GALILEAN SCHOOL COURSES CATALOG

CLASS OF NATURAL SCIENCES

ACADEMIC YEAR 2019-2020
Calculus

Teacher: Francesco Rossi – UniPd – francesco.rossi@math.unipd.it

Motivations.
The course introduces tools of mathematical analysis for modeling. The goal is to be able to write equations describing natural phenomena and to derive the behavior of the resulting system.

Targeted audience.
First year students.

Prerequisites.
High-school mathematics: polynomials, first- and second-order equations, graph of a function...

Syllabus.
Introduction to mathematical modeling: models in demography, biology, engineering.
Infinitesimal calculus: functions, neighborhoods, the infinity, limits.
The derivative: intuition, definition, computation, primitives.
Differential equations: intuition, definition, use for modeling, existence and uniqueness, stability.
Models with one-dimensional differential equations: demography (Malthus, logistics, Allee), physics (evaporation, evolution of temperatures).
Models with higher-dimension differential equations: epidemics (SIS-SIR), population dynamics (predator-prey, competition), mechanical systems (pendulum, spring, viscosity phenomena).

Teacher CV.
I earned my Ph.D. in Applied Mathematics in 2009, jointly at SISSA Trieste, Italy and University of Burgundy, France.
I was Assistant Professor in Control Theory at University of Aix-Marseille, France, from 2010 to 2017.
Since 2017, I am Associate Professor in Mathematical Analysis at University of Padova.
My main research interests cover control theory and mathematical modeling of crowds.

Textbooks/bibliography
Complements of analysis

Teacher: Luca Martinazzi - UniPd - luca.martinazzi@math.unipd.it

Motivations.
This course takes place in the first trimester of the first year; it requires only a minimal mathematical background. The aim is to cover topics that are related to, but not usually treated in the standard first-year courses in Analysis.
Targeted audience: First-year students in Sciences or Engineering.

Syllabus.
Elementary set theory: cardinality, well-orderings, Zorn's lemma.
Elements of topology: metric spaces, compactness, Cantor sets.
Complements of sequences and sequences of functions and their convergence. Ascoli’s theorem, Stone-Weierstrass theorem.
Semicontinuity, parametrized curves on surfaces, existence of geodesics.
Ordinary differential equations, fixed points and Peano’s theorem.

Teacher CV.
Born in 1981.
2011-2013 Assistant Professor at Rutgers University, New Jersey (USA)
2013-2017 SNF Professor at the University of Basel (CH)
2017-present Associate Professor in Mathematical Analysis, University of Padova.
Research interests: Calculus of variations, geometric analysis, partial differential equations.

Textbooks/bibliography.
L. Ambrosio, C. Mantegazza, Complementi di Matematica (available online)
W. Rudin, Principles of Mathematical Analysis
Introduction to probability models

Teacher: Alessandra Bianchi – UniPd – alessandra.bianchi@unipd.it

Motivations.
The aim of the course is to provide an introduction to elementary probability theory and its application to sciences. The typical environment will be that of discrete probability spaces that will be introduced in the first lectures together with some basic probability tools. By the construction and the analysis of suitable models, it will then be shown how probability can be applied to the study of phenomena in physics, computer science, engineering and social sciences. In turns, this will led to the discussion of some open problems of the field.

Targeted audience.
The course will be self-consistent and no specific mathematical knowledge is required. Logic and a scientific attitude are always helpful.

Syllabus.
First elements of probability theory: Discrete probability spaces; Combinatorics; Conditional probability; The Ising model in statistical mechanics: Definition and properties; Analysis of phase transitions in dimension 1 and 2; Discrete random variables: Discrete distributions, mean value, independence; Binomial and geometric distribution; Moments generating function; Applications to two common problems: The coupon collector problem; Shuffling a deck of cards; The symmetric random walk in one and higher dimensions: Definition and properties; Reflection principle and return probability at 0; Analysis of transience and recurrence; Electrical networks and random walk on graph: Elements of discrete potential theory; Harmonic functions and their probabilistic interpretation; Random walk on general graphs; Application to the gambler’s ruin problem: probability of loss and win in a gambling game; Markov chains (theory): Definition and classification of Markov chains in finite space; Stationary distribution and ergodic theorem; Markov chains (examples and applications): Ehrenfest model; Bernoulli-Laplace model; Galton-Watson branching process; Elements of Monte Carlo method: Definition of Monte Carlo Markov Chain (MCMC); examples and application to optimization problems.

