# SCHOOL OF SCIENCE UNIVERSITY OF PADOVA

# CATALOGUE OF ENGLISH LANGUAGE COURSES FOR ERASMUS, FOREIGN AND ITALIAN STUDENTS

## ACADEMIC YEAR 2017-2018:

First semester: October 2nd, 2017 to January 19th, 2018
Winter exams session: January 22nd, 2018 to February 23rd, 2018
Second semester: February 26th, 2018 to June 1st, 2018
Summer exams session: June 4th, 2018 to July 20th, 2018
Extra exams session: August 20th, 2018 to September 21st 2018

## ERASMUS MASTER DEGREES AND MASTER DEGREES WITH A PROGRAM OF COOPERATION WITH OTHER EUROPEAN UNIVERSITIES

1. ASTROMUNDUS
see information on http://www.astro.unipd.it/astromundus/

2. ALGANT (Algebra, Geometry And Number Theory)
see information on http://lauree.math.unipd.it/algant/

## MASTER DEGREES WITH A PROGRAM OF COOPERATION WITH OTHER EUROPEAN UNIVERSITIES FOR COMMON DEGREES

An agreement between the University of Padova and the French Universities Paris Diderot-Paris 7 and Paris Descartes. has been established since the academic year 2010-11 for the release of a common degree between the Master Degree in Molecular Biology and the Master de Sciences Santé et Application. This project requires the mobility of students (up to 6 per year) within the ERASMUS program. More information is available on http://biologia-molecolare.biologia.unipd.it/lauree-magistrali/lm-in-biologia-molecolare/

## INDEX

## SECOND CYCLE DEGREES WITH ALL THE COURSE UNITS HELD IN ENGLISH:

### DATA SCIENCE

### ALGORITHMIC METHODS AND MACHINE LEARNING

Master degree in **Data Science**, Second semester
Lecturer: Alessandro Sperduti
Credits: 12 ECTS

**Prerequisites:**
The student should have basic knowledge of programming.

**Short program:**
The course will cover the topics listed below:
- 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. Recurrence relations. Case study: sorting.
Dynamic programming: coping with repeating subproblems. Memoization of recursive code. Case study: optimization algorithms on sequences.
Greedy paradigm: solving by successive choices. Applicability of the paradigm. Case study: data compression.
- Machine Learning

Introduction to Machine Learning: why machine learning is useful; when to use it.; where to use it; Machine Learning paradigms; basic ingredients of Machine Learning; complexity of the hypothesis space; complexity measures; examples of supervised learning algorithms.
Application Issues: classification pipeline, representation and selection of categorical variables; model selection, evaluation measures.
in Depth (theory and practice using Python and Scikit-Learn): Support Vector Machines; Decision Trees and Random Forest; Neural Networks and Deep Learning; Manifold Learning; Kernel Density Estimation.

**Examination:**
Written exam and (individual) project. The project is due by the end of the course.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079257/N0

### BIG DATA COMPUTING

Master degree in **Data Science**, Second semester
Lecturer: Andrea Alberto Pietracaprina
Credits: 6 ECTS

**Prerequisites:**
Competences regarding the desing and analysis of algorithms and data structures, and knowledge of fundamental notions of probability and statistics.

**Short program:**
The course will cover the following topics:
Introduction to the Big Data phenomenon
Programming frameworks: MapReduce/Hadoop, Spark
Association Analysis
Clustering

Graph Analytics (metriche di centralità, scale-free/Power-law graphs, fenomeno dello small world, uncertain graphs)
Similarity and diversity search.
**Examination:**
Compulsory written exam and (group) project. Projects are presented and discussed at the end of the course or, at the student's discretion, after passing the written exam.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079297/N0

## BIOINFORMATICS AND COMPUTATIONAL BIOLOGY
Master degree in **Data Science**, Second semester
Lecturer: Silvio Tosatto
Credits: 6 ECTS
**Prerequisites:**
Basic knowledge of bioinformatics, e.g. alignment methods and databases.
**Short program:**
1) Evolutionary reletationship between protein structure / function / interactions
2) Folding and evolution theories of proteins
3) Prediction of 3D structure by homology and ab initio methods; The CASP experiment
4) Prediction of structural features
5) Prediction of protein function; The CAFA experiment
6) Interactions between proteins
7) Concepts of Network Biology
8) Genotype-phenotype correlation and proteins; The CAGI experiment.
**Examination:**
The exam is composed of four parts, each of which has to be passed: (weight in parenthesis)
1) Practicals (25%)
2) Journal club presentation (25%)
3) Final essay on an unknown protein (25%)
4) Oral exam (25%)
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079317/N0

## COGNITIVE SERVICES (OFFERED IN THE MASTER DEGREE IN COMPUTER SCIENCE)
Master degree in **Data Science**, Second semester
Lecturer: Alessandro Sperduti
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 smart cognitive services; brief intro to AI and ML paradigms.
- Cognitive Services:
Basic concepts; Language, Speech, and Vision Services; major services and API (IBM Watson, Microsoft, Google Cloud); enabling technologies.
- Machine Learning and Application Issues:
Classification; Representation learning and selection of categorical variables; Training and testing; Evaluation measures.
- Visual Recognition:

"Teaching computers to see": extract rich information from visual data; Challenges: why is computer vision hard?; Designing effective visual features; Representation learning in computer vision; Image understanding.
- 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 in a multi-modal scenario.
**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 realization. The student will present and discuss the project and, if deemed necessary by the teacher, pass an oral examination.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079279/N0

## COGNITIVE, BEHAVIORAL AND SOCIAL DATA

Master degree in **Data Science**, First semester
Lecturer: 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, fRMI, 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:**
Written and oral exam.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079219/N0

## FUNDAMENTALS OF INFORMATION SYSTEMS

Master degree in **Data Science**, First semester
Lecturer: Gabriele Tolomei
Credits: 12 ECTS

**Prerequisites:**
The student should have basic knowledge of programming and algorithms.

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

Introduction to relational databases: data model; relational algebra; SQL; DBMS;
NoSQL technologies: characteristics of NoSQL databases; aggregate data models: key value stores, document databases, column family stores, graph databases, others; distribution models: sharding, replication (master-slave,peer-to-peer).
Streams of Data: architecture(s); data modeling; query processing and optimization.
Networking
Networking Fundamentals: Network architectures (OSI Model); TCP and UDP Transport layer protocols; IP Addressing and Routing; Link Layer Forwarding; DNS and DHCP.
Advanced Networking: Virtual LAN (VLAN) and Virtual eXtensible Lan (VXLAN), Software Defined Networking: control, data plane and virtualization; concepts on Cloud Computing: service and deployment models: data centers architectures, topologies, addressing, routing, traffic characteristics; Case Study: The Web of Things (IoT standards and protocols).
- Programming

Programming for Data Scientist using Python: computational environment (IPython and Jupyter); storage and manipulation (NumPy and Pandas); data visualization (Matplotlib).

**Examination:**
The student is expected to pass a written and an oral exam.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7078720/N0

## HUMAN DATA ANALYTICS

Master degree in **Data Science**, Second semester
Lecturer: Michele Rossi
Credits: 6 ECTS

**Prerequisites:**
A basic course on probability theory is recommended. A basic programming course is also advised for a correct comprehension of the material.

**Short program:**
Part I – Introduction
- Intro: course outline, grading rules, office hours, etc.
- Applications: health, activity-aware services, security and emergency management, authentication systems, analyzing human dynamics

Part II - Tools
- Vector quantization (VQ):
-- Aims, quality metrics
-- Unsupervised VQ algorithms:
--- Self-Organizing Maps (SOM), Time Adaptive-SOM (TASOM)
--- Gas Neural Networks (GNG)
- Deep Neural Networks (DNN)
-- Neural networks brief: concept, examples, training
-- Convolutional Neural Networks (CNN): structure, training

- Sequential Data Analysis:
-- Hidden Markov Models (HMM):
--- Maximum Likelihood for the HMM
--- Forward-backward algorithm
--- Sum-product algorithm
--- Viterbi algorithm
-- Wald's sequential decision theory (iid case)
Part III – Applications (using the tools of Part II)
- Human Activity Learning
-- Activities & sensors: definitions, classes of activities
-- Features: sequence features, statistical features, spectral features, activity context features
-- Activity recognition: activity segmentation, sliding windows, unsupervised segmentation, performance measures and results
- Biometric Data Processing:
-- Quasi-periodic physiological signals
--- Dictionary learning & compression algorithms
- Inertial signals: identity recognition
- Inertial sensors and cameras: gait tracking & profiling
- Voice Recognition:
-- Deep neural network-HMM hybrid system
-- Architecture, training, performance evaluation

**Examination:**
The exam will be a written project where the student will have to solve a selected classification problem for a given dataset. The student will have to work on the code (software), produce and discuss the results.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079397/N0

## KNOWLEDGE AND DATA MINING

Master degree in **Data Science**, 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:**
Final examination based on: written examination or project development.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079318/N0

## OPTIMIZATION FOR DATA SCIENCE

Master degree in **Data Science**, Second semester
Lecturer: Francesco Rinaldi
Credits: 6 ECTS

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

**Short program:**
1. Linear optimization: Theory and algorithms
(a) Lp models for Data science;
(b) Duality (Farkas);
(c) Simplex method;
(d) 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) Poyhedral approximation methods;
(d) Gradient projection methods;
5. Large scale network optimization
(a) Network models in data science;
(b) Clustering methods.

**Examination:**
- Written exam
- Project (Optional)

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079229/N0

## STATISTICAL LEARNING (C.I.)

Master degree in **Data Science**, Annual
Credits: 12 ECTS
***Modules of the integrated course unit:***
- STATISTICAL LEARNING 1 (MOD. A)
- STATISTICAL LEARNING 2 (MOD. B)

***Common characteristics of the Integrated Course unit:***
**Prerequisites:**
Basic probability theory; multivariable calculus; linear algebra; basic computing skills.
**Examination:** written test.

**STATISTICAL LEARNING 1 (MOD. A)**
***Specific characteristics of the Module***
Lecturer: Monica Chiogna

**Short program:**
Part 1: Modes of Inference
- Data: summary statistics, displaying distributions; exploring relationships
- Likelihood: the likelihood, likelihood for several parameters
- Estimation: maximum likelihood estimation; accuracy of estimation; the sampling distribution of an estimator; the bootstrap
- Hypothesis testing
- Other approaches to inference.

**STATISTICAL LEARNING 2 (MOD. B)**
***Specific characteristics of the Module***
Lecturer: Monica Chiogna
**Short program:**
Part 2
- Models : normal linear models; inference for linear models; generalized linear models; inference for generalized linear models
- Model selection
- Multivariate Analysis: dimension reduction; classification; clustering.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079226/N0

## STOCHASTIC METHODS

Master degree in **Data Science**, First semester
Lecturer: Paolo Dai Pra
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
• approximation of probability distributions.
2. Markov chains and random walks
• Markov Chain and their stationary distribution
• Monte Carlo (MCMC), convergence of MCMC-based algorithms
• Electrical networks.
3. Random graphs
• Erdos-Renyi graphs: connectivity, giant component.
• Random regular graphs
• Dynamic graphs. Preferential attachment.

**Examination:**
Written exam.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079197/N0

## STRUCTURAL BIOINFORMATICS

Master degree in **Data Science**, Second semester
Lecturer: Silvio Tosatto
Credits: 6 ECTS
**Prerequisites:**
Basic knowledge of optimization methods and machine learning. C++ and/or Java programming languages.

**Short program:**
The course consists of two parts:
1) Introduction to living matter (2 credits):
1.1) Introduction to organic chemistry
1.2) Weak interactions and energy
1.3) Structure and function of DNA and proteins
1.4) Lipids, membranes and cellular transport
2) Computational Biochemistry (4 credits):
2.1) Biological Databases
2.2) Software libraries and concepts for sequence alignments, profiles and database searches
2.3) Sequence - structure - function relationship in proteins and classification
2.4) Methods for the prediction of protein structure from sequence. The CASP experiment.
2.5) Methods for the prediction of protein function. The CAFA experiment.
2.6) Introduction to network and systems biology.
2.7) Genotype – phenotype correlations. The CAGI experiment.
**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:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079278/N0

**PHYSICS**

**ADVANCED PHYSICS LABORATORY A**

Master degree in **Physics**, Second semester
Lecturer: 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:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081700/N0

**APPLIED ELECTRONICS**

Master degree in **Physics**, Second semester
Lecturer: To be defined
Credits: 6 ECTS
**Short program:**
Part I. ELECTRONICS AND ANALOG INSTRUMENTATION
1. Review: Basic analog electronic
2. Review: Feedback
3. Operational Amplifiers (Real, Freq. Behavior)
- Linear and non-linear Applications
4. Generation of signals and oscillators
- Power supplies

- Voltage / current reference generators
- Oscillators

5. Noise and analog signal recovery
- Noise in electronic circuits (analogue) (noise and power spectrum, types of noise (thermal, shot, 1 / f), noise in devices (transistors, op.amp.), ENC calculation, feedback effect on noise)
- Low noise amplifiers (Radeka amplifier → charge amplifier, other front-end amplifiers → Noise in transimpedance ampli.)
- Analog Filters and Signal Recovery Techniques (Approximation and Implementation, Switched Capacitor Filters, Frequency/Time Domain Filters)
- Signal Recovery Techniques (shaping for "energy" or "timing" and optimum filters, Lock-in, signal media, matched filters, mixing)

PART II. DIGITAL ELECTRONICS, DIGITAL DEVICES, CONVERSION AD / DA

6. Inverters and logic port families (TTL, ECL, MOS, ...)
- Inverters and logic ports (logic port function, bipolar/MOS inverters, inverters and ports TTL, ECL, MOS)
- fundamental circuits (combinatorial and sequential operations, flip-flop multiplexers, adder, shift registers, memories)

7. Convert A/D and D/A
- Instruments (z-transform) and noise (quantization noise)
- Digital-to-Analogue (Nyquist rate converters, DAC based on Resistors / Capacitors / Current sources)
- Analogue-to-Digital (Nyquist rate converters, time accuracy, ADC Flash, two-step, interpolating, successive approximations, samplers)
- Some conversion circuits in detail (sample & hold, switched emitter followers, ...)
- Oversampling → sigma-delta
- Signal Processing and Digital Filtering Techniques
- Examples of measurements of time and space

8. Complements
- Microprocessors, Microcontrollers and FPGAs
- Data Bus

9. Digital Laboratory → Introduction to VHDL

**Examination:**
oral exam
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081700/N0

## ASTROPARTICLE PHYSICS

Master degree in **Physics**, Second semester
Lecturer: Paride Paradisi
Credits: 6 ECTS
**Prerequisites:**
The course is self-contained as the necessary basics of relativistic quantum mechanics, quantum field theory and general relativity will be provided during the course.
**Short program:**
1) INTRODUCTION: the observable Universe and its expansion, Dark Matter, the left-overs from the Big Bang.
2) RELATIVISTIC QUANTUM MECHANICS: Dirac and Klein-Gordon Equations; nonrelativistic correspondence; antiparticles and their properties; discrete symmetries: P, T, and C and the CPT theorem.
3) QUANTUM FIELD THEORY: the Klein-Gordon, electromagnetic and Dirac fields; spin-statistics connection;

Noether's theorem; the energy-momenta tensor; radiation-matter interaction: covariant derivative and QED; scattering theory: S-matrix, Green functions, propagators, Feynman rules, cross-sections and decay rates.
4) SPONTANEOUS SYMMETRY BREAKING (SSB): SSB of discrete and continuous global symmetries; Goldstone theorem; SSB of continuous local symmetries: the Higgs mechanism; SSB at finite temperature.
5) THE STANDARD MODEL (SM) OF PARTICLE PHYSICS: Fermi theory; (V-A) x (V-A) theory; Yang-Mills theory; the standard electroweak theory; SSB of the electroweak symmetry; mass spectrum and particle interactions; CKM matrix; GIM mechanism; CP violation; flavor group of the SM: baryon and lepton (family) number conservation; the discovery of the Higgs boson at the LHC.
6) NEUTRINO PHYSICS: Dirac and Majorana masses; see-saw mechanism; massive neutrinos in the SM; PMNS matrix; GIM mechanism and the mu->e gamma decay rate; neutrinoless double beta-decay; neutrino oscillation in the vacuum and matter: the MSW effect; solar and atmospheric neutrinos; CP violation in neutrino physics; neutrino oscillation experiments; neutrinos from Supernovae.
7) BEYOND THE SM: Grand Unified Theories (GUTs); SU(5) model: SSB and Gauge hierarchy, coupling constant unification, proton decay, fermion masses and mixing angles; SO(10) and the see-saw mechanism.
8) GENERAL RELATIVITY: the Equivalence Principle; curved space-time, the energy-momentum tensor; Einstein's equations of Gravitation, the Schwarzschild solution.
9) COSMOLOGICAL MODELS: the de Sitter model; the Standard Model of Cosmology, FLRW metric, Friedmann equations; the Cosmological Constant.
10) THERMODYNAMICS IN THE EARLY UNIVERSE: equilibrium thermodynamics; entropy; decoupling temperatures.
11) DARK MATTER (DM): experimental evidences; freeze-out and DM; the Boltzmann equation; cold, hot and warm DM; Weakly Interacting Massive Particles (WIMPs); DM Candidates in Particle Physics; cosmological bounds on neutrino masses; direct and inderect searches of DM.
12) INFLATION: problems of the Standard Big Bang model, the horizon problem, the flatness problem, the monopole problem; the Inflation mechanism; quantum fluctuations of the Inflaton; models for Inflation; Dark Energy.
13) BARYOGENESIS: Sakharov conditions; baryon (B) and lepton (L) numbers violation in particle interactions; B and L violation in the SM via anomalies; B--L conservation in the SM; electroweak mechanism; B violation in GUTs; asymmetry generation in particle decays; baryon asymmetry and neutrino masses: Leptogenesis.

