SCUOLA DI SCIENZE

UNIVERSITÀ DEGLI STUDI DI PADOVA

SCHOOL OF SCIENCE UNIVERSITY OF PADOVA

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

ACADEMIC YEAR 2018-2019:

First semester: October 1st, 2018 to January 18th, 2019
Winter exams session: January 21st, 2019 to February 23rd, 2019
Second semester: February 25th, 2019 to June 14th, 2019
Summer exams session: June 17th, 2019 to July 27th, 2019
Extra exams session: August 19th, 2019 to September 21st 2019

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/

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<u>SECOND CYCLE DEGREES WITH ALL THE COURSE UNITS HELD IN ENGLISH:</u>

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/2018/LM/SC/SC2377/000ZZ/SCP7079257/N0

BIG DATA COMPUTING

Master degree in **Data Science**, Second semester
Lecturer: Andrea Alberto Pietracaprina
Credits: 6 ECTS
Prerequisites:
The course has the following prerequisites: competences regarding the desing and analysis of algorithms and data structures, knowledge of fundamental notions of probability and statistics, and programming skills in Java or Python.
Short program:
The course will cover the following topics:
Introduction to the Big Data phenomenon
Programming frameworks: MapReduce/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:
The exam consists of a number of programming homeworks, assigned approximately every 2-3 weeks and to be carried out in groups of 3-4 students, and of an individual written test comprising both theory questions and exercises.

More information:
http://en.didattica.unipd.it/off/2018/LM/SC/SC2377/000ZZ/SCP7079297/N0

BIOINFORMATICS (OFFERED IN THE MASTER DEGREE IN COMPUTER SCIENCE)

Master degree in **Data 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. However, a basic knowledge of genetics and molecular biology will help in the understanding of the biological motivations of bioinformatics.
The course is in English, therefore the students should have a reasonable command of spoken and written English.

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

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

More information:
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079405/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/2018/LM/SC/SC2377/000ZZ/SCP7079317/N0

BIOLOGICAL DATA

Master degree in **Data Science**, First semester
Lecturer: Silvio Tosatto
Credits: 6 ECTS

Prerequisites:

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

Short program:

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

Examination:

The exam covers three separate parts, which have to be all passed: (relative weights in parenthesis)
1) Test for the practicals (ca. 20%)
2) Project (ca. 50%)
3) Project presentation and critical evaluation (ca. 30%)

More information:

http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079337/N0

BUSINESS ECONOMIC AND FINANCIAL DATA

Master degree in **Data Science**, First semester
Lecturer: Omar Paccagnella
Credits: 6 ECTS
Prerequisites:
Basic statistics: descriptive statistics and probability. Inferential statistics: estimation, confidence intervals and hypothesis testing.
Short program:
Decomposing and analysing economic time series: latent component approaches and ARMA modelling.
Enhancing the analysis of economic and financial time series data: some case studies.
Business and marketing data analyses: the joint use of cross-sectional and temporal dimension and the introduction of dynamic modelling.
Examination:
Homework and Final Presentation.
More information:
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079231/N0

COGNITIVE SERVICES (OFFERED IN THE MASTER DEGREE IN COMPUTER SCIENCE)

Master degree in **Data Science**, Second semester
Lecturer: Lamberto Ballan
Credits: 6 ECTS
Prerequisites:
The student should have basic knowledge of programming and algorithms. It is also advisable to be familiar with basic concepts in probability and analysis of multivariate functions.
Short program:
The course will cover the topics listed below:
- Introduction:
From human cognition to 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/2018/LM/SC/SC2377/000ZZ/SCP7079279/N0

COGNITIVE, BEHAVIORAL AND SOCIAL DATA

Master degree in **Data Science**, First semester
Lecturer: To be defined

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/2018/LM/SC/SC2377/000ZZ/SCP7079219/N0

COMPUTER AND NETWORK SECURITY (OFFERED IN THE MASTER DEGREE IN COMPUTER SCIENCE)
Master degree in **Data 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/SC2377/000ZZ/SCP6076342/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 computer programming and problem solving skills.
Short program:
The course is structured into 3 submodules:
- Python Programming (for Data Science)
This submodule provides students with the foundational coding skills they need as data scientists. First, the basics of the Python programming language are covered (i.e., built-in data types, fuctions, I/O, etc.) along with the environment which is used throughout the class (i.e., Jupyter Notebook). Afterwards, students will dig into a set of the most up-to-date data science Python packages; those are: numpy/scipy (for numerical/scientific computing), pandas (for data manipulation), matplotlib/seaborn (for data visualization), and finally scikit-learn (for learning from data). Eventually, at the end of this submodule students will be able to implement all the stages of a typical machine learning pipeline: from collecting data to building predictive models for solving either a classification or a regression problem.
- Databases
This submodule is dedicated to data storaging, and it covers the following topics:
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
This submodule allows students to get familiar with computer networking. In particular, it focuses on the following topics:
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).
Examination:
The student is expected to pass a written and an oral exam.
More information:
http://en.didattica.unipd.it/off/2018/LM/SC/SC2377/000ZZ/SCP7078720/N0

GAME THEORY (OFFERED IN THE MASTER DEGREE IN COMPUTER ENGINEERING)
Master degree in **Data Science**, First semester
Lecturer: Leonardo Badia
Credits: 6 ECTS
Prerequisites:
A course, even a basic one, on probability theory.
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
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
Resource allocation
Utilities, choices, and paradoxes
Potential games, coordination
Bio-inspired algorithms
Evolutionary games
Cognitive networks
Selfish routing
Game-theory enabled multiple-input systems
Examination:
For the students of engineering programs with regular attendance to the course (differently from other kinds of students), the exam involves the development of a project in 1-3 person groups, on course-related topics applied to ICT. This is agreed half-way through the course together with the lecturer.
For all the students, in any event the exam also includes a mandatory open-book written test, containing four problems of game theory focusing on different topics of the course. Every

exercise involves three questions.
For engineering students with regular attendance to the course, the written test is limited to solving three exercises out of four. For the other students (non-engineering students or students without regular attendance), the written test involves all of the four exercises.
If the written test is sufficient, non-engineering students or students without regular attendance can directly finalize the passing score. Engineering students with regular attendance instead discuss their project with an oral exam after the written test. Oral exams are scheduled in the same day of written tests (even though students can decide to give the two parts on separate days). Both the written test and the oral exam must be sufficient to pass.
More information:
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079401/N0

HUMAN COMPUTER INTERACTION (OFFERED IN THE MASTER DEGREE IN APPLIED COGNITIVE PSYCHOLOGY)

Master degree in **Data Science**, First semester
Lecturer: Luciano Gamberini
Credits: 6 ECTS
Prerequisites:
There are no specific prerequisites.
Short program:
- Human limits and their implication for the design of technologies
- Interaction models and users style
- Paradigms and strategies for building interactive systems
- Designing for usability: methods and technique in interaction design
- UX Evaluation: part I "the lab"
- UX Evaluation: part II "the real world"
- UX Evaluation: part III "advanced techniques" (Eye tracking, physiological measurements, etc.)
- Accessibility and Universal design
- Social computing
- Special Topics and case studies (web sites usability, experiencing mobile apps, designing living environment and smart cities, virtual and augmented reality in HCI, human-robot interaction, Persuasive technology for behavioural change, ergonomics in e-health)
- Symbiotic interaction and other new topics in ergonomics and HCI.

Examination:
The examination will be in written modality, composed by two open questions and five closed questions. The first open question evaluates the student's ability of using the methods and techniques acquired during the course to solve specific design or evaluation cases regarding an interactive system or its interface. The second open question evaluates the ability to synthesize and comment on theories and methods learned in class or from the textbook.
The closed questions are multiple choice questions; they will assess the acquisition of theoretical and methodological knowledge.
More information:
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079403/N0

HUMAN DATA ANALYTICS

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

Prior knowledge on Calculus and Linear Algebra (vector spaces, singular value decomposition, etc.), Probability Theory (random variables, conditional probability and Bayes formulas, probability distributions), and some basic computer programming (e.g, Matlab and some exposure to Python) is useful. Although not strictly required, basic knowledge of signal processing techniques (e.g., discrete Fourier transforms) is also helpful.
Note that the instructor will review basic concepts from the above fields whenever necessary, providing material and/or pointer to refresh the related theories. So, although such previous knowledge is very helpful to the student, the course is intended to be self-contained.
Short program:
Part I – Introduction (2 hours)
- Intro: course outline, graduation rules, office hours, etc.
- Applications: health, activity-aware services, security and emergency management, authentication systems, analyzing human dynamics
Part II – Vector Quantization (12 hours)
- Vector quantization (VQ):
--- Aims, quality metrics
--- K-means, soft K-means, Expectation Maximization
- Unsupervised VQ algorithms:
--- Self-Organizing Maps (SOM), Gas Neural Networks (GNG)
- Application to quasi-periodic biometric signals (ECG):
-- Signal pre-processing, normalization, segmentation
--- Dictionary learning: concepts, architectures
--- Efficient representation of ECG signals: description of state-of-the-art algorithms
--- Unsupervised dictionary designs for ECG via GNG-based dictionaries
--- Final system design and numerical results
Part II – Sequential data analysis (10 hours)
- Hidden Markov Models (HMM):
--- Maximum Likelihood for the HMM
--- Forward-backward algorithm
--- Sum-product algorithm, Viterbi algorithm
- Applications
--- Authentication: user identification from keyboard keystroke dynamics
--- Speech recognition: audio feature extraction, automatic speech recognition through HMM
Part III - Deep Neural Networks (10 hours)
- Gradient descent and general concepts (supervised learning, overfitting, cost models, etc.)
- Feed Forward Neural Networks: models, training, back-propagation
- Convolutional Neural Networks (CNN): structure, description of constituting blocks, training
- Applications: 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
- User authentication from motion signals: combination of CNN-SVM and sequential estimation theory
- Object / face recognition through CNN
Part IV: Laboratory classes (12 hours)
In the laboratory classes the students will go through a guided tour through the construction of Python code for neural networks, writing all the building blocks related to: the creation of the neural network structure, its training using several gradient descent-based algorithms. The students will be exposed to Python programming, including the use of the Keras and TensorFlow frameworks for the implementation and training of neural network structures. The software composing the different blocks of the presented neural network architectures

will be pre-written and checked for correctness, so that the students, after attempting to implement their own version of it, will succeed to combine the various blocks and complete the assigned task. Upon connecting the blocks into the selected neural network architecture, the obtained neural network models will be trained using several gradient descent algorithms, and tested against selected and real datasets. The topics that will be covered are:
- Introduction to Python programming
- Solving a baseline inference problem
- Feed forward neural networks
- Convolutional neural networks

Examination:
This is a course on advance and applied machine learning techniques, that are applied to real world problem within the human data domain. Given this, the examination of the student will be carried out through a project which will involve the following phases of work:
1. The instructor will identify a problem to solve, using an open, rich, and freely accessible data set. The problem to tackle will be thus described by the instructor during a specific lesson where he will as well present how to carry out the final exam, which will consist of: 1) delivering a written report and 2) giving a conference-style talk
2. The students will split into groups, with a maximum of two students per group, and will start to work to the assigned project. The choice of the specific technique to use, the data pre-processing algorithm to obtain informative features, etc., will all be identified in full autonomy by the students, as a first step. The instructor will be available to steer the work and follow the students along all the work phases
3. Each group will solve the assigned problem using the selected technique and will: 1) present a final written report, 2) give a conference-style talk describing: the problem, the selected models / techniques, the software written as part of the project development, the obtained results. It is also recommended that the students will showcase their software during the presentation

A final grade will be provided by the instructor upon a close inspection of the written report at point 1) and the assessment of the talk at point 2).

More information:
http://en.didattica.unipd.it/off/2018/LM/SC/SC2377/000ZZ/SCP7079397/N0

INTRODUCTION TO OMIC DISCIPLINES

Master degree in **Data Science**, First semester
Lecturer: Maria Pennuto
Credits: 6 ECTS

Prerequisites:
Basic knowledge of theory of evolution, genetics and molecular biology.

Short program:
In this course the students will start from the theory of evolution to the concept of mutations, genes, genetics, and molecular biology to ultimately integrate the information and critically appreciate the molecular nature of the omics data. Specific topics are listed below:
1) Theory of evolution
2) Mendel's laws: The beginning of genetics
3) Mutations vs polymorphisms
4) The cell: Prokaryotic vs eukaryotic cells
5) Subcellular organelles: Nucleus, cytosol, mitochondria, reticulum endoplasmaticum/Golgi complex, lysosomes
6) Dogma: DNA, RNA, protein, from gene to protein
7) OMICS data from DNA (genomics): Heterochromatin, euchromatin, Coding vs non-coding DNA, replication
8) OMICS data from RNA (transcriptomics): Transcription, splicing, microRNA, lncRNA

9) OMICS data from proteins (Proteomics): The genetic code
10) Techniques of Molecular biology to process DNA: Sanger method, new generation sequencing tchnologies (NGS), PCR, cloning for gene expression analysis
11) Biochemistry techniques: Analysis of proteome via mass spectrometry, immunoprecipitation, protein-protein interaction, analysis of protein stability, analysis of metabolites
12) Effects of species, tissues, age, and sex on OMICS data
13) Effect of environment: Nature or nurture
14) Interpreting the theory of evolution through OMICS data.

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

More information:
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079400/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/2018/LM/SC/SC2377/000ZZ/SCP7079318/N0

LAW AND DATA

Master degree in **Data Science**, First semester
Lecturer: To be defined
Credits: 6 ECTS

Prerequisites:
No prerequisites

Short program:
- the concept of data; personal, sentitive and economic data; big data
- the concepts of identity and digital identity
- property of data, choices in the management of data
- supranational, international and national laws on data processing
- civil and criminal protection of privacy
- new contents and concepts of privacy: big data, cell phones; videos; wearable technologies,

etc.
- the right to be forgotten
- social network, right to be forgotten, responsability
- provider's criminal responsability
- civil and criminal aspects of profiling activity
- automatic data processing, human responsabilities
- big data (collection, analysis, processing) and their influence on fundamental rights
- the issue of genetic data
- big data and economy
- phishing
- financial crimes and artificial intelligence

Examination:
Oral Exam
More information:
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079399/N0

MATHEMATICAL MODELS AND NUMERICAL METHODS FOR BIG DATA
Master degree in **Data Science**, First semester
Lecturer: To be defined
Credits: 6 ECTS
Prerequisites:
Background on Matrix Theory: Type of matrices: Diagonal, Symmetric, Normal, Positive De nite; Matrix canonical forms: Diagonal, Schur; Matrix spectrum: Kernel, Range, Eigenvalues, Eigenvectors and Eigenspaces Matrix Factorizations: LU, Cholesky, QR, SVD
Short program:
Numerical methods for large linear systems
◦ Jacobi and Gauss-Seidel methods ◦ Subspace projection (Krylov) methods ◦ Arnoldi method for linear systems (FOM) ◦ (Optional) Sketches of GMRES ◦ Preconditioning: Sparse and incomplete matrix factorizations
Numerical methods for large eigenvalue problems
◦ The power method ◦ Subspace Iterations ◦ Krylov-type methods: Arnoldi (and sketches of Lanczos + Non-Hermitian Lanczos) ◦ (Optional) Sketches of their block implementation ◦ Singular values VS Eigenvalues ◦ Best rank-k approximation
Large scale numerical optimization
◦ Steepest descent and Newton's methods ◦ Quasi Newton methods: BFGS ◦ Stochastic steepest descent ◦ Sketches of inexact Newton methods ◦ Sketches Limited memory quasi Newton method
Network centrality
◦ Perron-Frobenius theorem ◦ Centrality based on eigenvectors (HITS and Pagerank) ◦ Centrality based on matrix functions
Data and network clustering
◦ K-Means algorithm ◦ Principal component analysis and dimensionality reduction ◦ Laplacian matrices, Cheeger constant, nodal domains ◦ Spectral embedding ◦ (Optional) Lovasz extension, exact relaxations, nonlinear power method (sketches)
Supervised learning
◦ Linear regression ◦ Logistic regression ◦ Multiclass classi cation ◦ (Optional) Neural networks (sketches)
Examination:
Written exam
More information:
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079406/N0

METHODS AND MODELS FOR COMBINATORIAL OPTIMIZATION (OFFERED IN THE MASTER DEGREE IN COMPUTER SCIENCE)

Master degree in **Data Science**, First semester
Lecturer: Luigi De Giovanni
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/2017/LM/SC/SC2377/000ZZ/SCP7079402/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;
- Probability theory.

Short program:
1. Linear optimization: Theory and algorithms
(a) LP models for Data science;
(b) Duality;
(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;
(d) Block coordinate gradient methods;
(e) Stochastic optimization methods;
4. Constrained convex optimization
(a) Models in data science;

(b) Characterizations of optimal sets;
(c) Polyhedral approximation methods;
(d) Gradient projection methods;
5. Large scale network optimization
(a) Network models in data science;
(b) Methods for distributed optimization.

Examination:

- Written exam
- Homeworks
- Project (Optional)

1) Homeworks will periodically be assigned based on reading and lecture and will be due at given deadlines.
2) Written exam consists of 5 open questions.
3) Project (optional) can be requested to better analyze specific topics.

Written exams represents 85% of grade.
Homeworks represent 15% of grade.
Project gives an increase (1 up to 3 points) of the grade.

More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2377/000ZZ/SCP7079229/N0

PROCESS MINING (ALSO OFFERED FOR STUDENTS OF THE MASTER DEGREE IN COMPUTER SCIENCE)

Master degree in **Data Science**, First semester
Lecturer: To be defined
Credits: 6 ECTS

Prerequisites:
Basic notions of algorithms, data structures and programming.