Teacher CV.
Born on 31/12/1977
Education and positions
- July 2003 degree in Mathematics - University of Bologna
- April 2007 PhD degree in Mathematics - University of Roma Tre
- 2007-2009 postdoc fellow at the WIAS of Berlin (Germany)
- 2010-2012 postdoc fellow at the Mathematics Dep. of Bologna
- Since May 2012 Assistant Professor (“Ricercatore”) of Probability and Statistics at the Mathematics Dep. of Padova.

Research interests: probability and Statistical Mechanics, Metastability in Markovian processes, Stochastic dynamics and relaxation time, Interacting particle systems on random structures

Textbooks/bibliography.

For consultation:
Introduction to Thermodynamics

Teacher: Fulvio Baldovin – UniPd – fulvio.baldovin@unipd.it

Motivations.
Thermodynamics is a basic interdisciplinary subject which bridges over different areas of science, including physics, mathematics, chemistry, engineering, biology, and medicine. Although common to many bachelor curricula, time constraints and needs of focusing on practical application in the specific field tend to hinder the presentation of the simple, symmetric structure which underlies Thermodynamics. As a consequence, students may turn out to be confused about the meaning and use of different thermodynamic potentials and response functions.

Goal of the present course is to introduce the thermodynamics of simple systems. While keeping mathematical aspects at a level suitable for first-year undergraduate students, emphasis will be given to the equivalence of the entropy and energy representations, which through Legendre transformations generate all other potentials. Exemplifications and case of study from different fields will help the comprehension and application the formal structure.

Targeted audience.
The course targets the Natural Science Class of the Galilean School of the University of Padova, including students in physics, mathematics, chemistry, engineering, biology, and medicine. The ideal audience has supposedly been exposed to an introductory course of mathematical analysis in one variable, while a practical knowledge of partial derivatives and Legendre transformations will be offered within the course's lectures.

Syllabus.
- The temporal nature of macroscopic measurements
- The spatial nature of macroscopic measurements
- Summary of thermodynamic parameters
- The postulate of thermodynamic equilibrium
- Walls and constraints
- Measurability of the energy
- Quantitative definition of heat
- The basic problem of equilibrium thermodynamics
- The entropy postulates
- Partial derivatives and differentials
- Intensive parameters and equations of state
- Thermal, mechanical, and chemical equilibrium
- The Euler equation
- The Gibbs-Duhem relation
- Fundamental relation and equations of state
- The simple ideal gas
- The van der Waals ideal fluid
- The electromagnetic radiation
- The “rubber band”
- Second derivatives of the fundamental relation
- Possible, impossible, quasi-static, and reversible processes
- The maximum work theorem
- Engine, refrigerator, and heat pump performance
- The Carnot cycle
- Insight: thermal conductance and conductivity
- Power output and endoreversible engines
- The energy minimum principle
- Legendre transformations
- Thermodynamic potentials
- Massieu functions
- The minimum principles for the potentials
- The Helmholtz potential and the Laplace equation
- The Gibbs potential and chemical reactions
- Maxwell relations
• Reduction of derivatives
• Reconstruction of a fundamental equation from response functions
• Thermodynamic stability in the entropy representation
• Thermodynamic stability for the potentials
• Introduction to phase transitions
• The Clapeyron equation
• Unstable isotherms and first-order transitions
• General attributes of first-order phase transitions
• Thermodynamics in the neighborhood of the critical point

Teacher CV.
Fulvio Baldovin is Assistant Professor in Physics at the Physics and Astronomy Department of the University of Padova. He is author of about 45 original research articles in international journals. He has been teaching Statistical Mechanics for the Ph.D. degree in Physics, and Biological Physics for the Bachelor degree in Molecular Biology. He has been tutor in Theoretical Physics for the Galilean School of the University of Padova. He actively collaborates with complex systems groups at the Weizmann Institute in Israel and at the Universidad Nacional Autonoma de Mexico (UNAM).