**Examination:**
Oral exam
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081703/N0

## BIOLOGICAL PHYSICS
Master degree in **Physics**, Second semester
Lecturer: Mario Bortolozzi
Credits: 6 ECTS
**Prerequisites:**
Italian knowledge (written and oral).
**Short program:**
Nucleic acids, proteins and lipids: the structure of living cells, the central dogma of biology, primary structure of DNA, double helix structure.
Molecular forces in biological structures: electrical nature of interaction energies, interaction

between charges and permanent dipoles, induced dipoles, dispersion forces, hydrogen bonds, steric repulsion.
Elementary properties of ions in solutions: random walk, electrodiffusion, the Nernst-Planck equation, hydration shells and diffusion coefficients of small ions.
Elementary properties of channels: the membrane as a capacitor, channel conductance and ion flux limitations by molecular factors. Properties of the K+ channel.
Selective permeability of membranes: the Goldman-Hodgkin-Katz current and voltage equations. Different permeabilities of ions for several types of channels. The nerve action potential as a regenerative wave of Na+ permeability increase.
Selective permeability of channels: the one-ion and multi-ion pore models. Application to Na+ and K+ channels.
Gating mechanisms of channels: kinetic models and single channel recording by patch-clamp. Voltage sensing, fast and slow inactivations. Modification of gating properties and blocking by specific agents.
Atomistic numerical simulations: simulation algorithms, periodic boundary conditions, termostats and barostats.
Energetic configuration: energy minimization, interactions and force fields, Lennard Jones potential, electrostatic interactions, chemical bounds, polarizations.
Protein dynamics: trajectories analysis, fluctuations, deviations, correlations. Salt bridges.
Advanced techniques: Free energy calculations. Potential of mean force.
Membrane channel structure and function: derivation of unitary permeability and conductance of connexin channels.
**Examination:**
The final check consists of an oral test in which the solution to some specific problems may be required.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081737/N0

## COMPUTATIONAL METHODS IN MATERIAL SCIENCE (OFFERED IN THE MASTER DEGREE IN MATERIAL SCIENCES)

Master degree in **Physics**, Second semester
Lecturer: Francesco Ancilotto - Alberta Ferrarini
Credits: 6 ECTS
**Prerequisites:**
Quantum and solid state physics, physical chemistry.
**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 software

packages that are currently employed in materials science, and they will learn how to interpret and present the results of simulations.

**Examination:**

Oral examination in which the students will discuss a written report, on the results of simple numerical simulations.

**More information:**

http://en.didattica.unipd.it/off/2017/LM/SC/SC1174/000ZZ/SC01122974/N0

## COSMOLOGY

Master degree in **Physics**, Second semester
Lecturer: 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 gravitazional 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

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 course) Short writtenm dissertation on a topic discussed during the course, to be agreed with the lecturer. The dissertation should contain a detailed of the chosen sunbject, 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:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/003PD/SCN1035989/N0

## GENERAL RELATIVITY
Master degree in **Physics**, First semester
Lecturer: Gianguido Dall'Agata
Credits: 6 ECTS
**Prerequisites:**
Theoretical Physics is recommended.
**Short program:**
Riemannian geometry; Differential forms; the Principle of Equivalence; Einstein's field equation; the Schwarzschild solution, the Newtonian limit; experimental tests; Maximally symmetric spaces; 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:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/003PD/SCP7081661/N0

## GRAVITATIONAL PHYSICS
Master degree in **Physics**, Second semester
Lecturer: Giacomo Ciani
Credits: 6 ECTS
**Prerequisites:**
General Relativity is recommended
**Short program:**
Fundamentals of general relativity and gravitational waves (GW) theory.
GW generation mechanisms and astrophysical sources.
Understanding of the working principles, main limitations and future prospects of GW detectors.
Overview of the current state of the field of GW astronomy.
**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:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/003PD/SCP7081719/N0

## INTRODUCTION TO MANY BODY THEORY
Master degree in **Physics**, Second semester
Lecturer: Pierluigi Silvestrelli
Credits: 6 ECTS

**Prerequisites:**
Metodi Matematici
**Short program:**
Second-quantization formalism.
Single-particle and two-particle operators in second quantization.
Hamiltonian of Coulomb systems.
Two-point Green functions; expectation value of a single-particle operator, ground-state energy, Lehmann representation.
Adiabatic theorem and perturbative evaluation of the ground state.
Wick's theorem and Feynman diagrams for fermionic systems at T=0.
Self-energy, polarization diagrams (effective interaction), Dyson's equations.
Ground-state energy of the degenerate electron gas ("jellium" model) in the ring approximation (RPA).
Linear-response theory; applications:
screening of the electric charge (Friedel oscillations),
plasma oscillations, electronic scattering cross section for the inelastic electron scattering.
Interacting Bose systems at T=0.
Temperature Green's functions: Wick-Matsubara' theorem and Feynman diagrams.
**Examination:**
Oral exam and home-work exercises.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081699/N0

## INTRODUCTION TO NANOPHYSICS (OFFERED IN THE MASTER DEGREE IN MATERIAL SCIENCES)

Master degree in **Physics**, Second semester
Lecturer: Giovanni Mattei
Credits: 6 ECTS
**Prerequisites:**
Quantum Physics, Solid State Physics.
**Short program:**
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 metallic nanostructures (Mie theory and its extensions); (ii) quantum confinement and photoluminescence in semiconductor quantum dots
Magnetic properties of nanostructured materials: super-paramagnetism.
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.
*** Mutuation ***
Fundamentals of NanoPhysics - MSc Degree in Physics (6 CFU)
Module A will be borrowed by the students of the 'Fundamentals of NanoPhysics' of the MSc. Degree in Physics and complemented by 2 additional CFUs on the following topics:
Fundamental description of the dynamics of electrons and photons
Confinement of electrons and photons in nanostructured or periodic materials:
Photon confinement in photonic crystals
Electron confinement in metal nanoparticles
Electron confinement in semiconductor nanoparticles
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:**
Written Exam.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081718/N0

## INTRODUCTION TO RADIATION DETECTORS

Master degree in **Physics**, Second semester
Lecturer: Roberto Stroili
Credits: 6 ECTS
**Prerequisites:**
Knowledge of electromagnetic phenomena, electromagnetic waves included.
Basic notions about special relativity and quantum mechanics.
**Short program:**
A. Description of the considered physical phenomena: introduction on the quantities measured in nuclear, high energy physics and astroparticle physics experiments. Charged particles energy loss. Bethe-Block formula, discussion and application to the particle detectors. Particle identification.
Multiple Coulomb scattering. Bremsstrahlung,radiation length, radiation spectrum.
Photon-matter interaction, absorption coefficient, photoelectric effect, Compton effect, pair production.
Cerenkov radiation. Mention of transition radiation. Nuclear interactions.
Scintillation in inorganic and organica materials. Energy loss in gases, diffusion, electric field

effect, drift velocity, magnetic field effect. Energy loss in semiconductors.
B. Detector requirements based on the described effects: scintillation counters, Cerenkov counters, ionizing energy counters. Multiwire proportional chambers, drift chambers and TPC's. Limited streamer tubes, RPC's. Semiconductor detectors. Some mentions on trigger and readout electronics. Energy and momentum measurements. General structure of current particle detectors.
C. The particle accelerators. Electrostatic accelerators. Linear accelerators. The cyclotron. The syncrotron: transverse stability, weak focusing, betatron oscillations, transport matrices, strong focusing, quadrupoles and split roles. Hints on emittance, phase stability, syncrotron oscillations, phase diagrams, packet structure. Hints on syncrotron radiation. Storage rings: luminosity, antiproton storage, stocastic cooling.
**Examination:**
Oral.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081437/N0

## INTRODUCTION TO RESEARCH ACTIVITIES
Master degree in **Physics**, Second semester
Lecturer: Alberto Carnera
Credits: 6 ECTS
**Prerequisites:**
No specific prerequisite needed.
**Short program:**
The student will attend a summer stage for a total working time of about 150 hours in a research group either belonging to the Department or to associated laboratories or to an external approved structure.
A list of the proposed activities will be available on the site of the "Corso di Laurea Magistrale" by the end of the spring and the students will choose among the published proposals. The activity will be performed under the supervision of a tutor.
**Examination:**
Oral. Presentation and discussion of the results of the research activity.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081705/N0

## MATHEMATICAL PHYSICS
Master degree in **Physics**, Second semester
Lecturer: Antonio Ponno
Credits: 6 ECTS
**Prerequisites:**
Knowledge of basic Hamiltonian mechanics (Hamiltonian formalism, canonical transformations, integrability).
**Short program:**
General properties. Poisson structures and extension of the canonical formalism. Elements of Hamiltonian perturbation theory: averaging principle (classical and quantum version).
Lie-Poisson systems and their connection with Lie groups and their relative algebras.
Lagrangian and Hamiltonian formalism for infinite-dimensional systems. Linear and nonlinear partial differential equations of physical interest.
Hamiltonian structure of quantum mechanics.

**Examination:**
Written examination on the topics treated in the course.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7080817/N0

## NUCLEAR ASTROPHYSICS

Master degree in **Physics**, Second semester
Lecturer: Paola Marigo
Credits: 6 ECTS
**Prerequisites:**
Elements of quantum mechanics 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:**
Oral/written examination on all topics covered during the course.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081704/N0

## NUCLEAR PHYSICS

Master degree in **Physics**, First semester
Lecturer: Silvia Monica Lenzi – Giovanna Montagnoli
Credits: 6 ECTS
**Prerequisites:**
Quantum mechanics.
**Short program:**
First part: Nuclear Structure and Nuclear Models
• Introduction: The nucleus as a laboratory of Quantum Mechanics
• Symmetries and the Nuclear Force
• Experimental methods
• Theoretical Models:

1) Collective Models:
LDM, Fermi Gas and Density-Functional Models,
Surface vibrations, Rotating nuclei
2) Microscopic Models: Mean-field Models,
Interacting Shell Model
The Nilsson Model
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
• Reactions of astrophysical interest

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081658/N0

**PHYSICS LABORATORY**

Master degree in **Physics**, First semester
Lecturer: Francesco Recchia – Alain Goasduff – Luca Stevanato
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:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081617/N0

## QUANTUM FIELD THEORY

Master degree in **Physics**, Second semester
Lecturer: Marco Matone
Credits: 6 ECTS
**Prerequisites:**
Relativistic quantum mechanics. Klein-Gordon equation. Dirac equation. Canonical quantization of the scalar and fermionic fields.
**Short program:**
INTRODUCTION. General aspects of Quantum Field Theories. Perturbative and non-perturbative formulations. Wigner and von Neumann theorems. Spontaneous symmetry breaking. Elitzur theorem. Minkowskian and euclidean formulations.
Overview of the axiomatic formulation: Wightman axioms, Wightman functions, Wightman reconstruction theorem. Schwinger functions and the Osterwalder-Schroeder reconstruction theorem.
OPERATOR FORMALISM. Covariance of the Dirac equation. Spin statistics theorem. PCT theorem. The Lehman, Symanzik and Zimmerman theorem.
PATH-INTEGRAL IN QUANTUM MECHANICS. Dirac paper at the basis of the Feynman idea. Forced harmonic oscillator. The vacuum-vacuum amplitude. Wick rotation. Quadratic lagrangians. Bohm-Aharonov effect.
PATH-INTEGRAL FOR SCALAR THEORIES. Functional derivative. General properties of the path-integral for scalar theories. Convergence methods Feynman propagator. Green functions. Effective action. Schwinger-Dyson equation. The case of phi^4. Linked-cluster theorem. Euclidean formulation. Computational techniques of functional determinants, the heat equation. Scaling properties of the coupling constant, determinants and anomaly under dilatation. Feynman rules. Computation of some Feynman diagrams for phi^4. Vertex functions and Jona-Lasinio theorem.
RENORMALIZATION. Ultraviolet and infrared divergences. Dimensional regularization. Super-renormalizable, renormalizable and non-renormalizable theories. Counterterms. Relation between renormalized and bare vertex functions. Beta function. Landau pole. Ultraviolet and infrared fixed points. Asymptotic freedom and confinement.
FERMIONIC PATH-INTEGRAL. Integration over Grassmann numbers. Path integral for the free fermion fields. Feynman rules for spinor fields. Fermion determinants.
QUANTUM ELECTRODYNAMICS (QED): Gauge symmetries. Feynman rules for the gauge fields. Gauge fixing. Evaluation of 1-loop Feynman diagrams of QED. Ward identities. Anomalous magnetic moment of the electron.
Renormalization of the QED.
**Examination:**
The examination is oral and concerns the full programm. It starts with the explicit calculation of a Feynman diagram (phi^4 or QED) to be chosen by the student.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081702/N0

## RADIOACTIVITY AND NUCLEAR MEASUREMENTS

Master degree in **Physics**, First semester
Lecturer: Marco Mazzocco
Credits: 6 ECTS
**Prerequisites:**
The student must have attended the courses of "Introduction of Nuclear Physics" and "Nuclear Physics"

**Short program:**
Radioactive decays. Summaries of the interaction of charged and neutral particles with matter in the energy range of nuclear physics and detection techniques.
Low energy nuclear energy: Ion accelerators: ion source, beam transport, magnetic analysis. Magnetic spectrometers, neutron detectors, charged particles and gamma radiation.
Dynamics of heavy ion reactions: the different types of nuclear reactions from elastic diffusion to complete fusion. Identification Techniques of Reaction Products, Detector Telescopes. Measurements of cross-section at energies around the Coulomb barrier. Angular distributions and excitation functions.
Gamma spectroscopy: energy calibration of gamma spectra, efficiency evaluation, activity computation. Angular distribution, multipolarity and polarization. Angular correlation and nuclear state description with statistical tensor. Average lifetime of excited states: electronic method, plunger, DSAM, Mossbauer.
Radioactive Beams: Production Methods "ISOL" and "IN-FLIGHT": Reactions with Secondary ISOL Beams: Coulombian excitation, nucleon transfer. Reactions with relativistic secondary beams: Coulombian and inelastic excitation, knock-out, charge exchange. Beta Decay: Measurements with Isol and In-flight beams, Total absorption spectrometry. Beta-delayed neutron emission.
Nuclear astrophysics: Exploring the nuclear reactions in the stars and the synthesis of elements, Gamow peak, S-factor. Deriving the thermonuclear reaction rate. Dependence on the temperature of the nuclear reaction rate. Combustion cycles: Combustion of hydrogen through the p-p chain and the CNO cycle. Helium combustion with 3-alpha and alpha + C reactions. Advanced nuclear combustion reactions. Relevant cross section measurements: direct underground measurements, indirect Trojan-horse measures, etc.
Low radioactivity techniques: The problem of environmental radioactivity, a good shielding material, a screening of shielding materials (lead, iron, OFHC copper, mercury). The Rn as contaminant in low radioactivity measures. Intrinsic Detector Radioactivity. Effects of cosmic radiation.
Applications: Date with radionuclides. Radionuclides in nuclear medicine. The melting of light nuclei for energy production. About nuclear reactors. Mass spectrometry with accelerators for trace analysis. Non destructive analysis with neutron activation.
**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:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/004PD/SCP7081740/N0

## RELATIVISTIC ASTROPHYSICS

Master degree in **Physics**, Second semester
Lecturer: Roberto Turolla
Credits: 6 ECTS
**Prerequisites:**
Classical electrodynamics, special relativity, general astronomy and astrophysics.
**Short program:**
Compact objects. Late stages of stellar evolution, core-collapse supernovae. White dwarfs, neutron stars and black holes.
General relativity. The vacuum Schwarzschild solution and its properties. Geodesic motion in the Schwarzschild spacetime. Interior Schwarzschild solution, hydrostatic equilibrium configurations, the Tolman-Oppenheimer-Volkoff equation. The Kerr solution (basics).
Degenerate systems. Quantum statistics (brief overview). Equation of state for a completely

degenerate gas; the non-relativistic and ultra-relativistic limits. The Chandrasekhar mass. Matter-radiation interaction. The radiation field. Emission, absorption and scattering. The radiative transfer equation. Optical depth. Simple solutions to the transfer equation: radiative diffusion and free streaming. Radiative processes: electron scattering and free-free. The Eddington limit.
Accretion onto compact objects. Spherical accretion, the Bondi-Hoyle solution. Compact objects in bynary systems. The Roche lobe geometry. Wind- and Roche lobe-fed accretion. Accretion discs. The standard disc model (alpha-disc). Radiation spectrum from an alpha-disc. Neutron stars. Magnetic field and rotation. Magneto-rotational braking and the period evolution. Estimate of the magnetic field and of the age from the period and the period derivative. The P-Pdot diagram. Magnetosphere, light cylinder. Goldreich-Julian currents. The Alfven radius, column accretion onto magnetized neutron stars. Internal structure of a neutron star. Neutronization. Neutron star cooling. Neutrino cooling, URCA and modified URCA. Radiative cooling. Cooling curves.

**Examination:**
Oral examination.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/003PD/SCP7081738/N0

## SOLID STATE PHYSICS

Master degree in **Physics**, First semester
Lecturer: 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.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081660/N0

## STANDARD MODEL

Master degree in **Physics**, Second semester
Lecturer: Ferruccio Feruglio
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:**
Lagrangian construction summary for the Standard Model; Yukawa interactions and flavor physics; Aspects of the physics of the B meson; Mass terms for neutrinos, leptonic mixing and neutrino oscillations; Anomalies and the decay of the pion into two photons; Standard Model Precision Tests; Production and decay of the Higgs boson.
**Examination:**
Oral examination.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081698/N0

## STATISTICAL MECHANICS
Master degree in **Physics**, First semester
Lecturer: Enzo Orlandini
Credits: 6 ECTS
**Prerequisites:**
Statistical Mechanics.
**Short program:**
Thermodynamics of phase transitions. Critical points, order parameters and critical exponents. Phase transitions and spontaneous symmetry breaking. Entropy-energy argument and the lower critical dimension. Ising model. Analytical tools to solve spins model in 1D, transfer matrix formalisms. Mean field theory. Variational theory. Landau theory. Ginzburg Landau theory. Ginzburg criterium and upper critical dimension. Scaling theory and r scaling relations between critical exponents. Homogeneity and scaling: Kadanoff block spin argument, Renormalisation group in real space. Universality. Spontaneous symmetry breaking for continuous symmetry. Goldstone's theorem.
**Examination:**
Written exam with some problem to be solved and some questions on the theory. Oral exam.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081659/N0

## STELLAR STRUCTURE AND EVOLUTION
Master degree in **Physics**, Second semester
Lecturer: Paola Marigo
Credits: 6 ECTS
**Prerequisites:**
Elements of plane trigonometry, derivatives, integrals, basic knowledge of physics relating to previous courses.
Preparatory courses: Astronomy I (two years) and Astronomy II (model A, third year).
**Short program:**
1. Introduction and overview. Observational constraints, the H-R diagram, mass-luminosity and mass-radius relations, stellar populations and abundances.
2. Hydrostatics, energetics and timescales. Derivation of three of the structure equations (mass, momentum and energy conservation). Hydrostatic and thermal equilibrium. Derivation of the virial theorem and its consequences for stellar evolution. Derivation of the characteristic timescales of stellar evolution.
3. Equation of state (EoS). Local Thermodynamical equilibrium. General derivation of n, U, P from statistical mechanics. Limiting cases: ideal gas, degeneracy. Mixture of gas and radiation.

