platforms • Photogrammetry, Digital Outcrop Models reconstruction and 3D geological analysis. • Principle of hyperspectral remote sensing and close range applications • Basic concepts and applications of 3D Geological models

**Examination:**
Evaluation of the products derived from the practical activities and oral presentation


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**EVOLUTIONARY BIOLOGY ORD. 2018**

Master's degree in **EVOLUTIONARY BIOLOGY ORD. 2018**, First semester
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:

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

More information:
https://en.didattica.unipd.it/offer/2021/LM/SC/SC1179/000ZZ/SCP054388/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. 2) The perception of the environment (1.5 CFU). Relationship between sensory structures and adaptive needs. Photoreception; Mechanoreception; electrosensation; thermoreception; chemoreception. 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/2021/LM/SC/SC1179/000ZZ/SCP8084977/NO

ETHOLOGY

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

Lecturer: Dott. BENIAMINO TULIOZI

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/2021/LM/SC/SC1179/000ZZ/SCN1031442/NO

EVOLUTION AND CONSERVATION

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

Lecturer: Prof. LEONARDO CONGIU

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 time scale. 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/2021/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:
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. 2) The perception of the environment (1.5 CFU). Relationship between sensory structures and adaptive needs. Photoreception; Mechanosensation; electrosensation; thermoception; chemosensation; magnetosensation. 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/2021/LM/SC/SC1179/000ZZ/SCP8084997/NO

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GEOLOGY AND TECHNICAL GEOLOGY ORD. 2009

APPLIED SEDIMENTARY GEOLOGY

Master's degree in GEOLOGY AND TECHNICAL GEOLOGY ORD. 2009, First semester

Lecturer: Prof. MASSIMILIANO GHINASSI

Credits: 6 ECTS

Prerequisites:
Basic concepts of geology (structural geology, geodynamic settings, lithology (different types of rocks) and geomorphology (geomorphic configuration of the main depositional environments). Complete view of the main geological processes and main basics of geology, geomorphology, sedimentary geology and paleontology. Comprehensive knowledge of sedimentology (depositional dynamics and stratal architecture of different depositional environments), lithology and sedimentary petrography (sedimentary rocks and sediments, optical microscope analyses), paleoecology and biostratigraphy (fossil determination and biostratigraphic meaning).

Short program:
The course will be based on a multidisciplinary approach and will be developed on the analyses of data collected in the frame of a 3-days excursion, which will be held within the first two weeks of the course. Content of the course will be as follows: Introduction to the main geomorphological, geological and stratigraphic features of the selected study area Introduction to the research program (goal of the study and schedule) and summary of the main research methodologies Field activities and data collection Sedimentology: facies analyses and reconstruction of depositional dynamics, architectural analyses and definition of 3D sedimentary bodies, summary Hydrology and hydrodynamics: data collection from modern systems and paleoflow reconstruction from te stratigraphic record Sedimentary petrography: sediment characterization, provenance analyses, summary Paleoeoecology and biostratigraphy: determination of fossil content, biostratigraphy and ecobiostratigraphy, paleoenvironmental reconstruction, summary

Examination:
Witten test. The test will be based on interpretation and elaboration (written report) of specific datasets, which will be provided consistently with the topics of the course.
CARBONATE SEDIMENTOLOGY

Master's degree in GEOLGY AND TECHNICAL GEOLOGY ORD. 2009, First semester

Lecturer: Prof. NEREO PRETO

Credits: 6 ECTS

Prerequisites:
Knowledges of sedimentary geology and clastic sedimentology; base notions of chemistry. Having taken, or being taking "Sedimentology" is recommended.

Short program:
- Te carbon cycle in the oceans, and some notions of physical oceanography; - the precipitation of carbonates as a chemical and biological process; - origin of carbonate platforms and deep-water carbonates; - types of carbonate platforms, their depositional architectures, and their dynamic stratigraphy; - sequence stratigraphy of carbonates - theory and practice; - dolomitization processes and principles.

Examination:
The marking is based on two documents: a mid-term report based on class excercises and a final exam. The report is the interpretation of a carbonate depositional system, presented as a idealized geological cross section of a carbonate platform, which is being studied during the course. The final exam is a written test, which requires to answer briefly, with a short text or with geological sketches, to open questions.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1180/000ZZ/SCP8083422/NO

COASTAL ENVIRONMENTS UNDER CLIMATE CHANGE

Master's degree in GEOLGY AND TECHNICAL GEOLOGY ORD. 2009, First semester

Lecturer: Prof. ANDREA D'ALPAOS

Credits: 6 ECTS

Prerequisites:
Basic mathematics and physics (Calculus 1 and 2, Experimental Physics).

Short program:
- Morphodynamics and biogemorphodynamics. Short introduction to coastal systems and to their morphodynamic evolution in response to physical and biological forcings (0.5 CFU). - Relative sea level and its variations. Tides, waves, currents, and sediment transport processes in shallow water systems (1.5 CFU). - Morphology and evolution of barrier islands, lagoons, deltas, and estuaries (2.5 CFU). - A case study: The Venice Lagoon and its morphological evolution during the past centuries. Will Venice survive? (0.5 CFU). - General effects of a rising sea level. Natural and anthropogenic forcings. Effects of a changing climate. Effects on lagoons, deltas, and estuaries (1.0 CFU).

Examination:
Written exam (open questions and exercises). Possibility to take a further oral exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1180/000ZZ/SCQ0094239/NO

ENVIRONMENTAL GEOPHYSICS

Master's degree in GEOLGY AND TECHNICAL GEOLOGY ORD. 2009, First semester

Lecturer: Prof. JACOPO BOAGA

Credits: 6 ECTS

Prerequisites:
Prerequisites are: the course of Applied Geophysics (I year)
Examination:
Systems • International, national, regional and local legislation on the use of geothermal resources. 
Sizing; numerical models of hydro-thermal simulation of pick-and-return well systems - applications of geothermal solution for space free cooling - day and solar and endogenous sources. Time-variant analysis of ground probe relations. • Open-loop systems with groundwater use, building criteria and well uncertainties, innovative experimental techniques and data analysis. • Assessments of the undisturbed subsurface temperature and its relationship with the Theory, working hypotheses, operational modes, data analysis, instrumentation for the test with heat injection and heat extraction, measurement uncertainties, innovative experimental techniques and data analysis. • Assessments of the undisturbed subsurface temperature and its relationship with the solar and endogenous sources. Time-variant analysis of ground probe relations. • Open-loop systems with groundwater use, building criteria and well sizing; numerical models of hydro-thermal simulation of pick-and-return well systems - applications of geothermal solution for space free cooling - day and seasonal thermal storage in the underground matrix and in aquifers. - The environmental component of geo-exchange, sustainability and renewable systems • International, national, regional and local legislation on the use of geothermal resources.
**MINERAL FORMING PROCESSES**

Master's degree in GEOLOGY AND TECHNICAL GEOLOGY ORD. 2009, Second semester

**Lecturer:** Prof. LUCA VALENTINI  

**Credits:** 6 ECTS  

**Prerequisites:**  
Basic knowledge of mathematics, physics, chemistry and mineralogy.

**Short program:**  
2. Surface properties and the mineral/water interface: specific surface area; surface defects; surface charge. Case studies: nanoparticles for environmental remediation.  

**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).

**More information:**  
https://en.didattica.unipd.it/off/2021/LM/SC/SC1180/000ZZ/SCQ0094238/NO

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**PALEOCLIMATOLOGY AND PALEOCEANOGRAPHY**

Master's degree in GEOLOGY AND TECHNICAL GEOLOGY ORD. 2009, First semester

**Lecturer:** Prof. LUCA CAPRARO  

**Credits:** 6 ECTS  

**Prerequisites:**  
Basic knowledge acquired during the BSc course (general geology, sedimentary geology, paleontology, geomorphology...)

**Short program:**  
1st Module: Past life One of the basic paradigms of geology is that the present is the key to the past. In recent years, however, and especially considering the increasingly important role played by humans in changing our Planet, scientists are turning that basic tenet around to the past is the key to the future. A proxy-based approach is fundamental to reconstruct past conditions. Proxies are physical, chemical and biological materials preserved in the geologic record allowing for the estimation of climatic or environmental parameters. Proxy-based reconstructions span all timescales, from year-to-year variations to those that occurred over millions of years and provide a tool in order to better understand how climate and environments has varied trough time both before and after human-related alteration of the Earth. In this context this course will focus on:  
1) Main geological archives (sediments, corals, trees, ice cores, speleothems, instrumental datasets). Completeness, Resolution and time frame.  
2) Main proxies in terms of their rationale, calibration (direct, indirect) and possible applications with the final aim to reconstruct past environments and climates. Proxies considered are: • Biotic: Terrestrial (pollen and spores; plant macrofossils) and aquatic (foraminifers, calcareous nanofossils, ostracodes, diatoms, radiolarians and silicoflagellates, corals, dinoflagellates cysts, mollusks); • Chemical: composition of shells; biomarkers, elemental analysis; • Physical: Sediment Composition. Types of minerals and fossils. The information acquired will be applied by means of a discussion of a case study and would serve to emphasize the potential of the fossil record in reconstructing the past (e.g., modern analogues) as well as interpreting changes observed in perturbated present day environments.  
2nd Module: Past Climates Compelling evidence indicates that, since the early days of its Byr-long history, our planet had to cope unceasingly with changes in regional and global climates, which occurred on different time scales and amplitudes. However, predictive models proved to fall short when attempting precise forecasts of future climate trends, since the Earth climate system is complex, manifold and hardly predictable in its behavior. Crucial insights are provided by investigating the climate history in the Geologic past, which holds the key for understanding the future of our planet. The Course will be organized as follows:  
1 - Introduction to the Climate System (2.5 CFU). Climate: definitions and calculation of the Earth radiative balance. Elements of descriptive and dynamic Oceanography. The astronomical theory of climate. Stable oxygen isotopes for paleoclimate reconstructions.  

**Examination:**  
1st Module: Past life The knowledge/skills acquired during the course is/are checked by means of a written examination during which the concepts, the scientific terminology, the syntesis ability and the critical spririt will be evaluated.  
2nd Module: Past Climates Student's grades will be ascertained by means of an oral, open-question exam, in order to gauge the ability of the candidate to engender connections between different subjects and to establish critical and original approaches to the matter in question.
GEOPHYSICS FOR NATURAL RISKS AND RESOURCES (ORD. 2020)

GEOPHYSICS FOR CULTURAL HERITAGE AND CIVIL ENGINEERING

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

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: Basic knowledge of applied geophysics

Short program:

Examination:
The exam includes an oral test focused on the discussion of a case study of the student's choice, including those proposed during the course.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1180/000ZZ/SCM0018542/NO

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

Prerequisites: None

Short program:
- review of basic concepts: probability, odds and rules, updating probabilities, uncertain numbers (probability functions) - from Bernoulli trials to Poisson processes and related distributions - Bernouilli theorem and Central Limit Theorem - Inference of the Bernouilli p; inference of lambda of the Poisson distribution. Inference of the Gaussian mu. Simultaneous inference of mu and sigma from a sample: general ideas and asymptotic results (large sample size). - fits as special case of parametric inference - Monte Carlo methods: rejection sampling, inversion of cumulative distributions, importance sampling. Metropolis algorithm as example of Markov Chain Monte Carlo. Simulated annealing - the R framework and language for applied statistics.

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/2021/LM/SC/SC2543/000ZZ/SCQ1098758/NO

APPLIED GEOPHYSICS

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

Lecturer: Prof. GIORGIO CASSIANI

Credits: 9 ECTS

Prerequisites: Essential prerequisites include: basics of physics and mathematics.

Short program:
The course will be composed of three parts: part 1: introduction to exploration geophysics; this part will introduce the general concepts of applied geophysics with particular regard to: • physical principles of the main electrical, electromagnetc, seismic, magnetic and gravimetric methods • concepts of resolution and penetration • general definition of geophysical inversion • basic concepts about data acquisition of the main methodologies Part 2: exploration methods: - seismic methods, with basics of reflection and refraction seismics, and basics of surface wave methods; - DC resistivity methods with tomographic applications; - Ground penetrating radar (GPR) - Electromagnetic Induction methods (EMI) - Gravimetric methods - Magnetic methods - Induced polarization methods For all methods special attention will be given to their applications, with examples from literature and from the experience of the lecturer. Part 3: Demonstration will be given of the main methods, followed by processing, inversion and interpretation of laboratory data.

Examination:
Oral examination. Possible discussion of a scientific paper to be chosen among the ones previously distributed to students.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089219/NO

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**APPLIED HYDROLOGY**

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

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

**Credits:** 6 ECTS

**Prerequisites:**
Basic knowledge of mathematics, physics, science, and elementary statistics is required for student success.

**Short program:**

**Examination:**
Written exam on theoretical issues and practical applications (open questions and exercises). Preliminary discussion of the results of the exercises carried out during classes.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089235/NO

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**EARTHQUAKE GEOLOGY AND FAULT MECHANICS**

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

**Lecturer:** to be defined

**Credits:** 6 ECTS

**Prerequisites:**
Very basic (= not in depth) knowledge in geology, geophysics, physics and calculus.

**Short program:**
Topics: Stress and Strain, Deformation Processes in the Lithosphere, Brittle fracture and friction of rocks, Faults and Structure of Fault Zones, Earthquake mechanics and the seismic cycle, Earthquakes and Tectonics, Earthquake forecasting and hazard (including earthquake-triggered landslides and tsunamis), Human-induced seismicity

**Examination:**
Evaluation of the gained abilities will be evaluated with a final written test on the topics discussed in the classes plus power-point presentations of (1) the laboratory activities and (2) the field trip (see below).

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ1098476/NO

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**ELECTROMAGNETISM**

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

**Lecturer:** Dott. ALVISE RACCANELLI

**Credits:** 6 ECTS

**Prerequisites:**
Basics of mechanics, gravitation and calculus I. Notions of vectors, integrals, differentials.

Short program:
Electrostatics, Magnetostatics Vector integral calculus Electric and magnetic fields. Potentials. Maxwell equations

Examination:
Oral exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089220/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 exam with discussion of a scientific paper from a list proposed by the Teacher.

More information:
https://en.didattica.unipd.it/off/2021/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. LORENZO PETRONIO

Credits: 6 ECTS

Prerequisites:
Essential prerequisites include: basics of physics and mathematics.

Short program:
1 - Introduction Exploration seismology: What? Why? How? Short history of the exploration seismic 2 - Fundamental theories Seismic waves Types of seismic waves, Attenuation, Reflection, Refraction and Diffraction of elastic waves. Effects of the medium on wave propagation, Partitioning of energy at an interface, Distinguishing features of seismic events, Events other than primary reflections, Characteristics of reflections, Types of seismic noise and their attenuation Signal theory Wavelets, Convolution, Frequency domain and analysis, Autocorrelation, Cross-correlation, Deconvolution, FK and Tau-pi domains. 3 - Seismic survey planning Targets, Depth, Resolution, Logistic, Budget. Geological/tectonic context, Evaluation of the method applicability, Synthetic data computation. Previous data analysis and complimentary information, Walkaway test. 4 - Seismic Data Acquisition Land equipments: sources, sensors and data recorder. Multi-component seismic data acquisition, Borehole seismic (VSP), transition zone. Marine equipment and methods: Marine operations, Marine energy sources and detectors (hydrophone and dual sensor). Airgun and environment. OBS, OBC. 5 - Seismic Data Processing Field QC. Basic processing: data editing, geometry, gain, 1D/2D filtering, deconvolution, static correction, NMO correction, stack, time to depth conversion, migration (basic concepts). 6 - Seismic Data Analysis and Interpretation Pre-stack and post-stack data analysis, data interpretation (basic concepts) 7 – Special topics Seismic while-drilling, Vibrometric measurements, Seismic nodes. 8 – Case histories Selected cases from teacher experience and literature.

Examination:
Oral exam based on the arguments covered by the course and discussion on the survey planning to solve a practical case.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089233/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

Prerequisites:
Basic knowledge in geology and geophysics.

Short program:
This course is structured to provide basic knowledge of geology that may be useful to a geophysicist in order to interpret observations made in the field. Rocks will be studied in relation to the geodynamic environments of formation, to describe the formation of sedimentary rocks, igneous rocks, and metamorphic rocks. The course will be practical in nature: from observation to interpretation. For this reason, three days of field trip will be carried out, in which the students will make observations, acquire geological data, and learn how to organize a fieldwork. The course will deal with how to read and interpret geologic maps. - Plate tectonics and the Wilson cycles. - Orogenic process and Introduction to the Apennines and Alps. - Sedimentary rock, in the context of Apennine-Alps evolution. - Igneous rock, in the context of Apennine-Alps evolution. - Metamorphic rock, in the context of Apennine-Alps evolution. - Rock deformation - surface processes - Geological mapping - Collecting and handling geological field data

Examination:
The examination consists in a written test focused on the different arguments of the course and on the observation made during the field trip

More information:
https://en.didattica.unipd.it/off/2021/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

Prerequisites:
Basic geological background

Short program:

Examination:
Written examination

More information:
https://en.didattica.unipd.it/off/2021/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. LORENZO BREZZI

Credits: 6 ECTS

Prerequisites:
There are no prerequisites

Short program:

Examination:
Oral exam

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

Lecturer: Prof. ANTONIO GALGARO

Credits: 6 ECTS

Prerequisites:
Basic knowledge in hydrogeology, thermodynamics, structural geology, geochemistry, physics of the Earth

Short program:
The course aims to deepen the application aspects of geothermal energy in relation to the following contents: thermo-physical properties of natural materials; relation between geothermal reservoirs and structural traps, geochemical and isotopic survey methodologies finalized to geothermal exploration, on site thermo-physical survey methodologies. Examples of the exploration and use of endogenous heat, as well as the use of the subsurface as a heat source and receptor, will be described in detail by assessing in particular the geological competence in a highly multidisciplinary perspective. Excursions in the geothermal construction site at various types of geooxchange plants under construction, and in Larderello Area (Tuscany) visiting the geothermal power plants of Enel Green Power Company excursion to thermal storage facilities underground. The geothermal resource and the current energy framework. High and medium entalpy resources. National and international situation, scenarios and possible technical regulatory developments • Fundamentals of thermophysics • Thermophysical properties of materials, heat transmission mechanisms with emphasis on aspects of transitory conduction processes, flow and geothermal gradient. Endogenous heat, sources and energy assessments • Subsurface classification, aquifers, soil permeability, wells and piezometers, surveys and other forms of detection. Hydrogeological aspects aimed at determining the characteristics of hydrothermal systems. High-medium entalpy geothermal systems Exploration methods, geothermal drilling, geothermal reservoir characterization, geothermal reservoir simulation models, relationships between tectonic and geothermal assessment, unconventional geothermal resources, social, economic and environmental impact assessments. Geothermal systems for air conditioning proposes with open groundwater and closed-circuit systems with wells and ground heat exchangers. Types of ground heat exchangers, energy geo-structures (geo-foundations), introduction to thermal storage systems, underground thermal storage systems (ATES). • The drilling site, the work realization of geothermal probes (open-air lesson - visit on site). • Geothermal heat pumps, integration of geothermal air conditioning systems with other renewable sources and hybrid systems • Closed-circuit ground heat exchange systems; examples of vertical probe sizing; procedure, parameters of influence, simplified analytical methods of sizing geothermal probes; The Ground Thermal Response Test. Theory, working hypotheses, operational modes, data analysis, instrumentation for the test with heat injection and heat extraction, measurement uncertainties, innovative experimental techniques and data analysis. • Assessments of the undisturbed subsurface temperature and its relationship with the solar and endogenous sources. Time-variant analysis of ground probe relations. • Open-loop systems with groundwater use, building criteria and well sizing; numerical models of hydro-thermal simulation of pick-and-return well systems - applications of geothermal solution for space free cooling - day and seasonal thermal storage in the underground matrix and in aquifers. - The environmental component of geo-exchange, sustainability and renewable systems • International, national, regional and local legislation on the use of geothermal resources.

Examination:
Oral examination. The test involves discussing about a topic, prepared individually by the student, regarding one or more course topics

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089232/NO

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

Lecturer: Prof. MARCO ZANETTI

Credits: 6 ECTS

Short program:
The working principles and logic schemes of a modern computer and its main components. Review of the available hardware solutions to face problems in various areas of scientific computing: parallel computing, cluster/cloud computing, distributed computing - The python programming language, from the bases to the advance programming for scientific computing; review of the modern libraries for the data management and analysis (numpy, scipy, pandas, sciiti-learn, etc.) - Monte Carlo methods for the simulation of physics phenomena - Techniques to assess and extract the statistical features of a physics datasets and comparison with model predictions - Visualisation and graphical representation of datasets and their properties

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089439/NO

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

Lecturer: Prof. PIETRO ZANUTTIGH

Credits: 6 ECTS

Prerequisites:
91/221
Basic knowledge of Mathematics, Probability Theory, Statistics, Linear Algebra, Algorithms and basic programming skills.

Short program:

Examination:
The evaluation of the acquired skills and knowledge will be performed using two contributions: 1. A written exam without the book, where the student must solve few problems, with the aim of verifying the acquisition of the main ingredients of a learning problem and of the main machine learning tools, the analytical ability to use these tools and the ability to interpret the typical results of a practical machine learning problem. 2. Computer simulations (optional) with the aim of acquiring the practical competences for using machine learning tools. These simulations, to be performed at home, allow to verify the ability of practically exploiting the acquired theoretical concepts. The student will have to provide a brief document explaining the employed methodologies used to solve the assigned problem together with the obtained results. The final grade will be based on the written test with a bonus up to 3 point for the students who will hand in also the lab assignments.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCP8082660/NO

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**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

**Short program:**
Part 1) Data Management Introduction to data structures Storage Models Reliability Availability Authentication, Authorization Local and Distributed File systems Cloud storage Databases Part 2) Data processing Introduction to parallel processing Distributed Computing Systems and the Grid paradigm Cloud computing service models Virtualization Containerization Hadoop as a paradigm for big data processing Data processing with Spark Data processing with Dask Kafka as a distributed streaming platform

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089438/NO

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**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

**Prerequisites:**
High-school level maths and physics (trigonometry, derivatives, integrals, Newton’s laws)

**Short program:**
• Elements of linear algebra and calculus • Theory of gravitation • Elements of fluid dynamics • Elements of acoustics • Elasticity theory • Linear inverse problems • Elements of informatics (Matlab/Octave)

**Examination:**
Written exams with questions on the contents of the course, and problem solving based on the methods learned during the course.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089222/NO

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**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
Prerequisites:
Basic knowledge on: - partial differential equations (PDEs) - finite element analysis; - linear algebra (and elements of functional analysis); - programming (e.g., matlab, python, ...)