Textbooks/bibliography.
A number of problems and examples will be explicitly solved at the blackboard.
Measure theory

Teacher: Paolo Ciatti – UniPd – paolo.ciatti@unipd.it

Motivations.
The course is an introduction to the Lebesgue theory of integration in Euclidean spaces. The Lebesgue integral is nowadays a standard tool in the scientific literature. It is a flexible instrument allowing the proof of powerful theorems such as the celebrated Lebesgue dominated convergence theorem. Its wide diffusion is related to the completeness of the Lebesgue spaces of functions, a result of fundamental importance not only in mathematics, but also in quantum physics.

Targeted audience.
This lecture course is particularly directed to students in Mathematics, Physics and Engineering. However, students from other scientific disciplines may take advantage of a rigorous presentation of fundamental notions from measure theory which are often assumed to be known without providing a proof. A basic course in calculus would cover all necessary prerequisites.

Syllabus.

Teacher CV.

Textbooks/bibliography.
Fluidodynamics

**Teacher:** Roberto Turolla – UniPD - turolla@pd.infn.it

**Motivations**
Fluids and their motions play a central role in many areas of physics, engineering, biology and physiology, from the scale of living cells to astronomical ones. Fluids are complex systems, the dynamics of which was (partly) understood only during the last century. The course aims at providing the basics of fluid mechanics, i.e. the dynamics of liquids, presenting at the same time a number of examples and applications.

**Targeted audience**
Second year students in physics, mathematics, chemistry and engineering. The course is suited also for students in life sciences with a sufficient mathematical background (only elementary notions of calculus and vector analysis are required).

**Syllabus**
Basic properties of fluids: pressure, density, viscosity. Newtonian and non-Newtonian fluids (interlude: how it is possible to walk on a liquid).
Conservation laws and equations of motion. The control volume and the Reynolds transport equation. The conservation of mass, the equations of momentum and energy. The Euler and Bernoulli equations.
Dimensional analysis and the similarity principle. The basic adimensional groups in fluidodynamics: force and pressure coefficients, the Reynolds, Froude, Rossby and Mach numbers. Adimensional form of the equations of motion and the role of “numbers” in their analysis.
The boundary layer for a plane surface, Blasius solution. The boundary layer for a curved surface. Geostrophic flows and the Ekman boudary layer.

**Teacher CV**
Roberto Turolla earned his Master degree in Physics at the University of Padova, attended a PhD programme at the International School for Advanced Studies in Trieste and is presently full professor at the Department of Physics and Astronomy, University of Padova. Since 2007 he holds a Honorary Professorship at Mullard Space Science Laboratory, University College London (UK).
Research interests: astrophysics of compact objects (black holes and neutron stars). In particular, his expertise is in astrophysical radiative transfer under strong field (gravitational and magnetic) conditions and in the interpretation of X-ray/optical radio data from collapsed stars in terms of physical models. Such an activity is sustained by several international collaborations with different institutions, both in Europe and the US. He published more than 200 papers on international refereed journals. He teaches General Physics for the bachelor degree in Astronomy and Relativistic Astrophysics for the master degree in Physics.

**Textbooks/bibliography**
J.F. Kreider *Principles of Fluid Mechanics*, Allyn & Bacon
Notes of the lectures (in pdf format)
An Introduction to category theory and applications

Teacher: Riccardo Colpi – UniPd – colpi@math.unipd.it

Motivations.
The lectures first provide a basic course in category theory and then develop some general notions and tools applying them to different mathematical contexts. The main goal is to show how different areas of mathematics can be unified by the theoretical language and techniques of categories, which on the one hand increase the knowledge of common general points of view and on the other hand feed a prolific synergy between different topics.