Short program:
The course will cover the topics listed below:
1. MODELING AND ANALISYS: THE BPMN PERSPECTIVE
- Process Identification
- Essential and Advanced Process Modeling in BPMN
- Qualitative Analysis
- Quantitative Analysis
- Process redesign

2. MODELING AND ANALISYS: THE PETRI NET PERSPECTIVE
- An introduction to Petri Nets
- Petri nets and colored petri nets
- Simulation based analysis
- Reachability and coverability analysis
- Process modeling and analysis with PN

3. PROCESS MINING
- Data & Process mining
- Getting the data: the construction of event logs
- An introduction to Process discovery
- Advanced process discovery
- Conformance checking - replay based
- Conformance checking - logic based
- Mining additional perspectives
- Typical use cases, e.g., medical processes

4. DECLARATIVE APPROACHES
- Declarative approaches and Declare

- Declarative process mining (discovery in Declare) and hybrid approaches
5. PREDICTIVE PROCESS MONITORING
- Basic Predictive Process Monitoring techniques
- Advanced Predictive Process Monitoring techniques

Examination:
Written exam and project. The project is due and has to be discussed by the end of the course.

More information:
http://en.didattica.unipd.it/off/2017/LM/SC/SC2377/000ZZ/SCP7079235/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/2018/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/2018/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. Python programming language.

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

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

More information:
http://en.didattica.unipd.it/off/2018/LM/SC/SC2377/000ZZ/SCP7079278/N0

MOLECULAR BIOLOGY

APPLIED STATISTICS
Master degree in **Molecular Biology**, First semester
Lecturer: Guido Masarotto
Credits: 6 ECTS

Prerequisites:

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

Short program:

- General ideas. From the research problem to the probabilistic models. Sampling. Observational and experimental studies. Statistical tests: hypotheses, p-value interpretation, error types, power. The problem of multiple comparisons/tests. Confidence intervals.
- Elementary methods. Inference on a proportion and comparisons of two proportions. Student's t: one sample, two samples, paired data. Large sample inference. Nonparametrics methods: Wilcoxon (one and two samples) and Kruskal-Wallis tests. Correlation coefficient.
- Advanced methods. One-way and two-way analysis of variance. Regression analysis: linear and logistic model. Exploring multivariate data: principal components and cluster analysis.

Examination:

Written examination. Students should answer to questions concerning the statistical analysis of a real data set.

More information:

http://en.didattica.unipd.it/off/2018/LM/SC/SC2445/000ZZ/SCP8085059/N0

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.

More information:

http://en.didattica.unipd.it/off/2018/LM/SC/SC2445/005PD/SCP8085067/N0

CELL BIOLOGY

Master degree in **Molecular Biology**, First semester

Lecturer: Chiara Rampazzo – Francesco Argenton

Credits: 8 ECTS

Prerequisites:

Basic level of Cell Biology, Molecular Biology and Genetics

Short program:

The 9 CFU course is organized in about 7 CFU of frontal lectures and 2 CFU dedicated to the presentation and discussion of recent articles on the topics covered in class. The discussion of the articles is an integral part of the program.
Lectures will cover 5 main topics:
1) In vitro cultures, methods for cellular molecular biology. Physical principles behind the most common microscopy techniques.

2) Chromatin Biology and nuclear organization to address fundamental questions in Epigenetics and Gene Regulation as well as in cellular differentiation and nuclear reprograming. Mechanisms of epigenetic regulation, including DNA methylation and post-translational modification of histones, and the roles of chromatin-assembly modifying complexes, non-coding RNAs and nuclear organization. X chromosome inactivation. Cell Memory and Genomic Imprinting. Centromeres and telomeres chromatin.
3) Main principles of autophagy and related diseases
4) Stem cell origins, plasticity and epigenetics. Bivalent Chromatin. Stem cell niche. Adult, Embryonic, and induced pluripotent Stem cells.
5) Signal transduction and cancer. Immortalization, role of telomeres. Malignant transformation, disturbances in signal transduction pathways resulting in malignant transformation, role of failure in signaling pathways regulating cellular proliferation, apoptosis and DNA-repair pathways. Cancer stem cells.

Examination:
The knowledge acquired by the student will be evaluated with a written exam organized in two parts.
First part (1 CFU) described in the course contents at section 1 will be assesed with one open question that include a long answer.
the second part (7 CFU) described in the course content at section 2 to 5 will be assessed with six questions that include short or longer answer.
The final grade is expressed as a weighted average between the two parties.

More information:
http://en.didattica.unipd.it/off/2018/LM/SC/SC2445/000ZZ/SCP8085218/N0

GENOMICS

Master degree in **Molecular Biology**, Second semester
Lecturer: Giorgio Valle – Chiara Romualdi
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 articulated into three parts: 1) a written session in which the student must describe the results of the laboratory practicals, that must be submitted at least one week before the official date of the exam, 2) a quiz session on Moodle, that will take place at the beginning of the day of the exam, 3) an oral discussion in which the student must describe his/her laboratory activity and answer questions on the topics of the course. A continuous process of assessment will be carried out throughout the course, to verify the level of understanding of the students.

More information:
http://en.didattica.unipd.it/off/2018/LM/SC/SC2445/000ZZ/SCP8085063/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/2017/LM/SC/SC1175/000ZZ/SCL1000227/N0

MOLECULAR BIOLOGY OF DEVELOPMENT

Master degree in **Molecular Biology**, Second semester

Lecturer: Francesco Argenton – Massimo Santoro
Credits: 8 ECTS
Prerequisites:
The students should have already acquired the fundamentals on eukariotic cellular biology, on control of gene expression, differentiation, histology and developmenta biology.
Short program:
1) Presentation of the course, history and principles of developmental genetics (1.5 CFU): cell fate analysis, organizers and transplants, mutagenesis, cellular asymmetry, chemoaffinity hypothesis, sex determination, lateral inhibition, somitogenesis.
2) Cellular Developmental Mechanisms (0.5 CFU): Survival, Apoptosis, Shape, Movement, Differentiation, Gene Expression
3) Morphogenetic theory (0.5 CFU): Diffusion reaction, French flag theory.
4) Genetic pathways controlling development, their function and visualization (1.5 CFU): Wnt, TGFb, BMP, HH, Notch, Hypoxia, Hippo, STAT
5) germ layers induction and regionalization of the main axes (DV, AP, LR) in vertebrates and Drosophila, Examples of organ formation. (1 CFU)
Angiogenesis in model animals (1 CFU): Use of genetic animal models to study angiogenesis. Molecular biology of endothelial cells. Developmental and pathological angiogenesis. Fluorescent and digital microscopy (1 CFU): Use of genetically encoded fluorophores in molecular genetic development. Different fluorescent techniques and microscopes. Advance microscopic techniques for in vivo studies.
Laboratory (1 CFU): manipulation of the zebrafish embryo: whole mount staining and imaging of fluorescent embryo; Pharmacological treatment of zebrafish embryos with non-specific teratogens (alcohol) and specific agonists or antagonists.
Examination:
Three essay on open questions on theoretical, practical and critical topics of the class.
For the laboratory experience, students must prepare a written report of their practicals on whole mount analysis of development.
Students are also asked during the progress of the class to present a developmental genetic topic.
More information:
http://en.didattica.unipd.it/off/2018/LM/SC/SC2445/000ZZ/SCP8085061/N0

MOLECULAR AND CELL BIOLOGY OF PLANTS

Master degree in **Molecular Biology**, First semester
Lecturer: Barbara Baldan – Lorella Navazio
Credits: 9 ECTS
Prerequisites:
Students should have already acquired a basic knowledge of Cell Biology, Plant Biology, Biochemistry and Molecular Biology.
Short program:
Ca2+-mediated signal transduction in response to biotic and abiotic stresses in plants: Ca2+, an intracellular second messenger; methods of measuring intracellular Ca2+ concentration; calcium transients and calcium signatures (4h).
Plant hormones (auxins, gibberellins, cytokinins, ethylene, abscissic acid): biosynthesis, actions, transport and developmental effects; signal transduction pathways (16h).
Growth and development: Shoot and root apical meristems: their establishment and maintenance. Determination of the developmental axes and the involved genes. Molecular aspects of lateral organ formation (6h).
Blue light and red light responses: light perception, signal transduction and plant responses to light environmental conditions (6h).

Plant reproductive development: floral meristem development, floral organ identity genes, ABCDE model to explain the flower development; the control of flowering (8h).
Molecular aspects in micro and macro-gametogenesis; self-incompatibility during the pollen-pistil interactions; genes involved in control of double fertilization; embryo, seed and fruit development (14h).
Plant–microorganism interactions: cellular and molecular surveys about mycorrhiza, Rhizobium-Leguminosae symbiosis and plant-Agrobacterium interaction (10h).
16h (1 CFU) of practical work are planned on the following topics:
1) Somatic embryogenesis in the model system Daucus carota, tobacco micropropagation
2) Isolation of protoplasts from plant cell suspension cultures; fluorescence imaging of intracellular compartments
3) Protein extraction and quantification from Arabidopsis thaliana cell cultures stably expressing the calcium-sensitive photoprotein aequorin
4) Analysis of protein expression by SDS-PAGE and immunoblotting
Examination:
To verify the acquired knowledge, the exam will be in written form, with open questions on theoretical topics dealt with during the course, as well as questions concerning the practical activity carried out in the laboratory. The active partecipation to the discussions proposed during teaching classrooms will also be considered.
More information:
http://en.didattica.unipd.it/off/2018/LM/SC/SC2445/000ZZ/SCP8085062/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:
The evaluation of the acquired knowledge will be based on a written exam based on 4 open questions. This will gauge the establishment of the proper knowledge, the scientific lexicon, the ability to discuss critically and to summarize the topics discussed in the lectures.
More information:
http://en.didattica.unipd.it/off/2017/LM/SC/SC1175/000ZZ/SCP5071893/N0

NEUROBIOLOGY
Master degree in **Molecular Biology**, Second semester
Lecturer: Daniela Pietrobon – Rodolfo Costa
Credits: 10 ECTS
Prerequisites:

Physiology, Genetics, Cellular Biology, Molecular biology
Short program:
Module A (Prof Pietrobon): 7 CFU (56 hours)of lectures
1. Introduction. 2. anatomical and functional organization of the human nervous system. 3. Electrophysiological and optical techniques for measurement of neuronal electrical activity. Optogenetic techniques for selective stimulation of specific neurons. Examples of applications. 4. Specific firing patterns in different neurons, physiological role and experimental methods to investigate their molecular mechanisms. 5. Techniques for measurement of synaptic transmission.Biophysical and molecular mechanisms of neurotransmitter release; experimental methods for their study. 6. Mechanisms of short-term synaptic plasticity (facilitation, post-tetanic potentiation, depression)and of long-term synaptic plasticity (LTP, LTD, STPD). Learning and memory. 7. General functional organization of sensory systems; in depth discussion of one sensory system.
Module B (Prof Costa): 2 CFU (16 hours) of lectures + 1 CFU (16 hours) of laboratory.
The physiological basis of biological rhythms and the ramifications for the sleep-wake cycle. the normal modulation of circadian cycles and the effects when these are disrupted. The circadian rhythm and its relationship to the sleep/wake cycle examined along with the concepts of photic and nonphotic zeitgebers. Drosophila melanogaster as a Model System for molecular chronobiology. The genetic basis of circadian rhythm generation. The fly's circadian clock. The mammalian circadian clock. The neurophysiology of the pacemaker in the suprachiasmatic nuclei. The genetic basis of circadian rhythm generation. The internal sleep structure is governed by circadian rhythms and these rhythms also impact upon levels of alertness and cognitive performance. General day-time performance and quality of life if these rhythms are disrupted such as with sleep fragmentation or jet lag. The effects of sleep deprivation and shift work. Changes in sleep wake patterns with ageing. Clock related sleep syndroms. Laboratory training: practical exercises are organised to define the chronotype of participants and to explore the hypothesis of a relationship between genetic variability in clock genes and sleep/wake preferences.
Examination:
Module A (Prof Pietrobon)
Written examination with three open questions, which aim to verify, besides the acquired knowledge on relevant topics, the ability of critical discussion and reasoning.
Module B (Prof Costa)
The examination is conducted in written form (open questions). The individual report on the practical experience maturated during the laboratory training is also evaluated.
The final mark is obtained as the weighted mean of the marks of the two modules.
More information:
http://en.didattica.unipd.it/off/2018/LM/SC/SC2445/000ZZ/SCP8085065/N0

STRUCTURAL BIOCHEMISTRY AND BIOPHYSICS

Master degree in **Molecular Biology**, First semester
Lecturer: Laura Cendron – Luigi Bubacco
Credits: 8 ECTS
Prerequisites:
General Biochemistry concepts. Basic Mathematics and Physics courses.
Short program:
The course will be divided in two parts. The first will be devoted to the introduction of basic principles of Biophysical techniques focused on structural and functional characterization of biological macromolecules, supramolecular assemblies and cells. In the second part, three recently described paradigms in the analysis of sensorial system study will be introduced. Such examples will be proposed mainly focusing on the Byophisical Methods that allowed disclosing important links between structure and function of macromolecules.

First part
- X-ray crystallography
1. Crystals, mathematical lattice, symmetry in crystals, space groups.
2. Crystallization techniques in biochemistry.
3. Production of X-rays;
4. Mathematics (equations useful in the interpretation of diffraction);
5. Diffraction of X-rays (waves, interference);
6. Single crystal X-rays diffraction; Bragg's law; X-rays diffraction pattern; structure factors; the concept of Resolution
7. X-ray data collection, indexing and processing
8. From diffraction data to the protein model
9. Advanced topics: The phase problem and solution methods, MIR, MAD, MR
10. Structure refinement; The R index; Treatment and analysis of structural data;
- Neutron and Electron diffraction (basic concepts and applications);
- Mid to high resolution microscopy techniques;
- EXAFS/EPR/NMR (basic concepts);
- Examples of structural data usage in the investigation of relevant questions in biochemistry as well as for purposes related to applied research.

Second part:
1. Visual perception and molecular basis of photoperception;
2. Molecules involved in mechano-perception and role of the tactile perception;
3. molecular basis of chemoperception in the gustatory and olfactory systems.

Examination:
Written examination. Both general and specific questions for each of the two parts of the course will be proposed.
More information:
http://en.didattica.unipd.it/off/2017/LM/SC/SC1175/000ZZ/SCO2045313/N0

PHYSICS
ADVANCED PHYSICS LABORATORY A
Master degree in **Physics**, Second semester
Lecturer: Giampaolo Mistura – Gianmaria Collazuol
Credits: 6 ECTS
Prerequisites:
Laboratory courses of previous years and basic skills in optics and electronics
Short program:
General experimental techniques for the physics laboratory, in particular: electronics, optics, cryogenics and vacuum.
Examination:
Written report and oral exam.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/001PD/SCP7081700/N0

ADVANCED PHYSICS LABORATORY B
Master degree in **Physics**, First semester
Lecturer: Marco Bazzan - Gianmaria Collazuol - Giampaolo Mistura – Giovanna Montagnoli – Gabriele Simi
Credits: 6 ECTS
Prerequisites:
Laboratory courses of preceding years and basic skills in optics and electronics
Short program:

General experimental techniques for the physics laboratory, in particular: electronics, optics, cryogenics and vacuum techniques.
Examination:
Written report and oral examination.
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081758/N0

ADVANCED QUANTUM FIELD THEORY

Master degree in **Physics**, First semester
Lecturer: Kurt Lechner
Credits: 6 ECTS
Prerequisites:
Students should know the canonical quantization approach of a field theory, in particular of Quantum Electrodynamics, and should be acquainted with the path-integral formalism and the technique of Feynman diagrams.
Short program:
1) INTRODUCTION TO QUANTUM FIELD THEORY. Perturbative and axiomatic aspects.
2) CONSISTENT QUANTUM INTERACTIONS. Coleman-Mandula theorem. Characteristics of interactions versus particle spin. Axion-scalar field duality.
3) CLASSICAL FIELD THEORIES. Action and equations of motion. Universality of couplings. Chiral and Yukawa couplings. Global symmetries and Noether theorem. Theories with local abelian and non-abelian symmetries. Yang-Mills (YM) connection and field strength. Covariant derivative. Conserved currents and covariant currents. Self-interaction of YM fields. Color charge.
4) FUNCTIONAL INTEGRAL METHODS. Brief review of basic concepts. Generating functionals. Analyticity and euclidean space. Background field method. Linear classical symmetries and their quantum implementation. Applications to QED. Determinants of commuting and anticommuting fields. Coleman-Weinberg effective potential and radiative symmetry breaking. Feynman rules for a generic local field theory. Scalar QED.
5) PERTURBATIVE METHOD AND RENORMALIZABILITY. Brief review of dimensional regularization and Feynman-parameters technique. Higher loop corrections. Locality of ultraviolet divergences. Perturbative renormalizability in diverse dimensions.
6) LAMBDA PHI^3 IN D = 6. Explicit one-loop renormalization. Exact one-loop propagator. Counterterms. Beta function and anomalous dimension. Asymptotic freedom and dimensional transmutation. Two-loop renormalization. Nested and overlapping divergences. Cancellation of non-local divergences.
7) QUANTIZATION OF YM THEORIES. Problems related with the quantization of non abelian gauge fields. Faddeev-Popov method and ghost fields. Independence of the gauge fixing. BRST invariance and physical Hilbert space. Slavnov-Taylor identities.
8) PERTURBATIVE ANALYSIS OF YM THEORIES. Feynman rules. Renormalizability. One loop counterterms and their interrelation. The role of ghosts. Beta function and asymptotic freedom. Lambda QCD. Finiteness of N = 4 Super-YM theories.
9) ANOMALIES. Classical and quantum chiral symmetries. Explicit evaluation of the chiral Schwinger action in two dimensions. ABJ anomalies, triangular graphs and extensions to higher dimensions. Anomalous vertex method. Adler-Bardeen theorem. Anomaly cancellation in the Standard Model. Index theorem.
10) INSTANTONS. Semi-classical solutions in field theory. Instantonic configurations. Theta vacua. The U(1) problem. Wilson-loops.
11) DEEP INELASTIC SCATTERING.
12) AXIOMATIC THEORY. Wightman functions and Schwinger functions. Reconstruction theorem. Triviality of lambda phi^4 theory. Infrared divergences and the problem of charged fields in QED. Goldstone theorem.