Adiabatic processes. Ionization (Saha equation, consequences for thermodynamic properties).
4. Energy transport in stellar interiors. The 4th equation of stellar structure: the energy transport equation. Diffusion approximation for radiation transport. The radiative temperature gradient . Opacity. Eddington luminosity. Convection: Derivation of stability criteria (Schwarzschild, Ledoux) .Convective energy transport: order-of-magnitude derivation. Mixing-length theory.
5.Nuclear reactions. Nuclear energy generation (binding energy). Derivation of thermonuclear reaction rates (cross sections, tunnel effect, Gamow peak). Temperature dependence of reaction rates .Nuclear burning cycles: H-burning by pp-chain and CNO-cycle. He burning by 3-alpha and alpha+C reactions. Advanced burning reactions.
6. Stellar evolution equations. Overview, time/space derivatives, limiting cases. Boundary conditions and their effect on stellar structure. How to obtain solutions.
7. Simple stellar models. Polytropic models.Homology relations: principles, derivations, application to contraction and the main sequence. Stability of stars: derivation of simplified criteria for dynamical and secular stability.
8. Schematic evolution from the virial theorem (VT). Evolution of the stellar centre combining the VT and the EoS: evolution tracks in terms of (P,rho) and (T,rho). Evolution towards degeneracy or not. The Chandrasekhar mass, low-mass vs massive stars . Critical ignition masses, brown dwarfs, nuclear burning cycles.
9. Detailed evolution: towards and on the main sequence. Simple derivation of Hayashi line, pre-MS evolution tracks properties of the ZAMS: M-L and M-R relations, occurrence of convection zones evolution across the MS band: structural changes, low-mass vs high-mass, effects of overshooting.
10. Post-MS evolution. The Schoenberg-Chandrasekhar limit, the mirror principle. H-shell burning: Hertzsprung-gap, red giant branch, first dredge-up. He-burning: horizontal branch, loops, Cepheids. RGB mass loss.
11. Late evolution of low- and intermediate-mass stars. The Asymptotic Giant Branch: thermal pulses, 2nd/3rd dredge-up, mass loss, nucleosynthesis. White dwarfs: structure, non-ideal effects, derivation of simple cooling theory.
12. Pre-SN evolution of massive stars. Importance of mass loss across the HRD (O stars, RSG, LBV and WR stars). Modern evolution tracks. Advanced evolution of the core: nuclear burning cycles and neutrino losses, acceleration of core evolution. Pre-SN structure
13. Explosions and remnants of massive stars. Evolution of the core towards collapse: Fe-disintegration, electron captures, role of neutrinos supernovae. Observed properties and relation to massive star evolution. Limiting masses for neutron star and black hole formation, dependence on mass loss and metallicity.
**Examination:**
Oral/written examination on all topics covered during the course.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/003PD/SCP7081739/N0

## STRUCTURE OF MATTER

Master degree in **Physics**, Second semester
Lecturer: Luca Salasnich
Credits: 6 ECTS
**Prerequisites:**
All the exams of the B.Sc. in Physics.
**Short program:**
1. Second quantization of the electromagnetic field. Properties of the classical electromagnetic field in the vacuum. Coulomb Gauge. Expansion in plane waves of the vector potential.

Quantum oscillators and quantization of the electromagnetic field. Fock states and coherent states of the electromagnetic field. Electromagnetic field at finite temperature.
2. Electromagnetic transitions. An atom in the presence of the electromagnetic field. Fermi golden rule. Diple approximation. Absorption, stimulated and spontaneus emission of radiation: Einstein coefficients. Selection rules. Lifetime of atomic states and linewidths. Population inversion and laser light.
3. Many-body quantum systems. Identical particles. Bosons and Bose-Einstein condensation. Fermions and Pauli exclusion principle. Veriational principle. Hartree variational method for bosons and the Gross-Pitaevskii equation. Hartree-Fock variational method for fermions. Density functional theory: theorems of Hoemberg-Kohn, density functional of Thomas-Fermi-Dirac-Von Weizsacker and density functional of Khom-Sham.
4. Second quantization of the Schrodinger field. Field operators for bosons and fermions. Fock and coherent states of the bosonic field operator. Schrodinger field at finite temperature. Matter field for interacting bosons and fermions. Bosons in a double-well potential and the two-site Bose-Hubbard model.
**Examination:**
Colloquium of about 30 minutes.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081438/N0

## SUBNUCLEAR PHYSICS
Master degree in **Physics**, Second semester
Lecturer: Franco Simonetto
Credits: 6 ECTS
**Prerequisites:**
Basic knowledge on quantum mechanics, relativity, nuclear and subnuclear physics. Quantum field theory and Feynman graphs. Interaction of radiation and particles with matter.
**Short program:**
A brief reminder of basic concepts: symmetries, conservation laws, quantum numbers and elementary particle classification. Lifetime, resonances and Breit Wigner distribution. QED: brief reminder of theoretical foundation, tree levels processes and loop diagrams. The running coupling constant. Experimental tests: success and open issues. Weak interactions of leptons and quarks. Fermi constant(Gf), weak gauge bosons, relation between Gf and MW. Muon and tau decays: lepton universality. P,C violation in charged and weak currents. Nuclei, baryon and meson weak decays: "helicity suppression". Neutrino scattering. Spontaneous symmetry breaking and the Higgs boson. Measurements at LEP and at the LHC. Status and perspectives. QCD. Hadron spectroscopy. ee annihilation to hadrons. Deep inelastic scattering of electrons and neutrinos; nucleon structure functions. Hadron flavour Physics. The CKM matrix. Flavour oscillations and CP violation.
**Examination:**
A written test, including numerical execises and multi-answer questions. An oral test: the student can choose to discuss in detail the contents of a published article (and all the issues pertinent to it) among a set of those proposed during the lessons, or to be questioned on all the subjects discussed during the course.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081697/N0

## THE PHYSICAL UNIVERSE
Master degree in **Physics**, First semester
Lecturer: Sabino Matarrese
Credits: 6 ECTS

**Prerequisites:**
Fundamental concepts of quantum mechanics and special relativitả.
**Short program:**
Basic concepts of Cosmology
* Main components of teh Universe. Observational evidence for the existsnce of dark amtter and dark energy. * Expanding Universe and Cosmological Principle. * Robertson-Walker line-element. * Hubble constant and deceleration parameter. * Distances in Cosmology; redshift and Hubble law. * Newtonian derivation of Friedmann equations (dust case). * Friedmann models. * Cosmological constant: Einstein's static solution and de Sitter solution.
* Cosmological solutions for the spatially flat case. Universe models with non-zero spatial curvature.
Thermal history and early Universe.
* Number density, energy density and pressure of a system of particles in thermodynamical 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. * Baryon asymmetry in the Universe (basic account). * 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 and Cold Dark matter: definition, present abundance and general cosmological properties.
Elements of stellar astrophysics.
* Primordial nucleosynthesis of light elements. * Gravitational contraction and conditions for hydrostatic equilibrium. * Adiabatic index and equilibrium. * Conditions for gravitational collapse. * Jeans theory of gravitational instability. * Linear evolution of perturbations in the expanding Universe (basic principles). * Spherical collapse of a cosmic protostructure. * Mass-function of cosmic structures: Press-Schechter theory. * Contraction of a proto-star. * Star formation and degenerate electron gas. * The Sun: general properties, radiative diffusion, thermonuclear fusion. * Stellar nucleosynthesis. * Stellar cycles. * Basic of stellar structure. Minimum and maximum mass for a star. * End-points of stellar evolution: white dwarfs, neutrron stars, black holes. * Hertzsprung-Russell diagram.
**Examination:**
Oral interview.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/003PD/SCP7081677/N0

## THEORETICAL PHYSICS
Master degree in **Physics**, First semester
Lecturer: Stefano Rigolin
Credits: 6 ECTS
**Prerequisites:**
Principle of Theoretical Physics
**Short program:**
Introduction to group theory: Lie groups and algebras and their representations. Lorentz and Poincaré groups and their representations. Relativistic waves equations. Introduction to classical field theory: Lagrangian and variational principle, Noether theorem, Schroedinger, Klein-Gordon, Dirac and Electromagnetic field theory. Canonical quantization of free field theories, non-relativistic and relativistic examples. Interacting quantum field theory: S-matrix expansion and Feynman rules.
**Examination:**

Written and oral exam.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081638/N0

**THEORETICAL PHYSICS OF THE FUNDAMENTAL INTERACTIONS**
Master degree in **Physics**, First semester
Lecturer: Pierpaolo Mastrolia
Credits: 6 ECTS
**Prerequisites:**
This course requires basic knowledge of theoretical physics and quantum field theory, for free fields.
**Short program:**
Outline:
1. Quantum Electrodynamics: Feynman rules; scattering processes at tree-level: Rutherford scattering, Compton scattering, Bhabha scattering and Bremsstrahlung.
2. Basics of Radiative corrections and Renormalization.
3. Non-Abelian gauge theories. Lie Algebra, covariant derivatives, kinetic terms and self-interaction of gauge fields.
4. SU(3) gauge theory and Quantum Chromodynamics. The color algebra. Feynman rules and tree-level scattering amplitudes for gluons and quarks.
5. Introduction to the Weak interaction. Fermi's theory: Feynman rules and the muon decay. SU(2) x U(1) gauge theory and Electroweak unification.
6. Spontaneous symmetry breaking: breaking of a discrete symmetry; spontaneous breaking of global U(1) symmetry; Goldstone theorem; the Higgs mechanism.
7. Spontaneous symmetry breaking of SU(2)xU(1) and the Higgs doublet.
8. The Standard Model Lagrangean.
**Examination:**
Written and oral exams.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081657/N0

**FIRST CYCLE DEGREES WITH SOME COURSE UNITS HELD IN ENGLISH:**

**ASTRONOMY**
**ASTROPHYSICS 2 (ALSO OFFERED AS THEORETICAL ASTROPHYSICS FOR STUDENTS OF THE MASTER DEGREE IN ASTRONOMY – DEGREE COURSE TRACK: ASTROMUNDUS)**
Degree in **Astronomy**, Second Semester
Lecturer: Paola Marigo
Credits: 6 ECTS
**Prerequisites:**
Elements of plane trigonometry, derivatives, integrals, basic knowledge of physics relating to previous courses. Preparatory courses: Astronomy I (two years) and Astronomy II (model A, third year).
**Short program:**
1. Introduction and overview.
Observational constraints, the H-R diagram, mass-luminosity and mass-radius relations, stellar populations and abundances.
2. Hydrostatics, energetics and timescales.
Derivation of three of the structure equations (mass, momentum and energy conservation). Hydrostatic and thermal equilibrium. Derivation of the virial theorem and its consequences for stellar evolution. Derivation of the characteristic timescales of stellar evolution.

3. Equation of state (EoS).
Local Thermodynamical equilibrium. General derivation of n, U, P from statistical mechanics. Limiting cases: ideal gas, degeneracy. Mixture of gas and radiation. Adiabatic processes. Ionization (Saha equation, consequences for thermodynamic properties).
4. Energy transport in stellar interiors.
The 4th equation of stellar structure: the energy transport equation. Diffusion approximation for radiation transport. The radiative temperature gradient . Opacity. Eddington luminosity. Convection: Derivation of stability criteria (Schwarzschild, Ledoux) .Convective energy transport: order-of-magnitude derivation. Mixing-length theory.
5.Nuclear reactions.
Nuclear energy generation (binding energy). Derivation of thermonuclear reaction rates (cross sections, tunnel effect, Gamow peak). Temperature dependence of reaction rates. Nuclear burning cycles: H-burning by pp-chain and CNO-cycle. He burning by 3-alpha and alpha+C reactions. Advanced burning reactions.
6. Stellar evolution equations.
Overview, time/space derivatives, limiting cases. Boundary conditions and their effect on stellar structure. How to obtain solutions.
7. Simple stellar models.
Polytropic models.Homology relations: principles, derivations, application to contraction and the main sequence. Stability of stars: derivation of simplified criteria for dynamical and secular stability.
8. Schematic evolution from the virial theorem (VT).
Evolution of the stellar centre combining the VT and the EoS: evolution tracks in terms of (P,rho) and (T,rho). Evolution towards degeneracy or not. The Chandrasekhar mass, low-mass vs massive stars. Critical ignition masses, brown dwarfs, nuclear burning cycles.
9. Detailed evolution: towards and on the main sequence.
Simple derivation of Hayashi line, pre-MS evolution tracks properties of the ZAMS: M-L and M-R relations, occurrence of convection zones evolution across the MS band: structural changes, low-mass vs high-mass, effects of overshooting.
10. Post-MS evolution.
The Schoenberg-Chandrasekhar limit, the mirror principle. H-shell burning: Hertzsprung-gap, red giant branch, first dredge-up. He-burning: horizontal branch, loops, Cepheids. RGB mass loss.
11. Late evolution of low- and intermediate-mass stars.
The Asymptotic Giant Branch: thermal pulses, 2nd/3rd dredge-up, mass loss, nucleosynthesis. White dwarfs: structure, non-ideal effects, derivation of simple cooling theory.
12. Pre-SN evolution of massive stars.
Importance of mass loss across the HRD (O stars, RSG, LBV and WR stars). Modern evolution tracks. Advanced evolution of the core: nuclear burning cycles and neutrino losses, acceleration of core evolution. Pre-SN structure.
13. Explosions and remnants of massive stars.
Evolution of the core towards collapse: Fe-disintegration, electron captures, role of neutrinos supernovae. Observed properties and relation to massive star evolution. Limiting masses for neutron star and black hole formation, dependence on mass loss and metallicity.
**Examination**:
Oral/written examination on all topics covered during the course.
**More information:**
http://en.didattica.unipd.it/off/2015/LT/SC/SC1160/000ZZ/SCM0014352/N0

## MATHEMATICS

### DISCRETE MATHEMATICS

Degree in **Mathematics**, Second Semester
Lecturer: Michelangelo Conforti
Credits: 6 ECTS
**Short program:**
- Preliminary definitions on graphs; - Edge-conenctivity and Menger Theorem; - Vertex-connectivity; - Minimum-weight spanning tree; - k-connected graphs; - Matchings and edge-colorings; - Planarity; - Vertex-colorings and 4-color Theorem; - Hamiltonian cycles and Eulerian tours.
**Examination**:
Written exam.
**More information:**
http://en.didattica.unipd.it/off/2015/LT/SC/SC1159/000ZZ/SC04105572/N0

### PHYSICAL- MATHEMATICAL MODELS

Degree in **Mathematics**, First Semester
Lecturer: Franco Cardin
Credits: 6 ECTS
**Prerequisites:**
Calculus, elementary algebra and geometry, and a first course in Mathematical Physics.
**Short program:**
1. Kinematics of Continuous systems, spatial and material representation.
2. Mass conservation principle. Balance and Conservation laws.
3. Cauchy tetrahedron theorem.
4. Principle of virtual works in continuum mechanics. Balance law and the first cardinal equation.
5. Material description of the stress tensor.Work-Energy Theorem. Constitutive equations and the principle of material indifference.
6. Ideal elastic fluids. Navier-Stokes, Vorticity.
7. Hagen-Poiseuille flow, plane motion of Navier-Stokes fluids, Bernoulli Theorem.
8. Elementary Meteorology: Cyclones and Anticyclones.
9. Variational formulation of classical field theories: hyper-elasticity and linear elasticity.
10. Principles of thermodynamics. Legendre transformation and thermodynamic potentials. First principle of thermodynamics for continuum systems. Balance laws and the first principle. The second principle in the Clausius-Duhem formulation. Balance laws and the second principle. Theorem of Clausius-Duhem. Thermoelastic materials.
11. Wave propagation. The method of characteristics: linear and quasi-linear theories. Singularities. Nonlinear theory and the Hamilton-Jacobi equation. Wave propagation in systems of conservation laws. Weak discontinuities, Hugoniot-Hadamard. Sound speed. High frequency asymptotic waves. Shock waves. Rankine-Hugoniot.
12. Fourier series and applications.

**Examination**:
Written.
**More information:**
http://en.didattica.unipd.it/off/2015/LT/SC/SC1159/000ZZ/SC01111314/N0

## OPTICS AND OPTOMETRY

### Advanced Optometry And Contattology

Degree in **Optics and Optometry**,  Second Semester
Lecturer: Marino Formenti

Credits: 6 ECTS
**Prerequisites:**
Ophthalmic Optics; Visual Optics; Optometry I; Optometry II.
**Short program:**
Behavioral Optometry; Philosofy; The behavioral approach to vision care; The optometric isual analysis: classical vs behavioral visual exam.
Vision and Stress; Nearpoint visual demands; Autonomic visual response to stress agents; Organism Stress response; Stress response in the visual function; Symptoms and signs of visual stress; Development of refractive errors and visual dysfunctions in response to visual stress.
Optometric Evaluation of learning problems; Developing lerning readiness; Learning related vision problems; Visuo-perceptual-motor optometric evaluation.
Myopia Control; Refraction in worlwide pediatric population; Myopia and environment; Effect of urbanization; Concept and importance of peripheral refraction; Optic defocus theory and philosophy: central vs peripheral vision; Studies in laboratory animals; New concepts in ophthalmic and contact lenses designs for myopia control; Spectacles lens design; Soft lenses: Aspheric, Multifocals.
Rigid Gas Permeable: a dynamic application of the sagittal philosophy; Design; Spherical; Aspherical; Multifocal; Reverse Geometry; Toric.
Orthokeratology; History of orthokeratology; Daily wear orthokeratology; Overnight orthokeratology; Orthokeratology design; Corneal changes; How it works; Guidelines and protocol.
**Examination**:
Written exam.
**More information:**
http://en.didattica.unipd.it/off/2015/LT/SC/SC1168/000ZZ/SC01123627/N0

## SECOND CYCLE DEGREES WITH SOME COURSE UNITS HELD IN ENGLISH:

### ASTRONOMY

### ASTRONOMICAL SPECTROSCOPY

Master degree in **Astronomy**, Second semester
Lecturer: Piero Rafanelli
Credits: 6 ECTS

**Prerequisites:**

Basic Physics I and II, Calculus I and II, Atomic Physics, Astrophysics I – II

**Short program:**

Radiation in the interstellar gas: definition of radiative terms; transfer equation; local thermodynamic equilibrium; equivalent thermodynamic equilibrium.
Emission and absorption lines in the interstellar environment: emission and absorption coefficients; statistic equilibrium; collisional processes and kinetic temperature; excitation in interstellar conditions; forbidden lines; recombination lines; intensity of lines as a function of density and temperature.
Continuum emission and absorption processes: free-free transitions; intensity of the thermal radio continuum; bound-free and free-bound transitions; synchrotron radiation.
Ionization: ionization equilibrium; ionization of hydrogen; HII regions; ionization of helium; dust extinction; HI regions; ionization of the heaviest elements.
Formation and dissociation of interstellar molecules: molecular hydrogen; CO, OH, H2O in diffuse nebulae; molecules in dense nebulae.
Thermal equilibrium and kinetic temperature of gas: Equation of thermal equilibrium; heating and cooling processes of gas; thermal equilibrium of HII regions; thermal state of HI regions.

**Examination:**

Oral exam, eventually integrated by the presentation of a topic related to the program me agreed in advance with the teacher.