Targeted audience: from the second-year onwards students.

Syllabus.
Basic tools:
1. Categories, functors, natural transformations
2. Monomorphisms, epimorphisms, isomorphisms
3. Products and limits, coproducts and colimits
4. Adjunctions, reflexive subcategories, equivalences and dualities
5. Functor categories, the Yoneda Lemma
Additive categories:
6. Predditive categories, kernels, cokernels
7. Additive and abelian categories
8. Pullbacks and pushouts, and their action on short exact sequences
9. Injectives, projectives, generators, cogenerators, finitely generated and finitely presented objects
Representing additive categories:
10. Grothendieck categories and Giraud subcategories
11. Representation of Abelian categories

Teacher CV.
- Ph.D. in Pure Mathematics in 1992 at the University of Bologna.
- Assistant Professor in Algebra at University of Padova from 1990 to 2002.
- Since 2002 Associate Professor in Algebra at the University of Padova.
My main research interests deal with additive category theory, ring and module theory, representation theory and in particular tilting and cotilting theory for abelian categories. My results are published on international journals and refereed conference proceedings.

Textbooks/bibliography
- S. Mac Lane, Categories for the Working Mathematician, Springer-Verlag GTM 5
- B. Mitchell, Theory of Categories, Elsevier vol. 17
- B. Stenstrom, Rings of Quotients, Springer-Verlag
Computational chemistry

Teacher: Antonino Polimeni – UniPd – antonino.polimeni@unipd.it

Motivations

An overview will be given of methods for modelling molecular properties, based on classical and quantum mechanics. The goal of the course is to describe the basic tools employed in modern computational chemistry to describe structural, dynamical and reactivity-related properties of molecular systems.

Targeted audience

The course is mainly directed to students in the Natural Sciences class. Students of other classes are welcome.

Prerequisites

The course will be self-contained but a basic knowledge of chemistry is advisable.

Syllabus.

1. Introduction to computational chemistry: modeling molecular systems.
2. Methods
   - classical molecular mechanics and molecular dynamics
   - quantum chemistry: self-consistent approaches, density functional theory, post-Hartree-Fock methods
   - hybrid, coarse-graining and multiscale approaches
3. Applications:
   - electronic structure calculations
   - molecular geometry optimization
   - computation of thermochemical, spectroscopic, structural and dynamic properties
4. Computational chemistry software tools: applications and case-studies.

Teacher CV.

Ph.D. in chemistry in 1990 at UniPd; post-doc at Cornell University from 1991 to 1993. Professor of Physical Chemistry at UniPd since 2010. Current research interests are the development of computational models of macromolecules and methods for the interpretation of molecular spectroscopic observables in condensed phases.

Textbooks/Bibliography

Lecture notes and slides, suggested review papers.
Physics Laboratory

**Teacher:** Marco Zanetti - UnPd - marco.zanetti@unipd.it

**Motivations:** This course aims at complementing the classical format of high level education by proposing a “hands-on” and research-oriented activity. The goal is to have the students experiencing what it takes to set up a physics experiment from scratch, setting up a plan for a long-term, complex project and confronting the various and unexpected issues that always arise when an open problem is tackled. The focus will be put on the development of practical skills, which result in most of the research domains to be as fundamental as the theoretical knowledge.

**Target audience:** Third and fourth year students.

**Prerequisites:** Knowledge of classical physics.

**Syllabus:** The course will consist on the planning and development of a physics experiment. The actual project will be chosen by the students among those proposed by the teacher; proposals from the students themselves will also be encouraged.

Examples of projects developed from scratch in the past by third year students are a cloud-chamber capable of continuous operations and an interferometer for the measurement of the refractive index of liquids.

The activity will be supported by the technical personnel of the Physics Department and it will take place in one of its laboratories.