Short program:

Examination:
To be defined.

More information:
https://en.didattica.unipd.it/off/2021/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

Prerequisites:
Basic vector calculus, numerical calculus, notion of partial differential equations, linear algebra

Short program:
Introduction, important PDEs of physics, mathematical nature of PDEs, Scale analysis of PDE, Finite volume, finite element and finite difference methods, coupled problems and solution strategies, solution of linear systems. Numerical project implementing a finite element/finite difference method in a computer for solving a transient 2D partial differential equation.

Examination:
Oral exam in which the student will be asked to discuss theoretical aspect of the discretization methods studied during the course. Moreover the student will present and critically discuss the results of a numerical project for the discretization by finite elements or finite differences of an elliptic or a parabolic equation.

More information:
https://en.didattica.unipd.it/off/2021/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

Credits: 6 ECTS

Prerequisites:
Basic knowledge of mathematics, physics and MatLab (provided during the Laurea Triennale)

Short program:

Examination:
Oral and practical test

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089223/NO

NUMERICAL METHODS FOR HIGH PERFORMANCE COMPUTING

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

Lecturer: Prof. CARLO JANNA
Credits: 6 ECTS

Prerequisites:
Numerical Methods for Differential Equations

Short program:

Examination:
Oral discussion of the numerical project carried out during the course.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089199/NO

PETROPHYSICS

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

Lecturer: Dott.ssa ELOISA DI SIPIO

Credits: 6 ECTS

Prerequisites:
Basic knowledge of mathematics, physics and geophysics acquired during the Bachelor degree.

Short program:

Examination:
An oral exam on the topics dealt with and discussed during the frontal lessons will verify the degree of knowledge acquired.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089224/NO

PHYSICS DATA ANALYSIS

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

Lecturer: Prof. MARCO BAIESI

Credits: 6 ECTS

Short program:
* Gradient descent methods * Ridge and LASSO regularization * Supervised learning and unsupervised learning * Deep neural networks and convolutional version * Clustering * Data visualization * Energy-based models * Restricted Boltzmann machines * Combination of models: bagging, random forests, boosting, XGBoost

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089405/NO

PROGRAMMABLE HARDWARE DEVICES

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

Lecturer: Prof. GIANMARIA COLLAZUOL

Credits: 6 ECTS

Short program:
PART I - Electronics for real-time data management systems 1) Data Sources - signal generation in sensors/detectors - early (analog) data processing

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089440/NO

SOLID EARTH GEOPHYSICS

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

Lecturer: Prof. LAPO BOSCHI

Credits: 9 ECTS

Prerequisites:
High-school level maths and physics (trigonometry, derivatives, integrals, Newton’s laws)

Short program:
• seismology: the structure of the earth • geochemistry: the composition of the earth • geodynamics: the origin of mountains • geodynamics: continental drift and plate tectonics • geodynamics: rheology and convection

Examination:
Written exams with questions on the contents of the course, and problem solving based on the methods learned during the course.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2543/000ZZ/SCQ0089218/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

Prerequisites:
Good knowledge of mathematical analysis, calculus and basic physics. For “Physics of Data” students the course has 6 CFU. However, if they are not adequately trained in statistical mechanics, they are encouraged to follow all 9 credits

Short program:
The program can be summarized as follows Statistical mechanics and Entropy Ising model Variational principles in statistical mechanics Complex networks Principle of maximum entropy and inference Diffusion Processes and stochastic dynamics Montecarlo simulations Dynamics of and on networks Population dynamics with applications to ecosystems Percolation on networks. Neural networks

Examination:
The first part of the verification of the acquired knowledge will evaluate the homework exercises and the participation of the students in the class discussions The second part will takes place through, a common written test with 1-2 exercises to be solved and open questions to test the knowledge on basic concepts, the scientific vocabulary, the ability to synthesis and critical discussion acquired during the course. The third 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/2021/LM/SC/SC2543/000ZZ/SCP8082536/NO

INDUSTRIAL BIOTECHNOLOGY ORD. 2014

METAGENOMICS AND INTERACTOMICS

Master’s degree in INDUSTRIAL BIOTECHNOLOGY ORD. 2014, First semester
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/2021/LM/SC/SC1731/000ZZ/SCQ0093438/NO

BIOENERGY PRODUCTION

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

Lecturer: Prof. STEFANO MAMMI

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

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/2021/LM/SC/SC1731/000ZZ/SCP9088068/NO

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**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 knowledge of environmental chemistry, microbiology, biochemistry, and toxicology.

**Short program:**

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

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1731/000ZZ/SCP9088082/NO

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**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 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.

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/2021/LM/SC/SC1731/000ZZ/SCP9088068/NO

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97/221
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/2021/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:
Knowledge of General, Inorganic and Organic Chemistry, Biology and Genetics.

Short program:

Examination:
The following mode of examination may change in an emergency. 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 aspects will be viewed positively.

More information:
https://en.didattica.unipd.it/off/2021/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/2021/LM/SC/SC1731/000ZZ/SCQ1097952/NO
ANALYTICAL CHEMISTRY OF INDUSTRIAL PROCESSES

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

Lecturer: Prof. MARCO FRASCONI

Credits: 6 ECTS

Prerequisites:
Knowledge of instrumental analysis: molecular spectroscopy (UV-Vis and infrared spectroscopies), electroanalytical chemistry (potentiometry and voltammetry), gas-chromatography and high-performance liquid chromatography.

Short program:

Examination:
The exam consists of a written essay, on a focused topic on process analytical control, and an oral exam with the presentation and discussion of the essay, followed by two questions on the core topics of the course. The final mark is calculated from the assessment marks of the written essay and oral exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1170/000ZZ/SCP9087648/NO

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/2021/LM/SC/SC1170/000ZZ/SCP9087647/NO

MARINE BIOLOGY ORD. 2020

BIODIVERSITY AND BEHAVIOUR
FARMING AND FEEDING OF AQUATIC SPECIES

Master's degree in MARINE BIOLOGY ORD. 2020, 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/2021/LM/SC/IF0360/000ZZ/SCQ0093501/NO

FISH REPRODUCTION IN AQUACULTURE

Master's degree in MARINE BIOLOGY ORD. 2020, 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 malting.

Examination:

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/IF0360/000ZZ/SCQ0093498/NO
**MARINE MICROBIOLOGY**

Master's degree in **MARINE BIOLOGY ORD. 2020**, First semester

**Lecturer:** Prof.ssa PAOLA VENIER  
**Credits:** 6 ECTS  
**Prerequisites:**  
No prerequisites. However, notions of microbiology and biochemistry are essential.

**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 microorganisms (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. The examination procedure could change in an emergency. The student will be tested on the contents of the course (50%) and one or two specific topics, previously agreed with the teacher and individually elaborated (50%).

**More information:**  
https://en.didattica.unipd.it/off/2021/LM/SC/IF0360/000ZZ/SCQ0093499/NO

**MARINE BIOLOGY ORD. 2021**

**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, poikilothermia 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 hyperoxia.

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

**Experimental Design and Statistical Analysis**

**Lecturer:** Dott. DUC KHANH TO

**Credits:** 6 ECTS

**Prerequisites:**
No prerequisites are required to attend the course

**Short program:**
First part (2 CFU + 1 CFU practical): Focus is on testing hypotheses for cause and effect. Via examples of selected experiments, discussions of hot topic articles, and group self-practice students will be introduced to the methodological and design issues in planning an experiment. The aim is building the knowledge basis to enable students to have a fully designed experiment, which can be carried out as a thesis dissertation proposal or research paper. We will go through controlled experiments and field experiments, single factor experiments and factorial designs, manipulation checks, environmental impact assessment etc., and walk through the steps in deciding which of these elements can be best used in the creation of each experiment. Specific topics include: 1) General structure of a scientific paper 2) The scientific method - a logical framework for hypothesis testing in ecology 3) components of an experimental test; hypothesis and statistical test; statistical population and representative sampling; variables, parameters, and frequency distributions; precision, accuracy and bias; 4) Experimental design: Factorial and nested designs; fixed and random factors; replication and pseudoreplication; random, systematic, stratified allocation of sampling units; interspersion and independence of sampling units; controls and experimental artefacts; BACI designs for impact assessment and other asymmetrical designs 5) Sampling: number of replicates; Sample size; how to allocate replication in space and time; measured response variables and sampling approaches 6) How to prepare a good data set and analyse collected data. 7) How to interpret and present the outcomes. Second part (2 CFU +1 CFU practical): univariate and multivariate methods to evaluate association among biotic and abiotic variables, their relationships and presence of structures with gradients in experimental data. Specifically: inferential methods; multiple regression; principal component analysis and multi dimensional scaling.

**Examination:**
The evaluation includes two parts, according to the course structure. The first part of the evaluation consists of a written exam with an open question on the application of the tools learnt during the course to a case study. The second part consists of a practical exam in informatics lab. The finale score is the weighted average of the two scores.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2596/000ZZ/SCQ0093518/NO

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

**Lifecycles and Adaptations of Marine Organisms**

**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/2021/LM/SC/SC2596/000ZZ/SCQ0093618/NO
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/2021/LM/SC/SC2596/000ZZ/SCQ0093620/NO

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

Examination:
Written exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2596/000ZZ/SCQ0093599/NO

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:
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.

More information:
https://en.didattica.unipd.it/it/2021/LM/SC/SC2596/000ZZ/SCQ0093552/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) Algal-stocks preparation - Method for culturing the unicellular green algae Scenedesmus dimorphus - Algal cell count on Burker's chamber - Centrifugation, pellet resuspension and storage of algal stocks 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 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. Alternatively, if it is impossible to carry out the assessment in presence, the oral exam will be taken remotely, using the ‘zoom’ software.

More information:
https://en.didattica.unipd.it/off/2021/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 and laboratories, visits at commercial plants. VET/04 Inspection and control of the hygienic status of fish 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/2021/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/2021/LM/SC/SC1174/000ZZ/SCQ1097162/NO

**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. Intermolecular interactions: force-fields; atomistic and coarse grained models. Variational methods for the solution of the Schrodinger 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/2021/LM/SC/SC1174/000ZZ/SCQ0090918/NO

**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 electroding 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/2021/LM/SC/SC1174/000ZZ/SCQ0090018/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:
1) Fundamentals of NanoScience (MSc in Materials Science and in Materials Engineering, 4 + 4 = 8 CFU) MODULE A (4 CFU) - Classification, characteristics and general properties of nanostructured materials: quantum confinement and electronic properties. Size Equations. - Thermodynamic properties of nanostructured materials: thermodynamic size effect, nucleation (Gibbs-Thomson equation) and growth of nanostructures (Diffusion-Limited Aggregation and Ostwald Ripening regimes). - Nanostructures embedded in solid matrices: ion implantation for the synthesis and processing of metallic nanostructures. Verification of the nucleation and growth models. - Optical properties of nanostructured materials: (i) plasmonic properties of non-interacting metallic nanostructures (Mie theory and its extensions); (ii) interacting nanostructures - Characterization techniques of nanostructures: transmission and scanning electron microscopy in transmission (TEM) and in scanning (SEM) mode. MODULE B (4 CFU) Overview of the preparation of nanostructures (both top-down and bottom-up, with particular emphasis on the latter). Structural aspects and energy of nanostructures and methods for their stabilization. Defects in nano dimensional materials. Solid with controlled porosity. Forms of nanoparticles: thermodynamics vs. kinetics. Core-shell nanoparticles. Self-assembly and self-organization. Colloidal method. Templating effect. Preparation of nanoparticles, nanowires, nanotubes, thin films. Self-assembled monolayers. Langmuir and Langmuir-Blodgett films. Coherent, semi-coherent, epitaxial and pseudomorphic interfaces. Growth methods for ultrathin films: CVD, MBE, PVD, ALE and PLD methods. Recall of the fundamental equations for electron and photon dynamics. Material properties for electron and photon confinement. Density of states for confined systems in one, two or three dimensions. Properties of low dimensional carbon nanostructures: graphene and nanotubes. Tight binding approach for the description of their conduction, optical properties (absorption and emission) and Raman scattering (Kataura plots). Models for the electron confinement in quantum dots in the weak and strong regime. Confinement of electrons in metallic nanoparticles and plasmonic properties. Froehlich conditions and far and near field optical properties. SERS effect with plasmonic nanostructures. Hints on the confinement of photons in photonic crystals. 2) Introduction to NanoPhysics (MSc in PHYSICS, 4 + 2 = 6 CFU The first 4 CFUs are the same as for MODULE A, previously described, which will be borrowed by the students of the 'Introduction to NanoPhysics' of the MSc Degree in Physics. The remaining 2 CFUs address the following topics: - Fundamental description of the dynamics of electrons and photons - Confinement of electrons and photons in nanostructured or periodic materials: - 2D and 3D photonic crystals: - Meta-materials: (i) with hyperbolic dispersion and (ii) with negative refractive index; - Practical laboratory activities: (i) synthesis of Au spherical nanoparticles in solution; (ii) measurement of their UV-VIS transmittance spectrum; (iii) simulation of the experimental spectra with the Mie theory; (iv) electron microscopy characterization.

Examination:
1) Fundamentals of NanoScience (MSc in Materials Science and in Materials Engineering) 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.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1174/000ZZ/SCP9087651/NO

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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/2021/LM/SC/SC1174/000ZZ/SCQ0090019/NO

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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 Eleftra 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/2021/LM/SC/SC1174/000ZZ/SCP9087654/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/2021/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 electrophile and nucleophile basicity and acidity addition reactions (alkenes) nucleophilic substitution (alcohols, halogenated compounds) Electrophilic aromatic substitution (reactions of aromatic compounds) Pericyclic reactions

**Short program:**

**Examination:**
Written exam.

More information:
https://en.didattica.unipd.it/off/2021/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
**SUPERCONDUCTING MATERIALS**

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

Lecturer: Dott. CRISTIAN PIRA

Credits: 6 ECTS

**Prerequisites:**
Solid State Physics

**Short program:**

**Examination:**
The evaluation exam on the knowledge and expected is based on an oral examination of about half an hour, structured as follows: a first part in which the student presents an application of superconductivity of his/her choice, and a second part in which open questions will be asked on all the topics covered in the course. In agreement with the students, the presentation of the applications can take place during the lectures’ semester.

**More information:**
https://en.didattica.unipd.it/it/2021/02/SC1174/000ZZ/SCP9087650/NO

**SUSTAINABLE ENERGY: MATERIALS AND TECHNOLOGIES**

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

Lecturer: Prof.ssa LAURA CALVILLO LAMANA

Credits: 8 ECTS

**Prerequisites:**

**Short program:**

**Examination:**
Oral exam. During the semester it will be possible to give a mid-term 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:**
https://en.didattica.unipd.it/it/2021/02/SC1174/000ZZ/SCP9087678/NO
Credits: 6 ECTS

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

Short program:
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 + laboratory reports

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1174/000ZZ/SCQ1097161/NO

MATHEMATICS ORD. 2011

ALGEBRAIC GEOMETRY 1

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

Lecturer: Prof.ssa ORSOLA TOMMASI

Credits: 8 ECTS

Prerequisites:
Many results are based on results from commutative algebra. Basic knowledge of commutative algebra (corresponding to roughly the first half of the commutative algebra course) is recommended.

Short program:
This course is intended as a foundational course in algebraic geometry, starting from the basics of the subject and progressing to more advanced techniques such as the study of sheaves and schemes. Contents: Affine varieties. The Zariski topology. The sheaf of regular functions on a variety. Morphisms of varieties. Projective varieties. Dimension of a variety. Introduction to schemes.

Examination:
Written exam, possibly taking homework assignments into account.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/001PD/SCQ0094306/NO

COMMUTATIVE ALGEBRA

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

Lecturer: Prof. REMKE NANNE KLOOSTERMAN

Credits: 8 ECTS

Prerequisites:
Basic notions of algebra (groups, rings, ideals, fields, quotients, etc.), as acquired in the "Algebra 1" course.

Short program:

Examination:
CRYPTOGRAPHY

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

**Lecturer:** Prof. ALESSANDRO LANGUASCO

**Credits:** 6 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. Migliardi; 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. Migliardi; 6 credits): Written Exam, Homeworks, oral test.


FUNCTIONS OF SEVERAL COMPLEX VARIABLES

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

**Lecturer:** Dott. LUCCA BARACCO

**Credits:** 6 ECTS

**Prerequisites:**
Integral and differential calculus in several real variables. Basic knowledge of Hilbert spaces. Holomorphic functions in one variable.

**Short program:**

**Examination:**
Students may choose between an Oral or written exam.


HOMOLOGY AND COHOMOLOGY

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

**Lecturer:** Prof. JAKOB SCHOLBACH

**Credits:** 6 ECTS

**Prerequisites:**
we expect the student knows that it is possible to associate some invariants (fundamental group...), basic commutative algebra.

**Short program:**
Starting from the basic definition of the algebraic topology we will introduce the definition of homology and cohomology for a topological space. Singular, simplicial, cellular, relative, excisin, mayer-vietoris. Tor and Ext: universal coefficients theorem. Cup and cap product: the ring structure on the cohomology of a projective space and some other particular topological spaces. Eventually Poincare' duality.

Examination:
taylored on the basis of the students attitudes: written and homeworks during the semester.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/001PD/SCQ0094302/NO

### INTRODUCTION TO GROUP THEORY

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

**Lecturer:** Prof. ANDREA LUCCHINI

**Credits:** 8 ECTS

**Prerequisites:**
Basic knowledges in general algebra

**Short program:**
General introduction to group theory: actions of groups, solvable and nilpotent groups, finitely presented groups. A short history of the classification of finite simple groups. Topological groups, profinite groups (characterizations, profinite completion, countable based profinite groups, arithmetical properties, subgroups of finite index in profinite groups, Galois groups of infinite dimensional extension). Probabilistic methods in group theory.

**Examination:**
Oral. The candidate will be asked to present the most important arguments presented in the course, proving the more significant results and solving some related exercise.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/001PD/SCQ0094303/NO

### INTRODUCTION TO RING THEORY

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

**Lecturer:** Prof. ALBERTO FACCHINI

**Credits:** 8 ECTS

**Prerequisites:**
Courses of "Algebra 1" and "Algebra 2". That is, standard undergraduate Algebra.

**Short program:**

**Examination:**
Oral examination and/or evaluation of the exercises solved by the students during the course.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/001PD/SCQ0094304/NO

### NUMBER THEORY 1

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

**Lecturer:** Prof. MATTEO LONGO

**Credits:** 13 ECTS

**Prerequisites:**
A standard Basic Algebra course; basic Linear Algebra; a basic course of Calculus; a short course in Galois Theory would be most useful; some familiarity with the theory of analytic functions of one complex variable would be useful.

**Short program:**

Examination:
Written and oral examination.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/001PD/SCQ0094301/NO

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**NUMBER THEORY 2**

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

**Lecturer:** Prof. ADRIAN IOVITA

**Credits:** 6 ECTS

**Prerequisites:**
Number Theory 1.

**Short program:**
The course will develop the theory of local fields following J.-P. Serre's book: Local fields. We will study: valuation rings, completions of valuation rings, complete discrete valuation fields of mixed characteristic and their finite extensions, the ramification filtration of the the Galois group of a finite, Galois extension of a local field. As an application we will study p-adic modular forms.

**Examination:**
Homework exercises will be handed in weekly, there will be a midterm exam and written final.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/001PD/SCQ0094300/NO

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**REPRESENTATION THEORY OF GROUPS**

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

**Lecturer:** Prof.ssa GIOVANNA CARNOVALE

**Credits:** 6 ECTS

**Prerequisites:**
Basic notions in linear algebra and group theory.

**Short program:**

**Examination:**
Unless sanitary emergency situation forces to do otherwise, the exam will be written, based on a series of exercises.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/001PD/SCQ0094299/NO

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**RINGS AND MODULES**

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

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

**Credits:** 6 ECTS

**Prerequisites:**
Notions from the Algebra courses of the first two years of the degree in Mathematics and basic notions on module theory over arbitrary rings.

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113/221
Short program:

Examination:
Oral examination.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/001PD/SCQ0094307/NO

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**SYMPLECTIC MECHANICS**

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

**Lecturer:** Prof. FRANCESCO FASSO`

**Credits:** 6 ECTS

**Prerequisites:**
Basic notions of Differential Geometry (manifolds, differential forms, vector fields), at the level at which they are treated in the course "Differential Geometry" at the first semester. Some knowledge of Lagrangian and Hamiltonian mechanics (at the level of the course "Fisica Matematica" of the II year of the Laurea Triennale) is useful but not strictly necessary.

**Short program:**

**Examination:**
Oral examination on the topics treated in the course.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/001PD/SCQ0094082/NO

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**TOPOLOGY 2**

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

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

**Credits:** 6 ECTS

**Short program:**
Algebraic Topology is usually approached via the study of the fundamental group and of homology, defined using chain complexes, whereas, here, the accent is put on the language of categories and sheaves, with particular attention to locally constant sheaves. Sheaves on topological spaces were invented by Jean Leray as a tool to deduce global properties from local ones. This tool turned out to be extremely powerful, and applies to many areas of Mathematics, from Algebraic Geometry to Quantum Field Theory. On a topological space, the functor associating to a sheaf the space of its global sections is left exact, but not right exact in general. The derived functors are cohomology groups that encode the obstructions to pass from local to global. The cohomology groups of the constant sheaf are topological (and even homotopical) invariants of the space, and we shall explain how to calculate them in various situations.