**More information:**

http://en.didattica.unipd.it/off/2017/LM/SC/SC1173/001PD/SCN1032616/N0

### CELESTIAL MECHANICS

Master degree in **Astronomy**, Second semester
Lecturer: 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:**

1. The equations of motion of gravitating systems
2. The Two-Body Problem and an initial value problem (IVP)
3. The Two-Body Problem and a boundary value problem (BVP)
4. Orbital maneuvers
5. Space and time reference systems
6. The computation of a Keplerian ephemeris
7. Preliminary orbit determination
8. Keplerian relative motion and its generalization
9. Regularization and Universal Formulation of the Two-Body Problem
10. The TBP as a boundary value problem (BVP) – Lambert targeting

11. The Problem of Three Bodies and its homographic solutions
12. The Circular Restricted Three-Body Problem – Jacobi's integral, surfaces of zero velocity, Lagrangian points, Stability, Periodic orbits
13. The theory of Patched Conics and the design of gravity-assist interplanetary trajectories
14. Elements of perturbations and a the motion of an artificial Earth satellite

**Examination:**

Homework, Final project report, Oral presentation of final report and discussion.

**More information:**

http://en.didattica.unipd.it/off/2017/LM/SC/SC1173/001PD/SCN1032619/N0

## COSMOLOGY

Master degree in **Astronomy**, Second semester
Lecturer: 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 gravitazional 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
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

**Examinaion:**

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 course) Short writtenm dissertation on a topic discussed during the course, to be agreed with the lecturer. The dissertation should contain a detailed of the chosen sunbject, 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 becokem acquainted with the main concepts presented in the lectures.

**More information:**

http://en.didattica.unipd.it/off/2017/LM/SC/SC2382/003PD/SCN1035989/N0

## GALAXY DYNAMICS

Master Degree in **Astronomy**, Second Semester
Lecturer: Enrico Maria Corsini
Credits: 6 ECTS

**Prerequisites:**

Basic knowledge of Physics, Astronomy, Astrophysics, and Numerical Analysis.

**Short program**:

1. OVERVIEW OF THE PROPERTIES OF GALAXIES. Morphology. Photometry. Kinematics. Scaling relations.
2. POTENTIAL THEORY. Gravitational potential. Poisson's equation. Laplace's equation. Gauss' theorem. Potential energy. Potential energy tensor. Spherical systems. Newton's theorems. Point mass. Homogeneous sphere. Hubble density profile. Power-law density profile. Axisymmetric systems. Logarithmic potential.
3. THE ORBITS OF THE STARS. Costants and integrals of the motion. Surfaces of section. Orbits in a static spherical potential. Orbits in a Keplerian potential. Orbits in a static axisymmetric potential. Motion in the meridional plane. Nearly circular orbits. Epicyclic approximation. Orbits in a two-dimensional non-axisymmetric non-rotating potential. Loop and box orbits. Stable and unstable orbits. Orbits in a two-dimensional non-axisymmetric rotating potential. Jacobi's integral. Lagrange's points. Corotation. Families of orbits x1, x2, x3, x4. Introduction to the orbits in a three-dimensional triaxial potential.
4. COLLISIONLESS SYSTEMS. Geometric collisions. Strong collisions. Weak collisions. Crossing time. Relaxation time. Distribution function. Collisionless Boltzmann equation. Continuity equation. Euler's equation. Jeans' equations. Applications of the Jeans' equations. Velocity ellipsoid. Asymmetric drift. Mass density in the Solar neighborhood. Velocity dispersions in spherical systems. Mass-anisotropy degeneracy. Spheroidal systems with isotropic velocity dispersions. Disk heating mechanisms. Virial theorem. Mass-to-light ratio of spherical systems. Rotation of elliptical galaxies. Jeans' theorem. Density profile from the distribution function. Spherical systems with isotropic velocity dispersion. Polytropes. Plummer's sphere. Isothermal sphere. Singular isothermal sphere. King's radius. King's method to derive the mass-to-light ratio. King's models. Tidal radius. Concentration parameter. Distribution function from the density profile. Eddington's equation. Introduction to spherical systems with anisotropic velocity dispersion. Michie's models.

**Examination**:

Oral exam.

**More information:**

http://en.didattica.unipd.it/off/2017/LM/SC/SC1173/002PD/SCN1035990/N0

## HIGH ENERGY ASTROPHYSICS

Master degree in **Astronomy**, First semester
Lecturer: Alberto Franceschini
Credits: 6 ECTS

**Prerequisites:**
The mandatory courses of 1st year of Laurea Magistrale in Astronomia.

**Short program**:

1. FUNDAMENTALS OF CLASSICAL ELECTRODYNAMICS. Basic formulae of electro-magnetism in the classical limit.Electromagnetic waves. The relationship of electric charges and the radiation fields (radiations from moving charges, Lienard-Wiekert potentials, fundamental equation,Larmor,dipole emission,multi-polar contributions,the radiation spectrum.
2. BREHMSSTRALUNG RADIATION. The classical limit,electric dipole contribution.The Gaunt factor.Thermal Bremsstrahlung.Plasma cooling by free-free emission.Radiative transfer and Bremsstrahlung self-absorption.Relativistic and non-thermal Bremsstrahlung. Applications of thermal free-free emissions by astrophysical plasmas.
3. GAS DYNAMICS AND PLASMA EFFECTS. Fundamentals of hydrodynamics. General equations and conservation laws.Adiabatic and isothermal stationary flows.Sound waves.Particle collisions in plasmas. Momentum transfer among particles:viscosity.Energy transfer and heat conduction.Shock waves. Effects of magnetic field.
4. HOT PLASMAS IN GALAXIES AND CLUSTERS OF GALAXIES.Fundamental physical parameters.Thermalization timescales.Heat conduction. Magnetic field effects.Ionization mechanisms.Collisional ionization.Line emissions.Metal abundances in the plasma.Models of plasma distribution.Cooling and heating mechanisms.Origin, astrophysical and cosmological significance of the IC plasma.
5. SYNCHROTRON RADIATION.Charges in magnetic fields.Total synchrotron emitted power.Aberration, beaming, angular distribution of radiation.Synchrotron spectrum of a single pulse and its spectrum.The transition from the cyclotron to the synchrotron spectrum.Emission by a non-thermal electron distribution.The full treatment. Synchrotron self-absorption and spectral cutoffs.Synchrotron polarization. Limits of validity of our treatment.Electron energy losses and synchrotron spectral evolution.Radio-galaxies and their synchrotron emission. Energetics of the synchrotron emission by radio galaxies. Radio-Quiet Active Nuclei:Quasars and Seyfert galaxies.
6. COSMIC RAYS AND ACCELERATION MECHANISMS. Observational properties of cosmic rays.Fermi first-order and second order acceleration mechanisms.
7. INVERSE COMPTON EMISSION.COMPTONIZATION OF RADIATION.Electron scattering.Quantum effects:the Klein-Nishina cross-section. Compton scattering and Inverse Compton.Emitted power from single scattering.Emission by many particles.Effects of multiple IC scatterings (Compton parameter, spectral distortions, Bose-Einstein distributions, thermal and kinetic Sunyaev–Zeldovich effect).X-ray emission of radio-quiet (and radio-loud) AGNs by thermal Comptonization.Compton reflection. AGN Unification Scheme and the X-ray Background. The BLAZAR phenomenon. Inverse Compton production of very high-energy photons: Synchrotron-Self Compton and External Compton emissions. Doppler boosting. Super-luminal motions.
8. ACCRETION POWER IN ASTROPHYSICS. The compactness parameter. The Eddington limit. Critical accretion regimes. Bondi and spherically-symmetric accretion. The analogue: accretion in binary systems. Plasma viscosity in disks. Thin accretion discs. Observational tests. Accretion in AGNs.
9. PROPAGATION OF RADIATION THROUGH PLASMAS. Propagation of electromagnetic waves through plasmas. Propagation along magnetic fields: the Faraday rotation. Cherenkov radiation. Electron-Positron Pair Production (in thermal and non-thermal plasmas).

10. CHERENKOV ASTRONOMY. Detection technique. Atmospheric showers. Imaging the shower. Existing and future facilities. The VHE extragalactic sky.
11. THE COSMIC PHOTON-PHOTON AND PARTICLE-PHOTON OPACITIES. Extragalactic background radiations, background energy density. The photon opacity, applications to current and future observations.

**Examination**:
Oral discussion.

**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1173/001PD/SCN1032610/N0

## LABORATORY OF ASTROPHYSICS 1

Degree in **Astronomy**, First Semester
Lecturer: Roberto Ragazzoni
Credits: 6 ECTS

**Prerequisites:**
Knowledge of the basis of physic and astronomy at the level of the Laurea in Astronomia.
Basic knowledge of scientific english.

**Short program**:
Recall of basic principles of optics and of 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.
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.
Oversizing and under-¬-sizing of the secondary mirror and natural ability to reject ground-¬-based thermal infrared.
Off-¬-axis sections in ground and space based optical telescopes. Collimation and pupil reimaging.
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.
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. High order aberrations and Hamilton, Zernike and Karhunen-¬-Loeve modes. Shack-¬-Hartman and Pyramid wavefront sensors.
Concept of Multi Conjugated Adaptive Optics. Star and Layer Oriented approaches. Detectors Charge Coupled Devices Detectors, principles of working and basic parameters. Quantum Efficiency, Charge Transfer Efficiency, Read Out Noise.
I3-¬-CCD principle of working and effects on the Poissonian apparent noise.
Concept of the Avalanche Photo Diodes and Quenching.
Laboratory
Poisson's spot, turbulence simulation and speckle formations.

Asiago Observatory
Speckle interferometry and possibly Kolmogorov turbulence.
**Examination**: Oral exam.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1173/001PD/SC03119283/N0

## MATHEMATICAL PHYSICS

Master degree in **Astronomy**, Second semester
Lecturer: Massimiliano Guzzo
Credits: 6 ECTS
**Prerequisites:**
Linear algebra and calculus with functions of several variables.
**Short program**:
1. Ordinary differential equations: Cauchy theorem, phase-space flow, dependence on the initial conditions; linear equations; phase-portraits, first integrals; equilibrium points; linearizations, stable, center and unstable spaces.
2. Integrable systems: elementary examples from population dynamics, from Mechanics and from Astronomy; integrability of mechanical systems, action-angle variables, examples.
3. Non-integrable Systems: discrete dynamical systems, Poincare' sections; bifurcations, elementary examples. Stable and Unstable manifols, homoclinic chaos; Lyapunov exponents, the forced pendulum and other examples; Center manifolds and partial hyperbolicity. The three body-problem, the Lagrange equilibria,
Laypunov orbits, the tube manifolds.
THE FOLLOWING TOPICS (4) AND (5) ARE ONLY IN THE PART FOR THE STUDENTS OF THE SECOND CYCLE DEGREE IN ASTRONOMY
4. Linear PDEs of first and second order, well-posed problems,
the vibrating string, 1-dimensional wave equation, normal modes of vibrations, heat equation, Fourier series, 2-dimensional wave equation, Laplace operator and polar coordinates, separation of variables, Bessel functions, eigenfunctions of the Laplacian operator.
5. Laplace operator and spherical coordinates, separation of variables, Legendre polynomials and associate functions, Spherical harmonics, multipole expansions, L2 operator-eigenvalues and eigenfunctions, complete solution of the wave equation in space, Schrodinger polynomials.
THE FOLLOWING TOPICS (6) ARE ONLY IN THE PART FOR THE STUDENTS OF THE SECOND CYCLE DEGREE IN MATHEMATICAL ENGINEERING
6. Examples and Applications: examples of analysis of three and four dimensional systems; limit cycles; the Lorenz system, the three-body problem; examples from fluid dynamics, non autonomous dynamical systems, chaos indicators, Lagrangian Coherent Structures.
**Examination**:
Written examination.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1173/001PD/SCN1032593/N0

## STELLAR POPULATIONS

Master degree in **Astronomy**, Second semester
Lecturer: Giovanni Carraro
Credits: 6 ECTS
**Prerequisites:**
Basic knowledge of stellar astrophysics: Stellar evolution, c-m diagrams, stellar photometry and spectroscopy, astrometry.

**Short program**:
Color magnitude diagrams.
Luminosity-magnitude and temperature-color transformation. Effects of the interstellar reddening on the color-magnitude diagrams.
The concept of stellar populations: Historical background.
Stellar populations: Modern view.
The Galactic model by Eggen, Lynden-Bell and Sandage.
The galactic halo model from Searle and Zinn.
Stellar populations in the solar neighbor
The interstellar medium near to the Sun and the local bubble.
Population II.
Measurement of population II main parameters: reddening,
distance, age, chemical content
Globular Clusters stellar populations
The concept of multiple stellar populations
The helium content of the population II stars.
The horizontal branch and the second parameter problem
The population I and the galactic disk. Open clusters and field population.
Stellar populations in dwarf Galaxies of the Local Group
The initial mass function.
Observational parameters of unresolved stellar population and their interpretation
Star formation History in galaxies
Basic principles of the chemical evolution of the stellar populations.
**Examination**:
Oral.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1173/001PD/SCN1032617/N0

## THEORETICAL ASTROPHYSICS

Master Degree in **Astronomy**, Second semester
Lecturer: Paola Marigo – Alberto Franceschini
Credits: 12 ECTS
**Prerequisites:**
The whole content of the Laurea in Astronomia and the mandatory course of the 1st year of the Master course.
**Short program**:
THEORETICAL ASTROPHYSICS (MOD. A)
1. White Dwarfs
Degenerate structure. Cristalization
External envelope.
Cooling laws.
Effects of diffferent chemical stratifications
2. Stellar Winds.
Introduction.
Coronal winds. Isothermal case. Generale case.
Radiative winds. Wind dynamics: basic laws.
Multiple line models.
3. Variable stars.
Elements of Pulsation Theory.
Adiabatic treatment.
Non-Adiabatic treatment.

Ionization-driven instability.
Radial pulsators.
Non-Radial pulsators.
Elements od Asterosismology.
THEORETICAL ASTROPHYSICS (MOD. B)
0. The Homogeneous and Isotropic (Friedmann) Universe. Hubble law. The Cosmological Principle. Isotropic curved spaces. The Robertson-Walker metric. Geometrical properties of the space-time. Cosmic dynamics, the Newtonian and general-relativistic approach. Cosmological models and parameters. Fundamental observables. The redshift. Luminosity and angular diameter distances. Time-redshift relations. Hubble diagrams. Generalized dynamical equations. The cosmological constant.
1. 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 ξ(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.
2. Deviations from homogeneity. Gravitational lensing. Point-like lenses and isothermal spherical distributions. Lens potentials. Einstein radius. Lensing cross-sections. Lensing effects on time lags. Caustics. Observations of the gravitational lensing and cosmological applications. Estimate of the total galaxy cluster mass. Estimates of H0. Effects of a cosmological constant L in the lensing statistics. Micro-lensing and weak-lensing. Mapping of the mass distribution.
3. Cosmological evolution of perturbations in the cosmic fluid. Cosmological evolution of perturbations in the thermo-dynamical parameters of the various components of the cosmic fluid. General equations in a static universe and in an expanding one. Evolution in a matter dominated universe. Hubble drag. Relationship of perturbations and velocity fields.
4. Perturbations in an expanding universe. Peculiar motions of galaxies and structures. Deviations from the Hubble flow, peculiar velocity fields in the cosmo. Observations of peculiar velocity fields. The cosmic viral theorem. Origin of the large scale motions. Constraints on the cosmological parameters from the large scale motions.
5. Brief thermal history of the Universe. The matter and radiation content of the Universe. Energy densities and their evolution. Radiation-dominated universes. The epoch of recombination and equivalence. Time-scales of cosmic evolution. Primordial nucleo-synthesis and its consequencies.
6. The Cosmic Microwave Background. 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 distorsions. The Sunyaev-Zeldovich effect. Polarization.
7. The Primordial Universe. Big Bang singularity. Planck time. Propagation of the information in the universe. Brief overview of the standard model of elementary particles, fundamental interactions. Cosmological phase transitions. Open questions about the standard Big Bang model. The horizon problem. The flatness problem. Cosmological inflation and solutions to the problems. The Anthropic Principle.
8. Origin and Evolution of the Cosmological Structure. Generation of the perturbation field. General composition of the cosmic fluid: the Dark Matter, Cold and Hot Dark Matter.

Stagnation of the Dark Matter perturbation before the equivalence. Transfer function. Non-linear evolution. The Press-Schechter theory.
**Examination**:
Oral examination.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1173/001PD/SCP4067979/N0

# CHEMISTRY

## CHEMISTRY OF ORGANIC MATERIALS

Master degree in **Chemistry**, Second semester
Lecturer: 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.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1169/000ZZ/SC01122913/N0

## ELECTROCHEMISTRY

Master degree in **Chemistry**, First semester
Lecturer: Flavio Maran
Credits: 6 ECTS
**Prerequisites:**
B.Sc. level knowledge of Physical Chemistry, Organic Chemistry, and Analytical Chemistry
**Short program:**
Fundamental equilibrium and nonequilibrium properties of electrochemical systems. Properties of electrolytic solutions. Metal surfaces in electrochemistry. Electrical double layer theories. Overpotentials. Electrode kinetics. Heterogeneous electron transfer. Mass transport. Effect of chemical reactions associated with electron transfer. Kinetic competitions. Activation mechanisms. Dependence of electron transfer rate on driving force. Insights into electron transfer theories. Dissociative electron transfer. Electron transfer through self-assembled monolayers. Most popular electrochemical methods to study electrode kinetics. Scanning probe microscopies with a special focus on electrochemical applications. Atomic force microscopy. Scanning tunneling microscopy. Scanning electrochemical microscopy.