**Teacher CV:** PhD at University of Padova, research fellow at CERN, research scientist at MIT, Associate Professor at University of Padova (as of 2015). Member of the CMS collaboration since 2004, taking part in numerous activities from the construction of the experiment to the discovery of the Higgs Boson in 2012. Member of the technical coordination for the LHC commissioning. Contributor to several next generation colliders projects (LEP3/TLEP, photon collider, muon collider).
Advanced Electromagnetism

**Teacher:** Massimo Passera – Istituto Nazionale di Fisica Nucleare, Sezione di Padova – passera@pd.infn.it

**Motivations:** The aim of the course is to introduce selected advanced topics in classical electrodynamics.

**Targeted audience:** Second & third year students.

**Syllabus:**
1. Review of Maxwell’s equations. Limits of classical E&M;
2. Electrostatics. Symmetries. Boundary conditions at interfaces;
3. Electrostatic energy;
4. Electric multipoles;
5. Electric dipoles. Motion of charges in electric dipole fields;
6. Spherical harmonics. Spherical & azimuthal multipoles;
7. Magnetic multipole expansion. Orbital & spin magnetic moments;
8. Magnetic monopoles. Motion of charges in external E&M fields;
9. Hall thrusters for spacecrafts. Larmor’s theorem;
10. Point magnetic dipoles in external B fields. Magnetic mirrors;
11. Precession of atomic magnets. Motion in time-dependent fields: the betatron;
12. Dynamic and quasi static fields;
13. Plane electromagnetic waves and wave propagation;
14. Retardation and radiation;
15. Scattering and diffraction.

**Teacher CV:** Degree in Physics at University of Torino, Italy; Ph.D. at New York University, New York, USA; Postdoctoral Fellow at the Institut for Theoretical Physics, University of Bern, Switzerland, at the Department of Theoretical Physics, University of Valencia, Spain, and at the Dipartimento di Fisica, University of Padova, Italy. Senior Researcher of the Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Italy.

Classic and Contemporary Cryptography

Teacher: Michele Elia – PoliTo – michele.elia@polito.it

Motivations.

Since the end of the II World War, cryptography has evolved in a prodigious way. Once a discipline limited to diplomatic or military environments, it now is an indispensable discipline to any activity of the civil society. Significant is the use of cryptography to allow the telecommunication ubiquity. In order to accomplish always-new requirement, it has used ever more abstract mathematics. The course is an introduction, ample but not superficial, to cryptography, presenting foundation, primitive algorithms, methods and applications. The target is to provide knowledge permitting to go in depth of abstract methods without difficulties, which obviously are necessary to who works in specific sector of transmissions, elaborations, and storage of information.

Targeted audience.

The course is oriented to students with many different backgrounds, nevertheless assuming that they have basic knowledge of algebra and probability theory, thus providing, or completing, the mathematical notions needed for a good understanding of cryptography.

Syllabus.

1. Excursus on the many practical areas that use cryptography and cryptanalysis.
3. The foundations of cryptography derived from Shannon’s information theory. Communication channel and cryptographic channel models. Perfect enciphering, and One-Time-Pad.
4. Cryptanalysis and its paradoxical axioms. Computational complexity. Different type of attacks: plain-text attacks and cipher text only attacks with encryption algorithm known or not. The lessons from the past.
5. Private-key cryptography: Block Ciphers (DES, AES).
7. Public-key and the notion of one-way function. Factorization, discrete logarithm, searching unsorted data.
10. Elliptic curves over finite fields as a rich source of finite groups where the discrete logarithm is difficult to compute.
12. Block chain technology and crypto-money.
13. Homomorphic cryptography, principle and applications (cloud computing, notarial activities, electronic vote).
14. Post-quantum cryptography: primitive cryptographic functions based on problems difficult to solve also by quantum computers.

Teacher CV.

Born on 02/01/1945.

Education and positions

- October 1970 degree in Engineering - Polytechnic of Torino
- 1971-1978 Teaching assistant - Polytechnic of Torino
- 1978 -1990 Teaching professor of Mathematical Analysis - Polytechnic of Torino
- 1990 - 2015 – Full professor of Information theory, coding and Cryptography - Polytechnic of Torino
- Since March 2017 Professor emeritus at Polytechnic of Torino.