Examination:
Written report and oral examination.
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081759/N0

ADVANCED TOPICS IN THE THEORY OF THE FUNDAMENTAL INTERACTIONS

Master degree in **Physics**, First semester
Lecturer: To be defined
Credits: 6 ECTS
Prerequisites:
Short program:
Examination:
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081741/N0

APPLICATIONS FOR THERAPY

Master degree in **Physics**, First semester
Lecturer: To be defined
Credits: 12 ECTS
Prerequisites:
Short program:
Examination:
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/004PD/SCP7081919/N0

APPLIED ELECTRONICS

Master degree in **Physics**, Second semester
Lecturer: Piero Giubilato
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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/001PD/SCP7081701/N0

ASTROPARTICLE PHYSICS

Master degree in **Physics**, Second semester
Lecturer: Francesco D'Eramo
Credits: 6 ECTS
Prerequisites:
It is suggested to take the following courses in the first semester: Theoretical Physics, Theoretical Physics of Fundamental Interactions and General Relativity.
Short program:
1) Symmetries and Conserved Quantities in the Standard Model of Particle Physics
2) Cosmic Particles
3) Thermodynamics of the Expanding Universe
4) Relics from the Big Bang
5) Big Bang Nucleosynthesis
6) Baryogenesis
7) Dark Matter and Dark Energy
8) Dark Matter Particle Candidates and Experimental Searches
9) Particle Physics in Stars
10) Inflation

Examination:
Oral exam
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/001PD/SCP7081703/N0

BIOLOGICAL PHYSICS

Master degree in **Physics**, Second semester
Lecturer: Mario Bortolozzi
Credits: 6 ECTS
Prerequisites:
The course will be held in English.
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 a multiple choice written test and the numerical simulation of an elementary biological model performed in Matlab.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/002PD/SCP7081737/N0

BIOPHOTONICS

Master degree in **Physics**, First semester
Lecturer: Fabio Mammano
Credits: 12 ECTS
Prerequisites:
Biological Physics
Short program:
Foundations of optics. Matrix formalism for geometric optics. Optical instruments. Aberrations. Fourier analysis in two dimensions. Invariant linear systems. Transfer functions. Sampling theorem.
Scalar theory of diffraction. Diffraction integrals, Fourier transforms and Huygens-Fresnel principle. Angular spectrum of plane waves. Propagation of fields and spectra. Propagation of light as a linear spatial filter.
Approximation of Fresnel and Fraunhofer. Diffraction of Fraunhofer from rectangular and circular openings. Diffraction lattices.
The thin lens as a phase transformation. Image formation as a convolution. Coherent and inconsistent lighting. Analysis of optical systems in the frequency space. Function of transfer of an optical system limited by the effects of diffraction alone. Effect of aberrations on the frequency response. Coma and condition of the breasts of Abbe.

Transmitted light microscopy: Conjugated planes and optical trains; Köhler's illumination conditions; Abbe theory and resolution; phase contrast; dark field imaging; differential interference contrast.
Fluorescence microscopy: molecular spectra; Jablonski diagram; Stokes' shift; life time and quantum efficiency; saturation of the excited state; structure of the conventional fluorescence microscope.
Confocal microscopy: impulse response of a converging lens in three dimensions; lateral resolution and axial resolution in the classical limit; optical sectioning and volume reconstruction; physical principles and applications of 2-photon excitation; advantages and disadvantages of different confocal systems.
STED microscopy and super-resolution.
Digital image processing: noise and its digital filtering; deconvolution; structured illumination and super-resolution.
Optical recording of changes in ion concentration: optical sensors of Ca2 + ions, protons and other physiologically relevant ionic species; imaging of Ca2+ at one and two wavelengths; local control of the concentration of Ca2+ and other active molecular species by UV photolysis of caged compounds; optochemogenetis; FRET, FLIM, FRAP, TIRFM; dynamics of intracellular messengers; reaction-diffusion equations, calcium waves.
Examination:
Written and an oral exam. The written part concerns topics developed during the course. The oral exam consists in the presentation by the student of one or more original articles related to optical super-resolution techniques.
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081799/N0

COMMON ADVANCED COURSE
Master degree in **Physics**, First semester
Lecturer: To be defined
Credits: 6 ECTS
Prerequisites:
Short program:
Examination:
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/004PD/SCP7081921/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:
Elementary notions of quantum physics and solid state physics.
Fundamentals of thermodynamics: principles, thermodynamic potentials.
No prior knowledge of computer programming is required.
Short program:
Basic concepts of thermodynamics and classical statistical mechanics.
Classical Molecular Dynamics simulations; numerical integration of Newton equations.
Monte Carlo method; Metropolis algorithm.
Simulations in various statistical ensembles.
Common features of simulations methods: initial and boundary conditions; calculation of inter-particle interactions.
Calculation of thermodynamic and transport properties.

Intermolecular interactions: force-fields; atomistic and coarse grained models.
Variational methods for the solution of the Schrodinger equation.
Hartree and Hartree-Fock theory.
Elements of Density Functional Theory (DFT).
'First principles' simulations.
The different computational methods will be discussed in relation their application to topics of interest for material science (crystals, surfaces, soft matter, nanostructured materials).
In the computer exercises, students will carry out simple simulations, using open-source software packages of current use in materials science, and will learn how to interpret and present the results of simulations.

Examination:

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

More information:

https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/002PD/SCP7081717/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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/003PD/SCN1035989/N0

COSMOLOGY OF THE EARLY UNIVERSE

Master degree in **Physics**, First semester
Lecturer: Nicola Bartolo
Credits: 6 ECTS

Prerequisites:
Fundamentals of Astrophysics and Cosmology (equivalently "The Physical Universe").

Short program:
General introduction. The problem of the initial conditions: primordial density perturbations at the origin of the formation of the Large Scale Structure of the Universe.
- Short recall of the main problems of the standard cosmological model
- Inflationary cosmology in the Early Universe as a solution to the problems of the standard model

Modeling:
- Inflationary models: vacuum energy and the inflation field; dynamics of a scalar field in a Friedman-Robertson-Walker Universe; possible realizations of the inflationary scenario
- Inflationary models within high-energy particle physics
- Observational predictions of the inflationary models: from the quantum perturbations in an expanding universe to the primordial density perturbations; generation of primordial gravitational waveband their observability
- Delta-in formalism for the cosmological perturbations (and in-in formalism); example: primordial non-Gaussianity

Cosmological perturbations in General Relativity
- scalar, vector and tensor perturbations
- gauge transformations
- Einstein equations linearly perturbed around the Robertson-Walker metric

Observational tests of the Early Universe

Examination:
Oral exam

More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/003PD/SCP7081761/N0

EXPERIMENTAL NUCLEAR PHYSICS AND ACCELERATORS

Master degree in **Physics**, First semester
Lecturer: To be defined

Credits: 6 ECTS
Prerequisites:
Short program:
Examination:
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/004PD/SCP7081918/N0

EXPERIMENTAL SUBNUCLEAR PHYSICS

Master degree in **Physics**, First semester
Lecturer: Riccardo Brugnera
Credits: 6 ECTS
Prerequisites:
One assumes some prior knowledge: basic information regarding High Energy Physics and Quantum Electrodynamicscoming from the courses of Subnuclear Physics, Theoretical Physics and Theoretical physics of the fundamental interactions
Short program:
Quantum Chromodynamics
======================
QCD lagrangian, renormalization group equations, alpha_s as running coupling constant.
Dokhshitzer-Gribov-Altarelli-Parisi evolution equations. Structure functions.
Hadronization processes.
Electroweak Theory
==================
SU(2)XU(1) model, radiative corrections, physics at the Z0, interference and asymmetries at LEP, LEPII.
Goldstone model, Higgs mechanism, Higgs phenomenology, search for the Higgs boson.
Physics at the hadronic colliders: search and properties of the top quark and of the vector bosons
CKM Matrix
==========
Hierarchy of the parameters, different parametrization. Unitarity triangle. Example of measurement of some elements of the CKM matrix
CP violation and oscillations
==============================
Oscillation and CP violation in the neutral B system
CP violation in the mesons decays
Neutrinos oscillations: two flavours oscillations, three flavours oscillations, matter effect.
Solar neutrino oscillations and related experiments. Atmospheric neutrinos oscillations and related experiments. Log-baseline experiments.
Examination:
Oral
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081760/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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/003PD/SCP7081661/N0

GRAVITATIONAL PHYSICS
Master degree in **Physics**, Second semester
Lecturer: Giacomo Ciani
Credits: 6 ECTS
Prerequisites:
Basic knowledge of general relativity is suggested, but not mandatory.
Short program:
Elements of general relativity. Gravitational waves (GW) in linearized theory; TT-gauge and detector frame; interaction with free falling masses and rigid bodies.
Generation of GW. Quadrupole and post-newtonian approximations. Energy and momentum loss by gravitational wave emission. Examples of GW sources: stable and coalescing binary systems, rotating rigid bodies, extreme mass-ratio inspirals.
GW detection. Hulse-Taylor system. Fundamentals of stochastic signals and noise theory. Resonant bars detectors. Modern GW interferometers: basic principle, noise sources, fundamental and technical limitations. Future GW experiments. Elements of data analysis. Astronomy and science with gravitational waves. Current observations of black hole and neutron star mergers. Tests of general relativity. Astrophysical implications. Multi-messenger 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:
https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/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 – Stefano Agnoli – Moreno Meneghetti
Credits: 6 ECTS
Prerequisites:
Quantum Physics (particle in a box, quantum confinement), Solid State Physics (phononic and electronic structures of solids, thermal and optical properties).
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:
The exam is written (duration 2 h) with two open questions and a set of multiple-choice questions.
*** Mutuation ***
The exam is written (duration 2 h) with an open question and an exercise with numerical applications of the learned topics.
More information:
https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/001PD/SCP7081705/N0

MATHEMATICAL PHYSICS

Master degree in **Physics**, Second semester
Lecturer: To be defined
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:
To be decided by the professor in charge of the course.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/002PD/SCP7080817/N0

METROLOGY AND DATA ANALYSIS

Master degree in **Physics**, First semester
Lecturer: To be defined
Credits: 6 ECTS
Prerequisites:
Short program:
Examination:

More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/004PD/SCP7081917/N0

MODELS OF THEORETICAL PHYSICS (OFFERED IN THE MASTER DEGREE IN DATA SCIENCE)

Master degree in **Physics**, First semester
Lecturer: Amos Maritan – Marco Baiesi
Credits: 6 ECTS
Prerequisites:
Good knoledge of mathematical analysis, calculus, elementary quantum mechanics and basic physics.
Short program:
Introduction; "The Unreasonable Efectiveness of Mathematics in the Natural Sciences (Wigner 1959)"; Gaussian integralsn Wick theorem
Perturbation theoryn connected contributionsn Steepest descent
Legendre transformationn Characteristic/Generating functions of general probability distributions/measures
The Wiener integraln geometric characteristics of Brownian paths and Hausdorf/fractal dimension
Brownian paths and polymer physicsn biopolymer elasticity. The random walk generating functionn the Gaussian feld theory and coupled quantum harmonic oscillators
Levy walksn violation of universality
Field theories as models of interacting systems
O(n) symmetric Phi^4– theory. The large n limit: Spherical (Berlin-Kac) model and 1/n expansion
Perturbative expansionn Universalityn critical dimensions
Generalized difusion and stochastic diferential equations
Path integrals representation of stochastic processes with general difusion operator (Brownian motion in curved spaces)
The Feynman-Kac formula: difusion with sinks and sources
Quantum mechanics (solvable modeln harmonic oscillatorn free particle)
Feynman path integrals and the quantum version of the Feynman-Kac formula.
Quantum vs stochastic phenomena: quantum tunneling and stochastic tunneling
Stochastic amplifcation and stochastic resonance
Nonperturbative methods, instantons
Difusion in random media and anomalous difusion
Quantum Mechanics in a random potentialn localization and random matrices
Statistical physics of random spin systems and the machine-learning problem
Random energy model, replica trick
Cavity method, Random Field Ising Model
Examination:
Final examination based on: Written and oral examination and weekly exercises proposed during the course
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/002PD/SCP8083597/N0

MULTIMESSENGER ASTROPHYSICS

Master degree in **Physics**, First semester
Lecturer: Elisa Bernardini
Credits: 6 ECTS
Prerequisites:

This course is aimed at students with a basic understanding of particle and nuclear physics
Short program:
The term "multi-messenger" is quite new and increasingly used in astronomy and astroparticle physics. It refers to the combination of various techniques at different photon wavelengths and with different 'messengers', to get a deep understanding of the astrophysical objects we observe in the sky.
Visible light only reveals a very small portion of the mysteries of the Universe. Astronomical observations are nowadays routinely performed with different telescopes across the electromagnetic spectrum, from radio waves through visible light, all the way to gamma-rays. At the highest energies, the most violent processes in the Universe are at work.
Whatever produces high energy gamma-rays, is expected to accelerate particles to energies that exceed the capabilities of man-made accelerators a billion times. Such particles can reach the Earth as cosmic rays, first discovered more than 10 years ago, still nowadays one of the most misterious "messages" from our Universe. Cosmic rays may interact in the vicinity or their sources or even along their way to Earth, to produce elusive particles called neutrinos. Neutrinos are extremely difficult to detect, but the year 2013 has seen the first clear observation of neutrinos from distant astrophysical objects by the IceCube detector at the South Pole, opening a new observational window to the Universe. Finally, most known sources of gamma-rays (and likely cosmic-rays and neutrinos) are associated with black holes or neutron stars. Whenver two such compact objects orbit around each other they are expected to produce gravitational waves. Most recently, in 2015, gravitational waves were first onserved by the LIGO detectors in the USA from the merger of two black holes.
The Nobel-prize winning direct detection of gravitational waves opened another window through which astronomers can observe the violent Universe.
Examination:
Oral examination.
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/003PD/SCP7081762/N0

NUCLEAR ASTROPHYSICS

Master degree in **Physics**, Second semester
Lecturer: Antonio Caaciolli - 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:

https://en.didattica.unipd.it/off/2018/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

Examination:

The exam consists on an oral examination with eventual presentation of a research work on one of the several subjects proposed by the professors.

More information:

https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/001PD/SCP7081658/N0

OPTICS AND LASER PHYSICS (OFFERED IN THE MASTER DEGREE IN MATERIAL SCIENCE)

Master degree in **Physics**, First semester
Lecturer: To be defined
Credits: 6 ECTS

Prerequisites:

Topics learned in basic courses of Mathematics and Physics.

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

Examination:
Written exam with numerical exercises to be solved and an open question on a specific topic presented during the course.

More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081800/N0

PHYSICS EDUCATION

Master degree in **Physics**, First semester
Lecturer: Ornella Pantano
Credits: 6 ECTS

Prerequisites:
Core knowledge of classic and modern physics.

Short program:
Physics teaching and learning: main topics and approaches in physics education research. Core ideas in physics, scientific practices and crosscutting concepts in natural sciences. Historical development of physics ideas that carry special significance for physics teaching and learning.
Different theoretical approaches to students' understanding of physics content and student difficulties, and their application in physics teaching. The role and importance of student interest, motivation and metacognition in learning physics. Student-centered approaches to physics teaching and learning.
The role of practical work and technologies in physics learning and teaching. Educational potential of out-of-school settings: benefits and opportunities offered by experiences outside the classroom.
Physics education research in different areas of physics, for example: mechanics, waves, optics, electromagnetism, relativity and quantum mechanics. Astronomy as a context in which proposing topics of classical and modern physics.

Examination:
The examination will consist of two parts:
(1) written assignments during the course (40%);
(2) a final written project at the end of the course on the development and implementation of an empirical study on a selected topic in physics (60%).

More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/001PD/SCP8084777/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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/001PD/SCP7081617/N0

PHYSICS OF COMPLEX SYSTEMS

Master degree in **Physics**, First semester
Lecturer: Attilio Stella
Credits: 6 ECTS
Short program:
Introduction to the physics of complexity and of emergent phenomena (general points of view of P.W. Anderson, N. Goldenfeld, L.P. Kadanoff, ...)

Selected topics in the statistics of polymers, percolation, fractals, and disorder. Continuous symmetries and Kosterliz Thouless transition.
Brownian motion. Mathematics of Brownian motion and stochastic differential equations. Stochastic processes.
Statistical mechanics out of equilibrium.
Microscopic reversibility and macroscopic irreversibility.
Detailed balance in equilibrium. Onsager reciprocity relations with examples (Seebeck and Peltier effects, etc.).
Fluctuation-response theorem, dynamic susceptivity and fluctuation-dissipation theorem. Kramers-Kronig relations.
Microscopic basis of Brownian motion.
Thermodynamics out of equilibrium at the micro- and nano-scales. Markovian description of

non-equilibrium dynamics.
Fluctuation theorems and work identities. Generalized detailed balance. Entropy production.
Asymmetric simple exclusion and related processes, some basic results. Theory of large deviations.
Molecular motors. Applications of Gallavotti-Cohen theorem.