**Examination**:
Tests and final exam. Active participation during the lectures, including discussions.
**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1169/000ZZ/SC01102528/N0

## PHYSICAL CHEMISTRY 4

Master degree in **Chemistry,** First semester
Lecturer: Alberta Ferrarini
Credits: 10 ECTS
**Prerequisites:**
B.Sc. level knowledge of Physical Chemistry and Physics.
**Short program:**
Part A.
Fundamentals of statistical thermodynamics: probability distribution, statistical ensembles, Boltzmann statistics, Maxwell velocity distribution, equipartition of energy. Applications: thermodynamic properties of the ideal gas, heat capacity of solids.
Electric properties of molecules (dipole and higher order multipoles, polarizability) and their connection with the dielectric properties of matter. Applications: dielectric constant of liquids, electrostatic contribution to the solvation free energy.
Inter.molecular interactions: pair interactions and their expressions in terms of molecular quantities. Applications: lattice energy of ionic crystals, equation of state of van der Waals fluids.
Interaction of molecules with electromagnetic fields: time-dependent perturbation theory, transition probability, Fermi golden rule.
Classroom activities will also concern practical application of the methods introduced during the lectures.
Part B.
The first part concerns chemical kinetics: fundamental principles, temperature effect on chemical reactions, Arrhenius equation. Afterward, we will introduce: the Collision theory; the Transition-State theory; mass-transport mechanisms; homogeneous and heterogeneous catalysis. The second part of the course focuses on electrode kinetics, with particular emphasis on mass transport and charge transfer as the rate-determining steps. These analyses are addressed with reference to the most popular electrochemical methods. In the third part, the Marcus theory and further quanto-mechanical developments are described together with the distance effect on electron transfer and some applications to specific systems.
Finally, laboratory experiments have been devised to blend the above concepts on a practical standpoint.
**Examination:**
Written and oral exams, as well as active participation in the course and associated laboratory experiments.
The written tests will focus on specific topics of the course, to facilitate a fast and progressive learning of the content of the classroom lectures.
The oral exam is meant to evaluate the students' capability of utilizing the acquired skills and methodologies to address chemical problems.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1169/000ZZ/SCN1036077/N0

## THEORETICAL CHEMISTRY

Master degree in **Chemistry**, Second semester
Lecturer: Diego Frezzato

Credits: 6 ECTS
**Prerequisites:**
Basic knowledge in chemistry, physics and mathematics.
**Short program:**
1. Stochastic approaches to molecular motions
2. Linear response theory
3. Tensorial quantities and their transformation properties
4. Electronic structure calculations and open quantum system dynamics
5. Stochastic Thermodynamics
**Examination:**
Oral questions and (optional) written paper on a chosen subject.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1169/000ZZ/SC01101389/N0

**COMPUTER SCIENCE**
**ADVANCED TOPICS IN COMPUTER SCIENCE**
Master degree in **Computer Science** , Annual
Lecturer: Francesco Ranzato
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 asses to what extent the student masters the subject.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1176/000ZZ/SCP6076301/N0

**BIOINFORMATICS**
Master degree in **Computer Science** , First semester
Lecturer: Giorgio Valle
Credits: 6 ECTS
**Prerequisites:**
There are no particular prerequisites other than what it is expected from a master student in informatics. Basic knowledge of genetics and molecular biology will help in the understanding of the biological motivations of bioinformatics.
As the course is given in English, the students should have a reasonable command of spoken and written English.
**Short program:**
This is a six-credit course: five credits will be from lessons while one credit will be from practical activities, such as 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 oral, but a continuous process of assessment will be carried out throughout the course, to verify the level of understanding of the students.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1176/000ZZ/SC06100856/N0

## COGNITIVE SERVICES (ALSO OFFERED FOR STUDENTS OF THE MASTER DEGREE IN DATA SCIENCE)

Master degree in **Computer Science**, Second semester
Lecturer: Alessandro Sperduti
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 smart cognitive services; brief intro to AI and ML paradigms.
- Cognitive Services:
Basic concepts; Language, Speech, and Vision Services; major services and API (IBM Watson, Microsoft, Google Cloud); enabling technologies.
- Machine Learning and Application Issues:
Classification; Representation learning and selection of categorical variables; Training and testing; Evaluation measures.
- Visual Recognition:
“Teaching computers to see”: extract rich information from visual data; Challenges: why is computer vision hard?; Designing effective visual features; Representation learning in computer vision; Image understanding.
- 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 in a multi-modal scenario.

**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 realization. The student will present and discuss the project and, if deemed necessary by the teacher, pass an oral examination.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1176/000ZZ/SCP7079279/N0

## COMPUTER AND NETWORK SECURITY

Master degree in **Computer Science**, First semester
Lecturer: 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:**
1) COMPUTER SECURITY TECHNOLOGY AND PRINCIPLES: Cryptographic Tools, User Authentication, Access Control, Database Security, Malicious Software, Denial-of-Service Attacks, Intrusion Detection, Firewalls and Intrusion Prevention Systems.
2) SOFTWARE SECURITY AND TRUSTED SYSTEMS: Buffer Overflow, Software Security, Operating System Security, Trusted Computing and Multilevel Security.
3) MANAGEMENT ISSUES: IT Security Management and Risk Assessment, IT Security Controls, Plans, and Procedures, Physical and Infrastructure Security, Human Resources Security, Security Auditing, Legal and Ethical Aspects.
4) PART FOUR CRYPTOGRAPHIC ALGORITHMS: Symmetric Encryption and Message Confidentiality, Public-Key Cryptography and Message Authentication.
5) NETWORK SECURITY: Internet Security Protocols and Standards, Internet Authentication Applications, Wireless Network Security.
The second part of the course takes the form of seminars based on a selection of scientific papers (that either have had a strong impact on security today, or explore novel ideas that may be important in the future).
**Examination**:
Written.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1176/000ZZ/SCP6076342/N0

## CRYPTOGRAPHY (OFFERED IN THE MASTER DEGREE IN MATHEMATICS)
Master degree in **Computer Science**, First semester
Lecturer: Alessandro Languasco
Credits: 6 ECTS
**Prerequisites:**
The topics of the following courses: Algebra, Calculus.
**Short program:**
First Part: Basic theoretical facts: Modular arithmetic. Prime numbers. Little Fermat theorem. Chinese remainder theorem. Finite fields: order of an element and primitive roots. Pseudoprimality tests. Agrawal-Kayal-Saxena's test. RSA method: first description, attacks. Rabin's method and its connection with the integer factorization. Discrete logarithm methods. How to compute the discrete log in a finite field. Elementary factorization methods. Some remarks on Pomerance's quadratic sieve.
Second Part: Protocols and algorithms. Fundamental crypto algorithms. Symmetric methods (historical ones, DES, AES) . Asymmetric methods. Attacks. Digital signature. Pseudorandom generators (remarks). Key exchange, Key exchange in three steps, secret splitting, secret sharing, secret broadcasting, timestamping. Signatures with RSA and discrete log.
**Examination**:
Written exam.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1176/000ZZ/SC04111836/N0

## DATA MINING
Master degree in **Computer Science**, Second semester
Lecturer: Annamaria Guolo
Credits: 6 ECTS

**Prerequisites:**
Basic knowledge of computer science, Databases.
**Short program:**
- Introduction to the course: Data analysis as a tool for decision support. Motivations and context for data mining.
- Linear and generalised linear predictive models
- Classification methods: logistic regression, linear discriminant analysis and extensions
- Cross validation
- Model selection and regularisation
- Nonlinear models: semi-parametric and non-parametric regression
- Tree-based methods

**Examination**:
The exam has the aim of evaluating the knowledge acquired by the students and its application to the analysis of a dataset.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1176/000ZZ/SC01111799/N0

## FUNCTIONAL LANGUAGES

Master degree in **Computer Science**, First semester
Lecturer: Gilberto Filè
Credits: 6 ECTS
**Prerequisites:**
Imperative and object oriented programming.
**Short program:**
Two functional languages are taught: ML and especially Haskell.
Pattern matching;
Curryfied and higher-order functions;
Type inference: what it is and how it is done;
Polymorphism;
Lazy evaluation;
Functors, applied functors and monads;
Exceptions and I/O;
Run-time support.
**Examination**:
The exam has a written and an oral part. Each part counts for 50% of the grade. The written part is on the general concepts taught in the course, whereas the oral part is a discussion on homeworks assigned during the course.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1176/000ZZ/SCP6076299/N0

## GAME THEORY (OFFERED IN THE MASTER DEGREE IN COMPUTER ENGINEERING)

Master degree in **Computer Science**, First semester
Lecturer: Leonardo Badia
Credits: 6 ECTS
**Prerequisites:**
A course, even a basic one, on statistics.
**Short program:**
Basic concepts of game theory
Utility, market, discount factor
Static games in normal form
Dominance, Nash equilibrium

Efficiency, price of anarchy
Zero-sum games, minmax games
Mixed strategies, mixed equilibria
Nash theorem, minmax theorem
Pure and mixed strategies
The tragedy of the commons
Dynamic games
Strategy and subgames
Backward utility
Stackelberg equilibria
Repeated games and cooperation
Dynamic duopolies, collusion
Cooperation, pricing
Imperfect/incomplete information
Bayesian games, signaling, beliefs
Revelation principle
Axiomatic game theory
Fictitious play
Best response dynamics
Distributed optimization
Algorithmic game theory
Computation, complexity, and completeness of equilibria
Auctions, bargaining
First-price and second-price auctions
VCG principle
Cooperative games: the core, the Shapley value
Duopolies and competition
Resource allocation
Utilities, choices, and paradoxes
Potential games, coordination
Bio-inspired algorithms
Evolutionary games
Cognitive networks
Selfish routing
Game-theory enabled multiple-input systems
Wireless spectrum auctions.

**Examination**:
Preliminary written exam (general exercises on the course). Development of a project in 1-3 person groups, on course-related topics but applied to ICT, and discussion of it (by appointment).

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1176/000ZZ/SCP7079401/N0

## METHODS AND MODELS FOR COMBINATORIAL OPTIMIZATION

Master degree in **Computer Science**, First semester
Lecturer: Luigi De Giovanni - Marco Di Summa
Credits: 6 ECTS

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

**Short program:**
1. Advanced linear programming and duality with applications: primal-dual simplex, column generation, applications to network optimization.
2. Advanced methods for Integer Linear Programming (ILP): Branch & Bound and relaxation techniques, alternative ILP formulations, cutting planes method and Branch & Cut, application to relevant examples (Traveling Salesman Problem, location, network design etc.).
3. Meta-heuristics for combinatorial optimization: local search based, evolutionary algorithms.
4. Application of graph modeling and optimization.
5. Labs: optimization software packages and libraries.

**Examination**:
Oral examination about course contents. Each student may chose to present a short project concerning models and exact/heuristic solution methods for a realistic application of combinatorial optimization.

**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1176/000ZZ/SC01122975/N0

**STRUCTURAL BIOINFORMATICS (ALSO OFFERED FOR STUDENTS OF THE MASTER DEGREE IN DATA SCIENCE)**

Master degree in **Computer Science**, Second semester
Lecturer: Silvio Tosatto – Tito Calì
Credits: 6 ECTS

**Prerequisites:**
Basic knowledge of optimization methods and machine learning. C++ and/or Java programming languages.

**Short program:**
The course consists of two parts:
1) Introduction to living matter (2 credits):
1.1) Introduction to organic chemistry
1.2) Weak interactions and energy
1.3) Structure and function of DNA and proteins
1.4) Lipids, membranes and cellular transport
2) Computational Biochemistry (4 credits):
2.1) Biological Databases
2.2) Software libraries and concepts for sequence alignments, profiles and database searches
2.3) Sequence - structure - function relationship in proteins and classification
2.4) Methods for the prediction of protein structure from sequence. The CASP experiment.
2.5) Methods for the prediction of protein function. The CAFA experiment.
2.6) Introduction to network and systems biology.
2.7) Genotype – phenotype correlations. The CAGI experiment.

**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%)
http://en.didattica.unipd.it/off/2017/LM/SC/SC1176/000ZZ/SCP7079278/N0

## WIRELESS NETWORKS

Master degree in **Computer Science**, First semester
Lecturer: Claudio Enrico Palazzi
Credits: 6 ECTS
**Prerequisites:** Computer Networks.
**Short program:**
Introduction to Wireless Networks.
Wireless network issues: error and collision losses, fairness and transmission delays, handoffs.
MAC layer standards: 802.11 a/b/g/n/p/s
Transport protocols in wireless environments: TCP Vegas, TCP Westwood, TCP Hybla, CUBIC.
Ad hoc networks and routing protocols: MANET, VANET, DSDV, AODV, DSR.
Applications and services on mobile networks.
**Examination**:
Written exam.
**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1176/000ZZ/SCP6076377/N0

# EVOLUTIONARY BIOLOGY

## ETHOLOGY

Master degree in **Evolutionary Biology**, First semester
Lecturer: Andrea Augusto Pilastro
Credits: 6 ECTS
**Prerequisites:**
Good knowledge in evolutionary biology, ecology, genetics, and zoology (advanced undergraduate course level).
**Short program:**
Main topics will regard the link between animal behavior 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 behavior, kin selection..
**Examination**:
Written test (multiple choice questions, open questions).
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1179/000ZZ/SCN1031442/N0

## EVOLUTION AND CONSERVATION

Master degree in **Evolutionary Biology**, First semester
Lecturer: Andrea Augusto Pilastro
Credits: 6 ECTS
**Prerequisites**:
Good knowledge in evolutionary biology, ecology, genetics, zoology and botany (advanced undergraduate course level).
**Short program:**
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, 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:**

http://en.didattica.unipd.it/off/2016/LM/SC/SC1179/000ZZ/SCO2043741/N0

**FISICA**

**THEORY OF FUNDAMENTAL INTERACTIONS**

Master degree in **Fisica**, First semester

Lecturer: Pierpaolo Mastrolia

Credits: 6 ECTS

**Prerequisites :**

This course requires good knowledge of theoretical physics, quantum field theory, and theory of fundamental interactions.

**Short program:**

- PART I: MODERN METHODS FOR SCATTERING AMPLITUDES
(P. Mastrolia)

1. Unitarity, Optical Theorem, Decay Rates
2. Cutkosky Rules, the Largest Time Equation, Feynman Tree Theorem
3. The Spinor Helicity Formalism
4. On-shell recurrence relation for tree-level amplitudes
5. One-Loop integrals and Integration-by-parts Identities
6. Unitarity-based methods
7. Integrand Reduction method
8. Differential Equations for Feynman Integrals

- PART II: TOPICS IN PRECISION ELECTROWEAK PHYSICS
(M. Passera)

1. Introduction to the quantum corrections: The loop expansion, UV Divergent integrals, Dimensional regularization (DR).
2. Basic loops in QED: The photon self-energy at one-loop in DR, The photon propagator, Renormalization of the electric charge, Example of cancellation of UV divergences, The effective electric charge, Mass renormalization, Wave-function renormalization for the external legs.
3. The electron-photon vertex in QED: Formal structure and one-loop expression, The Dirac and Pauli form factors F_1(q^2) and F_2(q^2).
4. The anomalous magnetic moment of the electron: Preliminary remarks: g=2, The QED contribution, Other contributions and the determination of the fine-structure constant alpha.
5. The anomalous magnetic moment of the muon in the full SM: The QED contribution, The hadronic contribution, The EW contribution, SM prediction vs. experiment.
6. Renormalization of the electroweak theory, Mass renormalization for unstable particles, The On-Shell scheme, The M_W-M_Z relation and Sirlin's Delta r, The MSbar scheme, Introduction to the renormalization group.
7. The SM Higgs boson: Indirect limits from EW precision tests, The LHC discovery.

**Examination**:

Oral exams.

**More information:**

http://en.didattica.unipd.it/off/2016/LM/SC/SC1171/000ZZ/SC01120613/N0

**GEOLOGY AND TECHNICAL GEOLOGY**

## APPLIED GEOCHEMISTRY

Master degree in **Geology and technical Geology** , First semester
Lecturer: 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:**
Isotope geochemistry plays an increasingly important role in a wide variety of geological, environmental, medical, forensic and archeological investigations. Isotope methods allow to determine the age of the Earth, reconstruct the climate of the past, detect adulterated foods and beverages, detect and monitor the progress of diseases in human and explain the formation of the chemical elements in the universe. This course is designed to provide an introduction to the principles and applications of isotope geochemistry. Systems discussed include the classic radiogenic systems (Rb-Sr, Sm-Nd, Lu-Hf and U-Th-Pb), traditional (e.g. H and O) as well as nontraditional (e.g. Fe) stable isotope systems, cosmogenic isotopes and extinct radioactivities. Applications as chronometers or tracers will be 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.

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

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1180/000ZZ/SCP5070181/N0

## APPLIED PETROGRAPHY

Master degree in **Geology and technical Geology** , First semester
Lecturer: Claudio Mazzoli
Credits: 6 ECTS

**Prerequisites:**
Basic knowledge in petrology, geochemistry and mineralogy.

**Short program:**
This course examines in depth application aspects of petrography with reference to the following arguments: physical-chemical properties and decay of natural ornamental and dimension stones; traditional ceramic materials; hydraulic and non-hydraulic binders; applications to archaeometry.

**Examination**:
Oral test.

**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1180/000ZZ/SCP3051232/N0

## BASIN ANALYSIS

Master degree in **Geology and technical Geology** , Second semester
Lecturer: Massimiliano Zattin
Credits: 6 ECTS

**Prerequisites:**
Basic knowledge of some courses of the first semester (Applied geophysics, Micropaleontology, Applied geochemistry).

**Short program:**
1) The foundations of sedimentary basins; classification and plate tectonics.
2) Basins due to lithospheric stretching: rifts and passive margins.

3) Basins due to lithospheric flexure: foredeep, foreland, buckling.
4) Dynamic topography.
5) Strike-slip and pull-apart basins.
6) Subsidence and thermal history.
7) Application to petroleum industry.
**Examination**:
Written examination.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1180/000ZZ/SCP3051165/N0

## CARBONATE SEDIMENTOLOGY
Master degree in **Geology and technical Geology**, First semester
Lecturer: Nereo Preto
Credits: 6 ECTS
**Prerequisites:**
Knowledges of sedimentary geology and clastic sedimentology; base notions of chemistry.
**Short program:**
- The 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;
- Diagenesis of carbonates and reconstruction of diagenetic histories;
- Dolomitization processes;
- Stable isotope geochemistry, as applied to problems of carbonate diagenesis;
- Sequence stratigraphy of carbonates.

**Examination**:
Written test.
**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1180/000ZZ/SCP5070180/N0

## METAMORPHIC PETROLOGY
Master degree in **Geology and technical Geology** , First semester
Lecturer: Bernardo Cesare
Credits: 6 ECTS
**Prerequisites:**
Basic knowledge of petrography, geochemistry and mineralogy.
**Short program:**
Focusing on the metapelitic system, and through extensive practice at the microscopic laboratory, the course will provide deep insight into the main aspects of metamorphic petrology, such as: metamorphic classification; equilibrium assemblages; metamorphic facies; chemographies and other graphical representations; metamorphic reactions and equilibria; role of fluids in metamorphism, fluid inclusions; geothermobarometry and phase equilibria calculations; metamorphism of pelites; contact metamorphism; crustal anatexis; microstructures of anatectic rocks; melt inclusions in migmatites and granulites.
**Examination**:
Oral examination in English.
**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1180/000ZZ/SCO2045754/N0

## MICROPALEONTOLOGY

Master degree in **Geology and technical Geology**, First semester
Lecturer: Claudia Agnini
Credits: 6 ECTS

**Prerequisites:**

Basic of Stratigraphy and Paleontology.

**Short program:**

History of micropaleontology and its position in the context of the geological sciences. Its developments and the importance of deep-sea drilling projects.