Research interests: Algebra, Coding Theory, Cryptography, Number theory

Textbooks/bibliography.

• Springer, 2008.
Quantum Optics and Information

Teachers: Paolo Villoresi e Giuseppe Vallone – UniPd – paolo.villoresi@dei.unipd.it, vallone@dei.unipd.it

Motivations.
The aim of the course is to give an introduction of Quantum Optics, from the theoretical to the experimental point of view and its exploitation for Quantum Information Applications. First, we will introduce the basic concepts of Quantum Optics, from the concept of single photon to the formalism necessary to describe quantum states of light. Using the photon and the correlations of entangled photons we will describe fundamental test of quantum mechanics and several applications. The concepts will be demonstrate in four laboratory experiences (within the 32 hours of the course).

Pre-requisite
The course targets the Natural Science Class of the Galileian School of the University of Padova, including students in Physics, Mathematics and Engineering. Students are required to have familiarity with Quantum Mechanics.

Syllabus.
1. Quantization of electromagnetic field, coherent states, statistic of light detection, correlation functions, characteristic functions of quantum states.
2. Laboratories of single photon interference and photon statistics.
3. Nonlinear effects, generation of entangled photons, tomography of quantum state (Theory and Lab),
4. Quantum key distribution with entangled photons (Theory and Lab)
5. Quantum communications
6. Hong-Ou-Mandel effect and Bell measurements
7. entropy extraction from quantum processes.

Teacher CV.
Paolo Villoresi is Full Professor of Experimental Physics. He studied Physics and Applied Mathematics at University of Padova, where he is permanent faculty since 1994. He proposed in 2002 and then realized the first single photon exchange with a satellite. He founded a research group on Quantum Communication (QC) and Quantum Optics, that demonstrated the first QC in Space using orbiting retroreflectors, adopting polarization and temporal modes. This UniPD group also have show the first use of OAM modes in QC, the generation of random numbers using DV and CV quantum processes at tens of Gbps, the study and mitigation of turbulence in free-space QC in the Canary Island links, as well the implementation of novel QKD protocols and of fundamental tests of Quantum Mechanics both in Space and in the Lab. (ORCID: 0000-0002-7977-015X, Google Scholar ID: link).

His past research topics include the Atomic Physics in the attosecond domain, multiphoton ionization, ultrafast optics in extreme ultraviolet and X-rays, often exploiting adaptive optics. He served as coordinator in several national and international research projects, including basic research as well as industrial and medical applications of lasers and photonics technologies, exploiting also his 11 industrial patents and patent applications.

He is the Italian delegate in the EU COST action MP1403 Nanoscale Quantum Optics and the deputy delegate for the EU COST action CA15220 Quantum Technologies in Space. He is in the Board of Stakeholders of the European technology platform Photonics21.

Giuseppe Vallone is Assistant Professor at the University of Padova from 2011. He got his Ph.D. degree in Physics at the University of Torino in 2006. From 2006 to 2011 he worked in the Quantum Optics Group of the Sapienza University of Rome. He teaches “Elementi di Fisica II” for the Bachelor degree in Informatic Engineering and “Quantum Information & Computing” in the Master degree of ICT for Internet and multimedia. His research is focused on quantum information, photonic states, quantum communication, quantum random number generators, Orbital Angular Momentum states. He has more than 100 publications including 83 peer-review papers in international journals in the area of quantum optics and quantum information (Researcher ID: H-7579-2012, Google Scholar ID: link).
http://quantumfuture.dei.unipd.it/

Textbooks/bibliography
2) M. A. Nielsen and I. L. Chuang “Quantum Computation and Quantum Information” (Cambridge 2010)
3) John Garrison, Raymond Chiao, Quantum Optics, Oxford University Press
4) Christopher Gerry, Peter Knight, Introductory Quantum Optics, Cambridge University Press
Game theory