**Examination:**
traditional

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/001PD/SCQ0094298/NO

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**ADVANCED ANALYSIS**

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

**Lecturer:** Prof. GIOVANNI COLOMBO
Credits: 8 ECTS

Prerequisites:
Basic real and functional analysis (some results will be recalled during the first lecture)

Short program:

Examination:
An oral exam on the topics covered by the course, that will include some exercises, among those that were assigned during the course.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0093998/NO

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

Lecturer: Prof.ssa ORSOLA TOMMASI

Credits: 8 ECTS

Prerequisites:
Many results are based on results from commutative algebra. Basic knowledge of commutative algebra (corresponding to roughly the first half of the commutative algebra course) is recommended.

Short program:
This course is intended as a foundational course in algebraic geometry, starting from the basics of the subject and progressing to more advanced techniques such as the study of sheaves and schemes. Contents: Affine varieties. The Zariski topology. The sheaf of regular functions on a variety. Morphisms of varieties. Projective varieties. Dimension of a variety. Introduction to schemes.

Examination:
Written exam, possibly taking homework assignments into account.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094306/NO

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

Lecturer: Prof. ROBERTO MONTI

Credits: 8 ECTS

Prerequisites:
The Analysis 1 and 2 and the Real Analysis courses

Short program:

Examination:
Homeworks and oral exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0093999/NO
COMMUTATIVE ALGEBRA

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

Lecturer: Prof. REMKE NANNE KLOOSTERMAN

Credits: 8 ECTS

Prerequisites:
Basic notions of algebra (groups, rings, ideals, fields, quotients, etc.), as acquired in the "Algebra 1" course.

Short program:

Examination:
Written exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094309/NO

CRYPTOGRAPHY

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

Lecturer: Prof. ALESSANDRO LANGUASCO

Credits: 6 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. Migliardi; 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. Migliardi; 6 credits): Written Exam, Homeworks, oral test.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0093658/NO

DIFFERENTIAL EQUATIONS

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

Lecturer: Prof. MARTINO BARDI
Differential Geometry

Master's degree in Mathematics Ord. 2011, First semester

Lecturer: Prof. DAVIDE BARILARI

Credits: 8 ECTS

Prerequisites:
The course requires notions of Linear Algebra (vector spaces, linear maps, matrices, bilinear forms, and more in general multilinear forms) and Analysis (differential and integral calculus for real functions of one or more variables). Some knowledge of general topology is also required (open and closed sets, connectedness, compactness and main properties).

Short program:

Examination:
The exam is based on a written test and an oral test. During written test the student is asked to solve some exercises where he must be able to apply theoretical notions studied during the course. The student who is admitted to the oral test will be asked to answer to some questions on the main notions and results about the course. The final mark is based on the results of both the written test and the oral test.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0093963/NO

Dynamical Systems

Master's degree in Mathematics Ord. 2011, First semester

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

Credits: 7 ECTS

Prerequisites:
1. Basic knowledge of the theory of ordinary differential equations (ODEs) and of the qualitative theory of ODEs, at the level of, e.g., the course "Fisica Matematica" which is offered as a a mandatory course at the second year of the Corso di Laurea in Matematica in this University. 2. A basic knowledge of the programming language "Mathematica" (at the level of the tutorials periodically offered by the CCS and available on the YouTube channel of the Department of Mathematics) is useful, as it will be used in the numerical part of the course.

Short program:

Examination:
Oral examination on the topics studied in the course, and with an evaluation and a discussion of the numerical assignments (which will be assigned during
the course). Students will prepare the numerical assignments by working either alone or in pairs, at their choice. This examination format allows to evaluate: 1) The level of the theoretical knowledge and mathematical comprehension of the subject reached by the student. 2) The abilities reached by the student in the analysis and comprehension of the numerical results.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094084/NO

FUNCTIONS OF SEVERAL COMPLEX VARIABLES

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

**Lecturer:** Dott. LUCA BARACCO

**Credits:** 6 ECTS

**Prerequisites:**
Integral and differential calculus in several real variables. Basic knowledge of Hilbert spaces. Holomorphic functions in one variable.

**Short program:**
1. Real and complex differentials
2. Cauchy formula in the polydisc
3. Subharmonic functions
4. Separate analyticity
5. Analytic functions and power series
6. The Levi form and the H. Lewy ‘s extension theorem
7. Continuity principle
8. Domains of holomorphy and pseudoconvex domains
9. L^2 estimates and the solution of the Levi problem

**Examination:**
Students may choose between an Oral or written exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ1098741/NO

FUNCTIONS THEORY

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

**Lecturer:** Prof. DAVIDE VITTONE

**Credits:** 8 ECTS

**Prerequisites:**
Besides the courses of Analysis 1 and 2, the courses of Real Analysis and Functional Analysis 1

**Short program:**
Between brackets we denote topics that might be skipped or exposed without proofs according to time availability and/or audience interests.

**THEORY OF DISTRIBUTIONS**
Definitions, derivatives in the sense of distributions, order of a distribution, compactly supported distributions, convolutions, tempered distributions, Fourier transform, applications.

**SOBOLEV SPACES**
Definition and elementary properties, approximation theorems, boundary trace and extension results, Sobolev-Gagliardo-Nirenberg, Poincaré and Morrey inequalities, compactness theorems.

**ELEMENTS OF GEOMETRIC MEASURE THEORY**
Recap of some measure theoretical tools, covering theorems and differentiation of measures, Hausdorff measure and dimension, Lipschitz functions and Rademacher theorem, rectifiable sets, approximate tangent space, [area and coarea formulae].

**FUNCTIONS WITH BOUNDED VARIATION**
Definition, approximation and compactness results, trace and extension theorems, coarea formula, sets with finite perimeter, [isoperimetric inequalities, reduced boundary and structure theorem for sets with finite perimeter, fine properties and decomposability of the derivative of a BV function]

**Examination:**
Home exercises (one exercises sheet for each of the four parts of the course), according to which a mark will be proposed to the student. Alternatively: written examination. An oral examination is optional.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094119/NO

HAMILTONIAN MECHANICS

Master's degree in **MATHEMATICS ORD. 2011**, 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:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094081/NO

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HARMONIC ANALYSIS

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

Lecturer: Prof. MASSIMO LANZA DE CRISTOFORIS

Credits: 6 ECTS

Prerequisites:
Analysis courses of the first two years, and preferably the following courses Real Analysis Mathematical Methods Functional Analysis 1 and the basic properties of harmonic functions, which will be anyway brushed up.

Short program:
Preliminaries on function spaces Integral operators with weakly singular and singular kernel Applications to the analysis of potentials Elements of potential theory Applications to boundary value problems for harmonic functions.

Examination:
Partial tests and final oral exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0093960/NO

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HOMOLOGY AND COHOMOLOGY

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

Lecturer: Prof. JAKOB SCHOLBACH

Credits: 6 ECTS

Prerequisites:
we expect the student knows that it is possible to associate some invariants (fundamental group...), basic commutative algebra.

Short program:
Starting from the basic definition of the algebraic topology we will introduce the definition of homology and cohomology for a topological space. Singular, simplicial, cellular, relative, excisin, mayer-vietoris. Tor and Ext: universal coefficients theorem. Cup and cap product: teh ring structure on the cohomology of a projective space and some other particular topological spaces. Eventually Poincare' duality.

Examination:
taylored on the basis of the students attitudes: written and homeworks during the semester.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094302/NO

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INTRODUCTION TO GROUP THEORY

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

Lecturer: Prof. ANDREA LUCCHINI

Credits: 8 ECTS

Prerequisites:
Basic knowedges in general algebra

Short program:
General introduction to group theory: actions of groups, solvable and nilpotent groups, finitely presented groups. A short history of the classification of finite simple groups. Topological groups, profinite groups (characterizations, profinite completion, countable based profinite groups, arithmetical properties, subgroups of finite index in profinite groups, Galois groups of infinite dimensional extension). Probabilistic methods in group theory.

Examination:
Oral. The candidate will be asked to present the most important arguments presented in the course, proving the more significant results and solving some related exercise.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094303/NO

INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS

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

Lecturer: Prof.ssa LAURA CARAVENNA

Credits: 8 ECTS

Prerequisites:
Differential and integral calculus: basis on integration and differentiation, explicit integrals and derivatives of elementary functions, the fundamental theorem of calculus, basics on curves and surfaces. Green-Gauss-Stokes theorems and the theorems concerning limiting procedures in integrals are important but they will be revised at an essential level. Elementary theory of ordinary differential equations and on the Cauchy problem. Gronwall estimates and classical well posedness for ODEs will be recalled at an essential level. Basic theory of complex variables, holomorphic and analytic functions, very essential properties as Cauchy–Riemann equations.

Short program:

Examination:
The exam consists of a final oral examination on the topics treated in class. There will be both theoretical questions and the discussion of some exercise to solve. The final exam could be reduced via in itinere activities.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094080/NO

INTRODUCTION TO RING THEORY

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

Lecturer: Prof. ALBERTO FACCHINI

Credits: 8 ECTS

Prerequisites:
Courses of "Algebra 1" and "Algebra 2". That is, standard undergraduate Algebra.

Short program:

Examination:
Oral examination and/or evaluation of the exercises solved by the students during the course.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094304/NO

INTRODUCTION TO STOCHASTIC PROCESSES

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

Lecturer: Prof. MARCO FORMENTIN

Credits: 8 ECTS

Prerequisites:
A basic course in Probability.

Short program:

Examination:
Written examination with exercises for solution similar to those solved in class. Statements and proofs of relevant theorems may be also asked.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0093964/NO

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NUMBER THEORY 1

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

**Lecturer:** Prof. MATTEO LONGO

**Credits:** 8 ECTS

**Prerequisites:**
A standard Basic Algebra course; basic Linear Algebra; a basic course of Calculus; a short course in Galois Theory would be most useful; some familiarity with the theory of analytic functions of one complex variable would be useful.

**Short program:**

**Examination:**
Written and oral examination.

More information:

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NUMBER THEORY 2

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

**Lecturer:** Prof. ADRIAN IOVITA

**Credits:** 6 ECTS

**Prerequisites:**
Number Theory 1.

**Short program:**
The course will develop the theory of local fields following J.-P. Serre's book: Local fields. We will study: valuation rings, completions of valuation rings, complete discrete valuation fields of mixed characteristic and their finite extensions, the ramification filtration of the the Galois group of a finite, Galois extension of a local field. As an application we will study p-adic modular forms.

**Examination:**
Homework exercises will be handed in weekly, there will be a midterm exam and written final.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094300/NO

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NUMERICAL LINEAR ALGEBRA AND LEARNING FROM DATA

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

**Lecturer:** Prof. FABIO MARCUZZI

**Credits:** 7 ECTS

**Prerequisites:**
A basic background, corresponding to a first academic course, on: - numerical analysis - linear algebra - mathematical analysis - computer programming

**Short program:**
• Basic definitions and properties of the mathematical models used in learning from data (linear and nonlinear): linear regression models, neural models, linear dynamical systems (ARMA, state-space); • numerical methods for QR and SVD and their application to PCA, least-squares, model reduction and Kalman filtering; recursive least-squares, • regularization methods in 2-norm; • underdetermined linear estimation problems and sparse recovery: numerical algorithms for mixed 1- and 2-norm regularization (e.g. the LASSO); • numerical algorithms for nonlinear parameter estimation: nonlinear least-squares (Levenberg-Marquardt), back-propagation learning for neural networks; • parsimony and reduced order models in learning from data; • model-based examples of learning from data, in various fields of application.

Examination:
Oral examination, dealing with the results obtained by the student on laboratory assignments and the background theory presented during the lectures.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ1098378/NO

### NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS

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

**Lecturer:** Prof. MARIO PUTTI

**Credits:** 7 ECTS

**Prerequisites:**
Mathematical Analysis 1 and 2, with elements of Differential Equations and functional analysis. Numerical Analysis and linear algebra. The lab projects require some knowledge of Matlab programming.

**Short program:**

**Examination:**
Oral examination with discussion on the lab projects.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094083/NO

### REPRESENTATION THEORY OF GROUPS

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

**Lecturer:** Prof.ssa GIOVANNA CARNOVALE Course not activated for the a.y. 2021/2022

**Credits:** 6 ECTS

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094299/NO

### RINGS AND MODULES

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

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

**Credits:** 6 ECTS

**Prerequisites:**
Notions from the Algebra courses of the first two years of the degree in Mathematics and basic notions on module theory over arbitrary rings.

**Short program:**

**Examination:**
Oral examination.
STOCHASTIC ANALYSIS

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

Lecturer: Prof. DAVID BARBATO

Credits: 7 ECTS

Prerequisites:
Basic probability theory, basic analysis (differential calculus in \(R^n\), ordinary differential equations), measure theory.

Short program:

Examination:
The exam consists of two partial parts, a written test and oral test.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0093961/NO

STOCHASTIC METHODS FOR FINANCE

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

Lecturer: Prof. MARTINO GRASSELLI

Credits: 7 ECTS

Prerequisites:
Stochastic analysis

Short program:

Examination:
Final examination based on: Written and oral examination.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094085/NO

SYMPLECTIC MECHANICS

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

Lecturer: Prof. FRANCESCO FASSO'

Credits: 6 ECTS

Prerequisites:
Basic notions of Differential Geometry (manifolds, differential forms, vector fields), at the level at which they are treated in the course "Differential Geometry" at the first semester. Some knowledge of Lagrangian and Hamiltonian mechanics (at the level of the course "Fisica Matematica" of the II year of the Laurea Triennale) is useful but not strictly necessary.

Short program:
1. Symplectic manifolds and Hamiltonian systems. Review of Hamiltonian mechanics in \(R^n(2n)\). Symplectic forms and symplectic geometry. Cotangent bundles, Hamiltonian vector fields and their Lie algebra. Symplectic maps and generating functions. Hamilton-Jacobi equation and Lagrangian submanifolds. Poisson manifolds. Examples. 2. Lie groups and their actions. Lie groups and their geometric structure (Lie algebras, exponential map,

Examination:
Oral examination on the topics treated in the course.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094082/NO

TOPOLOGY 2

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

Lecturer: Prof. ANDREA D’AGNOLO

Credits: 6 ECTS

Short program:
Algebraic Topology is usually approached via the study of the fundamental group and of homology, defined using chain complexes, whereas, here, the accent is put on the language of categories and sheaves, with particular attention to locally constant sheaves. Sheaves on topological spaces were invented by Jean Leray as a tool to deduce global properties from local ones. This tool turned out to be extremely powerful, and applies to many areas of Mathematics, from Algebraic Geometry to Quantum Field Theory. On a topological space, the functor associating to a sheaf the space of its global sections is left exact, but not right exact in general. The derived functors are cohomology groups that encode the obstructions to pass from local to global. The cohomology groups of the constant sheaf are topological (and even homotopical) invariants of the space, and we shall explain how to calculate them in various situations.

Examination:
traditional

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/010PD/SCQ0094298/NO

ADVANCED ANALYSIS

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

Lecturer: Prof. GIOVANNI COLOMBO

Credits: 8 ECTS

Prerequisites:
Basic real and functional analysis (some results will be recalled during the first lecture)

Short program:

Examination:
An oral exam on the topics covered by the course, that will include some exercises, among those that were assigned during the course.

More information:

CALCULUS OF VARIATIONS

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

Lecturer: to be defined

Credits: 8 ECTS
Prerequisites: The Analysis 1 and 2 and the Real Analysis courses


Examination: Homeworks and oral exam


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### DIFFERENTIAL EQUATIONS

Master’s degree in **MATHEMATICS ORD. 2011**, Second semester

**Lecturer:** Prof. MARTINO BARDI

**Credits:** 6 ECTS

**Prerequisites:** Differential and integral calculus for functions of several variables; elementary theory of ordinary differential equations; some classical results in Functional Analysis.

**Short program:**

**Examination:** Oral exam, either on the lectures of the course, including the exercises proposed to the students, or on some additional material related to the topics of the course.

**More information:** https://en.didattica.unipd.it/off/2021/LM/SC/SC1172/011PD/SCQ0093962/NO

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### DIFFERENTIAL GEOMETRY

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

**Lecturer:** Prof. DAVIDE BARILARI

**Credits:** 8 ECTS

**Prerequisites:** The course requires notions of Linear Algebra (vector spaces, linear maps, matrices, bilinear forms, and more in general multilinear forms) and Analysis (differential and integral calculus for real functions of one or more variables). Some knowledge of general topology is also required (open and closed sets, connectedness, compactness and main properties).

**Short program:**

**Examination:** The exam is based on a written test and an oral test. During written test the student is asked to solve some exercises where he must be able to apply theoretical notions studied during the course. The student who is admitted to the oral test will be asked to answer to some questions on the main notions and results about the course. The final mark is based on the results of both the written test and the oral test.
DYNAMICAL SYSTEMS

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

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

Credits: 7 ECTS

Prerequisites:
1. Basic knowledge of the theory of ordinary differential equations (ODEs) and of the qualitative theory of ODEs, at the level of, e.g., the course "Fisica Matematica" which is offered as a mandatory course at the second year of the Corso di Laurea in Matematica in this University. 2. A basic knowledge of the programming language "Mathematica" (at the level of the tutorials periodically offered by the CCS and available on the YouTube channel of the Department of Mathematics) is useful, as it will be used in the numerical part of the course.

Short program:

Examination:
Oral examination on the topics studied in the course, and with an evaluation and a discussion of the numerical assignments (which will be assigned during the course). Students will prepare the numerical assignments by working either alone or in pairs, at their choice. This examination format allows to evaluate: 1) The level of the theoretical knowledge and mathematical comprehension of the subject reached by the student. 2) The abilities reached by the student in the analysis and comprehension of the numerical results.

FUNCTIONS THEORY

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

Lecturer: Prof. DAVIDE VITTONE

Credits: 8 ECTS

Prerequisites:
Besides the courses of Analysis 1 and 2, the courses of Real Analysis and Functional Analysis 1

Short program:
Between brackets we denote topics that might be skipped or exposed without proofs according to time availability and/or audience interests. THEORY OF DISTRIBUTIONS Definitions, derivatives in the sense of distributions, order of a distribution, compactly supported distributions, convolutions, tempered distributions, Fourier transform, applications. SOBOLEV SPACES Definition and elementary properties, approximation theorems, boundary trace and extension results, Sobolev-Gagliardo-Nirenberg, Poincaré and Morrey inequalities, compactness theorems. ELEMENTS OF GEOMETRIC MEASURE THEORY Recap of some measure theoretical tools, covering theorems and differentiation of measures, Hausdorff measure and dimension, Lipschitz functions and Rademacher theorem, rectifiable sets, approximate tangent space, [area and coarea formulae]. FUNCTIONS WITH BOUNDED VARIATION Definition, approximation and compactness results, trace and extension theorems, coarea formula, sets with finite perimeter, [isoperimetric inequalities, reduced boundary and structure theorem for sets with finite perimeter, fine properties and decomposability of the derivative of a BV function]

Examination:
Home exercises (one exercises sheet for each of the four parts of the course), according to which a mark will be proposed to the student. Alternatively: written examination. An oral examination is optional.

HARMONIC ANALYSIS

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

Lecturer: Prof. MASSIMO LANZA DE CRISTOFORIS

Credits: 6 ECTS

Prerequisites:
Analysis courses of the first two years, and preferably the following courses Real Analysis Mathematical Methods Functional Analysis 1 and the basic properties of harmonic functions, which will be anyway brushed up.

**Short program:**
Preliminaries on function spaces Integral operators with weakly singular and singular kernel Applications to the analysis of potentials Elements of potential theory Applications to boundary value problems for harmonic functions.

**Examination:**
Partial tests and final oral exam

**More information:**

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### INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS

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

**Lecturer:** Prof.ssa LAURA CARAVENNA

**Credits:** 8 ECTS

**Prerequisites:**
Differential and integral calculus: basis on integration and differentiation, explicit integrals and derivatives of elementary functions, the fundamental theorem of calculus, basics on curves and surfaces. Green-Gauss-Stokes theorems, and the theorems concerning limiting procedures in integrals are important but they will be revised at an essential level. Elementary theory of ordinary differential equations and on the Cauchy problem. Gronwall estimates and classical well posedness for ODEs will be recalled at an essential level. Basic theory of complex analysis: what are functions of complex variables, holomorphic and analytic functions, very essential properties as Cauchy–Riemann equations.

**Short program:**
- First order PDEs: transport equation with constant coefficients, conservation laws (classical and weak solutions, Rankine-Hugoniot conditions, Riemann problem).

**Examination:**
The exam consists of a final oral examination on the topics treated in class. There will be both theoretical questions and the discussion of some exercise to solve. The final exam could be reduced via in itinere activities.

**More information:**

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### INTRODUCTION TO STOCHASTIC PROCESSES

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

**Lecturer:** Prof. MARCO FORMENTIN

**Credits:** 8 ECTS

**Prerequisites:**
A basic course in Probability.

**Short program:**

**Examination:**
Written examination with exercises for solution similar to those solved in class. Statements and proofs of relevant theorems may be also asked.

**More information:**

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### NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS

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

Lecturer: Prof. MARIO PUTTI

Credits: 7 ECTS

Prerequisites: Mathematical Analysis 1 and 2, with elements of Differential Equations and functional analysis. Numerical Analysis and linear algebra. The lab projects require some knowledge of Matlab programming.

Short program:

Examination:
Oral examination with discussion on the lab projects.


STOCHASTIC ANALYSIS

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

Lecturer: Prof. DAVID BARBATO

Credits: 7 ECTS

Prerequisites: Basic probability theory, basic analysis (differential calculus in R^n, ordinary differential equations), measure theory.

Short program:

Examination:
The exam consists of two partial parts, a written test and oral test.