Examination:

Oral examination covering three or four of the topics chosen by the teacher among all those treated in the course. To each topic ample time is devoted to the exposition and to the discussion of possible connections with other parts of the program. This allows to ascertain how the student masters the subject.

More information:

https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081763/N0

PHYSICS OF FLUIDS AND PLASMAS

Master degree in **Physics**, First semester
Lecturer: To be defined
Credits: 6 ECTS

Short program:

The course presents, at an advanced level, some of the main subjects of the physics of fluids and plasmas.
During the course examples and applications from both astrophysics and controlled fusion will be presented.
Introduction
Fluids and plasmas in nature and laboratory. Characteristics and limitations of theories describing neutral fluids and plasmas. Non-collisional Boltzmann equation.
Neutral fluids
Collisional Boltzmann equation.
Moment equations and fluid dynamics derivation.
Ideal fluids; macroscopic derivation of fluid dynamics.
Viscuous flows.
Linear theory of waves and instabilities. Perturbative approach.
Turbulence in neutral fluids; Kolmogorov theory.
Plasmas
Basic properties of plasmas; plasmas in nature and laboratory.
Plasma orbit theory.
Dynamic of many charged particles.
Kinetic theory of plasmas, BBGKY hierarchy, Vlasov equation.
Two fluid model.
Collisionless processes in plasmas; Landau damping.
Collisional processes and the one-fluid model.
Diffusion and transport.
Basic magnetohydrodynamics; some simple examples of MHD instabilities.
Theory of magnetic topologies; magnetic reconnection; Sweet-Parker model. Magnetic helicity.
Dynamo theory. Parker's turbulent dynamo. Mean field magnetohydrodynamics.

Examination:

Oral examination

More information:

https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081743/N0

PHYSICS OF NUCLEAR FUSION AND PLASMA APPLICATIONS

Master degree in **Physics**, First semester

Lecturer: To be defined
Credits: 6 ECTS
Prerequisites:
Knowledge of electromagnetism principles. A knowledge of the different plasma descriptions (kinetic, two-fluids, magnetohydrodynamics) is useful but not required, since essential notions will be provided during the course.
Short program:
First part: Nuclear fusion: main processes, cross sections, reactivity. Energy balance of a fusion reactor, break-even, ignition. Magnetic confinement and inertial confinement. Toroidal configurations for magnetic confinement. The tokamak configuration. Conceptual scheme of the reactor. MHD equilibria in cylindrical geometry, z-pinch, screw-pinch. MHD equilibria in toroidal geometry, flux functions, Grad-Shafranov equation. Safety factor, toroidal and poloidal beta. Tokamak operational limits: Hugill diagram, Greenwald limit, beta limit. Scaling laws for confinement time, L-mode and H-mode. Plasma heating: ohmic, with neutral beams, with radiofrequency. Outer region of the plasma, concepts of limiter and divertor. Formal analogy between magnetic field line trajectories and orbits of a Hamiltonian system. Alternative confinement schemes: stellarator and RFP. Status of fusion research: the ITER project. Safety and environmental impact of the fusion reactor.
Second part: Introduction to plasma applications. Methods of plasma formation. Planar diode model, Child-Langmuir law. Debye sheath, Bohm criterion, floating potential. Langmuir probe and its use to measure plasma properties. Double and triple probes. Radiofrequency discharges, capacitive and inductive coupling. Atmospheric pressure plasmas. Applications: "plasma medicine" applications, plasma propulsion for space applications.
Examination:
Oral examination
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081798/N0

PHYSICS OF SEMICONDUCTORS (OFFERED IN THE MASTER DEGREE IN MATERIAL SCIENCE)
Master degree in **Physics**, First semester
Lecturer: Davide De Salvador – Enrico Napolitani
Credits: 6 ECTS
Prerequisites:
Mathematical prerequisites:
Continuous functions. Derivatives. Fundamental theorems of differential calculus. Relative and absolute maxima and minima. Exponential and logarithmic trigonometric functions. Study of a function. Definite integrals. Solid volumes of rotation. Taylor and Maclaurin series. Complex numbers. Exponential in the complex field. Differential equations. Linear differential equations of first order and second order. Functions of multiple variables. Limitations. Partial derivatives. Maximum and minimum relative. Saddle points. Double integrals in polar coordinates. Solid volumes. Triple integral. Vector differential calculus: flow of a vector field across a surface. Divergence of a field and divergence theorem.
Basic Physics Prerequisites
Coulomb's law. Electrostatic field. Electrostatic potential. Gauss's law. Poisson and Laplace equations. Capacity; ideal capacitor. Dielectric constant. Electrical currents and current density. Conservation of the charge. Ohm's law. Joule effect. Magnetic field; Lorentz force.
Quantum Physics Prerequisites :
Light quanta and photo-electric effect. Wave packs. The Heisenberg uncertainty principle. Shroedinger equation particle in a box. Quantum harmonic oscillator. Expectation values. Observables and operators. Quantum uncertainty and properties of eigenvalues. Square barrier tunnel effect. Penetration of the barrier. Particle in a three-dimensional box. Hydrogen

atom and hydrogen atoms: fundamental state and excited states. Periodic table. Maxwell-Boltzmann distribution and density of states. Energy provision. Quantum statistics: Bose-Einstein and Fermi-Dirac distributions
Solid state physics Prerequisites
The crystalline structure of solids: the direct lattice and the reciprocal lattice. Phonons. The electrical conductivity of metals in the Drude model. Bloch's theorem.**Short program:**
First part: Nuclear fusion: main processes, cross sections, reactivity. Energy balance of a fusion reactor, break-even, ignition. Magnetic confinement and inertial confinement. Toroidal configurations for magnetic confinement. The tokamak configuration. Conceptual scheme of the reactor. MHD equilibria in cylindrical geometry, z-pinch, screw-pinch. MHD equilibria in toroidal geometry, flux functions, Grad-Shafranov equation. Safety factor, toroidal and poloidal beta. Tokamak operational limits: Hugill diagram, Greenwald limit, beta limit. Scaling laws for confinement time, L-mode and H-mode. Plasma heating: ohmic, with neutral beams, with radiofrequency. Outer region of the plasma, concepts of limiter and divertor. Formal analogy between magnetic field line trajectories and orbits of a Hamiltonian system. Alternative confinement schemes: stellarator and RFP. Status of fusion research: the ITER project. Safety and environmental impact of the fusion reactor.
Second part: Introduction to plasma applications. Methods of plasma formation. Planar diode model, Child-Langmuir law. Debye sheath, Bohm criterion, floating potential. Langmuir probe and its use to measure plasma properties. Double and triple probes. Radiofrequency discharges, capacitive and inductive coupling. Atmospheric pressure plasmas. Applications: "plasma medicine" applications, plasma propulsion for space applications.

Short program:

Review of the crystal structure of the main semiconductors. Elementary semiconductors , compounds and alloys.
Review of solid state basic concepts (Bloch theorem , effective mass , concept of hole) .
Origin and specificity of semiconductors band structure. The real bands (examples: GaAs , Si, Ge, AlGaAs) .
The envelope function method for the calculation of quantum states generated by aperiodic potential.
The mechanism of doping. The carriers in a homogeneous semiconductor as a function of doping and temperature (semic. non-degenerate, intrinsic, ionized , partially ionized , in saturation). The compensation by deep level.
The semiconductor non-homogeneous equilibrium. The case of the p-n junction .
Charge transport in semiconductors. Drift -diffusion equation. Intraband scattering phenomena and mobility in a semiconductor.
The mechanisms of generation and recombination in a semiconductor.
The equation of continuity. The case of the p-n junction under polarization.
The heterojunction joints metal / semiconductor , metal / oxide / semiconductor.
The quantum confinement in semiconductor quantum well , quantum wire , quantum dot .
LEDs , GaN based LED, photodetectors. Solid state laser architectures, quantum confinement effect on lasering. Photovoltaic cells. Different architectures and materials for photovoltaics. Efficiency. Mechanisms of loss of efficiency . Thin-film cells.
Produttive.Transistor bipolar and FET technologies . MOS structure.
Doping techniques. Ion implantation. Diffusion and defect .
Insulation, thermal oxidation.
Moore's Law and scaling. Issues and new materials.

Examination:

Oral exam. During the semester it will be possible to give a mid-term oral exam about the first part of the course concenrning on physical principle; at the end a second oral exam on the devices and processes will complete the final grade.

More information:

https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081797/N0

PLANETARY ASTROPHYSICS

Master degree in **Physics**, First semester
Lecturer: Francesco Marzari
Credits: 6 ECTS
Prerequisites:
Basic courses of the 3--year period.
Short program:
1) Dynamical and physical properties of planets and exoplanets.
2) Planetary formation from circumstellar disks, migration and planet-planet scattering. Short tutorial on fluid dynamics and tidal interaction between planets and disks.
3) Magnetic fields of the planets, origin and morphology.
4) Plasma motion in planetary fields, Van Allen Belts, magnetospheres and solar wind.
5) Tidal interaction planet-satellite and planet-star, lengthening of the terrestrial day and Moon outward drift.
6) Physics of planetary interiors, state and structure equations.
7) Non-gravitational forces acting on planetary precursors: Poyting-Robertson drag, Yarkowski effect, gas drag.
7) Three-body problem: Lagrangian points (Trojan orbits), their stability, Hill's sphere and its applications (cataclysmic variables, asteroid satellites).
8) Secular perturbations in multiple planet systems.
Examination:
Oral exam
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/003PD/SCP7081805/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. Then the knowledge and skills of the student will be verified with questions on the various topics of the course. However, the details of the proofs of the theorems introduced in the course are not required.

More information:

https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/001PD/SCP7081702/N0

QUANTUM INFORMATION

Master degree in **Physics**, First semester
Lecturer: Simone Montangero
Credits: 6 ECTS

Prerequisites:

Quantum mechanics and elements of programming.

Short program:

Basics in computational physics
1. Large matrix diagonalization
2. Numerical integration, optimizations, and solutions of PDE
3. Elements of Gnuplot, modern FORTRAN, python
4. Elements of object-oriented programming
5. Schrödinger equation (exact diagonalization, Split operator method, Suzuki-trotter decomposition, ...)

Basics of quantum information:
1. Density matrices and Liouville operators
2. Many-body Hamiltonians and states (Tensor products, Liouville representation, ...)
3. Entanglement measures
4. Entanglement in many-body quantum systems

Theory:
1. Numerical Renormalization Group
2. Density Matrix Renormalization group
3. Introduction to tensor networks
4. Tensor network properties
5. Symmetric tensor networks
6. Algorithms for tensor networks optimization
7. Exact solutions of benchmarking models

Applications:
1. Critical systems
2. Topological order and its characterization
3. Adiabatic quantum computation
4. Quantum annealing of classical hard problems
5. Kibble-Zurek mechanism

6. Optimal control of many-body quantum systems
7. Open quantum systems (quantum trajectories, MPDO, LPTN, ...)
8. Tensor networks for classical problems: regressions, classifications, and deep learning.

Examination:
The exam will be a final project composed of programming, data acquisition, and analysis, which will be discussed orally.

More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/002PD/SCP7081801/N0

RADIOACTIVITY AND NUCLEAR MEASUREMENTS

Master degree in **Physics**, First semester
Lecturer: Marco Mazzocco – Francesco Recchia
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:

https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/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:
https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/002PD/SCP7081660/N0

STANDARD MODEL

Master degree in **Physics**, Second semester
Lecturer: Paride Paradisi
Credits: 6 ECTS

Prerequisites:
Students should be familiar with the fundamental aspects of field theory, quantum electrodynamics and the calculation of amplitudes for physical processes through Feynman diagrams.

Short program:
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. The Standard Model as an effective theory and the hierarchy problem. Running of the Gauge coupling constants: Gauge coupling unification, asymptotic freedom and confinement. Grand unified theories.

Examination:
Oral examination.

More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/001PD/SCP7081698/N0

STATISTICAL MECHANICS

Master degree in **Physics**, First semester
Lecturer: Enzo Orlandini
Credits: 6 ECTS

Prerequisites:
Statistical Mechanics (course given at the third year of the laurea triennale)
Thermodynamics

Short program:
In short the contents of the program can be summarised as follows:
Thermodynamics of phase transitions.
Critical points, order parameters and critical exponents. Phase transitions and spontaneous symmetry breaking.
Analytical tools to solve spins model in 1D, transfer matrix formalisms.
Mean field theories.
Ginzburg Landau theory.
Ginzburg criterium and upper critical dimension. Scaling theory and Kadanoff block spin argument.
Renormalisation group in real space. Universality.
Please note that some topics may vary
Spontaneous symmetry breaking for continuous symmetry. Goldstone's theorem.

Examination:
The verification of the acquired knowledge takes place through a common written test with 1-2 exercises to be solved analytically and 1-2 open questions on basic concepts. In this way we should be able to test the knowledge, the scientific vocabulary, the ability to synthesis and

critical discussion acquired during the course.The second part of the exam will be oral and will be based on a discussion on the various topics discussed in class.

More information:

https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/002PD/SCP7081659/N0

STELLAR STRUCTURE AND EVOLUTION (OFFERED AS ASTROPHYSICS 2 IN THE FIRST CYCLE DEGREE IN ASTRONOMY)

Master degree in **Physics**, Second semester

Lecturer: Paola Marigo

Credits: 6 ECTS

Prerequisites:

Elements of plane trigonometry, derivatives, integrals, basic knowledge of physics.

Preparatory courses: Astronomy I and Astronomy II (mod. A) of the Bachelor in Astronomy.

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:

https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/003PD/SCP7081739/N0

STRUCTURE OF MATTER (ALSO OFFERED FOR STUDENTS OF THE MASTER DEGREE IN PHYSICS OF DATA)

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:

https://en.didattica.unipd.it/off/2018/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:

https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/001PD/SCP7081697/N0

THEORETICAL NUCLEAR, ATOMIC AND COLLISION PHYSICS

Master degree in **Physics**, First semester

Lecturer: To be defined

Credits: 12 ECTS

Prerequisites:

Short program:

Examination:

More information:

https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/004PD/SCP7081920/N0

THEORY OF STRONGLY CORRELATED SYSTEMS

Master degree in **Physics**, First semester

Lecturer: Luca Dell'Anna

Credits: 6 ECTS

Prerequisites:

Learning of some phenomena in condensed matter physics by means of the path integral approach

Short program:

Part 1: Introduction to the path integral

- Brief review of quantum mechanics for single particle and identical particles
- Second quantization: annihilation and creation operators
- Single-particle and double-particle operators
- Bosonic coherent states
- Grassmann algebra
- Fermionic coherent states
- Gaussian integrals with complex and grassmannian variables
- Feynmann integrals
- Patition function and imaginary time
- Equation of motion and stationary phase approximation
- Application of Feynman integrals for a double-well: instanton gas
- Functional integrals with coherent states
- Interacting particles: perturbation theory
- Functional integral for the electromagnetic field

Part 2: Applications

- Coulomb gas

* Perturbative approach
* Random Phase Approximation
* Functional integral method
- Non-interacting bosons: Bose-Einsten condensation
- Goldstone theorem
- Interacting bosons: Superfluidity
* Bogoliubov spectrum
* Landau criterion
* Action for the Goldstone mode
* Phenomenology
- Superconductivity
* Phenomenology and London equations
* Electron-phonon interaction
* Cooper problem
* BCS theory by functional approach: gap equation and critical temperature
* Ginzburg-Landau theory
* Action for the Goldstone mode
* Meissner effect and Higgs mechanism

Examination:
Oral examination
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081742/N0

THE PHYSICAL UNIVERSE

Master degree in **Physics**, First semester
Lecturer: Sabino Matarrese
Credits: 6 ECTS
Prerequisites:
Fundamental concepts of quantum mechanics and special relativity
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:

https://en.didattica.unipd.it/off/2018/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:

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 relativistic free field theories. Interacting quantum field theory: S-matrix expansion and Feynman rules. QED Feynman rules.

Examination:

Written and oral exam.

More information:

https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2382/001PD/SCP7081657/N0

PHYSICS OF DATA
ADVANCED STATISTICS FOR PHYSICS ANALYSIS
Master degree in **Physics Of Data**, Second semester
Lecturer: To be defined
Credits: 6 ECTS
Prerequisites:
None
Short program:
- review of basic concepts: probability, odds and rules, updating probabilites, uncertain numbers (probability functions)
- from Bernoulli trials to Poisson processes and related distributions
- Bernoulli theorem and Central Limit Theorem
- Inference of the Bernoulli p; inference of lambda of the Poisson distribution. Inference of the Gaussian mu. Simultaneous inference of mu and sigma from a sample: general ideas and asymptotic results (large sample size).
- fits as special case of parametric inference
- Monte Carlo methods: rejecion sampling, inversion of cumulative distributions, importance sampling. Metropolis algorithm as example of Markov Chain Monte Carlo. Simulated annealing
- the R framework and language for applied statistics.