**Teacher:** Leonardo Badia – UniPd – leonardo.badia@unipd.it

**Motivations**
Game theory is a subject generally belonging to the applied mathematics, originally exploited for micro-economic applications. In recent years, it is more and more often applied to many engineering and data analytics problems, especially in the context of telecommunication networks and distributed system management. More in general, it can be seen as a useful know-how for many students in different fields, both as a solution instrument and also to bridge together multiple subjects at once. The course is meant to give the basics of classic game theory concepts, exploring in detail basic static and dynamic games and giving pointers to more advanced subjects in the field (Bayesian games, collaborative games, evolutionary games).

**Targeted audience**
Due to its cross-disciplinary nature, the course does not target a specific class of the Galilean School of the University of Padova, even though, given the analytical formulation of many problems, students of the class of Natural Science can be more at ease with the subject. Still, students from the other classes, especially from economics, political systems, and/or social sciences may find it interesting and coherent with their studies. The course asks for some very basic prerequisites, generally available to any student with a grasp of mathematical analysis and probability theory, even from high-school concepts, namely: calculus in one variable (just limited to first-order derivative), expected value, probability distribution for a discrete random variable.

**Syllabus**
- Basic concepts: utility, market, discount factor
- Utility theory and preferences
- Static games in normal form
- Dominance, Nash equilibrium
- Efficiency, price of anarchy
- Mixed strategies, mixed equilibria
- The Nash theorem
- Zero-sum games, minimax games, minimax theorem
- The tragedy of the commons
- Dynamic games: strategies and subgames
- Backward utility, Stackelberg games
- Repeated games and cooperation
- Dynamic duopolies, collusion
- Cooperation, pricing
- Imperfect/incomplete information

**Teacher CV**
Leonardo Badia is Associate Professor in Telecommunications at the Department of Information Engineering. He is author of more than 150 original research articles in international journals and conferences. He is presently teaching the course of “Telecommunications” for the Bsc. Degree in Information Engineering, the courses of “Game theory” and “Life Data Epidemiology” for a bunch of Msc. programs (including “Computer engineering”, “Computer science”, “ICT for Internet and multimedia”, “Data science”, “Physics of Data”) and the course of “Social network analysis” for the Msc. degree in Strategies of Communication.

He is actively involved in the research of the SIGNET (Signals and Networks) group at the University of Padova and holds collaborations with many academic institutions in Italy and abroad. His research interests involve mathematical models for telecommunication systems, complex networks, energy harvesting, cross-layer optimization.

**Textbooks/bibliography.**
A handbook of exercises and solved problems is currently under preparation. The lecturer will also provide reference material (slides of the lectures and problems)
Quantum Mechanics

Teacher: Pieralberto Marchetti – UniPd – pieralberto.marchetti@unipd.it

Motivations
Quantum Mechanics (QM) is the theory describing the laws of physical phenomena at microscopic scales (atomic or sub-atomic), but its consequences appear also at the macroscopic level: impenetrability of bodies, stability of matter and colors, new states of matter such as superconductivity… It has a tremendous impact also on technology…no mobile phones without QM…. At first MQ creates problems to our concepts of particle and wave, but more deeply it calls our ideas of observable quantities and even of physical reality into question, at least on microscopic scales. On the mathematical side, the birth of QM was essential for the development of the theory of operators in Hilbert spaces. After a general didactic introduction stressing the puzzling features of QM, the course is structured in terms of thematic units, with a possible choice between the last ones of them depending on the main interests of the students. The proposed themes refers to the birth, the mathematical formalization of MQ and some applications where the quantum behavior is radically different from the classical one.