STOCHASTIC METHODS FOR FINANCE

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

Lecturer: Prof. MARTINO GRASSELLI

Credits: 7 ECTS

Prerequisites: Stochastic analysis

Short program:

Examination:
Final examination based on: Written and oral examination.

More information:
SYMPLECTIC MECHANICS

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

**Lecturer:** Prof. FRANCESCO FASSO

**Credits:** 6 ECTS

**Prerequisites:**
Basic notions of Differential Geometry (manifolds, differential forms, vector fields), at the level at which they are treated in the course "Differential Geometry" at the first semester. Some knowledge of Lagrangian and Hamiltonian mechanics (at the level of the course "Fisica Matematica" of the II year of the Laurea Triennale) is useful but not strictly necessary.

**Short program:**

**Examination:**
Oral examination on the topics treated in the course.

**More information:**

ADVANCED ANALYSIS

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

**Lecturer:** Prof. LORENZO COLOMBO

**Credits:** 8 ECTS

**Prerequisites:**
Basic real and functional analysis (some results will be recalled during the first lecture)

**Short program:**

**Examination:**
An oral exam on the topics covered by the course, that will include some exercises, among those that were assigned during the course.

**More information:**

CALCULUS OF VARIATIONS

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

**Lecturer:** Prof. ROBERTO MONTI

**Credits:** 8 ECTS

**Prerequisites:**
The Analysis 1 and 2 and the Real Analysis courses

**Short program:**
Introduction to the classical formalism of the Calculus of Variations: indirect methods, first variation, Euler-Lagrange equations, applications. Some examples, including minimal surfaces. The least action principle and the analytical mechanics of Lagrange. First direct methods, working in spaces of

Examination:
Homeworks and oral exam

More information:

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Differential Equations

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

Lecturer: Prof. MARTINO BARDI

Credits: 6 ECTS

Prerequisites:
Differential and integral calculus for functions of several variables; elementary theory of ordinary differential equations; some classical results in Functional Analysis.

Short program:

Examination:
Oral exam, either on the lectures of the course, including the exercises proposed to the students, or on some additional material related to the topics of the course.

More information:

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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

Prerequisites:
1. Basic knowledge of the theory of ordinary differential equations (ODEs) and of the qualitative theory of ODEs, at the level of, e.g., the course "Fisica Matematica" which is offered as a mandatory course at the second year of the Corso di Laurea in Matematica in this University. 2. A basic knowledge of the programming language "Mathematica" (at the level of the tutorials periodically offered by the CCS and available on the YouTube channel of the Department of Mathematics) is useful, as it will be used in the numerical part of the course.

Short program:

Examination:
Oral examination on the topics studied in the course, and with an evaluation and a discussion of the numerical assignments (which will be assigned during the course). Students will prepare the numerical assignments by working either alone or in pairs, at their choice. This examination format allows to evaluate: 1) The level of the theoretical knowledge and mathematical comprehension of the subject reached by the student. 2) The abilities reached by the student in the analysis and comprehension of the numerical results.

More information:

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Functions Theory

Master's degree in MATHEMATICS ORD. 2011

Lecturer: [Lecturer Name]

Credits: [Credits]

Prerequisites: [Prerequisites]

Short program: [Short program]

Examination: [Examination]

More information: [More information]
Master's degree in **MATHEMATICS ORD. 2011**, First semester

**Lecturer:** Prof. DAVIDE VITTONE

**Credits:** 8 ECTS

**Prerequisites:**
Besides the courses of Analysis 1 and 2, the courses of Real Analysis and Functional Analysis 1

**Short program:**
Between brackets we denote topics that might be skipped or exposed without proofs according to time availability and/or audience interests.

**THEORY OF DISTRIBUTIONS**
Definitions, derivatives in the sense of distributions, order of a distribution, compactly supported distributions, convolutions, tempered distributions, Fourier transform, applications. **SOBOLEV SPACES** Definition and elementary properties, approximation theorems, boundary trace and extension results, Sobolev-Gagliardo-Nirenberg, Poincaré and Morrey inequalities, compactness theorems.

**ELEMENTS OF GEOMETRIC MEASURE THEORY**
Recap of some measure theoretical tools, covering theorems and differentiation of measures, Hausdorff measure and dimension, Lipschitz functions and Rademacher theorem, rectifiable sets, approximate tangent space, [area and coarea formulæ].

**FUNCTIONS WITH BOUNDED VARIATION**
Definition, approximation and compactness results, trace and extension theorems, coarea formula, sets with finite perimeter, [isoperimetric inequalities, reduced boundary and structure theorem for sets with finite perimeter, fine properties and decomposability of the derivative of a BV function]

**Examination:**
Home exercises (one exercises sheet for each of the four parts of the course), according to which a mark will be proposed to the student. Alternatively: written examination. An oral examination is optional.

**More information:**

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HARMONIC ANALYSIS

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

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

**Credits:** 6 ECTS

**Prerequisites:**
Analysis courses of the first two years, and preferably the following courses Real Analysis Mathematical Methods Functional Analysis 1 and the basic properties of harmonic functions, which will be anyway brushed up.

**Short program:**
Preliminaries on function spaces Integral operators with weakly singular and singular kernel Applications to the analysis of potentials Elements of potential theory Applications to boundary value problems for harmonic functions.

**Examination:**
Partial tests and final oral exam

**More information:**

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INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS

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

**Lecturer:** Prof.ssa LAURA CARAVENNA

**Credits:** 8 ECTS

**Prerequisites:**
Differential and integral calculus: basis on integration and differentiation, explicit integrals and derivatives of elementary functions, the fundamental theorem of calculus, basics on curves and surfaces. Green-Gauss-Stokes theorems and the theorems concerning limiting procedures in integrals are important but they will be revised at an essential level. Elementary theory of ordinary differential equations and on the Cauchy problem. Gronwall estimates and classical well posedness for ODEs will be recalled at an essential level. Basic theory of complex analysis: what are functions of complex variables, holomorphic and analytic functions, very essential properties as Cauchy–Riemann equations.

**Short program:**

**Examination:**
The exam consists of a final oral examination on the topics treated in class. There will be both theoretical questions and the discussion of some exercise to solve. The final exam could be reduced via in itinere activities.

More information:

INTRODUCTION TO STOCHASTIC PROCESSES

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

Lecturer: Prof. MARCO FORMENTIN

Credits: 8 ECTS

Prerequisites:
A basic course in Probability.

Short program:

Examination:
Written examination with exercises for solution similar to those solved in class. Statements and proofs of relevant theorems may be also asked.

More information:

NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS

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

Lecturer: Prof. MARIO PUTTI

Credits: 7 ECTS

Prerequisites:
Mathematical Analysis 1 and 2, with elements of Differential Equations and functional analysis. Numerical Analysis and linear algebra. The lab projects require some knowledge of Matlab programming.

Short program:

Examination:
Oral examination with discussion on the lab projects.

More information:

NUMERICAL METHODS FOR TIME-DEPENDENT PROBLEMS

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

Lecturer: to be defined

Credits: 4 ECTS

Prerequisites:
CONTENT NOT PRESENT

Short program:
CONTENT NOT PRESENT

Examination:
OPTIMIZATION

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

**Lecturer:** to be defined  
**Course not activated for the a.y. 2021/2022**

**Credits:** 4 ECTS

Prerequisites: 

Short program: 

Examination: 


STOCHASTIC ANALYSIS

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

**Lecturer:** Prof. DAVID BARBATO

**Credits:** 7 ECTS

Prerequisites: 
Basic probability theory, basic analysis (differential calculus in $\mathbb{R}^d$, ordinary differential equations), measure theory.

Short program: 

Examination: 
The exam consists of two partial part, a written test and oral test.


STOCHASTIC METHODS FOR FINANCE

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

**Lecturer:** Prof. MARTINO GRASSELLI

**Credits:** 7 ECTS

Prerequisites: 
Stochastic analysis

Short program: 
**SYMPLECTIC MECHANICS**

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

**Lecturer:** Prof. FRANCESCO FASSO`

**Credits:** 6 ECTS

**Prerequisites:**
Basic notions of Differential Geometry (manifolds, differential forms, vector fields), at the level at which they are treated in the course "Differential Geometry" at the first semester. Some knowledge of Lagrangian and Hamiltonian mechanics (at the level of the course "Fisica Matematica" of the II year of the Laurea Triennale) is useful but not strictly necessary.

**Short program:**

**Examination:**
Oral examination on the topics treated in the course.

**More information:**

**ADVANCED ANALYSIS**

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

**Lecturer:** Prof. GIOVANNI COLOMBO

**Credits:** 8 ECTS

**Prerequisites:**
Basic real and functional analysis (some results will be recalled during the first lecture)

**Short program:**

**Examination:**
An oral exam on the topics covered by the course, that will include some exercises, among those that were assigned during the course.

**More information:**

**CALCULUS OF VARIATIONS**

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

**Lecturer:** Prof. ROBERTO MONTI

**Credits:** 8 ECTS

**Prerequisites:**
The Analysis 1 and 2 and the Real Analysis courses

**Short program:**

**Examination:**
Homeworks and oral exam

**More information:**

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**DIFFERENTIAL EQUATIONS**

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

**Lecturer:** Prof. MARTINO BARDI

**Credits:** 6 ECTS

**Prerequisites:**
Differential and integral calculus for functions of several variables; elementary theory of ordinary differential equations; some classical results in Functional Analysis.

**Short program:**

**Examination:**
Oral exam, either on the lectures of the course, including the exercises proposed to the students, or on some additional material related to the topics of the course.

**More information:**

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**DISCRETE PROCESSES**

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

**Lecturer:** to be defined

**Credits:** 4 ECTS

**Prerequisites:**
CONTENT NOT PRESENT

**Short program:**
CONTENT NOT PRESENT

**Examination:**
CONTENT NOT PRESENT

**More information:**

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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

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Credits: 7 ECTS

Prerequisites:
1. Basic knowledge of the theory of ordinary differential equations (ODEs) and of the qualitative theory of ODEs, at the level of, e.g., the course “Fisica Matematica” which is offered as a mandatory course at the second year of the Corso di Laurea in Matematica in this University. 2. A basic knowledge of the programming language “Mathematica” (at the level of the tutorials periodically offered by the CCS and available on the YouTube channel of the Department of Mathematics) is useful, as it will be used in the numerical part of the course.

Short program:

Examination:
Oral examination on the topics studied in the course, and with an evaluation and a discussion of the numerical assignments (which will be assigned during the course). Students will prepare the numerical assignments by working either alone or in pairs, at their choice. This examination format allows to evaluate: 1) The level of the theoretical knowledge and mathematical comprehension of the subject reached by the student. 2) The abilities reached by the student in the analysis and comprehension of the numerical results.

More information:

FUNCTIONAL ANALYSIS

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

Lecturer: to be defined

Credits: 8 ECTS

Prerequisites:
CONTENT NOT PRESENT

Short program:
CONTENT NOT PRESENT

Examination:
CONTENT NOT PRESENT

More information:

GEOMETRY AND DIFFERENTIAL EQUATIONS

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

Lecturer: to be defined

Credits: 4 ECTS

Prerequisites:
CONTENT NOT PRESENT

Short program:
CONTENT NOT PRESENT

Examination:
CONTENT NOT PRESENT

More information:

HARMONIC ANALYSIS

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

Lecturer: Prof. MASSIMO LANZA DE CRISTOFORIS
INTRODUCTION TO STOCHASTIC PROCESSES

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

Lecturer: Prof. MARCO FORMENTIN

Credits: 8 ECTS

Prerequisites:
A basic course in Probability.

Short program:

Examination:
Written examination with exercises for solution similar to those solved in class. Statements and proofs of relevant theorems may be also asked.

More information:

MONTE-CARLO

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

Lecturer: to be defined

Credits: 4 ECTS

Prerequisites:
CONTENT NOT PRESENT

Short program:
CONTENT NOT PRESENT

Examination:
CONTENT NOT PRESENT

More information:

NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS

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

Lecturer: Prof. MARIO PUTTI

Credits: 7 ECTS

Prerequisites:

Credits: 6 ECTS

Prerequisites:
Analysis courses of the first two years, and preferably the following courses Real Analysis Mathematical Methods Functional Analysis 1 and the basic properties of harmonic functions, which will be anyway brushed up.

Short program:
Preliminaries on function spaces Integral operators with weakly singular and singular kernel Applications to the analysis of potentials Elements of potential theory Applications to boundary value problems for harmonic functions.

Examination:
Partial tests and final oral exam

More information:
Mathematical Analysis 1 and 2, with elements of Differential Equations and functional analysis. Numerical Analysis and linear algebra. The lab projects require some knowledge of Matlab programming.

**Short program:**

**Examination:**
Oral examination with discussion on the lab projects.

**More information:**

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## OPTIMIZATION

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

**Lecturer:** to be defined Course not activated for the a.y. 2021/2022

**Credits:** 4 ECTS

**Prerequisites:**
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**Short program:**
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**Examination:**
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**More information:**

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## STOCHASTIC METHODS FOR FINANCE

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

**Lecturer:** Prof. MARTINO GRASSELLI

**Credits:** 7 ECTS

**Prerequisites:**
Stochastic analysis

**Short program:**

**Examination:**
Final examination based on: Written and oral examination.

**More information:**

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## MOLECULAR BIOLOGY (ORD. 2020)

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138/221
Master’s degree in Molecular Biology (Ord. 2020), First semester

Applied Statistics

Lecturer: Prof. Davide Riso
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/2021/LM/SC/SC2445/007PD/SCP8085059/NO

Behavioural Genetics

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? - 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 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:

Cell Biology

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 the topics covered in class. The discussion of the articles is an integral part of the program. Lectures will cover 5 main topics: 1) In vitro cultures, methods for cellular molecular biology. Physical principles behind the most common microscopy techniques. 2) Chromatin Biology and nuclear organization to address fundamental questions about cellular differentiation and nuclear reprogramming. Chromosome territories and subdomains. X chromosome inactivation. Centromeres and telomeres chromatin. 3) Main principles of autophagy and related diseases 4) Stem cell origins, plasticity and epigenetics. Bivalent Chromatin. Stem cell niche. Adult, Embryonic, and induced pluripotent Stem cells. 5) Signal transduction and cancer. Immortalization, role of telomeres. Malignant transformation, disturbances in signal transduction pathways resulting in malignant transformation, role of failure in signaling pathways regulating cellular proliferation, apoptosis and DNA-repair pathways. Cancer stem cells.

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 (7 CFU) described in the course content at section 2 to 5 will be assessed with six 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/2021/LM/SC/SC2445/007PD/SCP8085218/NO

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### COMPUTATIONAL 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:

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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 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? The composition of chromatin: the epigenome and molecules involved in chromatin regulation. 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) Proximal and distant DNA regions involved in genome regulation: DNA and chromatin modifications and regulation of genome expression (internal and external factors) 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-23Bb and miR-499 and muscle performance) 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 GAS5 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 Heritability of DNA modifications: global role during early development and gametogenesis, X-chromosome inactivation. Reversibility of epigenetic patterns: approaches for epigenome reprogramming (nuclear transfer, cell fusion, cell extracts, cloned genes or proteins, mRNAs) 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. 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).

Epigenetic modifications and multifactorial syndromes. Regulating the epigenome in the therapy of human diseases. Epigenetic control of the mitotic cell cycle. Epigenetics of cancer: uncontrolled replication, epigenetic changes leading to transformation, abnormal patterns of methylation, histone modifications and cancer, epigenetics of tumour metastasis.

Examination: written final exam (open questions) in presence or online.


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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.


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**GENOMICS AND NGS DATA ANALYSIS**

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

**Lecturer:** Prof. GIORGIO VALLE

**Credits:** 9 ECTS

**Prerequisites:**
The content of the course has been defined keeping in mind the program of the first level degree in Molecular Biology of the University of Padua. In particular it is expected that the students have a good knowledge of Genetics, Molecular Biology and Bioinformatics. It would be useful to have a basic knowledge in informatics and programming. The course is in English, therefore the students should have a reasonable command of spoken and written English.

**Short program:**
It is a 9 credits course that includes 56 hours of classroom teaching (7 credits) and 32 hours of practicals (2 credits). The activity is articulated into 6 sections as follows: Section 1) DNA sequencing technology and its application to genome sequencing, RNAseq, ChiPseq, BisulfiteSeq; Section 2) Analysis and management of “Next Generation Sequencing” (NGS): data: mapping sequences on the reference genome, de novo assembly of genomes, analysis of mate pairs, analysis of transcriptomic and splicing data, analysis of methylome, analysis of single cell sequencing; Section 3) Epigenomics: structure and function of non-coding RNA, nuclear architecture of the genome; Section 4) Functional genomics, proteomics, interactomics, gene inactivation, integration of complex data, gene prediction and genomic annotation; Section 5) Genomics and personalized medicine: analysis of polymorphisms, linkage disequilibrium and GWAS, resequencing of genomes and exomes, data integration and systems biology; Section 6) Practicals in the laboratory where the students will be able to challenge themselves in the production of NGS libraries and in the application of bioinformatics to analyse genomic and transcriptomic data.

**Examination:**
The final exam is oral, however the evaluation is articulated into three parts: 1) a written session in which the student must describe the results of the laboratory practicals, that must be submitted at least one week before the official date of the exam, 2) a quiz session on Moodle, that will take place at the beginning of the day of the exam, 3) an oral discussion on the topics of the course and on the results achieved on the practicals. A continuous process of assessment will be carried out throughout the course, to verify the level of understanding of the students.
INTEGRATIVE BIOLOGY AND NETWORK ANALYSIS

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: introduction of methods for integrative biology; multi-omic data integration, basis of network theory. - Experimental design for omic experiments: types of experimental design; how to choose the right experimental setting according to the biological questions. - Gene expression with RNA-seq; brief recall of RNAseq approaches; applications and differential expression. - Pathways and networks: pathway representation and analyses; gene set enrichment analyses. - R programming: 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) - Integration of microRNA and gene expression: role of microRNAs in biological signaling pathways; the miRNA interactome; computational tools to study miRNA and gene expression. - Integration of ChIP-seq and gene expression: bioinformatic identification of Transcription Factor motifs; databases of TF motifs; identification of TF DNA binding sites from ChIP-seq data; computational integration of ChIP-seq and RNA-seq; network representation. - Integration of epigenomic techniques: computational basis and tools for DNA Methylation (DNA methyl-seq), histone modifications and chromatin accessibility (ATAC-seq) and chromatin interactions and organization (HIC); computational integration of epigenomic and transcriptomic data. - Omics and multi-omics in cancers: review of cancer genomics, deconvolution of cell types, computational basis of copy number variations (CNV) of genomes, multi-omic signatures, personalized medicine. - Single-cell sequencing approaches: introduction to single-cell sequencing, dimensionality reduction, clustering and projections, pseudo-time and trajectories. - Spatial Transcriptomics: introduction to Spatial Transcriptomics: future perspectives and conclusions.

Examination:
Written exam

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:

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.
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:

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 development 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 asymmetric, chemoafinity 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): Diffusion reaction, French flag theory. 4) Genetic pathways controlling development, their function and visualization (1.5 CFU): Wnt, TGFb, BMP, HH, Notch, Hypoxia, Hippo, STAT 5) germ layers induction and regionalization of the main axes (DV, AP, LR) in vertebrates and Drosophila, Examples of organ formation. (1 CFU) Angiogenesis in model animals: Use of genetic animal models to study angiogenesis. Molecular biology of endothelial cells. Developmental and pathological angiogenesis. Fluorescent and digital microscopy (1 CFU): Use of genetically encoded fluorophores in molecular genetic development. Different fluorescent techniques and microscopes. Advance microscopic techniques for in vivo studies. Laboratory (1 CFU): manipulation of the zebrafish embryo: whole mount staining and imaging of fluorescent embryo; Pharmacological treatment of zebrafish embryos with non-specific teratogens (alcohol) and specific agonists or antagonists.

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:

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, alinement and structure prediction C. X-ray crystallography 1. Crystallization 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-rays 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 wavelenghts 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.

More information:

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:

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.