Examination:
Oral test examination.
A simple exercise, to be solved in the R framework, will be assigned few days before the oral examination.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP8082557/N0

COSMOLOGY (OFFERED IN THE MASTER DEGREE IN PHYSICS)
Master degree in **Physics Of Data**, 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 becokem acquainted with the main concepts presented in the lectures.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCN1035989/N0

GENERAL RELATIVITY (OFFERED IN THE MASTER DEGREE IN PHYSICS)
Master degree in **Physics Of Data**, 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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP7081661/N0

LABORATORY OF COMPUTATIONAL PHYSICS (C.I.)
Master degree in **Physics of Data**, Annual
Credits: 12 ECTS
Modules of the integrated course unit:

- LABORATORY OF COMPUTATIONAL PHYSICS (MOD. A)
- LABORATORY OF COMPUTATIONAL PHYSICS (MOD. B)

Common characteristics of the Integrated Course unit:

Prerequisites:

Even though not strictly required, the development of the class assumes the attendance of at least two physics laboratory classes during the bachelor degree

Examination:

To verify the proficiency of the students in the subjects covered by this course, the written reports on the lab experiences will be evaluated; such evaluation will have to be confirmed by an oral exam, during which the students will also be interviewed about what is thought during the lectures.

The oral exam will be split into two parts, each relevant to one of the two modules the class consists of.

LABORATORY OF COMPUTATIONAL PHYSICS (MOD. A)

Specific characteristics of the Module

Lecturer: Marco Zanetti

Short program:

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

LABORATORY OF COMPUTATIONAL PHYSICS (MOD. B)

Specific characteristics of the Module

Lecturer: Marco Baiesi – Marco Zanetti

Short program:

1. Introduction. Bias-Variance decomposition
2. Gradient descent methods
3. Linear regression: Ridge and LASSO
4. Logistic regression
5. Combining models: bagging, boosting, and random forests
6. Feed-forward deep neural networks: basics
7. Deep neural networks: regularization
8. Deep neural networks: examples
9. Clustering
10. Energy-based models
11. Restricted Boltzmann machines
12. Concluding examples

More information:

https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP8082524/N0

MACHINE LEARNING (OFFERED IN THE MASTER DEGREE IN ICT FOR INTERNET AND MULTIMEDIA)

Master degree in **Physics Of Data**, First semester

Lecturer: Pietro Zanuttigh

Credits: 6 ECTS

Prerequisites:

Basic Knowledge of Mathematics, Probability Theory, Statistics, Linear Algebra, Algorithms and basic Programming skills.
Short program:
Motivation; components of the learning problem and applications of Machine Learning. Supervised and unsupervised learning.
PART I: Supervised Learning
1. Introduction: Data, Classes of models, Losses.
2. Probabilistic models and assumptions on the data. The regression function. Regression and Classification.
3. When is a model good? Model complexity, bias variance tradeoff/generalization (VC dimension, generalization error).
4. Models for Regression: Linear Regression (scalar and multivariate), subset selection, linear-in-the-parameters models, regularization.
5. Classes of nonlinear models: Sigmoids, Neural Networks.
6. Kernel Methods: SVM.
7. Models for Classification: Logistic Regression, Neural Networks, Perceptron, Naïve Bayes Classifier, SVM, Deep Learning.
8. Validation and Model Selection: Generalization Error, Bias-Variance Tradeoff, Cross Validation. Model complexity determination.
PART II: Unsupervised learning
1. Cluster analysis: K-means Clustering, Mixtures of Gaussians and the EM estimation.
2. Dimensionality reduction: Principal Component Analysis (PCA).
Examination:
The evaluation of the acquired skills and knowledge will be performed using two contributions:
1. A written exam without the book, where the student must solve few problems, with the aim of verifying the acquisition of the main ingredients of a learning problem and of the main machine learning tools, the analytical ability to use these tools and the ability to interpret the typical results of a practical machine learning problem.
2. Computer simulations (optional) with the aim of acquiring the practical competences for using machine learning tools. These simulations, to be performed at home, allow to verify the ability of practically exploiting the acquired theoretical concepts. The student will have to provide a brief document explaining the employed methodologies used to solve the assigned problem together with the obtained results.
The final grade will be based on the written test with a bonus up to 3 point for the students who will hand in also the lab assignments.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP8082660/N0

MANAGEMENT AND ANALYSIS OF PHYSICS DATASET (C.I)
Master degree in **Physics of Data**, Annual
Credits: 12 ECTS
Modules of the integrated course unit:
- MANAGEMENT AND ANALYSIS OF PHYSICS DATASET (MOD. A)
- MANAGEMENT AND ANALYSIS OF PHYSICS DATASET (MOD. B)

Common characteristics of the Integrated Course unit:
Prerequisites:
Examination:
MANAGEMENT AND ANALYSIS OF PHYSICS DATASET (MOD. A)
Specific characteristics of the Module
Lecturer: Gianmaria Collazuol
Short program:

MANAGEMENT AND ANALYSIS OF PHYSICS DATASET (MOD. B)
Specific characteristics of the Module
Lecturer: Donatella Lucchesi
Short program:
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP8082533/N0

MODELS OF THEORETICAL PHYSICS (OFFERED IN THE MASTER DEGREE IN PHYSICS)
Master degree in **Physics Of Data**, First semester
Lecturer: Amos Maritan – Marco Baiesi
Credits: 6 ECTS
Prerequisites:
Good knoledge of mathematical analysis, calculus, elementary quantum mechanics and basic physics.
Short program:
Introduction; "The Unreasonable Efectiveness of Mathematics in the Natural Sciences (Wigner 1959)"; Gaussian integralsn Wick theorem
Perturbation theoryn connected contributionsn Steepest descent
Legendre transformationn Characteristic/Generating functions of general probability distributions/measures
The Wiener integraln geometric characteristics of Brownian paths and Hausdorf/fractal dimension
Brownian paths and polymer physicsn biopolymer elasticity. The random walk generating functionn the Gaussian feld theory and coupled quantum harmonic oscillators
Levy walksn violation of universality
Field theories as models of interacting systems
O(n) symmetric Phi^4– theory. The large n limit: Spherical (Berlin-Kac) model and 1/n expansion
Perturbative expansionn Universalityn critical dimensions
Generalized difusion and stochastic diferential equations
Path integrals representation of stochastic processes with general difusion operator (Brownian motion in curved spaces)
The Feynman-Kac formula: difusion with sinks and sources
Quantum mechanics (solvable modeln harmonic oscillatorn free particle)
Feynman path integrals and the quantum version of the Feynman-Kac formula.
Quantum vs stochastic phenomena: quantum tunneling and stochastic tunneling
Stochastic amplifcation and stochastic resonance
Nonperturbative methods, instantons
Difusion in random media and anomalous difusion
Quantum Mechanics in a random potentialn localization and random matrices
Statistical physics of random spin systems and the machine-learning problem
Random energy model, replica trick
Cavity method, Random Field Ising Model
Examination:
Final examination based on: Written and oral examination and weekly exercises proposed during the course
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP8083597/N0

NETWORK MODELLING (OFFERED IN THE MASTER DEGREE IN ICT FOR INTERNET AND MULTIMEDIA)

Master degree in **Physics Of Data**, Second semester
Lecturer: Michele Zorzi
Credits: 6 ECTS
Prerequisites:
The course requires preliminary knowledge of: Mathematical Analysis, Probability, random variables and random processes, networks and protocols. For the examples treated, a basic course in networks and protocols is useful (through not required).
Short program:
1. Review of probability and random processes
2. Markov chains: definitions and main results
3. Markov chains: asymptotic behavior
4. Study of multi-access systems and their stability properties
5. Poisson processes: definitions and main results
6. Renewal processes: definitions and main results, asymptotic behavior
7. Renewal reward, regenerative, and semi-Markov processes
8. Exercises and examples of applications

A detailed list of the topics covered during the course, with specific reference to chapters and pages of the texts, is available on the course website through the e-learning platform.
Examination:
The assessment of the knowledge and skills acquired is carried out by means of a written test divided into two parts.
Part A, with a duration of 90 minutes and open-book, consists of eleven numerical questions grouped into four exercises. Each question has a value of three points.
Part B, with a duration of 60 minutes and closed-book, consists of three theoretical questions (typically proofs of theorems seen in class). Each question has a value of eleven points.
If the student scores at least 15 points in part A and the average score of part A and part B is at least 18, the latter can be accepted as the final grade. If the score in part A is less than 15 or the average of the two tests is less than 18, the exam is not passed.
Even if the final exam can be passed by a successful written exam (in two parts), the student can always ask to take an oral exam if he/she wants to improve the grade. In no case can the oral exam replace the written test.
Examples of exams are available on the elearning platform course website, and are extensively covered in class.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP8082659/N0

NUCLEAR PHYSICS (OFFERED IN THE MASTER DEGREE IN PHYSICS)

Master degree in **Physics Of Data**, 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

Examination:
The exam consists on an oral examination with eventual presentation of a research work on one of the several subjects proposed by the professors.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP7081658/N0

RELATIVISTIC ASTROPHYSICS (OFFERED IN THE MASTER DEGREE IN PHYSICS)
Master degree in **Physics Of Data**, 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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP7081738/N0

SOLID STATE PHYSICS (OFFERED IN THE MASTER DEGREE IN PHYSICS)
Master degree in **Physics Of Data**, 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, ensemmble averages, etc.)
Short program:
Chemical bonds in solids;
The structure of crystals;
Bravais lattices and bases;
Simple crystal structures;
Reciprocal lattice;
Diffraction by periodic structures and experimental techniques;
The Bragg law;
Adiabatic approximation;
Lattice dynamics;
Harmonic approximation,
The dynamical Matrix;
phonons;
Monoatomic and diatomic linear chains;
Spectroscopy of phonons;
Thermal properties of crystals;
Lattice specific heat;
Anharmonic effects: thermal expansion, thermal conductivity of insulating materials;
"free" electrons model;
Electronic specific heat;
electrostatic screening in a Fermi gas.;
Bloch theorem;
Band structure;
"quasi-free" electron approximation;
"tight binding" approximation;
Examples of band structures;
Transport phenomena;
The Drude model;
Hall effect in metals;
Semiclassical model;
The concept of "hole";
Electrical and thermal conductivity in metals;
Law of Wiedemann and Franz;
Semiconductors;
Cyclotron Resonance;
Carriers concentration in intrinsic and extrinsic semiconductors;
"Doping" and dopant states;
electron and hole mobility;
Electrical conductivity in semiconductors;
Hall effect in semiconductors;
The Fermi surface in real metals.
Superconductivity.
Examination:
Oral exam
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP7081660/N0

STATISTICAL MECHANICS (OFFERED IN THE MASTER DEGREE IN PHYSICS)

Master degree in **Physics Of Data**, First semester
Lecturer: Enzo Orlandini
Credits: 6 ECTS
Prerequisites:
Statistical Mechanics (course given at the third year of the laurea triennale)
Thermodynamics
Short program:
In short the contents of the program can be summarised as follows:
Thermodynamics of phase transitions.
Critical points, order parameters and critical exponents. Phase transitions and spontaneous symmetry breaking.
Analytical tools to solve spins model in 1D, transfer matrix formalisms.
Mean field theories.
Ginzburg Landau theory.
Ginzburg criterium and upper critical dimension. Scaling theory and Kadanoff block spin argument.
Renormalisation group in real space. Universality.
Please note that some topics may vary
Spontaneous symmetry breaking for continuous symmetry. Goldstone's theorem.
Examination:
The verification of the acquired knowledge takes place through a common written test with 1-2 exercises to be solved analytically and 1-2 open questions on basic concepts. In this way we should be able to test the knowledge, the scientific vocabulary, the ability to synthesis and critical discussion acquired during the course.The second part of the exam will be oral and will be based on a discussion on the various topics discussed in class.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP7081659/N0

STATISTICAL MECHANICS OF COMPLEX SYSTEMS

Master degree in **Physics Of Data**, Second semester
Lecturer: Samir Simon Suweis
Credits: 6 ECTS
Prerequisites:
Stochastic processes: Brownian motion, Langevin equation, Master and Fokker-Planck equations. Thermodynamics of phase transitions.
Critical points, order parameters and critical exponents. Finite size scaling.
Ising model and mean field theories.
Short program:
The program can be summarized as follow
Complex networks: basic measures and statistics. Real networks and their property.
Null models and random graphs. Generating function formalism.
Cluster size and percolation on networks; phase transitions.
Dynamics of and on networks
Interacting particle models: voter model and contact process.
Gillespie algorithm, Master Equations and mean field.
Application to ecology, epidemics and neuroscience.
Please note that some topics may vary.
Examination:
The first part of the verification of the acquired knowledge will evaluated be through homework exercises (to do in groups) and the participation of the students in the class

discussions The second part will takes place through, a common written test with 1-2 exercises to be solved and open questions to test the knowledge on basic concepts, the scientific vocabulary, the ability to synthesis and critical discussion acquired during the course. The third facultative part of the exam will be oral and will be based on a discussion on the various topics discussed during the course.

More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP8082536/N0

STRUCTURE OF MATTER (OFFERED IN THE MASTER DEGREE IN PHYSICS)

Master degree in **Physics Of Data**, 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. The Spin of the Electron. Klein-Gordon and Dirac equations. The Pauli equation and the spin. Dirac equation with a central potential. Relativistic hydrogen atom and fine splitting.
5. 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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP7081438/N0

SUBNUCLEAR PHYSICS (OFFERED IN THE MASTER DEGREE IN PHYSICS)

Master degree in **Physics Of Data**, 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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP7081697/N0

THE PHYSICAL UNIVERSE (OFFERED IN THE MASTER DEGREE IN PHYSICS)
Master degree in **Physics Of Data**, First semester
Lecturer: Sabino Matarrese
Credits: 6 ECTS
Prerequisites:
Fundamental concepts of quantum mechanics and special relativity
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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP7081677/N0

THEORETICAL PHYSICS OF THE FUNDAMENTAL INTERACTIONS (OFFERED IN THE MASTER DEGREE IN PHYSICS)

Master degree in **Physics Of Data**, 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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC2443/000ZZ/SCP7081657/N0

FIRST CYCLE DEGREES WITH SOME COURSE UNITS HELD IN ENGLISH:

ASTRONOMY

ASTROPHYSICS 2 (ALSO OFFERED AS STELLAR STRUCTURE AND EVOLUTION FOR STUDENTS OF THE MASTER DEGREE IN PHYSICS)

Degree in **Astronomy**, Second Semester
Lecturer: Paola Marigo
Credits: 6 ECTS

Prerequisites:
Elements of plane trigonometry, derivatives, integrals, basic knowledge of physics.
Preparatory courses: Astronomy I and Astronomy II (mod. A) of the Bachelor in Astronomy.

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:
https://en.didattica.unipd.it/off/2016/LT/SC/SC1160/000ZZ/SCM0014352/N0

MATHEMATICS
DISCRETE MATHEMATICS
Degree in **Mathematics**, Second Semester
Lecturer: Michelangelo Conforti
Credits: 6 ECTS
Prerequisites:
basic knowledge of mathematics (including proof techniques, basic combinatorics etc.)
Short program:
Undirected graphs: Basic Definitions: walks, paths, cuts, connectivity. Classes of graphs: Bipartite, complete, k-regular, hypercubes.
Trees: Definitions, basic properties, fundamental cycles, minimum spanning tree: Kruskal's algorithm.
Bipartite Matchings: Definitions, alternating-augmenting paths. Hall's theorem, Konig's theorem, stable matchings.
General Matchings: Tutte's theorem, Berge's formula, Gallai's identities.
Directed Graphs: Basic definitions and properties. Strong connectivity, strongly connected components, acyclic digraphs, Tournaments, Hamiltonian paths and cycles in tournaments, Gallai-Milgram theorem, comparability graphs.
Connectivity: Edge and vertex connectivity, 3 Menger theorems, ear decompositions.
Graph Coloring: Edge-Chromatic number, Vizing's theorem, Chromatic number.
Planarity. Plane drawings and dual graphs, Euler's formula, colorability of planar graphs, Kuratowski theorem , Tait's theorem.
Traversability. Hamiltonian and Eulerian Graphs.
Examination:
Written exam.
More information:
https://en.didattica.unipd.it/off/2016/LT/SC/SC1159/000ZZ/SC04105572/N0

PHYSICAL-MATHEMATICAL MODELS
Degree in **Mathematics**, First Semester
Lecturer: To be defined
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 exam.
More information:
https://en.didattica.unipd.it/off/2016/LT/SC/SC1159/000ZZ/SC01111314/N0

OPTICS AND OPTOMETRY

Advanced Optometry And Contattology

Degree in **Optics and Optometry**, Second Semester
Lecturer: To be defined
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:
https://en.didattica.unipd.it/off/2016/LT/SC/SC1168/000ZZ/SC01123627/N0

SECOND CYCLE DEGREES WITH SOME COURSE UNITS HELD IN ENGLISH:

ASTRONOMY

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:
Evaluation of the homework and final project report. Oral presentation of final report and discussion of the results and other topics covered during the lectures.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1173/000ZZ/SCN1032619/N0

LABORATORY OF ASTROPHYSICS 1

Degree in **Astronomy**, First Semester
Lecturer: To be defined
Credits: 6 ECTS
Prerequisites:
Fundamentals of Physic and Astronomy at the level of the Bachelor Degree in Astronomy.
Short program:
1) Basic principles of optics and image formation: Nature of light and geometrical nature of thin lenses and of conical sections. Concept of stigmatic and non stigmatic imaging. Optical copies and Lagrange invariant. Relevance of the position and size of the stop in an optical system and its effects on the overall property.
2) Two mirrors telescope: Schwarzschild, Cassegrain, Gregorian and Ritchey-Chretienne solutions. The problem of the background in astronomical imaging and in particular in the infrared. Definition of the thermal and non-thermal infrared portion of the spectra. Vignetting and field of view in Cassegrain telescopes. Difference between images formed by parabolic and spherical mirrors and the case of Arecibo-like design. Examples of telescopes and instrumentation employing the various concepts devised.