The first part of the course deals with “pure” micropaleontology. An overview of the various microfossil groups of botanical and zoological origin, that are widely used both in academic research and oil and gas industry, by presenting their morphology, taxonomy, mode of life, environments and stratigraphic distribution. In this context, preparation- and research techniques of main microfossil groups and their geological importance in terms of dating, correlation, facies interpretation, paleoenviromental and paleoclimaticreconstruction is introduced to the students.

The second part of the course consists of practical microscope exercitations on micropaleontological samples which contain the main microfossil groups presented in the general theoretical part (e.g., calcareous nannofossils, foraminifera, radiolarians, diatoms, ….).

**Examination**:

Practical examination plus oral examination.

**More information:**

http://en.didattica.unipd.it/off/2017/LM/SC/SC1180/000ZZ/SCP7077717/N0

## MORPHODYNAMICS OF LAGOONS, DELTAS AND ESTUARIES UNDER CLIMATE CHANGE

Master degree in **Geology and technical Geology**, First semester
Lecturer: Andrea D’Alpaos – Massimiliano Ghinassi
Credits: 6 ECTS

**Short program:**

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

**Examination**:

Written and oral exam.

**More information:**

http://en.didattica.unipd.it/off/2016/LM/SC/SC1180/000ZZ/SCP3051173/N0

## NUMERICAL MODELING IN GEOSCIENCES

Master degree in **Geology and technical Geology**,  First semester
Lecturer: Manuele Faccenda
Credits: 6 ECTS

**Prerequisites:**

Basic mathematics, physics and MatLab.

**Short program:**

1. Mathematical basis for partial differential equations (derivatives, gradient, divergency, laplacian operator)

2. Rock physical properties (viscosity, elastic moduli, cohesion and friction coefficient, density, thermal conductivity and diffusivity, heat capacity)
3. Synthetic phase diagrams and thermodynamical database implementation
4. Stress, strain and strain rate tensors and constitutive relationships.
5. Visco-elasto-plastic deformation
6. Diffusion equation
7. Conservation of mass
8. Conservation of momentum
9. Conservation of energy
10. Numerical method: finite difference with particle-in-cell (mixed Eulerian-Lagrangian scheme)
11. Solution of systems of equation with iterative (Gauss-Siedel) or direct (Gauss elimination) methods.
12. Working with MatLab software to:
- save, read and plot data
- programming petrological-thermo-mechanical numerical codes with viscous deformation and variable physical properties.

**Examination:**
Oral and practical test.
**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1180/000ZZ/SCP4065499/N0

## PETROLEUM GEOLOGY

Master degree in **Geology and technical Geology**, Second semester
Lecturer: Massimiliano Zattin
Credits: 6 ECTS
**Prerequisites:**
Basic knowledge of some courses of the first semester (Sedimentology, Applied geophysics, Micropaleontology, Applied geochemistry).
**Short program:**
The course will delivery the key-concepts of petroleum geology and is integrated by seminars on specific topics (to be defined during the semester).
- The origin of petroluem; physico-chemical properties of hydrocarbons.
- The source rock, maturity of organic matter and petroleum migration.
- The seal rock.
- Reservoir geology, stratigraphic traps, structural traps.
- Main exploration and production techniques.

**Examination**:
Written examination.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1180/000ZZ/SCP3051098/N0

## SEDIMENTOLOGY

Master degree in **Geology and technical Geology**, Second semester
Lecturer: Massimiliano Ghinassi
Credits: 6 ECTS
**Prerequisites:**
Basic knowledge concerning sedimentology (textural features of the main types of sediments and sedimentary rocks) and stratigraphy (temporal and spatial variability of depositional systems).

**Short program:**
Introduction to Sedimentology
- facies and facies associations
- textural features of sediments, stratal geometries and terminology
Sediment transport and deposition
- tractional transport from unidirectional currents
- tractional transport from oscillatory currents
- mass transport
Post-depositional modifications
- soft-sediment deformations
- icnofossils
Depositional environment
- continental depositional environments (alluvial fan, fluvial, lacustrine, eolian)
- coastal depositional environment (wave-dominated coasts, deltas, tidal flats/lagoons )
- deep marine depositional environment (turbidites, conturites)
Sequence stratigraphy
- base level and accommodation space
- systems tracts
- sequences
- incised valleys
- non-marine sequence stratigraphy.

**Examination**:
Written test (open questions).
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1180/000ZZ/SCP3051016/N0

**INDUSTRIAL BIOTECHNOLOGY**
**ENVIRONMENTAL BIOTECHNOLOGY AND BIOENERGY PRODUCTION**
Master degree in **Industrial Biotechnology**, First semester
Lecturer: Fiorella Lo Schiavo - Tomas Morosinotto
Credits: 8 ECTS
**Short program:**
Environmental Biotechnology:
Responses of Plants To Abiotic Stresses: Stresses involving water deficit, osmotic stress and its role in tolerance to drought and salinity, impact of water deficit and salinity on transport across plant membranes. Freezing stress. Flooding and oxygen deficit. Oxidative stress. Heat/Cold stress.
Plant responses to mineral toxicity: Molecular Physiology of mineral nutrient, acquisition, transport and utilization. Aluminium toxicity, heavy metal ion toxicity ($Cd^{+2}$, $Hg^{2+}$, $Pb^{2+}$).
Phytoremediation approaches to remove soil/water contaminants.
Biotechnologies for Energy production:
Introduction: current energy sources and the necessity of renewable fuels.
Production of bioethanol from ligno-cellulosic biomasses.
Production of biodiesel from oleaginous crops.
Algae as biofuels producers. Evaluation of advantages and disadvantages with respect to plants.
Hydrogen production from algae and bacteria.
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:**
Oral discussion of the course contents and critical analysis of some recent scientific papers.
**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1731/000ZZ/SCO2044108/N0

## ENVIRONMENTAL CHEMISTRY AND GENETIC TOXICOLOGY

Master degree in **Industrial Biotechnology**, Second semester
Lecturer: Paola Venier
Credits: 8 ECTS
**Prerequisites:**
General and inorganic chemistry, Organic Chemistry, essentials of Life sciences and Genetics.
**Short program**
The following contents will be expanded or reduced according to the student skills and interest.
Part A (CHIM). Introduction to the environmental chemistry and chemical cycles. Evaluation of the pollutant distribution and transfer in the atmosphere, hydrosphere and lithosphere. Radioactivity: principles and chemistry of radiations, ionizing and non-ionizing radiations. Types of radioactive decay. Atmosphere: chemistry and atmospheric pollutants, photochemical smog, role of chemical substances in the ozone layer depletion, greenhouse effect, inorganic gaseous pollutants, organic pollutants, particulates. Hydrosphere: features, chemical behaviour of inorganic and inorganic pollutants; contamination of natural waters; 'heavy' metals and their transport; colloids. Lithosphere: soil composition and chemistry with special attention to pesticides, herbicides and 'heavy' metals.
Part B (BIO). Variety of toxic agents and possible adverse effects at different levels of biological organization, with evidence-based facts and short mention to chemical toxicokinetics and toxicodynamics. Biological targets, measures of exposure, effect and susceptibility. Dose-response and time-response relationships, hormesis. Toxicological databases, criteria for the identification of toxic agents and their characterization, included biotechnological products and nanoparticles/nanomaterials. Physical agents: dose units, molecular effects and responses induced by non-ionizing and ionizing radiations; adaptive response, bystander effects, genetic/epigenetic mechanisms of genomic instability. Genotoxic, mutagenic and carcinogenic agents: genetic activity profiles, action mechanisms, mutational spectra, mutagenesis strategies. Other cases (e.g., reproductive toxicity, neurotoxicity, antimicrobial/antiviral activity). Methods of toxicology and toxicogenomics (practical experience, examples).
**Examination:**
Oral or written evaluation depending on the student number. During the exam the student will also debate a free topic (toxic agent, biological process in terms of function/dysfunction, investigation method) agreed with the course teacher and based on the scientific literature. Effective reporting of biotechnological aspects will be positively evaluated.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1731/000ZZ/SCN1037598/N0

## IMMUNOLOGICAL BIOTECHNOLOGY

Master degree in **Industrial Biotechnology**, First semester
Lecturer: Emanuele Papini - Regina Tavano
Credits: 8 ECTS
**Prerequisites:**
The student must have a good preparation in general Immunology.
**Short program:**
- Classic Vaccinology

- Main problems in the development of a vaccine.
- production of recombinant vaccines
- Microbial, animal and vegetal models for vaccine production.
- Reverse vaccinology: genome based antigen individuation (in silico). Production, quality control

Main vaccines in the pediatric prevention in Italy
ADjuvants - Mucosal adjuvant- micro-nanosized new generation adjuvants.
- Use of dendritic cells in therapy: prespectives.

Practical part:
Evaluation in vitro of adjuvancy in human dendritic cells. Isolation of monocytes fromm blood, thier differentiation into Dendritic Cells (DCs). Stimulation of DCs with various adjuvants and analysis of cell activation by Elisa (TNFa) and flow cytometry (CD86, CD11), RT-PCR (tnfa gene transcription). Aultologous/heterologous T lymphocytes proliferation and characterisation of their immunological competence by FACS.

**Examination**:
Oral examination plus evaluation of a laboratory activity written report.

**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1731/000ZZ/SCO2044105/N0

## LARGE-SCALE CELL CULTURES AND BIOMOLECULES PRODUCTION

Master degree in **Industrial Biotechnology**, Second semester
Lecturer: Chiara Rampazzo
Credits: 8 ECTS

**Prerequisites:**
Students are expected to have knowledge and competence of cellular and molecular biology and of biochemistry to be able to understand the fundamental aspects of mammalian large scale cell culture in upstream and downstream processes.

**Short program:**
Overview of the biopharmaceutical industry. Upstream and downstream processes. GMP/GLP regulatory requirements for processing biopharmaceuticals. Lab/pilot scale process to implement full manufacturing scale. Consistency and robustness in a fermentation process. Large scale mammalian cell culture. Cell line engineering techniques and common host cell lines used. Bioreactor operation mode: batch, fed batch, continuous and perfusion culture. Selection of bioreactor type (spinner flask, stirred tank). Attachment systems for cell cultivation in adhesion (plates, roller bottle, and stacked plate system) packed bed bioreactor, microcarriers, fluidized bed bioreactor, hollow fiber and wave bioreactor. Perfusion systems for cell cultivation (hollow fiber, spin filter, acoustic cell separation, alternating tangential flow (ATF) system). Design of cell culture medium without serum and with low content of proteins. Scaffold and matrix in bioreactors. How to calibrate oxygen, pH, nutrients and metabolites, cell density and viability in the bioreactor. Design of large scale cell culture process for mammalian cell culture. How to improve cell viability in a process. Expression of cloned proteins in mammalian cells, e.g. interferon and insulin. Large scale production of monoclonal antibodies and their use. Vaccine process development in mammalian cells and manufacturing of vaccins. Embryonic and adult stem cell cultures and their application in cell therapy. Biomolecules of pharmaceutical interest. Cytokines: interleukins and interferons. Hormons: insulin and growth hormone. Enzymes: tissue plasminogen activator and DNase. Erithropoietin. Heparin. Monoclonal antibodies: pharmaceutical and therapeutic properties. Monoclonal antibody-based drugs for antitumor, immunosuppressive, antithrombotic, antiviral, antiasthma and antiangiogenic therapies. Antisense oligonucleotides: approved agent and clinical trials. Aptamers. Ribozymes.

**Examination**:
Final exam will be oral. Students will be evaluated collegially by both professors.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1731/000ZZ/SCN1037574/N0

## NANOBIOTECHNOLOGY

Master degree in **Industrial Biotechnology**, First semester
Lecturer: Alessandro Moretto - Emanuele Papini
Credits: 8 ECTS
**Prerequisites:**
Basic background in chemistry and organic chemistry acquired in the previous fundamental courses. Basic knowledge about formation and properties of nanoparticles.
Previous attendance of the "Nanosystems" course (I semester) is suggested.
**Short program:**
I. Introductory lessons that summarize the general features of nanoassembled systems; these lessons are meant to go over the main contents of the course "Nanosystems", for the benefit of those students who followed it; at the same time, they are meant to provide a basis for those student who do not have it. Outline of the essential features of nano-structured systems. The ideal nanostructure: components. Modified "natural" nanostructures (bacterial Outer Membrane Vescicles, viruses). Engineered nanoparticles: inorganic (silica, gold), organic (nanoformulations, polymers), liposomes and lipidic nanoparticles, quantum dots. Derivatization with small organic molecules (conjugation, orthogonal bioconjugation), with proteins or antibodies for specific cell targeting.
II. Lectures on nano-biomedicine and nanotoxicology. Physio-structural features of living organisms that come primarily into play in the interaction with nanomaterials.
Blood circulation, endothelial cells, renal filter. Reticuloendothelial system (RES): tissue-resident macrophages. Professional phagocytes: PMN, monocytes-macrophages, APCs. Accessibility to tissues and systems: physiological and pathological endothelial permeability (in chronic inflammation, and neoplasms); Permeabilisation Retention Effect (lymphatic system); "Shrines": blood-brain barrier: structure and its alteration. Cellular and humoral responses to nano-materials, toxicology and pharmacokinetic aspects. The chemical basis of the interaction between nanomaterials and biomolecules: multivalency and cooperativity. Acute cytotoxic cell damage. Toxic mechanisms, principles, measurements. Current knowledge on the toxicity of inorganic (silica, gold) and organic (microgels, liposomes, nanotubes, polymers)nanostructures. Uptake-clearance, endocytosis and phagocytosis. Opsonization: plasma opsonins. Complement. Concept of protein crown. Concept of stealth property (or "invisibility") of a nano-structure. PEGylation. Proinflammatory, pro-immune, pro-coagulant activities: cytokines induction, radicals production, leukocyte and endothelial activation. Complement and coagulation cascades induced by macroscopic or nanoscopic bio-materials. Immune reaction. Measurements in vitro. Biodegradation and elimination from the body (kidney, bile).
III. Bio-active (transported) portion and applications: drugs, immunostimulants, DNA. Direct action of the nanomaterial, photoactivation, magnetic field activation. Applications: fluorescent biomarking of tissues and cells, in vivo imaging, diagnosis. Drug and gene delivery. Vaccines. Immunological adjuvants. Detection of pathogens. Detection of proteins. Probing the structure of DNA. Tissue engineering.
Hyperthermal therapies. Separation and purification of biological molecules and cells. Contrast agents in magnetic resonance imaging (MRI). Phagokinetic studies.
IV. Laboratory. The practical part will be introduced by preparatory lectures. It will consist of the synthesis of nanosystems, among which will be nanoparticles (both organic and inorganic/metallic) coated with organic (charged) ligands; liposomes (some fluorophoric

molecules will be incapsulated and released by appropriate stimuli); hydrogels based on amino acids and peptides. These nanosystems will be characterized using spectroscopic techniques, such as UV-vis, fluorescence, and dinamic light scattering. Next, the student will test the biocompatibility of the nanosystems produced in biological a-cellular (plasma) or cellular (stabilized human cell lines) models. Examples of possible characterization are: blood coagulation tests, complement activation, citotoxicity, cellular uptake.

**Examination**:

The evaluation will be partly based on a written report on the experimental part, which will have to be turned in by the end of the course, and on an exam. The exam is written and consists of four open-answer questions on topics covered both in the practical and in the theoretical part of the course.

The time allotted to the discussion of the topics proposed is 2 hours.

**More information:**

http://en.didattica.unipd.it/off/2016/LM/SC/SC1731/000ZZ/SCO2044101/N0

## NANOSYSTEMS

Master degree in **Industrial Biotechnology**, Second semester
Lecturer: Sabrina Antonello - Flavio Maran
Credits: 8 ECTS

**Prerequisites:**

B.Sc. level knowledge of Physical Chemistry and Organic Chemistry

**Short program:**

Part A. Physical chemistry and characterization of nanosystems.
Size matters: nanoscale dimension and quantum size confinement.
Intermolecular forces: electrostatic forces, dispersion forces, hydrogen bonds.
Physical chemistry of interfaces.
Thermodynamics of self-assembly and self-organization.
Amphiphilic molecules: thermodynamics for aggregation of micelles, bilayers, vesicles, biological membranes.
Self-assembled monolayers and Langmuir-Blodgett films.
Electron and charge transfers.
Electrochemical techniques.
Scanning probe microscopies.
Optical microscopies and other surface characterization methods.
Part B. Properties and preparation of nanosystems.
Artificial and natural nanosystems.
Nanofabrication techniques.
Bottom-up approaches to nanosystem production.
Aggregates of amphiphilic molecules, nanoemulsions and organic nanoparticles.
Polymeric nanoparticles and dendrimers.
Stimuli-responsive nanosystems.
Carbon nanostructures (nanotubes, fullerenes, graphene).
Metal nanoparticles, nanoshells and nanorods.
Semiconductive nanoparticles : quantum dots.
Oxides nanoparticles : silica, titania.
Magnetic nanoparticles.

**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.

**More information:**

http://en.didattica.unipd.it/off/2017/LM/SC/SC1731/000ZZ/SCL1001625/N0

**INDUSTRIAL CHEMISTRY**

## ANALYTICAL CHEMISTRY OF INDUSTRIAL PROCESSES

Master degree in **Industrial Chemistry**, Second semester
Lecturer: Marco Frasconi
Credits: 6 ECTS

**Prerequisites:**
Analytical Chemistry I and II, in particular knowledges of instrumental analysis.

**Short program:**
1) Introduction to Process Analytical Chemistry.
2) Sampling for analytical purposes. Sampling systems.
3) Data domains and signal elaboration. Sources of noise in instrumental analysis and signal-to-noise optimization strategies.
4) On-line chromatographic techniques. Process gas-chromatography (GC) and liquid-chromatography. Applications of GC and GC-MS in the petrochemical industry.
5) Optical spectroscopy for process analyses. UV-Vis, infrared and Raman spectroscopy: instrumentation design and sampling interface. Analytical applications of IR and Raman spectroscopies in the pharmaceutical industry.
6) Analytical electrochemistry. Potentiometry and ion-selective electrodes. Ion-sensitive field-effect transistors (ISFET). High-temperature potentiometric oxygen sensor in combustion process monitoring. Amperometric methods for on-line analysis.
7) Principles of chemical sensors. Origins of sensor selectivity: thermodynamic and kinetic aspects. Types, preparation and properties of sensors. Immunosensors and DNA-based sensors. Enzyme biosensors. Applications of biosensors in bioprocess monitoring and control.
8) Optical sensors. Integrated sensor arrays for high throughput analysis.
9) Automated methods of analysis. Flow injection analysis and applications in industrial biotechnology.
10) Microanalytical systems. Overview of miniaturization of analytical instruments utilizing microfabrication technology. Application of lab-on-chip detection techniques in bioanalytical studies.
11) Chemometrics methods for process control and monitoring. Feedback optimization algorithms.