More information:

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

Lecturer: Prof. DAVIDE RISSO

Credits: 6 ECTS

Prerequisites:
CONTENT NOT PRESENT

Short program:
CONTENT NOT PRESENT

Examination:
CONTENT NOT PRESENT

More information:
### BIOCHEMISTRY

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

**Lecturer:** Prof.ssa ILDIKO SZABO  
**Credits:** 8 ECTS  
**Prerequisites:**  
CONTENT NOT PRESENT  
**Short program:**  
CONTENT NOT PRESENT  
**Examination:**  
CONTENT NOT PRESENT  
**More information:**  

### BIOCHEMISTRY OF DISEASES

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

**Lecturer:** Prof. LUCA SCORRANO  
**Credits:** 8 ECTS  
**Prerequisites:**  
CONTENT NOT PRESENT  
**Short program:**  
CONTENT NOT PRESENT  
**Examination:**  
CONTENT NOT PRESENT  
**More information:**  

### COMPUTATIONAL ANTHROPOLOGY

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

**Lecturer:** Prof. LUCA PAGANI  
**Credits:** 6 ECTS  
**Prerequisites:**  
CONTENT NOT PRESENT  
**Short program:**  
CONTENT NOT PRESENT  
**Examination:**  
CONTENT NOT PRESENT  
**More information:**  

### EPIGENETICS AND EPIGENOMICS

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

**Lecturer:** Prof. CARLO FIORE VISCOMI
FUNCTIONAL GENOMICS AND HUMAN GENETICS

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

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: CONTENT NOT PRESENT

Short program: CONTENT NOT PRESENT

Examination: CONTENT NOT PRESENT


HUMAN PHYSIOLOGY

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

Lecturer: Prof. LUIGI BUBACCO

Credits: 9 ECTS

Prerequisites: CONTENT NOT PRESENT

Short program: CONTENT NOT PRESENT

Examination: CONTENT NOT PRESENT


INTEGRATIVE BIOLOGY AND NETWORK ANALYSIS

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

Lecturer: Dott.ssa ENRICA CALURA

Credits: 6 ECTS

Prerequisites: CONTENT NOT PRESENT

Short program: CONTENT NOT PRESENT
MATHEMATICAL MODELING FOR BIOLOGISTS

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

**Lecturer:** to be defined

**Credits:** 2 ECTS

**Prerequisites:**
CONTENT NOT PRESENT

**Short program:**
CONTENT NOT PRESENT

**Examination:**
CONTENT NOT PRESENT

**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

**Prerequisites:**
CONTENT NOT PRESENT

**Short program:**
CONTENT NOT PRESENT

**Examination:**
CONTENT NOT PRESENT

**More information:**

MOLECULAR GENETICS

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

**Lecturer:** Prof. GABRIELE SALES

**Credits:** 6 ECTS

**Prerequisites:**
CONTENT NOT PRESENT

**Short program:**
CONTENT NOT PRESENT

**Examination:**
CONTENT NOT PRESENT

**More information:**
**SYSTEMS BIOLOGY**

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

**Lecturer:** Prof. GABRIELE SALES

**Credits:** 6 ECTS

**Prerequisites:**
CONTENT NOT PRESENT

**Short program:**
CONTENT NOT PRESENT

**Examination:**
CONTENT NOT PRESENT

**More information:**

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**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:**

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**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 the topics covered in class. The discussion of the articles is an integral part of the program. Lectures will cover 5 main topics: 1) In vitro cultures, methods for cellular molecular biology. Physical principles behind the most common microscopy techniques. 2) Chromatin Biology and nuclear organization to address fundamental questions about cellular differentiation and nuclear reprogramming. Chromosome territories and subdomains. X chromosome inactivation. Centromeres and telomeres chromatin. 3) Main principles of autophagy and related diseases 4) Stem cell origins, plasticity and epigenetics. Bivalent Chromatin. Stem cell niche. Adult, Embryonic, and induced pluripotent Stem cells. 5) Signal transduction and cancer. Immortalization, role of telomeres. Malignant transformation, disturbances in signal transduction pathways resulting in malignant transformation, role of failure in signaling pathways regulating cellular proliferation, apoptosis and DNA-repair pathways. Cancer stem cells.
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 (7 CFU) described in the course content at section 2 to 5 will be assessed with six 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/2021/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

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) Introggression 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:

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:
## 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:**

**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.

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**GENOMICS AND NGS DATA ANALYSIS**

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

**Lecturer:** Prof. GIORGIO VALLE

**Credits:** 9 ECTS

**Prerequisites:**
The content of the course has been defined keeping in mind the program of the first level degree in Molecular Biology of the University of Padua. In particular it is expected that the students have a good knowledge of Genetics, Molecular Biology and Bioinformatics. It would be useful to have a basic knowledge in informatics and programming. The course is in English, therefore the students should have a reasonable command of spoken and written English.

**Short program:**
It is a 9 credits course that includes 56 hours of classroom teaching (7 credits) and 32 hours of practicals (2 credits). The activity is articulated into 6 sections as follows: Section 1) DNA sequencing technology and its application to genome sequencing, RNA-seq, ChIP-seq, Bisulfite-seq; Section 2) Analysis and management of “Next Generation Sequencing” (NGS): data: mapping sequences on the reference genome, de novo assembly of genomes, analysis of mate pairs, analysis of transcriptomic and splicing data, analysis of methylation, analysis of single cell sequencing; Section 3) Epigenomics: structure and function of non-coding RNA, nuclear architecture of the genome; Section 4) Functional genomics, proteomics, interactomics, gene inactivation, integration of complex data, gene prediction and genomic annotation; Section 5) Genomics and personalized medicine: analysis of polymorphisms, linkage disequilibrium and GWAS, resequencing of genomes and exomes, data integration and systems biology; Section 6) Practicals in the laboratory where the students will be able to challenge themselves in the production of NGS libraries and in the application of bioinformatics to analyse genomic and transcriptomic data.

**Examination:**
The final exam is oral, however the evaluation is articulated into three parts: 1) a written session in which the student must describe the results of the laboratory practicals, that must be submitted at least one week before the official date of the exam, 2) a quiz session on Moodle, that will take place at the beginning of the day of the exam, 3) an oral discussion on the topics of the course and on the results achieved on the practicals. A continuous process of assessment will be carried out throughout the course, to verify the level of understanding of the students.

**More information:**

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**More information:**
MODELS IN GENETIC DISEASE RESEARCH

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

Lecturer: to be defined

Credits: 4 ECTS

Prerequisites: CONTENT NOT PRESENT

Short program: CONTENT NOT PRESENT

Examination: CONTENT NOT PRESENT


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 developmenta 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): Diffusion reaction, French flag theory. 4) Genetic pathways controlling development, their function and visualization (1.5 CFU): Wnt, TGFb, BMP, HH, Notch, Hypoxia, Hippo, STAT 5) germ layers induction and regionalization of the main axes (DV, AP, LR) in vertebrates and Drosophila, Examples of organ formation. (1 CFU) Angiogenesis in model animals (1 CFU): Use of genetic animal models to study angiogenesis. Molecular biology of endothelial cells. Developmental and pathological angiogenesis. Fluorescent and digital microscopy (1 CFU): Use of genetically encoded fluorophores in molecular genetic development. Different fluorescent techniques and microscopes. Advance microscopic techniques for in vivo studies. Laboratory (1 CFU): manipulation of the zebrafish embryo: whole mount staining and imaging of fluorescent embryo; Pharmacological treatment of zebrafish embryos with non-specific teratogens (alcohol) and specific agonists or antagonists.

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.


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:
- General ideas. From the research problem to probabilistic models. Sampling. Observational and experimental studies. Statistical tests: hypotheses, p-values and their interpretation, types of error, power. The problem of multiple comparisons/tests. Confidence intervals. - Elementary methods. Inference on
Examination:
Written exam

More information:

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BIOCHEMISTRY

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

Lecturer: Prof.ssa ILDIKO SZABO

Credits: 8 ECTS

Prerequisites: Basic level of biochemistry, cellular biology and physiology

Short program:
The course will give an in depth knowledge of some aspects of modern, advanced biochemistry regarding protein import mechanisms into organelles (mitochondria, chloroplasts and peroxisomes) including illustration of the importance of the above processes in plant and animal physiology. Connected to these themes, mechanisms of photoprotection in higher plants will be treated. In addition, the study of membrane proteins (topology, structure,structure/function relationship) will be discussed with illustration of advanced techniques, with particular reference to ion channels. In addition, the most important aspects of tumor metabolism will be discussed.

Examination:
Written exam comprising open questions.

More information:

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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 the topics covered in class. The discussion of the articles is an integral part of the program. Lectures will cover 5 main topics: 1) In vitro cultures, methods for cellular molecular biology. Physical principles behind the most common microscopy techniques. 2) Chromatin Biology and nuclear organization to address fundamental questions about cellular differentiation and nuclear reprogramming. Chromosome territories and subdomains. X chromosome inactivation. Centromeres and telomeres chromatin. 3) Main principles of autophagy and related diseases 4) Stem cell origins, plasticity and epigenetics. Bivalent Chromatin. Stem cell niche. Adult, Embryonic, and induced pluripotent Stem cells. 5) Signal transduction and cancer. Immortalization, role of telomeres. Malignant transformation, disturbances in signal transduction pathways resulting in malignant transformation, role of failure in signaling pathways regulating cellular proliferation, apoptosis and DNA-repair pathways. Cancer stem cells.

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 (7 CFU) described in the course content at section 2 to 5 will be assessed with six 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/2021/LM/SC/SC2445/006PD/SCP8085218/NO

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GENOMICS AND NGS DATA ANALYSIS

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

Lecturer: Prof. GIORGIO VALLE

Credits: 9 ECTS

Prerequisites:
The content of the course has been defined keeping in mind the program of the first level degree in Molecular Biology of the University of Padua. In particular it is expected that the students have a good knowledge of Genetics, Molecular Biology and Bioinformatics. It would be useful to have a basic knowledge in informatics and programming. The course is in English, therefore the students should have a reasonable command of spoken and written English.

**Short program:**
It is a 9 credits course that includes 56 hours of classroom teaching (7 credits) and 32 hours of practicals (2 credits). The activity is articulated into 6 sections as follows: Section 1) DNA sequencing technology and its application to genome sequencing, RNAseq, ChIPseq, BisulfiteSeq; Section 2) Analysis and management of "Next Generation Sequencing" (NGS): data: mapping sequences on the reference genome, de novo assembly of genomes, analysis of mate pairs, analysis of transcriptomic and splicing data, analysis of methylome, analysis of single cell sequencing; Section 3) Epigenomics: structure and function of non-coding RNA, nuclear architecture of the genome; Section 4) Functional genomics, proteomics, interactomics, gene inactivation, integration of complex data, gene prediction and genomic annotation; Section 5) Genomics and personalized medicine: analysis of polymorphisms, linkage disequilibrium and GWAS, resequencing of genomes and exomes, data integration and systems biology; Section 6) Practicals in the laboratory where the students will be able to challenge themselves in the production of NGS libraries and in the application of bioinformatics to analyse genomic and transcriptomic data.

**Examination:**
The final exam is oral, however the evaluation is articulated into three parts: 1) a written session in which the student must describe the results of the laboratory practicals, that must be submitted at least one week before the official date of the exam, 2) a quiz session on Moodle, that will take place at the beginning of the day of the exam, 3) an oral discussion on the topics of the course and on the results achieved on the practicals. A continuous process of assessment will be carried out throughout the course, to verify the level of understanding of the students.

**More information:**

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**MODELS IN GENETIC DISEASE RESEARCH**

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

**Lecturer:** to be defined

**Credits:** 4 ECTS

**Prerequisites:**
CONTENT NOT PRESENT

**Short program:**
CONTENT NOT PRESENT

**Examination:**
CONTENT NOT PRESENT

**More information:**

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**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 (4h). Plant hormones (auxins, gibberellins, cytokinins, ethylene, abscissic acid): biosynthesis, actions, transport and developmental effects; signal transduction pathways (16h). 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 (6h). Blue light and red light responses: light perception, signal transduction and plant responses to light environmental conditions (9h). Plant reproductive development: floral meristem development, floral organ identity genes, ABCDE model to explain the flower development; the control of flowering (8h). 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 (14h). Plant–microorganism interactions: cellular and molecular surveys about mycorrhiza, Rhizobium-Leguminosae symbiosis and plant-Agrobacterium interaction (10h). 16h (1 CFU) of practical work on the following topics: 1) Somatic embryogenesis in the model system Daucus carota, tobacco micropropagation 2) Isolation of protoplasts from plant cell suspension cultures; fluorescence imaging of intracellular compartments 3) Protein extraction and quantification from Arabidopsis thaliana cell cultures stably expressing the calcium-sensitive photoprotein aequorin 4) Analysis of protein expression by SDS-PAGE and immunoblotting
### 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, chemoafinity hypothesis, sex determination, lateral inhibition, somitogenesis.  
2) Cellular Developmental Mechanisms (0.5 CFU): Use of genetic animal models to study angiogenesis. Molecular biology of endothelial cells. Developmental and pathological angiogenesis. Fluorescent and digital microscopy (1 CFU): Use of genetically encoded fluorophores in molecular genetic development. Different fluorescent techniques and microscopes. Advance microscopic techniques for in vivo studies. Laboratory (1 CFU): manipulation of the zebrafish embryo: whole mount staining and imaging of fluorescent embryo; Pharmacological treatment of zebrafish embryos with non-specific teratogens (alcohol) and specific agonists or antagonists.

**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:**  

### NEUROBIOLOGY

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

**Lecturer:** Prof.ssa DANIELA PIETROBON  

**Credits:** 10 ECTS

**Prerequisites:**  
Physiology, Genetics, Cellular Biology, Molecular biology

**Short program:**  
1. Introduction. 2. Anatomical and functional organization of the human nervous system. 3. Specific firing patterns in different neurons, physiological role and experimental methods to investigate their molecular mechanisms. 4. Thalamocortical circuits and cerebral rhythms during sleep and wakefulness. 5. Circadian clocks: genetic, molecular and functional dissection. 6. Techniques for measurement of synaptic transmission, Biophysical and molecular mechanisms of neurotransmitter release; experimental methods for their study. 7. Mechanisms of short-term synaptic plasticity (facilitation, post-tetanic potentiation, depression) and long-term synaptic plasticity (LTP, LTD, STPD). Learning and memory. 8. General functional organization of sensory systems; in depth discussion of one sensory system. 9. Optical and optogenetic techniques for measurement of neuronal electrical activity. Optogenetic techniques for selective stimulation or inhibition of specific neurons. Applications of optogenetics in vitro and especially in vivo for the study of cerebral functions and dysfunctions in modern neurobiology. Laboratory training: it will be possible to choose between two different types of practical exercises. 1) Demonstration of how to perform and analyze recordings of electrical activity of specific neurons in brain slices using the patch-clamp technique, or (in alternative) how to perform recordings of cortical spreading depression (CSD) and how to obtain CSD threshold and velocity of propagation in brain slices using intrinsic optic signal and/or electrophysiological measurements. As exercise, the students will analyze and interpret a recording of electrical activity or CSD. 2) Students complete a set of self-administered electronic sleep quality [Pittsburgh Sleep Quality Index (PSQI)], chronotype and sleepiness [Epworth Sleepiness Scale (ESS)] questionnaires and sleep diaries for two weeks. They also wear an actigraph; wireless sensors for skin temperature, and follow a course of chronotherapy aimed at anticipating their sleep-wake timing. Analyses are performed as practicals, together with the students.

**Examination:**  
Written examination with three open questions, which aim to verify, besides the acquired knowledge on relevant topics, the ability of critical discussion and reasoning. The individual report on the practical experience matured during the laboratory training is also evaluated.

**More information:**  
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:

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:

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:

BIODEMOGRAPHY

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

Lecturer: to be defined
BIOTherapy

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

Lecturer: to be defined

Credits: 3 ECTS

Prerequisites: -

Short program: -

Examination: -

More information:

Cell Imaging

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

Lecturer: to be defined

Credits: 3 ECTS

Prerequisites: -

Short program: -

Examination: -

More information:

Cellular Aspects of Development

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

Lecturer: to be defined

Credits: 3 ECTS

Prerequisites: -

Short program: -

Examination: -

More information:
### 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:**

### 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:**

### EPIGENETICS

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

**Lecturer:** to be defined

**Credits:** 3 ECTS

**Prerequisites:**

**Short program:**

**Examination:**

**More information:**
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:**

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:**

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:**

GENOMIC ANALYSIS OF CANCERS

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

**Lecturer:** to be defined
GENOMICS

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

Lecturer: to be defined

Credits: 3 ECTS

Prerequisites: -

Short program: -

Examination: -

More information:

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:

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:

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:

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/2021/LM/SC/SC2445//SCQ0094456/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
SOMATIC GENETIC IN CANCER

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

Lecturer: to be defined

Credits: 3 ECTS

Prerequisites:

Short program:

Examination:

More information:

STEM CELLS

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

Lecturer: to be defined

Credits: 3 ECTS

Prerequisites:

Short program:

Examination:

More information:

VERTEBRATE DEVELOPMENT AND RELATED HUMAN PATHOLOGIES

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

Lecturer: to be defined

Credits: 3 ECTS

Prerequisites:

Short program:
**APPLIED STATISTICS**

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

**Lecturer:** Prof. Davide Rizzo

**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:**

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**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 character: 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 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 novelities - 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/2021/LM/SC/SC2445/005PD/SCP8085059/NO

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**BIOCHEMISTRY**

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

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163/221
Lecturer: Prof.ssa ILDIKO SZABO

Credits: 8 ECTS

Prerequisites:
Basic level of biochemistry, cellular biology and physiology

Short program:
The course will give an in depth knowledge of some aspects of modern, advanced biochemistry regarding protein import mechanisms into organelles (mitochondria, chloroplasts and peroxisomes) including illustration of the importance of the above processes in plant and animal physiology. Connected to these themes, mechanisms of photoprotection in higher plants will be treated. In addition, the study of membrane proteins (topology, structure,structure/functional relationship) will be discussed with illustration of advanced techniques, with particular reference to ion channels. In addition, the most important aspects of tumor metabolism will be discussed.

Examination:
Written exam comprising open questions.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2445/005PD/SCP8085067/NO

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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 the topics covered in class. The discussion of the articles is an integral part of the program. Lectures will cover 5 main topics: 1) In vitro cultures, methods for cellular molecular biology. Physical principles behind the most common microscopy techniques. 2) Chromatin Biology and nuclear organization to address fundamental questions about cellular differentiation and nuclear reprogramming. Chromosome territories and subdomains. X chromosome inactivation. Centromeres and telomeres chromatin. 3) Main principles of autophagy and related diseases 4) Stem cell origins, plasticity and epigenetics. Bivalent Chromatin. Stem cell niche. Adult, Embryonic, and induced pluripotent Stem cells. 5) Signal transduction and cancer. Immortalization, role of telomeres. Malignant transformation, disturbances in signal transduction pathways resulting in malignant transformation, role of failure in signaling pathways regulating cellular proliferation, apoptosis and DNA-repair pathways. Cancer stem cells.

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 (7 CFU) described in the course content at section 2 to 5 will be assessed with six 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/2021/LM/SC/SC2445/005PD/SCP8085218/NO

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COMPUTATIONAL 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
More information:

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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 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? The composition of chromatin: the epigenome and molecules involved in chromatin regulation 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) Proximal and distant DNA regions involved in genome regulation: DNA and chromatin modifications and regulation of genome expression (internal and external factors) 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) 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 GAS5 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 Heritability of DNA modifications: global role during early development and gametogenesis, X-chromosome inactivation. Reversibility of epigenetic patterns: approaches for epigenome reprogramming (nuclear transfer, cell fusion, cell controls, cloned genes or proteins, mRNAs) The epigenetic basis of gene imprinting: genomic imprinting, differential expression of paternal and maternal alleles, controls of monoallelic expression of imprinted genes; examples of imprinting; establishing differentially methylated genomic regions; disorders & imprinting. 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). Epigenetic modifications and multifactorial syndromes. Regulating the epigenome in the therapy of human diseases Epigenetic control of the mitotic cell cycle Epigenetics of cancer: uncontrolled replication, epigenetic changes leading to transformation, abnormal patterns of methylation, histone modifications and cancer, epigenetics of tumour metastasis.

**Examination:**

written final exam (open questions) in presence or online.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2445/005PD/SCP9087941/NO

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**GENOMICS AND NGS DATA ANALYSIS**

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

**Lecturer:** Prof. GIORGIO VALLE

**Credits:** 9 ECTS

**Prerequisites:**

The content of the course has been defined keeping in mind the program of the first level degree in Molecular Biology of the University of Padua. In particular it is expected that the students have a good knowledge of Genetics, Molecular Biology and Bioinformatics. It would be useful to have a basic knowledge in informatics and programming. The course is in English, therefore the students should have a reasonable command of spoken and written English.

**Short program:**

It is a 9 credits course that includes 56 hours of classroom teaching (7 credits) and 32 hours of practicals (2 credits). The activity is articulated into 6 sections as follows: Section 1) DNA sequencing technology and its application to genome sequencing, RNAseq, ChIPseq, BisulfiteSeq; Section 2) Analysis and management of "Next Generation Sequencing" (NGS): data: mapping sequences on the reference genome, de novo assembly of genomes, analysis of mate pairs, analysis transcriptomic and splicing data, analysis of methylome, analysis of single cell sequencing; Section 3) Epigenomics: structure and function of non-coding RNA, nuclear architecture of the genome; Section 4) Functional genomics, proteomics, interactomics, gene inactivation, integration of complex data, gene prediction and genomic annotation; Section 5) Genomics and personalized medicine: analysis of polymorphisms, linkage disequilibrium and GWAS, resequencing of genomes and exomes, data integration and systems biology; Section 6) Practicals in the laboratory where the students will be able to challenge themselves in the production of NGS libraries and in the application of bioinformatics to analyse genomic and transcriptomic data.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2445/005PD/SCP9087941/NO

165/221
**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:**

**Examination:**
The final exam is oral, however the evaluation is articulated into three parts: 1) a written session in which the student must describe the results of the laboratory practicals, that must be submitted at least one week before the official date of the exam, 2) a quiz session on Moodle, that will take place at the beginning of the day of the exam, 3) an oral discussion on the topics of the course and on the results achieved on the practicals. 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/2021/LM/SC/SC2445/005PD/SCQ0094199/NO

**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/2021/LM/SC/SC2445/005PD/SCP9087942/NO
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 (4h). Plant hormones (auxins, gibberellins, cytokinins, ethylene, abscissic acid): biosynthesis, actions, transport and developmental effects; signal transduction pathways (16h). 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 (6h). Blue light and red light responses: light perception, signal transduction and plant responses to light environmental conditions (6h). Plant reproductive development: floral meristem development, floral organ identity genes, ABCDE model to explain the flower development; the control of flowering (8h). 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 (14h). Plant–microorganism interactions: cellular and molecular surveys about mycorrhiza, Rhizobium-Leguminosae symbiosis and plant-Agrobacterium interaction (10h). 16h (1 CFU) of practical work on the following topics: 1) Somatic embryogenesis in the model system Daucus carota, tobacco micropropagation 2) Isolation of protoplasts from plant cell suspension cultures; fluorescence imaging of intracellular compartments 3) Protein extraction and quantification from Arabidopsis thaliana cell cultures stably expressing the calcium-sensitive photoprotein aequorin 4) Analysis of protein expression by SDS-PAGE and immunoblotting

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/2021/LM/SC/SC2445/005PD/SCP8085062/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 euarkriotic 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): Diffusion reaction, French flag theory. 4) Genetic pathways controlling development, their function and visualization (1.5 CFU): Wnt, TGFb, BMP, HH, Notch, Hypoxia, Hippo, STAT 5) germ layers induction and regionalization of the main axes (DV, AP, LR) in vertebrates and Drosophila, Examples of organ formation. (1 CFU) Angiogenesis in model animals (1 CFU): Use of genetic animal models to study angiogenesis. Molecular biology of endothelial cells. Developmental and pathological angiogenesis. Fluorescence and digital microscopy (1 CFU): Use of genetically encoded fluorophores in molecular genetic development. Different fluorescent techniques and microscopes. Advance microscopic techniques for in vivo studies. Laboratory (1 CFU): manipulation of the zebrafish embryo: whole mount staining and imaging of fluorescent embryo; Pharmacological treatment of zebrafish embryos with non-specific teratogens (alcohol) and specific agonists or antagonists.