3) Adaptive and active optics. Basic definitions, Kolmogorov turbulence and isoplanatic angle, Fried's parameter and Greenwood frequency. Deformable mirrors and wavefront sensors in open and closed loop operations. Tip-tilt four quadrants sensing and Poissonian nature of photons effect on them. 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. Adaptive optics with multiple field of views.
4) Detectors: Charge Coupled Devices Detectors, principles of working and basic parameters. Quantum efficiency, charge transfer efficiency, read out noise. CCD principle of working and effects on the Poissonian apparent noise. Concept of the avalanche photo diodes and quenching.
5) Experiments in the optical laboratory: Poisson's spot, turbulence simulation and speckle formations.
6) Observations at the Asiago Astronomical Observatory: Speckle interferometry.
Examination:
Oral exam about the topics discussed in the lectures.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1173/000ZZ/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:
The course is given for both students of the Master Degree in Astronomy and Master Degree in Mathematical Engineering. Topics in sections 4) and 5) are only students of the Master Degree in Astronomy, whereas topics in section 6) are only for students of the Master Degree in Mathematical Engineering.
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, Poincaré 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,
Lyapunov orbits, the tube manifolds.
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.
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 with open questions and exercises on the topics discussed during lectures.

More information:

https://en.didattica.unipd.it/off/2018/LM/SC/SC1173/000ZZ/SCN1032593/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 exam. The student can choose either English or Italian language. During 20-30 minutes, the student will be asked to expose briefly and rigorously some topics and to make connections among involved topics.

More information:

https://en.didattica.unipd.it/off/2018/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:

https://en.didattica.unipd.it/off/2017/LM/SC/SC1169/000ZZ/SC01102528/N0

COMPUTER SCIENCE

ADVANCED TOPICS IN COMPUTER SCIENCE

Master degree in **Computer Science** , Annual

Lecturer: To be defined

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:

Instructor assignments.

More information:

https://en.didattica.unipd.it/off/2018/LM/SC/SC1176/000ZZ/SCP6076301/N0

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

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 articulated into three parts: 1) a practical session in which the student must describe a project of data analysis, that must be submitted at least two days before the date of the exam, 2) a quiz session on Moodle, that will take place at the beginning of the exam day, 3) an oral discussion in which the student must describe his/her project and answer questions on the topics of the course. A continuous process of assessment will be carried out throughout the course, to verify the level of understanding of the students.
More information:
https://en.didattica.unipd.it/off/2018/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: Lamberto Ballan
Credits: 6 ECTS
Prerequisites:
The student should have basic knowledge of programming and algorithms. It is also advisable to be familiar with basic concepts in probability and analysis of multivariate functions.
Short program:
The course will cover the topics listed below:
- Introduction:
From human cognition to 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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1176/000ZZ/SCP7079279/N0

COMPUTER AND NETWORK SECURITY (ALSO OFFERED FOR STUDENTS OF THE MASTER DEGREE IN DATA SCIENCE)

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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1176/000ZZ/SCP6076342/N0

FUNCTIONAL LANGUAGES

Master degree in **Computer Science**, First semester
Lecturer: Gilberto Filè
Credits: 6 ECTS
Prerequisites:
Imperative and object oriented programming.
Short program:
The course introduced the functional language Haskell. In particular the following aspects are studied:
Pattern matching.
Curryfied and higher-order functions.
Type inference: what it is and how it is done.
I/O.
Parametric polymorphism.
Lazy evaluation.
Functors, applied functors and monads.
Run-time support.
Parsing with Monads
Examination:
The exam has a written and an oral part. The written part counts for 80% of the final grade and concerns the concepts and exercises studied during the course. The oral part is a discussion about the project that consists of a parser for a functional language.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1176/000ZZ/SCP6076299/N0

METHODS AND MODELS FOR COMBINATORIAL OPTIMIZATION (ALSO OFFERED FOR STUDENTS OF THE MASTER DEGREE IN DATA SCIENCE)

Master degree in **Computer Science**, First semester
Lecturer: Luigi De Giovanni
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:
https://en.didattica.unipd.it/off/2018/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 – Moises Di Sante
Credits: 6 ECTS
Prerequisites:
Basic knowledge of optimization methods and machine learning. Python programming language.
Short program:
The course consists of two parts:
1) Introduction to living matter (2 credits):
1.1) Introduction to organic chemistry, weak interactions and energy
1.2) Structure and function of DNA and proteins
1.3) Lipids, membranes and cellular transport
1.4) Experimental methods for structure determination
2) Computational Biochemistry (4 credits):
2.1) Biological Databases
2.2) Software libraries and concepts for sequence alignments and database searches
2.3) Sequence - structure relationship in proteins and structural classification
2.4) Methods for the prediction of protein structure from sequence, the CASP experiment
2.5) Methods for the prediction of protein function and interactions, the CAFA experiment
2.6) Non-globular proteins, disorder and structural repeats
Examination:
The exam covers three separate parts, which have to be all passed: (relative weights in parenthesis)
1) Written test of the biochemistry concepts (ca. 30%)
2) Software project (ca. 40%)
3) Project presentation and critical evaluation (ca. 30%)
https://en.didattica.unipd.it/off/2018/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:
Students are evaluated through individual/team projects and oral finals focused on all the topics discussed in class.
More information:
https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1179/000ZZ/SCN1031442/N0

EVOLUTION AND CONSERVATION

Master degree in **Evolutionary Biology**, First semester
Lecturer: Andrea Augusto Pilastro – Leonardo Congiu
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:

https://en.didattica.unipd.it/off/2017/LM/SC/SC1179/000ZZ/SCO2043741/N0

PHILOSOPHY OF BIOLOGICAL SCIENCES

Master degree in **Evolutionary Biology**, First semester
Lecturer: Dietelmo Pievani
Credits: 8 ECTS

Prerequisites:

Prior knowledge needed for the classes in Philosophy of Biological Sciences is that normally provided for students at the third year of the first degree (mainly in Biology, but not only). Particularly, the basic understanding of Evolutionary Biology, in its fundamental principles and processes, is required. Students should also have sufficient and basic capacities for argumentation and expression, enabling them to defend a thesis and grasp the contents of a scientific debate, actively participating in the discussion of case-studies. The classes (in English) are primarily intended for students from the Department of Biology, but the involvement of students from other careers, such as particularly Philosophy, is not precluded. The construction of a heterogeneous class of students every year is indeed an asset, given the interactive teaching provided in the classes. However, for logistic reasons, students enrolled in degrees other than Evoliìutionary Biology and Philosophy, will be accepted until the capacity of the assigned room is reached.

Short program:

The course aims at deepening the fundamental concepts, principles and analytical methods of the philosophy of biology, according to current International debates, namely: types of explanation and inferences in biological sciences; notions of theory, hypothesis, empirical basis, model, falsifiability, parsimony, prediction; biological terminology; biological ontology; selection of models and probability; research protocols; logic of scientific discovery in life sciences; scientific controversies; defensive and argumentative strategies. These general objectives are addressed through critical discussion of case-studies - both historical and taken from primary scientific literature - in particular about Evolutionary Biology and the structure of evolutionary theory.

The general themes in philosophy of life science will also be developed through the analysis of the logic of scientific discovery in Charles Darwin's work, extrapolated from his unpublished private texts, such as the Notebooks of Transmutation, and the working papers that led to the peculiar argumentative structure of the Origin of Species in its six editions. Darwin's thoughts, assumptions and insights, in their typical theoretical pluralism, will become another starting point to discuss evolutionary issues debated in the scientific literature today. Among the others:

- Notions of "species";
- Tempo and mode of speciation (gradualism and punctuationism);
- Variation and inheritance;
- Evolution, ecology and biogeography;

- Functional factors and structural factors (adaptations and constraints) in evolutionary change;
- Common descent (Tree Thinking) and natural selection;
- Explanatory power of selective mechanisms;
- Units of evolution and levels of selection (the debate about the evolution of altruism);
- Relationships between ontogeny and phylogeny;
- The role of "chance" in evolution;
- Teleology and contingency;
- Darwin's risky predictions.

Examination:
Examination is oral and aims at the evaluation of both scientific and philosophical skills acquired, through open-ended questions and requests for argumentation and comparison of different theses and models. The examination (in Italian or in English) is divided into a common part and a monographic part. The common part includes textbooks, books and articles that provide a general overview of the contents of the discipline. The examination also provides the monographic choice, by the students, of one of the cases discussed during the classes, on which a specific study with further bibliography (usually two chapters of books or additional papers) is required. Attendance is strongly recommended, due to the teaching by interactive methods and case-studies. Students unable to attend a percentage of classes have to agree the schedule personally with the teacher.

More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1179/000ZZ/SCP3054388/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.

COURSE CONTENT:

1.Introduction
2.Nuclear physics and nuclear stability
3.Radioactivity
4.Nucleosynthesis: when, where and how chemical elements are formed?
5.Principles of stable isotope geochemistry
6.Mass-balance calculations
7.Tracing the hydrologic cycle with stable isotopes
8.Radioactive decay and geochronometry
9.The Rb-Sr method
10.The Sm-Nd method
11.The Lu-Hf method
12.The U-Pb, Th-Pb and Pb-Pb methods

Examination:

Course learning goals will be assessed by written examinations.

More information:

https://en.didattica.unipd.it/off/2018/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.

In particular, the course deals with the application of petrographic methods to the study of ornamental and dimension stones, ceramic materials and artificial building materials. This course is therefore organised in the following parts:

1. Ornamental and dimension stones: quarrying activity, properties, durability; ageing and quality control for dimension stones; physical-mechanical properties; determination of compressive, flexural, tensile and shear strength; abrasion resistance, water absorption, etc. Decay of stone, description of alteration. Stone restoration: cleaning, strengthening, waterproofing.
2. Ceramic materials: traditional ceramic materials and archaeometric investigations. Reference groups, recognition of the source area for the raw materials or the production.
3. Non-hydraulic and hydraulic binders: mortar, plaster, gypsum, cement, aggregate, pigments.
4. Analytical methods for archaeometry and age determination in artefacts.

Examination:
Oral test.
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1180/000ZZ/SCP3051232/N0

APPLIED SEDIMENTARY GEOLOGY

Master degree in **Geology and technical Geology**, First semester
Lecturer: Massimiliano Ghinassi – Claudia Agnini – Anna Breda – Andrea D'Alpaos – Nereo Preto – Cristina Stefani
Credits: 6 ECTS
Prerequisites:
Basic concepts of geology (structural geology, geodynamic settings, lithology (different types of rocks) and geomorphology (geomorphic configuration of the main depositional environments). Complete view of the main geological processes and main basics of geology, geomorphology, sedimentary geology and paleontology. Comprehensive knowledge of sedimentology (depositional dynamics and stratal architecture of different depositional environments), lithology and sedimentary petrography (sedimentary rocks and sediments, optical microscope analyses), paleoecology and biostratigraphy (fossil determination and biostratigraphic meaning), carbonate petrography and geochemistry (biomineralizations, geochemetry of stable isotopes)
Short program:
The course will be based on a multidisciplinary approach and will be developed on the analyses of data collected in the frame of a 3-days excursion, which will be held within the first two weeks of the course.
Content of the course will be as follows:
Introduction to the main geomorphological, geological and stratigraphic features of the selected study area (credits 0.25)
Introduction to the research program (goal of the study and schedule) and summary of the main research methodologies (credits 0.5)
Field activities and data collection (credit 1)
Sedimentology (credit 1): facies analyses and reconstruction of depositional dynamics, architectural analyses and definition of 3D sedimentary bodies, summary
Sedimentary petrography (credit 1): sediment characterization, provenance analyses, summary
Paleoecology and biostratigraphy (credit 1): determination of fossil content, biostratigraphy and ecobiostratigraphy, paleoenvironmental reconstruction, summary
Carbonate petrography and geochemistry (credit 1): biomineralizations, sclerochronology, trace elements and stable isotope geochemistry, summary
Integration of the acquired datasets and final summary (credits 0.25)
Examination:
Written test. The test will be based on interpretation and elaboration (written report) of specific datasets, which will be provided consistently with the topics of the course.

More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1180/000ZZ/SCP8083422/N0

BASIN ANALYSIS
Master degree in **Geology and technical Geology**, Second semester
Lecturer: Massimiliano Zattin – Nereo Preto
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) Appication to petroleum industry.
8) Seismic reflection basics.
9) Geometric characterization of seismic reflectors and seismic facies; seismic surfaces; seismic sequences and units.
10) Seismic interpretation of rifting, passive margin and foreland settings.
11) Sequence stratigraphy applied to seismic interpretation.
Examination:
The exam is divided into two parts. Evaluation of the first one (chapters 1-7, see below) is provided by a written examination with open questions. Chapters 8-11 are evaluated through a practical test (i.e. interpretation of a seismic line). The student is asked to give a geological interpretation that includes the main deformation events and the type of sedimentary basin.
More information:
https://en.didattica.unipd.it/off/2018/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. Having taken, or being taking "Sedimentology" is recommended.
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;
- sequence stratigraphy of carbonates.

Examination:
The marking is based on two documents: a mid-term report based on class excercises and a final exam.
The report is the interpretation of a carbonate depositional system, presented as a idealized geological cross section of a carbonate platform, which is being studied during the course.

The final exam is a written test, which requires to answer briefly, with a short text or with geological sketches, to open questions.
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1180/000ZZ/SCP5070180/N0

METAMORPHIC PETROLOGY

Master degree in **Geology and technical Geology**, First semester
Lecturer: Bernardo Cesare
Credits: 6 ECTS
Prerequisites:
In order to take full advantage of the course and be able to fully follow the classes the student will already have basic knowledge of petrography, geochemistry and mineralogy, as well as of english.
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:
The acquired knowledges and skills will be assessed through an oral examination in english
More information:
https://en.didattica.unipd.it/off/2017/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:
The course can be subdivided in three main parts:
- History of micropaleontology and its position in the context of the geological sciences. Its developments and the importance of deep-sea drilling projects. (0.5 CFU)
- "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. (3.5 CFU)
- 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, ...). A daily field excursion is also proposed (2 CFU).
Examination:

The knownledge acquired during the course is checked by means of
-a practical test in which the students analyse a micropaleontological sample.
-an oral examination during which the concepts, the scientific terminology, the syntesis ability and the critical spririt are evaluated.
More information:
https://en.didattica.unipd.it/off/2018/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
Prerequisites:
Basic mathematics and physics (Calculus 1 and 2, Experimental Physics).
Short program:
- Morphodynamics and biogemorphodynamics. Short introduction to coastal systems and to their morphodynamic evolution in response to physical and biological forcings (0.5 credits).
- Relative sea level and its variations. Tides, waves, currrents, and sediment transport processes in shallow water systems (1.5 credits)..
- Morphology and evolution of lagoons, deltas, and estuaries (2.5 credits).
- A case study: The Venice Lagoon and its morphological evolution during the past centuries. Will Venice survive? (0.5 credits).
- General effects of a rising sea level. Natural and anthropogenic forcings. Effects of a changing climate. Effects on lagoons, deltas, and estuaries (1.0 credit).

Examination:
Written and oral exam.
More information:
https://en.didattica.unipd.it/off/2017/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 knowledge of mathematics, physics and MatLab (provided during the first cycle degree in Geological Sciences)
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. Diffusion equation
4. Stress, strain and strain rate tensors and constitutive relationships.
5. Visco-elasto-plastic deformation
6. Conservation of mass
7. Conservation of momentum
8. Conservation of energy
9. Numerical method: finite difference with particle-in-cell (mixed Eulerian-Lagrangian scheme)
10. Solution of systems of equation with iterative (Gauss-Siedel) ir direct (Gauss elimination) methods.

Examination:
Oral and practical test.

More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1180/000ZZ/SCP4065499/N0

PALEOCLIMATOLOGY AND PALEOCEANOGRAPHY

Master degree in **Geology and technical Geology**, First semester
Lecturer: Luca Capraro
Credits: 6 ECTS
Prerequisites:
Basic knowledge acquired during the BSc course (general geology, sedimentary geology, paleontology, geomorphology...)
Short program:
Climate: defintions. The components of the climate system. Feedbacks and synergies. Climate thresholds and their reversibility. "Historical" approaches to the study of past climates. Climate forcing. Insolation and its effects on climate: energy balance of a perfect Blackbody radiator at changing CO_2 concentrations in the atmosphere. The hydrosphere. Water masses. Anatomy of the oceans: marine currents, vertical and horizontal flows. The global circulation system. Circulation in the Mediterranean basin: genesis of the main water masses and basin budgets. The atmosphere. Ocean-atmosphere coupling. The monsoon system: origins and outcomes. The main short-term climate oscillations (AO, NAO, AMO, ENSO). Archives of past climates: trees, corals, ice caps, sediments.
Climate proxies. Stable isotopes: basics of isotope fractionation. Isotopic standards and the δ notation. Stable oxygen isotopes. Equilibrium fractionation in the water cycle. Rayleigh distillation: latitude and altitude effects. Stable oxygen isotopes as paleothermometers. Paleotemperatures and the glacial effect. Isotope stratigraphy (MIS). Stable carbon isotopes. Carbon reservoirs and flux mechanisms. The geochemical carbon cycle: hydrolisis and dissolution of rocks. The biochemical carbon cycle: d13C and life. d13C in the oceans: vertical and horizontal distributions.
Systems theory: linear and chaotic systems. The Poincaré problem and Lorenz attactor. Lyapunov time and the stability of the solar system. The minkavovian theory of climate. Spectral analysis: periodograms and wavelets. The Pleistocene System, a paradigm of natural climate changes: evolution of climate cycles and glacial dynamics. Forcing-response variability: consistency and inconsistencies. Hypotheses on the onset/demise of major glacial cycles in the Pleistocene. Mediterranean sapropels and their chronostratigraphic distribution: an independent tool for dating stratigraphic successions. Astrochronology and astrocyclestratigraphy. History of climate. The key climatic events in the geologic past: the Great Oxygenation Event, the Snowball Earth, the Createceous hyperthermal period. Climate during the Cenozoic: from the Greenhouse world to the Quaternary glaciations. High-frequency climate variability: Dansgaard-Oeschger cycles, Bond cycles, Heinrich events. The "Climate surprises”.
Examination:
Students' preparation will be ascertained by means of an oral, open-question exam, in order to gauge their ability to engender connections between different subjects and to establish critical and original approaches to the matter in question.
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1180/000ZZ/SCM0018542/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 (0.5 CFU)
- The source rock, maturity of organic matter and petroleum migration (1 CFU)
- The seal rock (0.5 CFU)
- Reservoir geology, stratigraphic traps, structural traps (2 CFU)
- Main exploration and production techniques (1 CFU)
- Hydrocarbon reserves in Italy and in the World (1 CFU)

Examination:

Written examination with essay questions.