**Examination:**
The exam consists of a written assay, on a focused topic on process analytical control, and an oral exam, on the core topics of the course.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1170/000ZZ/SC02119324/N0

## BIOPOLYMERS

Master degree in **Industrial Chemistry**, First semester
Lecturer: Stefano Mammi
Credits: 6 ECTS

**Short program:**
The program is divided into the following points:
1) Polypeptides and protein macromolecules.
Chemistry and stereochemistry of peptide residues. Concepts of primary, secondary, tertiary and quaternary structure. Fundamental aspects of sequencing and synthesis of polypeptides. Outline of molecular biology techniques for the production of proteins. Description of various types of ordered conformations of polypeptide chains. Outline of predictive methods of secondary and tertiary structures. Conformational analysis and forces that determine the structure of peptides and proteins.

2) Polynucleotides
Chemistry and stereochemistry of nucleotides. Typical properties of purine and pyrimidine bases and their derivatives. Primary, secondary, tertiary and quaternary structures of nucleic acids. Structural differences between DNA and RNA. Conformational analysis and forces that determine the structure of nucleic acids. PCR.
3) Polysaccharides
Chemistry and stereochemistry of structural units of polysaccharides. Structures of monosaccharides, disaccharides, homopolysaccharides, heteropolysaccharides. Mention of the structure of some peptidoglycan.
4) Industrial Biopolymers
Biomass. Concept of Biorefineries. Production of energy and chemicals from biomass.
Modified polysaccharides in the food industry.
Modified polysaccharides and plastics: blends of starch and synthetic polymers, acidic polysaccharides, cellulose, chitin, chitosan.
Development and production of polymers from renewable sources. Derivatives of vegetable oils. Polyhydroxyalkanoates. PLA. Protein derivatives.
Biocompatible polymers. Hyaluronic acid and derivatives. Polymeric biomaterials.
5) Analytical techniques for the study of the structural properties of biopolymers.
Characterization and separation of biopolymers on the basis of their hydrodynamic properties: ultracentrifugation, diffusion, electrophoresis, light scattering, size exclusion chromatography.
Spectroscopy applied to the study of biopolymers: absorption spectroscopy, circular dichroism, IR, fluorescence.
**Examination:**
Oral.
**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1170/000ZZ/SCL1001864/N0

## MARINE BIOLOGY

### BIODIVERSITY AND BEHAVIOR

Master degree in **Marine Biology**, First semester
Lecturer: Matteo Griggio
Credits: 8 ECTS
**Prerequisites:**
To successfully follow this course, it is desirable that the student has taken courses in ecology, and in particular in marine ecology, at different levels (population, community).
**Short program:**
Biodiversity: the concept of biodiversity, the diversity of organisms and the ecological systems in which they live. The key role of evolution in shaping biodiversity. Ecological pressures on the morphology and behaviour of marine species. Morphological and behavioural adaptations to different marine habitats (pelagic, benthic, abyssal, intertidal). Biodiversity as the web of complex interrelationships between organisms, the contribution of the study of animal behaviour to understanding the concept of biodiversity. The study of reproductive behaviour, parental care, mimicry and social life, using the most modern concepts of behavioural ecology. Anthropic pressures on marine species and marine habitats. Anthropic impacts on marine species behaviour.
**Examination**:
The evaluation is a written test consisting of three open questions.
**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/IF0360/000ZZ/SCO2046334/N0

## MOLECULAR ECOLOGY AND DEMOGRAPHY OF MARINE ORGANISMS

Master degree in **Marine Biology**, First semester
Lecturer: Lorenzo Zane
Credits: 7 ECTS

**Prerequisites:**

Basic knowledge of Population Genetics and Ecology.
Understanding of written and spoken English.

**Short program:**

The topics covered by the course will provide a link between marine population ecology and molecular ecology. The program will first highlight the traits of marine organisms relevant for population dynamics and for the determination of genetic variability and differentiation, and will then focus on the use of molecular markers for identification of individuals, stock, populations and species.

Molecular markers will be presented with a practical approach, including class and laboratory activity and literature analysis, with the aim of evidence the experimental approach currently used in molecular ecological studies, the kind of data produced and the available strategies for data analysis. The analysis of recently published papers will allow the student to understand the information that can be obtained using the molecular approach, with particular attention to individual identification, genetic tagging, historical demography and analysis of population differentiation.

**Examination**:

Written. Multiple choice questions and questions with short and essay type answers.

**More information:**

http://en.didattica.unipd.it/off/2017/LM/SC/IF0360/000ZZ/SCN1032607/N0

# MATERIALS SCIENCE

## COMPUTATIONAL METHODS IN MATERIALS SCIENCE (ALSO OFFERED FOR STUDENTS OF THE MASTER DEGREE IN PHYSICS)

Master degree in **Materials Science** , Second semester
Lecturer: Francesco Ancillotto/ Alberta Ferrarini
Credits: 6 ECTS

**Prerequisites:**

Quantum and solid state physics, physical chemistry.

**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 software packages that are currently employed in materials science, and they will learn how to interpret and present the results of simulations.

**Examination**:
Oral examination in which the students will discuss a written report, on the results of simple numerical simulations.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1174/000ZZ/SC01122974/N0

## NANOFABRICATION

Master degree in **Materials Science**, First semester
Lecturer: Filippo Romanato
Credits: 6 ECTS
**Prerequisites:**
Single-cycle degree.
**Short program:**
Many of the impressive technical and scientific progress of the last two decades and 'based on the ability' to control individual chemical and physical phenomena at the level of a few nanometers that 'the scale of size which occurs most natural phenomena. This control and 'was obtained by developing systems and processes of micro and nano fabrication for the realization of devices (also referred to as lab-on-chip) capable of exchanging signals (detection and implementation) systems with the size of few nanometers coining, in fact The definition of nanotechnology.
The course will discuss the process of miniaturization of the devices and the how the scale reduction can change or generate many (new) phenomena that distinguish the operation of nanodevices. We will present the main technologies for nanofabrication and we will show examples of application for the construction of devices and experiments at nanoscience. After a general distinction between processes top-down and bottom-up, we will explained the technology of lithography (UV, electronic, X-ray, ion imprinting, interference etc.), the processes of deposition (plasma assisted, or chemical vapor phase, sol-gel, etc.) and etching in the gas (reactive ion etching, milling) or liquid (chemical etching) phase. We will review manufacturing technology of electronic devices based on silicon.
The course is orinted to students in view of their thesis also looking at the broad correlation between physical, chemical, bio-chemical phenomena involved in the creation of nanostructures and nanodevices. The course covers issues of industrial nanotecnotecnology research.
The course is complemented by visits in nanofabrication laboratory in Trieste at the laboratories of the CNR nanofabrication at the synchrotron Elettra. During these visits they will have practical demonstrations of lithographic processes during the course in the classroom.
Syllabus: Nanofabrication:
Program
Nanofabrication: general concepts
Types of lithographs: Top down and bootom-up
Mask - mask less lithography parallel serial
Types of processes sotrattivi
Process development
The role of nanofabrication in production processes
The methodological approach of nanofabrication: interdisciplinary thematic.
Lithographs and Device Types
Diffractive optics,
Microfluidics,
Electronic devices, lab-on-chip, etc.
Lithographs 2D and 3D

Several step processes
Nanoimprinting
**Examination**:
Oral exam, presentation of the work and assessment of the main concepts of nano lithography. A depth study of a topic will presented after a written report preparation.
**More information:**
http://en.didattica.unipd.it/offerta/2016/SC/SC1174/2015/000ZZ/1133875

## OPTICS OF MATERIALS

Master degree in **Materials Science**, First semester
Lecturer: Moreno Meneghetti
Credits: 6 ECTS
**Prerequisites:**
Basic knowledge of electromagnetic wave propagation and of quantum mechanics.
**Short program:**
Optical susceptibility. Models for the description of the linear and non linear optical susceptibility of materials. Propagation of electromagnetic waves in linear and non linear media. Quantum theory of the optical susceptibility. Spectroscopic techniques for the measurements of linear and non linear properties of materials. Second order properties of non linear materials. Non linear index of refraction dependent processes. Multiphoton absorptions. Raman scattering and SERS spectroscopy of nanostructured materials.
**Examination**:
Examination will be an oral test.
**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1174/000ZZ/SCP3050267/N0

## ORGANIC FUNCTIONAL MATERIALS

Master degree in **Materials Science**, First semester
Lecturer: Miriam Mba Blazquez
Credits: 6 ECTS
**Prerequisites:**
Organic Chemistry courses of the 1st cycle Degree.
**Short program:**
1. Carbon nanostructures: fullerenes, carbon nanotubes, graphene
2. Organic molecules for photovoltaics (semiconductiving polymers, carbon nanostructures, bandgap engineering)
3. Organic molecules for non-linear optics
4. Organic molecules for electroluminescent materials (OLEDS)
5. Supramolecular soft materials.

**Examination**:
Written.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1174/000ZZ/SC01122969/N0

## SUPERCONDUCTING MATERIALS

Master degree in **Materials Science** , Second semester
Lecturer: Vincenzo Palmieri
Credits: 6 ECTS
**Prerequisites:**
Solid State Physics

**Short program:**
PRINCIPLES OF SUPERCONDUCTIVITY: Electrical conduction in metals; Phenomenology on superconducting materials; Two-Fluid model; London Electrodynamics; Superconducting Electrodynamics in Fourier Space; Type-II Superconductors; Thermodynamics of Superconducting Transition; Bose condensation; Microscopic Theory of Superconductivity; The Superconducting State; Quasiparticles Excitations; The Hydrodynamic approach to superconductivity.
SUPERCONDUCTING MATERIALS: Superconductivity on transition metals and Matthias' empirical rules; B1 and A15 compounds; High TC and magnesium diboride; Superconductivity Radio Frequency
INDUSTRIAL APPLICATIONS OF SUPERCONDUCTIVITY: Superconducting magnets, bearings and motors; Radiofrequency Cavities; Particles detectors.
**Examination:**
Oral.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1174/000ZZ/SCL1006644/N0

**MATHEMATICS**

## ADVANCED ANALYSIS

Master degree in **Mathematics**, First semester
Lecturer: Giovanni Colombo
Credits: 8 ECTS
**Prerequisites:**
Basic functional and Real Analysis.
**Short program:**
Theory of Distributions.
Convex Analysis.
Ekeland's Variational Principle and some of its applications.
PDE's of geometric type.
**Examination:**
Oral exam.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SCP6076557/N0

## ALGEBRAIC GEOMETRY 1

Master degree in **Mathematics**, Second semester
Lecturer: Orsola Tommasi
Credits: 8 ECTS
**Prerequisites:**
Basic commutative algebra and basic geometry of the first 3 years in math.
**Short program:**
Schemes, sheaves and basic algebraic geometry.
**Examination:**
Written.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC02119737/N0

## ALGEBRAIC GEOMETRY 2

Master degree in **Mathematics**, Second semester
Lecturer: Carla Novelli
Credits: 6 ECTS
**Prerequisites:**
Basics on topology and commutative algebra.
**Short program:**
Introduction to affine and projective varieties.
Morphisms, rational maps and birational maps.
Singularities and resolution of singularities. Blow-ups.
Introduction to sheaves and cohomology.
Rational curves and divisors on varieties.
Ampleness and cones of curves.
Extremal rays and extremal contractions.
Surfaces: Cone Theorem, birational classification and Minimal Model Program.
Higher dimensional varieties: Cone Theorem, Contraction Theorem, Extremal Rays, contractions associated with extremal rays, introduction to Minimal Model Program and Minimal Models.
**Examination:**
Seminar.

**More information:**
[http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC02120637/N0](http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC02120637/N0)

## COMMUTATIVE ALGEBRA

Master degree in **Mathematics**, First semester
Lecturer: Remke Nanne Kloosterman
Credits: 8 ECTS
**Prerequisites:**
Basic notions of algebra (rings, ideals, fields, quotients, etc.), as acquired in the class "Algebra 1" course.
**Short program:**
Commutative rings with unit, ideals, homomorphisms, quotient rings. Fields, integral domains, zero divisors, nilpotent elements. Prime ideals and maximal ideals. Local rings and their characterization. Operations on ideals (sum, intersection, product). Extension and contraction of ideals w.r.t. homomorphisms. Annihilator, radical ideal, nilradical and Jacobson radical of a ring. The Zariski topology on the prime spectrum Spec(R). Spec(R/I) as closed subset of Spec(A). Direct product of rings.
Modules, submodules and their operations (sums, intersection). Annihilator of a module. Faithful modules. Direct sums and direct products of modules. Exact sequences of modules, snake lemma. Projective and injective modules. Finitely generated and finitely presented modules, free modules. Cayley-Hamilton theorem and Nakayama's lemma.
Tensor product and its properties. Extension of scalars for modules. Algebras over a ring and their tensor product. Adjunction and exactness of the Hom and tensor product functors. Flat modules. Kahler differentials
Rings of fractions and localisation. Exactness of localisation. of rings and modules. Localisation and open subsets of Spec(R). Local properties. faithfully flat modules and descent theory. Projective and locally free modules.
Integral elements, integral extension of rings and integral closure. Going Up, Going Down and geometric translation. Norm, trace, discriminant. Valuation rings. Overview of completions.
Chain conditions, Artinian and Noetherian rings and modules. Hilbert's basis theorem. Normalization Lemma and Nullstellensatz.
Discrete valuation rings. Fractional ideals and invertible modules. Cartier and Weil divisors, Picard group, cycle map. Dedekind domains and their extensions. Decomposition of ideals, inertia, ramification.
Krull dimension, height of a prime ideal. Principal ideal theorem. Characterisation of factorial domains. Regular local rings. Finiteness of dimension for local noetherian rings.
**Examination**:
Written exam.
**More information:**
[http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SCP3050935/N0](http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SCP3050935/N0)

## CRYPTOGRAPHY (ALSO OFFERED FOR STUDENTS OF THE MASTER DEGREE IN COMPUTER SCIENCE)

Master degree in **Mathematics**, First semester
Lecturer: Alessandro Languasco
Credits: 6 ECTS
**Prerequisites:**
The topics of the following courses: Algebra, Calculus.
**Short program:**
First Part: Basic theoretical facts: Modular arithmetic. Prime numbers. Little Fermat theorem. Chinese remainder theorem. Finite fields: order of an element and primitive roots.

Pseudoprimality tests. Agrawal-Kayal-Saxena's test. RSA method: first description, attacks. Rabin's method and its connection with the integer factorization. Discrete logarithm methods. How to compute the discrete log in a finite field. Elementary factorization methods. Some remarks on Pomerance's quadratic sieve.
Second Part: Protocols and algorithms. Fundamental crypto algorithms. Symmetric methods (historical ones, DES, AES) . Asymmetric methods. Attacks. Digital signature. Pseudorandom generators (remarks). Key exchange, Key exchange in three steps, secret splitting, secret sharing, secret broadcasting, timestamping. Signatures with RSA and discrete log.
**Examination:**
Written exam.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC04111836/N0

## FUNCTIONS OF SEVERAL COMPLEX VARIABLES

Master degree in **Mathematics**, First semester
Lecturer: Luca Baracco
Credits: 6 ECTS
**Prerequisites:**
Basics on functions of one complex variable, differential calculus, differential geometry.
**Short program:**
1. Real and complex differentials
2. Cauchy formula on polydiscs
3. Subharmonic functions
4. Separate analytic functions
5. Analytic functions and convergent power series
6. Levi form and H. Lewy's extension theorem
7. Logarithmic Superharmonicity, Continuity principle, Propagation of holomorphic extendibility
8. Domains of holomorphy end pseudoconvex domains
9. L2 estimates and Neumann problem

**Examination**:
Oral examination.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SCN1037792/N0

## FUNCTIONS THEORY

Master degree in **Mathematics**, First semester
Lecturer: Massimo Lanza De Cristoforis
Credits: 8 ECTS
**Prerequisites:**
Analysis courses of the first two years, and preferably the following courses
Real Analysis
Mathematical Methods
Functional Analysis 1
**Short program:**
Differential Calculus in Banach spaces, including analytic functions.
Schauder spaces. Potential theory.
Elliptic boundary value problems. Singular perturbation problems.
Topological degree and its applications to the analysis of nonlinear differential and integral equations.
**Examination:**
Partial tests and final oral exam.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SCP3050963/N0

**HARMONIC ANALYSIS**

Master degree in **Mathematics**, Second semester
Lecturer: To be defined
Credits: 6 ECTS
**Short program:**
The lecture course is mainly devoted to the theory of singular integrals. Singular integral theory has its roots in the early 20th century and in complex function theory. In the 1950's, it was extended to real Euclidean spaces of arbitrary finite dimension, and linked to the Laplacian and other elliptic operators. It turned out to be a very useful tool to treat many partial differential equations, and this led to more general versions. The theory still relied heavily on Fourier analysis for the basic L^2 estimate. But in the 1980's, other methods were developed to deal with the L^2 case, the so-called T1 theorem and generalizations of it. This meant vast extensions of the theory and its applications. The course will start with the Hilbert and Riesz transforms, which is the classical theory, related to analytic functions and the Laplacian. These operators are invariant under translation, and given by a convolution kernel. Necessary notions such as weak L^p spaces, the Hardy-Littlewood maximal operator and real interpolation will be introduced. Then the Calderón-Zygmund decomposition will be given, as a fundamental tool to go from L^2 to L^p estimates. Here the singular integrals need not be translation invariant, and their kernels will depend on two variables. The space BMO (bounded mean oscillation) will then be defined, studied and applied to the singular integrals. This will allow us to state the important T1 theorem. Its proof requires the development of some tools, like Cotlar's lemma and Carleson measures. If time allows, we may move to some other model of harmonic analysis, defined in terms of expansion in classical orthogonal polynomials. These models are quite important in both classical and modern physics. There we shall deal with Riesz transforms and other singular integrals.
**Examination**:
Oral examination.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SCL1001879/N0

**HOMOLOGY AND COHOMOLOGY**

Master degree in **Mathematics**, Second semester
Lecturer: Bruno Chiarellotto
Credits: 6 ECTS
**Prerequisites:**
We expect the student knows that it is possible to associate some invariants (fundamental group..) to topological spaces and he knows the existence of some topologies as the Zariski's one.
**Short program:**
Starting from the basic definition of the algebraic topology we will introduce the definition of homology and cohomology for a topological space. Later we will see how such a idea can be "realized" in other cases by specializing the basic space in an algebraic variety and/or a complex analytic space (de Rham).
**Examination:**
taylored on the basis of the students attitudes: oral and homeworks.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC02111817/N0

## INTRODUCTION TO GROUP THEORY

Master degree in **Mathematics**, First semester
Lecturer: Andrea Lucchini
Credits: 8 ECTS

**Prerequisites:**
Basic knowledge 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:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC03111814/N0

## INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS

Master degree in **Mathematics**, First semester
Lecturer: Fabio Ancona
Credits: 8 ECTS

**Prerequisites:**
Differential and integral calculus.
Elementary theory of ordinary differential equations.
Basic theory of complex analysis (functions of complex variables, holomorphic and analytic functions).