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:

MOLECULAR GENETICS

167/221
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:**

**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.

**More information:**

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**NEUROBIOLOGY**

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

**Lecturer:** Prof.ssa DANIELA PIETROBON

**Credits:** 10 ECTS

**Prerequisites:**
Physiology, Genetics, Cellular Biology, Molecular biology

**Short program:**
1. Introduction. 2. Anatomical and functional organization of the human nervous system. 3. Specific firing patterns in different neurons, physiological role and experimental methods to investigate their molecular mechanisms. 4. Thalamocortical circuits and cerebral rhythms during sleep and wakefulness. 5. Circadian clocks: genetic, molecular and functional dissection 6. Techniques for measurement of synaptic transmission. Biophysical and molecular mechanisms of neurotransmitter release; experimental methods for their study. 7. Mechanisms of short-term synaptic plasticity (facilitation, post-tetanic potentiation, depression) and of long-term synaptic plasticity (LTP, LTD, STPD). Learning and memory. 8. General functional organization of sensory systems; in depth discussion of one sensory system. 9. Optical and optogenetic techniques for measurement of neuronal electrical activity. Optogenetic techniques for selective stimulation or inhibition of specific neurons. Applications of optogenetics in vitro and especially in vivo for the study of cerebral functions and dysfunctions in modern neurobiology. Laboratory training: it will be possible to choose between two different types of practical exercises. 1) Demonstration of how to perform and analyze recordings of electrical activity of specific neurons in brain slices using the patch-clamp technique, or (in alternative) how to perform recordings of cortical spreading depression (CSD) and how to obtain CSD threshold and velocity of propagation in brain slices using intrinsic optic signal and/or electrophysiological measurements. As exercise, the students will analyze and interpret a recording of electrical activity or CSD. 2) Students complete a set of self-administered electronic sleep quality [Pittsburgh Sleep Quality Index (PSQI)], chronotype and sleepiness [Epworth Sleepiness Scale (ESS)] questionnaires and sleep diaries for two weeks. They also wear an actigraph, wireless sensors for skin temperature, and follow a course of chronotherapy aimed at anticipating their sleep-wake timing. Analyses are performed as practicals, together with the students.

**Examination:**
Written examination with three open questions, which aim to verify, besides the acquired knowledge on relevant topics, the ability of critical discussion and reasoning. The individual report on the practical experience matured during the laboratory training is also evaluated.

**More information:**
https://en.didattica.unipd.it/off/2021/LM/SC/SC2445/005PD/SCP8085065/NO

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**STRUCTURAL BIOCHEMISTRY AND BIOPHYSICS**

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

**Lecturer:** Prof.ssa LAURA CENDRON

**Credits:** 8 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-rays diffraction; Bragg's law; X-
More information:

NATURAL SCIENCE ORD. 2014

ANTHROPOLOGY

Master’s degree in NATURAL SCIENCE ORD. 2014, Second semester

Lecturer: Prof. LUCA PAGANI

Credits: 6 ECTS

Prerequisites:
Prior knowledge needed for the classes in Anthropology is that normally provided for students at the final class of the first degree in Natural Sciences. Particularly, the basic understanding of Genetics, Statistics, Phylogeny, and Evolutionary Biology in their fundamental principles and processes, is required. Students should also have sufficient and basic capacities for argumentation and expression, enabling them to defend a thesis and grasp the contents of a scientific debate, actively participating in the discussion of case-studies. No prior knowledge is requested about specific contents in Population Genetics and Genomics.

Short program:
The course aims at deepening the fundamental concepts, principles and analytical methods of Molecular Anthropology within a broader international context. Particularly: - early phases of human evolution with an overview on the available fossil remains (8h); - genetic characterization of archaic humans (Neanderthals and Denisova) (4h); - human expansions out of Africa and interactions with pre-existing archaic humans (4h); - evidences of adaptive introgressions (genetic advantages derived from archaic genetic material) (2h); - peopling of the continents (Eurasia, America, Oceania) (6h); - dating of the divergence between various modern human populations (4h); - genetic adaptation to the diverse environments encountered inside and outside of Africa (4h); - how structured is the genetic diversity of our species (4h); - demographic growth and expansion/admixture events following technological revolutions (i.e. Neolithic) (4h); - patrilinear (Y chromosome) and matrilinear (mtDNA) perspectives on the diversification of modern populations (2h); - brief overview on the DNA sequencing and genotyping techniques and analyses; - introduction to the ground-breaking consequences of ancient DNA (aDNA) in the field of Molecular Anthropology; - succinct exploration of satellite topics introduced by the students themselves through Journal Clubs on recently published articles (6h) These general objectives are addressed through critical discussion of case-studies taken from primary scientific literature on Molecular Anthropology.

Examination:
Examination is oral and aims at evaluating the scientific skills acquired, through open-ended questions and requests for argumentation and comparison of different theses and models. The suggested reference books are meant to provide a general basis of knowledge which must be integrated with the material examined during the lectures as well as with the most recent scientific papers in the field of Molecular Anthropology (introduced during the lectures). If chosen by the candidate, the exam may start with the discussion of a specific scientific paper among the ones suggested by the teacher, followed by a discussion and additional questions on various topics from the lectures. Attendance is strongly recommended, due to the teaching by interactive methods and case-studies. Students unable to attend a sizeable number of classes must get in touch with the teacher before to discuss an adequate examination mode.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC1178/000ZZ/SCP8085142/NO

ENVIRONMENTAL IMPACT ASSESSMENT

Master’s degree in NATURAL SCIENCE ORD. 2014, First semester

Lecturer: Prof. MASSIMO DE MARCHI
ENVIRONMENTAL MINERALOGY

Master's degree in NATURAL SCIENCE ORD. 2014, Second semester

Lecturer: Prof. GIULIANO ARTICO

Credits: 8 ECTS

Prerequisites: Basic chemistry and chemical thermodynamics. Essentials of mineralogy and geology.

Short program:

Examination:
(1) mid-term presentation on an analytical technique selected by the teacher. The student will summarize: (a) the fundamentals of the technique, (b) the instrumental configuration, (c) the resulting information, (d) describe one application with environmental implications. (2) The student will deliver a final presentation on a topic with environmental implications agreed with the teacher. The student will present: (a) the scientific problem, (b) the data available in the literature, with critical discussion, (c) the prospected actions for a better definition or solution of the problem.

More information: https://en.didattica.unipd.it/off/2021/LM/SC/SC1178/000ZZ/SCP4065427/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

Prerequisites: None

Short program:
- review of basic concepts: probability, odds and rules, updating probabilites, uncertain numbers (probability functions) - from Bernoulli trials to Poisson processes and related distributions - Bernoulli theorem and Central Limit Theorem - Inference of the Bernoulli p; inference of lambda of the Poisson distribution. Inference of the Gaussian mu. Simultaneous inference of mu and sigma from a sample: general ideas and asymptotic results (large sample

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/2021/LM/SC/SC2443/000ZZ/SCP8082557/NO

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ASTRO-STATISTICS AND COSMOLOGY

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. MICHELE LIGUORI

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.

Short program:

Examination:
The exam is comprised of two phases. 1) Resolution of assigned homework during the course, eventually to undertake in group. 3) Oral examination with discussion of the course topics.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP8082722/NO

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BIOLOGICAL DATASETS FOR COMPUTATIONAL PHYSICS

Master's degree in PHYSICS OF DATA ORD. 2018, Second semester

Lecturer: Prof.ssa MONIKA FUXREITER

Credits: 6 ECTS

Prerequisites:
Unix and experience in programming is advised. Basic (high-school) chemistry and statistics can be helpful, but not obligatory.

Short program:

Examination:
In the practicals the students receive a project, which can be solved by independent work. These projects have to be submitted in the middle and at the end of the semester. These projects require independent thinking and usage of the information, which was given in lectures and practicals. It will show whether the student understood the material. As they do not have to submit each week, they have an opportunity to discuss in case a problem is encountered or something has not been clarified sufficiently. They can also contact the teacher by email in case of an urgent problem. 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. In some cases oral presentations in the form of flash-talks can be given, but this is not obligatory. It will only be used if the project is excellent, or concerns arise due to originality. The students will only have to do oral exams if the project performance has not been satisfactory. Oral exams will consist of two parts: i) description of a method ii) proposal to solve a biological problem.

More information:
https://en.didattica.unipd.it/off/2021/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:**
- 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.
- Population-synthesis codes: simulating single and binary stellar populations.
- Project Nr. 1: the formation of binary black holes from different stellar populations.
- General introduction to the astrophysical N-body problem.
- N-body simulations: definition of an N-body simulation; concept of computational complexity; N-body units; exercises on N-body units.
- Examples of numerical algorithms to solve the astrophysical N-body problem: Euler, Leapfrog schemes; exercises with Euler and Leapfrog (motion of a binary system).
- General introduction for an N-body simulation (position, velocities, masses) via Monte Carlo methods: the initial mass function, the Plummer sphere, the Navarro, White potential, Maxwellian distribution of velocities. Direct N-body codes for collisional systems: Hermite schemes, block time-step algorithm, regularization algorithms.
- How to interface population synthesis with direct N-body codes.
- Project Nr.2: integrate star cluster dynamics.
- General introduction to close encounters between single and binary stars.
- Project Nr.3: integrate binary black hole formation/disruption through close dynamical encounters.
- Special purpose hardware, graphics processing units and high-performance computing in astrophysics.
- Galaxy-scale and cosmological simulations.
- Tree codes, softening.
- Project Nr.4: simulation of a galaxy-galaxy interaction, or, as an alternative, analysis of the outputs of a cosmological simulation (EAGLE, IllustrisTNG).
- Gas dynamics and algorithms for gas dynamics: smoothed particle hydrodynamics, mesh codes, adaptive mesh refinement codes, hybrid moving mesh codes.
- Sub-grid physics: star formation, sink particles, supernovae, radiative transfer.
- Project Nr.5: molecular cloud collapse and star formation.

**Examination:**
Oral exam to discuss the final project, considering both its numerical and scientific aspects.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP9067518/NO

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**COSMOLOGY**

Master's degree in **PHYSICS OF DATA ORD. 2018**, Second semester

**Lecturer:** Prof. SABINO MATARRESE

**Credits:** 6 ECTS

**Prerequisites:**
Fundamentals of Cosmology and Astrophysics

**Short program:**
- General introduction to 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/2021/LM/SC/SC2443/000ZZ/SCN1035989/NO

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**DIGITAL SIGNAL PROCESSING**

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

**Lecturer:** Dott.ssa FEDERICA BATTISTI

**Credits:** 6 ECTS

**Short program:**
The module will address the following topics: 1. Shift-invariant discrete time linear systems; Systems defined by linear constant coefficient difference equations; Z-transform and its properties. 2. Discrete Fourier Transform (DFT); definition, properties and usage in practical contexts; FFT algorithms; fast convolution algorithms. 3. Design of linear phase FIR filters: windowed Fourier series technique; frequency sampling method; minimization of the Chebyshev norm (Remez algorithm). 4. IIR filter design using the bilinear transformation method; Butterworth, Chebyshev and Cauer filters; frequency transformations. 5. Multirate linear systems: interpolation and decimation; Efficient realizations; Examples of application

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP8082710/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

**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/2021/LM/SC/SC2443/000ZZ/SCP8082717/NO

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**GAME THEORY**

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

**Lecturer:** ELVINA GINDULLINA

**Credits:** 6 ECTS

**Prerequisites:**
A course, even a basic one, on probability theory.

**Short program:**

**Examination:**
For all the students, in any event the exam includes a mandatory open-book written test, containing problems of game theory focusing on different topics of the course. Every exercise involves multiple questions, typically three. For the students with regular attendance to the course, the exam may also involve, if
they want so, the development of a project in 1-3 person groups, on course-related topics applied to ICT. This is agreed half-way through the course together with the lecturer. If the written test is sufficient, students can directly finalize the passing score. Projects can be discussed with an oral exam after the written test. Oral exams are scheduled in the same day of written tests (even though students can decide to give the two parts on separate days). The project discussion integrates the mark of the written test.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP7079401/NO

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**GENERAL RELATIVITY**

Master's degree in **PHYSICS OF DATA ORD. 2018**, 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/2021/LM/SC/SC2443/000ZZ/SCP7081661/NO

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**LABORATORY OF COMPUTATIONAL PHYSICS (C.I.)**

**Lecturer:** Prof. MARCO ZANETTI

**Prerequisites:**
Even though not strictly required, the development of the class assumes the attendance of at least two physics laboratory classes during the bachelor degree

**Examination:**
To verify the proficiency of the students in the subjects covered by this course, the written reports on the lab experiences will be evaluated; such evaluation will have to be confirmed by an oral exam, during which the students will also be interviewed about what is thought during the lectures. The oral exam will be split into two parts, each relevant to one of the two modules the class consists of.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP8082524/NO

**Moduli del C.I.:**
LABORATORY OF COMPUTATIONAL PHYSICS
LABORATORY OF COMPUTATIONAL PHYSICS (MOD. B)

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**LABORATORY OF COMPUTATIONAL PHYSICS**

**Lecturer:** Prof. MARCO ZANETTI

Master's degree in **PHYSICS OF DATA ORD. 2018**, First and Second semester

**Credits:** 12 ECTS

**Short program:**
- The working principles and logic schemes of a modern computer and its main components. Review of the available hardware solutions to face problems in various areas of scientific computing: parallel computing, cluster/cloud computing, distributed computing - The python programming language, from the bases to the advance programming for scientific computing; review of the modern libraries for the data management and analysis (numpy, scipy, pandas,
LABORATORY OF COMPUTATIONAL PHYSICS (MOD. B)

Lecturer: Prof. MARCO BAIESI

Master's degree in PHYSICS OF DATA ORD. 2018, First and Second semester

Credits: 12 ECTS

Short program:

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/2021/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

Prerequisites:
Basic knowledge of Mathematics, Probability Theory, Statistics, Linear Algebra, Algorithms and basic programming skills.

Short program:

Examination:
The evaluation of the acquired skills and knowledge will be performed using two contributions: 1. A written exam without the book, where the student must solve few problems, with the aim of verifying the acquisition of the main ingredients of a learning problem and of the main machine learning tools, the analytical ability to use these tools and the ability to interpret the typical results of a practical machine learning problem. 2. Computer simulations (optional) with the aim of acquiring the practical competences for using machine learning tools. These simulations, to be performed at home, allow to verify the ability of practically exploiting the acquired theoretical concepts. The student will have to provide a brief document explaining the employed methodologies used to solve the assigned problem together with the obtained results. The final grade will be based on the written test with a bonus up to 3 point for the students who will hand in also the lab assignments.

More Information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP8082660/NO
Lecturer: to be defined

Prerequisites:
Elements of Analysis, Algebra, Statistics, Basic programming elements basics of unix Shell scripting, Python, Git

Examination:
There will be two separate exams related to modules A and B Regarding exam for Module A, a project about FPGA programming will be assigned at the end of the course. The exam will focus on the presentation and discussion of that project. In addition, questions on the material presented during lectures will be places and the discussion of a scientific paper to be chosen within a list of proposed articles will be requested. Regarding Module B, the exam will consist of two parts, related to two modules of data management and data processing respectively. Students will be required to carry out projects (individually or in small groups) regarding the management and data analysis topics covered in the course, and to discuss the adopted solutions and the results obtained.

More information:
https://en.didattica.unipd.it/off/2021/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: Prof. GIANMARIA COLLAZUOL
Master's degree in PHYSICS OF DATA ORD. 2018, First and Second semester
Credits: 12 ECTS
Short program:
PART I - Electronics for real-time data management systems 1) Data Sources - signal generation in sensors/detectors - early (analog) data processing (amplification, filtering, ...) - digitization (A/D, ADC, TDC, ...) - timing, sync and control signals distribution systems 2) Data Transport - Data Transport Architectures - Physical layers for data streams - Interconnections and buses 3) Real Time Data Processing - Digital ports and logics - Storage units - Memories - Processing units - focusing on FPGA - Parallel data streams 4) Real Time Data Filtering and System Control - Trigger generation and distribution - Transducers and System Control PART II - Hands-on Laboratory of data management with FPGA 1) Introduction to FPGA and intro to the ARTY A7 board 2) FPGA Programming framework, Simulation and Test-Bench 3) Combinational Logic Circuits 4) Sequential Logic Circuits 5) Virtual Input Output and Integrated Logic Analyzer 6) Arithmetic Operations - case study; DAC/ADC and FIR Filter 7) Finite State Machines 8) Memories 9) Buses and Protocols - case study; SPI interface for accessing Flash memory - case study: IPBUS - communication FPGA-PC via Ethernet interface NOTE - Examples and Case studies will be chosen in various fields: from High Energy Physics to Astro-particle and Space Physics Systems on satellites; from Nuclear Imaging Medicine to Low-Latency Market Data Feed Processing; from Biomedical and Neuro Sciences to Gravitational Wave Physics.

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
Credits: 12 ECTS
Short program:
Part 1) Data Management Introduction to data structures Storage Models Reliability Availability Authentication, Authorization Local and Distributed File systems Cloud storage Databases Part 2) Data processing Introduction to parallel processing Distributed Computing Systems and the Grid paradigm Cloud computing service models Virtualization Containerization Hadoop as a paradigm for big data processing Data processing with Spark Data processing with Dask Kafka as a distributed streaming platform

MODELS OF THEORETICAL PHYSICS
Lecturer: Prof. AMOS MARITAN
Credits: 6 ECTS
Prerequisites:
Good knowledge of mathematical analysis, calculus, elementary quantum mechanics and basic physics.
Short program:
Introduction; "The Unreasonable Effectiveness of Mathematics in the Natural Sciences (Wigner 1959)"; Gaussian integrals Wick theorem Perturbation theory connected contributions Steepest descent Legendre transformation Characteristic/Generating functions of general probability distributions/measures Brownian paths and polymer physics biopolymer elasticity. The random walk generating function, the Gaussian field theory and coupled quantum harmonic oscillators. Levy walks. Field theories as models of interacting systems O(n) symmetric Phi^4– theory. The large n limit: Spherical (Berlin-Kac) model.

Examination:
The first part of the verification of the acquired knowledge will evaluate the homework 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/2021/LM/SC/SC2443/000ZZ/SCP8083597/NO

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**MOLECULAR SIMULATIONS**

Master's degree in PHYSICS OF DATA ORD. 2018, Second semester

Lecturer: Prof.ssa MONIKA FUXREITER

Credits: 6 ECTS

Prerequisites:
Unix, programming experience, high-school chemistry are advised. Background in physical chemistry, statistical mechanics or quantum mechanics is helpful, but not absolutely necessary.

Short program:

Examination:
The students will learn to define biological questions so that they can be solved computationally. They will learn about the methods, as well as to design a computational study. In practicals, the students have to perform an independent work. These include reports on a scientific research in the area of computational study, and solving simple simulation problems. 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. These projects have to be submitted in the middle and at the end of the semester. These projects require independent thinking and usage of the information, which was given in lectures and practicals. It will show whether the student understood the material. As they do not have to submit each week, they have an opportunity to discuss in case a problem is encountered or something has not been clarified sufficiently. They can also contact the teacher by email in case of an urgent problem. In some cases, oral presentations in the form of flash-talks can be given, but this is not obligatory. In particular if concerns arise due to originality of the homework projects. The students will only have to do oral exams. Oral exams will consist of two parts: i) description of a method ii) proposal to solve a biological problem. A list of methods and topics will be defined for the exam from the material of the course. Students who carry out additional research work during the course, can be exempt from the exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCQ1098979/NO

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**NETWORK MODELLING**

Master's degree in PHYSICS OF DATA ORD. 2018, Second semester

Lecturer: Prof. MICHELE ZORZI

Credits: 6 ECTS

Prerequisites:
The course requires preliminary knowledge of: Mathematical Analysis, Probability, random variables and random processes, networks and protocols. For the examples treated, a basic course in networks and protocols is useful (through not required).

Short program:
Examination:
The assessment of the knowledge and skills acquired is carried out by means of a written test divided into two parts. Part A, with a duration of 90 minutes and open-book, consists of eleven numerical questions grouped into four exercises. Each question has a value of three points. Part B, with a duration of 60 minutes and closed-book, consists of three theoretical questions (typically proofs of theorems seen in class). Each question has a value of eleven points. If the student scores at least 15 points in part A and the average score of part A and part B is at least 18, the latter can be accepted as the final grade. If the score in part A is less than 15 or the average of the two tests is less than 18, the exam is not passed. Even if the final exam can be passed by a successful written exam (in two parts), the student can always ask to take an oral exam if he/she wants to improve the grade. In no case can the oral exam replace the written test. Examples of exams are available on the e-learning platform course website, and are extensively covered in class.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP8082659/NO

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**NETWORK SCIENCE**

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. TOMASO ERSEGHE

Credits: 6 ECTS

Prerequisites: This course has the following prerequisites: knowledge in Probability Theory, and Computer Programming in any language which is appropriate for network analysis (e.g., Matlab, Python, C, Java); knowledge in Calculus and Linear Algebra; any further knowledge of networking processes in economics, biology, telecommunications, semantics, etc. might be useful.