More information:

https://en.didattica.unipd.it/off/2018/LM/SC/SC1180/000ZZ/SCP3051098/N0

SEDIMENTOLOGY

Master degree in **Geology and technical Geology**, Second semester

Lecturer: Massimiliano Ghinassi

Credits: 6 ECTS

Prerequisites:

Basic concepts of geology (structural geology, geodynamic settings, lithology (different types of rocks) and geomorphology (geomorphic configuration of the main depositional environments).

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 (credits: 0.2)

- facies and facies associations
- textural features of sediments, stratal geometries and terminology

Sediment transport/deposition and post-depositional modifications (credits: 1.8)

- tractional transport from unidirectional currents
- tractional transport from oscillatory currents
- mass transport
- soft-sediment deformations
- icnofossils

Depositional environment (credits: 2.5)

- 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 (credits: 0.5)

- base level and accommodation space
- systems tracts
- sequences
- incised valleys
- non-marine sequence stratigraphy

Examination:

Written test with open questions on the main themes illustrated in the frame of the course (processes of sediment transport, depositional environments, sequence stratigraphy)

More information:

https://en.didattica.unipd.it/off/2018/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

Prerequisites:
No specific preprequisites. Students should have a general background in basics of plant biology and biotechnology

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, Hg2+, Pb2+).
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:
The evaluation consists of two parts:
1. Presentation and critical analysis of some recent scientific papers.
2. written test on the class contents

More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1731/000ZZ/SCO2044108/N0

ENVIRONMENTAL CHEMISTRY AND GENETIC TOXICOLOGY

Master degree in **Industrial Biotechnology**, Second semester
Lecturer: Paola Venier – Silvia Gross
Credits: 8 ECTS

Prerequisites:
Essentials of general, inorganic and organic Chemistry, Biology and Genetics

Short program
The following contents will be expanded or reduced according to the student's skills and interest.
Part A (CHIM).
Introduction to the environmental chemistry and geobiochemical cycles. Evaluation of the pollutant distribution and transfer in the atmosphere, hydrosphere and lithosphere (0.5 CFU). Radioactivity: principles and chemistry of radiations; ionizing and non-ionizing radiations. Types of radioactive decay (1 CFU). Atmosphere: chemistry and atmospheric pollutants; photochemical smog; role of chemical substances in the ozone layer depletion; greenhouse effect; inorganic gaseous pollutants; organic pollutants, particulates (1 CFU).

Hydrosphere: chemico-physical properties of water and water-based ecosystems; features, transport and chemical behaviour of inorganic and inorganic pollutants; contamination of natural waters; 'heavy' metals and their transport; colloids (1 CFU)
Lithosphere: soil composition and chemistry with special attention to pesticides, herbicides and 'heavy' metals (0.5 CFU).
Part B (BIO).
Variety of toxic agents and possible adverse effects at different levels of biological organization. Toxicokinetics and toxicodynamics (hints). Biological targets, measures of exposure, effect and susceptibility. Dose-response with/without threshold, hormesis. Hazard, risk, harm. Safety/precautionary symbols and regulations. Criteria for the identification of toxic agents and their characterization with traditional and innovative methods (1.5 CFU).
Effects and responses induced by non-ionizing and ionizing radiations. Dose units. Adaptive response, bystander effect, radio-resistance in cancer cells and in extremophilic bacteria (1 CFU). Genetic activity profiles, examples of the action mode of toxic chemicals (0.5 CFU). Practical experience in laboratory (1 CFU).
Examination:
The exam will be a verbal interview on Part A (CHIM, 4 CFU) and Part B (BIO, 4 CFU). For Part B, the student will also debate a topic (toxic agent, biological process in terms of function/ dysfunction, investigation method) agreed with the professor during the course and based on the scientific literature. Effective reporting of biotechnological aspects will be positively evaluated.
More information:
https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2017/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 of cellular and molecular biology and of biochemistry.
Short program:
1) 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. How to calibrate oxygen, pH, nutrients and metabolites, cell density and viability in the bioreactor. Design of cell culture medium without serum and with low content of proteins.
2) Design of large scale cell culture process for mammalian cell culture. How to improve cell viability in a process. 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). Scaffold and matrix in bioreactors. 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 vaccines.
3) Large scale Embryonic and adult stem cell cultures and their application in cell therapy.
4) 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.
Examination:
The final exam will be oral and organized in two parts. Students will be evaluated collegially by both professors on the knowledge acquired on all the material proposed during the course. First part (5 CFU) is described in the course contents at section 1, 2 and 3. The second part (3 CFU) is described in the course content at section 4. The final grade is expressed as a weighted average between the two parts.
More information:
https://en.didattica.unipd.it/off/2018/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. Basic background in anatomy/physiology, cell biology and protein biochemistry.
Previous attendance of the "Nanosystems" course (previous 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 oral exam. The oral exam consists in an 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 40 minutes.
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1731/000ZZ/SCO2044101/N0

NANOSYSTEMS
Master degree in **Industrial Biotechnology**, Second semester
Lecturer: Sabrina Antonello – Sara Bonacchi
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. Each test consist usually in four open questions that could require to draw graphs, report equations and make simple calculations.
More information:
https://en.didattica.unipd.it/off/2018/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:
Knowledge of instrumental analysis: molecular spectroscopy (UV-Vis and infrared spectroscopies), electroanalytical chemistry (potentiometry and voltammetry), gas-chromatography and high-performance liquid chromatography, mass spectrometry.
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. Multidimensional chromatography. Applications of GC and multidimensional GC in the petrochemical industry.
5) Optical spectroscopy for process analyses. Infrared and Raman spectroscopy:

instrumentation design and sampling interface. Practical examples of IR and Raman analytical applications in the pharmaceutical industry.
6) On-line analysis with mass spectrometry. Application in process control and monitoring in the food industry.
7) Principles of chemical sensors. Origins of sensor selectivity: thermodynamic and kinetic aspects. Types, preparation and properties of sensors.
8) Electrochemical sensors. Potentiometry and ion-selective electrodes. Ion-sensitive field-effect transistors (ISFET). High-temperature potentiometric oxygen sensor in combustion process monitoring. Amperometric sensors and biosensors. Applications of electrochemical sensors in bioprocess monitoring and control.
9) Conductometric sensors. Resistive and capacitive gas sensors. Impedance humidity sensors.
10) Optical sensors. Optical fibers as a basis for optical sensors. Optical ion sensors and immunosensors.
11) Automated methods of analysis. Flow injection analysis and applications in industrial biotechnology.
12) Microanalytical systems. Overview of miniaturization of analytical instruments utilizing microfabrication technology. Application of lab-on-chip detection techniques in bioanalytical studies.

Examination:

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

More information:

https://en.didattica.unipd.it/off/2018/LM/SC/SC1170/000ZZ/SC02119324/N0

BIOPOLYMERS

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

Prerequisites:

None beyond the requisites for admission to the Master's course.

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. Sequencing and synthesis of polypeptides. 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.
3) Industrial production of proteins
PCR. Main molecular biology techniques for the production of proteins. Industrial applications.
4) Polysaccharides

Chemistry and stereochemistry of structural units of polysaccharides. Structures of monosaccharides, disaccharides, homopolysaccharides, heteropolysaccharides. Mention of the structure of some peptidoglycan.
5) 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.
6) Analytical techniques for the study of the structural properties of biopolymers.
Characterization and separation of biopolymers on the basis of their hydrodynamic properties: ultracentrifugation, electrophoresis, light scattering, size exclusion chromatography.
Spectroscopy applied to the study of biopolymers: UV-Vis, circular dichroism, IR, fluorescence, MS.
Examination:
The exam is oral and consists in a discussion over the properties, the production, the experiments and the instrumental techniques to study one of the classes of biopolymers described in the lectures.
More information:
https://en.didattica.unipd.it/off/2017/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:
https://en.didattica.unipd.it/off/2017/LM/SC/IF0360/000ZZ/SCO2046334/N0

MARINE MICROBIOLOGY
Master degree in **Marine Biology**, First semester
Lecturer: Paola Venier
Credits: 6 ECTS
Prerequisites:

Essentials of Microbiology, Biochemistry, Genetics.
Short program:
The course contents could be modulated according to the starting knowledge and curiosity of the students.
Introduction to Marine microbiology. Main types of marine microorganisms in relation to the variety of habitats and dynamic features of seas and oceans. Investigation methods in the time (e.g. cultures, microscopy, flow cytometry, biochemical typing, analyses based on the identification of nucleic acids and proteins) (1 CFU).
Marine Bacteria and Archea: molecular diversity, examples of morpho-functional features (1 CFU)
Marine microeukaryotes, marine viruses: molecular diversity, examples of morpho-functional features (1 CFU).
Metabolic types, ecophysiology and interactions in marine microorganisms, with attention to: production/decomposition of particulate (POM) and dissolved (DOM) organic matter, microbial and viral loops, biogeochemical cycles (1.5 CFU). Microbial biofilms. Quality assessment of coastal waters: microorganisms pathogenic to humans and current regulations. Biotechnological potential of marine microorganisms (0.5 CFU).
Practice in laboratory and informatics rooms (1 CFU).
Examination:
Depending on the number of listed students, the exam will be a written questionnaire (up to 20 answers to be completed /multiple-choice /free-text) or a comprehensive interview on the general course concepts and specific topics proposed to the class.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/IF0360/000ZZ/SCN1031841/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:
https://en.didattica.unipd.it/off/2018/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:
Elementary notions of quantum physics and solid state physics.
Fundamentals of thermodynamics: principles, thermodynamic potentials.
No prior knowledge of computer programming is required.
Short Program:
Basic concepts of thermodynamics and classical statistical mechanics.
Classical Molecular Dynamics simulations; numerical integration of Newton equations.
Monte Carlo method; Metropolis algorithm.
Simulations in various statistical ensembles.
Common features of simulations methods: initial and boundary conditions; calculation of inter-particle interactions.
Calculation of thermodynamic and transport properties.
Intermolecular interactions: force-fields; atomistic and coarse grained models.
Variational methods for the solution of the Schrodinger equation.
Hartree and Hartree-Fock theory.
Elements of Density Functional Theory (DFT).
'First principles' simulations.
The different computational methods will be discussed in relation their application to topics of interest for material science (crystals, surfaces, soft matter, nanostructured materials).
In the computer exercises, students will carry out simple simulations, using open-source software packages of current use in materials science, and will learn how to interpret and present the results of simulations.
Examination:
Oral examination in which the students will discuss written reports, on the results of three numerical simulations (Monte Carlo, Molecular Dynamics and DFT calculations).
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1174/000ZZ/SC01122974/N0

FUNDAMENTALS OF NANOSCIENCE (ALSO OFFERED FOR STUDENTS OF THE MASTER DEGREE IN PHYSICS)

Master degree in **Materials Science**, Second semester
Lecturer: Giovanni Mattei – Stefano Agnoli – Moreno Meneghetti
Credits: 8 ECTS
Prerequisites:
Quantum Physics (particle in a box, quantum confinement), Solid State Physics (phononic and electronic structures of solids, thermal and optical properties)
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:
The exam is written (duration 2 h) with two open questions and a set of multiple-choice questions.
*** Mutuation ***
The exam is written (duration 2 h) with an open question and an exercise with numerical applications of the learned topics.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1174/000ZZ/SCO2045511/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
Resolutions vs. throughput
Lithographs tridimensioni
Combinations of lithographs
FIB (Focused ion beam)
Resist less
Mask less lithography
First type of lithography
Resist
Introduction to resist: ownership 'and lithographic process
types of resist
Processes on the resist
Spinning
Baking

Dose and development
Contrast, resolution,
Litographic sensibility
Photochemical Quantum efficiency
Plasma etching resistance
Electron beam lithography
Electron sources
Vector scan
Beam blanking
Interaction with electron beam
Energy dependence
Proximity effects - dose correlation
Resolution limit
Exposure time
Stitching
Overlay
Single LEVEL- multi levels
Examples
Generality 'on lithographic techniques parallel
Replica of pattern
Masks
Molds
UV lithography
UV lithography proximity '
UV lithography far field
Optical lithography
General principles
Diffraction
Interference Lithography
Principle of 'interference
Mode '
Property '
X-ray lithography
LTX proximity '
X-ray lithography far field
Deep X-ray
Next generation Deep EUV
Alignment and exposure
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:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1174/000ZZ/SCL1000406/N0

OPTICS AND LASER PHYSICS
Master degree in **Materials Science**, First semester
Lecturer: To be defined
Credits: 6 ECTS
Prerequisites:
Topics learned in basic courses of Mathematics and Physics.

Short program:
Classical optics:
- propagation of electromagnetic waves;
- polarization, birefringence, interference and diffraction;
- geometrical optics and matrix method; main optical instruments;
Lasers:
- the laser idea and proprieties of laser beams;
- absorption, spontaneous emission, stimulated emission;
- gain and population inversion;
- optical cavities and pumping;
- cw lasers;
- pulsed lasers: Q-switch and mode-locking;
- examples of main different laser types: gas lasers, solid-state lasers
Introduction to Quantum Optics:
- Photon statistics
- buching and antibuching;
- weak and strong coupling: Purcell effect and Rabi splitting.
Examination:
Written exam with numerical exercises to be solved and an open question on a specific topic presented during the course.
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1174/000ZZ/SCN1037878/N0

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:
https://en.didattica.unipd.it/off/2017/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:
nomenclature of organic molecules, organic functional groups
electrofile and nucleofile
basicity and acidity
addition reactions (alkenes)
nucleophilic substitution (alcohols, halogenated compounds)

Electrophilic aromatic substitution (reactions of aromatic compounds)
Pericyclic reactions
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 exam.
six questions
two hours time
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1174/000ZZ/SC01122969/N0

PHYSIC AND TECHNOLOGY OF SEMICONDUCTORS
Master degree in **Materials Science**, First semester
Lecturer: Davide De Salvador
Credits: 8 ECTS
Prerequisites:
Mathematical prerequisites:
Continuous functions. Derivatives. Fundamental theorems of differential calculus. Relative and absolute maxima and minima. Exponential and logarithmic trigonometric functions. Study of a function. Definite integrals. Solid volumes of rotation. Taylor and Maclaurin series. Complex numbers. Exponential in the complex field. Differential equations. Linear differential equations of first order and second order. Functions of multiple variables. Limitations. Partial derivatives. Maximum and minimum relative. Saddle points. Double integrals in polar coordinates. Solid volumes. Triple integral. Vector differential calculus: flow of a vector field across a surface. Divergence of a field and divergence theorem.
Basic Physics Prerequisites
Coulomb's law. Electrostatic field. Electrostatic potential. Gauss's law. Poisson and Laplace equations. Capacity; ideal capacitor. Dielectric constant. Electrical currents and current density. Conservation of the charge. Ohm's law. Joule effect. Magnetic field; Lorentz force.
Quantum Physics Prerequisites :
Light quanta and photo-electric effect. Wave packs. The Heisenberg uncertainty principle. Shroedinger equation particle in a box. Quantum harmonic oscillator. Expectation values. Observables and operators. Quantum uncertainty and properties of eigenvalues. Square barrier tunnel effect. Penetration of the barrier. Particle in a three-dimensional box. Hydrogen atom and hydrogen atoms: fundamental state and excited states. Periodic table. Maxwell-Boltzmann distribution and density of states. Energy provision. Quantum statistics: Bose-Einstein and Fermi-Dirac distributions
Solid state physics Prerequisites
The crystalline structure of solids: the direct lattice and the reciprocal lattice. Phonons. The electrical conductivity of metals in the Drude model. Bloch's theorem.
Short program:
Review of the crystal structure of the main semiconductors. Elementary semiconductors , compounds and alloys.
Review of solid state basic concepts (Bloch theorem , effective mass , concept of hole) .
Origin and specificity of semiconductors band structure. The real bands (examples: GaAs , Si, Ge, AlGaAs) .
The envelope function method for the calculation of quantum states generated by aperiodic

potential.
The mechanism of doping. The carriers in a homogeneous semiconductor as a function of doping and temperature (semic. non-degenerate, intrinsic, ionized , partially ionized , in saturation). The compensation by deep level.
The semiconductor non-homogeneous equilibrium. The case of the p-n junction .
Charge transport in semiconductors. Drift -diffusion equation. Intraband scattering phenomena and mobility in a semiconductor.
The mechanisms of generation and recombination in a semiconductor.
The equation of continuity. The case of the p-n junction under polarization.
The heterojunction joints metal / semiconductor , metal / oxide / semiconductor.
The quantum confinement in semiconductor quantum well , quantum wire , quantum dot .
LEDs , GaN based LED, photodetectors. Solid state laser architectures, quantum confinement effect on lasering. Photovoltaic cells. Different architectures and materials for photovoltaics. Efficiency. Mechanisms of loss of efficiency . Thin-film cells.
Produttive.Transistor bipolar and FET technologies . MOS structure.
Doping techniques. Ion implantation. Diffusion and defect .
Insulation, thermal oxidation.
Moore's Law and scaling. Issues and new materials.