**Short program:**
Didactic plan:
- First order PDEs: transport equation with constant coefficients, conservation laws (classical and weak solutions, Rankine-Hugoniot conditions, Riemann problem).
- Wave equation: existence of solutions, D'alembert formnula, method of spherical means, Duhamel's principle, uniqueness, finite speed of propagation.
- Laplace equation: fundamental solution, harmonic functions and main properties, mean value formulas, Harnack's inequality, maximum principle. Poisson equation. Green's function and Poisson's representation formula of solutions.
- Heat equation: fundamental solution, existence of solutions for the Cauchy problem and representation formula. Uniqueness and stability of solutions. Mean value formulas, maximum principle, Hopf's maximum principle.

**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.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SCP3050960/N0

## INTRODUCTION TO RING THEORY

Master degree in **Mathematics**, First semester
Lecturer: Alberto Facchini
Credits: 8 ECTS

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

**Short program:**
Rings. Categories, functors. Modules and their homomorphisms, bimodules, submodules and quotients. Natural transformations. Sets of generators, maximal submodules, free modules and IBN rings, exact sequences, projective modules, tensor product of modules, projective modules over Z. Subcategories. Simple modules, semisimple modules, noetherian modules, artinian modules, modules of finite composition length. Semisimple artinian rings, artinian rings, the Jacobson radical, group representations, local rings, injective modules, projective covers, injective envelopes.
**Examination:**
Oral examination and/or evaluation of the exercises solved by the students during the course.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC03111812/N0

## NUMBERS THEORY1

Master degree in **Mathematics**, First semester
Lecturer: Francesco Baldassarri
Credits: 8 ECTS
**Prerequisites:**
A standard Basic Algebra course; the experience of a short course in Galois Theory would be most useful; Linear Algebra; Notions of Calculus; some familiarity with complex functions of one variable might be useful.
**Short program:**
1. Basic algebra of commutative groups and rings.
2. Factorization of elements and ideals
3. Dedekind domains
4. Algebraic number fields. Cyclotomic and quadratic fields.
5. Rings of integers. Factorization properties.
6. Finite extensions, decomposition, ramification. Hilbert decomposition theory.
7. Frobenius automorphism, Artin map;
8. Quadratic and cyclotomic fields. Quadratic reciprocity law. Gauss sums.
9. An introduction to Class Field Theory (from Kato-Kurokawa-Saito Vol. 2, Chap. 5)
10. Minkowski Theory (finiteness of class number and the unit theorem).
11. Dirichlet series, zeta function, special values and class number formula (from Kato-Kurokawa-Saito, Vol. 1).

The whole material is to be found in the single textbook: Daniel A. Marcus "Number Theory", Springer-Verlag. Our essential program consists of Chapters 1 to 5, with those exercises which are used in the body of the textbook. The complex-analytic proofs in Chapter 5 will not be required.
We recommend, for cultural reasons, reading through the two volumes of Kato-Kurokawa-Saito, possibly without studying proofs.
**Examination:**
We will propose the preparation of 2 or 3 written reports during the course. These are supposed to check the step-by-step understanding of the topics presented and the interest of the students in the subject. A final all-inclusive exam will be proposed for those who have not presented satisfactory reports during the year as well as to those who are not satisfied with the mark obtained.
Students will be offered to present one topic agreed with the teacher in a 45 minutes lecture during the course. A final oral examination is reserved for those who aim at top grades.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SCP4063857/N0

## NUMBER THEORY2

Master degree in **Mathematics**, Second semester
Lecturer: 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 charatcteristic and their fnite extensions, the ramification filtration of the Galois group of a finite, Galois extesnion of a local field. As an application we will study p-adic modular forms.
**Examination**:
Homework exercices will be handed in weekly, there will be a midterm exam and written final.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC01120636/N0

## REPRESENTATION THEORY OF GROUPS

Master degree in **Mathematics**, Second semester
Lecturer: Giovanna Carnovale
Credits: 6 ECTS
**Prerequisites:**
Basic notions of linear algebra and group theory.
**Short Program:**
Representations. Irreducible representations. Maschke's theorem. Orthogonality of characters. Induced representations. Frobenius reciprocity. Rappresentazioni Indotte, formual di Mackey. Reciprocita' di Frobenius. Frobenius-Scur Indicator. Compact groups. Linear algebraic groups and their Lie algebras. Solvable, nilpotent and semisimple Lie algebras. Cartan's criterion. Killing form. Weyl's theorem. Root space decomposition. Root systems. Classification of semisimple Lie algebras. Universal enveloping algebras. Finite dimensional irreducible representations of a semisimple Lie algebra..
**Examination:**
Written, involving a series of exercises.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC01120635/N0

## RINGS AND MODULES

Master degree in **Mathematics**, Second semester
Lecturer: Silvana Bazzoni
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:**
Additive and Abelian categories. Functor categories. Freyd-Mitchell embedding theorem. Pull-back and push-out. Limits and colimits. Adjoint functors. Categories of chain complexes and the homotopy category. Foundamental Theorem in homology. Left and right derived functors. The functors Tor, flatness and purity. The funtors Ext and Yoneda extensions. Flat, projective and injective dimensions of modules and their characterization in terms of derived functors. Applications to the global dimension of rings and Hilbert's syzygies Theorem.

**Examination:**
Written exam with a discussion on the composition.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SCL1001443/N0

## STOCASTIC METHODS FOR FINANCE

Master degree in **Mathematics**, Second semester
Lecturer: Martino Grasselli
Credits: 7 ECTS
**Prerequisites:**
Stochastic analysis.
**Short program:**
The pricing problem in the binomial models
Risk neutral pricing in the discrete time world
European and American options in the binomial model.
Arbitrage and risk neutral pricing in continuous time.
Pricing of contingent claims in continuous time: the Black&Scholes formula.
Black&Sholes via PDE and via Girsanov.
Hedging and completeness in the Black&Scholes framework.
Feynman-Kac formula and risk neutral pricing in continuous time.
Pur Call parity, dividends and static vs dynamic hedging.
The Greeks and the Delta-Gamma hedging. Delta-Gamma-Vega neutral portfolios.
Barrier options pricing in the Black&Scholes model.
Quanto option pricing in the Black&Scholes model.
Multi asset markets, pricing and hedging.
Exchange options pricing in the multi-asset Black&Scholes model.
Incomplete markets: quadratic hedging.
Smile and skew stylized facts.
Beyond the Black&Scholes model: stochastic volatility.
The Heston model.
Bonds and interest rates. Pre-crisis and multiple-curve frameworks.
Short rate models, Vasicek, CIR, Hull-White models, affine models.
Cap&Floor pricing in the short rate approaches. The pricing of swaptions.
Forward rate models: HJM approach, the drift condition and BGM models.
Change of numeraire and Forward Risk Neutral measure.
LIBOR and Swap models.
**Examination**:
Final examination based on: Written and oral examination.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC03111823/N0

## SYMPLECTIC MECHANICS

Master degree in **Mathematics**, First semester
Lecturer: Franco Cardin
Credits: 6 ECTS
**Prerequisites:**
Elementary Calculus and Geometry
**Short program:**
Essential of Differential Geometry and Exterior Differential Calculus.
Cohomology.
Riemannian manifolds: Existence of metrics, Whitney theorem.

Symplectic Geometry: Symplectic manifolds.
Introduction and developments of Hamiltonian Mechanics on symplectic manifolds.
Local and global parameterization of the Lagrangian submanifolds and their generating functions. Theorem of Maslov-H\"ormander.
Hamilton-Jacobi equation, its geometrical solutions and links to the Calculus of Variations. Conjugate points theory in calculus of variations.
Relative cohomology and Lusternik-Schnirelman theory. Introduction to Symplectic Topology: existence and classification of critical points of functions and applications to generating functions of Lagrangian submanifolds.
The min-max solution of Hamilton-Jacobi equation. Symplectic Topology by Viterbo: towards the solution of the Arnol'd conjecture. Morse theory.
**Examination**:
Written.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC02119743/N0

## THEORY OF APPROXIMATION AND APPLICATIONS

Master degree in **Mathematics**, First semester
Lecturer: Stefano De Marchi
Credits: 7 ECTS
**Prerequisites:**
The course requires the basic courses of Numerical Calculus and Numerical Analysis. It is also useful to have attended a course of Functional Analysis. It is assumed that the students know the programming language Matlab.
**Short program:**
The course can be subdvided in 2 theoretical parts of 24h each, in total 48h corresponding to 6CFU. Moreover there will be 16h of lab exercises.
PART I (20h+6h): polynomial approximation
- best approximation approximation
- modulus of continuity and Lebesgue constant
- nearly optimal distribution of points in 1-dimension
- Padua points for interpolation and cubature
- (Weakly) admissible meshes
- applications and lab (6h)

PART II (28h+10h): Radial Basis Functions (RBF)
- learning from splines
- positive and conditionally definite functions
- native spaces, power function and error estimates
- application to the solution of elliptic PDEs
- applications and lab (10h).

**Examination**:
The final exam is a written test on the topics of the course. There will be also an oral part in which the student will discuss the lab exercises given during the course.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SCN1037767/N0

## TOPOLOGY 2

Master degree in **Mathematics**, First semester
Lecturer: 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**:
Oral exam.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1172/010PD/SC03111819/N0

**MOLECULAR BIOLOGY**

**BIOCHEMISTRY**

Master degree in **Molecular Biology**, First semester
Lecturer: Ildiko' Szabo' – Tomas Morosinotto
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) and the mechanisms of protein degradation pathways (via ub ubiquitination)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 (various spectroscopies, EPR, 2D/PAGE), with particular reference to intracellular ion channels. In addition, the most important aspects of tumor metabolism will be discussed.

**Examination**:

Written exam comprising open questions and multiple choice tests.

**More information:**

http://en.didattica.unipd.it/off/2017/LM/SC/SC1175/000ZZ/SCN1028730/N0

**GENOMICS**

Master degree in **Molecular Biology**, Second semester
Lecturer: 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. The course is in English, therefore the students should have a reasonable command of spoken and written English.

**Short program:**

This is a 9 credit course, 7 of which will be lessons, the remaining 2 will be practicals. Each title reported below corresponds to approximately two hours of classroom teaching plus four hours of home study. The lessons will be articulated as follows.

Part 1.
Presentation of course and practicals
Introduction: Life, Biology, Information, Genomes, Evolution
History of genomics
Next Generation sequencing (NGS)
NGS: data formats for reads
Classical sequence alignment and assembly algorithms
NGS read alignment
Alignment formats: gff, sam and bam
Genome assembly with NGS data
Mate pair libraries and scaffolding
Metagenomics
Part 2
Transcriptome: Northern, EST, Full length, Microarrays
RNAseq

Analysis of RNAseq data
Proteomics
miRNA,
miRNA target prediction; lincRNA
Interactomics, and functional associations
Gene prediction, gene ontology and gene annotation
DNA methylation and methylome analysis
Histone modification and ChIP analysis"
Part 3
Analysis of human mutations and polymorphisms
GWAS
Genome re-sequencing and Exome sequencing
Personalized medicine and related bioinformatics
Genome browsers
Data integration and systems biology
General summary, discussion and conclusions.

**Examination**:
The exam will be written, but a continuous process of assessment will be carried out throughout the course, to verify the level of understanding of the students.

**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1175/000ZZ/SCN1028833/N0

## MODELS IN GENETIC DISEASE RESEARCH

Master degree in **Molecular Biology**, First semester
Lecturer: 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:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1175/000ZZ/SCL1000227/N0

## MOLECULAR BIOLOGY OF DEVELOPMENT

Master degree in **Molecular Biology**, Second semester
Lecturer: Francesco Argenton
Credits: 8 ECTS

**Prerequisites:**
Students should have already acquired a basic knowledge of eukaryotic cell biology, control of gene expression, differentiation, histology and developmental biology.

**Short program:**
History and problems of developmental genetics, Molecular cellular mechanisms controlling development, digital imaging quantification of genetic effects, fate mapping, signaling pathways and their function and visualization (FGF, TGFb, BMP, HH, Notch, Hypoxia, Hippo, STATs etc), induction of main axis (DV, AP and LR) in vertebrates and drosophila, examples in organ formation.
**Examination**:
Essays on theoretical arguments treated during the course.
Lab tests of digital imaging applied to developmental biology.
Journal club presentation of a specific publication.
Report of lab activities.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1175/000ZZ/SCN1028823/N0

**MOLECULAR GENETICS**
Master degree in **Molecular Biology**, First semester
Lecturer: Gabriele Sales
Credits: 6 ECTS
**Prerequisites:**
The basic knowledge deriving from the subjects of the first year of the Master Degree.
**Short program:**
Introduction to Systems Biology.
Basics of Derivatives, Integrals and Differential Equations
Mathematical Modeling.
Static Network Models.
Markov Models.
Mutual Information, Relevance Networks and Bayesian Networks.
The Mathematics of Biological Systems.
Parameter Estimation from Noisy Data: Grid Searches, Hill Climbing, Genetic Algorithms.
Signaling Systems.
Population Systems.
SIR Model Simulation.
**Examination**:
Written exam.
**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1175/000ZZ/SCP5071893/N0

**NATURAL SCIENCE**
**ENVIRONMENTAL IMPACT ASSESSMENT**
Master degree in **Natural Science**, First semester
Lecturer: Massimo De Marchi
Credits: 6 ECTS
**Prerequisites:**
Ecology and environmental law.
**Short program:**
-The role and need for evaluation
-Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA): regulations, procedures, case studies, European and International comparisons
-Art. 6 of Habitat directive and assessment of implications on Natura 2000 sites: procedures and case studies
-Social Impact Assessment and interaction with environmental assessment: key case studies

-Ecosystem services approach in environmental assessment
-GIS techniques and Multi Criteria Models for environmental assessments
-Accounting methods for environmental good and services: Contingent Evaluation, Cost/Benefits Analysis
-The management of participation inside environmental assessment procedures.

**Examination**:
Working group evaluation report plus oral examination.

**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1178/000ZZ/SCP4063900/N0

## ENVIRONMENTAL MINERALOGY

Master degree in **Natural Science**, Second semester
Lecturer: Gilberto Artioli
Credits: 8 ECTS

**Prerequisites:**
Basic chemistry and chemical thermodynamics. Essentials of mineralogy and geology.

**Short program:**
Natural solid materials: basic concepts of mineralogy and crystal-chemistry.
Natural processes. Introduction on the distribution of the chemical elements on the Earth's crust, on the geological processes, on the geochemical cycles. Processes and fluid-solid interactions at the mineral surfaces. Experimental techniques to study materials surfaces.
Case studies:
(1) Hazardous minerals in nature and in working places:
asbestos, free silica. Environmental monitoring, assessment, mineral quantification, disposal.
(2) Microporous materials and inclusion compounds: clays, zeolites, clathrates, gas hydrates. Crystal structure, crystal chemistry, absorption properties, ionic exchange properties, catalysis. Their use in environmental, agricultural, and industrial applications.
(3) Mineral dust. Origin, characterization. Implications for the palaeoclimatic and environmental reconstructions of the investigations of mineral dust entrapped in polar ice and ocean sediments.
(4) Metals and the environment. Dispersion and re-mobilization of toxic elements during mineral deposits exploitation and industrial transformation of raw resources. Acid mine drainage. The case of arsenic dispersion: inorganic vs bio-controlled processes.
(5) Binders and cements. Their use in history and in present societies as building materials. Environmental applications in solidification and inertization processes of wastes and polluted soils.
(6) Rare Earth Elements. REE cycle and natural resources. Their role in technological products, recovery from e-waste

**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:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1178/000ZZ/SCP4065427/N0

**SANITARY BIOLOGY**

## BIOCHEMISTRY OF DISEASES

Master degree in **Sanitary Biology**, First semester
Lecturer: Luca Scorrano
Credits: 8 ECTS

**Prerequisites:**
Biochemistry, Physiology and Pathology.

**Short program:**
1. Introduction to the course
2. Mechanisms of protein homeostasis
3. Mechanisms of cellular ion homeostasis
4. Mechanisms of redox homeostasis and cellular bioenergetics
5. Biochemical mechanisms of reversible cellular damage

a. atrophy
b. hypertrophy
c. Metaplasia (EMT)

6. Biochemical mechanisms of irreversible cellular damage

a. apoptosis
b. necrosis
c. necroptosis
d. Autosis

7. Biochemical mechanisms of senescence and aging
8. Biochemical mechanisms of cell transformation and oncogenesis
9. Role of biochemistry in mitochondrial disease

These topics will be covered in specific workshops, Journal Clubs, lectures held by the teacher and by ad-hoc invited international experts.
Tutorials
Laboratory tutorials on biochemical assays of cell death and autophagy and on the analysis of mitochondrial dysfunction.

**Examination**:
Evaluation of the reports handled to the teachers during the course. A final written exam (multiple choice+small essays) might be foreseen under particular circumstances.

**More information:**
http://en.didattica.unipd.it/off/2016/LM/SC/SC1177/000ZZ/SCP5073118/N0

## HUMAN PHYSIOLOGY

Master degree in **Sanitary Biology**, First semester
Lecturer: Luigi Bubacco
Credits: 9 ECTS

**Prerequisites:**
Biochemistry 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 questions to be answered in two hours.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SC1177/000ZZ/SCN1032657/N0

**STATISTICAL SCIENCES**
**COMPUTATIONAL FINANCE**
Master degree in **Statistical Sciences**, First Semester
Lecturer: Massimiliano Caporin
Credits: 9 ECTS
**Prerequisites:**
Elements of Economics and Mathematics of Financial Markets, elements of Statistics and Econometrics.
**Short program:**
Introduction (minor module)
- Introduction to financial instruments and markets;
- Investment choices under uncertainty and the approach of Markowitz;
- Market equilibrium, CAPM and APT, and market efficiency.

Main module:
1. The formalization of computational problems into a statistical package
2. Asset Allocation: from the approach of Markowitz to Risk Budgeting
3. Backtesting and performance evaluation
4. Introduction to Market Risk Management

The program might be subject to changes depending on a number of elements including: the interest of the students and their ability to solve computational problems with the statistical sowftare; the occurrence of particular events in the financial markets. Changes to the program content will affect the list of tasks included in the team work.
**Examination**:
The exam will be given in the form of a group homework. Each group (a team), will receive, at a beginning of the course (groups will be formed within the first two weeks of lectures), a list of tasks pointing at computational finance questions. The tasks list will be interated during the course. Each team will have to coordinate activities, inducing team members to interact. During the exam session, each team will show results in the form of a presentation (PowerPoint-like). Each team member must have full knowledge of the presentation and of the analyses performed by the team and of the main findings.
**More information:**
http://en.didattica.unipd.it/off/2017/LM/SC/SS1736/000ZZ/SCP4063078/N0