Short program:
The module will cover the following topics: 1. Basic network properties - graphs, adjacency matrix, degree distribution, connectivity, distance and diameter, clustering coefficient. 2. Network models - Erdos-Renyi model; Random graphs with general degree distribution; Power laws and scale free networks; Small world phenomena; Hubs; Network generation and expansion; Barabasi-Albert model; Preferential attachment; Evolving networks. 3. Centrality measures: Hubs and authorities; PageRank; teleportation, topic specific ranking, proximity measures, trust rank; betweenness, closeness, eigenvector and Katz centralities. 4. Other analytics: homophily ( assortativity), polarisation, innovation, clustering, robustness, link prediction. 5. Community detection - Dendrograms; Girvan Newman method and betweenness; Louvain modularity optimisation; Spectral clustering; Consensus clustering; Measuring similarities in clustering outcomes; Algorithms for overlapping communities. 6. Network representation - Gephi and R/Python graphical functions; rationale of force directed graph layout algorithms. 7. Twitter Lab - How to extract a semantic network from Twitter data.

Examination:
The verification of the expected knowledge and skills is carried out with the DEVELOPMENT OF A PROJECT aimed at verifying the ability to apply theory in interdisciplinary contexts, and which requires: the choice, the collection of data, and the analysis of a different network for each student; computer implementation (in any programming language known to the student) of the algorithms required for the analysis; the drafting of an essay; the oral presentation of the main project outcomes. A bonus of up to 3 points is available for attending students that take part to an INTERDISCIPLINARY PROJECT with social science students attending the twin course on SOCIAL NETWORK ANALYSIS.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP8082273/NO

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**NEURAL NETWORKS AND DEEP LEARNING**

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Dott. ALBERTO TESTOLIN

Credits: 6 ECTS

Prerequisites: The course relies on preliminary knowledge of mathematical analysis, linear algebra and probability theory. Familiarity with machine learning concepts is desired, though not mandatory. Python programming skills are required.

Short program:

Examination:
Evaluation of knowledge and abilities acquired will consist on 3 individual assignments, which will be discussed during the oral exam. The assignments will
require a software implementation of computational models and analyses discussed during the course, along with a short essay in which the student will describe and discuss the results. The oral exam will also include general theoretical questions related to the course content.

More information:
https://en.didattica.unipd.it/off/2021/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

**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/2021/LM/SC/SC2443/000ZZ/SCP7081658/NO

**PHYSICS OF COMPLEX SYSTEMS**

Master's degree in **PHYSICS OF DATA ORD. 2018**, 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/2021/LM/SC/SC2443/000ZZ/SCP7081763/NO

**QUANTITATIVE LIFE SCIENCE**

Master's degree in **PHYSICS OF DATA ORD. 2018**, First semester

**Lecturer:** Prof. SAMIR SIMON SUWEIS

**Credits:** 6 ECTS

**Prerequisites:**
Basics of Stochastic processes and Statistical Mechanics. If you never attended the class “Statistical Mechanics of Complex Systems” or “Models of Theoretical Physics” you will need to work a little to recover some topics through personal additional study guided by me.

Short program:

Examination:
The first part of the verification of the acquired knowledge will evaluated be through homework exercises (to do in groups) and the participation of the students in the class discussions The second part will takes place through, a common written test with 1-2 exercises to be solved and open questions to test the knowledge on basic concepts, the scientific vocabulary, the ability to synthesis and critical discussion acquired during the course. The third facultative part of the exam will be oral and will be based on a discussion on the various topics discussed during the course.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP8082720/NO

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. SIMONE MONTANER

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/2021/LM/SC/SC2443/000ZZ/SCP8082721/NO

Master's degree in PHYSICS OF DATA ORD. 2018, Second semester

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/2021/LM/SC/SC2443/000ZZ/SCP8082720/NO

RELATIVISTIC ASTROPHYSICS
SOLID STATE PHYSICS

Master's degree in PHYSICS OF DATA ORD. 2018, 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/2021/LM/SC/SC2443/000ZZ/SCP7081660/NO

STAGE

Master's degree in PHYSICS OF DATA ORD. 2018, Second semester

Lecturer: Prof. MARCO ZANETTI

Credits: 8 ECTS

Short program:
The internship can be hosted by a company or a research center. The subject must be coherent with the main topics covered in the Physics of Data programme. The duration of the internship should be at least 3-4 months and should not exceed 6-7 months. The research activity must be supervised by a staff member of the company or research center; such activity can be the subject of the student's thesis.

More information:
https://en.didattica.unipd.it/off/2021/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

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.

https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP7081738/NO
STATISTICAL MECHANICS OF COMPLEX SYSTEMS

Master's degree in PHYSICS OF DATA ORD. 2018, Second semester

Lecturer: Prof. AMOS MARITAN

Credits: 6 ECTS

Prerequisites:
Good knowledge of mathematical analysis, calculus and basic physics. For "Physics of Data" students the course has 6 CFU. However, if they are not adequately trained in statistical mechanics, they are encouraged to follow all 9 credits

Short program:
The program can be summarized as follows Statistical mechanics and Entropy Ising model Variational principles in statistical mechanics Complex networks Principle of maximum entropy and inference Diffusion Processes and stochastic dynamics Montecarlo simulations Dynamics of and on networks Population dynamics with applications to ecosystems Percolation on networks. Neural networks

Examination:
The first part of the verification of the acquired knowledge will evaluate the homework exercises and the participation of the students in the class discussions The second part will take place through, a common written test with 1-2 exercises to be solved and open questions to test the knowledge on basic concepts, the scientific vocabulary, the ability to synthesis and critical discussion acquired during the course. The third 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/2021/LM/SC/SC2443/000ZZ/SCP7081659/NO

STRUCTURE OF MATTER

Master's degree in PHYSICS OF DATA ORD. 2018, 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:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP8082536/NO

SUBNUCLEAR PHYSICS

Master's degree in PHYSICS OF DATA ORD. 2018, 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/2021/LM/SC/SC2443/000ZZ/SCP7081697/NO

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THE PHYSICAL UNIVERSE

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/2021/LM/SC/SC2443/000ZZ/SCP7081677/NO

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THEORETICAL PHYSICS

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. PIERPAOLO MASTROLIA

Credits: 6 ECTS

Short program:

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP7081638/NO
THEORETICAL PHYSICS OF THE FUNDAMENTAL INTERACTIONS

Master's degree in PHYSICS OF DATA ORD. 2018, First semester

Lecturer: Prof. STEFANO RIGOLIN

Credits: 6 ECTS

Short program:

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2443/000ZZ/SCP7081657/NO

PHYSICS ORD. 2017

APPLICATIONS FOR THERAPY

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: to be defined

Credits: 12 ECTS

Prerequisites: CONTENT NOT PRESENT

Short program: CONTENT NOT PRESENT

Examination: CONTENT NOT PRESENT

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2382/004PD/SCP7081919/NO

COMMON ADVANCED COURSE

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: CONTENT NOT PRESENT

Short program: CONTENT NOT PRESENT

Examination: CONTENT NOT PRESENT

More information:
EXPERIMENTAL NUCLEAR PHYSICS AND ACCELERATORS

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: to be defined
Credits: 6 ECTS
Prerequisites: CONTENT NOT PRESENT
Short program: CONTENT NOT PRESENT
Examination: CONTENT NOT PRESENT

METROLOGY AND DATA ANALYSIS

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: to be defined
Credits: 6 ECTS
Prerequisites: CONTENT NOT PRESENT
Short program: CONTENT NOT PRESENT
Examination: CONTENT NOT PRESENT

THEORETICAL NUCLEAR, ATOMIC AND COLLISION PHYSICS

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: to be defined
Credits: 12 ECTS
Prerequisites: CONTENT NOT PRESENT
Short program: CONTENT NOT PRESENT
Examination: CONTENT NOT PRESENT

ADVANCED OPTICS AND METROLOGY

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: Prof. GIACOMO CIANI
**ADVANCED PHYSICS LABORATORY B**

Master's degree in **PHYSICS ORD. 2017**, 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.

**More information:**

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**BIOPHOTONICS**

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

**Lecturer:** Prof. FABIO MAMMANO

**Credits:** 6 ECTS

**Prerequisites:**
Biological Physics

**Short program:**
Electromagnetic wave propagation: plane waves, spherical waves, phase velocity, irradiance, wave packets, group velocity, coherence length, interference. Scalar diffraction theories: the Kirchhoff formulation, the Rayleigh-Sommertfeld formulation, the Huygens-Fresnel principle. Geometrical optics: Optical path length, the principle of Fermat, ideal imaging systems, matrix methods in paraxial imaging, cardinal points and planes. Apertures and stops, image-forming instruments, brightness and illumination of images, intensity fluctuations, detection noise. The Debye integral representation of focused fields, irradiance distribution near focus (three-dimensional point spread function). Resolving power: the Rayleigh criterion. Minimum angular separation, visual acuity, phototransduction. Transmitted light microscopy: angular spectrum of plane waves, diffraction gratings, abbe theory and resolution. Phase contrast, dark field, and differential interference contrast microscopy. Fluorescence microscopy: molecular spectra, Jablonski diagram, Stokes' shift, life time and quantum efficiency, saturation of the excited state. Structure of the conventional fluorescence microscope, Confocal microscopy: lateral resolution and axial resolution in the classical limit; optical sectioning and volume reconstruction; physical principles and applications of 2-photon excitation; advantages and disadvantages of different confocal systems. Stimulated emission depletion (STED) nanoscopy and super-resolution. Selected biophotonics applications: optical recording of changes in ion concentration. Optical sensors of Ca2+ ions, protons and other physiologically relevant ionic species. Imaging of Ca2+ at one and two wavelengths; local control of the concentration of Ca2+ and other active molecular species by UV photolysis of caged compounds; FRET, FRAP. Intravital microscopy: biosensors, optochemogenetics, photodynamic therapy of cancer.

**Examination:**
Written and an oral exam. The written part concerns topics developed during the course. The oral exam consists in the presentation by the student of one or more original articles related to optical super-resolution techniques.

**More information:**
FUNDAMENTALS OF ASTROPHYSICS AND COSMOLOGY

Master's degree in PHYSICS ORD. 2017, 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:

GENERAL RELATIVITY

Master's degree in PHYSICS ORD. 2017, 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.
NANOFABRICATION

Master's degree in **PHYSICS ORD. 2017**, 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 Eletrra 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:

NON-PERTURBATIVE QUANTUM FIELD THEORY

Master's degree in **PHYSICS ORD. 2017**, 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:

NUCLEAR PHYSICS

Master's degree in **PHYSICS ORD. 2017**, 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:

PHYSICS OF COMPLEX SYSTEMS

Master's degree in PHYSICS ORD. 2017, 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:

PHYSICS OF FLUIDS AND PLASMAS

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: Dott. TOMMASO BOLZONELLA

Credits: 6 ECTS

Prerequisites:
None
Short program:

Examination:
The exam modality will be presented at the beginning of the course.

More information:

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PHYSICS OF NUCLEAR FUSION AND PLASMA APPLICATIONS

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: Dott.ssa LIDIA PIRON

Credits: 6 ECTS

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.

Short program:

Examination:
Le modalità d’esame saranno presentate all’inizio del corso.

More information:

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PHYSICS OF SEMICONDUCTORS

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: Prof. DAVIDE DE SALVADOR

Credits: 6 ECTS

Prerequisites:

Short program:
Review of the crystal structure of the main semiconductors. Elementary semiconductors, compounds and alloys. Review of solid state basic concepts (Bloch theorem, effective mass, concept of hole). Origin and specificity of semiconductors band structure. The real bands (examples: GaAs, Si, Ge, ...

Examination:
During the semester it will be possible to give a mid-term 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:

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QUANTUM INFORMATION AND COMPUTING

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: Prof. SIMONE MONTANGERO

Credits: 6 ECTS

Prerequisites:
Quantum mechanics and elements of programming.

Short program:
1. Basics in computational physics
2. Large matrix diagonalization
3. Numerical integration, optimizations, and solutions of PDE
4. Elements of Gnuplot, modern FORTRAN, python
5. Elements of object-oriented programming
6. Schrödinger equation (exact diagonalization, Split operator method, Suzuki-trotter decomposition)
8. Entanglement measures
9. Entanglement in many-body quantum systems
10. Numerical Renormalization Group
11. Density Matrix Renormalization group
12. Introduction to tensor networks
13. Symmetric tensor networks
15. Exact solutions of benchmarking models
16. Critical systems
17. Topological order and its characterization
18. Adiabatic quantum computation
19. Quantum annealing of classical hard problems
20. Kibble-Zurek mechanism
21. Optimal control of many-body quantum systems
22. Open quantum systems (quantum trajectories, MPDO, LPTN, ...)

Examination:
The exam will be a final project composed of programming, data acquisition, and analysis, which will be discussed orally.

More information:

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THEORY OF STRONGLY CORRELATED SYSTEMS

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: Prof. LUCA DELL'ANNA

Credits: 6 ECTS

Short program:
1. Introduction to the path integral
2. Brief review of quantum mechanics for single particle and identical particles
3. Second quantization: annihilation and creation operators
4. Single-particle and double-particle operators
5. Bosonic coherent states
6. Gaussian integrals with complex and Grassmannian variables
7. Feynmann integrals
8. Partition function and imaginary time
9. Equation of motion and stationary phase approximation
10. Application of Feynman integrals for a double-well: instanton gas
11. Functional integrals with coherent states
12. Interacting particles: perturbation theory
13. Functional integral for the electromagnetic field

Examination:
Oral examination

More information:
**ADVANCED PHYSICS LABORATORY B**

Master's degree in **PHYSICS ORD. 2017**, 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.


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**ADVANCED QUANTUM FIELD THEORY**

Master's degree in **PHYSICS ORD. 2017**, 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 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.


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**ADVANCED TOPICS IN THE THEORY OF THE FUNDAMENTAL INTERACTIONS**

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

**Lecturer:** Dott. LUCA DI LUZIO

**Credits:** 6 ECTS

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Prerequisites:
A basic knowledge of theoretical physics of the fundamental interactions, in particular of quantum field theory.

Short program:
- INTRODUCTION AND EXAMPLES: Characterization of a physical system: degrees of freedom, relevant scales, symmetries. Examples of Effective Field Theories (EFTs): the Fermi theory of weak interactions, the Standard Model as an EFT, and other examples. - FORMAL ASPECTS: EFT and power counting; integrating out heavy modes at tree level and one loop; decoupling theorem. The Wilsonian action; evaluation in perturbation theory and exact results at the tree level. S-matrix equivalence theorem: local field redefinitions and equivalent effective Lagrangians. One-loop EFT: running coupling constant, operator mixing and anomalous dimensions. - EFT IN THE PERTURBATIVE REGIME: THE EULER-HEISENBERG LAGRANGIAN Symmetry considerations and bottom-up approach; derivation from QED and other completions. Birefringence of the vacuum; equations of motion of electromagnetic field from Euler-Heisenberg theory. Landscape and swampland of Euler-Heisenberg EFT; positivity bounds from analyticity, crossing symmetry and unitarity applied to light-by-light forward scattering amplitude. - EFT IN THE NON-PERTURBATIVE REGIME: THE CHIRAL LAGRANGIAN Symmetries of the strong interactions; the Chiral Lagrangian for low-energy QCD. Anomalies of global symmetries of strong and electromagnetic interactions and physical consequences. QCD vacuum structure, electric dipole moment of the neutron, strong CP problem and its solutions. Axion EFT and phenomenology. Callan-Coleman-Wess-Zumino formalism and applications in theories of Composite Higgs and strongly-interacting Dark Matter.

Examination:
Problems assigned during the course and oral exam.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2382/001PD/SCP7081741/NO

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COSMOLOGY OF THE EARLY UNIVERSE

Master's degree in PHYSICS ORD. 2017, 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:

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EXPERIMENTAL SUBNUCLEAR PHYSICS

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: Prof. RICCARDO BRUGNERA

Credits: 6 ECTS

Prerequisites:
One assumes some prior knowledge: basic information regarding High Energy Physics and Quantum Electrodynamics coming from the courses of Subnuclear Physics, Theoretical Physics and Theoretical physics of the fundamental interactions

Short program:

Examination:
FUNDAMENTALS OF ASTROPHYSICS AND COSMOLOGY

Master's degree in PHYSICS ORD. 2017, 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/2021/LM/SC/SC2382/001PD/SCP9086381/NO

MEDICAL PHYSICS

Master's degree in PHYSICS ORD. 2017, 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:
• Introduction to dosimetry of ionizing radiation. Radiation dose and health risk. • 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). • Introduction to magnetic resonance imaging (MRI). • NIR and introduction to echography imaging. • Principles of radiotherapy with photons, electron and hadrons. • Principles of hyperthermia.

Examination:
Oral examination. The student will present by Power Point slides a detailed analysis of one or more recent scientific papers related to arguments of the course. The topic of the presentation will be agreed with the teacher. Questions concerning this presentation and other topics presented during the lectures are foreseen.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2382/001PD/SCP9088180/NO

MULTIMESSENGER ASTROPHYSICS
Master's degree in PHYSICS ORD. 2017, Second semester

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. 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:

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NON-PERTURBATIVE QUANTUM FIELD THEORY

Master's degree in PHYSICS ORD. 2017, 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 (φ4, polyacetylene), 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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SOLID STATE PHYSICS

Master's degree in PHYSICS ORD. 2017, 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; Monatomic 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/2021/LM/SC/SC2382/001PD/SCP7081660/NO

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### STATISTICAL MECHANICS

Master's degree in PHYSICS ORD. 2017, 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/2021/LM/SC/SC2382/001PD/SCP7081659/NO

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### THEORY OF STRONGLY CORRELATED SYSTEMS

Master's degree in PHYSICS ORD. 2017, First semester

Lecturer: Prof. LUCA DELL'ANNA

Credits: 6 ECTS

Short program:

Examination:
Oral examination

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2382/001PD/SCP7081742/NO
HADRONE PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites:
CONTENT NOT PRESENT

Short program:
CONTENT NOT PRESENT

Examination:
CONTENT NOT PRESENT

More information:

ACCELERATOR PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Dott. ANDREA PISENT

Credits: 6 ECTS

Prerequisites:
CONTENT NOT PRESENT

Short program:
CONTENT NOT PRESENT

Examination:
CONTENT NOT PRESENT

More information:

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:

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:

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ATOMIC AND PLASMA PHYSICS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: CONTENT NOT PRESENT

Short program: CONTENT NOT PRESENT

Examination: CONTENT NOT PRESENT

More information:

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BASIC EXPERIMENTAL NUCLEAR PHYSICS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: CONTENT NOT PRESENT

Short program: CONTENT NOT PRESENT

Examination: CONTENT NOT PRESENT

More information:

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COMPUTING AND NUMERICAL METHODS

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: CONTENT NOT PRESENT
HEAVY ION REACTIONS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof.ssa GIOVANNA MONTAGNOLI

Credits: 6 ECTS

Prerequisites:
Knowledge of the basic concepts of quantum mechanics and of nuclear physics is required

Short program:
Introduction • Basic concepts on Nuclear Reactions • Nucleon-Nucleon Scattering • Heavy-ion interactions • Direct Reactions and Nuclear Structure • Transfer Reactions between Heavy-ions • Compound Nucleus Reactions • Sub-barrier Fusion and related experimental techniques • Barrier Distributions and Fusion Hindrance • Nuclear reactions of astrophysical interest. Relativistic Heavy-ions collisions. Evidence of the Quark-Gluon Plasma formation

Examination:
The exam will be oral including the whole program of the course The students have to be able to solve the exercises proposed during the course.

More information:

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:

MANY BODY THEORIES IN NUCLEAR PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites:
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, 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/2021/LM/SC/SC2382/004PD/SCP7081704/NO

NUCLEAR REACTIONS

Master’s degree in PHYSICS ORD. 2021, Second semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites:
CONTENT NOT PRESENT

Short program:
CONTENT NOT PRESENT

Examination:
CONTENT NOT PRESENT

More information:

NUCLEAR STRUCTURE: PROPERTIES AND MODELS

Master’s degree in PHYSICS ORD. 2021, First semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites:
CONTENT NOT PRESENT

Short program:
CONTENT NOT PRESENT
**QUANTUM MECHANICS**

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

**Lecturer:** to be defined

**Credits:** 6 ECTS

**Prerequisites:** CONTENT NOT PRESENT

**Short program:**

CONTENT NOT PRESENT

**Examination:**

CONTENT NOT PRESENT

**More information:**


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**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:**


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**RELATIVISTIC QUANTUM THEORY: NUCLEAR PROCESSES**

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

**Lecturer:** to be defined

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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.


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.


WEAK INTERACTIONS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: to be defined

Credits: 6 ECTS

Prerequisites: CONTENT NOT PRESENT

Short program: CONTENT NOT PRESENT

Examination: CONTENT NOT PRESENT


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/2021/LM/SC2382/002PD/SCP7081700/NO

ADVANCED TOPICS IN PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. GRIGORI KORTCHEMSKI

Credits: 6 ECTS

Prerequisites:
Theoretical physics of the fundamental interactions

Short program:
Course unit contents: Poincaré group; review of the free scalar, fermion and abelian gauge fields; the supersymmetry algebra; examples of supersymmetric theories: free fields, Wess-Zumino model; N = 1 chiral supermultiplet; on-shell supercharges; extended supersymmetry; review of non-abelian gauge theories; N=4 supersymmetric Yang-Mills theory; supersymmetric Ward identities; on-shell states; S-matrix; properties of scattering amplitudes in gauge theories; spinor-helicity formalism; color ordered amplitudes; classification of amplitudes by helicity violation; Parke-Taylor amplitudes; Britto-Cachazo-Feng-Witten recursion.

Examination:
Oral Exam

More information:
https://en.didattica.unipd.it/off/2021/LM/SC2382/002PD/SCQ0093399/NO

BIOLOGICAL PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. MARIO BORTOLOZZI

Credits: 6 ECTS

Prerequisites:
The course will be held in English.