Targeted audience
The course is targeted for students possessing a basic knowledge of Classical Physics (Mechanics, Electromagnetism and possibly Special Relativity)

Syllabus
-Introduction: the crisis of classical physics, the photoelectric effect, the de Broglie waves, the puzzling behavior of quantum particles; mathematical description of physical systems.
-The axiomatization of Dirac and von Neumann: the Hilbert space of state vectors, ray vectors as pure states, self-adjoint operators as observable quantities and their spectra as possible result of measurements, causal evolution and measurements in quantum systems, symmetries as unitary operators. General consequences of axioms: Heisenberg uncertainty principle, relation between simultaneous measurability and commutativity of observables.
-Applications: harmonic oscillator and quantization of energy spectra, quantization of spectra of angular momentum and relations of the spin with representations of rotations, tunnel effect and relation to radioactivity.
-Interpretations of QM: EPR paradox, Bell inequalities and dilemma non-locality/ non realism.

Teacher CV
Academic Positions -Researcher in Theoretical Physics, 1983-1993, University of Padua -Associate Professor of Theoretical Physics, 1993-present, University of Padua -Member of the teaching activity Commitee of the Council of Study in Physics, 2000-present -Member of the Scientific Council of CIRSFIS/CISFIS (Interdepartmental Center for History and Philosophy of Sciences of the University of Padua), 2004-present Research Activity My research activity mainly developed within the framework of Quantum Field Theory, in particular: quantum field theory of solitons with the functional integral, often in mathematical-physics style, with application also to monopoles, dyons and anyons; applications of gauge theory and quantum solitons to condensed matter systems: bosonization in planar systems and Chern-Simons spin-charge gauge theory for high Tc superconductors; anomaly cancellations in p-brane theories.

Textbooks/bibliography
M. Born, “Atomic physics” 1989 Dover (Italian version “Fisica Atomica” Boringhieri)
MOLECULAR PATTERNS THAT CONNECT METABOLISM WITH LONGEVITY

Teacher: Prof. Marco Sandri – UniPd – marco.sandri@unipd.it

Syllabus
La longevità e la qualità della vita sono influenzate da una serie di vie di segnale che sono controllate sia dalla dieta che dall’esercizio fisico. Infatti, al momento, solo la restrizione calorica e l’esercizio fisico sono i processi di cui si è potuto documentare che allungano e migliorino la vita (health span) in diverse specie animali incluso l’uomo. Viceversa, l’obesità e la vita sedentaria sono noti accorciare l’aspettativa di vita (unhealthy ageing). I geni della longevità riguardano fattori di trascrizione, enzimi del metabolismo glicidico e lipidico, sensori di energia, ormoni e anche la proteostasi ovvero i meccanismi che controllano la qualità delle proteine cellulari, come l’autofagia. La recente scoperta dei geni che controllano l’autofagia ha valso il premio nobel per la Medicina a Yoshinori Ohsumi. In questo corso si descriveranno i legami molecolari che connettono la dieta, la regolazione dei geni dell’autofagia, le vie bioenergetiche attivate dall’esercizio fisico, ed i processi biochimici molecolari che riducono la senescenza nelle cellule staminali e differenziate. In particolare si approfondiranno i dettagli della via dell’insulina e le connessioni con le vie dei lipidi, il perché i soggetti obesi hanno sempre fame e diventano resistenti all’ormone anoressizzante, la leptina, la scoperta delle sirtuine presenti nel vino rosso e delle loro proprietà nella regolazione dell’autofagia, e le similarità molecolari tra una dieta ipocalorica e l’attività fisica (AMPK, PGC1a) nella bioenergetica cellulare.

Vie di segnale analizzate nel corso:
Ruolo dei carboidrati e proteine nel controllo dell’autofagia:
Insulina/AKT/mTOR/FoxO e regolazione dell’autofagia (ULK1/Beclin1/LC3)
Ruolo dell’esercizio fisico nella riposta allo stress, longevità e regolazione autofagia:
AMPK/PGC1a e regolazione attività mitocondriale
Sirtuine e vie della longevità e metabolismo
SIRT1/FoxO e SIRT1/acetilazione proteine autofagia e SIRT1/PGC1a
Lipidi e Resistenza all’azione di ormoni anoressizzanti
Leptina/Insulina e azione citochine infiammatorie su via Jak/Stat e Akt/FoxO nei neuroni