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

More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1174/000ZZ/SC01122935/N0

MATHEMATICS

ADVANCED ANALYSIS

Master degree in **Mathematics**, First semester
Lecturer: Franco Rampazzo – Giovanni Colombo
Credits: 8 ECTS

Prerequisites:
Basic real and functional analysis

Short program:
Fixed point theorems by Brouwer and Schauder, with applications; the hairy ball theorem.
Gateaux and Fréchet differentiability. The differential of the norm in L^p spaces.
Ekeland variational principle with some applications (Banach fixed point theorem; Bishop-Phelps theorem; local inveribility of smooth functions in infinite dimensional spaces).
An introduction to Convex analysis: regularity of convex functions ; subdifferential and normal vectors to convex sets; the convex conjugate; convex minimization problems and variational inequalities.
An introduction the the mathematical Control Theory. Closedness of the set of trajectories under convexity assumptions; existence of optimal controls for minimum problems. Set separation and cone (non-)transversality as basic tools for abstract constrained minimization.
Optimal Control.
Nonlinear ordinary differential equations and transport of vectors and co-vectors.
Necessary conditions for constrained minima. Pontryagin Maximum principle.
Families of vector fields and controllability of control systems. Theorem di Rashewskii-Chow.

Examination:
An oral exam on the topics covered by the course, that may include doing some simple exercises.

More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1172/010PD/SCP6076557/N0

ALGEBRAIC GEOMETRY 1

Master degree in **Mathematics**, Second semester
Lecturer: Orsola Tommasi
Credits: 8 ECTS

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

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

Examination:
Written exam.

More information:
https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1172/010PD/SCP3050935/N0

COMPLEX ANALYSIS

Master degree in **Mathematics**, First semester
Lecturer: Pietro Polesello
Credits: 6 ECTS

Prerequisites:
- Undergraduate courses in Calculus and Geometry
- Elementary notions on complex functions of one complex variable. In particular:

Cauchy-Riemann identities and complex differentiation; holomorphic functions. Line integrals of complex functions and their homotopy invariance.
Logarithm of a path and winding number. Cauchy formula for a circle. Analiticity of holomorphic functions.
Zero-set of a holomorphic function; the identity theorem.
Laurent series and isolated singularities. Residue theorem and its use for the computation of integrals.
(All these notions will be recalled in the first lectures.)

Short program:
- The Argument principle and applications
- Conformal maps and the Riemann Mapping theorem
- The Schwarz reflection principle
- Runge's theory and applications
- Infinite products and the Weierstrass factorization theorem
- Partial Fraction Decompositions and Mittag-Leffler's theorem
- Principal ideals of holomorphic functions
- Some special functions (Gamma, Zeta)
- The Prime Number theorem

Examination:
Written exam (exercises, theoretical exercises, statements and proofs; duration: 2h30) with possible additional oral exam to improve the mark.

More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1172/010PD/SCN1037789/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 (congruences, groups and cyclic groups, finite fields), Calculus (differential and integral calculus, numerical series) both for the BA in Mathematics.

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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1172/010PD/SC04111836/N0

FUNCTIONS THEORY

Master degree in **Mathematics**, First semester
Lecturer: Davide Vittone
Credits: 8 ECTS
Prerequisites:
Besides the courses of Analysis 1 and 2, the courses of Real Analysis and Functional Analysis 1
Short program:
Between brackets we denote topics that might be skipped or exposed without proofs according to time availability and/or audience interests.
THEORY OF DISTRIBUTIONS
Definitions, derivatives in the sense of distributions, order of a distribution, compactly supported distributions, convolutions, tempered distributions, Fourier transform, applications.
SOBOLEV SPACES
Definition and elementary properties, approximation theorems, boundary trace and extension results, Sobolev-Gagliardo-Nirenberg, Poincaré and Morrey inequalities, compactness theorems, [capacity and fine properties of Sobolev functions].
ELEMENTS OF GEOMETRIC MEASURE THEORY
Recap of some measure theoretical tools, covering theorems and differentiation of measures, Hausdorff measure and dimension, Lipschitz functions and Rademacher theorem, rectifiable sets, [approximate tangent space, area and coarea formulae].
FUNCTIONS WITH BOUNDED VARIATION
Definition, approximation and compactness results, [trace and extension theorems], coarea formula, sets with finite perimeter, [isoperimetric inequalities, reduced boundary and structure theorem for sets with finite perimeter, fine properties and decommposability of the derivative of a BV function]
Examination:
Home exercises (one exercise sheet for each of the four parts of the course), according to which a mark will be proposed to the student. An oral examination is optional.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1172/010PD/SCP3050963/N0

HARMONIC ANALYSIS

Master degree in **Mathematics**, Second semester
Lecturer: Massimo Lanza De Cristoforis
Credits: 6 ECTS
Prerequisites:

Analysis courses of the first two years, and preferably the following courses
Real Analysis
Mathematical Methods
Functional Analysis 1
and the basic properties of harmonic functions, which will be anyway brushed up.
Short program:
Preliminaries on function spaces
Integral operators with weakly singular and singular kernel
Applications to the analysis of potentials
Elements of potential theory
Applications to boundary value problems for harmonic functions.
Examination:
Partial tests and final oral exam
More information:
https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1172/010PD/SC03111814/N0

INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS

Master degree in **Mathematics**, First semester
Lecturer: Fabio Ancona – Francesco Rossi
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:
https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/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; basic Linear Algebra; a basic course of Calculus; a short course in Galois Theory would be most useful; some familiarity with the theory of analytic functions of one complex variable would be useful.

Short program:

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.

The whole material is to be found in the single textbook: Daniel A. Marcus "Number Theory", Springer-Verlag. The essential part of the program consists of Chapters 1 to 5, with those exercises which are used in the body of the textbook.

Chapters 6 and 7 are required to get a higher grade. The lengthy real-analytic proofs in Chapters 5/6/7 are not essential. A good understanding of the complex-analytic strategy is necessary.

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 1 or 2 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. The exam will be concluded by a final report on a topic chosen by the teacher that the student will prepare individually at home.

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:

https://en.didattica.unipd.it/off/2018/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:

The Homework exercices will be handed in weekly, there will be a midterm exam and written final.

More information:

https://en.didattica.unipd.it/off/2018/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:
https://en.didattica.unipd.it/off/2018/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 consisting in answering to questions from the theory and in solving exercises. Discussion of the composition and possible oral exam.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1172/010PD/SCL1001443/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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1172/010PD/SC02119743/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:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1172/010PD/SC03111819/N0

NATURAL SCIENCE

ANTHROPOLOGY

Master degree in **Evolutionary Biology**, Second semester
Lecturer: Luca Pagani
Credits: 6 ECTS

Prerequisites:

Prior knowledge needed for the classes in Anthropology is that normally provided for students at the final class of the first degree in Natural Sciences. Particularly, the basic understanding of Genetics, Statistics, Phylogeny, and Evolutionary Biology in their fundamental principles and processes, is required. Students should also have sufficient and basic capacities for argumentation and expression, enabling them to defend a thesis and grasp the contents of a scientific debate, actively participating in the discussion of case-studies. No prior knowledge is requested about specific contents in Population Genetics and Genomics.

Short program:

The course aims at deepening the fundamental concepts, principles and analytical methods of Molecular Anthropology within a broader international context. Particularly:
- early phases of human evolution with an overview on the available fossil remains (8h);
- genetic characterization of archaic humans (Neanderthals and Denisova) (4h);
- human expansions out of Africa and interactions with pre-existing archaic humans (4h);
- evidences of adaptive introgressions (genetic advantages derived from archaic genetic material) (2h);
- peopling of the continents (Eurasia, America, Oceania) (6h);
- dating of the divergence between various modern human populations (4h);
- genetic adaptation to the diverse environments encountered inside and outside of Africa (4h);
- how structured is the genetic diversity of our species (4h);
- demographic growth and expansion/admixture events following technological revolutions (i.e. Neolithic) (4h);
- patrilinear (Y chromosome) and matrilinear (mtDNA) perspectives on the diversification of modern populations (2h);
- brief overview on the DNA sequencing and genotyping techniques and analyses ;
- introduction to the ground-breaking consequences of ancient DNA (aDNA) in the field of Molecular Anthropology;
- succint exploration of satellite topics introduced by the students themselves through Journal Clubs on recently published articles (6h)

These general objectives are addressed through critical discussion of case-studies taken from primary scientific literature on Molecular Anthropology.

Examination:

Examination is oral and aims at evaluating the scientific skills acquired, through open-ended questions and requests for argumentation and comparison of different theses and models. The suggested reference books are meant to provide a general basis of knowledge which must be integrated with the material examined during the lectures as well as with the most recent scientific papers in the field of Molecular Anthropology (introduced during the lectures). If chosen by the candidate, the exam may start with the discussion of a specific scientific paper among the ones suggested by the teacher, followed by a discussion and additional questions on various topics from the lectures. Attendance is strongly recommended, due to the teaching by interactive methods and case-studies. Students unable to attend a sizeable number of classes must get in touch with the teacher before to discuss an adequate examination mode.

More information:

https://en.didattica.unipd.it/off/2018/LM/SC/SC1178/000ZZ/SCP8085142/N0

ENVIRONMENTAL IMPACT ASSESSMENT

Master degree in **Evolutionary Biology**, 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:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1178/000ZZ/SCP4063900/N0

SANITARY BIOLOGY

BIOCHEMISTRY OF DISEASES

Master degree in **Sanitary Biology**, First semester
Lecturer: Luca Scorrano – Marta Giacomello
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 overall active participation to classes and tutorials (30%)
Evaluation of the lab report (30%)
Evaluation of the final public presentation (40%)
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SC1177/000ZZ/SCP5073118/N0

HUMAN PHYSIOLOGY
Master degree in **Sanitary Biology**, First semester
Lecturer: Luigi Bubacco
Credits: 9 ECTS
Prerequisites:
The class requires previous knowledge of basic Biochemistry, cell Biology and General Physiology
Short program:
The Central Nervous System (8 hours)
Neurons: Cellular and Network organization and Properties,
Efferent Division: (10 hours) Autonomic and Somatic Motor Control. Sensory Physiology.
Muscles physiology (8 hours) Control of Body Movement
Cardiovascular Physiology (10 hours) Blood Flow and the Control of Blood Pressure and functional properties of Blood
Respiratory Physiology (8 hours) Mechanics of Breathing. Gas Exchange and Transport
The Kidneys (8 hours) Fluid and Electrolyte Balance
Digestion (8 hours) Energy Balance and Metabolism.
Endocrine Control of Growth and Metabolism (8 hours)
Reproduction and Development (8 hours).
Examination:
Written exam, four questions to be answered in two hours.
More information:
https://en.didattica.unipd.it/off/2018/LM/SC/SC1177/000ZZ/SCN1032657/N0

STATISTICAL SCIENCES
COMPUTATIONAL FINANCE
Master degree in **Statistical Sciences**, First Semester
Lecturer: Massimiliano Caporin
Credits: 9 ECTS
Prerequisites:
Not strinctly necessary but kindly suggested.
1) Basic elements of statistics for financial applications.
2) Basic elements of mathematical finance.
3) Basic knowledge of microeconomics and macroeconomics, knowledge of the Markowitz model, knowledge of the Capital Asset Pricing Model (CAPM).
The prerequisites at point 3) correspond to the content of the course of Economics of Financial Market taugth in the three-year degree in Statistica per l'Economia e l'Impresa.
Short program:
1. The Matlab suite: introduction and coding.
2. Basic Asset Allocation: Markowitz with and without the risk free; Markowitz under standard constraints.
3. Advanced Asset Allocation: Risk Budgeting; non-linear and cardinality constraints; penalization methods in the asset allocation framework;the Michaud approach for

resampling; Black-Litterman model; Chow-Kritzman model.
4. Backtesting and performance evaluation.
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. 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. 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:
https://en.didattica.unipd.it/off/2018/LM/SC/SS1736/000ZZ/SCP4063078/N0

STATISTICAL MODELS
Master degree in **Statistical Sciences**, Second Semester
Lecturer: To be defined
Credits: 9 ECTS
Prerequisites:
First year Unipd Master of Statistics courses,
especially Calcolo delle probabilità, Statistica
progredito
Short program:
Generalized linear mixed models
o Introduction to the course: basic ideas
o Generalized linear models: structure and inference
o Extending GLMs: First instances of models for hierarchical data
o Generalized linear mixed models
o Introduction to hierarchical models and to GLMMs
o Likelihood inference in GLMMs
o Bayesian Hierarchical Models
o Practical sessions with R and R-Bugs
Time series analysis
o Introduction. Linear time series models.
o Linear time series models: model specification.
o Linear time series models: parameter estimation and forecasting.
o Introduction to spectral analysis
o Nonlinear models: an introduction
o Nonlinear models: Markov-Switching Models and Threshold Autoregression Models
o Long-memory models. Integer AutoRegressive models
Spatial statistics
1. Introduction to spatial statistics:
2. Estimation and modeling of spatial correlations:
3. Prediction and Interpolation (kriging):
4. Spatio-temporal modeling:
5. Second order spatial models for network data:
6. Gibbs-Markov random fields on networks:
7. Simulation and estimation of a Markov random field on a network:
8. Hierarchical spatial models and Bayesian statistics:
Examination:
Written and oral exams.
More information:
https://en.didattica.unipd.it/off/2017/LM/SC/SS1736/000ZZ/SCP4063245/N0

THEORY AND METHODS OF INFERENCE

Master degree in **Statistical Sciences**, Second Semester
Lecturer: Alessandra Salvan
Credits: 9 ECTS

Prerequisites:

First year Masters courses of the Department of Statistical Sciences, especially Probability Theory and Statistics (Advanced).

Short program:

- Statistical models and uncertainty in inference. Statistical models. Paradigms of inference: the Bayesian and frequentist paradigms. Prior specification. Model specification (data variability). Levels of model specification. Problems of distribution (variability of statistics). Simulation. Asymptotic approximations and delta method.
- Generating functions, moment approximations, transformations. Moments, cumulants and their generating functions. Generating functions of sums of independent random variables. Edgeworth and Cornish-Fisher expansions. Notations $O_p(\cdot)$ and $o_p(\cdot)$. Approximations of moments and transformations. Laplace approximation.
- Likelihood: observed and expected quantities, exact properties. Dominated statistical models. Sufficiency. Likelihood: observed quantities. Examples: a two-parameter model, grouped data, censored data, sequential sampling, Markov chains, Poisson processes. Likelihood and sufficiency. Invariance properties. Expected likelihood quantities and exact sampling properties.

Reparameterizations.

- Likelihood inference: first-order asymptotics. Likelihood inference procedures. Consistency of the maximum likelihood estimator. Asymptotic distribution of the maximum likelihood estimator. Asymptotic distribution of the log-likelihood ratio: simple null hypothesis, likelihood confidence regions, asymptotically equivalent forms, non-null asymptotic distributions, composite null hypothesis (nuisance parameters), profile likelihood, asymptotically equivalent forms and one-sided versions, testing constraints on the components of the parameter. Non-regular models.
- Bayesian Inference. Non-informative priors. Inference based on the posterior distribution. Point estimation and credibility regions. Hypothesis testing and the Bayes factor. Linear models.
- Likelihood and Bayesian inference: numerical and graphical aspects in R. Scalar and vector parameter examples. EM algorithm.
- Estimating equations and pseudolikelihoods. Misspecification. Estimating equations. Quasi likelihood. Composite likelihood. Empirical likelihood.
- Data and model reduction by marginalization and conditioning. Distribution constant statistics. Completeness. Ancillary statistics. Data and model reduction with nuisance parameters: lack of information with nuisance parameters, pseudo-likelihoods. Marginal likelihood. Conditional likelihood. Profile and integrated likelihoods.
- The frequency-decision paradigm. Statistical decision problems. Optimality in estimation: Cram´er-Rao lower bound, asymptoticefficiency, Godambe efficiency, Rao-Blackwell-Lehmann-Scheffe theorem. Optimal tests: Neyman-Pearson lemma, composite hypotheses: families with monotone likelihood ratio, locally most powerful tests, two-sided alternatives, other constraint criteria. Optimal confidence regions.
- Exponential families, Exponential dispersion families, Generalized linear models. Exponential families of order 1. Mean value mapping and variance function. Multiparameter exponential families. Marginal and conditional distributions. Sufficiency and completeness. Likelihood and exponential families: likelihood quantities, conditional likelihood, profile likelihood and mixed parameterization. Procedures with finite sample optimality properties. First-order asymptotic theory. Exponential dispersion families. Generalized linear models.

- Group families. Groups of transformations. Orbits and maximal invariants. Simple group families and conditional inference. Composite group families and marginal inference.

Examination:

1/3 homework, 1/3 final written exam, 1/3 written and oral presentation rewiewing one or two recent research papers.

More information:

https://en.didattica.unipd.it/off/2017/LM/SC/SS1736/000ZZ/SCP4063245/N0