Short program:
Introduction: what is biophysics, top-down and bottom-up approaches. The living cell: eukariotyc and prokaryotic cells, cell structure and function of its constituents, cell division. The water: structure and chimical-physical properties, water-protein interaction, optical properties of water, pH and buffering systems, cell incubators. Membranes and channels: conductance, cell equivalent circuit, Nernst potential, voltage-clamp technique, Hodgkin-Huxley model, neuronal action potential and its simulation, saltatory conduction and Schwann cell, patch-clamp, electrophysiology setup, derivation of cell electrical parameters, single channel current measurement, voltage-activated channel types and blockers, muscle and hair cell synapse, two-state channel model, three- and multi-state models, receptors, activation energies of a channel. Diffusion: Fick’s laws, diffusion from a point source, random walk and Monte Carlo approach, particle interaction with boundaries, random walk on a grid, numerical simulations of the diffusion process, discretization of the diffusive Laplacian, hydration shells, Kramer equation, electrical mobility, Nernst-Planck equation. Permeability: partition coefficient, Goldman-Hodgkin-Kats equations, deviation from Ohm’s law, ionic selectivity, single channel permeability, saturation, Eyring’s theory, sodium and potassium channel models. Chemical reactions: enzymatic reactions, Michaelis-Menten equation, SERCA and PMCA pumps, fluorescent dyes, calcium (Ca2+) dyes, configuration of a fluorescence microscope, relationship between dye fluorescence and Ca2+ concentration, photobleaching, ratiometric dyes, non-equilibrium conditions between Ca2+ and the dye, numerical simulations of Ca2+ dynamics, generation of a reaction-diffusion model and comparison with experiments, Ca2+ dynamics in the inner ear and in cardiac cells, modeling a complex geometry using meshes. Molecular dynamics: DNA, RNA and proteins, the central dogma of biology, amino acids, folding and protein structures, simulation of protein dynamics, potential energy formula, computational algorithms, boundary conditions and examples of models. Neural networks: machine learning, learning approaches, artificial neuron and schemes of neural networks, error backpropagation, artificial vision and speech recognition, cerebral organoids, Boltzmann machines. Mathematical appendix: introduction to Matlab, variables and functions, how to write a simulation code, code optimization and debugging, numerical methods for the solution of a differential equation system, examples and exercises, development of a graphical interface in Matlab.

Examination:
The final check is composed of a written and an oral part. The written exam consists of writing a report on a biological model solved by the student using a numerical simulation in Matlab. The oral exam consists of presenting by Power Point slides a recent scientific paper related to the course arguments.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC2382/002PD/SCP7081737/NO
Master's degree in PHYSICS ORD. 2021, 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. Intermolecular interactions: force-fields; atomistic and coarse grained models. Variational methods for the solution of the Schrodinger 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:**

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**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:**

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**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:**
1) Fundamentals of NanoScience (MSc in Materials Science and in Materials Engineering, 4 + 4 = 8 CFU) MODULE A (4 CFU) - Classification, characteristics and general properties of nanostructured materials: quantum confinement and electronic properties. Size Equations. - Thermodynamic properties of nanostructured materials: thermodynamic size effect, nucleation (Gibbs-Thomson equation) and growth of nanostructures (Diffusion-Limited Aggregation and Ostwald Ripening regimes). - Nanostructures embedded in solid matrices: Ion implantation for the synthesis and processing of metallic
nanostructures. Verification of the nucleation and growth models. - Optical properties of nanostructured materials: (i) plasmonic properties of non-interacting metallic nanostructures (Mie theory and its extensions); (ii) interacting nanostructures - Characterization techniques of nanostructures: transmission and scanning electron microscopy in transmission (TEM) and in scanning (SEM) mode. MODULE B (4 CFU) Overview of the preparation methods of nanostructures (both top-down and bottom-up, with particular emphasis on the latter). Structural aspects and energy of nanostructures and methods for their stabilization. Defects in nano dimensional materials. Solid with controlled porosity. Forms of nanoparticles: thermodynamics vs. kinetics. Core-shell nanoparticles. Self-assembly and self-organization. Colloidal method. Templating effect. Preparation of nanoparticles, nanowires, nanotubes, thin films. Self-assembled monolayers. Langmuir and Langmuir-Blodget films. Coherent, semi-coherent, epitaxial and pseudomorphic interfaces. Growth methods for ultrathin films: CVD, MBE, PVD, ALE and PLD methods. Recall of the fundamental equations for electron and photon dynamics. Material properties for electron and photon confinement. Density of states for confined systems in one, two or three dimensions. Properties of low dimensional carbon nanostructures: graphene and nanotubes. Tight binding approach for the description of their conduction, optical properties (absorption and emission) and Raman scattering (Kataura plots). Models for the electron confinement in quantum dots in the weak and strong regime. Confinement of electrons in metallic nanoparticles and plasmonic properties. Froehlich conditions and far and near field optical properties. SERS effect with plasmonic nanostructures. Hints on the confinement of photons in photonic crystals. 2) Introduction to NanoPhysics (MSc in PHYSICS, 4 + 2 = 6 CFU The first 4 CFUs are the same as for MODULE A, previously described, which will be borrowed by the students of the 'Introduction to NanoPhysics' of the MSc Degree in Physics. The remaining 2 CFUs address the following topics: - Fundamental description of the dynamics of electrons and photons - Confinement of electrons and photons in nanostructured or periodic materials; - 2D and 3D photonic crystals; - Meta-materials: (i) with hyperbolic dispersion and (ii) with negative refractive index; - Practical laboratory activities: (i) synthesis of Au spherical nanoparticles in solution; (ii) measurement of their UV-VIS transmittance spectrum; (iii) simulation of the experimental spectra with the Mie theory; (iv) electron microscopy characterization.

Examination:
1) Fundamentals of NanoScience (MSc in Materials Science and in Materials Engineering) 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.

More information:

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**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:**

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**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:**
Introduction; "The Unreasonable Effectiveness of Mathematics in the Natural Sciences (Wigner 1959)"; Gaussian integrals Wick theorem Perturbation theory connected contributions Steepest descent Legendre transformation Characteristic/Generating functions of general probability distributions/measures Brownian paths and polymer physics biopolymer elasticity. The random walk generating function, the Gaussian field theory and coupled quantum harmonic oscillators. Levy walks. Field theories as models of interacting systems O(n) symmetric Phi^4– theory. The large n limit: Spherical (Berlin-Kac) model. Brownian paths and polymer physics biopolymer elasticity. The random walk generating function, the Gaussian field theory and coupled quantum harmonic oscillators. Levy walks. Field theories as models of interacting systems O(n) symmetric Phi^4– theory. The large n limit: Spherical (Berlin-Kac) model.

**Examination:**
The first part of the verification of the acquired knowledge will evaluate the homework 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:

PHYSICS LABORATORY

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. GABRIELE SIMI

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 experiments 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:

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:

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:

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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 and Second 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 practical 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. Astronomy as a context in which proposing topics of classical and modern physics.

Examination:
The examination will consist of two parts: (1) written assignments during the course (40%); (2) a final written project at the end of the course on the development and implementation of an empirical study on a selected topic in physics (60%).
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 TOPICS IN PHYSICS

Master's degree in PHYSICS ORD. 2021, Second semester

Lecturer: Prof. GRIGORI KORTCHEMSKI

Credits: 6 ECTS

Prerequisites: Theoretical physics of the fundamental interactions

Short program:
Course unit contents: Poincaré group; review of the free scalar, fermion and abelian gauge fields; the supersymmetry algebra; examples of supersymmetric theories: free fields, Wess-Zumino model; N = 1 chiral supermultiplet; on-shell supercharges; extended supersymmetry; review of non-abelian gauge theories; N=4 supersymmetric Yang-Mills theory; supersymmetric Ward identities; on-shell states; S-matrix; properties of scattering amplitudes in gauge theories; spinor-helicity formalism; color ordered amplitudes; classification of amplitudes by helicity violation; Parke-Taylor amplitudes; Britto-Cachazo-Feng-Witten recursion.

Examination:
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. - More complex basic logic blocks: adder, multiplexer, parity checker, LUT. - Timing and power considerations in the realization of the basic gates. - Memory elements basic blocks: mono-stable, bi-stable, S-R flip-flop, J-K flip-flop, D flip-flop and their properties. PART 3 - Digital systems (4 weeks) - 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..). - Synchronous systems: how to deal with large system by using a common time-base. The clock properties (frequency, jitter) and implications. Description of the clock network, examples on how to cross different clock domains. - Usage of memory elements to build a complete synchronous system. The reset procedure - Finite State Machines types, principle of operation, and building elements. FSM analytical description and basic coding in Verilog. - Actual memories type and use in computer and other logic: ROM, RAM, FLASH, EPROM, basic characteristics, behavior and device realization. - Clock synthesis elements: VCO, DCO, PLLs, architecture and usage. PART 4 - FPGA devices (3 weeks) - FPGA basic architecture: configuration RAM, switching matrix, CLB blocks, LUT and registers. How to synthesize arbitrary functions by using LTUs. - FPGA resources, usage of registers and counters. Implementation of simple state machines, connection of modules in a hierarchical structure. IO interfaces, serializers, deserializers, transceivers. - Implementation of simple synchronous circuits in FPGA through Verilog description. Definition of inputs, outputs, clock, and reset. - Usage of device primitive (MMCM) to synthesize high-frequency clocks within the device. Phase alignments of the clocks. Cross-domain clocks. - 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. - Failure rate estimation through Markov Chains, protection schemes and their effectiveness, practical implem

Examination:
Oral exam

More information:

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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:

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**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:

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**INTRODUCTION TO MANY BODY THEORY**

Master's degree in PHYSICS ORD. 2021, Second semester
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.


MULTIMESSENERG 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 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 (icCube-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:

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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, 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/2021/LM/SC/SC2382/001PD/SCP7081704/NO

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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.
PHYSICS LABORATORY

Master's degree in PHYSICS ORD. 2021, First semester

Lecturer: Prof. GABRIELE SIMI

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 experiments 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/2021/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 the scalar and fermionic fields. Basic QED.

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 1p1 effective action. 5. Path integral quantization of \( \Phi^4 \). 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 \( \Phi^4 \). 7.4 On-shell renormalisation. 7.5 Dimensional regularization. 7.6 ? ?4 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-Fishler 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 Fadeev Popov determinants and ghosts 10.4 BRST symmetry and the physical Hilbert space.

Examination:
The examination is split in two parts. First there is a written admission test where the student is required to solve one of the problems assigned during the course. The oral examination will be performed with general questions on the topics of the course, including the derivation of the main results.

More information:

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:**

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**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/2021/LM/SC/SC2382/001PD/SCP7081698/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:**
**Short program:**


**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:**

### THEORETICAL PHYSICS OF THE FUNDAMENTAL INTERACTIONS (MOD. B)

**Lecturer:** Prof. STEFANO RIGOLIN  
Master's degree in PHYSICS ORD. 2021, First and Second semester  
**Credits:** 12 ECTS  
**Short program:**  
1. Quantum Electrodynamics: Feynman rules, tree level processes (Rutherford, Compton and Bhabha scattering, Bremsstrahlung).  
3. Quantum Chromodynamics: The “colour” algebra, Feynman rules and scattering amplitudes for gluons and quarks at tree level.  
4. Electroweak gauge theory. The Fermi effective Lagrangian: Feynman rules and muon decay. SU(2)xU(1) gauge theory and Electroweak unification.  
7. The electroweak Lagrangian for one and three families.

### SANITARY BIOLOGY

### APPLIED STATISTICS

**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 OF DISEASES

**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%)
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

More information:

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 2. Carcinogenesis and Cancer Genetics - Oncogenes and Signal Transduction - Tumor Suppressor Genes - DNA Repair Pathways and Human Cancer - Epigenetics and Cancer - Infectious Agents and Cancer - Environmental Carcinogenesis 3. Cancer Biology: - 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: - Use of next-gen sequencing in cancer - Cancer System Biology - Introduction to Pan-Cancer Analysis 5. Molecular Pathology and Diagnostic: - Biomarkers for diagnosis, risk and therapy assessment 6. Notes on the molecular basis of cancer therapy: - Cancer Therapeutics - Natural and Acquired Resistance to Cancer Therapies 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.

Examination:
A written exam will be held. The journal club and activities in the bioinformatic laboratories will be also scored.

More information:

STATISTICAL SCIENCES ORD. 2014

INTRODUCTION TO STOCHASTIC PROCESSES

Master's degree in STATISTICAL SCIENCES ORD. 2014, Second semester

Lecturer: Prof. MARCO FORMENTIN
MACHINE LEARNING

Master's degree in STATISTICAL SCIENCES ORD. 2014, 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.


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.

**SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021**

**CIRCULAR AND SUSTAINABLE WASTE MANAGEMENT**

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First semester

Lecturer: Prof.ssa MARIA CRISTINA LAVAGNOLO

Credits: 9 ECTS

Prerequisites: Basic knowledge of chemistry and biochemistry

Short program:
- ICAR/03 (6 ECTS) • Waste management systems and strategies: circularity, sustainability and closing the loop of the materials • Worldwide waste production and quality (including experiences in laboratory) • Glance at the current international legislations about waste management: definitions, European Waste Catalogue, Hazardous waste classification • Scheme of resource recovery and disposal of residues • Waste collection and transport, separate collection and material recovery • Mechanical selection schemes and processes, efficiencies and possibilities, separation of single fractions • Recycling and recovery processes of materials • Bio-stabilization processes for the biodegradable fraction: biochemical aerobic and anaerobic processes (1 ECTS- CHIM/11) • Technologies of composting and anaerobic digestion • Biorefinery of waste: biochemistry and processes (1 ECTS- CHIM/11), future possibilities • Thermal energy recovery from waste: thermal processes (gasification, pyrolysis, incinerator); RDF (refuse derived fuel) production and possibilities • Management and disposal of residues: strategies, landfill technologies and design (materials, barriers; leachate and biogas collection, treatment, land reutilisation); the sustainable landfill and the geological repository • Hazardous waste management • Innovative visions: Integrated waste and water management and recovery. • Health and Waste • The experiences of Private and Public Companies (ARPAV, UTILITALIA) in the management of waste (1 ECTS - D)

Examination:
The exam consists into two parts: 1. Three quizzes (using moodle) during the course: questions based on classroom lectures to test knowledge 2. Homeworks, on some specific insights to be carried out in groups of two people during the course, homeworks will be presented and discussed in class.


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**ECONOMICS FOR THE CIRCULAR ECONOMY**

Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, Second semester

Lecturer: Dott.ssa MARTA CASTELLINI

Credits: 6 ECTS

Prerequisites: None

Short program:
- The economic functions of the environment • Natural resources and the circular economy: optimal management of renewable and non-renewable natural resources • The roots of environmental problems and the role of environmental politics • Command and control, market-based instruments and voluntary approaches

Examination:
Teamwork / written exam
EUROPEAN UNION ENVIRONMENTAL AND ENERGY LAW

Master’s degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, Second semester

Lecturer: Prof. BERNARDO CORTESE

Credits: 6 ECTS

Prerequisites:
No particular prerequisite

Short program:
General Part • Introductory Unit: Law, National Law(s), International Law, European Union Law; The role of law, and of EU law in particular, in the regulation of economic activities, with special focus on goods production; The role of law, and of EU law in particular, in the regulation of technological innovation • The Law of the EU Internal Market, including EU Competition Law a) Freedom of Circulation of Goods: The notion of goods, including waste and energy; national (technical) rules applicable to goods as obstacles to trade between Member States – justifications – the principle of mutual recognition; (EU Directives:) harmonization vs coordination of national measures; EU “comitology”/delegated uniform executive measures (technical progress); national measures implementing EU directives; the “new approach” and the role of EU “harmonized standards” – co-regulation; b) EU competition law: Rules applicable to undertakings (agreements, abuse of dominant position), rules applicable to States (State Aid) Special Part • EU Environmental and Energy Law: Waste, recyclable waste; Industrial emissions; REACH; Product labelling; Eco-management and audit scheme (EMAS); EU energy policy and renewables; EU approach to water; New technologies, R&D and competition law; EU State Aid Law in the field of environmental standards and in the field of energy transition schemes

Examination:
Oral discussion of a written paper on the influence of EU law on the development of CE projects/activities.

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2590/000ZZ/SCQ1095593/NO

GREEN CHEMISTRY AND INNOVATIVE CHEMICAL PROCESS

Master’s degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, First semester

Lecturer: Prof. MAURO CARRARO

Credits: 9 ECTS

Prerequisites:
Basic knowledge of general and of organic chemistry.

Short program:

Examination:
Oral exam; the student will also report on a case study.

More information:

OPERATIONS AND SUPPLY CHAIN MANAGEMENT

Master’s degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021, Second semester

Lecturer: Dott.ssa LAURA MACCHION

Credits: 6 ECTS
Prerequisites:
None

Short program:
--->Lean management and process optimisation: presentation of principles and techniques that made significant changes to traditional production processes with a new view of continuous improvement. -->Quality system. Starting from traditional quality management models, the principles and tools that allow the application of advanced systems in the Quality area are presented: the Total Quality Management (TQM) approach, the organization for the TQM, the application of the TQM, the techniques and tools to apply and sustain the TQM over time (for example Six Sigma, SS, Value stream mapping, PDCA, statistical techniques for quality control). -->Supply Chain Management: the physical structure of the supply networks and the relationships between actors of the same network will be discussed. Furthermore, inter-organizational processes will be analysed. -->Closed loop supply chain and reverse logistics

Examination:
--->Written test -->Analysis of case studies: teamwork during the course

More information:
https://en.didattica.unipd.it/off/2021/LM/SC/SC2590/000ZZ/SCQ1095595/NO

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<th>RENEWABLE ENERGY TECHNOLOGIES</th>
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<tbody>
<tr>
<td>Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021. First semester</td>
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<tr>
<td>Lecturer: Prof. DAVIDE DE COL</td>
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<td>Credits: 6 ECTS</td>
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<tr>
<td>Prerequisites: Basic knowledge of applied thermodynamics (laws of thermodynamics, thermodynamic processes, cycles, fluids), heat transfer and energy science.</td>
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<td>Examination: The exam consists of a written test, comprehensive of numerical exercises and theory questions.</td>
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<tr>
<th>THERMODYNAMICS AND CATALYSIS FOR CIRCULAR ECONOMY (C.I.)</th>
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<tr>
<td>Lecturer: Prof. ANTONINO POLIMENO</td>
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<tr>
<td>Prerequisites: Basic knowledge of mathematics, physics, general &amp; inorganic chemistry, organic chemistry and physical chemistry.</td>
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<td>Examination: Teamwork/oral exam; the student, either alone or in a team, will have the opportunity of reporting on a specific topic, or reading and commenting a reviewed paper</td>
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<tr>
<td>Moduli del C.I.: Catalysis for circular economy (Mod. B) Thermodynamics of processes and materials (Mod. A)</td>
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Catalysis for circular economy (Mod. B)
Thermodynamics of processes and materials (Mod. A)

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<tr>
<th>CATALYSIS FOR CIRCULAR ECONOMY (MOD. B)</th>
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<tr>
<td>Lecturer: Prof. MARCO ZECCA</td>
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<tr>
<td>Master's degree in SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021. First and Second semester</td>
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<tr>
<td>Credits: 12 ECTS</td>
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<td>Short program: Chemical kinetics in catalysis: catalytic cycle, catalytic site, single- and multi-site catalysis; TON and TOF; reaction rates and catalytic activity. Homogeneous catalysis in the liquid phase; specific and general acid (or base) catalysis; the Hammett acidity function; metal ions as Lewis acids; case</td>
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**THERMODYNAMICS OF PROCESSES AND MATERIALS (MOD. A)**

**Lecturer:** Prof. ANTONINO POLIMENO

Master's degree in **SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021**, First and Second semester

**Credits:** 12 ECTS

**Short program:**

MOD A - I semester • Circular Economy for sustainable development: introduction to the concept of Life Cycle Assessment, input/output models, thermodynamic interpretation. • Basic concepts of thermodynamics: systems, laws of thermodynamics, cycles and processes • Mass and energy conservation principles for control volume analysis; steady state and transient analyses of open and closed systems • Entropy analysis for closed and open systems; energy analysis for closed and open systems • Thermodynamics insights on the assessment of circular economy processes through case studies (e.g. food waste, steel production, other materials production, product refurbishment, vehicle provision, construction and equipment manufacture) • Chemical kinetics in solutions: reaction rate and its dependence on experimental conditions, energy of activation, energy vs reaction coordinate diagrams, kinetic laws from reaction mechanisms (elementary reactions, order and molecularity, steady-state approximation, rate determining step, complex mechanisms).

**WATER RESOURCES MANAGEMENT IN THE CIRCULAR ECONOMY**

Master's degree in **SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY ORD. 2021**, First semester

**Lecturer:** Dott.ssa GIULIA ZUECCO

**Credits:** 6 ECTS

**Prerequisites:**

Basic knowledge of mathematics, physics, chemistry

**Short program:**

Lectures, seminars, discussion • Introduction o Humans, Water, and Earth: the actual global challenges • Climate o Climate change and natural disasters (floods & drought) • Extremes, new trends, critical scenarios - Case studies - Roundtable Discussion • Society o Socio-economic impact on Earth: The Great Acceleration o Population dynamics and land use changes o Water scarcity and hydro-political risk o Water pollution and human health - Case studies - Roundtable Discussion • Water resources management o Water management in land reclamation areas o Water for agriculture o Water for urban areas - Case studies in EU and Italy - Roundtable Discussion • Sustainable water cycle o Integrated watershed management approach o Water and ecosystem services o Water for a sustainable socio-economic development - Case studies - Roundtable Discussion GIS Lab • Lab.1 - Remote sensing o Satellite, laser scanners, drones o Land use changes scenarios o NDVI and water stress • Lab.2 - Digital terrain analysis o Digital Elevation Models o Drainage system analysis

**Examination:**

Discussion of a case study through a technical report

**More Information:**

https://en.didattica.unipd.it/off/2021/LM/SC/SC2590/000ZZ/SCQ1095580/NO